Australian Government

Great Barrier Reef
Marine Park Authority

GREAT BARRIER REEF
OUTLOOK REPORT
2019

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Aboriginal and Torres Strait Islander readers are advised this publication may contain names and images of deceased persons.

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LETTER OF TRANSMITTAL

Australian Government

Great Barrier Reef
Marine Park Authority

Hon. Sussan Ley
Minister for the Environment
Parliament House
CANBERRA

Dear Minister

I am pleased to provide the ***Great Barrier Reef Outlook Report 2019*** 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 2019 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* (Cth). 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 legislation requires that an Outlook Report be prepared every five years. As in the first Outlook Report in 2009 and second report in 2014, this third report identifies that the Great Barrier Reef Region faces significant pressures ranging in scale from local to global. Since 2014, management initiatives and local actions have demonstrated positive outcomes for small scale, less complex activities. However, achieving outcomes on the ground continues to be difficult for complex and spatially broad topics, such as climate change, land-based run-off and biodiversity.

While the Great Barrier Reef is retaining its outstanding universal value as a World Heritage Area, its integrity is being increasingly challenged. Cumulative pressures, predominantly from climate change, combined with the time 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 very poor. These findings will be best addressed through timely and coordinated action across governments, industries and the community to address climate change, improve water quality and strengthen effective on-ground management actions.

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

Yours sincerely

Ian Poiner
Chair
Great Barrier Reef Marine Park Authority

ACKNOWLEDGEMENTS

The *Great Barrier Reef Outlook Report 2019* 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.

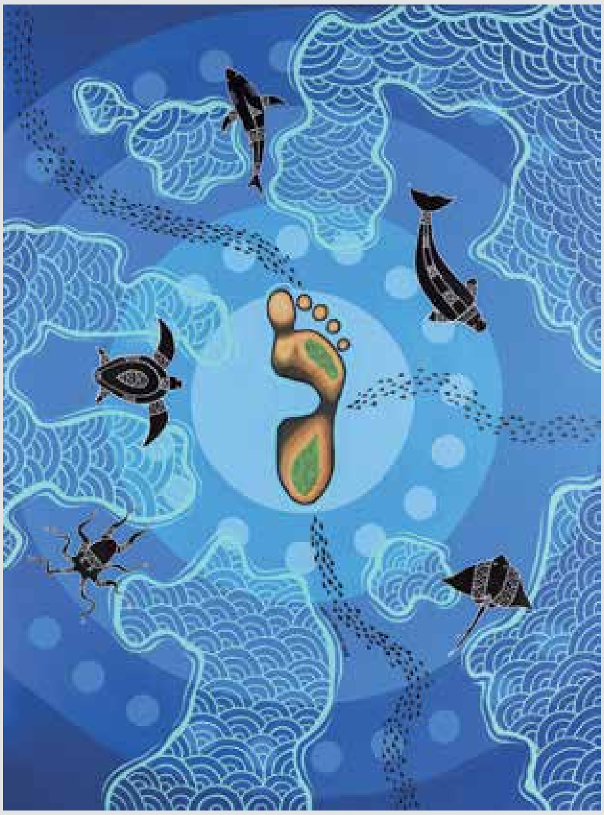
Many Great Barrier Reef scientists willingly contributed their knowledge and information, both formally through an expert elicitation workshop and informally by reviewing information used in the report to ensure the correct interpretation of results. The expert elicitation workshop was independently facilitated by Terraform Design Pty Ltd (Terry Harper).

The independent assessment of the existing measures to protect and manage the Great Barrier Reef was led by Uniquest Pty Ltd (Marc Hockings, Andrea Leverington and Fiona Leverington) with assistance from Ground Zero Environmental Pty Ltd (Colin Trinder and John Polglaze) for the topics of defence, ports and shipping.

Finally, the contents of the Outlook Report were formally peer reviewed by Kate Auty (ACT Commissioner for Sustainability and Environment, Australia), Karen Hussey (The University of Queensland, Australia), Terry Hughes (ARC Centre of Excellence for Coral Reef Studies, Australia) and Helene Marsh (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.

The Great Barrier Reef Marine Park Authority further acknowledges the Wulgurukaba and Bindal Traditional Owners of the Great Barrier Reef and their continuing connections to the land and sea country of this region. We pay respect to them, their cultures and their Elders, both past and present.



‘Step of Change’ by Nicky Bidju Pryor commissioned as part of the Great Barrier Reef Marine Park Authority’s Reconciliation Action Plan.

EXECUTIVE SUMMARY

The Great Barrier Reef is a vast and spectacular ecosystem and one of the most complex natural systems on Earth. The Great Barrier Reef Region's natural beauty and natural phenomena endure, but they are showing signs of deterioration in several areas. In 2009, the Reef was considered to be at a crossroads between a positive, well-managed future and a less certain one. In 2014, it was seen as an icon under pressure, with continued efforts needed to address key threats. Since then, the Region has further deteriorated and, in 2019, Australia is caring for a changed and less resilient Reef. The challenge to restore Reef resilience is big, but not insurmountable. However, it requires mitigation of climate change and effective implementation of the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan).

The scientific evidence is clear: initiatives that will halt and reverse the effects of climate change at a global level and effectively improve water quality at a regional scale are the most urgent to improve the Region's long-term outlook. More than ever before, uses of the Region must be sustainable and effectively managed. To protect and restore habitats, species and heritage values, management agencies must complement proven techniques with innovative approaches that are targeted, science-based and risk-managed.

Climate change is escalating and is the most significant threat to the Region's long-term outlook. Significant global action to address climate change is critical to slowing deterioration of the Reef's ecosystem and heritage values and supporting recovery. Such action will complement and greatly increase the effectiveness of local management actions in the Reef and its catchment.

Gradual sea temperature increase and extremes, such as marine heat waves, are the most immediate threats to the Region as a whole and pose the highest risk. Sea temperature extremes caused successive mass bleaching events in 2016 and 2017. These events led to unprecedented and widespread coral loss, and flow on effects to fish and invertebrate communities. Such impacts also weaken Traditional Owners' enduring connection to sea country and the quality and quantity of economic and social wellbeing provided by the Reef.

Inshore water quality is improving on a regional scale, but too slowly; poor water quality continues to affect many inshore areas of the Reef. The rate of reduction of pollutant loads has been slow, reflecting modest improvements in agricultural land management practices. Future initiatives need to deliver timely, best practice agricultural land management over a wider area to improve water quality.

Natural values of the Region include species, habitats and ecosystem processes. Overall, habitats are assessed as being in *poor* condition. Habitat loss, degradation and alteration have occurred in a number of areas, substantially affecting populations of some dependent species. For example, the significant and large-scale impacts from record-breaking sea surface temperatures have resulted in coral reef habitat transitioning from *poor* to *very poor* condition. Not all habitats have been equally affected and their condition varies across the Region. For instance, coral reefs that have escaped impacts of bleaching, cyclones and crown-of-thorns starfish outbreaks remain in *good* condition.

Concern for the condition of the Region's species is also high; many species and species groups are assessed as being in *poor* to *very poor* condition. Species assessments reflect both ongoing effects of past significant population declines (for example, from historical commercial harvesting of dugongs and turtles) and current impacts that add further pressure. Humpback whales and the southern green turtle population continue to recover and the breeding rate of urban coast dugongs has improved since the impacts of cyclone Yasi and floods in 2011.

The Region relies upon the healthy functioning of a range of physical, chemical and ecological processes, and connection to functioning coastal ecosystems. Of the 31 ecosystem health components assessed, about 60 per cent remain in *good* to *very good* condition, but the remainder are in *poor* to *very poor* condition. Some critical ecosystem functions have deteriorated since 2014, mainly due to declines in ecological processes, such as symbiosis and recruitment, and deterioration of some physical processes, such as sea temperature and light. Some processes important to replenishment and recovery of species and habitats, such as currents, connectivity and primary production, remain in *good to very good* condition.

Many of the Region's heritage values are closely tied to the condition of the ecosystem, particularly Indigenous heritage value. Overall, many heritage values remain in *good* condition, with the exception of Indigenous heritage and some aspects of historic heritage, which are assessed as being in *poor* condition. Community awareness and appreciation of the Region's Indigenous and historic heritage values are important to their protection and resilience. While significant work has occurred, identification and monitoring of the broad range of Indigenous, historic and other heritage values is not yet comprehensive. Greater shared knowledge of heritage values among the Region's managers, Traditional Owners and stakeholders is critical to ensuring recognition and continued protection of those values.

While the property's outstanding universal value as a World Heritage Area remains whole and intact, its integrity is challenged and deteriorating. Given the global scale of human-induced climate change, the size of the property is becoming a less effective buffer to broadscale and cumulative impacts. Attributes that remain in good condition at a Region-wide scale include the spectacular scenery, over half of the ecosystem processes, and some species components.

The Great Barrier Reef remains a significant economic resource for regional communities and Australia as a whole. 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 heavily on a functioning, resilient ecosystem. As Reef waters continue to heat, coral reefs will become less diverse than a decade ago, and the fishes seen while snorkelling and caught while fishing, will also change. Reef-dependent users need to prepare for this change.

The Region is protected and managed by a partnership between many government agencies, Traditional Owners, stakeholders and community members, and is influenced by activities occurring within and adjacent to the Region. An independent assessment of the Region's management found it to be *effective* for small-scale, less complex activities. Port management is already achieving positive outcomes following improvements in planning. Fisheries management is also expected to improve over the next five years with the proper implementation and resourcing of the *Queensland Sustainable Fisheries Strategy 2017–2027*.

Implementation of the Reef 2050 Plan began in 2015, marking a shift in how the Australian and Queensland governments and their partners collaborate in addressing challenges that face the Reef. Independent assessors determined the Reef 2050 Plan had improved jurisdictional consistency, coordination and resourcing across many management topics. However, achieving on-ground outcomes continues to be difficult for complex and spatially broad topics, such as climate change, land-based run-off and biodiversity.

Global, regional and local actions taken now can influence the Reef's future. Since 2014, investment in management of the Reef and its catchment has been unprecedented. This has enabled the delivery of significant protections and tangible actions through the *Great Barrier Reef Blueprint for Resilience* and the *Reef 2050 Water Quality Improvement Plan,* which have set the framework for improved resilience-based management and protection of values.

Threats to the Reef are multiple, cumulative and increasing. Researchers and management agencies are constantly being challenged as research and monitoring efforts strive to keep pace with a rapidly changing Reef. The Reef 2050 Integrated Monitoring and Reporting Program, once established, will be a game-changer — providing coordinated access to information about the Reef, its catchment and human use of the Region.

A comprehensive risk assessment of 45 threats to the Region's ecosystem and heritage values considered the residual risk, after taking into account the current management regime. The 10 threats identified in 2014 as presenting a *very high* risk to the Region's ecosystem and heritage values are again the highest ranked in 2019. Of the *very high* risk threats, most relate to climate change or land-based run-off (water quality) affecting values on a Region-wide scale. Given the current state of the Region's values, actions to reduce the highest risks have never been more time-critical.

Without additional local, national and global action on the greatest threats, the overall outlook for the Great Barrier Reef's ecosystem will remain very poor, with continuing consequences for its heritage values also. The window of opportunity to improve the Reef's long-term future is now. Strong and effective management actions are urgent at global, regional and local scales. The Reef is core to Australia's identity and improving its outlook is critical. For the Region to remain resilient and maintain its myriad of values, society must play a pivotal and urgent role in mitigating impacts and adapting to change. It is important to remain vigilant, active and optimistic in managing the Reef. Actions taken now by managers, Traditional Owners, researchers, stakeholders and the community will matter and make a difference to the Region's long-term outlook.

TABLE OF CONTENTS

FIGURES, TABLES & BOXES

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

CHAPTER 1

ABOUT THIS REPORT

« *A beautiful reefscape.* © Matt Curnock 2017

ABOUT THIS REPORT

1.1 Background

The Great Barrier Reef Marine Park Authority (the Marine Park Authority) prepares an Outlook Report for the Great Barrier Reef Region (the Region) every five years. The *Great Barrier Reef Marine Park Act 1975* (Cth) (the Act) and the regulations applying to the Great Barrier Reef Marine Park (the Marine Park) (Appendix 1) specify what the report must contain and the relevant statutory timeframes.

The first Great Barrier Reef Outlook Report[1] (Outlook Report) was released in 2009 and the second in 2014[2]. This Outlook Report, like previous reports, plays a significant role in informing Australia's reports to the World Heritage Committee addressing the property's world heritage status, the review of the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan) and effective management of the Great Barrier Reef (the Reef).

Outlook Reports are a regular and reliable means of assessing the overall performance of all measures to protect and manage the Reef in an accountable and transparent manner. The report provides a summary of the long-term outlook for the Reef based on assessments of condition, use, influencing factors, management effectiveness, resilience and risks.

The Act does not provide for the Outlook Report to include recommendations about future protection or management initiatives. Rather, the report provides an evidence-based assessment that identifies future trends, risks and threats, to inform future protection and management initiatives. It builds upon previous reports by providing a snapshot of the current condition of the Reef and examines how its condition has changed from previous reporting, predominantly since 2014. While much of the report's assessment focuses on the retrospective performance over a five-year period, a forward-looking long-term outlook is also provided (Chapter 10).

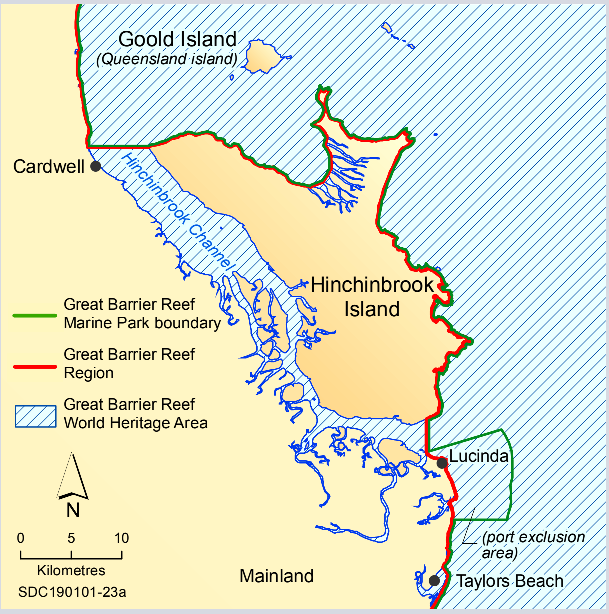
1.2 Scope

The jurisdictional scope of the report covers the entire Great Barrier Reef Region (Figure 1.1). The Region is a Commonwealth jurisdiction covering approximately 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 to the eastern border with the Coral Sea Marine Park. It excludes the Torres Strait Region. The Region's boundary is slightly larger than the Marine Park and it includes the air above to a height of 915 metres, the subsoil beneath the surface of any land to a depth of 1000 metres, and about 70 Commonwealth islands.[3] The State of Queensland has jurisdiction over the majority of islands in the Reef (approximately 980 islands) which are, therefore, not included formally within the Region. However, where it is relevant to the health of, or factors influencing, 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 the Great Barrier Reef river catchments (the Catchment). Jurisdictional differences between the various areas described in the report are outlined below (Table 1.1 and Figure 1.2). Additional information on jurisdictions and management responsibilities is provided in Chapter 7 (Section 7.1.1).

Figure 1.1 Great Barrier Reef Region and Catchment

Table 1.1 Differences between the Great Barrier Reef Marine Park, Region, World Heritage Area and Catchment
The square kilometres of each area is an approximation only. Terms relating to ports are described in Section 5.7.

Great Barrier Reef Marine Park	Great Barrier Reef Region	Great Barrier Reef World Heritage Area	Great Barrier Reef Catchment
Declared in sections between 1979 and 2001; amalgamated into one section by proclamation in 2004	Established 1975	Inscribed 1981	
344,400 km^2	346,000 km^2	348,000 km^2	424,000 km^2
Includes: • approximately 70 Commonwealth islands • all waters seaward of low water mark (excluding Queensland internal waters and trading ports)	Includes: • approximately 70 Commonwealth islands • all waters seaward of low water mark (excluding Queensland internal waters) • 12 coastal exclusion areas (12 trading ports) and maritime port infrastructure	Includes: • all islands within outer boundary (approximately 1050), comprising approximately 70 Commonwealth islands and approximately 980 Queensland islands • all waters seaward of low water mark (including Queensland internal waters) • 12 coastal exclusion areas (12 trading ports) and maritime port infrastructure	Includes: • 35 river basins that flow into the Great Barrier Reef Region • six natural resource management regions: Cape York, Wet Tropics, Burdekin, Mackay–Whitsunday, Fitzroy and Burnett–Mary • land-based port infrastructure
Does NOT include: • internal waters of Queensland • Queensland islands (approximately 980) • 12 coastal exclusion areas (trading ports)	Does NOT include: • internal waters of Queensland • Queensland islands (approximately 980)		Does NOT include: • land seaward of low water mark • maritime port infrastructure



This map shows examples of the differences between the boundaries of the Marine Park, Region and World Heritage Area. It also includes a Queensland island (Goold Island) that is positioned within, but not part of, the Region.

The Outlook Report assesses all parts of the ecosystem within the Region, ranging from species and habitats to key ecosystem processes. For the purposes of this report, the ecosystem components within the Region are collectively referred to as the Great Barrier Reef ecosystem or simply the Great Barrier Reef. The report also assesses all aspects of the Region's heritage values, including Indigenous and historic heritage values and its world heritage value.

The Reef was inscribed on the World Heritage List in 1981 for all four natural criteria. The assessment of the condition of the Region's world heritage value in Chapter 4 is directly informed by Chapters 2 and 3, which provide grades for a suite of natural heritage components. In addition, Appendix 3 presents a matrix describing how the components assessed in this report correspond with the attributes (outstanding features) that comprise the statement of outstanding universal value.

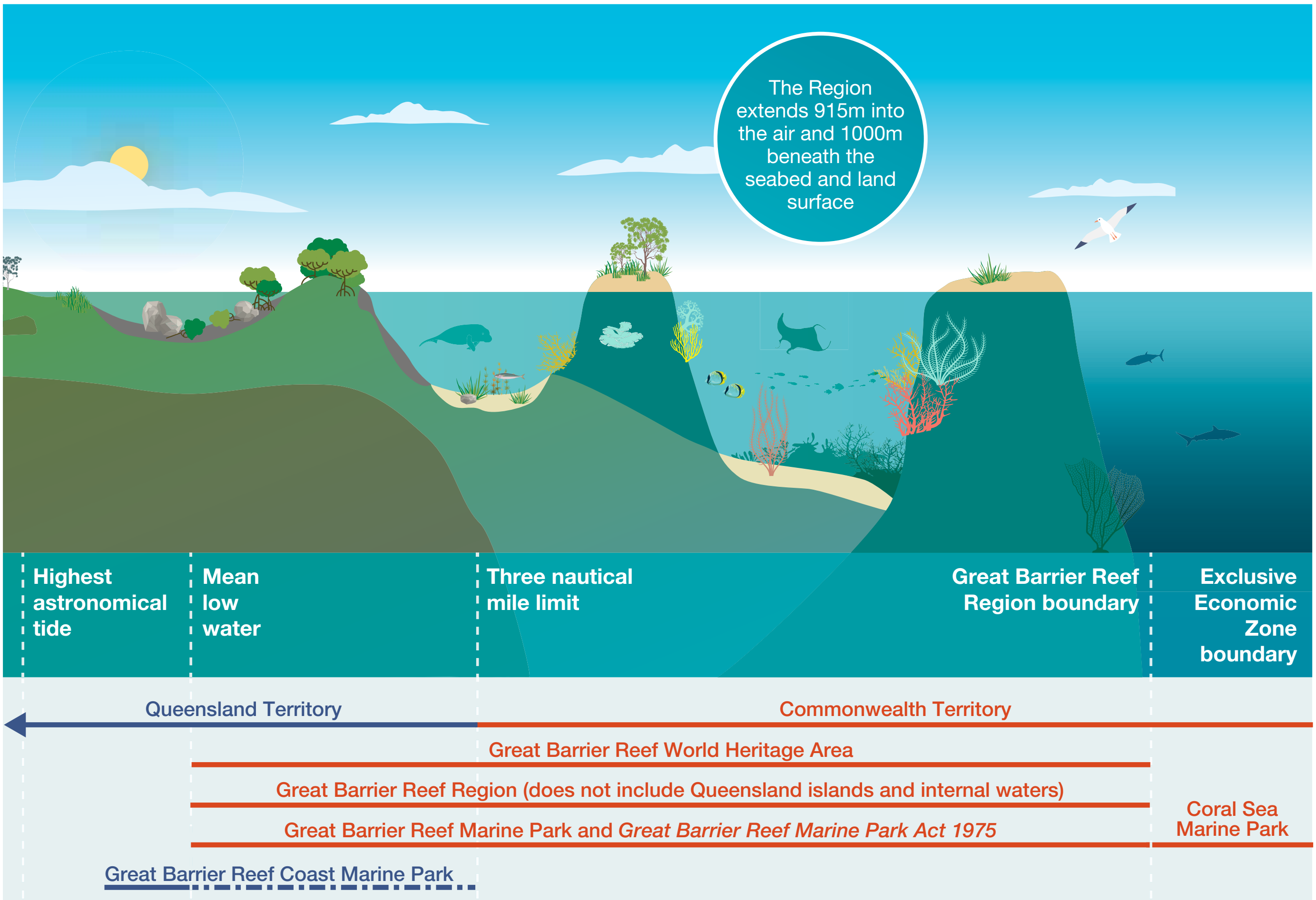


Figure 1.2 Jurisdictional boundaries
The Great Barrier Reef Region encompasses both Commonwealth (red) and Queensland (blue) jurisdictions. The Queensland territory extends from the land to the three nautical mile limit (and around Queensland islands). The dashed line indicates that the Great Barrier Reef Coast Marine Park includes the Queensland-owned islands that lie within the Region. Additional information on jurisdictions and management responsibilities is provided in the expanded version of this diagram in Chapter 7 (Section 7.1.1).

1.3 Structure

The Outlook Report looks back over the last five years and collates a Region-wide assessment of the current condition of the Reef's ecosystem and heritage values. The report is structured around the nine assessments required by the Act and its regulations, with each assessment forming a chapter of the report (Figure 1.3). Chapters fall into three main themes: (i) values; (ii) threats, management responses, resilience and risk; and (iii) the long-term outlook for the Region. The four chapters on the values of the Reef focus on current condition and trends. Likely future trends in those values depend on the drivers influencing them, which are discussed in later chapters.

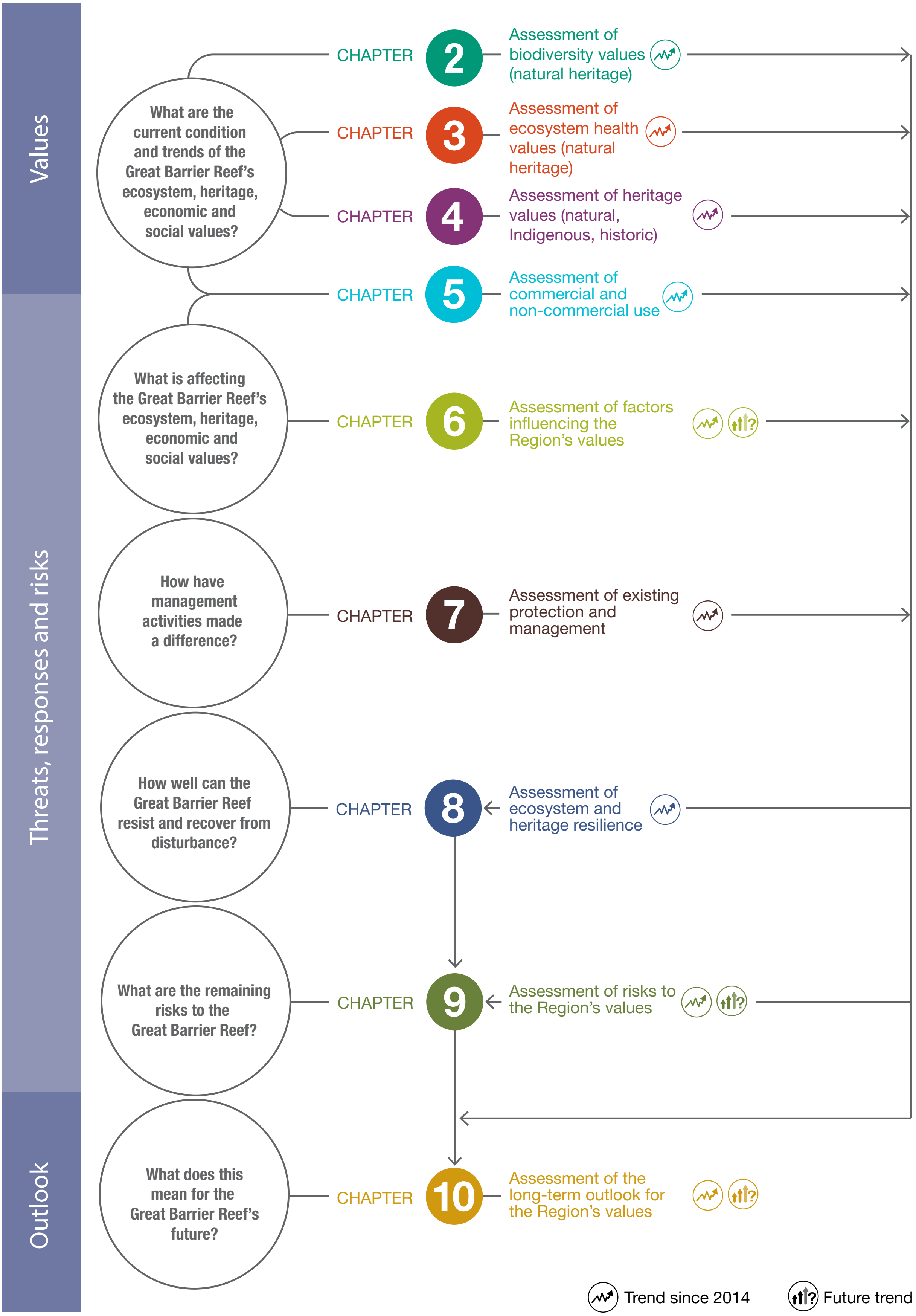


Figure 1.3 Assessments within the 2019 Outlook Report
Each of the assessments required under the Act and regulations applying to the Great Barrier Reef Marine Park forms a chapter of the report. The assessments relate to the condition of the Great Barrier Reef Region's ecosystem and its heritage value and examine threats, responses and risks. These then inform an assessment of the likely outlook for the Region's values.

1.4 Assessment approach

For each of the required statutory assessments (Appendix 1), specific criteria and grading statements guide the analysis of available evidence and provide transparency (Figure 1.4 and Table 1.2). For example, the assessment of biodiversity (Chapter 2) uses two assessment criteria: (i) habitats to support species, and (ii) populations of species or groups of species. Each assessment criterion comprises several components (Table 1.2). Based on analysis of the evidence available, each component receives an assessment grade (Section 1.4.1) and trend since the last Outlook Report (Section 1.4.2) at the scale of the Region. The component results are then combined to inform the grade for the overarching assessment criterion (Figure 1.5). Determination of both criteria grades and component level grades are guided by reference to standard grading statements (Section 1.4.1). Criteria and component assessments are presented in a table in the assessment summary at the end of each chapter.

In Chapters 2 to 4, over 80 components of the Region's natural, Indigenous and historic value are assessed (Table 1.2). Economic and social values of the Reef, which depend on the health of the ecosystem, are considered in a range of places in the report, particularly in Chapters 4 to 6.

To maintain the comparative value of the Outlook Report over time, changes to the assessed components have been limited to instances where they significantly improve the validity or utility of the assessment. For example, some changes to the assessment components examined in 2014 have occurred, predominantly the name of components that have not affected the scope of what is assessed or continuity of grades (changes are listed in Appendix 2).

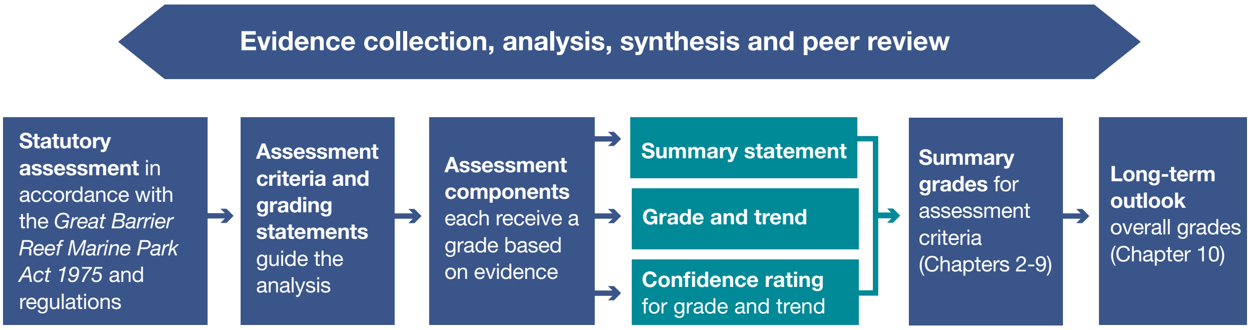


Figure 1.4 Assessment approach to determine final grades
The required assessments are based on the best available evidence. Grades are standardised against grading statements presented with each assessment summary.

Tabular corals. © Tane Sinclair-Taylor 2016

Table 1.2 Assessment criteria and their components

Each chapter of the report contains assessments of a specific set of criteria (bold text) and components (bullet points).

Chapter 2: Biodiversity	
Habitats to support species • Islands • Mainland beaches and coastlines • Mangrove forests • Seagrass meadows • Coral reefs • Lagoon floor • Shoals • Halimeda banks • Continental slope • Water column	**Populations of species and groups of species** • Mangroves • Seagrasses • Benthic algae • Corals • Other invertebrates • Plankton and microbes • Bony fishes • Sharks and rays • Sea snakes • Marine turtles • Estuarine crocodiles • Seabirds • Shorebirds • Whales • Dolphins • Dugongs

Chapter 3: Ecosystem health	
Physical processes • Currents • Cyclones and wind • Freshwater inflow • Sediment exposure • Sea level • Sea temperature • Light **Chemical processes** • Nutrient cycling • Ocean pH • Ocean salinity **Ecological processes** • Microbial processes • Particle feeding • Primary production • Herbivory • Predation • Symbiosis • Recruitment • Reef building • Competition • Connectivity	**Coastal ecosystems that support the Great Barrier Reef** • Saltmarshes • Freshwater wetlands • Forested floodplains • Heath and shrublands • Grass and sedgelands • Woodlands and forests • Rainforests **Outbreaks of disease, introduced species and pest species** • Outbreaks of disease • Outbreaks of crown-of-thorns starfish • Introduced species • Other outbreaks

Chapter 4: Heritage values	
Natural heritage values — world heritage and national heritage value • Natural beauty and natural phenomena • Major stages of the Earth's evolutionary history • Ecological and biological processes • Habitats for conservation of biodiversity • Integrity • Natural heritage values **Indigenous heritage values** • 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	**Historic heritage values — Commonwealth heritage values** • Commonwealth heritage value **Historic heritage values** • Commonwealth lightstations • Other historic lightstations and lighthouses • Historic voyages and shipwrecks • World War II features and sites • Other places of historic significance **Heritage values — other** • Social heritage value • Aesthetic heritage value • Scientific heritage value

Chapter 5: Commercial and non-commercial use	
Economic and social benefits of use • Commercial marine tourism • Defence activities • Fishing • Recreation (not including fishing) • Research and educational activities • Ports • Shipping • Traditional use of marine resources	**Impacts of use on the Region's values** • Commercial marine tourism • Defence activities • Fishing • Recreation (not including fishing) • Research and educational activities • Ports • Shipping • Traditional use of marine resources

Chapter 6: Factors influencing the Region's values	
Impacts on ecological values • Climate change • Coastal development in the Catchment • Land-based run-off • Direct use **Impacts on heritage values** • Climate change • Coastal development in the Catchment • Land-based run-off • Direct use	**Impacts on economic values** • Climate change • Coastal development in the Catchment • Land-based run-off • Direct use **Impacts on social values** • Climate change • Coastal development in the Catchment • Land-based run-off • Direct use

Chapter 7: Existing protection and management	
Elements of the management cycle (overall assessment) • Understanding of context • Planning • Financial, staffing and information inputs • Management systems and processes • Delivery of outputs • Achievement of outcomes	**Individual management topics** • Climate change • Coastal development • Land-based run-off • Commercial marine tourism • Defence activities • Fishing • Ports • Recreation (not including fishing) • Research activities • Shipping • Traditional use of marine resources • Biodiversity values • Heritage values • Community benefits of the environment

Chapter 8: Resilience	
Ecosystem resilience • Coral reef habitats • Lagoon floor habitats • Black teatfish (sea cucumber) • Coral trout • Loggerhead turtles • Urban coast dugongs • Humpback whales	**Heritage resilience** • Cultural practices, observances, customs and lore • Lightstations • Historic shipwrecks

Chapter 9: Risks to the Region's values
Overall risk to the ecosystem (natural heritage values) **Overall risk to heritage values** (Indigenous, historic and other)

Chapter 10: Long-term outlook
Outlook for the Region's ecosystem **Outlook for the Region's heritage values**

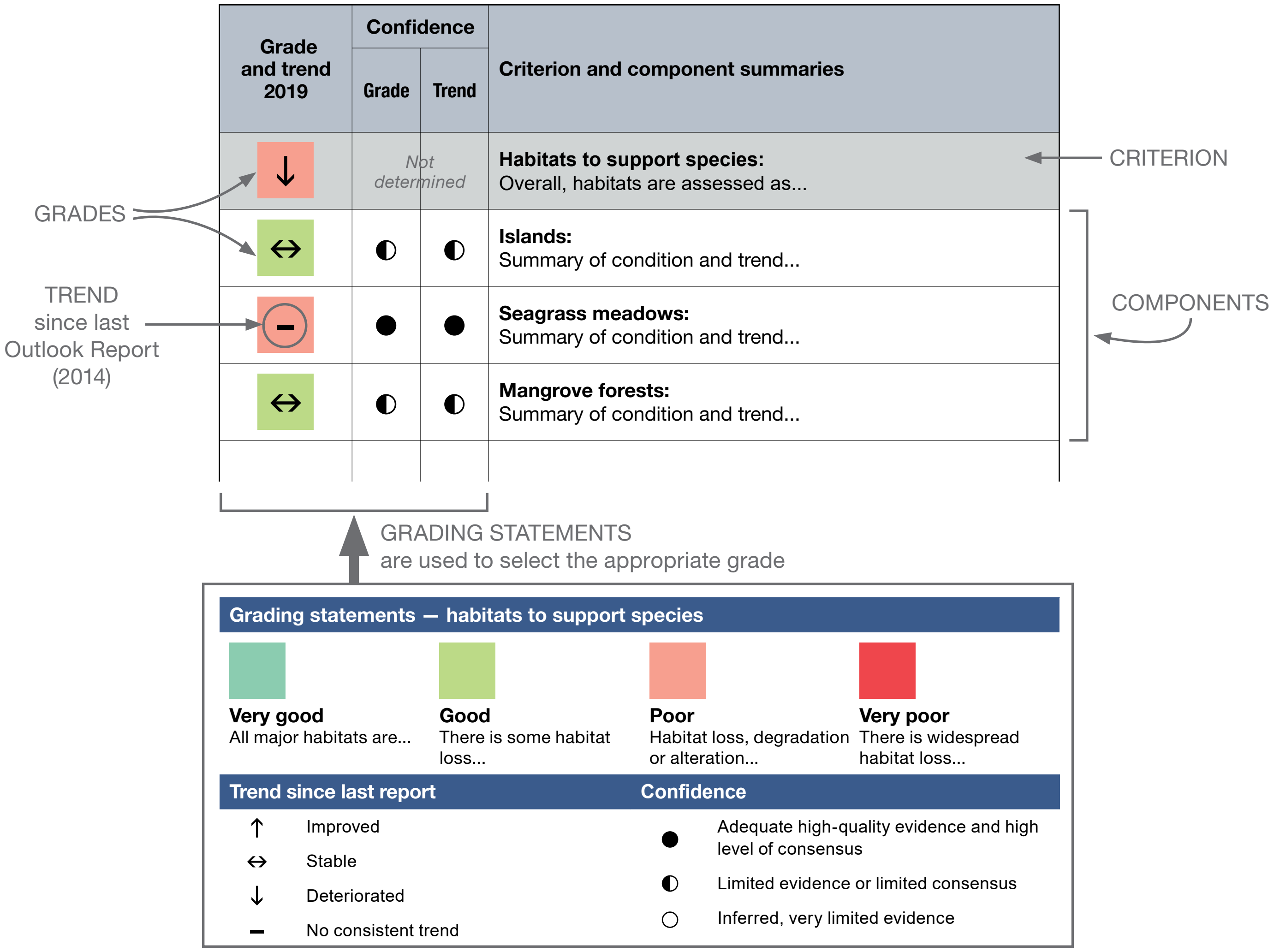


Figure 1.5 Grades for criteria are informed by grades for components
This figure shows an example extract from an assessment table for one of the biodiversity assessment criteria and illustrates the relationship between findings for a criterion and findings for its components. The grades for individual components (in this example, islands, seagrass meadows and mangrove forests) are key in informing the grade for the criterion (in this example, habitats to support species). Ultimately, both the criterion and component level assessments are guided by the relevant set of grading statements.

1.4.1 Assessment grades and grading statements

A series of grading statements standardise the allocation of grades for each criterion and all components examined in an assessment. A four-point grading scale has been used since 2009 and is continued for consistency. An example is shown in Figure 1.5. There is no option for ‘moderate’, so a decision is required about whether a component is in a positive or negative state. This application is consistent with the Australian State of the Environment Report.[4]

The grade allocated is a ‘grade of best fit’, based on a qualitative assessment of the available evidence and scaled to the Region (or Catchment for coastal ecosystems and coastal development). It is not a comparison of the Region in relation to other tropical ecosystems around the world. It is recognised that the condition grade of a component may not be consistent across the entire Region. Where there are important sub-regional differences in condition and trend that are supported by evidence (for example, corals), they are identified in the discussion and graphics within the main text of the chapter and considered in the grade and trend.

1.4.2 Trend and confidence

The grading is refined by including an indication of trend and confidence, similar to the Australian State of the Environment Report[4]. Trends are assessed in relation to the assessment of the component in the last Outlook Report (2014) as well as other available information on the trend in that component, if available. The trend reflects how the component has changed over the past five years. Previous grades (from 2009 and 2014) and trends (from 2014) are included in the assessment summary tables.

Chapters relating to factors that influence the Region's values, risks and long-term outlook contain forward-looking assessments. In these chapters (6, 9 and 10), trends in criteria and components are forecast for the next five years and beyond.

Four categories of trend are applied: 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 determine a trend. The terms 'improved' and 'deteriorated' are replaced with 'increased' and 'decreased' in assessments of impacts, threats and risks (Chapters 6 and 9). Trends are not indicated for components that were not assessed in previous Outlook Reports.

Outlook Reports are evidence-based and peer-reviewed. To increase transparency and reliability in the current grades, a level of confidence is provided. The categories used are:

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

For components where the confidence level is 'inferred, very limited evidence', the assessment grade should be treated with some level of caution given it is based on a limited amount of published peer-reviewed literature. Inferred assessments may also be based on knowledge from managing agencies, Traditional Owners, topic experts and informed stakeholders. Confidence levels are not provided for criteria assessments, as aggregating across components is difficult and there can be a high level of variability. A confidence level is also not provided for the assessment of existing protection and management (Chapter 7) because this assessment is conducted by independent reviewers and confidence levels are not currently part of that methodology.[5]

1.5 Evidence used

The Outlook Report contains brief background information on the Region, its ecosystem, heritage value, use and management, and the key evidence for the assessments required under legislation.

The information featured in this Outlook Report is only a small portion of all that is known about the Region. The evidence is derived from existing research and information sources from the past five years. The reporting period generally includes data from January 2014 to December 2018 and, where possible, compares it with historical trends. Evidence is drawn from the best available published science and data sets 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

Published peer-reviewed literature from technical experts is prioritised over other forms of evidence. Long-term data sets and peer-reviewed monitoring program reports are also considered highly persuasive evidence. Statistics from government-managed entities (for example, Australian Bureau of Statistics, Australian Maritime Safety Authority) are integral to the analyses in several chapters. Consultant reports may also be considered as part of the available evidence, but do not hold as much weight (particularly if not peer-reviewed). In some cases, information that became available in early 2019 has been included, where it was considered to make a significant difference to a key finding of the Outlook Report. Sources for the evidence used in each chapter are cited in the text. Web addresses provided in the report's reference list were correct at the time of writing. Despite the volume of information available, many aspects of the Region — its values, uses and threats, in particular cumulative effects — remain poorly understood. Significant information gaps[6] are noted in the text.

1.6 Terminology

Studies used in this Outlook Report vary in the spatial scales they cover. While only one grade is given for the Region, information available about a component (for example, seagrasses) may differ on a regional scale. The report attempts to discuss and summarise regional differences in condition and trend — however, there is no standard way of dividing up the Region when interpreting the data. Where evidence covers larger areas, for ease of reading and comparison, results are summarised into three sub-regional marine areas (or 'thirds of the Reef'): northern, central and southern. Their boundaries are not precisely defined, but the northern area extends from the tip of Cape York to approximately Port Douglas (which marks the division between the less-developed and developed catchments adjacent to the Region). The central area extends from the northern area south to the Whitsundays area. The southern area extends south of the Whitsundays area to the Region's southern boundary just north of Bundaberg. The term 'southern two thirds of the Region' is often used to describe the combined central and southern areas.

Great Barrier Reef Marine Park 'management areas' are sometimes used to describe the main zoning sections within the Region: Far Northern (or far north), Cairns–Cooktown, Townsville–Whitsunday and Mackay–Capricorn. Within the Catchment and inshore locations, sectors are described by natural resource management regions: Cape York, Wet Tropics, Burdekin, Mackay–Whitsunday, Fitzroy and Burnett–Mary.

The Region is defined by the Act, whereas the Catchment is managed by multiple jurisdictions and is not specifically defined by Queensland legislation. The Catchment (Figure 1.1) encompasses the 35 river basins flowing into the Region. Across the Region, the term 'inshore' may be applied differently for water quality, biodiversity and ecosystem health components. Inshore areas broadly correspond to enclosed coastal water bodies adjoining inter-tidal areas and habitats adjacent to the coast, and inshore from mid-shelf reefs. Areas beyond are generally referred to as 'offshore'. For coral reefs, the term 'outer shelf' refers to reefs along the edge of the continental shelf and 'mid-shelf' refers to reefs between inshore areas and the outer shelf.

1.7 Developing the report

This Outlook Report has been prepared by the Marine Park Authority, with contributions of evidence from a number of Australian and Queensland Government agencies, researchers from a range of institutions, industry data-holders and Traditional Owners.

The outcomes of an expert elicitation workshop[7], involving more than 30 scientists and other stakeholders, contributed to the biodiversity, ecosystem health and heritage value assessments (Chapters 2, 3 and 4). The outcomes also informed the forward-looking risk and resilience assessments (Chapters 8 and 9). The methodology for the expert elicitation workshop was modelled on similar workshops used for previous Outlook Reports.[2]

Five independent experts specialising in protected area management, monitoring and evaluation, public policy and governance assessed the effectiveness of existing protection and management arrangements for the Region's ecosystem and its heritage value and, where relevant, the Catchment[5]. This independent assessment of management effectiveness also incorporated evidence from structured stakeholder interviews. The assessment identified gaps, improvements and deficiencies, and produced a comparative analysis with the 2009 and 2014 assessments. An additional synthesis report was developed to provide insights into the Reef 2050 Plan's contributions to effective management of the Region. The assessors' reports[5,8] form the basis of the assessment of existing measures to protect and manage the Region (Chapter 7).

Four expert reviewers, appointed by the Australian Minister for the Environment, independently reviewed the draft Outlook Report. These reviewers are recognised national and international experts with biophysical, heritage and/or socio-economic expertise and achievements, including conducting high-level policy and scientific reviews. Their comments were considered and incorporated into the final report.

Herbivorous surgeonfish forage on a reef flat. © Matt Curnock 2015

BOX 1

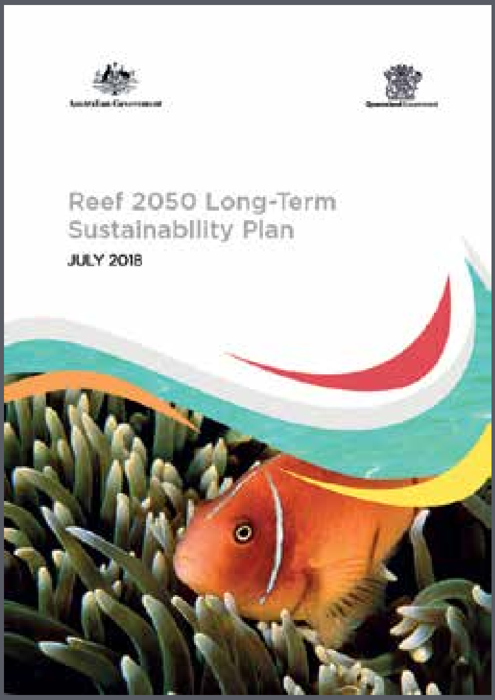
Reef 2050 Long-Term Sustainability Plan

In 2015, the Australian and Queensland governments released the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan)[9] following extensive consultation with Traditional Owners, stakeholders and scientists. A mid-term review updated the plan in 2018 to incorporate revised water quality targets and stronger recognition of climate change as a key pressure.[9]

The Reef 2050 Plan marks a shift in how the Australian and Queensland governments and their partners collaborate in addressing challenges that the Reef is currently facing. For the first time, all key partners are working together to build on the management foundations laid over the past 40 years. The plan was developed in response to the World Heritage Centre's request for a coordinated and long-term plan for the sustainable management of the Reef.

The Reef 2050 Plan articulates a 35-year strategy to protect and improve the components and attributes that contribute to the Reef's outstanding universal value through a robust scientific adaptive management framework. It focuses improvement actions under seven themes: ecosystem health, biodiversity, heritage, water quality, community benefits, economic benefits and governance. These themes were influenced by the Outlook Report 2014. Similarly, the Outlook Report 2019 will inform a review of the Reef 2050 Plan in 2020.

To support the implementation of the Reef 2050 Plan, an investment framework[10] was developed in 2016 to guide investment decisions for the delivery of Reef 2050 Plan actions. The revised Reef 2050 Plan identifies priorities for immediate attention and new actions to protect the values of the Reef and improve the Reef's resilience. It reaffirms the importance of a strong, coordinated approach to managing the Reef.

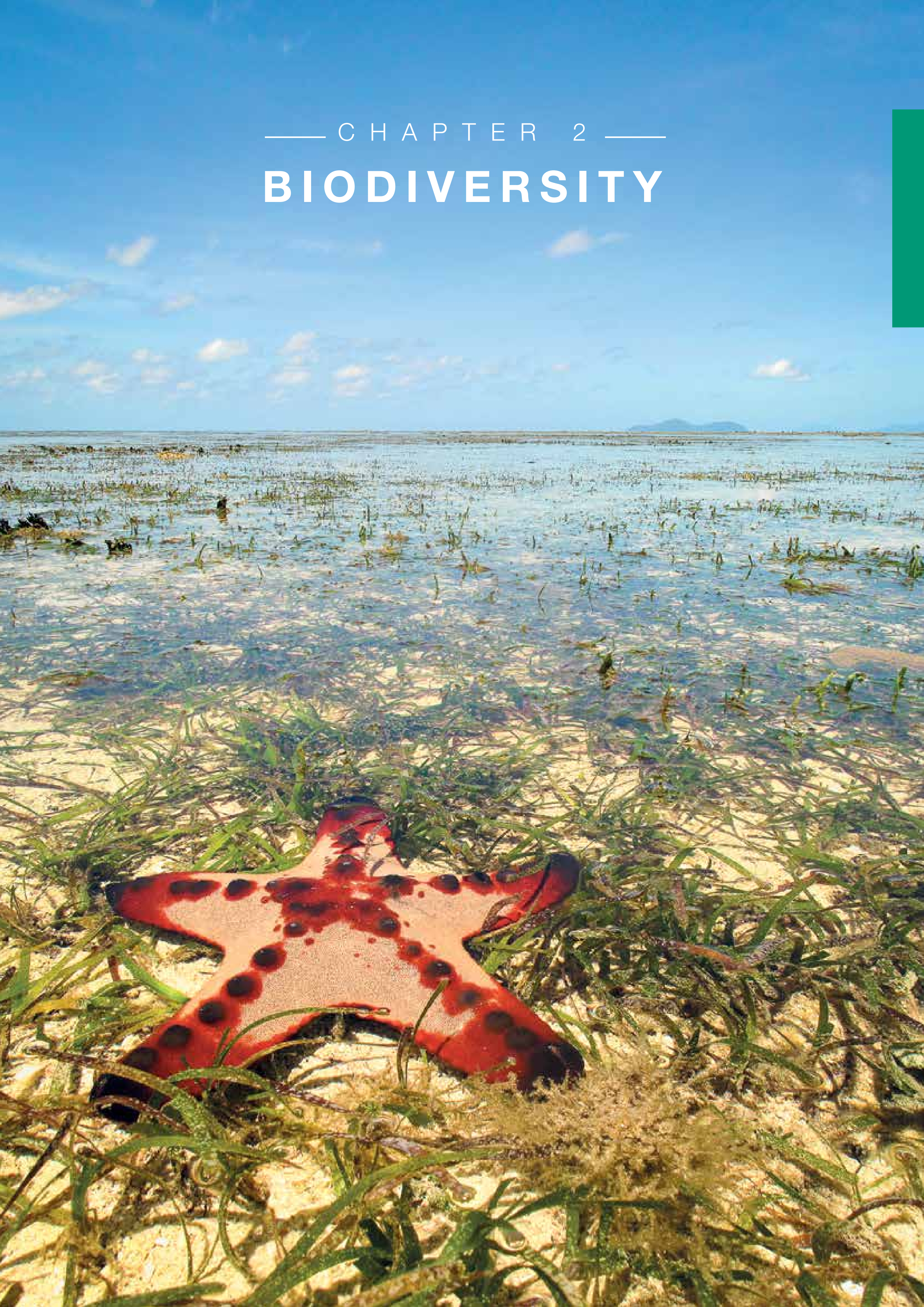


Reef 2050 Long-Term Sustainability Plan

JULY 2018

CHAPTER 2

BIODIVERSITY



« *A horned seastar nestled in the seagrass at Green Island.* © Dieter Tracey 2014

BIODIVERSITY

(an element of natural heritage)

'an assessment of the current biodiversity …' within the Great Barrier Reef Region, s 54(3)(b) of the *Great Barrier Reef Marine Park Act 1975*

2.1 Background

Biodiversity is the variety of all living things, including plants, animals and microbes (and their genetic information). Biodiversity forms an important component of natural heritage and is integral to ecosystem resilience (Chapter 8). Species diversity, or the number of species in a given area, is often used as a measure of biodiversity. In order to understand ecosystem health, an understanding of species diversity, species abundance and ecosystem processes are required, rather than biodiversity alone. The Reef remains one of the world's most diverse and remarkable ecosystems and is the largest coral reef system in the world. Biodiversity is critical to the Traditional Owners of the Reef and the outstanding universal value of the world heritage property. Interactions between species and communities, and the processes that underpin and support biodiversity, are addressed in Chapter 3.

The assessment in this chapter focuses on the broad habitats that make up the Region's ecosystem (Figure 2.1), and the species and groups of species supported by these habitats. It includes an assessment of beaches, coastlines and island habitats, some of which fall outside the jurisdiction of the Region, but are connected to and critical to the health of the Region. Condition and trend assessments for coastal ecosystems that support the Reef (for example, woodlands, Figure 2.1) are assessed in Chapter 3. The species and habitats assessed are consistent with those in the 2009 and 2014 Outlook Reports, with the exception of macroalgae and benthic microalgae; these have been combined into a single component called benthic algae (Appendix 2).

Islands support a variety of plants and animals. © GBRMPA

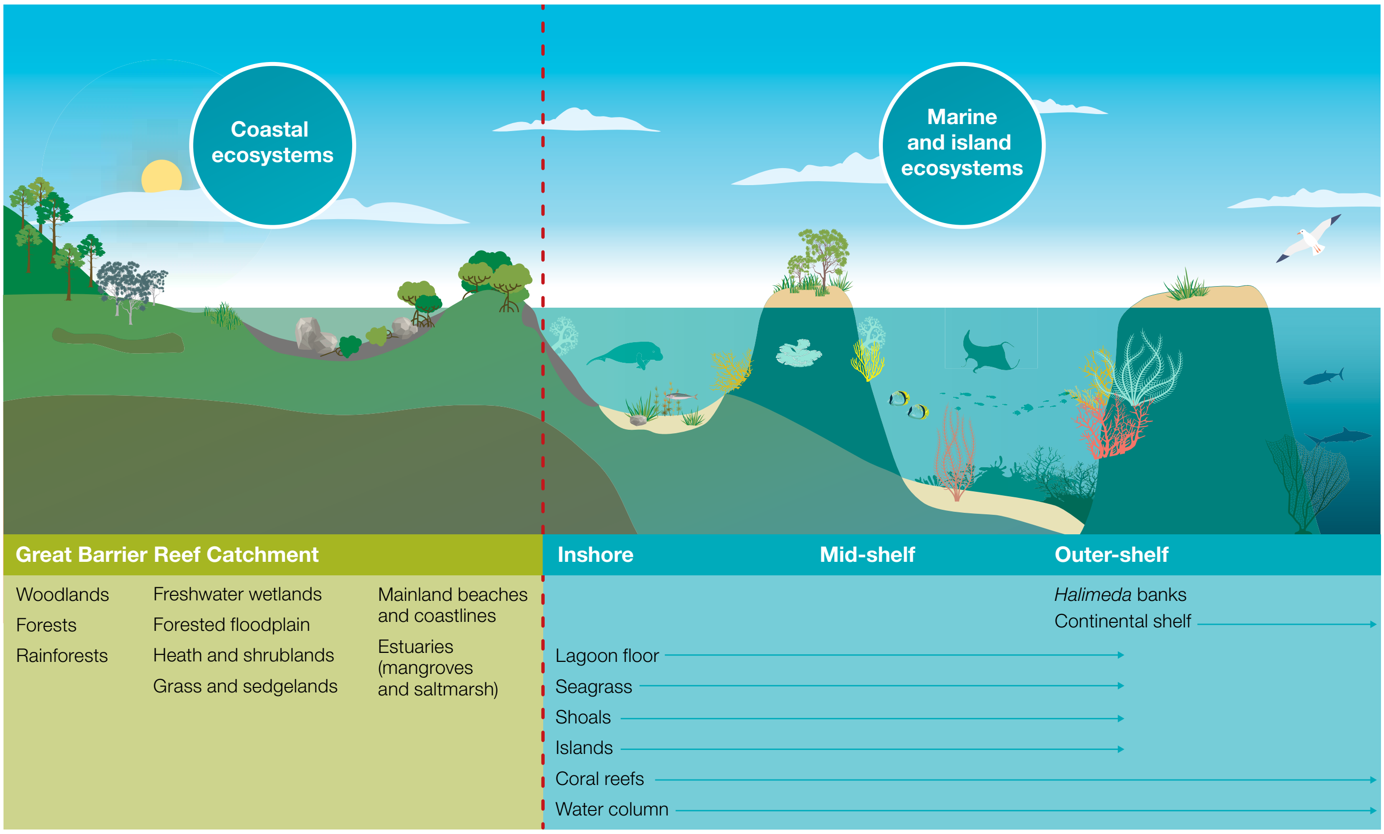


Figure 2.1 Major habitats that comprise the overarching ecosystems of the Reef and Catchment
A wide variety of habitats make up the Reef's coastal and marine ecosystem. The most pronounced variation is across the continental shelf from the inshore coastal habitats, such as mangroves and beaches, eastwards to the continental slope and deep ocean.

2.2 Legacies and shifted baselines

2.2.1 Legacy impacts

Legacy human use impacts encompass activities, such as historical land clearing and overfishing, that caused significant environmental change in the past and continue to have major effects today.[11] Some species and habitats that were commercially exploited in the past are showing signs of recovery (for example, humpback whales Sections 2.4.14 and 8.3.7), while others are not (for example, some marine turtle stocks).

It may take decades or longer for populations and habitats to fully recover to their pre-disturbance state. Species and habitats that are still recovering include dugongs, turtles and some islands that were cleared and mined for guano (Sections 2.3.1, 2.4.10, 2.4.16 and 8.3.6). For example, after 100 years of European settlement, many Reef islands still require active pest management programs to treat the legacy of pests introduced over a century ago (Sections 3.6.1).

Introduced goats on High Peak Island remove native vegetation and cause erosion. © Queensland Parks and Wildlife Service, photographer: Ben Geddes

2.2.2 Shifting baselines

Human activity has caused significant environmental change for centuries. Identifying the pristine state, or natural baseline, from which to measure environmental change can be problematic. This is due to shifting baseline syndrome, whereby the natural baseline gradually shifts over human generations as accepted norms for the condition of the natural environment change due to a lack of experience, memory and knowledge of its past condition.[12] A shifted baseline can result in increased tolerance for progressive environmental degradation.[13] In this way, progressive

Trevor Fuller holding two 33 kilogram Spanish mackerel caught at the Palm islands, Townsville, ca. 1988. © Trevor Fuller

degradation, such as large declines in species over long periods of time[12] or the current pace of global warming[14], may not be clearly recognised. Therefore, it is important to acknowledge the risk of using a shifted baseline to underpin a current assessment.

Within the Region, long-term scientific data and multi-generational knowledge enable a relatively accurate assessment of the condition and trend of Reef values over time. However, early accounts of the Reef may consist of first-hand observations or unwritten records, which some may consider to be anecdotes. The use of such information can provide important knowledge about the past, complement scientific records and help avoid a shifting baseline syndrome. The concept of a shifting baseline is described below using two examples within the Region.

Spanish mackerel fishery: Spanish mackerel (*Scomberomorous commerson*) is among the top three fish prized by recreational fishers and is one of Queensland's most valuable commercial fish species (Section 5.4). Today's recreational fishers are limited to three fish per person per day, and commercial catch rates are approximately 11 fish per vessel per trip.[15] Young fishers just beginning their careers might perceive this as a good day's catch, accepting the current catch rate as normal and the baseline from which they will evaluate future change. However, the previous generation of fishers may recall that only 15 years ago (2004) the recreational catch limit was 10 fish per person, and 80 years ago (1940s) commercial catch rates averaged 120 fish per vessel per trip.[15] Compared to their baseline, older generations of fishers will perceive drastic changes in the fishery that modern fishers might not recognise. Recent research has reconstructed catch rates and exploitation trends of this fishery by collecting information from newspaper archives, fisher knowledge, and contemporary fishery logbooks.[15,16] The findings have validated older generations' perceptions of drastic change, indicating that over-exploitation of vulnerable spawning aggregations led to a 90 per cent decline in catch rates from 1934 to 2011.[15,16] Incorporating historical information can provide a more accurate baseline from which to assess the sustainability of a fishery, determine current management actions, and potentially help overcome shifting baseline syndrome.

Coral composition (Section 2.3.5): An individual's perception of a baseline will be influenced by their recollection of what the coral reef looked like from a previous visit. The actual natural baseline may be very different and may have changed several times over thousands of years. A change in the types of coral present is a critical factor in determining a shifted baseline. While historical photographs may not provide definitive quantitative proof of change, they can provide a useful qualitative benchmark to identify a potential shifted baseline.[17] It is also possible to identify changes to the Reef from a past baseline through coral coring and reef sediment coring techniques that infer historical coral reef condition. Quantitative data, ongoing long-term monitoring programs of reef condition and oral histories can help identify changes to the Reef. When combined with geological dating and monitoring, time-series photographs that are taken with precision can provide a valuable reference point.[17]

To demonstrate this concept, historical inshore reef flat photos were compared with recent images from four locations between Cairns and Townsville, following previous methodology (Figure 2.2).[18] Changes in coral cover varied over time and across locations. The greatest visual changes in coral cover were evident at Dickson Inlet (near Cairns, top series) and Geoffrey Bay (Magnetic Island, third series). At these sites, previously diverse reef flats characterised by high coral cover are now predominantly dominated by algae and sediment, interspersed with only small amounts of live coral. Coral cover and assemblages on a Fitzroy Island reef flat (second series) and Middle Reef (on Magnetic Island, bottom series) have also changed over time but not to the same extent.

The visible changes in reef structure on the photographed inshore reefs may reflect higher exposure to land-based run-off and they align with results from more rigorous quantitative studies on inshore reefs.[19] Some of the photographs and coring research[20,21] also highlight that, despite being exposed to more land-based influences now than in the past, certain inshore corals can grow and persist in marginal conditions.[22,23]

Reef users understand the condition of the Reef has deteriorated in their lifetime. This deterioration was accelerated by unprecedented back-to-back mass bleaching events in 2016 and 2017. Since then, research and development funding to explore reef restoration and intervention techniques has increased.[24] Permit applications to undertake small-scale restoration research projects have also increased. From a shifting baseline perspective, performance indicators that do not recognise historical baselines[25] may be working towards a desired state set on the basis of recent social perception rather than the historical ecological baseline.[26]

Figure 2.2 Potential shifting baselines — inshore coral reefs over time
First row: Dickson Inlet (Cairns) 1950 (© Lee Middleton) *and 2018* (© Qld Government – Graham Barnes)
Second row: Fitzroy Island (Cairns) 1900s (© James Cook University), *1995* (© GBRMPA), *and 2018* (© Qld Government – Tayce Cook)
Third row: Geoffrey Bay (Magnetic Island) 1995 (© Stuart McAulay) *and 2018 (*© Qld Government – Patrick Centurio)
Fourth row: Middle Reef (Magnetic Island) 1996 (© GBRMPA) *and 2018* (© Qld Government – Sarah Ballard)

2.3 Current condition and trends of habitats to support species

Ten habitats are assessed; a large amount of variability in condition occurs across the Region. *Halimeda* banks continue to be considered in very good condition (although data are limited) and the continental slope has been upgraded to very good. Islands, mainland beaches and coastlines, mangrove forests, lagoon floor, shoals, and the water column remain in good condition (although data are limited and water column condition is considered borderline with poor). However, seagrass meadows continue to be assessed as poor, and coral reefs have deteriorated to a very poor condition (based on adequate data).

↓

Full assessment summary: see Section 2.5.1

The Region comprises a range of habitats (Figure 2.3). The entire Region (habitats, species and processes) is under increasing threat from the broad-scale impacts of climate change. Also, human activities in the Region and Catchment continue to affect biodiversity values, with areas of the Region adjacent to large human populations and significant agricultural use generally under higher pressure.

Climate change and climate extremes have been the primary causes of habitat deterioration since 2014, adding to legacy and current impacts, such as pollutants in land-based run-off and an ongoing crown-of-thorns starfish outbreak. Unprecedented ocean warming causing mass coral bleaching in 2016 and 2017 has significantly affected large areas of the Region. Large-scale loss of coral habitat has resulted, and flow-on effects for species and ecosystem processes are still unfolding.

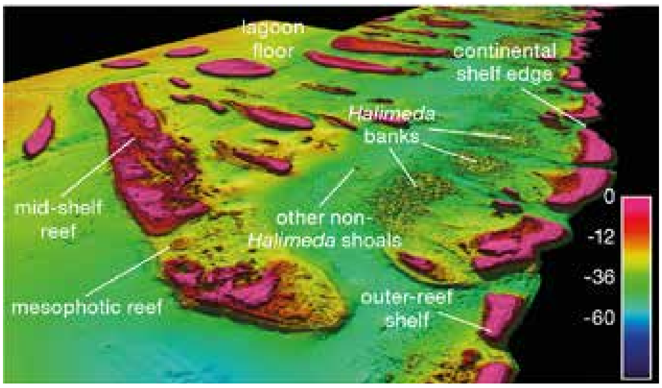


Figure 2.3 Reef geomorphological features
A 3D image of the Ribbon reefs in the northern Great Barrier Reef identifying different habitat types. © Dr Robin Beaman, James Cook University

Habitats can be highly variable across space and time, creating challenges for monitoring and evaluation of their condition at a Region-wide scale. Where good quality information is available, assessments are given a higher confidence rating compared to where data are more limited or lacking (Section 2.5.1 assessment summary table).

2.3.1 Islands

The Reef ecosystem includes approximately 1050 islands, comprising coral cays, continental islands and mangrove islands. The islands within the Region include 70 under Commonwealth jurisdiction, with the remainder under Queensland Government jurisdiction or privately owned. This assessment includes all islands because of their connection to, and influence on, the values of the Region. Islands support unique assemblages of flora and fauna and are critical to the life cycles of many species.[27] The diversity of islands and the habitats they provide are attributes that contribute to the Reef's outstanding universal value.[28]

Some islands are showing signs of recovery from past impacts

Continental islands, cays and mangrove islands support over 200 bird species and provide important nesting sites for marine turtles. Islands are important refugia for animals and plants, such as *Pisonia* forests which, in Australia, are largely restricted to coral cays within the Region.[27] Islands also provide a number of ecosystem services, such as buffering the coast from storms, supporting nutrient cycling to adjacent marine ecosystems, and contributing to soil and sand formation.[27,29]

While long-term standardised data on the condition of most islands and species that depend on them are lacking, considerable efforts and monitoring programs are currently directed towards improving this.[30] Since 2015, 118 islands have been assessed, resulting in several detections of invasive species and rapid management responses. While the data-set remains limited to short-term assessments of approximately 10 per cent of the Region's islands, it remains difficult to assess the overall state of the Region's islands. Where data are available on the condition and trend of islands, generally their condition remains good.

In locations where islands have suffered recent disturbances (for example, Whitsunday Island), recovery is being observed. Intervention actions over many years have aimed to remove or mitigate threats, enable recovery and build resilience to future threats. These actions include habitat restoration through replanting, re-profiling beaches, installing fencing (for example, Raine Island) and fire management.

Islands around the world, particularly low-lying islands, are already threatened by sea-level rise and coastal erosion. Evidence suggests that these stressors are already affecting the Region's islands. Coral reef islands, such as Raine Island, are one of the most vulnerable habitats to climate change because they are low-lying and growth and maintenance depend on sediment accumulation. These sediments are derived from reef organisms, such as benthic foraminifera, and are particularly susceptible to ocean acidification.[31,32] Since 2014, some Reef islands, such as Whitsunday and Curtis islands, have been affected by severe cyclones, wildfires, and changes driven by coastal development and industrial and residential infrastructure. Marine debris and invasive plant and animal pests also remain a significant threat to island values (Section 3.6.3).[33,34,35,36,37] Although localised damage has occurred on some islands, the overall condition remains stable across the Region.

2.3.2 Mainland beaches and coastlines

The mainland beaches and coastlines of the Reef stretch for approximately 2300 kilometres. Beaches and coastlines provide important habitats for a range of species, such as marine turtles[38], shorebirds[39], crustaceans, worms and molluscs. Intertidal and shallow coastlines provide suitable hard surfaces for attachment of corals, algae and invertebrates, while soft sediments support seagrass meadows and burrowing invertebrates. Beaches and coastlines provide significant natural resources and valuable ecosystem services, including recreation, spiritual values and coastal protection against cyclones and waves.[40]

Coastlines are constantly changing as a result of natural processes.[41] The coastal zone north of Port Douglas is relatively unaltered due to intact vegetation and limited coastal development. Nonetheless, this remote area can be affected by cyclones and marine debris transported by currents.[42,43] Climate change impacts, including extreme weather events, increased erosion and changes in sea level, are affecting beaches and coastlines.[41] Whitehaven Beach was one of the sites most affected by cyclone Debbie in 2017.[35] Fallen trees and debris were removed by machinery, and 10,000 cubic metres of sand was shifted to reinstate the beach profile.[35] There are knowledge gaps in relation to the current condition and trend of mainland beaches and coastlines due to limited monitoring across the Region. However, these habitats are generally considered stable across the Region.

Beaches and coastlines provide significant natural resources and valuable ecosystem services

2.3.3 Mangrove forests

Mangrove forests are tidal habitats defined by the trees, shrubs and palms adapted to grow in the salty, oxygen-limited soils of the upper intertidal zone. These habitats cover an estimated 2710 square kilometres in, and adjacent to, the Region.[44] They occur in estuaries, rivers and bays and around islands, often where sediments accumulate and seawater regularly inundates the habitat during the tidal cycle.[45] Mangrove forests are a critically important habitat providing nursery and breeding areas for many commercial and non-commercial species, such as mangrove jack and prawns.[46,47,48] They also provide important ecosystem services, including coastal protection, pollution absorption, nutrient cycling, primary production and carbon storage.[47,49,50,51]

Several cyclones have resulted in localised mangrove forest dieback in some locations, including Starcke River, Cape York (cyclone Ita, 2014 and cyclone Nathan, 2015), Hinchinbrook Island (cyclone Yasi, 2011) and the Whitsundays (cyclone Debbie, 2017).[52] Before cyclone Marcia crossed the coast in 2015, mangrove extent in the Fitzroy region was relatively stable. After exposure to wind speeds at or above Category 4, the Fitzroy region experienced a decline in canopy cover, from 30 square kilometres to one.[53] After three years, the canopy cover is showing signs of recovery with increases in both open and closed forest (Figure 2.4).[53]

Globally, most mangrove loss is caused by coastal development, although weather-related events can also cause significant impact, particularly cyclones, extreme sea-level variation and heatwaves.[54] Clearing of mangroves occurred widely as a result of coastal development and legacy issues still exist. However, clearing is now strictly regulated. Therefore, the main driver of change in mangrove condition within the Region is currently cyclones, which are projected to increase in intensity.[52,55,56] Localised mangrove forest damage from cyclones is expected to have long-term effects on Reef habitats and species[52,57] due to reduced filtration of land-based run-off. Evidence to date indicates the reduction in localised canopy cover from cyclones is likely to recover in less than a decade[57], in the absence of other pressures (sea level rise and extreme temperature). However these pressures are expected to increase under climate change projections.

Severe tropical cyclones have reduced mangrove canopy cover in some local areas

Some mangrove forests will be negatively affected by the continuing intensification of El Niño with climate change and associated sea-level fluctuations and temperature increases.[49] Shoreline retreat and erosion are occurring along the Queensland coast, with sea-levels rising faster in the north than in the south.[52] Although localised loss of mangrove forests has occurred, recovery has been observed and overall they remain in a stable condition.

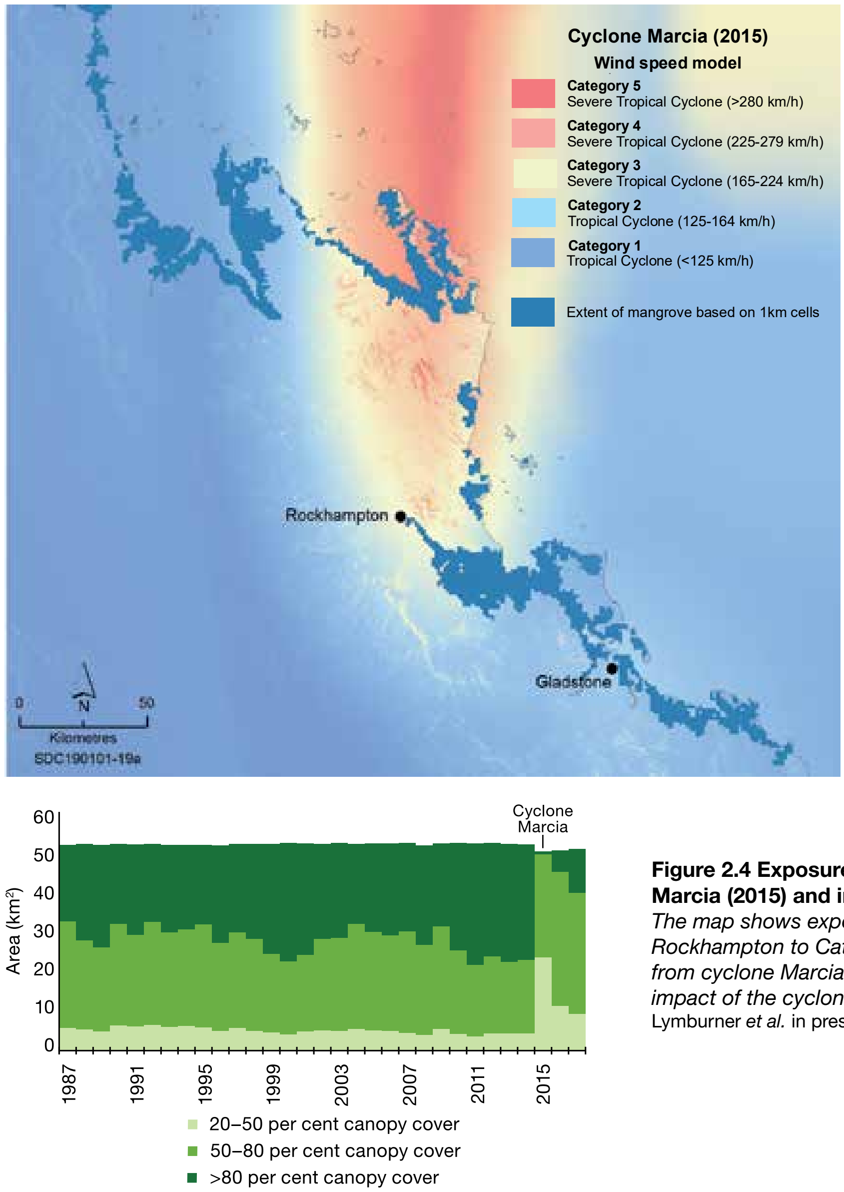


Figure 2.4 Exposure of mangrove forests to cyclone Marcia (2015) and impact on canopy cover
The map shows exposure of mangrove forests near Rockhampton to Category 1, 2, 3, 4 and 5 wind speeds from cyclone Marcia (2015) and the graph shows the impact of the cyclone on mangrove canopy cover. Source: Lymburner *et al.* in press[53]

2.3.4 Seagrass meadows

Seagrass meadows are one of the most important habitats in the Region. They stabilise the seafloor, protecting it from erosion and cyclones, and play an important role in nutrient cycling and carbon sequestration.[58,59,60,61] Seagrass meadows form highly productive habitats for fish, invertebrates and algae[59] and are the primary food source for dugongs and green turtles.[62,63,64] In turn, dugongs and green turtles assist in connecting seagrass meadows by potentially distributing viable seagrass seeds through faecal matter.[65] Inshore seagrass habitats provide important connectivity pathways for many reef fish, such as emperor and tuskfish.[59,66,67,68] Deep-water seagrasses have been found down to 61 metres. Though generally sparse compared to shallower inshore meadows, they can be denser in some locations, such as around Green and Lizard islands.[69,70,71,72]

Recovery of inshore seagrass meadows stalled in 2016–17 as a result of marine heatwaves and cyclone Debbie

Inshore seagrass abundance and condition varies across the Region. Inshore seagrass abundance increased at most locations from 2011 to 2016, following multiple years of above average rainfall and climate-related impacts (Figure 2.5).[64,73] However, recovery slowed or stalled across most of the Region in 2016–17.[74] The disruption to recovery was due to a number of factors, including marine heatwaves that affected all inshore seagrass meadows in the northern and central sectors in 2016 and 2017, increased nutrients and sediments from land-based run-off, increased turbidity from Cyclone Debbie in 2017 (the Whitsundays), and above-average winds which, may have contributed increased inshore turbidity in the far northern and central regions.[74,75] Assessment of the overall seagrass condition also considered reproductive effort (a measure of seeds and fruits). Reproductive effort within inshore seagrass meadows remains low in the Region.[74] The absence of seed banks and low reproductive effort has resulted in many seagrass meadows being vulnerable to future disturbances.[74]

Reduced resilience following multiple stressors means that seagrass meadows may take longer than five years to recover.[76,77,78,79] Recovery will depend on available seed resources[59], connectivity[80] (Section 3.4.10), good water quality and adequate recovery windows. Climate change impacts (such as heavier rainfall events and marine heatwaves) have already caused seagrass diebacks in Australia (Section 6.3.2). The loss of seagrass meadows causes the releases of stored carbon, further contributing to global warming.[51,61] Overall, seagrass abundance has been positive, albeit with some variability across the Region. Seagrass meadows, however, remain vulnerable to ecosystem disturbances and inadequate recovery windows.

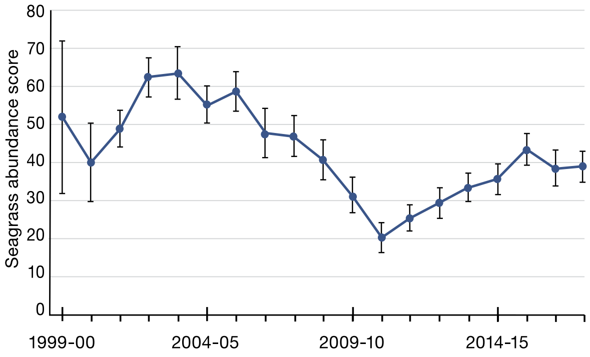


Figure 2.5 Seagrass abundance score for inshore meadows, 1999–2018
Abundance scores (with standard errors) for inshore seagrass meadows from Cape York to Burnett–Mary region. Note: more sites, including intertidal and subtidal, were added since Outlook Report 2014, which may have affected the scores. Source: McKenzie *et al.* 2019.[74]

2.3.5 Coral reefs

Of all the habitats within the Reef ecosystem, coral reefs are the most iconic and support the greatest known diversity of plant and animal species.[81,82,83] The Reef is the world's largest coral reef ecosystem, stretching 2300 kilometres and comprising almost 3000 individual reefs.[84] The Region's reefs occur in various depths, from very shallow estuarine areas to deeper oceanic waters off the continental shelf.[85] Coral reefs provide the Region's communities with substantial benefits, such as tourism, productive fisheries[86] and coastal protection against natural hazards, such as damaging waves.[87] The Region's coral reefs are key contributors to its outstanding universal value as a World Heritage Area.[28]

The Region was affected by consecutive mass bleaching events in the summers of 2016 and 2017. In 2016, intense heat exposure caused severe bleaching in the northern third of the Reef, while in 2017 severe bleaching mainly affected the central region.[88] Aerial surveys conducted in both years along the entire length of the Reef measured the spatial extent and scored the severity of coral bleaching.[89] The combined footprint of severe bleaching extended along the northern two thirds of the Region, while most of the southern third escaped impact (Figure 2.6).

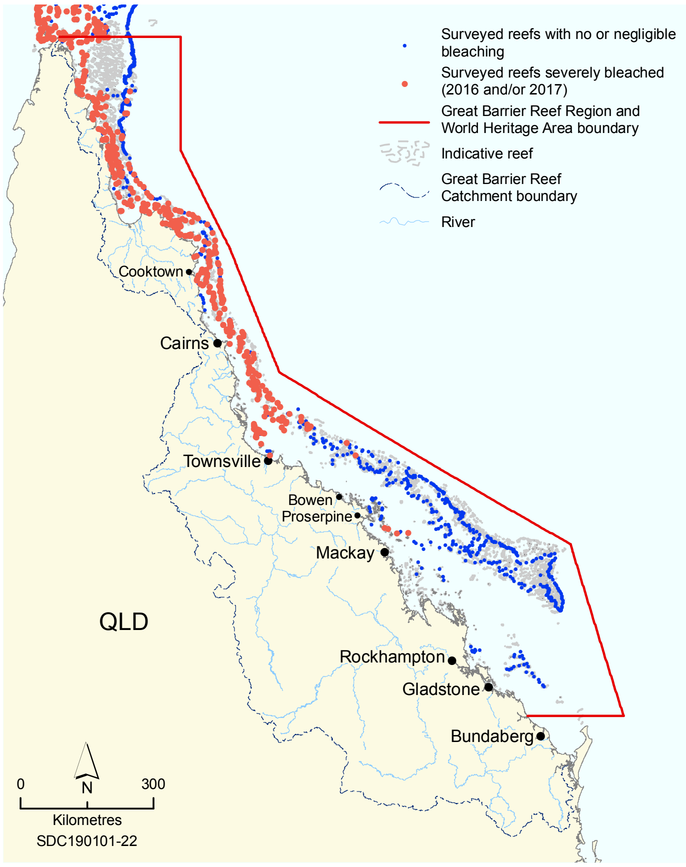


Figure 2.6 Cumulative footprint of coral bleaching in the Great Barrier Reef during the summers of 2016 and 2017
Dots indicate: (red) surveyed reefs where >60 per cent of corals were bleached; and (blue) reefs that were surveyed but had no or negligible bleaching. Source: ARC Centre of Excellence for Coral Reef Studies[94]

In late 2016, underwater surveys were conducted at depths between two and 10 metres, to ground-truth aerial surveys and record the level of post-bleaching coral mortality on over 100 reefs.[89,90] An estimated 30 per cent of shallow-water coral cover was lost.[90,91] Severe bleaching and some mortality of corals were also observed on northern mesophotic (deep) reefs at 40 metres depth along the outer shelf.[92] However, coral bleaching and mortality generally declined with increasing depth.[93] In 2017, the spatial extent of severe bleaching was estimated by aerial surveys only (Figure 2.6)[88], therefore coral mortality was not quantified. However, given the severity of bleaching observed, it is certain that the 2017 bleaching event caused a further decline in coral cover across the northern two thirds of the Marine Park.[90,91]

> *Severe disturbances since 2014 have resulted in the greatest loss of coral habitat ever recorded on the Reef*

In addition, five severe cyclones (Section 3.2.2) have affected various parts of the Region since 2014. Cyclone Debbie crossed over the Whitsundays area in late March 2017 as a slow-moving Category 4 cyclone. Damaging waves cause up to 97 per cent loss of coral cover on some shallow reefs in that area (Figure 2.7).[95] A recent increase in crown-of-thorns starfish outbreaks has reduced mean coral cover on the Swain Reefs in the southern Region since 2017.[95] As at mid–2018, trends in mean hard coral cover on shallow-water reefs in all three regions (northern, central and southern) show steep declines; such widespread decline following these events has not been observed in the historical record of coral reef monitoring.[95] The substantial loss of adult corals caused a subsequent 89 per cent decline in coral recruitment across the Region in 2018[96] and evidence is emerging of flow-on effects to fish populations (Section 2.4.7). Not all reefs in the Region have been affected; reefs that escaped impacts of bleaching, cyclones and crown-of-thorns remain in good condition.

Coral recovery requires adequate periods of time without further disturbance, favourable environmental conditions, inter-reef connectivity, an adequate supply of coral larvae, and successful coral recruitment. Survey data from 2019 found widespread, low-level coral bleaching and recent storm damage on some outer-shelf reefs in the northern Region, probably due to cyclone Penny in January 2019.[97,98] Coral juveniles were observed in densities likely to support future reef recovery.[97] The back-to-back bleaching events in 2016 and 2017 are indicative of the global trend toward more frequent extreme temperatures resulting from global warming. They also illustrate the reduced opportunity for recovery of corals between recurrent bleaching events.[99] The cumulative effects of prolonged thermal stress and unprecedented peaks in summer temperatures in 2016 and 2017, crown-of-thorns starfish predation, and regional cyclone damage have caused widespread loss of corals and significant deterioration in the condition of coral reef habitats since 2014.

Figure 2.7 Changes to coral communities from disturbances since 2014
Time series photographs depicting changes to coral reef habitats due to mass coral bleaching and cyclone Debbie.
First row: Opal Reef in the northern Great Barrier Reef before, during and after the 2016 mass bleaching event.
(left to right: September 2015, April 2016, November 2016). High mortality of all coral types was observed, with turf algae growing over dead coral skeletons. © Taylor Simpkins
Second row: Double Cone Island in the Whitsundays area of the Great Barrier Reef in 2014, post-cyclone Debbie in 2017 and mid-2018 (left to right). This inshore reef monitoring site exhibited a 97 per cent reduction in coral cover and removal of coral structure by destructive waves. © Australian Institute of Marine Science 2019

2.3.6 Lagoon floor

The lagoon floor is a diverse and important habitat within the broader coral reef ecosystem, accounting for approximately 61 per cent of the Region and supporting over 5000 species.[100,101] It includes the non-reefal seafloor inside the outer barrier reefs, typically at depths of between 20 and 40 metres.[102]

The lagoon floor consists of variable surfaces, including structurally simple muddy and sandy sediments, and more complex structures formed by algae, sponges, corals, ascidians, gorgonians and other sessile organisms. Economically, these inter-reefal habitats are vital to the prawn, scallop and sea cucumber fisheries.[103] Ecologically, lagoon floors are important in primary production, nutrient cycling, carbon sequestration and sediment trapping.[102]

Thousands of species of echinoderms, molluscs, crustaceans and worms inhabit the sediment and are vital in supporting the food web.[104] Large organisms, such as sharks, turtles and fish, rely on the surface and structures found on the lagoon floor for food, shelter and breeding.[104,105] Smaller organisms, such as deposit-feeding sea cucumbers, burrow in the sediments and influence sediment community structure and function.[106] Culturally, the lagoon floor is also a place of underwater sacred sites and sites of particular significance for Traditional Owner groups.[107]

Nutrients, pollutants and heavy metals in the water column (Section 2.3.10) can settle onto and penetrate the lagoon floor, contaminating the associated fauna.[108] Climate change, bottom trawling and dredging pose the greatest current threats to this habitat.[109,110,111] The current and projected effects of climate change (Section 6.2), such as gradually rising temperatures, extreme heatwaves and an increase in storm severity, directly threaten a broad suite of lagoonal species, particularly those with limited mobility, such as sponges and molluscs.[109] Bottom trawling (Section 5.4) can remove key habitat-forming species (such as corals, algae and sponges) and damage the seafloor. However, trawl paths often overlap, reducing the potential impact footprint.[110] Trawl bycatch of non-target species is also a concern.[112,113] Reduced trawling effort and better management since 1999 have reduced the area of lagoon floor affected by trawling by approximately 40 per cent.[110,114] Impacts of dredging include burying or smothering lagoon floor plants and animals (Section 5.7.3).[115] Additional impacts to the lagoon floor originate from land-based run-off, anchoring and strong storm activity.

Knowledge of the condition and trend of the Region's lagoon floor is limited. Since 2014, portions of the lagoon floor habitat have been exposed to prolonged thermal stress and damaging waves from severe tropical cyclones (Section 8.3.1). It is probable these impacts have caused some habitat loss, degradation or alteration in some areas.

2.3.7 Shoals

Shoals are submerged features, ridges or banks on the seafloor separated from the surrounding lagoon floor and emergent coral reefs.[116] These habitats vary in shape and size, and are found anywhere from 10 metres depth to the shelf break at 130 metres depth, covering an estimated area of 25,600 square kilometres.[117,118] Shoals generally comprise hard and soft corals, gorgonians, sponges, algae and seagrasses.[119,120,121] Because shoals can harbour high densities of fish, they are valued by fishers. Shoals are also important culturally, containing underwater sacred sites and sites of particular significance for Traditional Owner groups.

Shoals dominated by coral are often referred to as 'submerged reefs' due to their potential to grow into larger emergent reefs over time[122] and because they support an abundance of coral.[85,123,124] However, a significant proportion of shoals, particularly in the northern Reef, were built and are maintained by calcareous algae and are referred to as *Halimeda* banks (Section 2.3.8). Non-*Halimeda* shoals comprise approximately 14,000 square kilometres of coral reef habitat within the Region.[118] These shoals are numerous on the outer shelf in approximately 15 metres depth.[85,120]

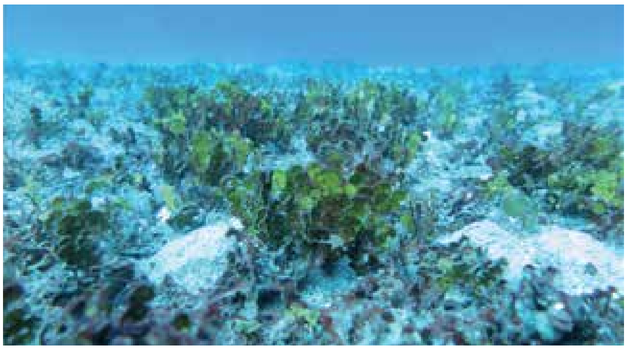
Over 1580 shoals have been mapped in the Region.[117,125] While the location and shape of these shoals is known, knowledge of their condition and how they have changed over time is lacking. Although their deeper location may buffer shoals from some disturbances, such as cyclonic waves and extreme sea surface temperatures, cyclone impacts have been recorded down to 65 metres in the central section of the Reef.[126] The five severe cyclones that crossed the Reef since 2014 have potentially exposed over 160 shoals (10–11 per cent of the total) to damaging waves (Section 3.2.2). Increased sea temperatures responsible for mass coral bleaching in 2016 were recorded down to 40 metres[92] and probably affected many coral-dominated shoals in the northern region.

Since 2014, it is highly likely that the overall condition of shoals across the entire Region has deteriorated due to exposure of shallow shoals to thermal stress in 2016 and 2017, and damaging waves from severe cyclones (Section 8.3.1).

2.3.8 *Halimeda* banks

Halimeda banks are composed of large expanses of accumulated skeletons of calcareous green macroalgae (genus *Halimeda*).[85] The surface layer of these banks consists of meadows of live *Halimeda* algae.[127] The geological accumulation process contributes to the Reef's outstanding universal value. *Halimeda* banks form in deeper waters (greater than 20 metres) adjacent to the inside of outer barrier reefs where clean, cold, nutrient-rich water upwells and is forced across inter-reefal areas by tidal jets pushing through openings between the reefs.[128]

The undulating banks of *Halimeda* can be up to 20 metres thick, with structurally complex topography. The banks provide a



Halimeda bank in the northern Great Barrier Reef.
© McNeil and Kennedy 2018[129]

unique and ecologically important inter-reef habitat for fish and invertebrates.[130,131] Significant areas of inter-reefal habitat support *Halimeda* banks in the northern Reef (Figure 2.8), and small areas also exist in the Swain Reefs.

Since 2014, improved mapping technology has increased understanding of the distribution of *Halimeda* banks. A large area (1740 square kilometres) of *Halimeda* banks has been re-mapped to the north of Raine Island (Figure 2.8). These banks have a diverse shape and morphology, with some forming large craters approximately 250 metres across and 20–40 metres deep.[132]

Climate change, ocean warming, acidification[133] and changes to water circulation patterns remain the main pressures affecting the future condition of *Halimeda* banks and the species that rely on them.

Although understanding of the extent of *Halimeda* banks has improved since the 2014 Outlook Report, information on the condition and trend of this habitat and its ecological role is limited. Exposure to potentially damaging cyclonic waves and thermal stress has occurred since 2014 (Section 8.3.1), but this has not affected all *Halimeda* banks, resulting in no consistent trend in their condition.

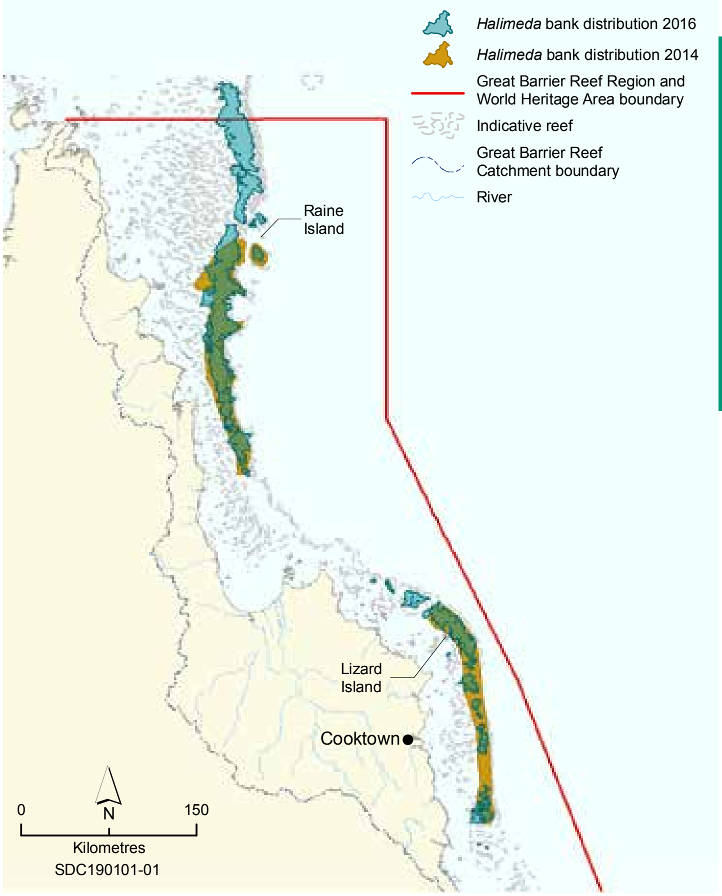


Figure 2.8 *Halimeda* bank extent in the Ribbon Reefs, 2014 and 2016
Areas in the northern section of the Region containing known Halimeda banks from new lidar LADS data (blue sections) compared to earlier mapping (2014). Source: Adapted from McNeil *et al.* 2016[132]

2.3.9 Continental slope

At the edge of Australia's continental shelf is the continental slope — a transition from the shallow shelf to the adjacent deep ocean basins, extending down to more than 1000 metres and characterised by vast submarine canyons and numerous undersea landslides (Figure 2.9).[134,135] On the Reef, the shelf edge is generally around 100 metres deep and the continental slope is defined as the deepening sea floor out from the shelf edge to the upper limit of the continental rise, or the point where there is a general decrease in steepness. The slope comprises approximately 15 per cent of the Region (about 51,900 square kilometres).[1]

The continental slope's submarine canyons are potential hotspots for benthic production and habitat for diverse marine life.[136,137,138] Bathymetry data have revealed over 100 canyons stretching from the central Reef to the far northern Reef and Torres Strait (for example, Figure 2.9). High-resolution mapping of these canyons has also revealed a complex and active system of channels along the canyon axis, internal sand waves, and localised submarine landslides.[139]

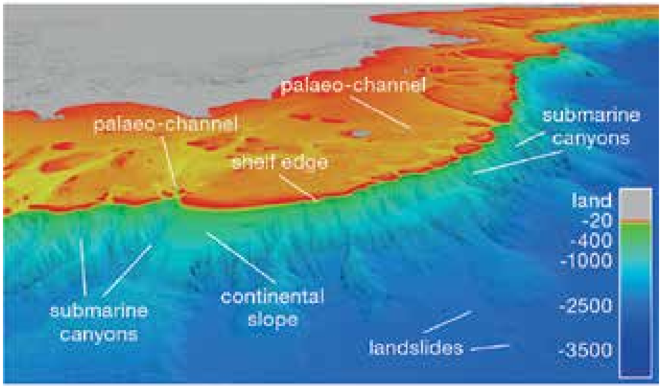


Figure 2.9 Continental slope features
The morphology of the continental margin of north-eastern Australia, indicating the continental shelf edge, slope depth, submarine canyons and underwater landslides. © Dr. Robin Beaman, James Cook University

Upwelling also occurs along the continental slope, delivering both nutrients and cooler water up from deeper water mass layers within the Coral Sea onto the Reef shelf through inter-reef passages.[92,140] This upwelling supports phytoplankton blooms and increased biological productivity. Upwelling can also reduce thermal stress on offshore reefs during bleaching events, producing a gradient towards less severe bleaching from inshore to offshore.[88,141]

While the Ribbon Reef canyons[142] are relatively well-mapped, the current condition and trend of the continental slope is largely unknown. Deeper sections of the continental slope may be buffered from storm-driven wave activity[143] and thermal stress.[144] However, the depth of the thermocline can vary substantially, depending on factors, such as the El Niño–Southern Oscillation.[145,146] The upper continental slope (to about 300 metres) around the Swain Reefs in the southern Reef is exposed to high levels of trawl effort from the deepwater eastern king prawn fishery (part of the East Coast Otter Trawler Fishery, Section 5.4).[110] Damage to seabed communities and bycatch of vulnerable and protected species is a concern for this area, and more ecological and biological information is required to more confidently assess the risks posed by this fishery.[110,147]

Based on expert opinion, the extent of the continental slope has been determined to be slightly deeper than was assessed in the 2014 Outlook Report. Mesophotic coral reefs had been included as part of the continental slope assessment, but as they form part of the shelf edge rather than the slope, they are now assessed in coral reef habitats (Section 2.3.5). This change led to the continental slope being considered in better condition in 2019 than in 2014, but the change reflects the adjustment to spatial boundaries rather than any improvement in the habitat's actual condition.

2.3.10 Water column

For the purposes of this section, the water column (previously referred to as 'open waters') comprises the pelagic (open ocean) zone between the coast and the continental shelf. It connects all habitat types. The Region has a total water volume of around 7200 cubic kilometres.[148] The water column serves as the main habitat for many species of fish, cetaceans, dugong, turtles, invertebrates and microbes and provides critical links between benthic and pelagic communities. The water column is the primary medium through which energy and nutrients cycle[149] and larvae are dispersed. It also supports plankton communities that form the basis of marine food webs.[150]

Water movement and flow are generated by ocean currents, wind, tides and upwelling across the Region. This movement transports organic matter, nutrients, larvae and plankton communities. Run-off, upwelling, tides, rain, winds and cyclones also affect nutrient concentrations and, in turn, primary productivity in this habitat.[85,151,152]

The water column links all habitats within the Region

The condition of the water column habitat can be inferred by measuring parameters such as nutrient and sediment concentrations, pollution, temperature and pH. The decline of inshore water quality associated with land-based run-off (Section 6.5) from the adjacent Catchment is a major cause of the current poor state of the inshore water column along the coast.[43,153,154,155] Mid-shelf and offshore waters are typically less influenced by land-based run-off, and water quality in those areas is considered to be in better condition.[43,156,157] However, sediment run-off and resuspension can also affect mid-shelf and offshore areas, and may take up to six months to dissipate.[158] Marine debris is also a growing threat to species throughout the water column (Section 6.5.2).[159,160,161]

Inshore reefs (those within 10 kilometers of the coast) are more vulnerable to ocean acidification than offshore reefs.[162,163,164] The reason is unclear but may be linked to changes in temperature and biological processes in the water column.[162] Water temperatures are warmer now than ever before[165] and are probably affecting the suitability of this habitat for sensitive species.

Water residence times within the Region show flushing time of a few weeks for most of the lagoon.[166] This indicates that the water column habitat may recover relatively quickly after a disturbance, such as a heat wave. Conversely, fine sediments, nitrogen, phosphorus, pesticides and trace metals in the water column may be present for years to decades.[167] Important gaps remain in knowledge of the water column, such as how temperature increases affect plankton and pelagic species. The suitability of the water column as a habitat has continued to deteriorate since 2014, because a number of processes (including temperature and land-based run-off) that significantly affect this habitat have also declined.

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

Sixteen species groups are assessed; a large amount of variability in condition occurs across the Region. Mangroves continue to be graded in very good condition. Benthic algae, bony fishes, estuarine crocodiles, whales and dolphins remain in good condition. Several components have deteriorated (plankton and microbes are graded good, other invertebrates are poor and corals are very poor). Condition of seagrasses, sharks and rays, sea snakes, marine turtles, seabirds, shorebirds and dugongs remains poor.

↓

Full assessment summary: see Section 2.5.2

The Region is home to thousands of species (Table 2.1), with new species still being identified.[168,169,170,171] It provides particularly important habitat for species of conservation concern, such as dugongs, whales, dolphins, seabirds, marine turtles, sharks and rays. Given the changing thermal regime, the previous ranges of some species are changing[172], resulting in new records in some areas.[173] The Great Barrier Reef's inscription on the World Heritage List recognises the global significance of its species diversity.[28]

2.4.1 Mangroves

The Region's mangroves are highly diverse, encompassing at least 41 mangrove species and hybrids recorded from 20 plant families; the highest diversity occurs north of Port Douglas.[169,170,177,178] In total, this diversity represents 50 per cent of mangrove species worldwide.[46]

Since 2016, three new species of mangrove been recorded in the Region, through either new species identification or range extension. *Bruguiera hainesii*, never before recorded in Australia, was found in Trinity Inlet (Cairns) by a citizen scientist.[170] This species is listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). This discovery is considered to be the largest population of this rare species in the world. Another species, *Bruguiera cylindrical*, previously thought to occur between Cooktown and Cape York, was discovered in the Cairns region in 2016, extending our knowledge of its southern range by approximately 150 kilometres.[52] A recently described hybrid species, *Bruguiera x dungarra*, was discovered from the Cape York to Fitzroy regions.[169] The identification of new species of a mature size in close proximity to the urban coast highlights the lack of comprehensive data on mangrove diversity and extent along the Catchment.

Mangrove species are exposed to a range of impacts (Section 2.3.3). Although new species have been found in some locations, the overall condition of mangrove species remains stable across the Region.

Table 2.1 Species diversity of plants and animals in the Region
For some, the number of species recorded is provided; for others the most up-to-date estimate is given.[174,175,176,266] *The table includes the number of listed migratory species (M) and listed threatened species (T) under the Environment Protection and Biodiversity Conservation Act 1999 (Cth).*

Plants and animals of the Great Barrier Reef	Number of species recorded
Mangroves	41 (T:1)
Seagrass	15
Benthic algae	880
Sponges	at least 2500
Soft corals and sea pens	at least 1000
Hard corals	450
Echinoderms	630
Crustaceans	at least 1300
Molluscs	at least 6000
Worms	at least 1000
Bryozoans	332 species
Jellyfish	at least 100 species
Anemones	at least 150 species
Tunicates	at least 300 species
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)

2.4.2 Seagrasses

Species composition of disturbed inshore seagrass meadows is maturing, a sign of recovery

The Region contains some of the greatest species diversity of seagrasses in the world.[64,179] Fifteen seagrass species occur within the Region, with one deep-water species, *Halophila tricostata*, being endemic to the area.[64] Most seagrass species in the Region are found in water shallower than 10 metres. *Halophila* is the only genus in the Region found in deep-water meadows (occurring in water greater than 15 metres).[64,71,180] Species composition within seagrass meadows changes as it recovers from disturbance. Seagrass species are typically either colonising (fast growing), opportunistic (mixture of fast and slow growing) or persistent (slow growing).[181] Generally, the Region is dominated by disturbance-tolerant species, such as *Halophila, Halodule* and *Zostera*.[59] These colonising species generally have low abundance and high turnover rates.[182,183] The composition of inshore seagrass meadows in the Region matured from 2011 to 2018, switching to more opportunistic (*Zostera*) and persistent (*Thalassia* and *Enhalus*) species, replacing colonising species (*Halophila*) that establish post disturbance.[74] This indicates a transitioning system, which is becoming more tolerant of disturbances.[181,184]

Seawater temperatures measured within inshore seagrass meadows in 2016–17 and 2017–18 were warmer than the long-term (11-year) average, a trend observed for the past five years.[74] The current trend of higher sea temperatures is likely to have chronic impacts on some species of seagrass, particularly heat-sensitive species, such as *Zostera muelleri* or species sensitive to light reductions (as high temperatures increase seagrasses' light requirements).[184,185]

Seagrass species are exposed to a range of impacts (Section 2.3.4). Although still in poor condition, seagrass species composition is recovering at many inshore sites following extensive losses in previous years.

2.4.3 Benthic algae

Following disturbances, corals may be replaced by benthic algae

Benthic algae includes three main growth forms: large fleshy macroalgae, crustose coralline algae (which form a photosynthesising 'cement' layer over some parts of the seafloor), and short turf algae (Figure 2.10). Turfing algae are one of the most abundant benthic habitats in the Region and an important source of primary productivity on coral reefs for crustaceans and microbes.[186,187] More than 880 species of benthic algae exist in the Region.[127,188] The three different growth forms provide a variety of ecosystem services, food for many organisms, primary production (Section 3.4.3), reef building (Section 3.4.8), stabilisation of the seafloor, and settlement habitat for juvenile fish and invertebrates. On inshore reef flats, macroalgal stands can provide important nursery habitats for herbivorous fish (for example, rabbitfish and parrotfish).[189]

The total number of species of large, fleshy macroalgae on the Reef is unquantified. These algae are generally more common on inshore reefs where nutrient levels are higher, and their cover decreases with distance from the coast.[188,190,191] Fleshy macroalgae can be highly seasonal, the largest species (for example, *Sargassum* species, which grow up to three metres high) can dominate shallow inshore habitats in summer before partially detaching in winter[192]; the habitat then transitions to compact winter species. However, this seasonality may be changing with some of the summer-blooming species persisting longer through winter.[193] Following disturbances, algae may inhibit coral recruitment and replace coral as the dominant benthic cover.[194,195]

How benthic algal abundance has changed over time and across the Region is not well understood, with quantitative data only available in limited areas. The trend in abundance of inshore macroalgae has been variable since 2014 (Figure 2.11).

Figure 2.10 Benthic algae growth forms
Left: Fleshy macroalgae growing in and around coral on an inshore reef. © GBRMPA
Middle: Pink coloured crustose coralline algae. © Andrew Hoey
Right: Turf algae. © Andrew Hoey

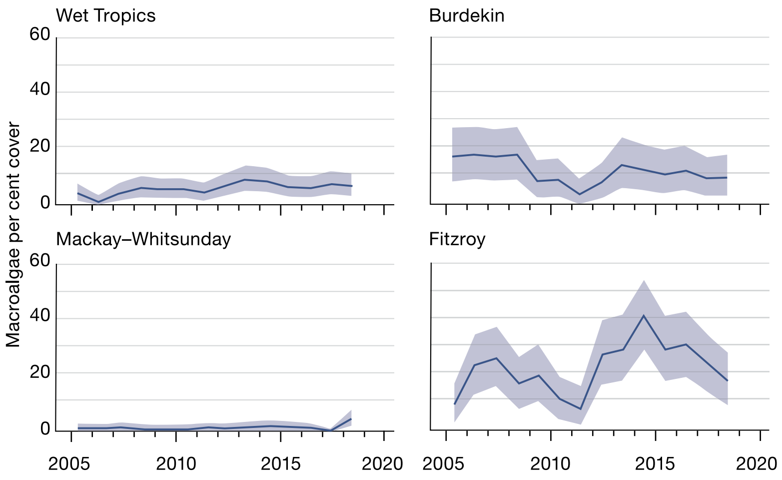


Figure 2.11 Macroalgae abundance, 2005–2017

Mean abundance of macroalgae from inshore reefs in four natural resource management regions: Wet Tropics (n=19), Burdekin (n=10), Mackay–Whitsunday (n=10) and Fitzroy (n=6). Totals calculated for a financial year.

Source: Thompson *et al.* 2018[193]

Of the inshore reefs monitored, large fleshy macroalgae appear to have slightly increased in the Wet Tropics and Mackay–Whitsunday areas, probably in response to reduced coral cover following bleaching, crown-of-thorns starfish predation and cyclone damage (particularly around the Whitsundays). Conversely, macroalgal cover peaked in 2014 then declined in the Fitzroy region and has gradually decreased in the Burdekin region.[193] These declines may be attributed to a number of factors: reduced recruitment of macroalgae, herbivory, or coral returning as these sites recover from disturbance.

Crustose coralline algae plays an important stabilising role, creating a cement-like mat over the seafloor and dead and broken coral, strengthening the reef structure. These benthic algae, being a more encrusting form, reinforce a coral-dominated state by repelling fleshy macroalgae recruits, and they can provide a suitable surface for coral larval settlement.[168] In the northern and central areas of the Reef, 30 species of crustose coralline algae have been identified; their diversity and relative abundance are greatest on mid and outer-shelf locations.[196] The abundance of crustose coralline algae varies latitudinally, with the northern Ribbon Reefs having, on average, five times more coverage than the southern Swain Reefs.[197] While there are some site-specific studies on crustose coralline algae, broadscale and long-term trends in its condition and abundance are poorly understood.

There is limited information to indicate a Region-wide increase in turf algae abundance following broad scale decline in coral cover. The condition and abundance of turf algae is likely to decrease over time if sedimentation increases, resulting in long, sediment-laden turfs, which deter fish feeding, coral settlement and productivity.[198] Nutrients, sediments, outflows from rivers and cyclones are significant drivers of algal turf composition.[199] Sediment levels in coastal algal turfs were more than ten times that of offshore reefs, and double that of inshore reefs.[23]

The most serious impacts to benthic algae as a group include sediment exposure and light limitation (from both natural and anthropogenic influences, such as dredging and disposal[200] and land-based run-off); increased sea temperatures[201] (which can cause bleaching of crustose coralline algae); and ocean acidification[202]. Benthic algae are a diverse group of species that provide important habitat for many organisms. Overall, benthic algal diversity has been maintained and abundance has increased in some areas.

2.4.4 Corals

The Region is home to more than 1200 species of hard (skeletonised) and soft corals[203,204,205], and this high diversity contributes to the outstanding universal value of the World Heritage Area.[28] Hard corals are the key habitat-forming species of coral reefs. These corals have microscopic algae, called zooxanthellae, living within their tissue that provide them with food produced during photosynthesis. Corals are mainly found in shallow waters (less than 30 metres), due to their dependency on light, but mesophotic reefs can be found down to 150 metres.[206]

Global warming has transformed coral species assemblages, with key coral species exhibiting significant declines

Corals exhibit a high degree of variation in growth rates and forms, including slow-growing boulder-shaped species (which grow at 1.3 centimetres per year)[207], and fast-growing branching species (which grow at 10–30 centimetres per year).[208] Corals tolerate a narrow range of temperatures and are adapted to their local conditions.[209] Slight increases in sea surface temperatures due to global warming can cause significant coral mortality.[88,91,141] Tabular and branching corals, such as acroporids and pocilloporids, are particularly important in creating three-dimensional structures that provide critical habitat to the majority of coral-reliant fish and invertebrate species.[83,210,211] These corals are also the most susceptible to disturbances, including bleaching due to thermal stress[212,213], breakage from cyclones[214], predation from crown-of-thorns starfish and *Drupella* snails[215,216], and coral disease[217].

Climate change, specifically temperature extremes, is the primary driver of coral degradation in the Region and has substantially altered the abundance and species composition of coral communities. Consecutive thermal stress events in 2016 and 2017 caused mass coral bleaching in the northern two thirds of the Region, resulting in unprecedented levels of coral mortality.[90] Acroporid and pocilloporid coral species, which dominate many shallow reefs, declined by more than 75 per cent on severely bleached reefs, resulting in the significant loss of three-dimensional structure.[91] Juvenile corals were generally less affected by bleaching than adults, with the exception of *Pocillopora* and merulinid corals.[218] Overall, juvenile *Acropora* and *Pocillopora* corals suffered greater mortality than juveniles of other corals.[218] As a result of mass mortality of adult corals, coral recruitment across the entire Region declined by 89 per cent in 2018 compared to recruitment levels before 2016. For acroporids, the decline was 93 per cent.[96] Recovery depends on successful recruitment of new corals, growth of existing corals and absence of further stressors (Section 2.3.5). Global warming has resulted in a five-fold increase in the frequency of severe coral bleaching events in the past four decades[99] and slowed the rate of coral recovery[219].

Cumulative impacts since 2014, such as unprecedented mass coral bleaching, crown-of-thorns starfish predation and regional cyclone damage, have caused widespread loss in populations of many coral species across the Region, with some species having deteriorated significantly.

Bleaching susceptibility varies among coral species, with branching and tabular varieties (bleached in the photo) more vulnerable to thermal stress and bleaching-related mortality than massive coral (unbleached underneath).
© GBRMPA 2016, photographer: Jessica Stella

2.4.5 Other invertebrates

The Region is home to 32 invertebrate phyla (major groups), consisting of over 12,000 described species.[220,221,222] This biodiversity is nationally and internationally significant.

Small, mobile invertebrates often live in symbiosis with sedentary host invertebrates, such as corals, sponges and sea cucumbers (Section 3.4.6).[106,223] Some symbiotic invertebrates, such as those that live with coral hosts, are completely reliant upon their host for survival and are at high risk of population decline with any loss of coral habitat.[83] Other invertebrates, such as bivalves and sponges that bore into, and break down (bioerode), dead coral skeletons, benefit from habitat degradation. Invertebrates account for the greatest animal diversity and biomass in the Region[224,225], and are key elements of the food web[226]. They are important recyclers of nutrients[106], bioeroders[227] and providers of services vital to the health of other reef organisms.[83,228,229] Invertebrates are also a valuable source of food and medicine for humans.[229,230]

Rising sea temperatures due to global warming are affecting many invertebrate species

A range of factors directly affect invertebrates, particularly climate change.[109,229,231,232] Most invertebrate species are sensitive to changes in temperature.[233,234] For example, in 2016 mass mortality of shrimp and crabs attributed to temperature stress was observed in a shallow-water lagoon in the northern Region.[235] Ocean acidification also threatens calcifying invertebrates, such as foraminifera[236] and sea urchins[231,237]. Sponges appear to be an exception among invertebrates, exhibiting high tolerance of both ocean warming and acidification.[238] Pesticides and changes to salinity from freshwater inflow can have acute, lethal effects on many types of invertebrates, particularly crustaceans.[239,240] Overfishing and habitat destruction can cause rapid declines in invertebrate communities, as evidenced by the historical collapse of the black teatfish sea cucumber population (Section 8.3.3)[241,242] and more recently the saucer scallop stock (Section 5.4).[113] Nutrients and pollutants settling out from the water column can contaminate lagoon sediment and associated fauna.[108] Trawl discards of invertebrates remain largely unquantified, as there are no requirements to report discards of most bycatch (Section 5.4.1).[2] Some target species, such as mud crabs and blue swimmer crabs, are susceptible to local depletions from overfishing (Section 5.4.1).

The majority of invertebrates take refuge within the reef matrix to avoid predators. This coral crab hides between the branches of a Pocillopora coral.
© Jessica Stella 2010

Current knowledge of the condition and trend of invertebrates is limited, largely due to the sheer number of species and the variety of life history characteristics and habitat requirements. The majority of invertebrate species are cryptic, which means they are hidden from view and difficult to survey. Given the recent widespread reduction in coral habitat due to climate extremes[91], it is probable that many coral-reliant invertebrate species have been negatively affected.[83,243] Changes in invertebrate communities independent of coral loss have also been recorded along the entire Region, attributed directly to prolonged thermal stress.[244] Exposure to elevated nutrient levels, high sediment loads and freshwater is likely to have affected invertebrates distributed closer to shore. Given their exposure to a range of impacts (Section 8.3.1) and the widespread loss of coral reef habitat, it is likely that the condition of many invertebrate groups has deteriorated since 2014.

2.4.6 Plankton and microbes

Plankton and microbes are highly abundant and diverse; they include single-celled plants, bacteria, viruses, animals and animal larvae.[245,246] The density of plankton and microbes can exceed more than one billion microorganisms living in each litre of seawater, however, the number of species found within the Region is unknown.

Plankton and microbes are critical to ecosystem health and functioning.[247,248,249,250] Plankton are the primary food source for many animals and are the base of most marine food webs.[150] Zooplankton are an important food source for corals, particularly for bleached corals that may starve without their zooxanthellae.[251,252] Approximately half of global primary production is carried out by oceanic phytoplankton.[253] Microbes constitute the bulk of marine biomass and are significant contributors to metabolic activity, the carbon, nitrogen and sulphur cycles, and the exchange of trace gases that have direct impacts on local climate.[247,254] Microbes play an essential role in many ecosystem processes (Sections 3.3.1 and 3.4.1) and form symbiotic relationships with other organisms, such as corals, sponges and algae.[247,248,249,250] These relationships are specific and stable associations[255], and can assist organisms to acclimatise to prevailing environmental conditions.[256,257,258] Microbes are also agents of disease, which can be a sign of an imbalance in microbial communities (Section 3.4.1).

Plankton and microbes respond relatively quickly to changes in the environment, such as lowered salinity, temperature increases and elevated nutrients.[259] Changes in ocean conditions resulting from climate change are affecting their distribution and abundance.[260] For example, large changes in microbial community structure were seen in the Region during the extreme wet season of 2010–11, following riverine floods.[261] Sea surface temperatures have had large-scale effects on zooplankton[262,263], with declines of zooplankton biomass recorded during warmer El Niño conditions[264].

Despite a growing understanding of the importance of microbes and plankton to ecosystem health, they are overlooked in most large-scale monitoring programs and, therefore, remain a key knowledge gap.[265] Factors affecting these communities are increased temperature, elevated nutrients and reduced pH (for plankton with carbonate skeletons)[266], all of which are occurring in the Region. Localised plankton declines have been recorded in the central Region[267], and a higher incidence of coral and fish disease was reported after thermal stress (Section 3.6.1). It is likely that widespread thermal stress and ongoing poor water quality in some areas of the Region have led to a deterioration in the overall condition of plankton and microbes since 2014.

2.4.7 Bony fishes

Bony fishes (Class Osteichthyes) are fish with skeletons made of bone rather than cartilage. Approximately 1625 bony fish species are found in the Region, with the majority (1468) classified as coral reef species.[175] Bony fishes have high ecological and economic values (Section 5.4.2). They influence habitat structure and the flow of energy and nutrient cycling.[268] Bony fishes occur in a wide range of habitats, including coral reefs, shoals, seagrass meadows and open waters.

Coral-dependent fishes are declining

Some fishes, for example, small corallivorous fishes, depend heavily on coral reef habitats. Pelagic fishes associated with reefs (such as trevallies and scombrids) depend less on benthic habitat, but may decline in response to changes in their reef-associated prey.[269] Disturbances that deplete coral cover by as little as 10 per cent can reduce fish abundance across a range of species.[270] Declines in bony fishes following coral disturbance can manifest quickly (within six months) or take up to several years.[270] Changes in seagrass and mangrove habitats, which are important feeding, breeding and nursery grounds, can also influence the condition of bony fish and their recruitment.[64]

The full impacts of recent environmental disturbances to the Region's coral reef habitats (including the 2016 and 2017 mass coral bleaching events) on bony fishes are still being determined. Time-lags are expected in fish responses to habitat loss.[271] However, early indications are that coral bleaching has clearly affected bony fishes[272,273], including through decreased diversity and sub-lethal effects, such as reduced fitness.[272,273] Elsewhere, productivity of fisheries has been estimated to decline three-fold when habitat structure is lost following disturbance.[86] On the Reef, the full flow-on effect to fisheries is not yet understood and remains an area of research interest.

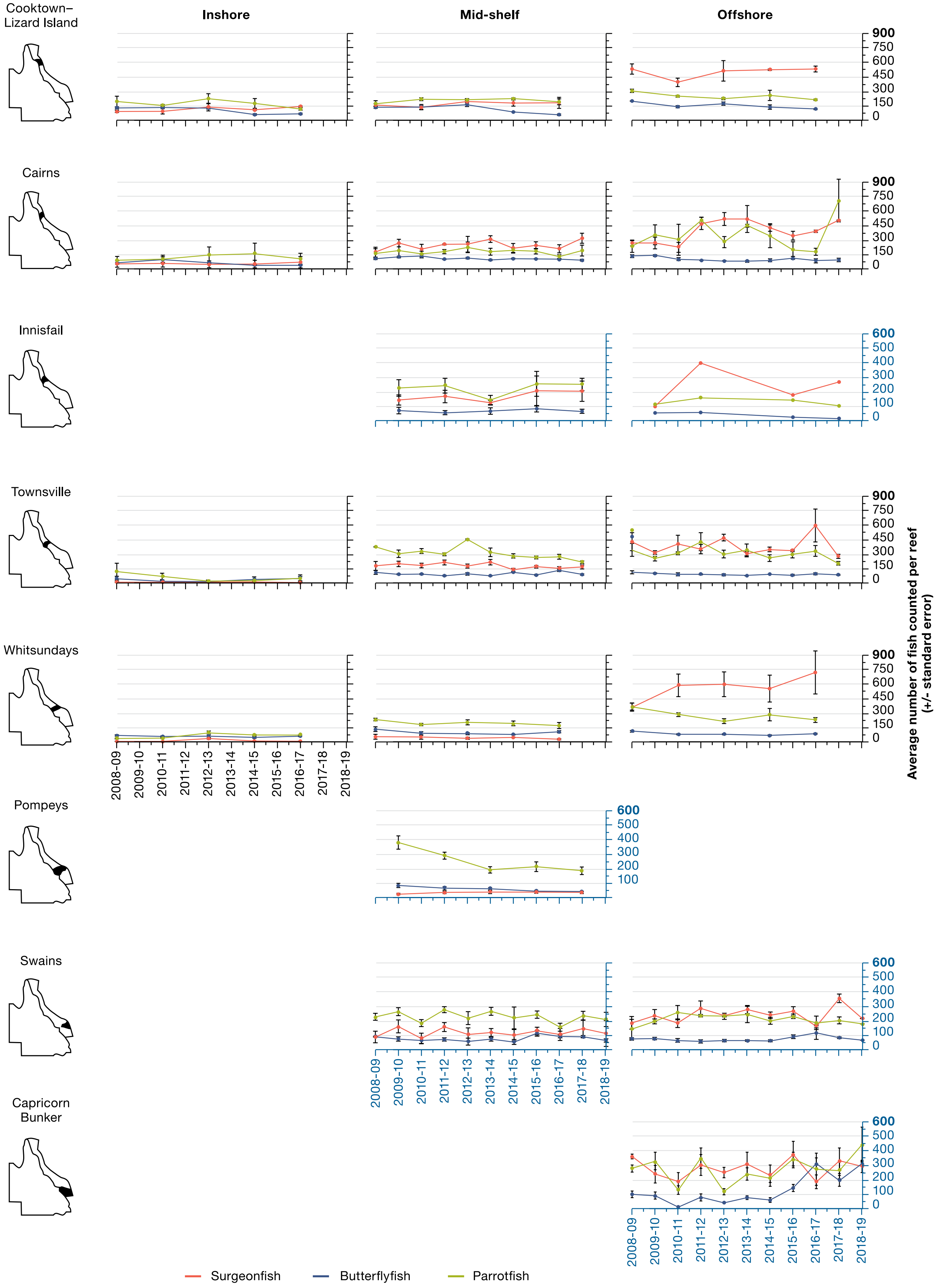


Figure 2.12 Abundance of some coral reef fishes, 2008–2019

Surgeonfish, butterflyfish and parrotfish are diverse bony fish groups present across the Region. Fish abundance is estimated by visual census of a total of fifteen 50 metre by five metre transects at each reef. Where possible, three or more reefs were surveyed at inshore, mid-shelf and offshore positions across the continental shelf. Note the differences in scale between the black and blue y-axes.

Source: Australian Institute of Marine Science Long-term Monitoring Program[282]

Long-term monitoring of three key fish groups (butterflyfish, parrotfish and surgeonfish) across the Region has identified some changes in mean abundance since 2009 (Figure 2.12). Butterflyfish, which rely heavily on coral and other invertebrates for food, showed small declines since 2016–17 at the Cooktown–Lizard Island, Innisfail (mid-shelf) and Townsville (mid-shelf) reefs and the Swain Reefs. Abundances of surgeonfish and parrotfish, which feed on a combination of algae and detritus, have been more variable over time. The greatest increases in parrotfish were observed offshore Cairns and the Capricorn Bunker group, while some declines were observed on reefs around Townsville and offshore Whitsundays. The greatest increase in surgeonfish abundance was observed offshore Whitsundays and Cairns in 2016–17 (Figure 2.12).

Climate change, over-fishing (including illegal fishing) and habitat alteration are the greatest current impacts on most fish species.[274,275,276] New research since 2014 has improved understanding of the effects of climate change on bony fishes.[277,278,279,280] Management tools, such as spatial zoning (including no-take areas), protect fish and contribute to the maintenance and recovery of target fisheries species through spillover of larvae from unfished to fished zones (Section 7.3.3 Box 11). Current extraction rates for some fished bony fish species are considered sustainable. However, there are concerns for others (Sections 5.4 and 8.3.4).

Little is known about the condition of most bony fish species on a Region-wide scale, given it is a highly diverse group. Monitoring ecological processes performed by bony fishes, such as herbivore feeding rates, can help diagnose problems early, before fish populations start to decline.[281]

Overall, some deterioration in the condition of bony fishes (as a group) has occurred, particularly in those dependent on coral and seagrass meadows for food, shelter or some part of their lifecycle. Current extraction rates are considered sustainable for some species, but may not be for others.

2.4.8 Sharks and rays

Chondrichthyan fishes have skeletons of cartilage, rather than bone; they include all sharks, rays, skates and chimaeras. Approximately 136 different species are known to inhabit the Region, 82 of which are sharks.[283] This has led to the Region being identified as a global hotspot of shark species richness, functional diversity and endemicity.[284]

The ecological roles and importance of different sharks and rays vary depending on abundance, body size, trophic level and how specialised their diet is.[285] Large apex predators, such as the great hammerhead shark and the tiger shark, are most likely to influence the population dynamics of prey species.[285] Smaller sharks, such as blacktip reef sharks, are functionally equivalent to other middle-order predators, such as coral groupers. Many species of sharks and rays are relatively long-lived, grow slowly, mature later, and produce few offspring; these traits make them particularly susceptible to overfishing.

Reef sharks patrolling the reef crest. © Matt Curnock

In the Region, at least 46 shark species are caught in the East Coast Inshore Fishery, with 17 species considered to be highly vulnerable to exploitation.[286] Green sawfish, the Australian blacktip shark, the pigeye shark, the grey, blacktip and whitetip reef sharks and hammerhead sharks are among the most vulnerable species that interact with fisheries.[287,288] Species richness and abundance of deep-water shark and ray species in the Region are naturally lower with increasing depth.[289] Eleven species of rays and skates have been identified as highly vulnerable to the East Coast Otter Trawl Fishery.[176] Deep-water species are more susceptible to overfishing than are shelf and pelagic species, because their populations take longer to recover from exploitation.[290] Large-bodied, shallow-water species of sharks and rays are the most vulnerable to depletion, with sawfishes being the most threatened.[291,292] Climate change also threatens shark and ray populations, with 30 species within the Region highly or moderately vulnerable to climate change, mainly freshwater/estuarine and reef-associated species.[293]

Sharks and rays are vulnerable to multiple threats, particularly from overfishing and climate change

In 2018, the scalloped hammerhead shark (*Sphyrna lewini*) was listed in the conservation-dependent category of threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth)[294] due to declines throughout its entire Australian distribution and continued threats posed principally by commercial fishing.

The population status of many species in the Region remains a knowledge gap, but modelling of mortality rates has predicted potential declines in reef-shark abundance.[295] Several species of sharks in the Region rely on coral reefs. A higher number of species of reef-associated sharks are found in areas of greater structural complexity (for example, rocky shoals and coral reefs) and their abundance is higher in areas with higher coral cover.[296] No-entry zones within the Region contain significantly more reef sharks than no-take zones and areas open to fishing.[297] A recent publication using analysis of the entire Queensland Shark Control Program dataset, which includes data from outside the Region, indicates that there may be declines in tiger, hammerhead, whaler and white sharks.[298] There are likely to be multiple causes of decline and further analysis is required. Declines in sawfish populations have occurred since 1970 across their entire range, including within the Region.[299] The conservation status and sustainability of some shark species in the East Coast Inshore Fishery remain uncertain and cause for concern[286], although the catch of some target species is well below that which can be sustained. Given the widespread loss of coral cover and ongoing fishing pressure, the condition of some shark and ray species may have deteriorated since the 2014 assessment. However, there is no consistent trend for sharks and rays as a group.

2.4.9 Sea snakes

Sixteen species of true sea snakes have been recorded in the Region, and 14 species maintain permanent breeding populations.[300] True sea snakes produce live young and are entirely marine, never venturing onto land. The Region is situated within the global hotspot of sea snake diversity.[301] Sea snake species within the Region are protected under both Queensland and Commonwealth legislation.

Life history characteristics of sea snakes, such as low reproductive output (two to three live young every couple of years), and low dispersal make them particularly vulnerable to threats.[301] As air-breathing organisms, sea snakes are susceptible to significant mortality when captured in trawl nets.[302] Two species, the ornate reef sea snake and the elegant sea snake, have been identified as being at high risk from otter trawling.[176] However, management changes in the trawl industry have reduced the capture of sea snakes by 60 per cent.[302] The spine-bellied sea snake and the elegant sea snake use shallow bays associated with freshwater inflows.[303] Inshore areas remain under pressure from direct or indirect anthropogenic impacts.[43]

While broad patterns in the distribution of sea snakes have been documented,[300,302] up-to-date information about the distribution and abundance of individual sea snake species remains limited. No regular population monitoring occurs, in part due to logistical difficulties associated with counting sea snakes.[304] Sea snakes within inshore regions of the central and southern Reef occur in relatively high abundance and diversity.[305] In the north, research station staff have anecdotally reported localised depletion at a site known for high sea snake abundance near Lizard Island. However, the cause is unknown. Unexplained declines have been documented for two species of sea snake in the southern Reef.[306]

Although trawl bycatch has been reduced, some localised depletions of sea snake populations have been recorded, probably due to other impacts, such as thermal stress. Overall, based on the evidence available, the condition of sea snakes has remained stable across the Region since the Outlook Report 2014 assessment.

2.4.10 Marine turtles

Six species of marine turtle occur on the Reef and all are listed as threatened under Commonwealth and Queensland legislation. The Region has globally significant nesting and foraging areas for green, loggerhead, hawksbill and flatback turtles.[307,308] Marine turtles provide a number of ecological services, including herbivory and seagrass dispersal (green turtles), and contribute to nutrient cycling and sediment production.[65,308,309,310] These iconic animals are also highly valued by Traditional Owners (cultural use), the tourism industry, visitors and residents.

Concerns are growing for the future of loggerhead, hawksbill and northern green turtles due to climate change and overseas fishing pressures

Ninety per cent of nesting by green turtles from the southern (Heron, Wreck and North West islands) and northern populations (Raine Island and Moulter Cay) occurs within protected areas.[311] The previously depleted southern population has more than doubled in the last 40 years[312], reflecting the value of large-scale habitat protection and the cessation of commercial harvesting in 1950[313].

Since the mid-1990s, concerns have been expressed about declines in nesting and hatchling success of green turtles nesting at Raine Island.[2,311] Extra management interventions implemented on some parts of the island since 2014 are slightly improving reproductive success.[27,314,315,316] Despite this, the previous period of low hatchling productivity is expected to cause a future decline in nesting turtle numbers on Raine Island because there will be fewer new adult females entering the population. Given an estimated 90 per cent of northern population females nest on Raine Island[317] or nearby Moulter Cay[318], there may be significant implications for the northern population as a whole. Warming temperatures are resulting in the feminisation of green turtles originating from nesting beaches in the northern Region, potentially leading to significant scarcity or absence of adult males in the future.[319]

A young flatback turtle. © Matt Curnock

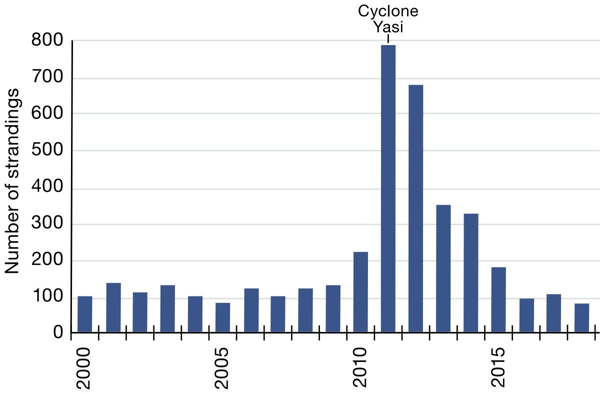


Figure 2.13 Green turtle strandings in the Region, 2000–2018
Green turtle strandings (dead or alive) in the Region from 2000 to 2018. Stranded turtles that were not identified to species level are not included in the graphed data, so the total is potentially higher than shown. Most records are from Cairns to the southern end of the Region. Cyclone Yasi and associated flooding occurred in early 2011 and led to widespread damage of inshore seagrass meadows (foraging habitats).
Source: Department of Environment and Science (Qld) 2018[337]

Loggerhead turtle nesting numbers declined at all eastern Australian nesting sites in the 1970s through to 2001. The positive management response in Australia to past issues (Section 8.3.5) is reflected in the increased numbers nesting at Woongarra coast (Mon Repos Beach) — from 118 nesting females in 1997 to 421 in 2017 (Figure 8.5).[320] However, recruitment of the Region's loggerhead turtles is being affected by overseas fisheries and marine debris, and this will subsequently affect nesting populations (Section 8.3.5).[321]

In 2016, the Torres Strait – northern Great Barrier Reef hawksbill turtle population was reclassified under Queensland legislation from vulnerable to endangered.[322] Hawksbill turtles are known to only nest north of Princess Charlotte Bay. Milman Island in the north of the Region is the only nesting site in Queensland for which there is sufficient information to allow trend analysis. Nesting numbers at Milman Island continue to decline, although more slowly than previously observed.[323]

Flatback turtles occur only on the continental shelf of Australia, Papua New Guinea and Indonesia. Key nesting sites for the Region's flatback turtles include Peak, Avoid, Curtis and Wild Duck islands (off central Queensland).[324] Lower density nesting occurs on beaches within the port limits of Port Alma and Port Curtis and around Mackay.[325] Some of these nesting sites are in the Region, while others are adjacent to it. At Peak Island, the nesting population appears to have stabilised, or is declining at a much slower rate.[326,327] At Curtis Island, the size of the nesting population has halved in the last decade.[326] There are insufficient long-term data to determine a clear trend for nesting at Avoid Island.[326,327]

The olive ridley turtle is not known to nest in the Region but it forages throughout the sub-tidal and non-reef habitats of the Region. Very limited information is available on the species' foraging habits. Leatherback turtles have not been recorded nesting in eastern Australia for 22 years.[328]

Rising air and sand temperature as a result of climate change are the most immediate and broadscale threats to marine turtles because the gender of hatchlings is determined by temperatures experienced within the nest.[329] Elevated air temperature has already strongly skewed the sex ratio in eastern Queensland foraging aggregations of hawksbill turtles towards females.[328] An increase in feminisation has also occurred for flatback turtles at Peak Island.[327,330]

Artificial light from urban and industrial areas can reduce nesting success and the number of hatchlings finding their way to the ocean.[331,332,333] Hotspots for elevated light include the Woongarra coast (outside the Region) (Section 8.3.5), Gladstone and Mackay.[327] Flatback turtle nesting areas on the east coast of Australia are experiencing a faster increase in light pollution than are nesting areas at other Australian locations.[332]

Smaller, oceanic-stage turtles are more likely to be affected by fragmented hard plastics in domestic and international waters than are turtles foraging along the coast.[334,335,336] Vessel strike and ingestion of fishing line and hooks are primarily experienced by green and loggerhead turtles. These impacts appear to be more often caused by recreational than commercial activities, at least in certain locations.[337,338,339] Hawksbill turtles are exposed to mortality from predation (for example by pigs, goannas and humans) and ghost net entanglement.[308]

Strandings of marine turtles can be related to food supply or occur due to marine debris ingestion and entanglement, vessel strike, interactions with fishing gear and disease.[334,337,338,340] In the last few years, green turtle strandings have returned to levels similar to those observed before the significant 2010–11 disturbances (cyclone Yasi and subsequent flooding) to seagrass beds (Figure 2.13, Section 2.3.4).

Overall, there has been recovery of the southern green turtle populations. However, there are growing concerns for the future of loggerhead, hawksbill and the northern green turtle populations due to a number of external pressures, including climate change and overseas fishing morality (in Chile and Peru). The recovery of flatback turtle population has no consistent trend.

2.4.11 Estuarine crocodiles

North Kennedy, Normanby and Proserpine rivers support the highest estuarine crocodile population densities adjacent to the Region

The estuarine crocodile (*Crocodylus porosus*) is the largest living reptile.[341] Crocodiles occur in most coastal waters of the Region, commonly in tidal reaches of rivers and along beaches and islands.[342,343,344] Adult crocodiles are important apex predators in the ecosystem[345], and their eggs and hatchlings are economically and socially important.[345]

Current condition and trend of crocodile populations remains an information gap. A three-year state-wide monitoring program to survey crocodile density along 28 waterways from Cape York to Gladstone began in 2017. Preliminary results of vessel-based spotlight surveys indicate an overall low density of crocodiles, averaging just one per linear kilometre, compared to five to 10 per linear kilometre in the Northern Territory.[343] The North Kennedy, Normanby and Proserpine rivers support the highest densities of crocodiles from Bundaberg to Cape York, ranging from an average of 2.3 to 5.1 crocodiles sighted per kilometre. No crocodiles were observed in the rivers south of the Fitzroy River.[343]

Illegal poaching, habitat loss and climate change are the main threats to crocodiles.[330,346,347] Coastal development encroaching on swamplands, mangroves and riverbanks threatens crocodile populations south of Cooktown. However, climate change will probably affect all populations. Because crocodiles are cold-blooded animals, their physiology is affected by air and water temperatures. Warmer temperatures increase metabolism and, therefore, decrease energy conservation.[348,349,350] Elevated water temperatures decrease diving times in juvenile crocodiles[351], and temperatures above 33 degrees Celsius decrease sustained swimming speed[352].

Crocodiles are important apex predators. © GBRMPA

Because the sex ratio of hatchlings is temperature dependent and temperature plays an important role in embryo development and incubation time, climate change will influence population dynamics by exposing nesting sites to increased air temperatures.[353,354] More frequent encounters between humans and crocodiles has necessitated an increased focus on the removal of high-risk animals by authorities.[343] Climate change may contribute to a future increase in human-crocodile interactions, as crocodiles grow faster and to larger sizes in warmer temperatures.[354,355]

With no recently recorded impacts to crocodile populations, they have probably stabilised since the 2014 assessment.

2.4.12 Seabirds

Breeding populations of six seabird species in the Region have declined, while one species has increased

The Region supports breeding populations of 20 seabird species.[356] Seabirds have profound influences on island ecosystems by bringing nutrients from sea to land, including guano and by-products of breeding (such as unconsumed regurgitate, dead chicks and eggs).[357] These nutrients may be vital to the fertility and biodiversity of some of the Region's islands and surrounding reefs.[30,358]

Average Reef-wide trends indicate slight declines from 1980 to 2017 for breeding populations of six species: crested tern, brown booby, masked booby, common noddy, sooty tern and roseate tern.[359] However, trends were inconsistent across islands and cays within the Reef. The population of breeding red-tailed tropicbirds on Raine Island has increased, on average, by approximately 1.4 per cent per year since 1980.[359] Monitoring of trend and condition of the other 13 seabirds found in the Region remains a significant knowledge gap. The condition of seabirds in general remains poor and no consistent overall trend can be identified.

Raine Island is the only known breeding site in Australia for the critically endangered herald petrel (*Pterodroma heraldica*), which is rarely seen in the Region. In 2017, 26 birds were seen at Raine Island and one pair was observed breeding (the first confirmed breeding sighting since 1987).[360]

Changes in sea surface temperature affect food supplies for seabirds and can have implications at a population level.[361] Other threats to seabirds include, but are not limited to, commercial and recreational fishing impacts on prey species, direct disturbance by recreation and tourism visitors to islands, the introduction of exotic plants and animals[362,363], and ingestion (especially in inshore areas) and use in nesting of marine debris.[364,365,366]

Limited information exists on the populations of seabird species in the Region. Where information is available, the condition of most species is deteriorating.

Fluffy herald petrel chick on Raine Island. © Queensland Parks and Wildlife Service, photographer: G. Burrows

2.4.13 Shorebirds

Approximately 41 (80 per cent) of Australia's shorebird species are known to inhabit the Region and adjacent coastline.[367] Two of Queensland's five Ramsar sites (wetlands of international importance) are adjacent to the Region: Bowling Green Bay[368] and Shoalwater and Corio Bays[369]. These sites support internationally significant numbers of migratory shorebirds, including endangered curlew sandpiper, eastern curlew and Australian pied oystercatcher.

Long-term shorebird population trends have not been analysed specifically for the coastline adjacent to the Region. However, national level analysis provides an insight to the regional trends of many migratory and non-migratory species.[370,371] At a national level, 12 of 19 migratory shorebird species, all of which occur in the Region, declined significantly from 1973 to 2014[370], despite high levels of habitat protection in Australia.[372] Climate change and loss of intertidal habitats through pollution and degradation (for example, Yellow Sea tidal mudflats of East Asia) are primarily driving the decline.[370,371,373,374] Of the Region's seven non-migratory species whose populations were assessed at a national level, red-capped plovers, Australian pied oystercatchers and sooty oystercatchers were found to be stable or increasing from 1973 to 2014, whereas the other four species were declining.[370] Within the Region, the Mackay area appeared to be losing large numbers of multiple shorebird species. In contrast, Bushland Beach, Lucinda and Cape Bowling Green had the highest retention of shorebird species from 1973 to 2014.[370]

Shorebird populations face a number of threats, including habitat loss and degradation from coastal development, human disturbance, predation and disturbance by domestic and feral animals, commercial and recreational fishing impacts on prey species, and the introduction of exotic plants to important nesting locations.[367] These threats are generally heightened during and after migration or when non-migratory shorebirds are breeding and caring for their eggs and young. The major migration route, known as the East Asian – Australasian Flyway, is among the most highly threatened flyways in the world due to widespread declines in, and degradation of, habitat.[371,373,375] Climate change represents a significant threat to shorebirds, with increasing temperatures already causing earlier migration times[376], changes to egg-laying times, timing mismatches with food resources[377,378] and loss of habitat[379]. Coastal development and human disturbance within Australia can reduce local shorebird abundance[380], which could have important cumulative effects at the species level. These potential impacts highlight the importance of protecting habitat in the Region and Catchment.

The condition of shorebirds in the Region is difficult to determine due to limited Region-specific information, although significant declines across Australia have occurred.

2.4.14 Whales

Whales and dolphins belong to the group of marine mammals called cetaceans. They vary greatly in size, feeding habit and behaviour. There are two major groups (suborders) of cetaceans, the Mysticeti (baleen whales) and the Odontoceti (toothed whales and dolphins). Approximately 15 species of whales are known to occur within the Region. Humpback and dwarf minke whales (both baleen whales) are the most commonly encountered species. The first recorded sighting of a rare Omura's whale in the Reef was filmed in 2016.

Migratory baleen whales, such as the humpback whale, can move nutrients thousands of kilometres from productive feeding areas in the Southern Ocean to calving areas in the Region.[381,382] Little is known of the current condition and trend of the toothed whale species that visit the Region. Most are believed to be oceanic species that spend only short periods of time there. Whales are economically important to the Region, as reliable and extremely popular tourist attractions.[383,384]

The condition of most whale populations is unknown, however, humpback whales continue to recover strongly

All species of whales within the Region are protected by legislation. Since being protected from hunting in Australian waters in 1980, the eastern Australian humpback whale population has exhibited a strong recovery, with an annual growth rate of around 10–11 per cent.[385,386] The last survey, in 2015, recorded more than 24,000 whales; an estimated recovery of 58–98 per cent of the original population.[385] This rate of recovery suggested that the humpback whale population was likely to be more than 30,000 in 2018. As the population approaches its carrying capacity, estimated to be up to 40,000 whales, climate change, food availability and disease may become important limiting factors for the population.[387] Dwarf minke whales also migrate from the Southern Ocean to the north of the Region each winter, potentially for breeding.[388] While tourism interactions record the number of small dwarf minke whale aggregations, it is unknown how representative these numbers are of the overall population size.[383]

Although threats to individual whales while transiting through the Region include entanglements in nets, underwater noise and vessel strikes, the greatest threat to the population persistence of baleen whales is climate change and the related effect on their food sources outside the Region.[385,389,390,391] The increasing abundance of humpback whales and ships in the Region is likely to increase ship and vessel strikes (Section 5.8.3).[392]

Populations of whale species within the Region are believed to be currently stable, apart from humpback whales that are probably still increasing.

2.4.15 Dolphins

An estimated 18 species of dolphin occur in the Region. Dolphins are important top-level predators that feed on a variety of fish, crustaceans, shellfish and squid.[393] Dolphins can concentrate contaminants in their tissues; high levels of contaminants can be an indication of ecosystem stress.[394,395,396] Economically, dolphins are important to tourism and recreational users as iconic marine megafauna.

Four dolphin species reside in the Region year round. The spinner dolphin (*Stenella longirostris*) is found from the coast to the eastern boundary of the Region. The other three species — the Australian snubfin dolphin (*Orcaella heinsohni*), Australian humpback dolphin (*Sousa sahulensis*, formerly the Indo-Pacific humpback),[397] and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) — inhabit inshore waters. Another 14 species are occasionally found on the outer waters of the Reef, but limited information exists for these species.

Two inshore dolphin species, snubfin and humpback dolphins, are particularly at risk

All dolphin species within the Region are protected by legislation. In 2015, Australian humpback and snubfin dolphins were listed as high-priority species for conservation under the Reef 2050 Plan.[9] No Region-wide abundance assessments exist for these two species. However, recent estimates indicate there are several, fragmented populations of each species (ranging from 70 to 150 individuals) along the Queensland coast, similar in size to populations found in other Australian states.[393,398,399,400] Population modelling shows that losing more than one dolphin per year from any of these isolated populations, as a result of human causes, is not sustainable.[399,401] Three snubfin dolphins and five Australian humpback dolphins were reported to have died between 2014 and 2017,[337] so it is possible that at least some of the isolated populations in the Region are in decline. However, it is unclear how accurately these observations reflect total mortality within the current population.

A small pod of snubfin dolphins socialising near Repulse Bay, south of Airlie Beach, as captured by a drone. © GBRMPA

Several anthropogenic processes cumulatively threaten dolphin populations, including vessel strikes, coastal development resulting in habitat degradation and modification, incidental capture in commercial set mesh nets, shark control nets set for safety (noting that, as of 2019, there are only two left within the Region and none within the Marine Park), water pollution and climate extremes.[401,402,403,404] The effects of thermal stress in 2016 and 2017 on the Region's dolphin populations are unknown. However, an unprecedented marine heatwave in Western Australia had long-lasting negative impacts on both survival and birth rates of a resident population of Indo-Pacific bottlenose dolphins; this was associated with loss of seagrass habitat and mass mortality of invertebrate and fish communities.[405] All three inshore species are vulnerable to human activities, such as habitat loss, vessel strikes, and incidental capture and drowning in mesh nets.[394,406] Offshore dolphin species are less likely to be exposed to nearshore threats, but remain vulnerable to anthropogenic climate change. Overall, due to multiple and cumulative threats, populations of dolphin species within the Region have probably deteriorated since 2014.

2.4.16 Dugongs

The dugong (*Dugong dugon*) is the only remaining species of the family Dugongidae. The Region is home to a globally significant population of dugongs recognised as contributing to the Reef's outstanding universal value.[28,407]

Dugongs are the only herbivorous mammals that are strictly marine, and they play a fundamentally important ecological role in the functioning of coastal marine habitats, particularly seagrass systems.[408,409,410] As large herbivores, dugongs consume a considerable amount of seagrass (approximately seven per cent of their body weight per day).[62] This consumption strongly influences the productivity of seagrass ecosystems, which in turn provides other ecosystem services, such as carbon sequestration and storage.[410] Individual dugongs can move several hundred kilometres in a few days, potentially supporting large-scale seagrass dispersal and thereby contributing to connectivity between seagrass meadows and aiding seagrass resilience and recovery.[65] Dugongs are also important cultural keystone species for local communities in the tropics.[411,412]

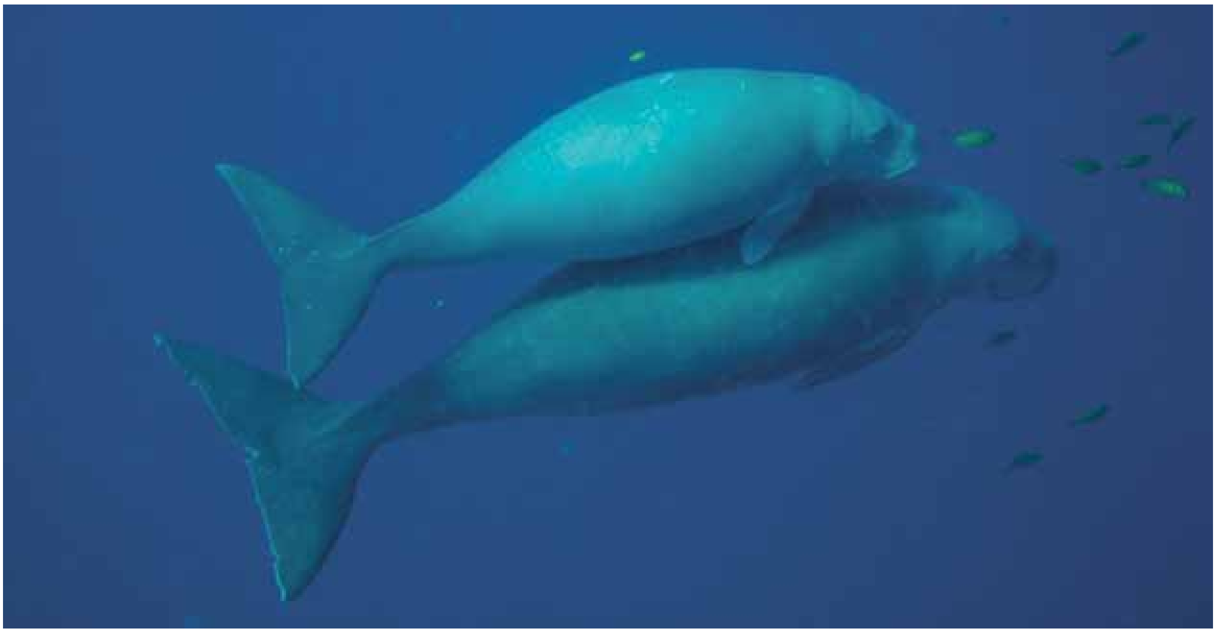
Dugongs occur along the length of the Region, and their abundance and distribution is monitored periodically. The nature and scale of human impacts on dugong populations and their habitats vary geographically. Two distinct areas are recognised: the remote coast (from Cooktown to the northern boundary of the Marine Park) and the urban coast (from Cooktown south to the southern boundary of the Marine Park). A series of aerial surveys conducted about every five years since the 1980s indicates the dugong population along the urban coast was significantly higher in 2016 than in 2011.[413] This difference is attributed to dugongs migrating into the area as the condition of seagrass communities recovered following flood and cyclone impacts in 2011.[59] The percentage of calves observed also increased from zero in 2011 to more than 10 per cent of the population in 2016.[413] Unsuitable weather caused cancellation of remote coast surveys planned for late 2018, and these will now occur in 2019.

In the southern Great Barrier Reef, more dugong calves were observed in 2016 than in 2011

Statistical analyses of the aerial survey data[414] suggest an overall decline in dugongs across the entire Region of 2.3 per cent per annum between 2005 and 2016. The probability that dugong abundance declined in the remote coast area between 2005 and 2013 is 0.79 (out of a possible 1.00), with an estimated decline of 3.1 per cent per year. For the urban coast area, the probability that the population declined over the same period is 0.69, with an estimated decline of 1.5 per cent per year.

Key impacts on dugongs include incidental drowning in commercial fishing nets, vessel strikes, habitat degradation and poaching.[415] Loss or degradation of seagrass habitats, due to prolonged periods of rain, floods or cyclones, can severely and acutely deplete the populations, because the reduced food availability delays reproduction and ultimately causes starvation.[62,416] Climate change is a threat to dugong populations, since it affects coastal environmental conditions and flood events, both of which affect dugongs and the seagrass habitats they rely upon.[62,417]

Although the Region's dugong population exhibits an overall long-term decline, there has been some recent recovery for the urban coast dugong population since 2014.



A dugong mother and calf swim near Low Isles. © Chris Jones

2.5 Assessment summary — Biodiversity

Paragraph 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

Grading statements — habitats to support species

🟩 **Very good**
All major habitats are essentially structurally and functionally intact and able to support all dependent species.

🟨 **Good**
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.

🟧 **Poor**
Habitat loss, degradation or alteration has occurred in a number of areas leading to persistent, substantial effects on populations of some dependent species.

🟥 **Very poor**
Widespread habitat loss, degradation or alteration has occurred in a number of areas leading to persistent, substantial effects on many populations of dependent species.

⬜⬜ **Borderline**
Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟨	🟨 ↓	🟧 ↓			**Habitats to support species:** The condition of habitats overall is poor at a Region-wide scale, because 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 a high level of variability in the scale and condition of all habitats assessed, and data for the majority of habitats are limited. For many habitats considered in good condition overall, condition is usually lower closer to the coast and in the vicinity of developed areas. The isolation of *Halimeda* banks and continental slope from the mainland, and their depth, contribute to their very good condition. Extreme sea surface temperatures and localised flood plumes have affected many habitats, particularly seagrass meadows and the water column, and caused widespread deterioration in coral reef habitats.
🟨	🟨 ↓	🟨 ↔	◐	◐	**Islands:** Localised damage to some islands has occurred from severe weather, temperature extremes and pests. Recovery from past impacts is occurring and monitoring of island condition is increasing.
🟨	🟨 ↔	🟨 ↔	◐	◐	**Mainland beaches and coastlines:** Some beaches and coastlines have been modified as a result of natural processes, coastal development and climate change. However, most remain in a relatively natural state.
🟨	🟨 ↔	🟨 ↔	◐	◐	**Mangrove forests:** Cyclones have caused localised habitat loss and degradation; recovery is occurring.
🟨	🟧 ↓	🟧 –	●	●	**Seagrass meadows:** Degradation of inshore seagrass meadows has occurred in a number of areas and recovery has been slowed by a number of disturbances. The absence of seed banks and low reproductive effort have resulted in many seagrass meadows being vulnerable.
🟨	🟧 ↓	🟥 ↓	●	●	**Coral reefs:** Multiple severe disturbances have caused widespread damage and loss of coral reef habitat in a number of areas. Coral recruitment has declined significantly. Evidence of cascading effects on coral dependent species, such as fish and invertebrates is emerging.
🟨	🟨 ↔	🟨 ↓	◐	○	**Lagoon floor:** Some areas of the lagoon floor have been exposed to prolonged thermal stress, impacts associated with dredging and disposal, bottom trawling, shipping and potentially damaging cyclonic waves.
🟨	🟨 ↔	🟨 ↓	◐	○	**Shoals:** Underwater mapping has increased understanding of shoal extent but not condition. Since 2014, over 10 per cent of shoals have been exposed to potentially damaging cyclonic waves and many have been exposed to prolonged thermal stress.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟩 ↔	🟩 ▬	○	○	***Halimeda* banks:** Improved spatial analysis has increased understanding of the spatial coverage of *Halimeda* banks. Understanding its ecological role and condition remains limited. Exposure to potentially damaging cyclonic waves and thermal stress has occurred since 2014, but impacts are inferred to be limited given their isolation and depth.
🟩	🟨 ↓	🟩 ↔	○	○	**Continental slope:** Much of this habitat remains undisturbed and minimally affected. The upper continental slope around the Swain Reefs is exposed to high levels of trawl effort. Clarification on the extent of this habitat has resulted in a grade of very good.
🟨	🟨 ↓	🟨 ↓ 🟧	◐	◐	**Water column:** The water column has deteriorated in some inshore areas due to the impacts of land-based run-off. Alteration of the water column may have occurred in a number of areas following record-breaking temperature extremes potentially leading to substantial effects on some species. The condition of water column habitat is good borderline poor.

2.5.2 Populations of species and groups of species

Grading statements — populations of species and groups of species

🟩	🟨	🟧	🟥	⬜⬜
Very good	**Good**	**Poor**	**Very poor**	**Borderline**
Only a few, if any, species populations have deteriorated as a result of human activities or declining environmental conditions.	Populations of some species (but no species groups) have deteriorated significantly as a result of human activities or declining environmental conditions.	Populations of many species or some species groups have deteriorated significantly as a result of human activities or declining environmental conditions.	Populations of a large number of species have deteriorated significantly.	Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟨	🟨 ↓	🟧 ↓			**Populations of species and groups of species:** The majority of species or groups of species have declined, mainly due to human activities and climate change impacts. Findings reflect both ongoing effects of past significant population declines (for example, from historic commercial harvesting) and impacts on the habitats they depend on. Deterioration (to varying extents) has now occurred throughout the Region, not just the southern two thirds, and is particularly evident in coral species. Some species (such as humpback whales and some turtle populations) show continuing recovery from historical declines.
🟩	🟩 ↔	🟩 ↔	◐	◐	**Mangroves:** The diversity and abundance of mangrove species are being maintained, with several new species being recorded in the Region.
🟨	🟧 ↓	🟧 ↔	◐	◐	**Seagrasses:** Inshore seagrass community composition continues to change in many inshore meadows as the habitat recovers from past disturbances.
		🟨	◐		**Benthic algae:** Overall benthic algal diversity appears to be maintained and abundance has increased in some areas, resulting in good condition across the Region. However, some species of coralline algae were affected by thermal stress in 2016 and 2017 and are showing signs of stress from ocean acidification. Turf algal condition is also deteriorating in some inshore locations due to sedimentation. A trend cannot be provided due to macroalgae and benthic microalgae being combined in 2019.
🟨	🟨 ↔				**Macroalgae:** Combined into benthic algae assessment.
🟩	🟩 ↓				**Benthic microalgae:** Combined into benthic algae assessment.
🟨	🟧 ↓	🟥 ↓	●	●	**Corals:** Unprecedented mass coral bleaching due to global warming, outbreaks of crown-of-thorns starfish and cyclone impacts have reduced coral diversity and abundance, with widespread loss of key habitat-forming coral species at many locations.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟨 ↓	🟧 ↓	○	○	**Other invertebrates:** Prolonged thermal stress, substantial loss of coral habitat, poor water quality and fishing have probably adversely affected many invertebrate species across a range of habitats. Populations of bioeroding species may have increased with more dead coral substrata available in affected areas.
🟩	🟩 ↓	🟨 ↓	○	○	**Plankton and microbes:** There is little information on plankton and microbe populations in the Region. Changes in water temperature and water quality are likely to be negatively impacting plankton and microbial communities.
🟨	🟨 ↓	🟨 ↓	◐	◐	**Bony fishes:** Little is known about the condition of most bony fish species on a Region-wide scale given it is a highly diverse group. Some coral-dependent fishes have decreased in areas affected by mass bleaching events. Some herbivore populations have remained stable or increased in some areas. Current extraction rates for some fished bony fish species are considered sustainable, however, there are concerns for other species. There is likely to be a lag in detecting effects on bony fishes following multiple impacts on their habitat.
🟧	🟧 ↓	🟧 −	◐	◐	**Sharks and rays:** Quantitative information does not exist for most species of sharks and rays in the Region; some species have declined, others recovered and trends for most species are unknown. Fishing (and incidental catch) and climate change are the primary threats to sharks and rays, with at least 17 species considered highly vulnerable to exploitation and 30 species at risk from climate change.
🟧	🟧 ↔	🟧 ↔	○	○	**Sea snakes:** The trawl fishery continues to kill sea snakes through bycatch. Management changes in the trawl industry have reduced capture. Localised depletions have been reported. Condition information is a knowledge gap because no ongoing monitoring occurs.
🟧	🟧 −	🟧 −	●	◐	**Marine turtles:** Heightened concerns exist for the future of loggerhead, hawksbill and northern green turtle populations. The southern green turtle population continues to recover. The trend for flatback turtles is not clear.
🟨	🟨 ↑	🟨 ↔	◐	◐	**Estuarine crocodiles:** Estuarine crocodile population density across the Region is estimated to be low. Climate change may be altering the sex ratios of hatchlings and increasing the maximum size of adults.
🟧	🟧 −	🟧 −	◐	◐	**Seabirds:** Limited information is available on the condition and trend of seabirds. Reef-wide trends indicate slight declines in six seabird populations between 1980 and 2017. The population of one species is increasing.
	🟧	🟧 −	○	○	**Shorebirds:** Population estimates for the Region's shorebirds are not differentiated from the national level analyses, making condition assessments difficult for the Region. Large numbers of multiple shorebird species have declined in the Mackay area, whereas other areas have retained populations of shorebird species.
🟨	🟨 ↑	🟨 ↔	◐	◐	**Whales:** Populations of whale species within the Region are believed to be currently stable. Humpback whales have recovered strongly. Climate change is the greatest threat to baleen whale populations and the related effect on their food sources outside the Region.
🟨	🟨 ↓	🟨 ↓	○	○	**Dolphins:** Data on the Region's dolphins are very limited. Offshore dolphin species are considered more stable as they are less likely to be exposed to human-related threats than inshore dolphin species. Concerns continue for the condition of Australian humpback and snubfin dolphins (both inshore species), which may be in decline due to human-related mortality.
🟧	🟧 ↓	🟧 ↑	●	●	**Dugongs:** The Region is home to globally significant populations of dugongs. Over the entire Region there is a high probability that the dugong population declined between 2005 and 2016. Along the urban coast, from Hinchinbrook south, the breeding rate has improved since the impacts of cyclone Yasi and widespread flooding in 2011.

2.6 Overall summary of biodiversity

The Region is one of the world's most diverse and remarkable ecosystems and contains the largest coral reef system in the world. This biodiversity is a critical component of the Reef's outstanding universal value and natural heritage value. Biodiversity was assessed in terms of habitats and populations of species.

The Region is one of the world's most diverse and remarkable ecosystems and contains the largest coral reef system in the world

Across the entire Region, the condition of habitats (as a group) was rated poor, compared with a rating of good in 2014. This deterioration reflects that habitat loss and degradation or alteration in a number of areas have had persistent and substantial effects on populations of some dependent species. The significant and large-scale impacts on coral reef habitats and coral species from extreme sea surface temperatures due to global warming has resulted in these components transitioning from poor to very poor condition for the first time in the history of Outlook reporting. Exposure to high sea surface temperatures and severe cyclones are also likely to have influenced the condition of other habitats, such as the lagoon floor, shoals and the water column, which are rated good but deteriorating.

Coastal habitats, including mangroves, islands and mainland beaches and coastlines, remain in good condition across the Region. However, confidence in these grades is limited given a lack of broadscale quantitative data and ongoing monitoring. Many habitats have declining trends, and the two key habitats where confidence in grades is adequate (seagrass meadows and coral reefs) are rated as being in poor and very poor condition, respectively.

Significant and large-scale impacts on coral reefs from extreme ocean temperatures has resulted in this habitat transitioning from poor to very poor condition

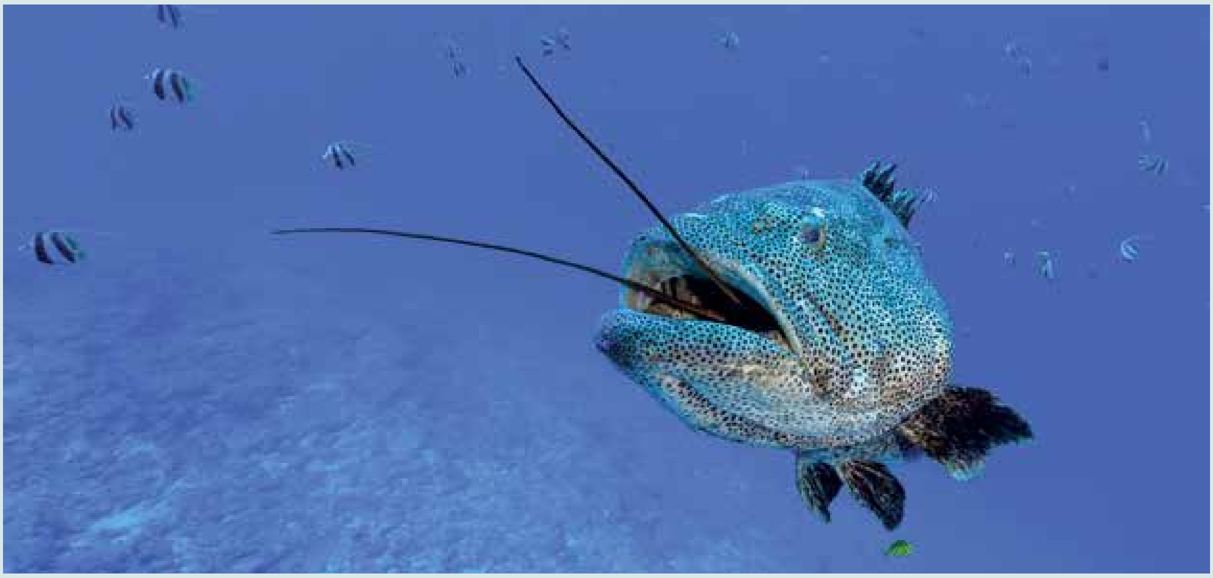
The condition of the Region's species is also of concern, with the overall assessment of species' populations deteriorating from good in 2014 to poor. Condition declined in most of the assessed species components, and over half are graded as being in poor or very poor condition. Species assessments reflect both long-lasting effects of significant past population declines (for example, from historical commercial harvesting) and effects of deterioration of the habitats they depend on. There are a few instances where species have improved in condition. Humpback whales and the southern population of green turtles continue to recover, and the breeding rate of urban coast dugongs has improved since the impacts of the cyclone and flooding in 2011.

For both habitats and species, grades provided are for the entire Region. The size of the Region is extensive and variability in condition exists. For example, reefs that escaped impacts of bleaching, cyclones and crown-of-thorns outbreaks remain in good condition.

Humpback whales and the southern green turtle population continue to recover

Key knowledge gaps remain for many species and habitats that are not comprehensively monitored. The lack of information on most groups of species is concerning, because declines may not be evident until critical thresholds are exceeded. Condition is inferred for some of the deeper and less accessible habitats, such as *Halimeda* banks, the continental slope and lagoon floor, because these habitats are not frequently monitored and large knowledge gaps remain.

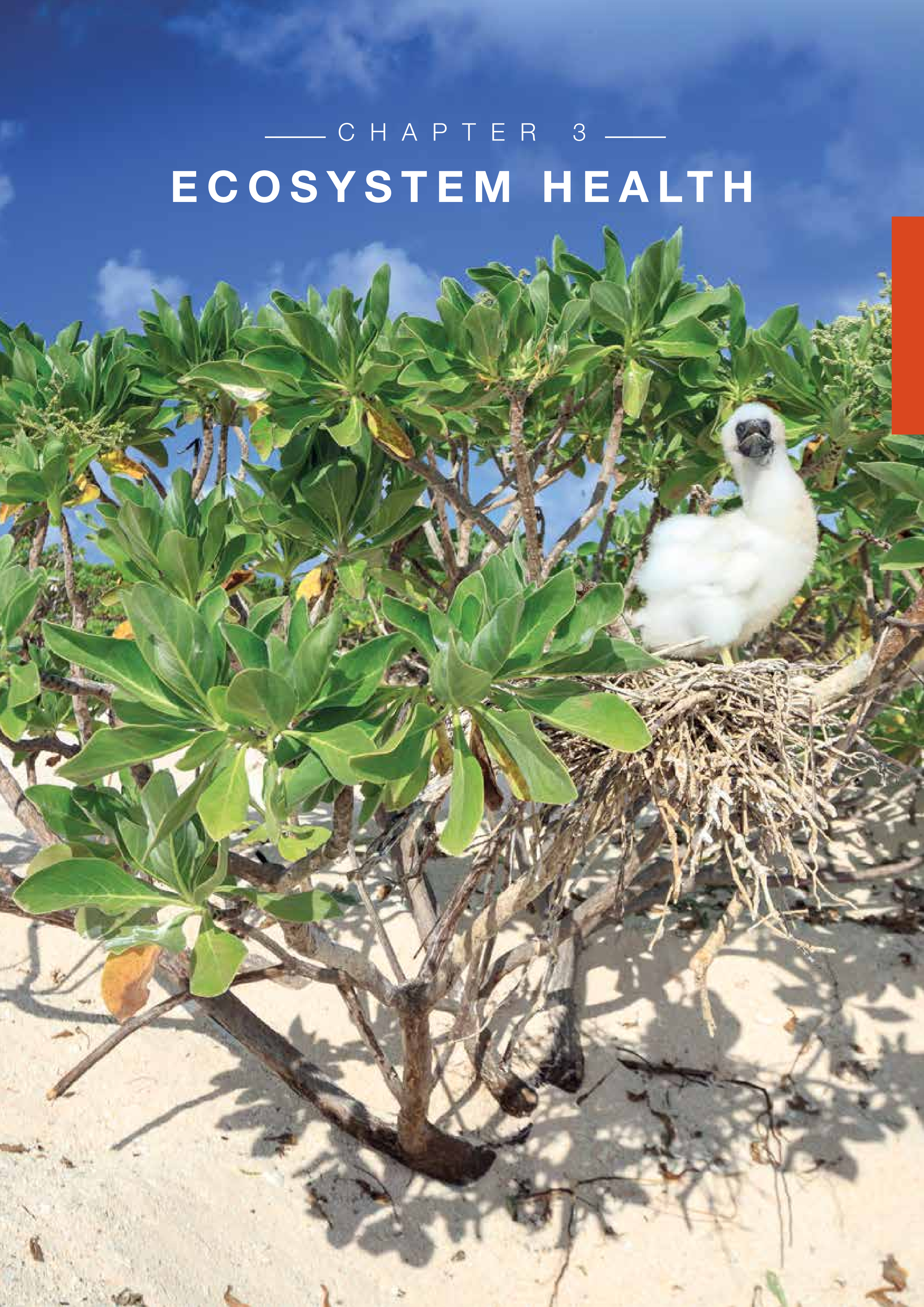
The Region has experienced an unprecedented level of widespread cumulative stress since 2014. Further deterioration in the condition of habitats and species is likely in future if threats persist and recovery windows are no longer adequate.



Groper swallowing a crayfish. © Tane Sinclair-Taylor

CHAPTER 3

ECOSYSTEM HEALTH



« *A seabird chick waits for a parent to return with food — recruitment of new individuals into populations is an important ecological process.* © Tane Sinclair-Taylor

ECOSYSTEM HEALTH

(an element of natural heritage)

‘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’, s 54(3)(a) of the *Great Barrier Reef Marine Park Act 1975*

3.1 Background

The Region’s ecosystem includes all of its species interacting together within the physical and chemical environment. Ecosystem health encompasses these key interactions and processes that operate to keep an ecosystem functioning. For example, without the process of larval dispersal by currents, species and habitats would not replenish after disturbances. Broadscale impacts have more potential than smaller localised impacts to disrupt ecosystem processes.

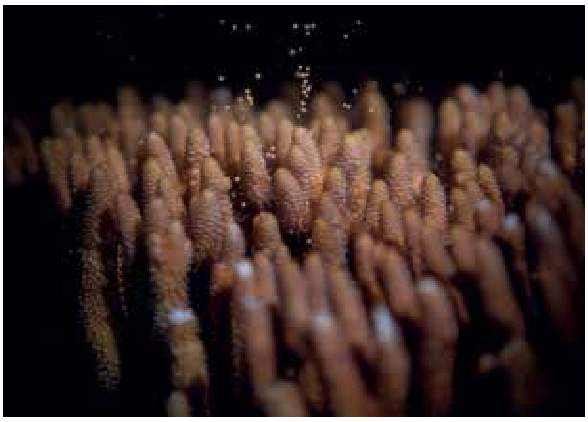
Change in biodiversity can only be used as an approximate indicator of ecosystem status.[418,419] An ecosystem is considered healthy if it is able to maintain its structure and function in the face of external pressures.[420] A functioning ecosystem provides a range of services and benefits to humans, including supporting, provisioning, regulating and cultural services.[421,422]

This systematic assessment of the health of the Reef ecosystem is based on five assessment criteria, which consider the Region’s main processes (Figure 3.1):

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

The scope of the components assessed remain the same as the previous Outlook Report, with a few minor updates to titles (Appendix 2).

Predation is a key ecological process. © Tane Sinclair-Taylor



Coral spawning is a well known recruitment phenomenon. © Mikaela Nordborg

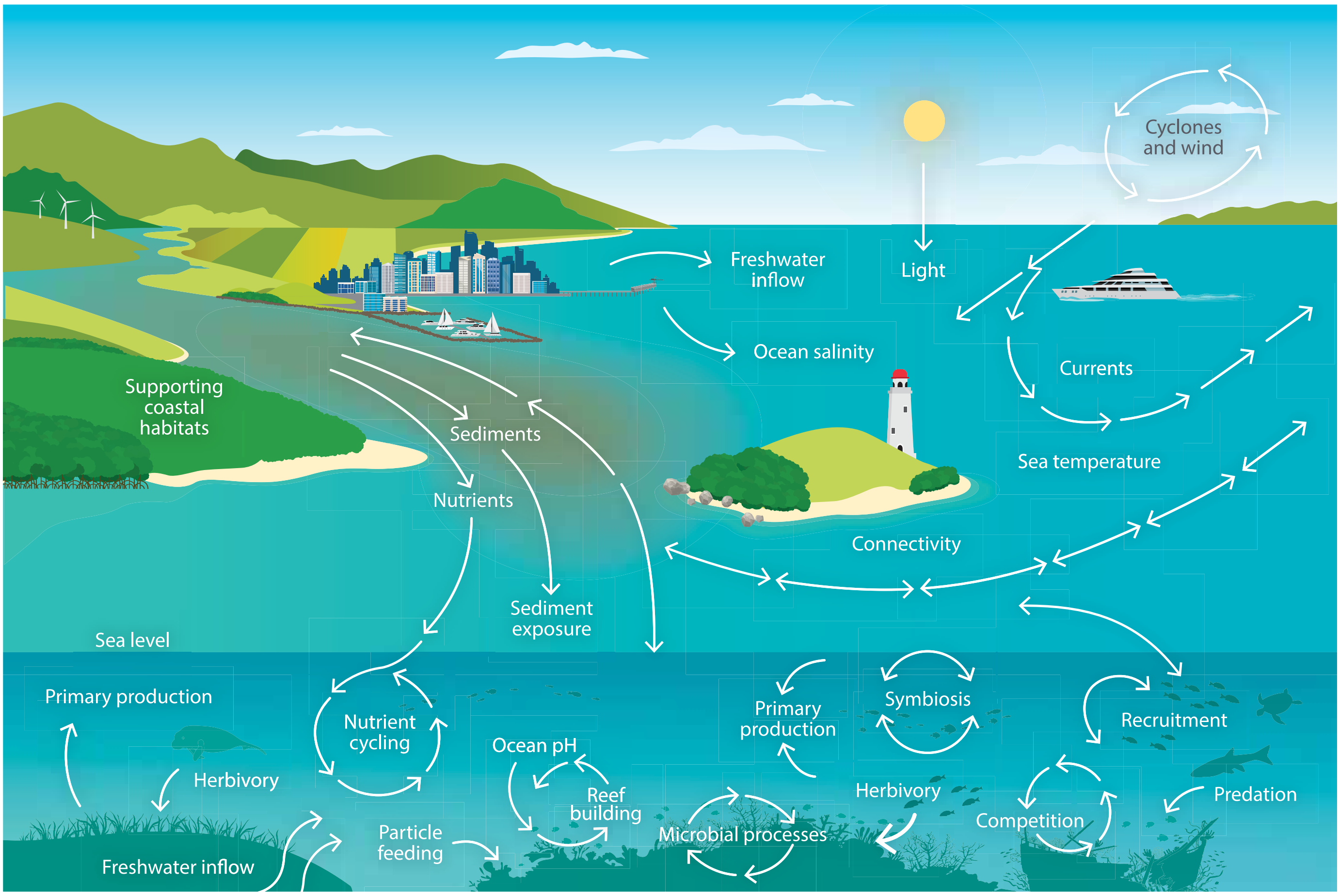


Figure 3.1 Major physical, chemical and ecological processes
The health of the Reef ecosystem is assessed by considering its physical, chemical and ecological processes as well as the condition of its supporting coastal ecosystems. Outbreaks of pests and diseases are also considered as a guide to overall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

3.2 Current condition and trends of physical processes

Seven physical processes are graded. Currents remain in very good condition and four physical processes (cyclones and wind, freshwater inflow, sea level and light) remain in good condition. Sediment exposure remains poor and sea temperature has deteriorated to very poor. ↓

Full assessment summary: see Section 3.7.1

3.2.1 Currents

Types of currents that affect the Region include oceanic, wind-driven and tidal. Currents support biodiversity and ecosystem functions within the Region, via exchange of shelf and Coral Sea waters and upwelling, promoting larval dispersal and connectivity.[152,423,424,425,426] Currents also transport pollutants and contaminants, such as land-based run-off, dredge spoil and microplastics, from Australia and distant regions to the Reef.[161]

Two branches of the South Equatorial Current enter the Region and split into the North Queensland Current (Hiri Current) flowing north and the East Australian Current flowing south.[426] The South Equatorial Current influences the Region at multiple locations and controls the relative strength of the North Queensland Current and the East Australian Current.[426] The East Australian Current is the predominant current around reefs and island chains, and together with tidal currents create eddies, jets and other fine-scale circulation features that affect local reef-scale processes and connectivity.[152] Generally, the North Queensland Current and East Australian Current are of similar strength. However, this changes during extreme El Niño and La Niña events. The southerly flow is more dominant on mid-shelf reefs during El Niño and the northern flow is stronger during La Niña.[424]

The East Australian Current has already warmed and extended south by approximately 350 kilometres

While currents as a physical process in the Region have continued to connect and transport species and nutrients, changes are occurring. For example, the East Australian Current has already warmed and has extended south of the Region by approximately 350 kilometres.[427] This pattern is expected to increase under climate change projections (Section 6.3). Overall, there have been no significant changes to currents within the Region, and they continue to transport and connect species and habitats.

3.2.2 Cyclones and wind

Cyclones track through much of the world's tropical regions and are significant drivers of ecosystem change.[428] During El Niño events, there are typically fewer tropical cyclones than average, while more tend to occur during La Niña events. Destructive waves generated by cyclones can cause extensive damage; for example, they can kill coral and damage reef structure[429], destroy mangrove forests[54] and cause high levels of erosion on islands.[430]

Since 2014, over 50 per cent of the Reef area has been exposed to destructive waves from six tropical cyclones

Damage to ecosystems from cyclones is usually patchy and highly variable at local scales (less than 10 metres).[274,431,432] The likelihood of destructive waves in a particular location depends on the cyclone's intensity, size, speed of forward motion and fetch.[433,434] Weaker cyclones of sufficient fetch that move slowly over areas can generate waves that are just as destructive as those from the strongest cyclone.[434] The spatial[435] and temporal distributions[436] of cyclones are important attributes in assessing the vulnerability of habitats and species, as is the overall disturbance history.[437]

Long-term monitoring indicates that, before the 2016 mass bleaching, cyclones had caused the greatest overall coral loss in the Region.[438] Since 2014, six tropical cyclones have made landfall along the Region's coastline, with five of those being severe (Category 3 or above, Figure 3.2), affecting 68 per cent of reef area in the Region.[434] Past cyclones have caused extensive declines in hard coral cover[432] and coral trout abundance.[439] Surveys conducted following cyclone Ita in 2014 found a decline in biomass of several damselfish species and an increase in herbivores around Lizard Island.[274] The effects of cyclone Debbie on reefs in the Whitsundays are still being determined. However, six reefs surveyed in 2017 exhibited an average 70 per cent loss of coral cover at two metres depth and 64 per cent loss at five metres depth, but this ranged up to 98 per cent in some areas.[440] Because cyclone Debbie moved extremely slowly (average forward speed of just over seven kilometres per hour), gales near the reefs persisted for a maximum of 56 hours, making it the third most persistent cyclone since 1985.[441,442] Although the cumulative effect of cyclone impacts since 2014 has not been quantified, it is likely that many affected species are still recovering.

Wind influences the marine ecosystem, shaping islands and coastlines, and influencing waves and currents and the pathways of marine pollution.[443,444] Established wind patterns also influence reef animals, such as corals[445] and fish.[446] Any changes in wind patterns may also alter connectivity within the Region, via the distribution of wind-borne seeds and larvae from coral, fish and invertebrates.[447,448,449,450]

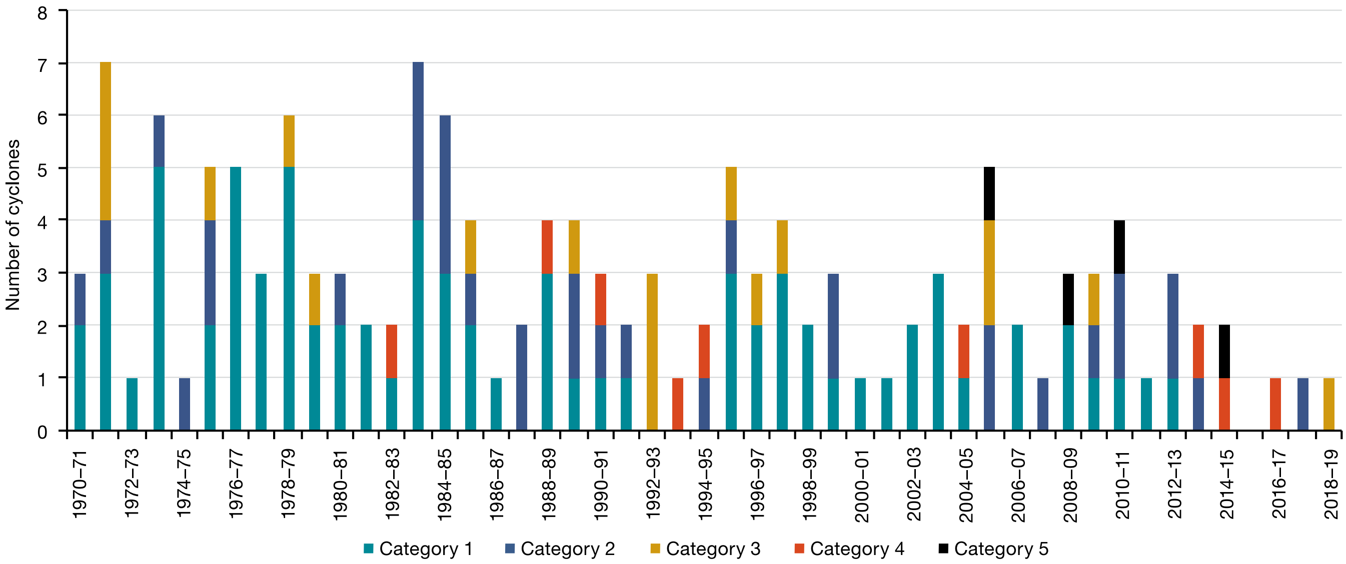


Figure 3.2 Number and severity of cyclones, 1970–71 to 2018–19
Five severe cyclones (Category 3, 4 or 5) have affected the Region since 2013–14. Source: Bureau of Meteorology 2019[451]

Wind patterns and the intensity of cyclones have not measurably changed since the 2014 Outlook Report assessment.[452] Forward speeds of tropical cyclones over Australia have slowed by an average of 22 per cent between 1946 and 2016; this slowdown has been linked to rising temperatures associated with human-induced climate change.[453] Nonetheless, these changes have not yet had a demonstrable effect on ecosystem function and no consistent trend was detected in the 2014–2018 assessment period.

3.2.3 Freshwater inflow

Rivers and streams from the Catchment drain an approximate area of 424,000 square kilometres. Rivers in the Cape York, Wet Tropics and Mackay–Whitsunday natural resource management (NRM) areas generally have groundwater flow all year round and high rainfall events every year. By comparison, the Burdekin, Fitzroy and Burnett–Mary areas have less frequent but higher discharge events.[454,455]

Between 2013 and 2018, freshwater flow was near or below the long-term average for the Catchment

Freshwater input lowers salinity and introduces sediment, nutrients, pesticides, herbicides and other pollutants into the marine environment, which can have significant effects on inshore and mid-shelf habitats and species.[43,456,457] Lower salinity and light can lead to localised coral and seagrass mortality. For example, a large-scale flood plume from the Fitzroy River in 2010 lowered seawater salinity and caused 40–100 per cent coral mortality at Keppel Bay.[458]

Freshwater flow has also become more variable since European settlement, with more extremes experienced during wet and dry seasons.[459] Substantial changes in freshwater flow into the marine environment appear to be associated with changes in the El Niño-Southern Oscillation.[457] Cores taken from long-lived corals indicate that the frequency of high freshwater flows into the Region has increased over the past two centuries, from every 20 years in 1748–1847 to every six years in 1948–2011.[457,460] Along with climate change, extensive land clearing and changes in land use (Section 6.4) have occurred over this time period, and are likely to have altered hydrology, contributing to higher freshwater discharges.[457]

The frequency of freshwater flows has increased cumulative pressures on the Region since European settlement. This has affected recovery of inshore coral and seagrass habitats, which are inhibited by the reduced time between high-flow periods.[59,457,461] Despite this longer-term change, freshwater flow was near or below the long-term average for the Catchment between 2013 and 2018, similar to the period 2004–2007 (Figure 3.3).[460] The correlation between low rainfall, low flows and coral recovery was observed in the Burdekin region from 2013 to 2018, where coral condition improved from poor to moderate.[440,462,463] As described above, human activities have caused significant changes in freshwater inflow, although over the past five years freshwater flow has been near or below the long-term average, resulting in a stable trend in condition since 2014.

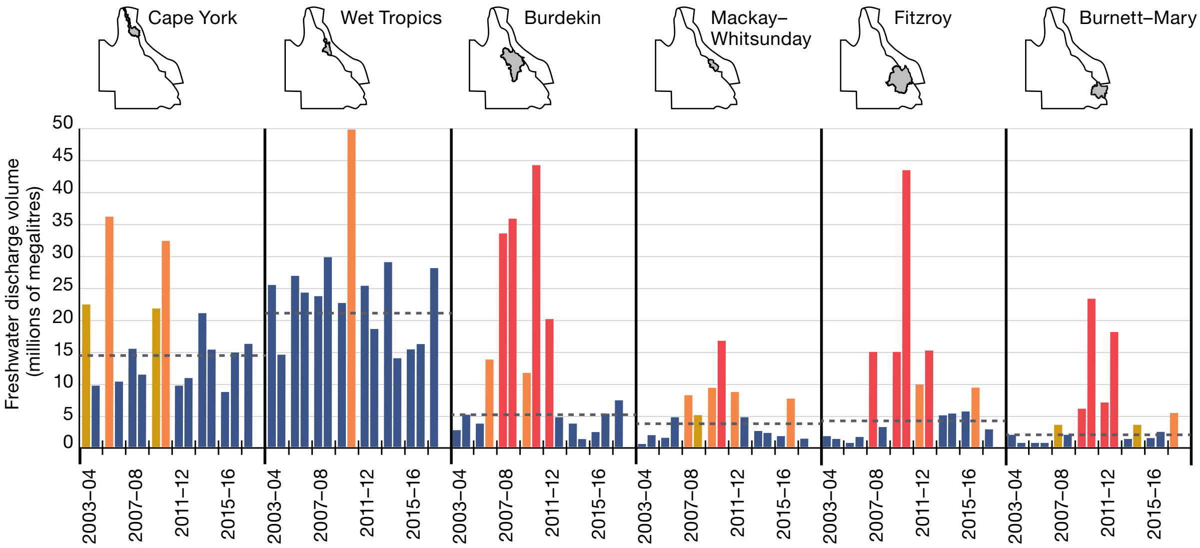


Figure 3.3 Annual freshwater discharge from major rivers, 2003–04 to 2016–17
Discharge in millions of megalitres (ML) (hydrological year: 1 October to 30 September) for the 35 main Reef rivers, combined for each of the six NRM regions. Bar colours: red = ≥3 times long-term median flow, orange = 2–3 times, yellow = 1.5–2 times, blue = <1.5 times. Dashed grey line indicates long-term median for each natural resource management region. Source: Data supplied by Department of Science, Information Technology and Innovation (Qld) 2018. Compiled by James Cook University (Gruber *et al*. 2019[155])

BOX 2

Freshwater inflow — 2019 event

In February 2019, an active monsoon trough led to extreme rainfall and subsequent flooding around Townsville (approximately 1.3 metres of rain fell in 10 days).[464] Heavy rainfalls occurred from Cape York to the Mackay–Whitsunday natural resource management region. The volume of water discharged from the Burdekin River was the largest in eight years (14.5 million megalitres in three weeks), and it extended to the outer-shelf reefs.[465] Greenish waters, indicating high phytoplankton (algae) levels, were observed in mid-February. The flood plume extended beyond the outer shelf and moved south (potentially being carried by the East Australian Current).[465] The flooding is likely to have affected water quality via reduced salinity and elevated nutrient and sediment loads from major river systems, with consequent impacts on seagrass meadows, crown-of-thorns starfish larvae and coral reef ecosystems.[465] Freshwater bleaching and disease may have occurred on some inshore reefs.[465]

Left: Burdekin River flood plume inundates Old Reef, Stanley and Darley reefs. © Queensland and Australian Government agencies/programs: TropWATER (JCU), Marine Monitoring Program (GBRMPA), Office of the Great Barrier Reef, NQ Dry Tropics, CSIRO and NESP (Tropical Water Quality Hub), photographer: Matt Curnock, 2019.

Right: River flood emerging from the Burdekin River (12 February 2019) after unprecedented levels of rain and flooding. The use of imagery from the NASA Worldview application (https://worldview.earthdata.nasa.gov/), part of the NASA Earth Observing System Data and Information System (EOSDIS) is acknowledged.

3.2.4 Sediment exposure

The process of sediment exposure includes the transport of sediment into and throughout the Region, including through resuspension and increased turbidity, and sediment settling on plants and animals. The inflow, dispersion, resuspension and consolidation of sediments from land to the sea is a natural process that has occurred in the Region since the current sea level was reached about 6500 years ago.[85,154,466]

Sediment loads continue to contribute to the poor state of many inshore coastal and marine ecosystems

Since European settlement, suspended sediments entering the Reef lagoon are estimated to have increased five-fold[154,467], which can be largely attributed to human influences.[43] This increase is a result of soil erosion from rangeland grazing and cropping, urban development, deforestation and mining. Some of the increase can also be attributed to fluctuation in weather, climate change and associated changes in rainfall and land-based run-off.[467,468]

Most sediment is delivered to the Region during flood events[469], with the amount varying along the coast between the six NRM regions and individual catchments.[467] Modelling of land-derived total suspended solids indicate that the highest exposure levels from anthropogenic sediment loads are concentrated in the inshore areas, with the largest inputs from the Burdekin River (Figure 3.4).

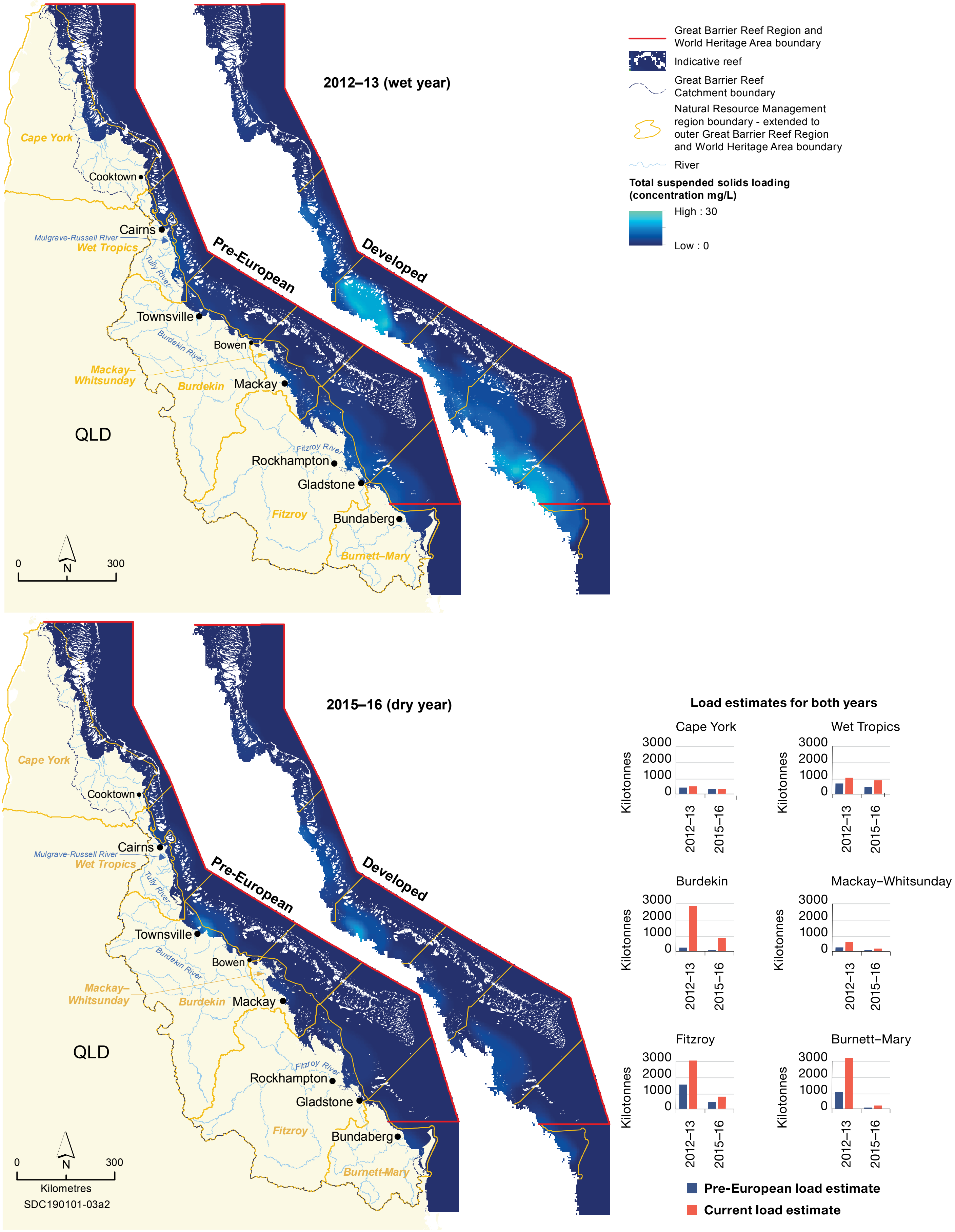


Figure 3.4 Modelled total suspended solids catchment loads, 2012–13 and 2015–16

Modelled distribution of total suspended solids in end-of-catchment loads, based on annual average pre-European (left) and current (right) years, highlighting the difference between a wet year (2012–13 top) and a dry year (2015–16 bottom). The graphs show the modelled annual average loads for each period for the six natural resource management region. The blue bars are pre-development and red bars are current.

Source: Based on the Marine Monitoring Program, compiled by James Cook University (Gruber *et al.* 2019[155])

Most sediments delivered from flood plumes settle relatively close to river mouths (within 50 metres).[470,471] However, fine sediment (smaller than 16 micrometres) is more likely to be carried in suspension and reach the inshore and mid-shelf areas of the Reef.[467,472] Fine sediment can be resuspended by wind and strong tidal currents in shallow waters, and may persist in the water column for at least six to eight months following river input, with the potential to be transported large distances, including to the outer shelf.[43,153,158,467,473,474] Delivery and resuspension of new sediments and resuspension of historic sediments can combine to affect water quality condition all year round.[467,471,475] Sediment exposure can result in the degradation of coral reefs, seagrass meadows and freshwater wetlands, as well as affecting filter feeders and fish.[43,153,473,476,477,478] Specifically, sediment exposure can lead to physical disturbance, burying of organisms and increased susceptibility to disease.[43]

Wet season river influence from 2013–14 to 2017–18 rarely extended seaward of inshore waters.[155] Therefore, impacts to mid-shelf and offshore ecosystems from land-derived sediment exposure during this period were low.[43,469] However, sediment exposure was still significantly higher than pre-European settlement levels, despite low rainfall in the last five years. Across the Region, the relative influence of sediments sourced from river discharge compared to resuspension of sediments pre-existing in the ecosystem remains poorly understood.[469] There have been substantial changes in sediment exposure since European settlement and these changes are significantly affecting inshore coral and seagrass habitats. Overall, the process of sediment exposure has deteriorated in the Region.

3.2.5 Sea level

Sea level in the Region reached its current level about 6500 years ago.[85] Although tides and weather patterns cause local temporal and spatial sea level variation, global sea level is primarily driven by two main processes: thermal expansion (an increase in the volume of sea water as it warms) and increased melting of land-based ice.[479,480] Fluctuations in sea level have played a major role in the evolution of the modern Reef by influencing light availability (a function of water depth), which is the primary driver of photosynthesis and enhanced calcification.[481] Sea level also affects the distribution and functioning of tidal habitats, such as mangroves and low-lying freshwater habitats, due to its strong influence on salinity levels.[482]

Sea-level rise in the Region is increasing faster than the global average

By 2018, global sea level was 82 millimetres above the 1993 average, the highest annual average since systematic monitoring began at a global scale.[452] There is a lag in the response of sea-level rise to global warming.[483,484] Thus global sea-level rise is accelerating as the ocean north continues to warm.[485] Australian sea levels are rising, with the greatest increases being recorded in the northwest, north and southeast (Figure 3.5).[486] Since 1993, the average rate of sea-level rise in the Region was between five and seven millimetres per year[486], well above the global average of 3.3 millimetres per year.[480] Limiting future temperature increases will slow the rate of sea-level rise and provide more options for species and coastal communities to adapt.[487]

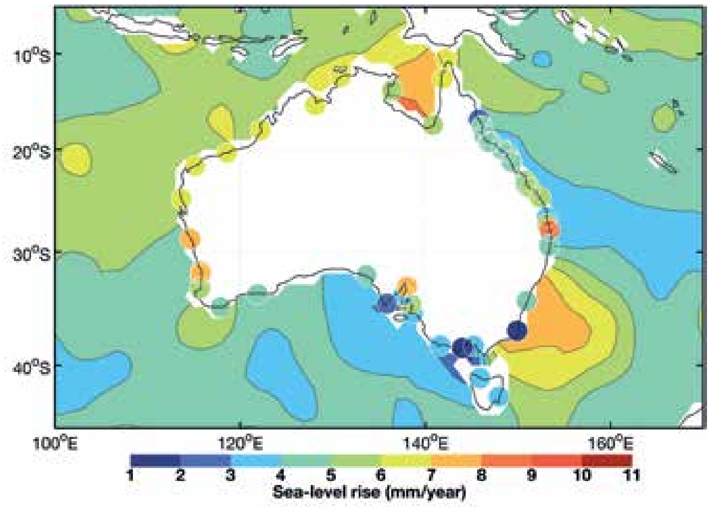


Figure 3.5 Sea level trend annual increase, 1993–2017
Linear trends from January 1993 to December 2017 for the Australian region from the satellite-altimeter data (contours), overlaid with estimates from the tide gauges (coloured dots). Both datasets show the largest sea-level rises occurring in the north and north-west and the lowest rises occurring along the east coast of Australia between latitude 20° south (Bowen) and 35° south (Nora).
Source: White *et al.* 2014[486] and CSIRO 2018[452]

Sea-level rise may reduce coastal protection through the loss of areas of key habitats, such as coral reefs. Although current sea-level rise poses little risk to the Region's coral reefs, future projected sea-level rise may exceed coral reef growth capacity.[488] Increased salinity from sea-level rise may lead to changes in the species composition of wetland communities and their ecosystem functions.[489] While some ecosystems (for example, mangrove forests and seagrass meadows) may be able to move shoreward as sea levels increase, coastal development often curtails these opportunities.[490] Small islands and cays are at risk of inundation and erosion from sea-level rise[491,492,493], directly threatening marine turtles, crocodiles and birds relying on those islands for nesting and roosting.[494,495,496,497] Reef tourism and recreational use of low-lying areas will also be affected given sea-level rise will continue long after emissions of greenhouse gases have stopped.[498]

Sea-level rise is continuous and small increases have occurred since 2014. Although this process is slowly deteriorating, impacts on the Region have not yet been detected.

3.2.6 Sea temperature

The temperature of the surface layers of the ocean is affected by both regional and global-scale processes. On a regional scale, sea temperature is influenced by seasonal variations in solar energy, cloud cover, currents, surface winds and the tidal regime. Globally, large-scale climate drivers include the El Niño–Southern Oscillation and anthropogenic heating. The world's oceans also play a major role in climate by absorbing surplus heat and energy.[499] Oceans have absorbed more than 90 per cent of the extra heat trapped by increased greenhouse gases since the 1970s.[500] As a result, the ocean is warming at an unprecedented rate.[501,502,503]

Sea temperature influences the distribution, survival, reproduction, growth, physiology and productivity of marine organisms.[377,504,505] Most marine animals are ectotherms, unable to heat and cool their body. Therefore, sea temperature determines their body temperature, and any changes can alter their distribution, metabolism, respiration and behaviour.[504,505] Temperature also affects marine organisms by altering other water properties; higher sea temperatures limit the concentration of dissolved oxygen available for respiration[506] and increase the solubility and toxicity of some heavy metals.[507] Temperature is also important in regulating the rate of coral calcification[508,509] and the productivity of seagrasses and mangroves.[510] Therefore, extremes in sea surface temperatures can reduce fitness and cause mass mortality of sensitive organisms.[91,99,141]

Record high sea temperatures have occurred in the past four years with widespread, severe impacts on species and habitats

Corals are particularly sensitive to small changes in temperature because of their narrow thermal tolerance range (Section 2.4.4).[511] Thermal stress of just one degree Celsius above the long-term summer maximum temperature for a few weeks can cause reef-building corals to eject the algae that live in their tissue, a process known as coral bleaching.

Above-average annual sea surface temperatures have been observed for the Reef every year since 2012, and present day temperatures of Reef waters are approximately 0.8 degrees Celsius warmer than when records began (Figure 3.6). The Region's sea temperatures were the warmest on record in 2016 (1.03 degrees Celsius above the 1961–1990 average, Figure 3.6), part of a long-lasting marine heatwave[512] that resulted in a severe mass bleaching event.[90] When unusually warm summer sea temperatures occurred again in 2017, a second mass bleaching event affected the Region. This was the first back-to-back bleaching event ever recorded on the Reef, and it caused widespread mortality of shallow-water corals (Section 2.3.5).[141]

There have been ongoing, substantial increases in sea temperature across most of the Region due to climate change, indicating deterioration of sea temperature processes since 2014.

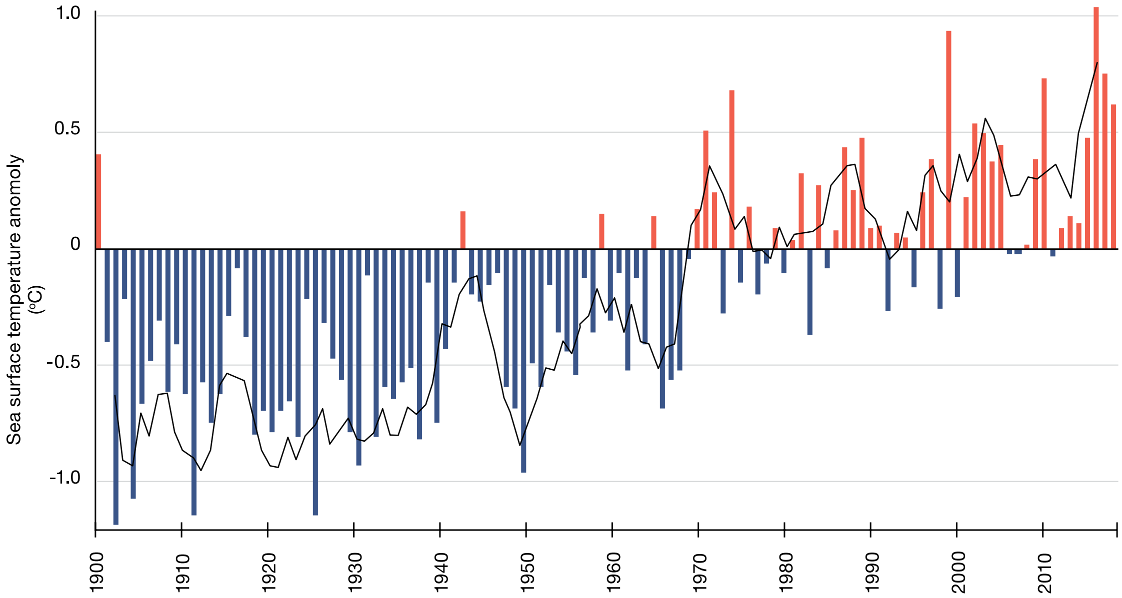


Figure 3.6 Sea surface temperature anomalies for Great Barrier Reef waters, 1900–2018
Above-average annual sea surface temperatures have been observed for the Region every year between 2012 and the present, and have been persistently high for the past two decades. Anomalies are the departures from the 1961–1990 standard averaging period. Black line indicates a five year running average. Source: Australian Bureau of Meteorology 2019[513]

3.2.7 Light

Light availability in the marine environment is variable and governed by a combination of suspended sediment, cloud cover and the optical properties of water, which bends and absorbs light waves. The rate at which light decreases in the water column is determined by water depth and turbidity, which is a measure of the degree to which the water loses its transparency due to the presence of suspended particles.[514] In clear water, such as the open ocean, light may penetrate down to 200 metres. However, inshore waters typically contain particles that scatter light and affect its transmission. These particles can originate from naturally occurring sediments or as a result of direct or indirect human activities (Section 3.2.4).

Light availability in the inshore areas has decreased over the past decade

Light is an important determinant of the distribution, growth, depth range and productivity of organisms reliant upon photosynthesis, including seagrasses, phytoplankton and corals.[70,200,515] Water quality affects light reaching seagrass meadows, and light in turn controls the productivity, abundance and distribution of seagrasses.[516,517] Reduced light, coupled with recent warmer sea temperatures, has probably hampered seagrass recovery.[74] For visual predators, light influences prey visibility and affects the energy needed to search and acquire food.[518] Exposure to light plays a key role in coral ecology, affecting settlement[519,520], direction of growth[521], competition with other organisms[522], calcification rates[515], and susceptibility to thermal stress and disease.[523,524,525] Light also affects the dispersal, settlement, feeding and mating patterns of fish and invertebrates.[526]

Light availability within the Region is affected by seasonal rainfall, weather and activities that resuspend sediments (currents, winds, tides, land-based run-off, anchoring and dredging). Turbidity of inshore waters in the Region, which has been measured since 2007[527], has shown a general increase over the past decade, resulting in an overall deterioration of the process of light availability (Sections 3.2.4 and 6.5)[460] and an overall deterioration of this process of light availability.

Light penetrating the surface waters above a shallow reef. © Matt Curnock

3.3 Current condition and trends of chemical processes

Three chemical processes are graded. Ocean pH and ocean salinity remain in good condition and nutrient cycling continues to be graded as poor. ↔

Full assessment summary: see Section 3.7.2

3.3.1 Nutrient cycling

Nutrients are essential for the growth and survival of organisms. Nutrient cycling is one of the most important ecosystem processes, transferring nutrients from the physical environment through uptake by organisms, passing them through food chains, and returning them to the physical environment when organisms decay or die. Nitrogen, phosphorus and carbon are the main nutrient cycles in the marine environment.[528,529] Marine microbes (Section 2.4.6) play an important role in the ocean's nutrient cycle by decomposing organic matter.[530,531] This ongoing cycling of nutrients by microorganisms is critical for sustaining productivity in the marine environment.[532] Within the Region, the nutrient cycle is critical for the persistence of most organisms, particularly corals.[533] Concentrations of nutrients, such as nitrogen and phosphorus are naturally low in the open ocean.

Most southern inshore areas of the Region are exposed to elevated nutrient concentrations, particularly during the wet season

The anthropogenic load of dissolved inorganic nitrogen discharged from the Catchment since 2012 has been generally lower than the previous five years.[155] While small improvements in land management practices to reduce dissolved inorganic nitrogen inputs have been reported[43,463], the observed reduction in loads over this period can mostly be attributed to reduced flow [460,469] (Section 6.5).

Nutrient loads in the Region have noticeably increased since European settlement in the adjacent Catchment (Figure 3.7). Modelling of land-derived dissolved inorganic nitrogen indicates that the highest exposure levels are concentrated in inshore areas, with higher contributions from the Wet Tropics region in both wet and dry years compared with other NRM regions (Figure 3.7). The influence of land-based dissolved inorganic nitrogen extends to mid-shelf areas from the Catchment in wetter years, such as 2012–13 (Figure 3.7). The Fitzroy and Burnett–Mary regions are not monitored frequently enough to assess trends.[460,469]

The multi-year trends of concentration of dissolved inorganic nitrogen vary across the Region.[155] Dissolved organic carbon increased sharply in all monitored regions since monitoring began in 2005.[460,469] Dissolved organic carbon drives microbial growth and promotes a higher incidence of coral diseases.[534] High concentrations of dissolved inorganic and organic carbon may lead, in the longer term, to reduced growth of reefs, loss of substrate and reef erosion.[535]

Land-derived nutrient inputs to the Region largely occur during the wet season[536], with most dissolved nutrients being rapidly taken up biologically or bound chemically onto particles in the ocean. Excess dissolved inorganic nitrogen poses the greatest risk to the Region because it is readily taken up by phytoplankton and microalgae, causing an imbalance in the system.[43,537] In years of large river flow, these nutrients can be transported large distances.[43,458,537]

The increase in nutrient loads during flood events can exacerbate the spread and persistence of crown-of-thorns starfish larvae, which feed on phytoplankton that thrive on dissolved nutrients (Section 3.6.2).[193,538] Higher nutrient levels also increase the susceptibility of corals to disease and thermal stress[539,540], affect coral reproduction[514], reduce light for seagrass and corals[184,514], and promote fleshy macroalgal growth in some areas.[43,461,541] Although considered stable, there have been substantial changes to nutrient cycling occurring since European settlement, affecting inshore ecosystems, especially seagrasses and corals.

Algae overgrowing a branching coral. © GBRMPA 2016, photographer: Jessica Stella

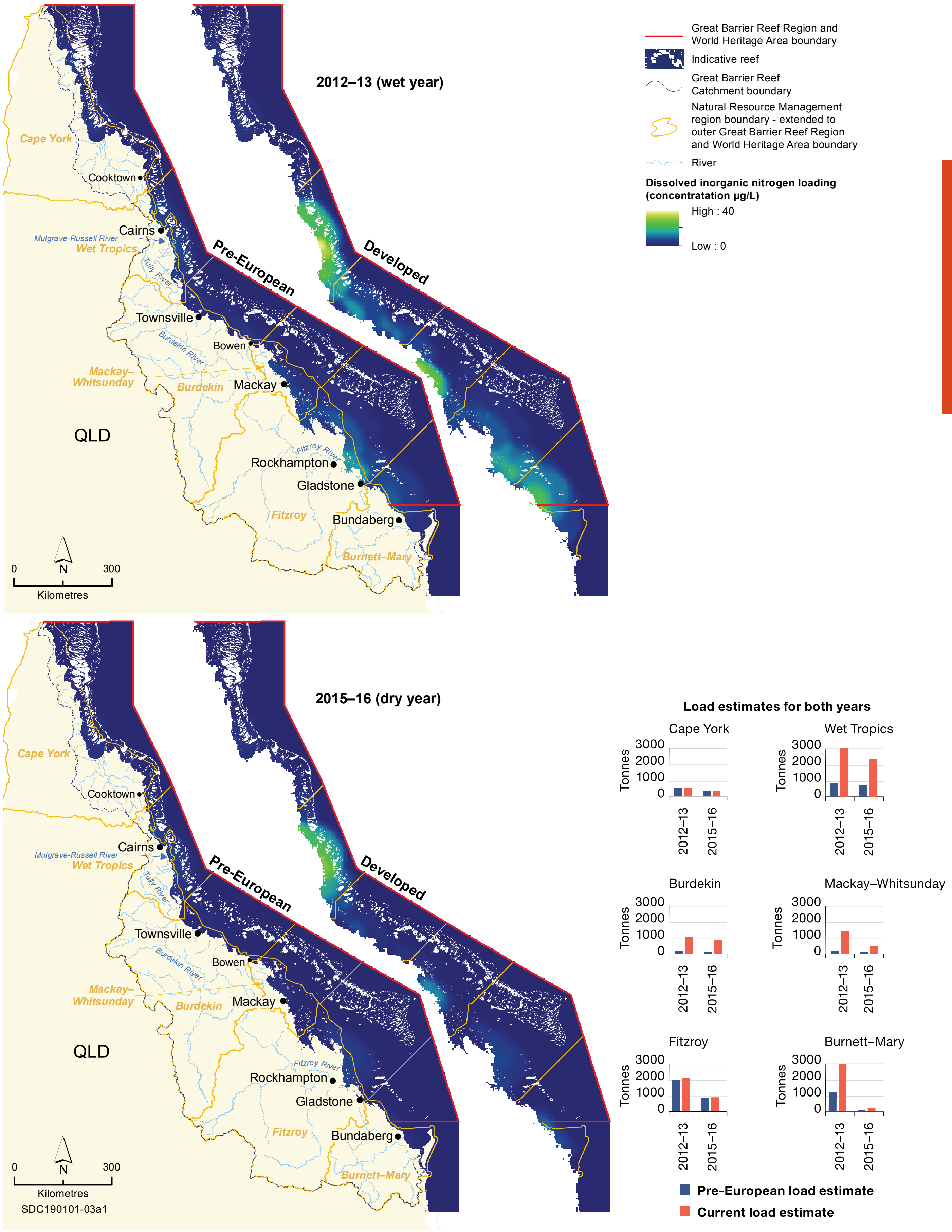


Figure 3.7 Modelled dissolved inorganic nitrogen catchment loads, 2012–13 and 2015–16
Modelled distribution of dissolved inorganic nitrogen end-of-catchment loads, based on annual average pre-European (left) and current (right) years, highlighting the difference between a wet year (2012–13 top) and a dry year (2015–16 bottom). The graphs show the modelled annual average loads for each period for the six natural resource management regions. The blue bars are pre-development and red bars are current.
Source: Based on the Marine Monitoring Program, complied by James Cook University (Gruber *et al.* 2019[155])

3.3.2 Ocean pH

Ocean acidification is often expressed in terms of the pH of seawater. It is measured on a scale from zero to 14, with values below seven considered acidic and values above seven considered basic. The baseline pH of the oceans is a slightly basic 8.2.[542,543] The largest driver of increased acidity of seawater is emissions of carbon dioxide into the atmosphere, causing increased dissolved carbon dioxide in the ocean. Although carbon dioxide is a major component of the carbon cycle, the proportion of carbon dioxide in the atmosphere is increasing as a result of human activities, predominantly burning of fossil fuels.[544,545]

The ongoing decrease in ocean pH will reduce calcification, making coral reefs more vulnerable to intensifying storms

The ocean has already absorbed approximately 30 per cent of the atmospheric carbon dioxide that has originated from human activities, lowering the pH by approximately 0.1 pH unit.[545] This uptake reduces the seawater concentration of carbonate ions, which are required by most organisms that build shells, including corals and shellfish.[546] The potential and actual effects of ocean acidification on marine organisms has become better understood in the past 15 years.[547] Experimental studies have identified impacts, including altered survival, calcification, growth, development and abundance of a broad range of reef organisms[548], including fish[549], phytoplankton[550,551], marine plants[552,553,554], corals[555], microbes[254] and other reef invertebrates.[556,557] Crustose coralline algae, which provide important surfaces for coral settlement, appear to be particularly sensitive to increases in ocean acidity[202,558]; hence, coral recruitment rates could be adversely affected as the ocean acidifies.[559,560,561]

Perhaps the largest risk from ocean acidification is a change in the net rate of calcium carbonate accretion (the deposition of calcium carbonate by calcifying organisms). For reefs to grow, net accretion must be higher than net dissolution. Reduced calcification can result in coral skeletons being more brittle and at greater risk of breakage from strong waves.[562] Changes to ocean pH are having, and are likely to continue to have, fundamental and substantial impacts on a wide variety of organisms.[487]

Current ocean pH varies within the Region, exhibiting a cross-shelf gradient. On mid and outer-shelf reefs, the partial pressure of carbon dioxide has risen at the same rate as atmospheric values over 30 years. By contrast, values on inshore reefs have increased up to three times faster, due to higher respiration and nutrient levels.[162] Given the small but continuous decreases in ocean pH, the ocean pH process has deteriorated since 2014.

3.3.3 Ocean salinity

Overall, salinity remains stable across most of the Region

Salinity refers to the concentration of salt in a given volume of water, often expressed as parts per thousand. The average salinity of the ocean is 35 parts per thousand (every kilogram of seawater contains 35 grams of salt). Salinity levels can change drastically over the course of a day as a result of rainfall, river flows, evaporation and water movement due to wind, currents and tidal mixing.[563,564] Because seawater is denser than fresh water, salinity can change rapidly with depth during flood events, with low-salinity plumes predominantly remaining on or near the surface while salt water remains deeper.[565] Salinity fluctuates following high-rainfall events or prolonged drought.

Salinity within the Region has remained at 35 parts per thousand.[460,566] Reefs closest to the coast, such as those off Cape York and the Wet Tropics, are subject to more regular low-salinity inflows.[565]

Low salinity associated with floodwaters can cause extensive mortality of a range of Reef species, including corals, crustaceans, molluscs, sponges, fishes and seagrasses.[458,567,568] Low salinity can also have sub-lethal effects on Reef organisms, such as reduced coral growth rates[569] and reduced seagrass flowering in response to physiological stress.[567] Combined pressures from lower salinity and higher water temperatures can also have a significant effect on organisms. For example, blooms of dinoflagelates (plankton) can be triggered, leading to increased frequencies of ciguatera fish poisoning.[570] Changes in salinity have largely been a result of freshwater inflow, affecting the condition of inshore areas. Overall, the ocean salinity process is considered stable across most of the Region.

3.4 Current condition and trends of ecological processes

Ten ecological processes are graded. Primary production remains in very good condition, and five processes (microbial processes, particle feeding, herbivory, competition and connectivity) remain in good condition. Predation and recruitment continue to be graded as poor, whereas symbiosis and reef building have deteriorated to a poor grade.

↓

Full assessment summary: see Section 3.7.3

3.4.1 Microbial processes

Microbes play a significant role in cycling carbon and nitrogen, largely through the decomposition of organic matter[571], and are important vectors of disease. Microbial processes are critical for regulating the composition of the atmosphere, influencing the climate, recycling nutrients and decomposing pollutants.[572] Despite their importance, most microbial processes remain poorly understood, particularly in the marine environment.[573]

Microbial processes are often the unseen driver in ecosystem processes.[574,575] As the basis of the marine food chain, microbes convert dissolved nutrients into plankton biomass[259], which supports the marine food web. Microbial communities can influence the health of other organisms through important symbiotic relationships. For example, beneficial microbes that cycle nitrogen may be central to the stability of the coral–algae symbiosis by influencing the growth and density of the *algae symbiont zooxanthellae*.[533,576] Harmful microbes (pathogens) can affect the health of corals, sponges, seagrasses and other organisms, causing disease and mortality.[576,577] Over-abundance of harmful microbes in the ecosystem has been linked to stressors, such as overfishing, exposure to elevated nutrient concentrations and increased temperatures.[573,578,579] Pathogenic microbes carried by plastic pollution can promote disease when in contact with coral.[580]

Although critically important to ecosystem health, the status of most microbial processes remains poorly understood

Information on the status of most microbial processes in the Region, one of the main drivers underpinning ecosystem function, is limited and represents a large knowledge gap. Diseases were observed in coral trout and corals in areas of the Region affected by temperature extremes in 2016 and 2017 (Section 3.6.1). However, the impact of this across the entire Region has not been quantified. Increases in fleshy macoalgae can occur during times of elevated nutrient concentrations (Section 2.4.3), due to an over-abundance of bacterial communities that thrive in high nutrient environments.[581] Seagrass meadows reduce the relative abundance of disease-causing bacteria (by up to 50 per cent), indicating seagrass ecosystems may play an important role in regulating harmful microbial processes in the Region.[58] Although some spikes in disease have occurred for some species, no clear trend is apparent for the Region's microbial processes.

3.4.2 Particle feeding

Particle feeders encompass a broad group of animals, including filter, suspension and deposit feeders that consume particulate matter. These animals include sea cucumbers, feather stars, fishes, corals, molluscs, sponges and worms. Particle feeding supports the ecosystem's nutrient cycle (Section 3.3.1), cleans large quantities of water and sediment by filtering out particles, bacteria, algae and zooplankton, and links the benthic and pelagic environments.[582,583,584] Particle feeders can exert a considerable influence on the ecosystem. For example, giant clams (*Tridacna gigas*) can filter large volumes of water, reducing the amount of nutrients in the water column.[585,586]

The process of particle feeding is likely to have deteriorated

Although extensive information is available on trends in the abundance of corals, it is difficult to quantify the current condition and trend of this process as a whole, given information on other particle feeders (such as sponges and echinoderms) is limited.

Suspended sediments and nutrients in the water column can harm particle feeders, such as sponges, by clogging the filtration apparatus and hindering feeding. Since 2014, inshore areas in the Region have continued to experience repeated and elevated levels of nutrients[155]; therefore, it is likely that particle feeding in these areas has declined. In addition, following bleaching events in 2016 and 2017, filter feeding corals have decreased in abundance to the lowest levels ever recorded.[88] It is likely that particle-feeding fish[273], which rely heavily on coral habitats for shelter, have also decreased since 2016. However, coral reef sponges, which are more resilient to environmental stressors than corals[587], are assumed to be less affected by recent impacts.

Overall, there have been some significant changes in particle feeding in some areas as a result of high nutrient levels and thermal stress events in 2016 and 2017. As a result, the condition of particle feeding as a process has deteriorated.

3.4.3 Primary production

Primary production and photosynthesis are closely linked to the availability of light and concentrations of available inorganic nutrients and generally occur in the upper water column at depths of less than 100 metres. Nitrogen and phosphorus sources play a significant role in determining the rate of primary production.[588,589,590] Land-based run-off, inflow from the Coral Sea, upwelling and resuspension all support productivity within phytoplankton communities.[424,591]

In the Region, primary producers include phytoplankton, mangroves, seagrasses, benthic algae and symbiotic algae in the tissues of Reef organisms, especially corals. In lieu of direct measurements of primary production, a higher abundance of primary producers can be used as a proxy to indicate overall condition. Chlorophyll-*a* is often used as a proxy for estimating phytoplankton biomass.[592] Frequent phytoplankton blooms and associated higher primary production occurs during the wet season when more nutrients are available.[593] Primary production is higher in inshore areas (except Cape York) due to year-round elevated nutrient loads.[155] The extent and condition of seagrasses have generally increased since 2014, which may have enhanced their primary production in the Region, although abundance has declined slightly since 2015–16 (Section 2.4.2).[74] Mangroves have remained relatively stable within the Region (Section 2.4.1) and benthic algae have generally increased in abundance at disturbed sites (Section 2.4.)[193,594], potentially increasing primary production in these areas. Following the bleaching events in 2016 and 2017, it can be assumed that primary production from coral–algae symbioses has reduced as a result of coral mass mortality, particularly in the northern two thirds of the Region. Overall, the condition of primary production is variable, with no consistent trend.

3.4.4 Herbivory

Herbivory is the removal and consumption of plant matter, which provides nutrition for the consumer and shapes the location and health of the plant matter.[595] Herbivory includes removal of plant matter by large herbivores (such as green turtles and dugongs) and cropping, grazing and excavation of algae, which is performed predominantly by herbivorous fish (over 178 species)[596] and to a lesser extent by molluscs, echinoderms and crustaceans.

Herbivorous fish and green turtles avoid sediment-laden turf algae

The process of herbivory supports nutrient cycling and can facilitate dispersal of seagrass species[65] (Section 8.3.6). Following disturbance, herbivory plays an important role in reef recovery.[597] However, coral replenishment and herbivory can be overcome when macroalgae get too dense and form underwater forests[419,598] (Section 2.4.4). Herbivores can be deterred from entering and feeding on algal forests due to fear of predation[598], resulting in less herbivory and further expansion of a macroalgal-dominated state.[599]

Having a number of herbivorous species that can fulfil a range of ecological roles provides a level of 'insurance' for the ecosystem, and can increase recovery capacity following disturbance (Figure 3.8). Benthic turf algae are usually the first species to establish or regrow after a disturbance, and there is a diverse group of herbivores (both fish and invertebrates) that feed on this type of algae. Grazing fish differ in their feeding behaviour (for example, in their ability to remove algae from specific key microhabitats across the Reef).[600] By contrast, few fish species can effectively remove larger fleshy macroalgae. In the northern Reef, large fleshy macroalgae are removed by one key species, the unicorn fish, which is responsible for approximately 90 per cent of macroalgal removal.[418]

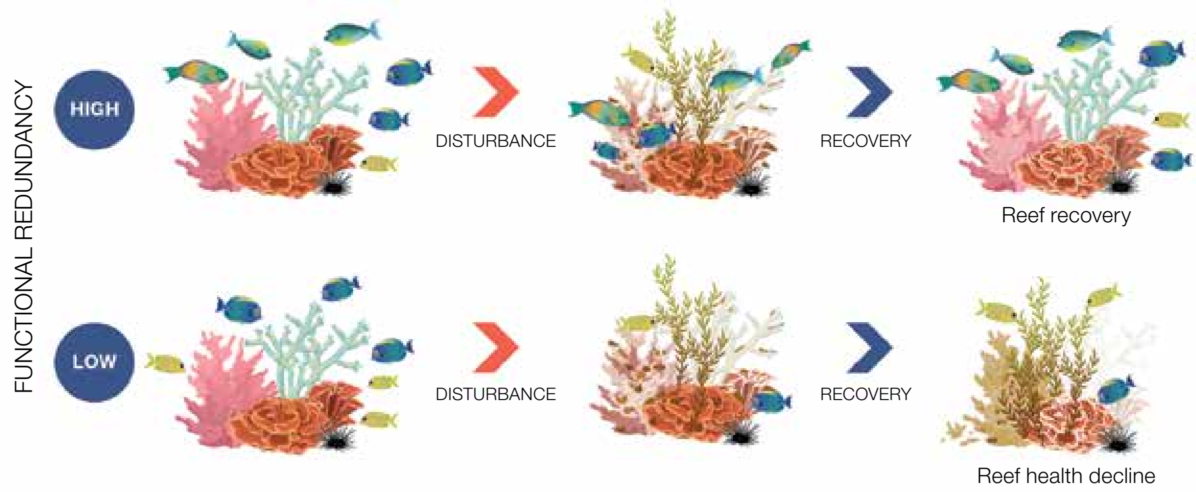


Figure 3.8 Herbivore functional redundancy
Reefs with high functional redundancy (top) have a higher number of animals that perform important functions, such as algal removal, which helps reefs recover faster following disturbance. Reefs with low functional redundancy (bottom) have less capacity to respond to, and recovery from, disturbances. Source: Adapted from Nash *et al.* 2016[601]

Fish herbivore abundance is generally higher on offshore and mid-shelf locations, with reef exposure (to wave energy and other factors) greatly affecting food availability and fish size.[602] The process of herbivory is not regularly monitored across the Region and remains a knowledge gap. However, the presence of herbivores can provide some indication of potential herbivory rates. Long-term monitoring of herbivorous parrotfish and surgeonfish (Section 2.4.7) indicate that abundances across the Region have generally remained stable, with some variability cross-shelf (Section 2.4.7, Figure 2.12). Offshore locations have the greatest variability since 2016–17, with parrotfish increasing five-fold offshore Cairns and surgeonfish decreasing by half offshore Townsville. Elsewhere, on inshore and mid-shelf locations, parrotfish and surgeonfish abundance has generally remained stable since 2009, with the exception of the Pompey Complex reefs, where parrotfish declined by half between 2009 and 2014.[282] At two southern locations, where 2018–19 surveys were completed, parrotfish and surgeonfish declined in abundance around the Swain Reefs. Whereas on offshore reefs around the Capricorn Bunker group, parrotfish abundance increased by approximately 40 per cent.[282]

On a smaller scale within reefs, many factors (including sediment load and particle size) combine to influence the location of herbivory. For example, some parrotfish avoid feeding on algal surfaces coated with poor-quality coarse sediments.[603] Following cyclone Yasi in 2011, large increases in sediment loads around Orpheus Island led to a dramatic decrease in grazing by herbivorous fish (92 per cent reduction in feeding by rabbitfish).[281] Green turtles were also deterred from feeding on sediment-laden turf algae.[604]

The condition of herbivory as a process across the Region and the mechanisms that affect it are not well understood. There is some variability in herbivory across the Region, but not to the extent of significantly affecting ecosystem function, and overall the condition of this process has remained stable.

3.4.5 Predation

Predation (the process of animals consuming other animals) influences the distribution, abundance, behaviour, fitness and evolution of prey species.[269,285,605,606] For example, predator abundance can alter prey behaviours, such as wariness and shelter seeking. In turn, predator presence affects prey species' distributions at small scales, leading to changes in other processes (such as reduced rates of herbivory)[607].

Apex predators include large-bodied animals that generally have large home ranges[608], such as large sharks, pelagic fishes (such as trevally and tuna), birds, and some marine mammals and reptiles. Smaller reef sharks are considered middle-order (meso) predators, as are other large predatory fishes (such as coral trout). Meso-predators generally have smaller home ranges than apex predators and feed on smaller prey.[609,610] Predatory fishes have high cultural, social and economic value to recreational, commercial and Indigenous fishers (Section 5.4). They are generally equally spread across the inner, mid and outer-shelf reefs within the Region.[611]

The abundance of reef sharks on the outer-shelf reefs varies, with significantly higher abundance and diversity occurring on deeper reef slope habitats.[612] The 2009 and 2014 Outlook Reports noted reef shark and coral trout abundances were depleted by fishing[2,613]; recent research suggests it may take 20–40 years of effective no-entry protection to restore shark population numbers.[297] Analysis of the trend in sharks caught in the shark control program since the 1960s indicates a regional depletion of sharks, particularly large mature individuals.[298,614] Sharks and rays are still considered to be in poor condition overall (Section 2.4.8) due to overfishing, bycatch and poaching.

Trends in long-term abundance of reef-associated predators are variable, with some increases in coral trout occurring in mid-shelf and offshore reefs in the Swain Reefs since 2012.[611] Whereas other meso-predators (labrids and lethrinids) declined.[611] Offshore Townsville (around Magnetic Island and the Palm islands), the population density of coral trout halved between 2007 and 2012[615]; and although gradual increases have occurred since then, they have not yet returned to the higher densities recorded prior to 2007.[615]

The key drivers and threats affecting predation include climate change, habitat loss and fishing.[361,611,616,617] All of these drivers are increasing. Predation is likely to decrease further in the Region as a result of both bottom-up effects (such as decreases in availability of habitat and prey for seabirds) and top-down effects (such as fishing) (Section 8.3.4). A growing body of research demonstrates that well-managed no-take zones effectively protect predatory fishes and sharks over small and large scales.[618,619,620] These trends may change if habitat structure declines, particularly for coral trout, which are dependent on habitat complexity (Section 8.3.4).[210,621,622]

The overall level of change in the process of predation since 2014 is not clear. While recovery is occurring for some predators in some locations, concerns remain for others.

3.4.6 Symbiosis

The high occurrence of symbiotic relationships in the Region is one of the biggest drivers of biodiversity

Symbiosis is a close ecological relationship between at least two different species. This relationship can be beneficial to all participants (mutualism), beneficial to one participant and harmless to the other (commensalism), harmful to one participant while not benefiting the other (amensalism) and beneficial to one and harmful to the other (mainly parasitism). Symbioses develop over long evolutionary timeframes, maintained by natural selection, and have been a major driver in the formation of new species.[623,624] Many symbionts are keystone species; these are usually inconspicuous, smaller organisms that have a disproportionately significant impact on the greater biodiversity of the ecosystem.[625] Symbioses usually, but not always, involve strong interdependencies.[626] They enable species to obtain resources that would otherwise be unobtainable and are, therefore, a critical ecological process.

Within the Region, the coral–zooxanthellae and clownfish–anemone relationships are perhaps the best known examples of symbioses. Other important symbiotic relationships include coral guard crabs (*Trapezia* species) that live within *Pocillopora* corals and clean[627] and defend their coral hosts.[628,629,630] An estimated 40 per cent of known species are parasitic symbionts[631,632], and approximately 75 per cent of the links in food webs involve a parasitic species.[633] The loss of any one of these symbiotic interactions may have unforeseen and serious consequences for ecosystem function.

Figure 3.9 Clownfish in a bleached anemone
The clownfish (Amphiprion percula) nestled within a bleached host anemone during the 2016 marine heatwave on the Great Barrier Reef.
© GBRMPA 2016, photographer: Jessica Stella

Symbioses are particularly susceptible to disturbances, since a direct impact on one symbiont will affect the other.[83,634] Environmental changes, such as thermal stress due to climate change, have the potential to alter the nature of symbioses (for example, changing a mutualistic relationship to a parasitic[635] or competitive one[636]). Bleaching of a symbiont's host, such as coral and anemones, has negative effects on the fitness and survival of the symbiotic animals that rely on them, such as coral crabs[243,636] and anemonefish.[637,638] Due to the strong inter-dependencies common between symbiotic partners, symbiont abundance and distribution can be used as a proxy for the condition and trend of symbiosis in the Region.

Based on the unprecedented decline of hard coral cover and changes in coral community composition following mass bleaching in 2016 and 2017[91], it is highly likely that symbioses involving coral have significantly deteriorated.[243,637] Anemones were also susceptible to severe bleaching (Figure 3.9) and mortality, resulting in a subsequent loss of anemonefish.[243,637] Observations of severe bleaching in other habitat-forming species, such as giant clams, probably resulted in a decline of symbiotic species. The recent decline of fish diversity and reduction in abundance of some species[273] will also affect associated symbioses. As a result, the condition of this process has deteriorated since 2014.

3.4.7 Recruitment

Recruitment has declined sharply to the lowest levels recorded for many key species

Recruitment is a process by which new individuals are added to an existing population. Successful recruitment relies on sufficient individuals surviving through various life history stages to become part of the reproductive population.[639,640] The process of recruitment is one of the key ways in which depleted populations are replenished (Figure 3.10).[641] New recruits can either be sourced locally (self-seeding within the same reef) or from afar (larvae carried by currents). Generally, self-seeding populations (such as brooding corals) have relatively low connectivity, while populations that disperse over greater distances (such as spawning corals) have relatively high connectivity (Section 3.4.10).[642]

The condition of recruitment across the Region is only well known for some species. The natural replacement of corals after a disturbance relies on successful recruitment of new individuals. Since 2014, inshore juvenile coral densities (an indicator of recruitment and subsequent survival) have generally declined in the Wet Tropics, Burdekin and Mackay–Whitsunday regions.[440] The density of juvenile corals remains low in the Fitzroy region due to prevalence of macroalgae suppressing recruitment and a decline in settlement of coral larvae.[193]

In 2018, coral larval recruitment, averaged across the Region, declined by 89 per cent compared with historical levels (Figure 3.11).[96] The loss of adult coral brood stock after the mass bleaching events was the dominant driver of this widespread and unprecedented decline in recruitment (Section 8.3.1).[96] The southern region, which escaped severe bleaching in 2016 and 2017[88,141], had higher recruitment in 2018 compared with historical levels.[96]

Figure 3.10 Recruitment can be complex, relying on many different habitats and processes

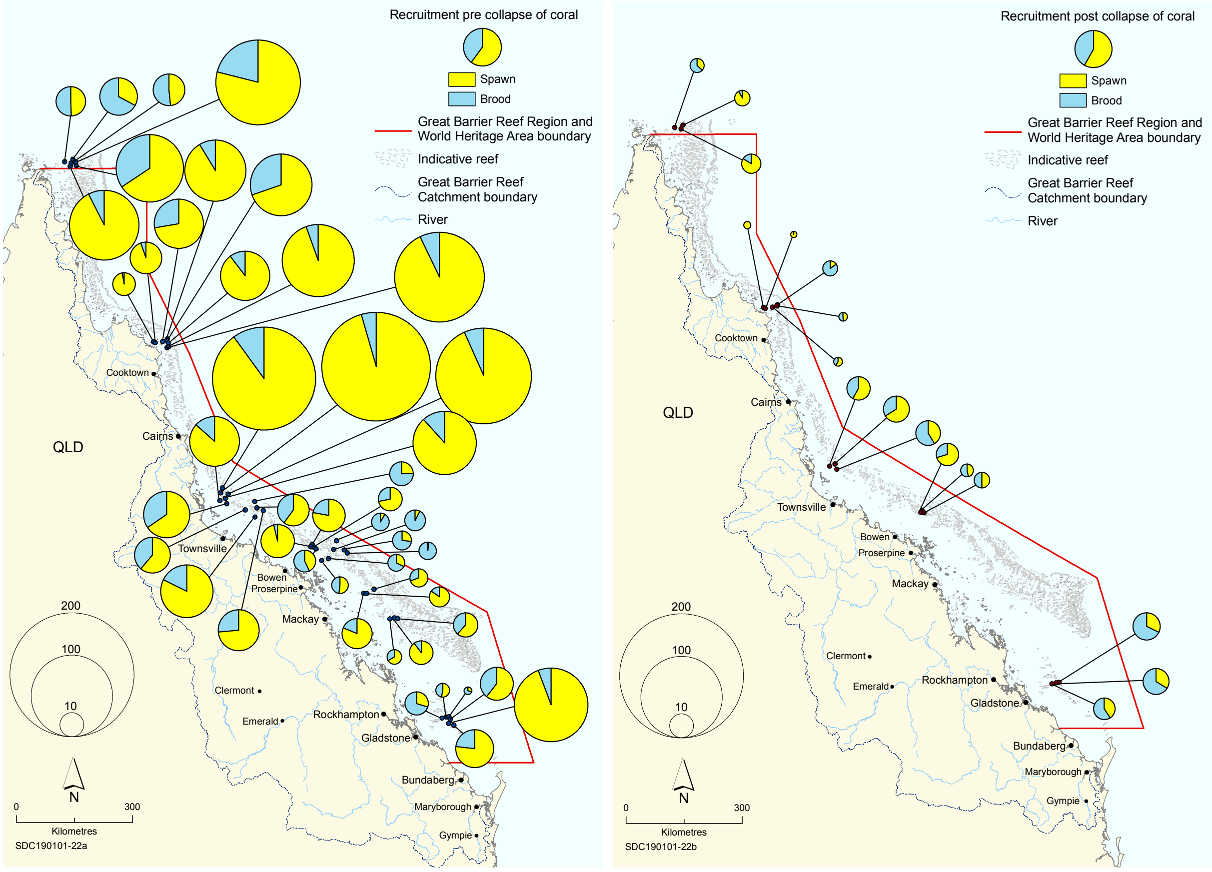


Figure 3.11 Coral recruitment along the 2300 km length of the Reef before and after consecutive mass bleaching events in 2016 and 2017

Left: Average density of recruits (mean number of settled coral larvae per sampling panel on each reef), measured over three decades, from 1996 to 2016 (sample size of 47 reefs, 1784 panels).

Right: Density of recruits after mass mortality of corals in 2016 and 2017 due to back-to-back bleaching events (sample size of 17 reefs, 977 panels). Yellow and blue indicate the proportion of spawning and brooding coral species, respectively. The size of each circle represents the overall recruit density for spawners and brooders combined. Source: Hughes *et al.* 2019[96]

Effective no-take and no-entry zones have been shown to produce and export recruits of commercially important fish species (Section 7.3.3 Box 11).[619,643] Most coral reef fish larvae spend days to weeks in the open ocean before settling on coral reefs.[644] Given the strong swimming abilities of larval reef fish[645] and ocean currents, dispersal of reef fishes within the Region can be large. Some reefs can be a source of larvae for other reefs up to 250 kilometres away.[619,646] Alternatively, on some geographically isolated reefs, populations generally rely on self-recruitment.[619,643]

Across the Region there is no long-term monitoring of reef fish recruitment. It is likely that the recent mass mortality of corals in 2016 and 2017 will have reduced the recruitment of fishes that rely on coral as a settlement habitat.[270,440] These temperature extremes may have also reduced the reproductive capability of some adult fish.[504]

Recruitment has decreased for green turtles at Raine Island[647] (Section 2.4.10) and for loggerhead turtles on the Woongarra coast[648] (Section 8.3.5). Feminisation of turtle populations due to global warming is occurring at several northern Reef rookeries (for example, Raine Island and Moulter Cay), which will reduce male recruitment into the Region.[319] Ingestion of marine debris by post-hatchling turtles and pest predation of eggs and hatchlings at nesting areas[649,650] may also reduce marine turtle recruitment.

Breeding populations of six seabird species are declining within the Region[359] (Section 2.4.12). The declines may be attributed to inadequate food supplies due to warming sea surface temperatures.[361] Declining breeding populations directly affect recruitment and the success of future populations.

Substantial changes in recruitment have occurred, significantly affecting a number of species, and overall the condition of the process of recruitment has deteriorated since 2014.

3.4.8 Reef building

Reef building is under increasing threat from mass bleaching of corals and future ocean acidification

Reef building, or the growth of coral reefs, occurs when net accretion of calcium carbonate by calcifying organisms exceeds net erosion.[85,651] Hard coral growth is the primary driver of reef building, contributing up to 75 per cent of the total calcium carbonate.[652] Other calcifiers, such as *Halimeda*, foraminifera and crustose coralline algae, also contribute a significant amount of carbonate sediments to inter-reefal areas and reef-building ‘cement’, consolidating the reef framework.[31,653,654] For example, the northern *Halimeda* banks (Section 2.3.8) are estimated to contain up to four times the calcium carbonate of adjacent coral reefs[653], contributing significantly to the overall carbon budget of the Reef.[655] Rates of calcification are influenced by many factors, such as the abundance of calcifying organisms, light availability[515], sea temperature[508,656] and the concentration of carbonate ion in seawater.[657,658]

Reefs can erode in three ways: mechanical erosion due to waves and currents; bioerosion caused by reef animals, such as boring worms, sponges, crustaceans[584,659,660] and fishes, (for example, the bumphead parrotfish [661]); and dissolution caused by ocean acidification.[562,662] For reef building to remain stable, calcification rates must be greater than the rate of erosion.[656] Within coral reef habitats, any reduction in either live coral tissue or colony growth rates can tip the scale to the side of erosion.[91,163,545]

The contribution of coral to the reef-building process is likely to be higher in the southern areas of the Region where coral cover is moderate.[95] The unprecedented decline in coral in the northern two thirds of the Region since 2016 is likely to have affected its contribution to reef-building processes.[90,91,141] Throughout the Reef, calcification declined by 14 per cent between 1990 and 2005.[508] Increasing sea surface temperatures and ocean acidification have been implicated as the primary drivers contributing to this decline, with the trend expected to continue in the future.[508,663]

The condition of reef building has deteriorated since 2014, largely due to the effects of unprecedented declines in coral cover.

3.4.9 Competition

Competition is the interaction between organisms for the same resource and is one of many processes influencing community structure.[428] When resources are scarce, competitive interactions can increase in frequency, duration and intensity. Since most tropical marine ecosystems have a limited number or abundance of resources, such as space, light, shelter and food, competition for resources can be intense.

Competition for space is evident among many species within coral reef habitats. Of particular importance is the interaction between corals and macroalgae; the balance can be tipped from coral to algal dominance through higher nutrient levels, coral bleaching events, declining coral recruitment and overfishing of herbivorous species.[664]

Availability of suitable habitat and the density of competitors are the main factors mediating competitive interactions between fishes and invertebrates on the Reef.[636,665,666] Loss of coral cover and habitat complexity can affect reef fish diversity and abundance.[667,668] Changes in coral composition, as occurred after the two consecutive mass bleaching events in the Region[91], have affected competition between juvenile coral reef fish by changing their behaviours and interactions.[669] Although the understanding of competitive interactions has improved since 2014, knowledge gaps remain for this complex process.

Decreasing ocean pH could change the balance of coral macroalgae competition in favour of algae, possibly as a result of slower coral growth rates[670] and changes in chemical competitive mechanisms of corals.[671,672] Large reef fish compete for shelter under suitable plating corals.[210,621] However, the significant loss of habitat-forming corals (Section 2.3.5) increases competition for shelter. This may subsequently affect fish fitness and the ecological functions they perform.[622] Changes in environmental variables, such as thermal stress, also increase and alter the frequency or nature of competitive interactions[504,636,673] (for example, increasing aggression between species[636]).

Overall, changes in habitat availability, sea temperature and nutrient cycling have increased competition across the Region. The increase in competition is likely to be having a negative effect on species and habitats, and the process is therefore considered to have deteriorated in condition since 2014.

3.4.10 Connectivity

Connectivity encompasses linkages between different habitats and the movement of species between landscapes and seascapes. It includes processes such as larval dispersal, migration, current flows, and those that connect coastal ecosystems to the Reef. For marine habitats, the main connectivity mechanism is water currents that link habitats and transport larvae. Due to their isolation, islands are highly reliant on wind, water and migratory birds to transport plant seeds.[674] Coastal ecosystems are also connected to the Region by the intertidal areas, river catchments, and groundwater, and they can influence the condition and resilience of the Reef (Section 3.5).[675]

Connectivity operates on a variety of spatial and temporal scales and is fundamental in determining a species' population dynamics and structure, genetic diversity, and resilience.[676,677] Patterns of connectivity among reefs within the Region play a critical role in supporting fisheries production. For example, fish populations in no-take marine reserves supply 83 per cent of coral trout larvae and 55 per cent of stripey snapper larvae to areas open to fishing in the Keppel Island group.[618]

Animal migration patterns are an important component of population and ecosystem connectivity. Migrations can range from small (between reefs) to long-range movements of hundreds or thousands of kilometres.[678] Whale migration is recognised as one of the superlative natural phenomena that contribute to the Reef's outstanding universal value. Several species of conservation concern (for example, humpback and dwarf minke whales), migrate through the Region from May to September for feeding and breeding, connecting the Region to feeding grounds in Antarctica. Nesting and foraging grounds of marine turtles connect the Region with the Arafura and Coral seas.[679,680] Seabirds and shorebirds also use the Region and adjacent Coral Sea as important stopover points to rest and feed as part of their larger migration.[371,373,375] For example, wedge-tailed shearwater birds travel between 300 and 1100 kilometres from their breeding colony at Heron Island to feed in the Coral Sea.[681] Emerging evidence indicates that coastal sharks migrate through coastal habitats and mid-shelf reefs of the Region.[682]

Connectivity within the Region is crucial for recovery from disturbance

Barriers to connectivity can reduce water quality and biodiversity.[43] Artificial barriers, such as dams, in the Catchment impede connections for fish and other aquatic fauna.[683] Many fish species use coastal wetlands as nurseries or breeding grounds, and habitat removal or alteration disrupts their life cycles.[684,685,686] The movements of juvenile blacktip reef sharks from sheltered coastal habitats to offshore coral reefs when they reach maturity highlight the importance of connectivity patterns to species conservation in the Region.[687]

Currents and wind can play major roles in connectivity, acting as transport highways for water, food and larvae (Section 3.2.1). Modelling has predicted that the recovery potential of seagrass meadows in the northern Region is greatly influenced by floating fragments, fruits and seeds from southern meadows, and that highly connected meadows, such as Cleveland Bay in Townsville, have higher resilience and assist the recovery of other meadows.[80,688] Modelling has also predicted a high level of connectivity of crown-of-thorns starfish across the Region, whereby some reefs could act as important sources and sinks for larval dispersal.[423] The dominant pattern of connectivity for coral larvae is from north to south[689], exemplified by the decline of coral recruitment in the northern and central regions in 2018.[96] Currents are influenced by a range of factors, and can shift in response to changing thermal patterns (Section 3.2.1). Slight shifts in currents could have significant effects on the Region's connectivity, increasing foraging distances for birds, changing dispersal of turtle hatchlings[38] and reducing or enhancing larval flow in some areas.[424]

Changes to connectivity patterns can drive a redistribution of species.[690] Evidence indicates this is already occurring with poleward transitions of reef fishes to subtropical areas.[691,692] Any changes to spatial and temporal connectivity patterns will have flow-on implications for species and the communities that rely on the Reef.[693,694] This could profoundly affect marine ecosystems by forging new connections that enable introduction of invasive species[691,695,696,697] and disease.[698]

Connectivity with some coastal ecosystems remains disrupted and the effects of climate change have radically altered connectivity patterns of corals. Overall, connectivity of species and habitats within the Region has deteriorated since 2014.

3.5 Current condition and trends in coastal ecosystems that support the Great Barrier Reef

Seven coastal ecosystems are graded. Heath and shrublands remain in very good condition and two coastal ecosystems (saltmarshes and rainforests) remain in good condition. Four coastal ecosystems continue to be in poor condition.

↔

Full assessment summary: see Section 3.7.4

Coastal ecosystems include those from the top of the Catchment (defined by the Great Dividing Range) to the marine inshore ecosystems within the Region, they are not restricted to waterways or the coastline. The coastal ecosystems referred to in this section are predominantly terrestrial and include: saltmarshes, freshwater wetlands, forested floodplains, heath and shrublands, grass and sedgelands, woodlands and forests, and rainforests (Section 2.1 Figure 2.1).[102,675]

The condition of the Reef benefits from connections with healthy and functioning ecosystems in the Catchment.[699] The functions coastal ecosystems provide to the Reef include physical processes (such as sediment and water distribution and cycling), biogeochemical processes (such as nutrient and chemical cycling), and biological processes (such as connectivity, habitat and food provisioning).[43,102] For a coastal ecosystem to function normally, the interactions between these natural ecological processes, the physical environment and its organisms must be reasonably intact and working efficiently.

Healthy, functioning coastal ecosystems are critical for the long-term health of the Reef

Coastal ecosystems also provide ecological services. In the context of this section, ecological services include benefits to the values of the Reef.[102] For example, intact coastal ecosystems can prevent major erosive processes (like gully erosion) and abundant ground cover may decrease sediment and nutrient loads entering the Region.[467] Connectivity is an essential function of coastal ecosystems (Section 3.4.10). The connectivity between coastal ecosystems and the Reef is provided by ecosystems dominated by both remnant and regrowth (non-remnant or previously cleared) vegetation, as well as modified coastal ecosystems. Connectivity plays an important role in providing suitable feeding and breeding areas for many marine species.[102] For example, it is known that at least 78 reef and estuarine fish species, including mangrove jack[700], use freshwater systems for part of their life cycle.[102]

In 2014, the assessment of condition of coastal ecosystems relied on an analysis of the importance of maintaining their function for the health and resilience of the World Heritage Area.[102] That analysis remains useful and informs this assessment, but has not been repeated. Since 2014, management tools (such as hydrological connectivity maps that inform catchment management approaches) have improved understanding of function.[462,701] However, management tools do not measure current condition (or function). Instead, the remaining spatial extent of each coastal ecosystem is the primary indicator of condition until such time as more broadscale current condition and function data are available.

Rainforest canopy, Green Island. © Dieter Tracey

The current vegetation extent data are compared to the vegetation extent before European settlement (Table 3.1). The coastal ecosystems have been grouped based on broad vegetation group classifications.[702] Broad vegetation groups are higher level groupings of vegetation communities and regional ecosystems that provide an overview of major ecological patterns and relationships across Queensland. Since 2014, these classifications have been updated, so some coastal ecosystems are grouped differently compared with 2014; for example, some dry eucalypt and open woodlands are now included in woodlands (rather than heath and shrublands). For this reason, the previously published pre-European settlement data and the 2009 data of remaining vegetation extents have been re-analysed (Table 3.1). The data in the table are distinguished from the woody vegetation clearing rates[703,704], which include vegetation that has previously been cleared (Box 3).

Table 3.1 Changes in the extent of coastal ecosystems in the Catchment before European settlement, 2009 and 2015
The 2014 Outlook Report outlined the remaining extent of terrestrial habitats (renamed to coastal ecosystems) since European settlement. The current extent and trend since 2009 of coastal ecosystems is presented (being remnant vegetation only; or more broadly, vegetation that has not previously been cleared). Source: Adapted from Neldner *et al.* 2017[702] and Kelley and Ryan 2018[705]

Coastal ecosystem (remnant)	Total area before European settlement (km²)	Total area remaining (km²)		Proportion remaining in Catchment (per cent)
		2009	2015	2015
Saltmarshes	2187	1870	1867	85
Freshwater wetlands	1668	1357	1357	81
Forested floodplains	50,060	29,116	29,037	58
Heath and shrublands	3178	2972	2970	93
Grass and sedgelands	11,897	5730	5721	48
Woodlands and forests	323,809	196,532	195,938	60
Woodlands	228,642	157,088	156,609	68
Forests	95,167	39,444	39,329	41
Rainforests	27,413	17,878	17,869	65

Forest stream in the upper Mulgrave River catchment. © GBRMPA 2014

BOX 3

Deforestation — woody vegetation loss

Vegetation clearing in the Catchment, specifically of woody vegetation, has increased since 2009 (Figure 3.12). Woody vegetation occurs across several coastal ecosystems (including some freshwater wetlands, forested floodplains, shrublands, woodlands, forests and rainforests). Woody vegetation includes both remnant and non-remnant vegetation[703], so its remaining extent cannot be assessed within just one of the coastal ecosystems discussed in this section.

The *Statewide Landcover and Tree Study*[703,704] is a vegetation monitoring program that reports annually on the woody vegetation loss in Queensland. The total area of woody vegetation cleared in the Catchment was at its lowest between 2008 and 2010, at approximately 250 square kilometres per year. The 2009 Outlook Report highlighted further clearing of coastal habitats as a high risk, which led to a new and separate assessment of terrestrial ecosystems in 2014. The 2014 Outlook Report elevated the risk posed by modifying coastal habitats to very high. Since that time, the clearing rate in the Catchment increased overall, peaking at 47 per cent (1660 square kilometres) of the total statewide woody vegetation clearing rates in 2016–17.[703,704] The increase in clearing of woody vegetation coincided with major changes to the Queensland vegetation clearing legislation in 2013.[706,707] These vegetation management laws were reinstated in mid-2018 to provide consistent protection to regrowth vegetation in all Reef catchments.[708]

Land clearing is a major contributor to climate change due to the loss of carbon storage habitats, as well as changes in rainfall and temperature dynamics.[701] Historically, intensive and sprawling anthropogenic land uses across the Catchment have shaped the extent of clearing; this has not altered (Section 6.4). In 2017–18, 93 per cent (approximately 3690 square kilometres) of the total statewide woody vegetation cleared was primarily for increased pasture for grazing. This represents a two per cent increase since 2014–15. Whereas, secondary purposes accounted for a very small proportion of the total clearing: forestry (six per cent), cropping (one per cent), and mining, infrastructure and settlement (less than two per cent in total).[704]

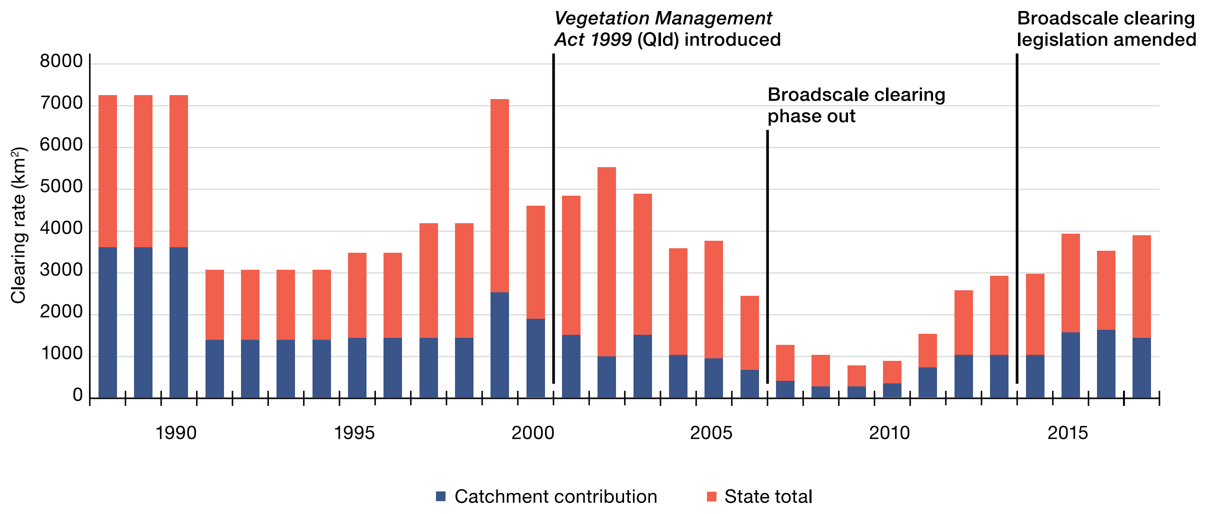


Figure 3.12 Woody vegetation clearing rates in the Catchment, 1988–2017
Values in this figure are an estimate of the clearing rate occurring in the 12-month period to 1 August.[703] Source: Adapted from Department of Science, Information Technology and Innovation (Qld) 2017[703] and Department of Environment and Science (Qld) 2018[704]

3.5.1 Saltmarshes

Saltmarshes are coastal ecosystems that occur in the upper intertidal area of estuaries and at the interface of marine and terrestrial environments.[709,710] This ecosystem provides intermittent feeding areas for many marine species, including various commercial fish and prawn species such as mullet and tiger prawns. Saltmarshes are vulnerable to anthropogenic pressures (such as direct use by vehicles[711], fishing and illegal dumping), as well as excess nutrient, sediment and pesticide loads.[43] Even so, little change in extent has occurred since 2014 (approximately 85 per cent of the pre-European settlement extent remains; Table 3.1).[705] A major threat to saltmarsh function is artificial barriers that prevent tidal influence into the ecosystem (Section 6.4). Given statewide regulatory controls have prohibited the construction of infrastructure like ponded pastures since the early 2000s, new infrastructure of this kind is no longer considered a widespread threat.[712,713] However, ongoing management of legacy infrastructure remains a risk to the ecosystem services saltmarshes provide to the Reef. In an attempt to remediate some of the impact from existing infrastructure, projects have been undertaken on a limited scale since 2014 to re-establish connection through culverts.[714]

Saltmarshes are essential for ecological function, however, their condition is not well known

Regulations protecting against unlawful destruction, removal or damage influence the extent of all marine plants (many of which are found in saltmarshes). The interaction between mangroves and saltmarshes also influences the extent of saltmarshes. It is evident that the movement of mangroves into pockets of saltmarsh ecosystems may result from sea-level rise and climate-driven environmental change.[711] While the estimated extent of saltmarshes is monitored remotely, condition data are limited to localised detailed surveys completed on an *ad hoc* basis.[715]

3.5.2 Freshwater wetlands

While freshwater wetlands can include rivers, for the purpose of this report, this coastal ecosystem only includes lacustrine (lake) and palustrine (vegetated swamp) wetlands located on coastal lowlands and floodplains characterised by seasonal inundation.[705,716] This coastal ecosystem is included in the extent of woody vegetation (Box 3). Freshwater wetlands provide essential functions and services in, and to, coastal and marine ecosystems. For example they provide nurseries for freshwater and marine species[43] and are used by barramundi moving between estuarine and freshwater habitats at different life stages.[717] However, cumulative pressures on this ecosystem's ability to function efficiently continue to come from poor water quality and changes in hydrology.[43] Human-induced pressures include: expanding urban land uses and transport infrastructure (roads); the introduction and spread of aquatic and terrestrial invasive species;[43] and, for some sites, unrestricted access of livestock.[43,718] A changing climate is a significant threat to wetlands, potentially altering wetting and drying cycles, increasing fire frequency and intensity, and raising sea levels.[719]

Connectivity between wetlands and the Reef is essential to the health of the Region

The importance of freshwater wetlands is reflected in new Queensland Government catchment targets requiring no net loss of wetland extent[527], and a net improvement in the condition of natural wetlands and riparian vegetation that contribute to the Reef's resilience and ecosystem health.[9] Since 2009, no additional clearing of freshwater wetlands has been recorded; 81 per cent of the pre-European extent is estimated to remain in the Catchment (Table 3.1).[705] Managers reported on wetland condition for the first time in 2016.[43] Measured against the *Reef Water Quality Protection Plan* 2013[720] target, floodplain wetlands overall are in moderate condition and under moderate exposure to pressures.[721]

3.5.3 Forested floodplains

Forested floodplains are open forests and woodlands on drainage lines or low-lying areas that intermittently flood.[702] This coastal ecosystem is included in the extent of woody vegetation (Section 3.5 Box 3). Forested floodplains benefit the marine ecosystem by providing physical processes that slow, capture and transform or retain nutrients and sediments before they enter the Region. The main threats to forested floodplains continue to be anthropogenic impacts and climate change. Limited contemporary studies have considered the condition of forested floodplains.[102] The current extent of this ecosystem is approximately 58 per cent of the extent before European settlement (Table 3.1).[705]

3.5.4 Heath and shrublands

Heath and shrublands often occurs in coastal locations, including dunefields, sandplains and headlands.[702] This ecosystem helps slow the overland flow of water, prevents erosion, transforms nutrients and sediments, and is important as a buffer on steep coastal hill slopes.[102] About 42 per cent of this coastal ecosystem is located in protected areas,[705] which may have resulted in the ecosystem being reasonably intact (93 per cent of the extent before European settlement remains; Table 3.1). The Cape York NRM region is estimated to have retained all of its remnant heath and shrubland areas.[705] This ecosystem is vulnerable to anthropogenic impacts (clearing and grazing) and climate change, specifically sea-level rise. Condition data are lacking for heath and shrublands.

Overall, the extent of heath and shrublands is stable, although highly sensitive to human disturbances

3.5.5 Grass and sedgelands

Grass and sedgelands is typically composed of perennial native grasses (such as Mitchell, tussock and bluegrass) with limited trees.[702] This coastal ecosystem often occurs in temporarily waterlogged areas within minor basins or small depressions, and can be associated with wetlands. More than half of the grass and sedgelands in the Catchment has been cleared since European settlement; the Mackay–Whitsunday region has had the greatest loss (approximately 14 per cent remaining of the extent before European settlement). Since 2014, no further loss of this ecosystem has been recorded (Table 3.1).[705] The grass and sedgeland ecosystem continues to be susceptible to anthropogenic impacts, specifically altered hydrological processes. Data on the condition data of this coastal ecosystem remains a knowledge gap.

More than half of the grass and sedgelands has been cleared since European settlement, but the current extent remains stable

Vegetation and ground cover are the primary controls of gully erosion, providing protection against scouring and reducing overland flow velocity. Image: Springvale Station, Cape York. © Department of Environment and Science (Qld) 2017

3.5.6 Woodlands and forests

Woodlands and forests in the Catchment are located on flat to gently undulating coastal lowlands and alluvial plains, characterised by a number of eucalypt species making up the canopy. The woodland and forest ecosystem affects the Reef's physical processes through its contribution to regulating sediment supply. Furthermore, it reduces the velocity of floodwaters by slowing overland flow, moderating erosion that may lead to gully erosion and sediment loss.[102] Monitoring the area of this ecosystem is well established; it makes up the greatest extent of the woody vegetation monitoring study (Section 3.5 Box 3). Forests are generally stable in extent, whereas steeper reductions have been observed in the extent of woodlands (Table 3.1). The Cape York and the Wet Tropics regions have the greatest extent of remaining remnant woodlands and forests ecosystem (88–99 per cent of the extent before European settlement), whereas the Fitzroy and Burnett–Mary regions have dropped to approximately 30–37 per cent of the extent before European settlement.[705] No new data on the condition of this coastal ecosystem have been released since 2014.

The extent of woodlands and forests is greatly reduced compared to that before European settlement, however, reductions since 2009 have been limited

3.5.7 Rainforests

Rainforests include vine forests of the Wet Tropics and Cape York regions and stretch south to the evergreen vine forests in the Burnett–Mary NRM region. Rainforests are located in high-rainfall highland areas, and occasionally on lowlands, beach ridges and islands.[702] Rainforests are included in the extent of woody vegetation (Section 3.5 Box 3).

The Cape York and Mackay–Whitsunday regions retain nearly all the rainforest ecosystem they had before European settlement

Monitoring the extent of this ecosystem is well established and published annually.[703,704] Rainforests in the Burnett–Mary and Fitzroy NRM regions have experienced the greatest clearing rates since European settlement; their remaining extents being 30 and 35 per cent, respectively. Conversely, the Cape York and Mackay–Whitsunday NRM regions retain near full extent of their pre-European settlement rainforest ecosystems (99 and 91 per cent, respectively).[705] However, in late 2018 the Mackay hinterland was devastated by bushfires. At the time of writing, no published data are available on the impacts of the fires. Overall, it is estimated that 62 per cent of the Catchment's rainforests are located in protected areas. Limited areas of remnant rainforest have been allocated to protected areas since 2014. The main threats to this coastal ecosystem continues to be climate change (specifically the increase in frequency and intensity of extreme temperatures and fires), feral animals and ongoing fragmentation as a result of anthropogenic pressures.[722] The broad condition of rainforests is a knowledge gap.

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

Four components are graded. Outbreaks of disease, introduced species and other outbreaks remain in good condition. However, outbreaks of crown-of-thorns starfish continues to be graded as very poor.

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Full assessment summary: see Section 3.7.5

3.6.1 Outbreaks of disease

Diseases are infections of plants and animals by pathogenic microorganisms, such as bacteria, viruses, fungi and parasites. Although many of these microorganisms are naturally present in the environment and usually do not cause widespread disease, outbreaks can occur when microorganism abundance increases rapidly or the immunity of a potential host is compromised.[578,723] Factors such as climate change, a general decline in habitat condition and increased population density, increase disease prevalence and virulence, and rates of disease transmission.[724,725,726]

Disease can have a significant negative effect on population structure, causing rapid population declines or, in extreme cases, hastening species extinctions.[578] Disease affects both host organisms and associated species. It can have flow-on effects to ecosystem function, particularly if the disease impairs or kills habitat-forming species, such as corals.[727,728,729] Not all diseases are lethal; sublethal effects of disease include reduced rates of reproduction and growth.[212]

Diseases are known to have affected a number of marine organisms, such as turtles, dolphins, urchins, sponges, molluscs, seagrasses, fishes and crabs.[730,731,732] For example, disease prevalence was 25 per cent higher for fishes and mud crabs assessed in and around Gladstone harbour in 2012 than those from control sites[733]. Since 2018, mud crab lesions have dropped to less than three per cent.

Figure 3.13 Coral trout exhibiting symptoms of disease
Coral trout exhibiting symptoms of disease (fin rot, red eruptive sores, small cysts on pectoral fins) were caught in the vicinity of severely and moderately bleached reefs offshore northern Queensland in June, 2016. © Department of Agriculture and Fisheries (Qld) 2016

In the Region, at least eight different diseases have been recorded from 40 different coral species.[217,734] Surveys undertaken between 2014 and 2018 recorded disease on several reefs across the entire Region.[735] The incidence of coral disease increased sharply in the winter of 2016 following mass bleaching and continued into the summer of 2017. Incidence of coral disease was greatest on reefs that had experienced the longest exposure to warmer than average sea surface temperatures in the winter of 2016 and summer of 2017.[96,736] Although it is unknown what proportion of corals in the Region were affected, one study observed a reduction in coral cover by more than half due to a combination of bleaching and white syndromes disease in early 2017.[736]

With increasing global warming and poor water quality, disease prevalence may also increase in fish species.[725] For example, in April 2016, disease was detected in coral trout caught near reefs in the northern Reef that had been exposed to record-breaking sea surface temperatures during the summer. Although the disease was never identified, symptoms included fin rot, red eruptive sores, small cysts on pectoral fins and widespread sandpaper bumps on the body of the fish (Figure 3.13). Given the prolonged exposure to high sea surface temperatures in 2016, it is likely these fish succumbed to physiological stress. It is unclear what longer-term ecological implications will manifest in coral trout and other fish species across the northern two thirds of the Reef following the 2016 and 2017 mass bleaching events.

Incidence of disease in the Region will increase with temperature increases associated with global warming, potentially resulting in disease hotspots.[737,738,739,740] Injuries to corals from coral predators[741,742,743] and damselfish[744], increased sediment and turbidity[745] and abrasion from marine debris[580] also influence disease transmission in coral. *Drupella*, a coral-feeding snail, can transmit brown band coral disease between colonies.[742] These small predatory snails can aggregate in large numbers (Section 3.6.4)[746,747], and so they are a significant disease vector.[742] New diseases arriving in the Region as a result of changes in ocean currents (and consequent connectivity patterns) due to climate change are an emerging risk.[698]

Marine turtles have been found with blood flukes, septicaemia and fibropapilloma infections[337], but only in small numbers, and these diseases do not appear to have increased since 2014. Overall, outbreaks of disease have been fairly stable since 2014, with higher incidences after thermal extremes in 2016 and 2017.

3.6.2 Outbreaks of crown-of-thorns starfish

Outbreaks of crown-of-thorns starfish are ongoing and causing coral decline

Crown-of-thorns starfish (previously referred to as *Acanthaster planci*, reclassified as *Acanthaster* cf. *solaris*[748]) are native coral predators on the Reef. At natural densities (less than one starfish per hectare)[749], the starfish do not pose a threat to coral reefs because coral growth rates exceed predation rates. However, when densities of starfish reach a point where the consumption of coral tissue exceeds coral growth (approximately 15 starfish per hectare)[750], an outbreak is established.[751] Since the early 1960s, the Region has experienced four destructive outbreaks. This frequency is unsustainable, particularly given other cumulative and broadscale pressures affecting the Region.

An outbreak spreads along the Region primarily when adults spawn (in the warmer months from December to February) and their larvae are transported by currents to other reefs, some tens to hundreds of kilometres away.[752] Once larvae settle on the reef, they feed initially on crustose coralline algae[753] before transitioning to a diet of coral tissue (Figure 3.14).

Figure 3.14 Juvenile and adult crown-of-thorns starfish
Left: Juvenile starfish feeding on crustose coralline algae before switching to a coral diet. © Jennifer Wilmes.
Right: Lethal injection of adult starfish feeding on a large plate coral. © GBRMPA, photographer: Daniel Schultz

In 2010, the Reef experienced the initial stages of its fourth crown-of-thorns starfish outbreak since the 1960s.[752] These outbreaks have followed a common pattern, initiating approximately every 15 to 17 years in the region between Lizard Island and Cairns on reefs offshore from the Wet Tropics river catchment.[424,752] These primary outbreaks subsequently spread out from the initiation zone in waves, mainly through the transport of crown-of-thorns starfish larvae on ocean currents. These waves of secondary outbreaks spread southward at a rate of approximately 60 kilometres per year and can persist for more than 10 years.[754] The primary outbreaks that initiate in the region between Lizard Island and Cairns may also spread north, however, the dynamics of a northern spread are not well understood.

Between 2014 and 2018, the outbreak that started in 2010 in the Cairns–Cooktown Management Area, gradually spread south, to reefs off Innisfail and Townsville.[735] In 2017, an independent outbreak was identified in the Swain Reefs.[735] In 2018–19, surveys of 57 reefs in the Far Northern Management Area found no signs of outbreaks, while surveys in the Mackay–Capricorn Management Area found outbreaks on 16 per cent of the 75 reefs surveyed.[735]

Outbreaks of coral-feeding crown-of-thorns starfish, coupled with impacts from coral bleaching, have caused extensive coral decline across the Region.[755] In the absence of other disturbances, the recovery of coral reefs following starfish outbreaks takes at least 10 years, with coral reefs protected in no-take areas recovering more quickly than those where fishing is allowed.[756] However, windows of opportunity for recovery following outbreaks are decreasing, given other cumulative stressors affecting coral reefs.

Attempts to manage crown-of-thorns starfish outbreaks includes mitigating several factors that contribute to outbreaks and their prevalence (including poor water quality and removal of predators through fishing), and direct control through culling[751] (Section 7.3.12 Box 13). Controlling outbreaks at a local scale is considered one of the most feasible management actions to reduce rates of coral mortality after an outbreak has established and to enable the ecosystem to cope with other pressures.[757,758] As well as direct loss of coral tissue from crown-of-thorns starfish predation, the potential flow-on effects (such as loss of diversity, damage to reef structure and algal overgrowth) also degrade the overall resilience of the ecosystem[759] (Chapter 8).

The underlying causes of outbreaks are multifaceted with no single trigger categorically proven to initiate outbreaks.[757,758] Nutrients in the water column from natural upwelling and land-based run-off, hydrodynamic conditions, coral availability and low abundance of predators of crown-of-thorns starfish may all combine to provide positive outbreak conditions on the Reef.[424,760,761,762] For some time, the giant triton snail was considered one of the few predators of crown-of-thorns starfish.[763] However, it is increasingly clear that many coral reef organisms, including other invertebrates and fish (for example, small damselfish and emperors), prey on crown-of-thorns starfish at some stage in their life cycle.[764] Some of these predators (such as emperors) are fisheries targets. Healthy predator populations are likely to be important in the top-down control of starfish populations and prevention of future outbreaks.[754,762]

As at 2019, outbreaks are most severe in the central and southern areas of the Reef. Overall the trend remains stable.

3.6.3 Introduced species

Introduced species or 'pests' include non-native plants or animals that establish beyond their natural range and threaten values within their new range. Pests can be spread by both natural vectors (wind, currents and birds)[765,766] and human-related vectors (on camping equipment, the hull of a ship, or materials moved to and between islands). Introduced species are a threat to native plants and animals because they compete for food and space, and in some cases may directly prey on native species (for example, feral pigs prey on marine turtle eggs).

Since 2014, several pests have been eradicated from islands

Australian waters house approximately 200 introduced marine species.[767] The majority have been transported within the marine environment by ships (for example, the Asian green mussel) or have entered Australian waters from legacy aquaculture outflows. Since 2009, seven exotic marine pest detections have occurred within Queensland ports, four of which were in the Region (Gladstone 2009, Cairns 2012 and 2014, and Hay Point 2013). The last recorded incursion within the Region was in December 2014, when two Asian green mussels were found on a navy ship in Cairns.

Coordinated marine pest monitoring is not undertaken at smaller marinas and ports used by recreational and commercial vessels travelling from international waters through the Reef. However, Biosecurity Queensland is currently working on a *Marine Pest Prevention and Preparedness Project* to increase maritime stakeholder knowledge and awareness of how to minimise the threat of marine pests through surveillance, reporting and recommended boat hygiene practices. Biosecurity Queensland is also developing a pilot port surveillance program, working with the five major Queensland ports to build capability in marine pest surveillance and monitoring.

Established terrestrial pests are more likely to persist on islands and cays that are disturbed or have been modified in some way.[765] With an increasing coastal population and greater promotion of island-based tourism in areas where the Reef is recovering from disturbances (for example, the Whitsunday islands), there may be an increased risk of

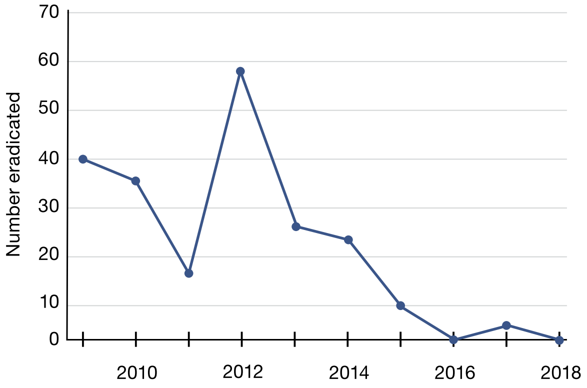


Figure 3.15 Number of goats removed from High Peak Island, 2009 to 2018
An ongoing targeted program began in 2009 and resulted in full eradication in 2018. Source: Queensland Parks and Wildlife Service

human transmission of pests to islands and cays. Since 2014, an improved approach to island biosecurity has been implemented through prescriptive quarantine and surveillance measures. The Queensland Government 'Be Pest Free' community awareness and education program educates island visitors on how to avoid the inadvertent introduction of pest plants and animals. Islands that receive regular barge services (such as Magnetic Island, Green Island and some Whitsunday islands) and campers have a higher risk of receiving new pest introductions than more isolated, less visited islands.

Since the 1970s, there has been a gradual trend of increasing eradication successes on islands and cays around the Whitsundays and Capricorn Bunker group (Box 4). Since the 2014 Outlook Report, several introduced species have been eradicated from islands where they were previously recorded (for example, goats have been eradicated from High Peak and St Bees islands (Figure 3.15), and rats from Frankland and Barnard islands). Pest management is ongoing on other islands, mainland beaches and coastlines.

The occurance of introduced species has remained stable across the Region. Effective eradication has occurred in some areas and limited infestations have been recorded in, and adjacent to, the Region.

BOX 4

Pest eradication restores *Pisonia* forest and seabird breeding site

The scale insect (*Pulvinaria urbicola*) in outbreak numbers can be a pest, attaching to plants and extracting sap, weakening and eventually killing the plant. Certain species of ladybird and parasitic wasp are natural predators of the scale insect; however, if their numbers are low it is hard to control without intervention. On two islands off Yeppoon (Tryon and Wilson islands), infestations of the scale insect grew to devastating levels when aided by the introduced African big-headed ant. The ant protects the scale insect from natural predators and feeds on a honey dew excretion produced by the scale insect. As well as undermining natural predation, the ant moves scale insects between plants, spreading the infestation.

Pisonia forests provide critical seabird nesting habitat, stabilise sediments and suppress other plants through shading.[27] From 1993 to 2003, the scale insect infestation had severe ecological impacts at Tryon Island, decimating the island's *Pisonia* forests. This led to a change in the composition of the island's vegetation and seabird communities. Wedge-tailed shearwaters continued to breed, however, thick grasses and weeds hindered ground movement of birds and their take-off runways. Transient species, such as the tawny grassbird were recorded more regularly after the vegetation had shifted from forest to more open habitat.

Pest ants were baited from 2006, and in 2016 eradication of the island's African big-headed ants was confirmed. The intervention program also focussed on restoring the island's original forest. More than 3000 *Pisonia* cuttings were planted and the forest has started to recover its closed canopy, supressing weeds. This vegetation renewal has also re-established nesting habitat for black noddies and wedge-tailed shearwaters, with numbers of both increasing.

Top: Decimated area of Pisonia grandis forest on Tryon Island. © Queensland Parks and Wildlife Service 2006, photographer: Joy Brushe
Bottom: The same location in 2016. © Queensland Parks and Wildlife Service 2016, photographer: Joy Brushe

The lessons learned at Tryon Island provided the basis for the highly successful outbreak response at Wilson Island in 2006 and 2007. Knowledge was gained on how to bait and kill the introduced ants, bolster natural predator numbers and effectively restore *Pisonia* forest ecosystems.[768] Managers now have the science and intervention knowledge to successfully prevent, treat and protect *Pisonia* forests from the scale insect pest throughout the Reef.

3.6.4 Other outbreaks

Other outbreaks includes native species (as opposed to introduced species; Section 3.6.3) that experience a rapid increase in abundance, biomass or population. Outbreaks of the naturally occurring crown-of-thorns starfish and coral disease were examined previously (Sections 3.6.1 and 3.6.2). Outbreaks and blooms are often a sign of ecosystem stress and can be harmful or lethal to other marine species. Some outbreaks can also pose a threat to human health, either through direct consumption of ciguatoxins in fish, inhalation of microscopic organisms causing the outbreak[769], or exposure to toxic cyanobacteria in water.

Trichodesmium is a pelagic blue-green alga that can create slicks when significant numbers of the cells join together and float to the water surface. When these slicks are exposed to light the algae die, leaving floating pungent slicks that look like sawdust on the surface of the water and are commonly mistaken for oil spills (Figure 3.16). Slicks are more common under hot, calm, doldrum conditions in spring and summer, and accumulation is aided by slow, circulating surface currents.[770] *Trichodesmium* plays an important role in nitrogen fixation, and produces a large amount of the nitrogen available to the Reef system.[771,772]

Figure 3.16 *Trichodesmium* slick around Hinchinbrook Island
© GBRMPA 2019

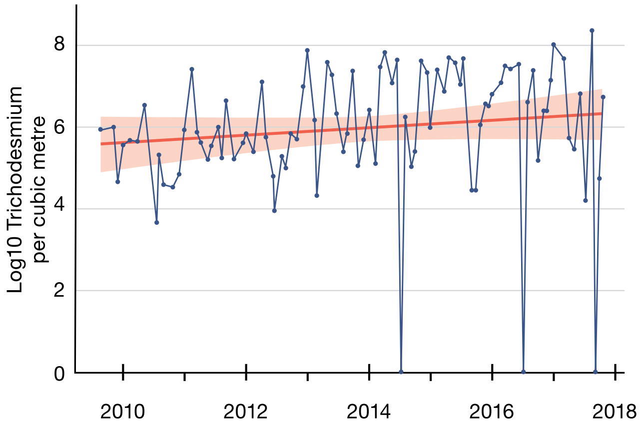


Figure 3.17 Abundance of *Trichodesmium*, Yongala IMOS National Reference Station, 2009–2017
Source: IMOS National Reference Station 2010-2018[773]

When the blooms outbreak into large slicks, they can become toxic, particularly in shallow, still waters, affecting other marine life (predominantly fish) and posing a risk to human health. While limited broadscale monitoring of *Trichodesmium* occurs across the Region, long-term data have been recorded near the Yongala Wreck (offshore from Ayr) since 2010, indicating a long-term gradual increase in the abundance of *Trichodesmium*[773] (Figure 3.17). Seasonal fluctuations in abundance occur, with lower abundances associated with winter periods.[773]

Drupella are coral-eating marine snails that occur naturally on the Reef. When *Drupella* snails increase to outbreak numbers they can significantly damage corals through direct predation and spreading disease.[742] There is no evidence to suggest that *Drupella* snails undergo regular, large-scale outbreaks like crown-of-thorns starfish. The triggers for *Drupella* snail outbreaks are also not well understood. However, overfishing of predators (such as triggerfish and wrasses)[774], elevated nutrients and global warming may exacerbate outbreaks.[775] Recent evidence from the Maldives identified a significant increase in *Drupella* snails following a coral bleaching event in 2016, with snails targeting colonies that had resisted the bleaching.[776] On the Reef, some tourism operators have reported high densities of *Drupella* snails at several tourism sites off Cairns.[777] However, due to lack of data it is unclear whether *Drupella* outbreaks have increased across the Region following the 2016–2017 coral bleaching events.

Outbreaks and blooms can be triggered by changed environmental conditions. For example, blooms of irukandji jellyfish in the Region during summer months coincide with the easing of prevailing south-easterly trade winds.[778] Elsewhere in the Pacific, toxic algal blooms associated with record-breaking high sea surface temperatures in 2016 have occurred. For example, a region in Chile declared a state of emergency when a widespread toxic algal outbreak caused mass mortality of fishes, shellfish, and birds, and hundreds of whale strandings.[779] This resulted in significant economic losses, with impacts on both human health and recreational use.

Outbreaks of some species are increasing in some areas, while *Drupella* abundance appears similar to levels seen before 2014, resulting in no consistent trend.

3.7 Assessment summary — Ecosystem health

Paragraph 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
- coastal ecosystems that support the Great Barrier Reef
- outbreaks of disease, introduced species and pest species.

3.7.1 Physical processes

Grading statements — physical, chemical and ecological processes				
🟩	🟨	🟧	🟥	☐☐
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.	**Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report	
↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟨	🟨 ↓	🟨 ↓			**Physical processes:** The majority of physical processes have remained stable or continued to decline, except currents and cyclones and wind. Further changes to these processes are expected due to the continued influence of climate change and land-based run-off, with broad implications for the Region.
🟩	🟩 ↓	🟩 −	○	○	**Currents:** Ocean currents continue to transport and connect species and habitats.
🟨	🟨 ↓	🟨 −	●	●	**Cyclones and wind:** Since 2014, over 60 per cent of the reef area within the Region has been exposed to destructive waves from five severe tropical cyclones. Location and intensity of cyclones remain highly variable. Given other cumulative impacts, cyclones have damaged the Region's structure and impacted its function, particularly around Lizard Island and the Whitsundays.
🟨	🟨 ↓	🟨 ↔	●	●	**Freshwater inflow:** Between 2013 and 2018, freshwater flow was near or below the long-term average for the Catchment.
🟧	🟧 ↓	🟧 ↔	●	●	**Sediment exposure:** Sediment loads continue to contribute to the poor state of many inshore coastal and marine ecosystems. The majority of sediment is delivered to the Region during flood events and the amount varies between catchments.
🟨	🟨 ↓	🟨 ↓	●	●	**Sea level:** Sea level is rising, with the fastest rates being recorded in the Region's north. Coastal areas, islands and cays will be most affected by increases in sea level.
🟧	🟧 ↓	🟥 ↓	●	●	**Sea temperature:** Extreme thermal stress due to global warming occurred in the summers of 2016 and 2017, resulting in widespread coral mortality. Impacts on other organisms (such as fish and seabirds) are emerging.
🟨	🟨 ↓	🟨 ↓	◐	◐	**Light:** It is likely that underwater light availability has decreased substantially in the inshore areas of the southern two thirds of the Region due to land-based run-off, resuspension of existing sediment in the system and extreme weather.

3.7.2 Chemical processes

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟧	🟩 ↓	🟩 ↔			**Chemical processes:** The chemical processes within the Reef are generally in good condition. However, nutrient cycling continues to be affected by land-based run-off. Ocean salinity has remained stable largely as a result of low rainfall. Ocean pH has decreased as a result of climate change.
🟧	🟧 ↓	🟧 ↔	●	●	**Nutrient cycling:** Since 2012, the dissolved inorganic nitrogen discharged to the Catchment has been generally lower than previous years, primarily due to low river flow.
🟩	🟩 ↓	🟩 ↓	●	●	**Ocean pH:** Inshore areas are more vulnerable to ocean acidification than the open ocean due to higher respiration and nutrient levels. Ocean pH is slowly decreasing.
🟦	🟩 ↓	🟩 ↔	●	◐	**Ocean salinity:** Localised changes to salinity occur as a result of freshwater inflow, largely affecting inshore areas. Overall, this process is stable.

3.7.3 Ecological processes

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟩 ↓	🟩 ↓			**Ecological processes:** The majority of ecological processes on the Reef have deteriorated. Significant declines in the majority of coral cover throughout the Region are likely to have affected some key ecological processes, such as connectivity, symbiosis, reef building, competition and recruitment. However, as time lag effects are common after mass bleaching events, impacts may still be unfolding. Ecological processes are expected to continue to decline due to climate change impacts and inshore land-based run-off.
🟩	🟩 ↔	🟩 –	○	○	**Microbial processes:** Microbial processes are central to the flow of carbon through the ecosystem and are sensitive to changes in environmental conditions. Environmental stressors associated with a warming climate have disrupted microbial processes in corals and other organisms, lowering their ability to resist bleaching and disease. Very little information exists on microbial processes across the Region.
🟩	🟩 ↓	🟩 ↓	◐	◐	**Particle feeding:** Particle feeding is undertaken by a broad range of species, including echinoderms, molluscs, sponges and corals. High nutrient levels have affected some particle feeders. Following two thermal stress events, there have been significant declines in particle-feeding corals in some areas. It is also likely that particle-feeding fish, which rely heavily on coral habitats for shelter, have also decreased.
🟦	🟦 –	🟦 –	◐	◐	**Primary production:** Some seafloor primary producers, such as seagrasses and benthic algae, have increased in some areas. However, high levels of nutrients, sediment and temperature are causing negative impacts. Corals have declined sharply. Phytoplankton is variable across the Region and depends on a combination of freshwater inflow and nutrients.
🟩	🟩 ↓	🟩 ↔	◐	◐	**Herbivory:** The process of herbivory supports nutrient cycling, is important for reinforcing a coral-dominated state through the removal of competing algae, and increases the productivity of seagrass meadows. Fish herbivore abundance has generally remained stable across the Region, with some changes in offshore locations. In high-sediment areas, and where macroalgae are dense, herbivory is reduced. The condition of herbivory as a process across the Region and the mechanisms that affect it are not well understood.
🟧	🟧 –	🟧 –	◐	◐	**Predation:** Generally, changes in the abundance of reef-associated predators across the Region have been variable. A large group of predators, the sharks and rays, has been assessed as being in poor condition.
🟩	🟩 ↓	🟧 ↓	◐	●	**Symbiosis:** Based on the unprecedented decline of coral cover and the changes in coral community composition, the majority of symbioses involving coral have been significantly affected since 2016. Many symbiotic relationships between small benthic invertebrates remain data deficient.
	🟧	🟧 ↓	◐	◐	**Recruitment:** Recruitment is reduced for many key species, in particular, corals, fishes and some marine turtles and seabirds, largely due to chronic and acute disturbances.
🟩	🟩 ↓	🟧 ↓	◐	◐	**Reef building:** Reef building has deteriorated, largely due to the combined effects of unprecedented declines in coral cover and crustose coralline algae in some areas in response to thermal bleaching events. The slow decrease in ocean pH affects reef building.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟩 ↔	🟩 ↓	○	○	**Competition:** Habitat loss and population declines are changing competition on a broad scale, which is likely to have flow-on effects on the fitness of organisms. It is likely that coral–algal competition has increased.
🟩	🟩 ↓	🟩 ↓	◐	◐	**Connectivity:** Marine species and habitats remain connected. However, effects of climate change have altered connectivity patterns. Connectivity with some coastal ecosystems remains disrupted.

3.7.4 Coastal ecosystems that support the Great Barrier Reef

Grading statements — coastal ecosystems that support the Great Barrier Reef

🟦	🟩	🟧	🟥	☐☐
Very good All major habitats are essentially structurally and functionally intact and able to support all dependent species.	**Good** 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.	**Poor** Habitat loss, degradation or alteration has occurred in a number of areas leading to persistent substantial effects on populations of some dependent species.	**Very poor** There is widespread habitat loss, degradation or alteration leading to persistent, substantial effects on many populations of dependent species.	**Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟧	🟧 ↔			**Coastal ecosystems that support the Great Barrier Reef:** A broad understanding of the condition of each coastal ecosystem remains a significant knowledge gap, even though some are subject to extensive management effort (saltmarshes, wetlands, woodlands and forests). Many grades and trends are limited or inferred. Since 2014, the woody vegetation clearing rate in the Catchment continued to increase. The main purpose for this clearing was for agriculture.
	🟩	🟩 ↔	◐	◐	**Saltmarshes:** Historically, a small area of this ecosystem has been modified in the Catchment. More evidence is emerging about saltmarshes, yet little is known about the condition of this ecosystem.
	🟧	🟧 ↔	◐	◐	**Freshwater wetlands:** No significant loss of extent and no significant new threats have occurred, but the impacts of climate change are unclear.
	🟧	🟧 ↔	◐	○	**Forested floodplains:** Given the limited remaining extent and limited condition data available about the performance of this ecosystem for services and function to the Reef, the grade and trend are uncertain. There is insufficient new evidence to substantiate a change in grade or trend.
	🟦	🟦 ↔	◐	◐	**Heath and shrublands:** Given the extent of heath and shrublands remains stable at nearly the full extent of the ecosystem pre-European clearing, the ecosystem is considered to be very good. However, little is known about the condition of this ecosystem.
	🟧	🟧 ↔	◐	○	**Grass and sedgelands:** Grass and sedgeland extent remains stable, but overall this ecosystem has seen the greatest loss of all coastal ecosystems since European settlement. Limited condition data are available.
	🟧	🟧 ↓	●	◐	**Woodlands and forests:** The extent of this ecosystem is stable, but continues to reduce from the nominal extent that remains from clearing after European settlement. Annual data are produced on the extent of woody vegetation clearing rates, and are the most robust data available.
	🟩	🟩 ↔	◐	◐	**Rainforests:** Extent in the catchment remains stable. Although little is known about the condition of this ecosystem, the inferred protection of rainforests in protected areas increases the confidence in this grade.

3.7.5 Outbreaks of disease, introduced species and pest species

Grading statements — outbreaks				
🟦 **Very good** No records of diseases above expected natural levels; no introduced species recorded; no outbreaks; pest populations within naturally expected levels.	🟩 **Good** Disease occasionally above expected natural levels but recovery prompt; any occurrences of introduced species successfully addressed; pests sometimes present above natural levels with limited effects on ecosystem function.	🟧 **Poor** Unnaturally high levels of disease regularly recorded in some areas; occurrences of introduced species require significant intervention; pest outbreaks in some areas affect ecosystem function more than expected under natural conditions.	🟥 **Very poor** Unnaturally high levels of disease often recorded in many areas; uncontrollable outbreaks of introduced pests; opportunistic pests seriously affecting ecosystem function in many areas.	▯▯ **Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report	
↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟧	🟧 ↔	🟧 ↔			**Outbreaks of disease, introduced species and pest species:** Outbreaks of disease are localised and patchy across the Region. Although pest control programs have been successful on local scales, introduced species continue to be recorded. Other outbreaks, such as *Trichodesmium,* have increased, but data are limited on a broad scale. The severity of the crown-of-thorns starfish outbreak continues to seriously affect coral reef habitats.
🟩	🟩 ↔	🟩 ↔	○	○	**Outbreaks of disease:** The incidence of disease is localised and patchy across the Region. Disease has affected corals, turtles, dolphins, coral trout and prawns since 2014. Reports of coral disease peaked following mass bleaching events in 2016 and 2017. Incidence of disease will increase with global warming.
🟧	🟥 ↓	🟥 ↔	●	●	**Outbreaks of crown-of-thorns starfish:** The Region is still experiencing an outbreak of crown-of-thorns starfish which began around 2010, seriously affecting ecosystem function in many areas. The areas most heavily affected by starfish predation have shifted from reefs offshore of Cairns to those south of Innisfail, with the Swain Reefs also experiencing significant impacts.
🟩	🟩 ↔	🟩 ↔	○	○	**Introduced species:** Eradication of certain introduced species on a number of islands has been confirmed since 2014, and other infestations are being effectively managed. New incursions of introduced marine species in the Region have not been recorded since 2014.
🟩	🟩 ↔	🟩 −	◐	○	**Other outbreaks:** Outbreaks of some species are likely to have resulted from declining ecosystem conditions. *Trichodesmium* blooms are increasing in particular areas, whereas *Drupella* predation appears similar to levels seen before 2014.

3.8 Overall summary of ecosystem health

The condition of the Region depends on a range of chemical, physical and ecological processes, the health of connected coastal ecosystems, and impacts of disease and pest outbreaks. Of the 31 ecosystem health components assessed across those five areas, about 60 per cent remain in good to very good condition; the rest are in poor to very poor condition. Eleven of the 31 components have deteriorated since 2014, mainly due to declines in ecological processes (such as symbiosis and recruitment) and changes to some physical processes (such as sea temperature and light).

Exposure to both acute and chronic disturbances, such as record high sea temperatures and poor water quality, have contributed to an overall decline in ecosystem condition, with both ecological and physical processes assessed as deteriorating

The decline in ecosystem condition in the Region over the past five years has been exacerbated by both acute and chronic disturbances, such as record high sea temperatures and poor water quality. Extreme sea temperatures caused by global warming have had the greatest impact: heat stress has caused unprecedented loss of coral reef habitat along two-thirds of the Reef and had flow-on impacts on dependent species. The unprecedented chronic and acute spikes in sea temperature across much of the Region have driven the change in grade for sea temperature from poor to very poor. Sea temperature and other physical and chemical processes (such as sea level and ocean pH) will continue to deteriorate as the effects of climate change accelerate. Other physical processes, such as sediment exposure and freshwater inflow, have remained stable since 2014.

Extreme thermal stress in 2016 and 2017 underscored the deterioration of sea temperature to very poor. The effect has influenced the deterioration of symbiosis and reef building

Apart from ocean pH, which has deteriorated since 2014, chemical processes are relatively stable: ocean salinity is unchanged and nutrient cycling remains in poor but stable condition. Although some improvements are being made in land management practices to reduce nutrients and sediments from land-based run-off, there are significant time lags between changes in management and improvements in marine processes (Section 6.5).

Ecological processes, including microbial processes, particle feeding, primary production and competition remain poorly understood. The loss of some coral habitats in 2016 and 2017 has affected some key ecological processes, particularly those associated with coral, such as particle feeding, primary production, recruitment and reef building. The deteriorating condition of many ecological processes has affected the integrity of the Region's outstanding universal value.

Some processes important to replenishment and recovery of species and habitats, such as currents, connectivity and primary production remain in good to very good condition

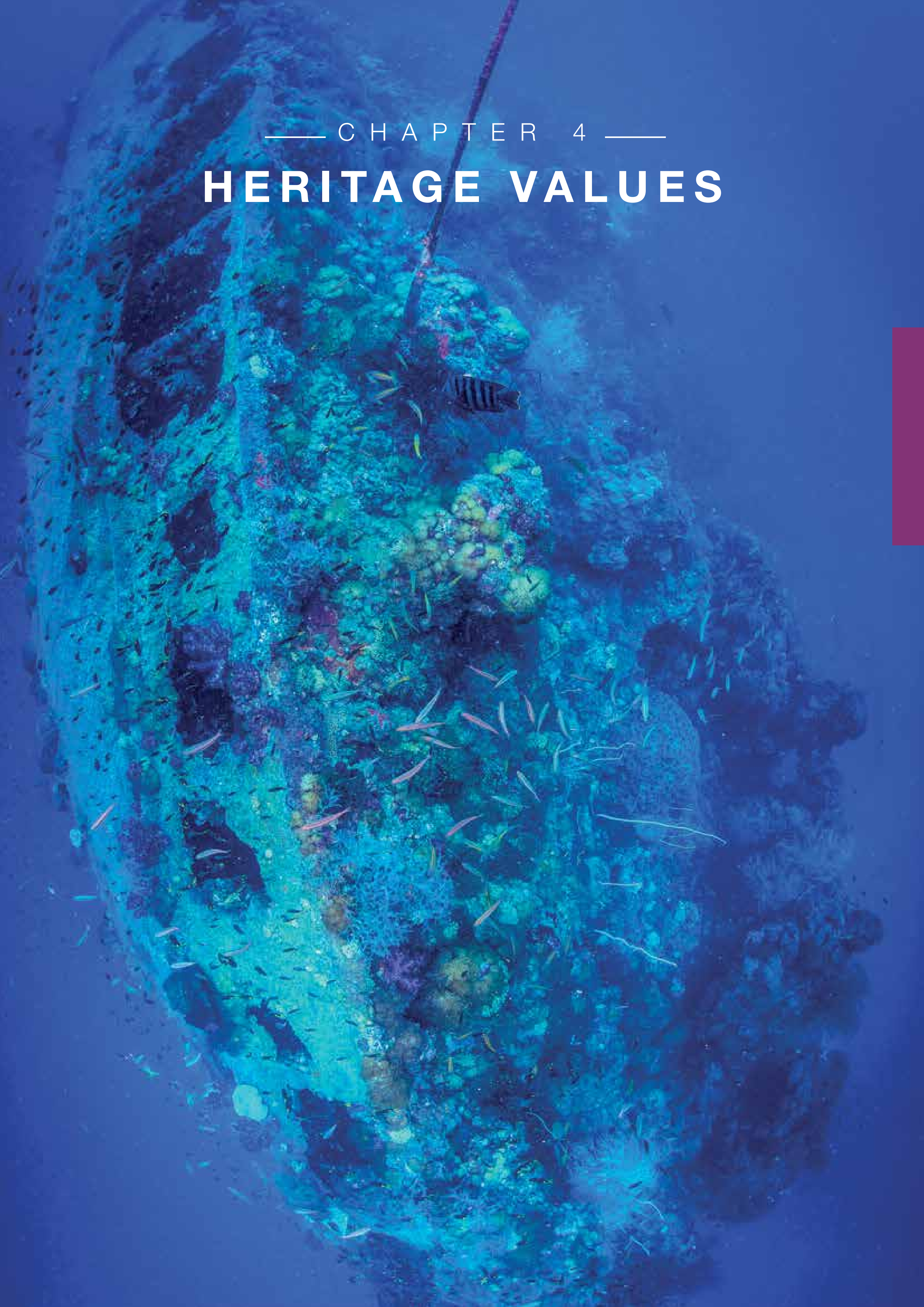
Coastal ecosystems that support the Reef remain in poor condition overall. However, the trends of most components have stabilised. Woodlands and forests is the only coastal ecosystem type that continues to deteriorate following a further reduction in its extent. Continued modification of coastal ecosystems will increase sediment inflow, reduce connectivity to the Reef and reduce capacity of these habitats to support the Region's ecosystems and species.

Outbreaks of crown-of-thorns starfish persist in the Region, especially affecting offshore reefs from Innisfail and Townsville. A more recent outbreak has been identified in the Swain Reefs. The severity of these outbreaks continues to reduced live coral reef habitat. Programs to eradicate introduced pests have been successful on some islands.

Reefscape during the 2016 mass coral bleaching event. Some bleached corals appear white, while others appear fluorescent.
© GBRMPA

CHAPTER 4

HERITAGE VALUES



« *The SS Yongala is one of the Region's historic shipwrecks and a popular dive site.* © Matt Curnock 2015

HERITAGE VALUES

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

4.1 Background

Heritage values of the Region were considered in the Outlook Report for the first time in 2014, following amendments to the *Great Barrier Reef Marine Park Act 1975* (Cth) in 2008. The scope of the assessment includes the Region's natural, Indigenous and historic heritage value (Table 4.1),[780] some of which extend beyond the Region's boundary. For example, Indigenous heritage values of the Region include Traditional Owners' connection to both land and sea. Therefore, the assessment of Indigenous heritage values may include areas outside the Region (such as islands and the coastline, irrespective of jurisdiction) that affect the Region (Section 4.3).

Table 4.1 Scope of assessment of the heritage values of the Region

Domains of heritage values	Scope of assessment
Natural	The Region and ecosystems outside the Region to the extent they affect the Region (Chapters 2 and 3). The regulatory requirements for assessing natural heritage values (biodiversity and ecosystem health) extend beyond the Region.
Indigenous	The Region and areas outside the Region to the extent they affect the Indigenous heritage value of the Region.
Historic	The Region, including Commonwealth islands. Queensland islands, internal waters and the Catchment above mean low water mark are excluded from the assessment.

Traditional Owner and researcher working in partnership on Raine Island. © Department of Environment and Science (Qld)

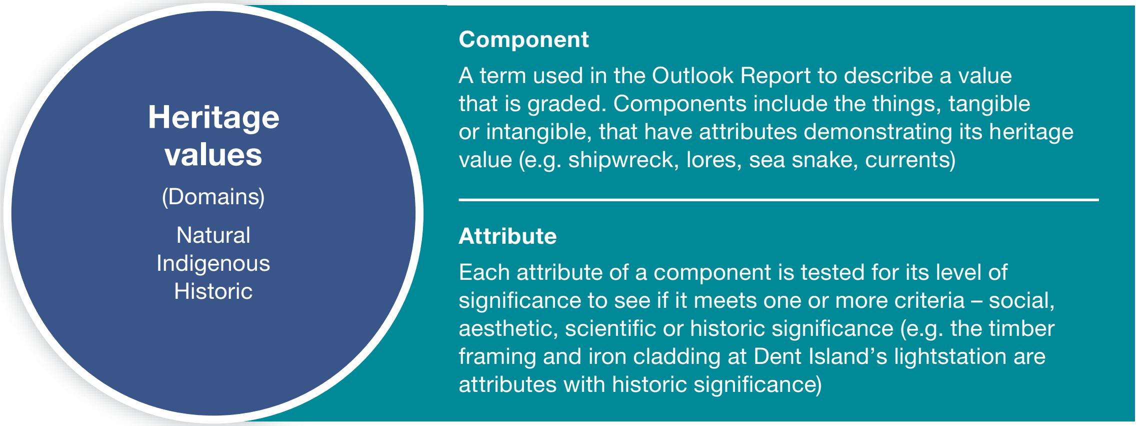
4.1.1 Structure of assessment

In Australia, three heritage domains (or types of heritage value) are recognised: natural, Indigenous and historic (Table 4.1)[780]. In this Outlook Report, some sections have been reordered to better align with these three domains (Table 4.2) and the requirements set out in the regulations applying to the Marine Park (Marine Park regulations).

The Outlook Report describes aspects of heritage values in terms of components (values that are graded) and attributes (attributes of a component used to assess significance) (Figure 4.1). The Marine Park regulations set the parameters for the heritage assessment in the Outlook Report; in some instances, the prescribed values are equivalent to things considered attributes in other settings. For example, for consistency with previous Outlook Reports, aesthetic heritage values are given a grade, whereas in other settings, a value's aesthetic attributes demonstrate the value's historic significance.

Table 4.2 Structure of heritage values assessment — comparison between Outlook Reports
The Marine Park regulations establish the scope of the Outlook Report heritage assessment.

2014 Structure of heritage values assessment	2019 Restructure of heritage values assessment
• Indigenous heritage values • Historic heritage values • Other heritage values • World heritage values and national heritage values • Commonwealth heritage values • Natural heritage values	• Natural heritage values o world heritage value o national heritage value • Indigenous heritage values • Historic heritage values o Commonwealth heritage values • Other heritage values – attributes of heritage significance (social, aesthetic and scientific)



Component

A term used in the Outlook Report to describe a value that is graded. Components include the things, tangible or intangible, that have attributes demonstrating its heritage value (e.g. shipwreck, lores, sea snake, currents)

Attribute

Each attribute of a component is tested for its level of significance to see if it meets one or more criteria – social, aesthetic, scientific or historic significance (e.g. the timber framing and iron cladding at Dent Island's lightstation are attributes with historic significance)

Figure 4.1 Heritage values matrix
Source: Commonwealth of Australia 2015[780]

4.2 Current condition and trends — natural heritage values

Five components of natural heritage values are graded. Three components are considered in good condition, but borderline with poor. Habitats for conservation of biodiversity has deteriorated to a poor grade. Major stages of the Earth's evolutionary history has deteriorated to good condition. ↓

Full assessment summary: see Section 4.6.1

The Great Barrier Reef was inscribed on the World Heritage List in 1981 and included on the National Heritage List in 2007. These two listings recognise the Region for the same natural heritage value. Therefore, for the purpose of this assessment, the Region's world and national heritage value is assessed together as a natural heritage value, with reference to Chapter 2 (biodiversity values) and Chapter 3 (ecosystem health values) for evidence of the condition of the Region's natural heritage value.

4.2.1 World heritage value and national heritage value

All properties inscribed on the World Heritage List have a common thread; they all have outstanding universal value. Outstanding universal value can be described 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'[781]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) explains outstanding universal value as having three pillars, of which some aspects are assessed within the Outlook Report. Under the *Operational Guidelines for Implementation of the World Heritage Convention*[781], to have outstanding universal value a property must:

- meet one or more of the 10 world heritage criteria (Pillar 1)
- meet the condition of integrity (wholeness and intactness) (Pillar 2). Cultural heritage properties must also meet the condition of authenticity, however, this is not applicable to the Great Barrier Reef
- have an adequate system of protection and management to safeguard its future (Pillar 3).

The Reef is inscribed under four natural world heritage criteria (Table 4.3). Any component contributing to these criteria not assessed in Chapters 2 and 3 (for example, natural beauty, aesthetics and major stages of the Earth's evolutionary history) are assessed in this chapter. The assessment also includes a brief assessment of the integrity of the property (Section 4.2.6).[781] Safeguards for the property (protection and management effectiveness) are briefly assessed here in relation to heritage values. However, the broader and more comprehensive assessment of management effectiveness is included in Chapter 7.

Table 4.3 World heritage criteria relevant to the Reef and how they are assessed
This table summarises how the Outlook Report chapters relate to the world heritage criteria; more detail is shown in Appendix 3.

Short title (component of Outlook Report)	Current world heritage criteria	Outlook Report assessment of natural heritage values
Natural beauty and natural phenomena	(vii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance	The natural beauty of the property is assessed in Chapter 4. Chapters 2 and 3 inform an assessment of natural phenomena
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	The major stages of Earth's evolutionary history are assessed in Chapter 4 and informed by Chapters 2 and 3.
Ecological and biological processes	(ix) be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals	Ecological and biological processes are assessed in Chapters 3 and 8.
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	Habitats and biodiversity are assessed in Chapters 2, 4 and 8.
Integrity	The integrity of the property relates to its wholeness and intactness. Integrity is an additional component (not a criterion) of the assessment of the Region's world heritage and national heritage values	The integrity of the property is assessed in Chapter 4 and Appendix 4.

4.2.2 Natural beauty and natural phenomena (criterion vii)

The natural beauty of the property endures, however, it is under increasing pressure from cumulative impacts above and below the water

The Reef was inscribed as a world heritage property as an example of superlative natural beauty above and below the water.[28] The property is noted to have spectacular scenery creating an unparalleled aerial panorama of seascapes, and it is visible from space.[28] At a whole-of-Region level, overall habitats are assessed to be in poor condition, affecting aspects of its natural beauty and phenomena. Widespread coral mortality (as a result of sea temperature extremes in combination with predation by crown-of-thorns starfish) and impacts from severe cyclones, have affected the aesthetics and natural beauty of some parts of the Region above and below the water (Section 4.5.2).

The Whitsunday islands rank as a cornerstone feature of the world heritage property. The vistas created by the vegetated islands, sandy beaches and turquoise seas, remain largely intact above the water. Nearly 90 per cent of the Whitsunday islands are retained as national park and restricted access to these areas reduces the impact of pressures from human use. However, cyclone Debbie passed through the Whitsundays in 2017, significantly affecting its aesthetic values above and, to a large extent, below the water. Management intervention actions carried out following the cyclone have gone part way to assisting recovery of the land-based vistas. For example, approximately 10,000 cubic metres of sand was re-profiled on Whitehaven Beach in April 2017 to accelerate beach recovery. Further clean-up activities were undertaken in 2018 (Figure 4.2).[35]

Figure 4.2 Cyclone damage on Whitehaven Beach, 2017
Whitehaven Beach in the Whitsundays is renowned for its long white sandy beach.
Left: Post-cyclone clean-up.
Right: Re-profiled beach. © Queensland Parks and Wildlife Service 2017

The significant elements that make up the Reef's superlative natural phenomena include annual coral spawning, migrating whales, nesting turtles and significant spawning aggregations of many fish species.[28] These species and processes endure, but they are under increasing pressure from cumulative impacts. Closely aligned to the Reef's naturalness are the aesthetic attributes of the Reef (Section 4.5.2), above and below the water. The aesthetic values of the world heritage property rely heavily on the condition of the Region's ecosystem. The condition, trend and recovery of the Region's biodiversity and ecosystem health (the Region's natural heritage values) are assessed in Chapters 2 and 3. The most prominent threats to the Region's ecosystem include the ongoing chronic effects of increased sea temperature, poor water quality[782] and acute die-offs of corals caused by spikes in summer temperatures. For example, visual elements of inshore underwater scapes are particularly affected by water clarity[782,783], with Reef users stating water clarity contributes to their aesthetic appreciation of the Reef[783,784]. These threats are compounded by coral predation from crown-of-thorns starfish and the acute effects of recurrent cyclones.

Contemporary studies[785] have identified that isolated pockets of the Reef are more likely to be affected by visual pollution through increased coastal and island development (Section 6.4) and increased marine debris (Section 6.5). On the land, damage to coastal and island vegetation from severe weather events has occurred. While the Region has shown signs of recovery following these events, aesthetic values can be significantly affected in the short to medium term. Examples include where island infrastructure remains unrepaired and habitats are not restored. Significant progress towards understanding the human dimensions of the Reef has been made, focusing on societal attitudes and how people value the Reef (Section 4.5.1).

Taken as a whole, the Region's natural beauty and natural phenomena endure but have deteriorated in several areas. Since 2014, some elements necessary to maintain outstanding universal value have been altered. Some aspects of natural phenomena (for example, coral spawning) have been significantly reduced following back-to-back bleaching events[96] (Chapters 2 and 3).

4.2.3 Major stages of the Earth's evolutionary history (criterion viii)

The Reef has evolved over millennia, but it is relatively young in geological terms. The continental shelf upon which the Reef has formed was largely in place by approximately 2.6 million years ago.[786] Although it was capable of supporting reef growth, it appears widespread coral reef development (similar to contemporary inshore shoals) did not occur until after 700,000 years ago.[787] True reef growth, comparable to that of the modern reef, took place prior to approximately 450,000 years ago.[788]

While the current impacts and changes from disturbances are minor on an evolutionary scale, they are unprecedented and will be long-lasting

Since that time, there have been at least six phases of reef growth during periods when interglacial sea-levels have inundated the continental shelf, punctuated by six periods of emergence when sea-levels fell during glacial periods.[787,788] In the context of Earth's evolutionary history, long-term active calcification and accretion, which are important ecological and biological processes, add to its outstanding universal value.[789] Since 2014, scientific understanding of reef and low-lying island formation, the distribution of submerged coral reefs and other key habitats (such as *Halimeda* bioherms), and the effects of a range of processes over the millennia has been extended.[21,790,791,792,793] While the Reef continues to provide outstanding examples of the Earth's evolutionary history and geomorphological diversity, such as Raine Island and the Ribbon Reefs[32], unprecedented recent disturbances, as outlined in Chapters 2 and 3, will have long-lasting effects.

Many reefs have experienced significant episodic pauses in reef growth that lasted for several centuries during the mid to late Holocene.[122,791,794] Numerous studies have considered the cause of these turn-off periods, including falling sea level, resuspension of terrigenous material (from the erosion of rocks on land) and severe cyclones, all of which may explain a gap in the core data implying a hiatus in reef growth.[21,794,795] An analysis of sediment cores has established a new estimate for the duration of the last significant interglacial period of reef growth in the southern Reef: from at least 129,000 to a younger 121,000 years ago.[795] Reef and coral cores provide a reliable history of reef growth[796] and environmental information (such as water chemistry), which can extend back decades to centuries depending on the length of the core.[509] Coral cores from the Great Barrier Reef (and reefs globally) indicate that coral calcification rates have decreased in the last 25 years[797] as a result of extreme temperatures and coral bleaching.

The Reef's ability to regenerate and laterally extend seaward over millennia following periods of climatic and sea-level change is well documented.[21,795] However, processes that influence reef formation and maintain sediment accumulation on reef islands (for example, ocean acidification, sea temperature and sea-level rise) are intensifying in a negative way due to climate change[32,485,798], and pose the greatest threat to the Reef's contemporary geomorphology.[799,800] This intensification will change how reefs and low-lying islands grow and maintain their shape.[31] The ecological process of reef building has deteriorated since 2014 and is considered poor (Section 3.4.8). Due to these widespread threats to geomorphology, the Reef's resilience is decreasing and its size is becoming a less effective buffer for this world heritage criterion.

Overall, there has been alteration of some elements important to major stages of the Earth's evolutionary history, such as accretion, sea-level rise and sea temperature. This component has deteriorated since 2014.

4.2.4 Ecological and biological processes (criterion ix)

Ecological and biological processes form part of the Reef's outstanding universal value. The assessment of this criterion is considered against these processes being intact across the whole of the property. Processes are assessed on the system's ability to maintain its structure and function in the face of external pressures.

At a Region-wide scale, ecosystem processes have not ceased to operate. However, ecological and biological processes that are fundamental to a functioning ecosystem (for example, reef building, recruitment and symbiosis) are considered to be in poor condition (Chapter 3). This poor condition is partially dependent on the condition of other physical and chemical processes, like sediment exposure and nutrient cycling. Some ecological and biological processes remain in very good to good condition, such as primary production, microbial processes, and herbivory.

Reefs, islands, cays and the mainland remain connected by functioning ocean current systems and weather patterns. However, since 2014, the condition of one of the most critical physical processes, sea temperature, has deteriorated to very poor condition across a wide area as a result of climate change. This has led to substantial changes in some processes. The global significance of the Reef continues to be underpinned by the form and structure of its organisms, as well as the interconnectedness of the Reef's complex physical, chemical and ecological processes.[28] Overall, the condition of processes across the Region is variable, with deterioration in some areas. The potential implications on the Region's intactness is assessed in Section 4.2.6.

4.2.5 Habitats for conservation of biodiversity (criterion x)

Overall, habitats for conservation of biodiversity are deteriorating

The Reef's biodiversity, its vast network of habitats and range of species, is an important part of the Region's outstanding universal value. The assessment of the Reef's biodiversity under criterion (x) is considered as a value distributed throughout the whole of the property. While the Reef continues to be one of the most remarkable places on Earth, for the first time since Outlook Report assessments began in 2009, habitat loss and degradation has occurred in a number of areas, its condition overall is poor and biodiversity is being affected (Chapter 2). Key habitats, such as coral reefs and seagrass meadows, are considered to be in very poor and poor condition, respectively. More spatially extensive habitats, such as lagoon floor and the water column, are considered to be in good condition (with the latter borderline poor), although there is less confidence in these grades due to limited data.

The habitat and species condition grades reflect the increasing cumulative pressures the Region faces from a changing climate and other anthropogenic impacts. Multiple disturbances have transformed coral reef structures on a broad scale across the entire Region[95,97] and cumulatively hindered the recovery of some coral-dependent species (Sections 2.3.5 and 8.3.1). Historically, the Region's size has provided a buffer to periodic and dispersed damage, due to its broad latitudinal extent. Given the global scale of human-induced climate change, the size of the Region is becoming a less effective buffer to some broadscale impacts.

At the time of inscription in 1981, some 400 species of corals in 60 genera were known to occur in the Region.[28] It is now known the Region is home to more than 1200 species, including hard and soft corals.[203,204] World-leading management decisions are based on scientific exploration that continues to uncover and expand current knowledge of the Reef. For example, in 2014 a new species of mangrove (*Bruguiera hainesii*), never before recorded in Australia, was found in the Trinity Inlet, Cairns.[170] This species is listed as critically endangered on the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). The scalloped hammerhead shark (*Sphyrna lewini*) has recently been listed as a 'conservation dependent' species under Commonwealth legislation (Section 2.4.8).[294,801] In 2016, the northern Great Barrier Reef hawksbill turtle population (*Eretmochelys imbricata*) was reclassified under Queensland legislation from vulnerable to endangered (Section 2.4.10).[322]

Habitats for conservation of biodiversity are deteriorating, with observed loss and alteration of many elements necessary to maintain outstanding universal value. The potential implications on the Region's intactness is assessed in Section 4.2.6.

4.2.6 Integrity

Human-induced climate change is challenging the integrity of the World Heritage Area; its size is becoming a less effective buffer against broadscale impacts

Integrity is a measure of the wholeness and intactness of a place's natural heritage value[781], and is an important prerequisite for a property to be inscribed on the World Heritage List. UNESCO recognises that the Great Barrier Reef is not a pristine ecosystem[781] and exists in a dynamic state. Because the dynamic state involves interaction with people, management and domestic policies are an element of the integrity test. The current condition and trend of the biodiversity and ecosystem health of the Reef informs the integrity test.

The spatial extent of the World Heritage Area has remained generally unchanged since the time of inscription. The property's size, at least for some of its habitats, is becoming a less effective buffer against ongoing multiple Reef-wide disturbances (Appendix 4). The widespread loss of coral habitat, warming seas and intensifying external pressures from outside the Region are affecting the property's intactness.

The multi-tiered governance and management regime for the Reef aims to protect its biodiversity, ecosystem and heritage values through management tools, such as the *Great Barrier Reef Marine Park Zoning Plan 2003,* and enforcement. However, this multi-tiered management regime is not designed to directly address the effects of a changing climate. Climate change remains the greatest risk to the outstanding universal value of the World Heritage Area and its integrity. As such, managers are increasingly intervening where critical habitats or species require assistance. Some measureable benefits are being seen at a local scale, where timely actions were taken (Chapter 8). The effectiveness of the tools currently used to manage these pressures are independently assessed in Chapter 7. While the property remains whole and intact, the condition of many elements that make up the four world heritage criteria are deteriorating.

4.3 Current condition and trends — Indigenous heritage values

Four components of Indigenous heritage values are graded. The component 'cultural practices, observances, customs and lore' remains in good condition. The remaining three components continue to be poor. ↔

Full assessment summary: see Section 4.6.2

Indigenous heritage is living heritage because Traditional Owners continue to maintain a connection with their heritage. Indigenous heritage is all-encompassing and includes natural components, such as species and ecological processes. Many traditional cultural practices include plants, animals and places. In this way, the condition of natural components of the Region are inseparable from Indigenous cultural identity (Figure 4.3). Therefore, the natural heritage values assessed in Chapters 2 and 3 are fundamental to the condition of Indigenous heritage values and Traditional Owners' connection to land and sea country.

Indigenous heritage values are recognised nationally as a standalone heritage domain (Table 4.1). Information on Indigenous heritage values are presented under the following four discrete 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.

In reality, these components are interconnected and the description of each value should be viewed in this context.

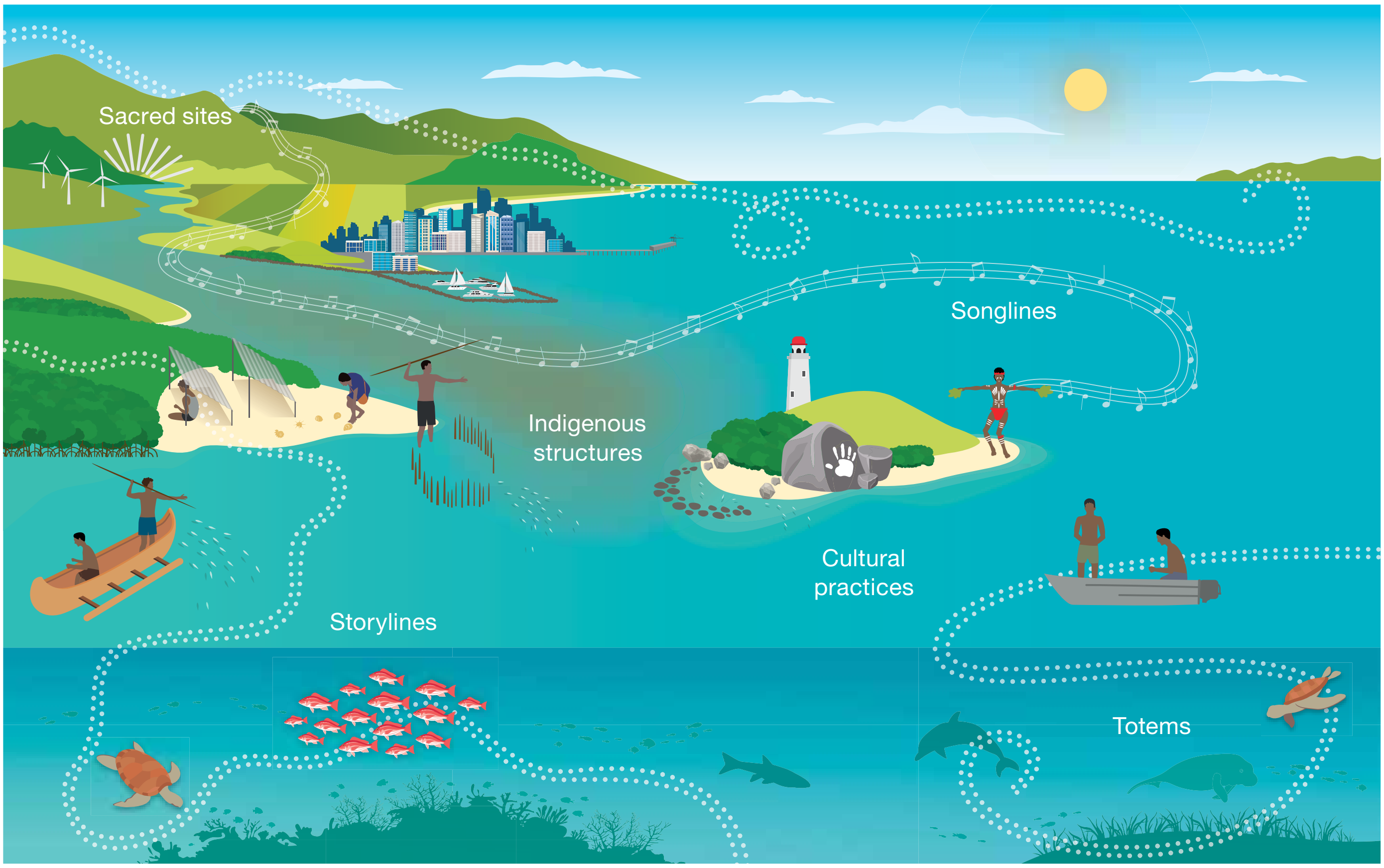


Figure 4.3 Nature is inseparable from Indigenous cultural identity
Songlines, stories, cultural practices, significant places, totems, structures and other elements of tangible and intangible Indigenous heritage weave people and the natural world together.

The Region is rich in Indigenous heritage. A survey of approximately 1900 people (tourism operators, tourists and commercial fishers) identified that people valued the Reef because of its rich traditional heritage[785]. People also value the Reef because it provides a place where people can continue to pass down wisdom, traditions and a way of life. Traditional Owners perceive heritage as everything in sea country, recognising that Indigenous heritage is biocultural (meaning heritage is dependent on biological resources, tradition and knowledge)[802] and includes the environment and intangible components.

In 2017, the Marine Park Authority undertook extensive consultation with Traditional Owners of the Reef to identify how Indigenous heritage can be better recognised, protected and managed.[803] The consultation led to several indicators that have been identified in the Marine Park Authority's 2019 *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park.*[803] The strategy aligns with the four Indigenous heritage components assessed in the Outlook Report. Traditional Owners also validated indicators for the Reef 2050 Integrated Monitoring and Reporting Program (RIMReP) targets and objectives under the Strong Peoples – Strong Country framework (Figure 4.4). Coastal development, climate change, and loss of Indigenous knowledge are considered the greatest threats to Indigenous heritage values (Chapter 9).

Figure 4.4 Strong Peoples – Strong Country
The Aboriginal and Torres Strait Islander Heritage Strategy[803] *supports the development of Indigenous heritage indicators and monitoring to assess the condition of Indigenous heritage values over time through the Reef 2050 Integrated Monitoring and Reporting Program (RIMReP). As part of this program, an Indigenous Heritage Expert Group identified six key hubs relevant to Strong Peoples – Strong Country: country health; people's health; heritage and knowledge; culture and community; education; and empowerment and economics.* Source: Artwork for Strong Peoples – Strong Country. © Luke Mallie, Mallie Designs (licensed for use by RIMReP partners).

4.3.1 Cultural practices, observances, customs and lore

Cultural practices, observances, customs and lore are aspects of Indigenous heritage values that are passed down from generation to generation. They can form an important aspect of day-to-day life, such as satisfying personal, domestic or communal needs, such as fishing and collecting. This component includes skills, folklore, rituals, religious beliefs and intellectual traditions. Approximately 20,000 years ago, the sea level around the Australian coast was around 120 metres lower than present.[804] Traditional lands would have extended out to the continental shelf; these areas are now underwater. The earliest direct date for traditional use of coastal resources in the Reef is approximately 6440 years ago, when sea level stabilised at close to its current position, with evidence of foraging for oysters and gastropods around the Whitsundays area.[805] The long established cultural practice of turtle and dugong hunting, dating back at least 5000 years ago[806,807], is linked to spiritual renewal[808], and while technology has evolved over time, the practice itself remains a critical part of cultural practice, observances, customs, and lore.[809]

> *Indigenous heritage is all-encompassing and includes natural (biodiversity) and other (aesthetics of a landscape) components*

While there have been advances in technology over time (for example, global positioning systems and cultural heritage databases), cultural practices, observances, customs and lore is largely intangible and can be difficult to record. Some Great Barrier Reef Traditional Owner groups manage databases and records of these values. One of the greatest threats to this type of Indigenous heritage is loss of Indigenous knowledge if Elders and knowledge keepers pass away and/or knowledge transfer does not occur. Other contributing threats include difficulties Traditional Owners face in exercising their cultural rights and responsibilities. For example, if access to an area important for cultural observance is blocked (by infrastructure) or reduced (through increased visitation by other users) it affects the ability for the transfer that knowledge to younger generations. There have been ongoing attempts to erode these rights through lobbying to ban turtle and dugong hunting[810], on animal cruelty grounds, and where the cultural practice occurs in the vicinity of tourism activities (for example, around Green Island).[811]

Traditional Owners at the entrance to Leekes Creek, Great Keppel Island — launched as a protected fish habitat area in 2017. © GBRMPA

Access to country is an important aspect of maintaining cultural practices, observances, customs and lore. In 2017, over 30 Woppaburra Traditional Owners from the Keppel Island group attended the launch of a culturally and ecologically important fish habitat area at Leekes Creek (*Balban Dara Guya*) on Great Keppel Island. The fish habitat area, declared under Queensland legislation, is the first to be declared on an off-shore continental island to have an Indigenous language name as its primary title.

4.3.2 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 values. The locations of sacred sites are not widely known outside Traditional Owner groups to respect cultural traditions and protect the sites. A public record of mapped Indigenous heritage archaeological studies (Figure 4.5) includes large areas of the Reef coastline for which there are few or no archaeological studies. This lack of knowledge is most pronounced between Princess Charlotte Bay and the tip of Cape York and south to Goold Island (excluding Lizard Island where several studies have been undertaken). In addition, only 16 of the approximately 900 islands in the Region have dated archaeological sites, contributing to a lack of understanding and recognition of these important areas in management frameworks, such as spatial planning and permitting. In addition to terrestrial and intertidal sacred sites, many sites lie submerged within the inner and mid-shelf reefs. These nearshore locations have been influenced by glacial and interglacial cycles on sea level. Sacred sites and sites of particular significance also contribute to intangible aspects of heritage and are closely linked to customary practices and songlines. It is unclear how the condition of tangible aspects (sacred sites and sites of particular significance) and intangible aspects (for example, songlines) have changed since 2014. However, it can inferred that in areas where the habitat has been modified (such as port expansions and island marina development), or areas significantly degraded by severe weather and climate change, impacts to this type of Indigenous heritage value would have occurred.

Several sites of Indigenous significance within the Keppel Island region are well documented

The Keppel Island region is one area that has been studied and well documented. This area has numerous published records of sacred sites, burial grounds, middens and sites of significance.[813] The site at Mazie Bay is the most archaeologically significant in the Keppel Island group, with numerous occupation sites dating from approximately 4200 years ago.[813] In 2017, the Woppaburra Traditional Owners worked with the Marine Park Authority to detail some sites of importance on their country and developed guidelines for consideration in the permitting and assessment processes.[814]

Scarred trees made by Aboriginal and Torres Strait Islander peoples through the removal of bark and some of the wood to make canoes, are important features of the Indigenous cultural landscape. Middens are also sites of importance to Aboriginal and Torres Strait Islander peoples and have archaeological significance. They are often material remains of historically important communal food preparation areas, burials and toolmaking areas. Middens are often located in intertidal areas, which makes them vulnerable to severe weather and human interaction.[815] Some records of damage to these material Indigenous heritage values are documented (for example, middens around Hinchinbrook Island and Cape Upstart south of Townsville, have been affected by cyclonic activity[816,817]), but managers generally lack knowledge of

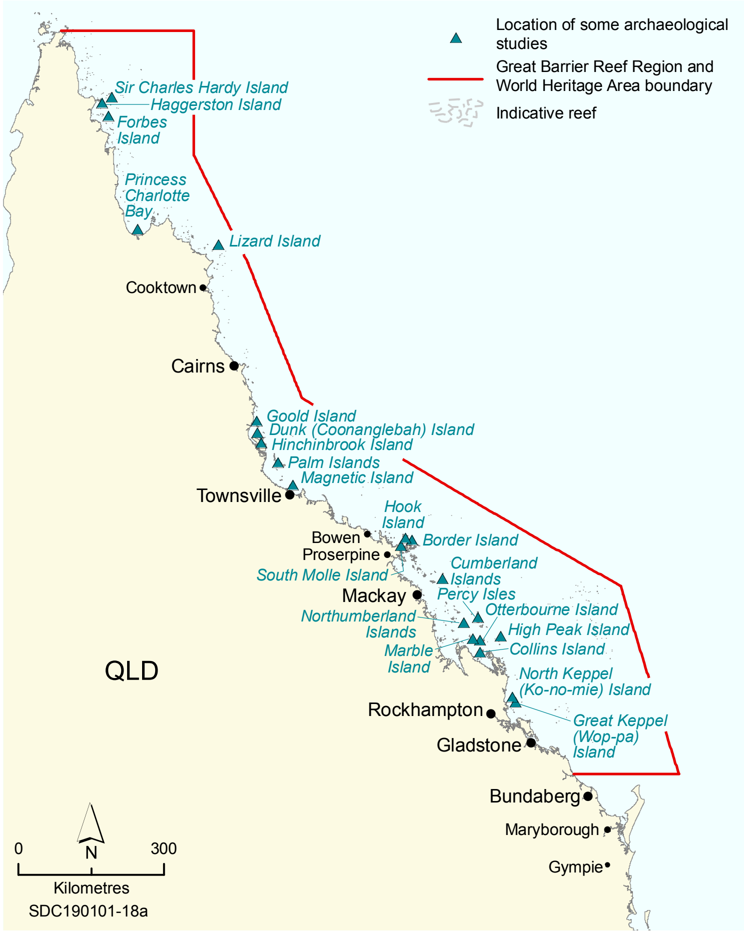


Figure 4.5 Indigenous heritage archaeological studies
Location of some archaeological studies and places of known Aboriginal and Torres Strait Islander activities within the Great Barrier Reef Marine Park.
Source: Adapted from Rowland *et al.* 2015[812]

their location and condition across the Region. Submersion of these artefacts can in some instances protect them from anchor damage and human interference (for example, removal of shells from a midden). Whereas, exposed or damaged sacred sites along the coast are likely to be more at risk from climate change and severe cyclones. Sacred sites and other important material and non-material Indigenous cultural places in the vicinity of areas of development or intensive use are more vulnerable to direct human pressure. Damage to sites, whether intentional, unintentional or by illegal activities, can result in the loss of irreplaceable material heritage and have other non-material implications (such as inability to undertake cultural practices). For example, fishing and collecting cultural practices are affected if fish trap rocks are moved and the trap is no longer functional. Other examples include cutting down or defacing scar trees.

4.3.3 Stories, songlines, totems and languages

Storytelling is embedded within Indigenous customs and cultural practices to encourage passing down of knowledge

Knowledge of the environment and the responsibility to maintain all living species, places or objects is passed down through generations in stories, songlines, totems and languages.[818] Stories also interact closely with customs and lore. Stories, songs, dance, dress, art and language are expressions of Traditional Owners' relationships with country, people, belief, knowledge, lore, language, symbols, ways of living, sea, land and objects — all arising from Indigenous spirituality.[819] Stories, songlines, totems and languages, and an understanding of their condition and trend, form part of the Indigenous knowledge held by Traditional Owners. Managing agencies, such as the Marine Park Authority, are working with Traditional Owners to ascertain whether they would like to share knowledge for reporting and management purposes.

Historical sea-level rise and changes to the entire northern fringe of the Australian continent around Cape York to Princess Charlotte Bay, is reflected within some stories and songlines, which have been recently recorded.[820] For example, many of the large offshore islands, such as Lizard Island and the Whitsunday islands further south, were part of the mainland until about 13,000 years ago, and this is reflected in the stories and histories told.[820]

For tens of thousands of years, Aboriginal and Torres Strait Islander peoples lived on land that is now the Reef.[805] Aboriginal stories recall the ability to walk across to Hinchinbrook Island and the Palm islands.[107] For example, Traditional Owners recall that, during the last glaciation, the coastline was the current outer barrier reef and a large river entered the Reef near Fitzroy Island (south of Cairns).[818] Oral histories from the Yidindji people recall a place "halfway between Fitzroy Island and King Beach that was called *mugada* ('pencil cedar') after the trees that grew there".[821] This area is now completely submerged, forming an inner coral reef habitat within the Region.

A totem is a natural object, plant or animal that is inherited by individual members of a clan or family as their spiritual emblem. Totems are an important part of Indigenous cultural identity and can be incorporated in song, dance, music and tools.[822] For the Woppaburra Traditional Owners of the Keppel Island group, the humpback whale (*mugga mugga*) is an important saltwater spiritual totem and forms a core part of their stories and traditional seasonal calendar (Figure 4.6); it cannot be hunted or harmed. The seasonal calendar demonstrates the Woppaburra people's connection to the land and sea — it depicts the tide and ocean movements and the coastal flora and marine species. In the colder months, when there are high tides and low winds (Figure 4.6, bottom left of the calendar), Woppaburra Traditional Owners know it is the time to forage for mud crabs on short days, and for mullet as they migrate from estuaries in early winter.[814] The condition of species (Chapter 2) informs an assessment of the condition of totems. Humpback whales are assessed to be in very good condition (Section 8.3.7), so that totem is also considered in very good condition. However, across the Region, managers (or western scientists) do not have a comprehensive understanding of which species are important totems to Traditional Owners. The inherent location-based importance of stories, songlines, totems and languages, which can span land and sea, means other uses and pressures on an area can break, damage or displace these values.

Figure 4.6 Woppaburra seasonal calendar showing important totems
© Dr Harry Van Issum, artwork by Glenn Barry 2016

4.3.4 Indigenous structures, technology, tools and archaeology

Indigenous structures, technology, tools and archaeology are tangible aspects of Indigenous heritage values. While some structures and sites are located within the Region, many are located on the adjacent coast and islands and are important to the Region's heritage significance. Indigenous structures include dwellings, middens, technology and tools used by Aboriginal and Torres Strait Islander peoples. Reef managers do not have a good understanding of the condition of Indigenous structures, technology, tools and archaeology.

Some heritage components have been documented (for example, on the Keppel Island group, Lizard Island and the Whitsunday islands), but little formal monitoring of their condition occurs. Gaining more knowledge of the location, condition and trend of these components will require working with Traditional Owner groups, such as through data-sharing arrangements, to access Indigenous knowledge. For this to occur, Traditional Owners may require support to access country, monitor sites and transmit knowledge. These values may be vulnerable to threats generated by coastal development in the Catchment and direct use activities within the Region.

The Region is a focus for coastal resource use by Aboriginal and Torres Strait Islander peoples. Over time, tools and technologies have been developed to support activities like shell fishing, crabbing, fin fishing and customary harvesting of turtles and dugongs. For example, handmade single-piece bark canoes were used along much of the Reef coastline.[823,824] The canoes enabled significant journeys (up to 50 kilometres from the mainland) in some locations, however it is unclear whether these voyages were uninterrupted journeys or whether people 'hopped' from island to island.[812] Lizard Island, a large granitic island north of Cairns, is the only location on the Reef known to contain a record of historic pottery development by Aboriginal people.[825] Analysis of pottery shards from the area indicate the pottery was made locally on the island using sand and granite.[825]

4.4 Current condition and trends — historic heritage values

Seven components for Commonwealth heritage values are graded. Processes continues to be very good. Rarity, research, characteristic value, aesthetic characteristics, technical achievement and Indigenous tradition remain in good condition. ↔

Full assessment summary: see Section 4.6.3

Five components are graded for historic heritage values – other. All components, except Commonwealth lightstations, continue to be poor. –

Full assessment summary: see Section 4.6.4

Historic heritage values relate to the occupation and use of the Region (including Commonwealth islands) since the arrival of European settlers and other migrants. By its nature, historic heritage will continue to evolve, representing the flow of history, changing community perceptions and contemporary attributes.[826] The assessment of the Region's historic heritage values does not include the heritage values on Queensland islands or parts of the Catchment (above low water mark). An exception is applied, however, where values are critical to transmitting (sharing) knowledge about the condition and trend of the Region's historic heritage value (for example, new shipwrecks in the intertidal zone).

4.4.1 Commonwealth heritage value

The Commonwealth Heritage List, created under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), is a list of natural, Indigenous and historic heritage properties or places owned or managed by the Australian Government. Five properties in the Region are on the Commonwealth Heritage List: Low Island and Low Islets lightstation; the lightstations on Dent Island, Lady Elliot Island and North Reef (Figure 4.7); and the Shoalwater Bay Military Training Area (Figure 4.10). No new places in the Region have been added to the Commonwealth Heritage List since 2014.

The condition and trend of Commonwealth heritage values are assessed in Section 4.6.3 against the EPBC Act criteria (processes, rarity, research, characteristic value, aesthetic characteristics, technical achievement, and Indigenous tradition). Not all places are included for all criteria; only the relevant places are assessed (and noted) against each criterion.

Management of the Commonwealth heritage places remains constant. Their management effectiveness is discussed in Chapter 7. A noteworthy management initiative since 2014 is the Marine Park Authority's adoption of the *Great Barrier Reef Marine Park Commonwealth Heritage Listed Places and Properties Heritage Strategy 2018–21*[827] in December 2017. The strategy fulfils a requirement under the EPBC Act and will be reviewed every three years.

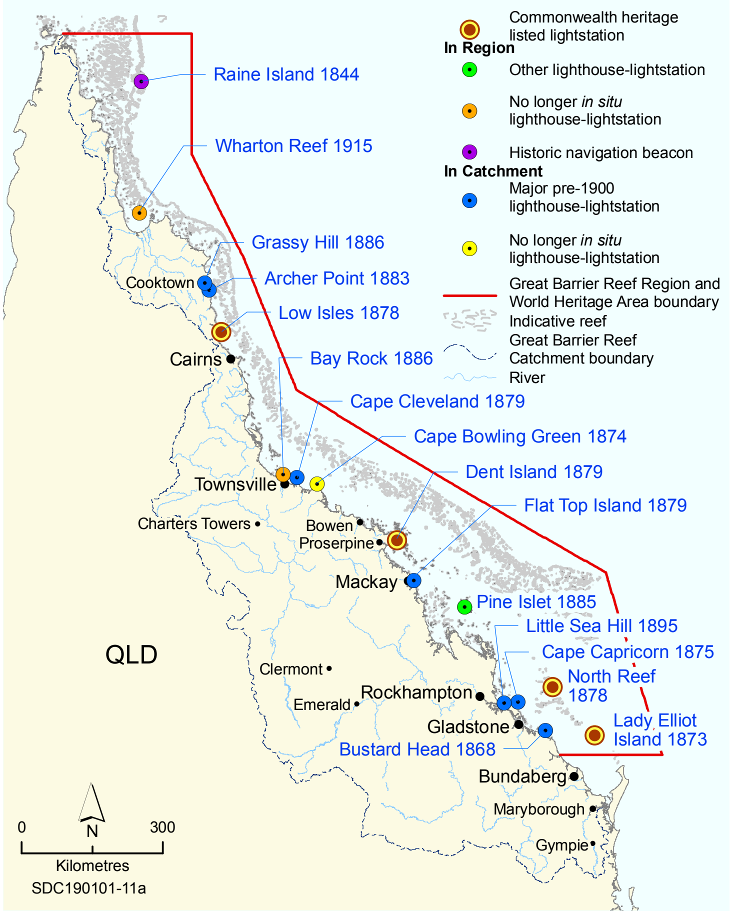


Figure 4.7 Historic lightstations and lighthouses in the World Heritage Area
The historic lightstations and lighthouses in the World Heritage Area demonstrate a phase in the evolution of maritime travel through the treacherous waters of the Great Barrier Reef. Few lighthouses remain in situ in the Region; many have been relocated to the mainland for preservation and display. Source: Adapted from Department of the Environment (Cth)[828] and Department of Environment and Science (Qld)[829]

Low Island and Low Islets lightstation The lighthouse was first lit in 1878 and was the first lighthouse in the northern part of the Reef (Figure 4.7).[828] The lightstation is situated on Low Island, about 15 kilometres north-east of Port Douglas. Low Island is included on the Commonwealth Heritage List because of its significance to the Kuku Yalanji and Yirrganydji Traditional Owner groups as part of their Dreamings. No new evidence is available regarding the condition of the island's Indigenous heritage values. The current condition and trend of the lightstation has been monitored by managers through an annual monitoring and maintenance program. In late 2014, an asbestos audit of the lightstation structures was completed and a maintenance overcoating of the lighthouse structure was undertaken in 2018.[830] The display at the Low Islets lightstation museum was upgraded in 2017.

The lightstation is situated just above sea level on a small unprotected cay (Figure 4.8), and is susceptible to sea-level rise. Given its location, more frequent intense storms predicted under climate change scenarios, could affect the historic and Indigenous heritage value of the place. The place was included on the Commonwealth Heritage List in 2008 against the process (importance in the course, or pattern, of Australia's cultural history) and Indigenous tradition criteria.[828] Despite ongoing management and maintenance of this site, published long-term condition data on these criteria are limited.

Dent Island lightstation The lightstation is located four kilometres south-west of Hamilton Island in the Whitsundays. The lightstation was included as a Commonwealth heritage place in 2004.[831] The property's listed values include processes and characteristic attributes. Extreme weather events are the main threat to the Dent Island lightstation, which is situated on the leeward side of the island on an elevated rocky outcrop. Exposure to the marine elements also makes the structures more vulnerable to corrosion, a problem that requires ongoing management. The physical condition of the property has been improved since it was outlined in the 2013 Dent Island Lightstation Heritage Management Plan.[831] In 2013–14, a maintenance overcoating of the lighthouse structure was undertaken[830] and the winch house and derrick crane were significantly refurbished as part of the maintenance program. An asbestos audit undertaken for the structures on the island in late 2014 concluded the buildings and structures were generally in good condition. Managers are confident the condition and trend of this place's historic heritage value remain good and improving, however published data are limited.

Lady Elliot Island lightstation was included as a Commonwealth heritage place in 2004.[832,833] Of the five Commonwealth heritage places in the Region, the Lady Elliot Island lightstation is recognised for the greatest number of attributes: processes, rarity, characteristic, aesthetic characteristic and technical achievement. The place's architectural and structural elements (such as the cast iron external cladding) are significant, and the use of timber

Figure 4.8 Low Islets lighthouse, Low Island, 2015
© GBRMPA 2015

Figure 4.9 North Reef lighthouse
© Australian Maritime Safety Authority 2014

framing for the staircase is a rare example of this construction method. The property was outlined in 2012 as being generally in a good and stable condition, having been well built and generally well maintained.[833] The lightstation is located 75 kilometres north-east of Bundaberg. Its location on a remote low-lying vegetated cay makes it susceptible to impacts from sea-level rise and extreme weather events. Structural corrosion is the main threat given the place's exposed location. Managers are confident this historic property has maintained good condition since 2014 given the maintenance and management actions that have preserved it.[832] An asbestos audit was undertaken on the lightstation structures in June 2015. However, updated published condition data are limited.

North Reef lightstation The lighthouse was built in 1878 and is located on North Reef, about 77 kilometres north-east of Curtis Island off Gladstone (Figure 4.7). It is recognised for its rarity as one of the few lighthouses built on a coral reef (Figure 4.9).[834] The lightstation is located on a small unprotected cay and is susceptible to sea-level rise and any increase in frequency and intensity of cyclones. Exposure to the marine environment makes the structures vulnerable to corrosion. The property was included on the Commonwealth Heritage List in 2004. The lighthouse was fully refurbished in 2011. Failed protective coating systems were removed from the internal and external surfaces and the structure was completely repainted.[830] Its listed attributes (processes, rarity and technical achievement) have been well maintained and continue to be protected, although up-to-date published evidence is limited.

Commonwealth heritage places are well maintained

Shoalwater Bay Military Training Area was included as a Commonwealth heritage place in 2004 under several criteria (rarity and technical achievement).[828] The Commonwealth heritage place reflects the boundaries and values of the Shoalwater and Corio Bays Area Ramsar wetland and the military training area owned by the Department of Defence (Figure 4.10). The place spans marine and terrestrial ecosystems, and is partly within the Region. Shoalwater Bay is an important habitat for several listed vulnerable species forming part of the place's rare attributes: dugongs, humpback whales, and green, hawksbill and loggerhead marine turtles. The condition of these species are varied. Population of dugongs are improved (Section 2.4.16) and concerns are mounting for the future of the marine turtles (Section 2.4.10). Humpback whales are considered in very good condition (Section 8.3.7). The place also satisfies the processes criterion, being a nationally significant place for geomorphological, ecological and biological processes in the marine hinterland interface. The Shoalwater Bay Military Training Area Commonwealth heritage place will, therefore, be affected by drivers and pressures, such as climate change and anthropogenic threats. The current condition is generally monitored as part of the ongoing management of the Defence estate. Also, condition reports are prepared for the Talisman Sabre military exercises that occur in the area every two years (Section 5.3).

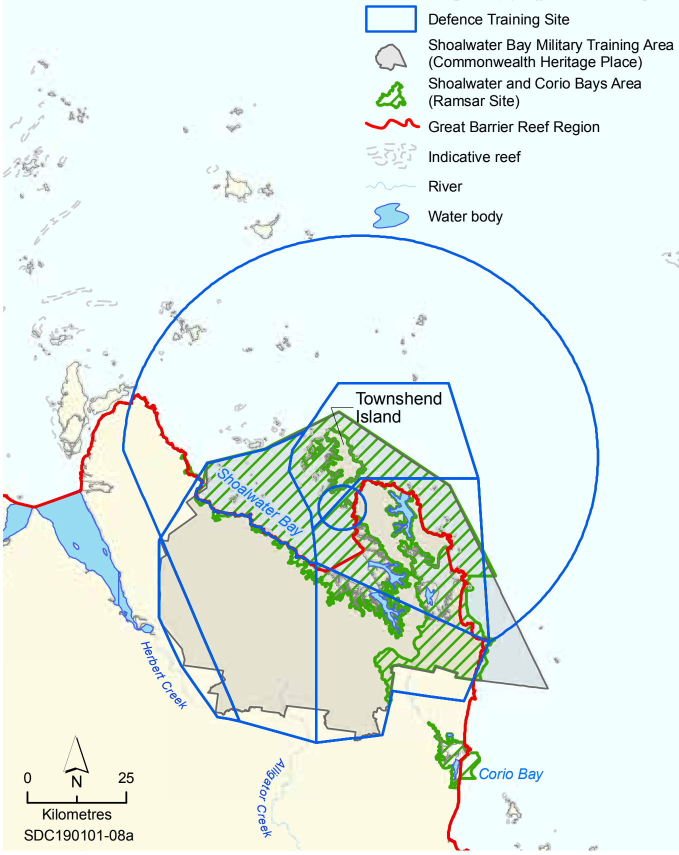


Figure 4.10 Shoalwater Bay Military Training Area Commonwealth heritage place
The Commonwealth heritage place reflects the boundaries and values of the Shoalwater and Corio Bays Area Ramsar wetland and the military training area owned by the Department of Defence.

4.4.2 Other historic lightstations and lighthouses

In 2014, this component was assessed together with the Commonwealth and Queensland historic heritage values. Commonwealth heritage lightstations are now assessed separately (Section 4.4.1) to remove duplication. Pine Islet lightstation is the only other known historic lightstation in the Region (that is, located on a Commonwealth island, reef or cay). Pine Islet lightstation, south-east of Mackay (Figure 4.7), is dilapidated and contains asbestos material. The lighthouse was automated in 1985 and relocated to the Port of Mackay in 1995. Pine Islet lightstation is an example of historic heritage being lost through modernisation and automation. Its current condition is a data gap.

Regardless of whether historic lightstations remain *in situ*, are working or have been automated, the place where they once stood holds historic heritage value to the Region. In most cases, even if the location of the historic feature is known, baseline data on the condition of their historic heritage value have not been systematically identified.

Lighthouses and aids to navigation (both historic and modern replacements) are scattered throughout the World Heritage Area (that is, including Queensland islands). Lightstations and lighthouses outside the Region are well recorded, and many are on the Queensland Heritage List (Figure 4.7). Condition reporting on the historic significance of aids to navigation in the Region is a data gap.

4.4.3 Historic voyages and shipwrecks

Shipwrecks are protected for their historic heritage value and maintained for their recreational, scientific and educational attributes. Protected zones can be declared up to two square kilometres around a relic. Protected zones have been declared for six historic shipwrecks in the Region: SS *Yongala*, HMS *Pandora*, SS *Gothenburg*, SS *Llewellyn*, HMCS *Mermaid*, and the *Foam*. These wrecks are assumed to be in good condition but, because they are in a dynamic marine environment, are assumed to be declining at different rates depending on their location.

Managers have inspected around 10 shipwrecks in high-priority sections of the Region

Since 2014, managers have undertaken several maritime cultural heritage surveys in high-priority sections of the Reef, inspecting around 10 shipwrecks (for example, Box 5). Data from this work, often unpublished, have been added to the Australian National Shipwreck Database to inform management activities and decisions. Noteworthy activities in this period include expeditions in 2015 to the *Foam* on Myrmidon Reef (Section 8.5.3)[835] and the *Valetta* in the Whitsundays in 2016. Archival research on the shipwrecks around Magnetic Island in 2016 resulted in a display in the Magnetic Island museum and extensive additional information for the national database. Information on physical location, monitoring of current condition and gathering of new evidence for the majority of shipwrecks remain poor, but are improving.

Historic shipwrecks and their associated relics older than 75 years, or those declared to be historic, are protected regardless of whether their exact location is known. In mid-2019, the *Underwater Cultural Heritage Act 2018* (Cth) will replace the *Historic Shipwrecks Act 1976* (Cth) to protect underwater cultural heritage more broadly. The enactment of this legislation will extend protections currently afforded to historic shipwrecks to aircraft wrecks and other forms of underwater cultural heritage in Commonwealth waters. The effectiveness of these and other management tools is assessed in Chapter 7.

New laws will protect a broader range of underwater heritage values, including shipwrecks and other forms of cultural heritage

BOX 5

Locating our lost maritime heritage — *Martha Ridgway*

In late 2018, management agencies discovered the *Martha Ridgway* shipwreck[836], which was lost over 170 years ago on a voyage from New Zealand to Bombay (now Mumbai). Martha Ridgway Reef was named after the wreck many years ago, yet the precise location of the wreck had never been established. This reef forms part of Wreck Bay near Raine Island in the far northern part of the Region. The *Martha Ridgway* shipwreck was found on the reef of the same name using a variety of survey methods and remote sensing equipment, including aerial survey (drone), magnetometer survey and visual census. The wreck is significant for many reasons, including its size and its association with the historic Raine Island beacon. In 1844, parts of the wreck were used to build the tower, which is now the oldest European structure north of Brisbane.

Aerial view of the location of the Martha Ridgway shipwreck (the group of underwater shapes below the boat in the middle of the image).
© GBRMPA 2018

4.4.4 World War II features and sites

In 2015, two Catalina aircraft wrecks were protected through special management areas

World War II features and sites in the Region include aircraft wrecks (underwater, on Commonwealth islands or in intertidal areas), as well as forts and structures on Commonwealth islands. Aircraft wrecks are the dominant World War II features in the Region and are listed in the Australian National Shipwreck Database.[836] Limited records exist on condition or trend for these historic features, partly because none of them have the status of being a Commonwealth heritage place, so lack a structured monitoring plan. Wrecks and other underwater features are susceptible to damage from severe weather events through physical movement and abrasion from wave action containing suspended sediments. The abrasive action often removes the protective marine growth, exposing the fabric of the site to corrosion and frequently uncovering fragile artefacts.[837] Most World War II features and sites are on the mainland or on Queensland islands outside the Region. However, limited progress has been made in systematically recording the majority of other relics. On a Reef-wide scale up-to-date information on condition is generally unpublished, even though five inspections of World War II features and sites have been undertaken since 2014.

Catalina A24-25 wreck located off the Frankland islands, 2013.
© Kevin Coombs

The Marine Park regulations were amended in 2015 to protect underwater maritime cultural heritage through special management areas. In 2013, the wreck of a Catalina PBY 5 flying boat (A24-24) was found off Bowen. In the same year, a second Catalina A24-25 wreck was located off the Frankland islands about 50 kilometres south-east of Cairns. Special management areas, each one kilometre square, are now in place around these wrecks. In 2013, underwater historic aircraft and associated relics located in Commonwealth waters outside a special management area, had no specific legislative protection. In mid-2019, the new *Underwater Cultural Heritage Act 2018* (Cth) will include mechanisms to provide protection to any aircraft or aircraft relic discovered in the Region that is over 75 years old or declared to be historic. The management effectiveness of historic heritage, which includes underwater historic aircraft wrecks and relics, is addressed in Chapter 7.

4.4.5 Other places of historic significance

Other places of historic significance in the Region include tangible components, such as structures, ruins or wrecks. There are also intangible components, such as sites where the mistreatment of Indigenous peoples occurred, (for example, drowning caves in the Keppel islands[814]), sites of early explorations, and places with strong science exploration history, such as Low Isles and Lizard Island.

New evidence is improving understanding about human occupation in the Region before European settlement by people not of Aboriginal or Torres Strait Islander heritage. For example, early Polynesian and south-east Asian artefacts found in the Region provide an added dimension to the historic significance of the Great Barrier Reef.[838] Reef names and the associated stories honouring prominent people connected to the Reef also provide an important record of the people's historic significance. For example, in 2014 a reef was named in honour of the late Dr Bob Endean (1925–1997), a leading marine biologist and ecotoxicologist during the 1960s environmental movement.[839] Bob Endean Reef is located approximately 65 kilometres east of Mission Beach, an area where Dr Endean undertook significant field research. Five other reefs have been named after prominent scientists since 2014. Most intangible components of historic significance in the Region are either not recorded, or their records have not been recovered or have been lost. Published evidence about intangible historic heritage values remains a significant information gap.

Carter Reef research platform (offshore Lizard Island), where researchers would stay overnight, was demolished in the early 1990s.
© Australian Museum

4.5 Current condition and trends — other heritage values

Three components are graded for other heritage values. Social, aesthetic and scientific heritage values continue to be in good condition

–

Full assessment summary: see Section 4.6.5

Heritage values include ‘a place’s natural and cultural environment having aesthetic, historic, scientific or social significance, or other significance, for current and future generations of Australians’.[294,840] Therefore, as well as a component being a natural, Indigenous or historic heritage value, a place may also have ‘other’ heritage value — social, aesthetic or scientific attributes (Figure 4.11).

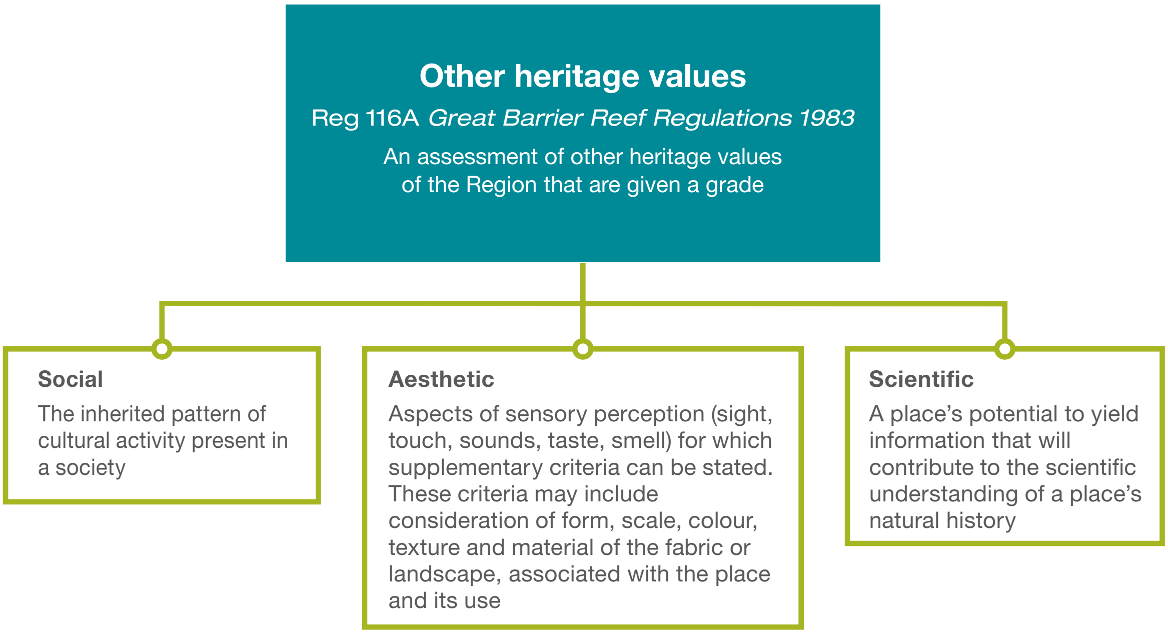


Figure 4.11 Other heritage values
The Outlook Report assesses ‘other heritage values’ in addition to the components outlined in the Marine Park regulations. Some overlap occurs between this assessment and the heritage matrix in Figure 4.1. Source: Commonwealth of Australia[840,841] and Pocock *et al.* 2002[842]

4.5.1 Social heritage values

Social heritage values involve inherited patterns of activities embedded in society by the way communities access, use or think about the Reef. The Reef is considered Australia’s most inspiring landmark by the general Australian population.[785,843] The Reef remains, nationally, the most socially significant natural environment.[844] This section describes and assesses the range of social heritage values of the Region. The inherent social significance of the Region for Traditional Owners is discussed in Section 4.3.

Human dimensions of the Reef have been monitored on a large scale since 2013. Up to the end of 2017, more than 12,000 people had contributed to this monitoring, representing communities of the Catchment, domestic and international tourists, Reef-dependent industries, and the broader Australian population.[785] How society thinks and feels about the state of the Reef is at the heart of the Region‘s social heritage value.

For Australians, the Great Barrier Reef remains the most socially significant natural environment

Of the Australian residents surveyed in 2017 (about 1000), 85 per cent were proud of the Reef and felt a sense of responsibility to protect it.[785,845] They were less optimistic about the Reef’s future (54 per cent, down from 56 per cent in 2013). The relationship that Australian residents have with the Reef remains positive overall, with around 85 per cent believing that the beauty of the Reef is outstanding and is an asset for the Australian economy. Many Australian residents (73 per cent) felt the Reef is part of their Australian identity. Climate change, pollution and agricultural run-off were considered by Australian residents to be the biggest threats to the Reef.

About 1900 local residents of coastal towns in the Reef Catchment participated in the 2017 survey.[785] Of those surveyed, over 80 per cent felt that the Reef contributes to their quality of life and wellbeing, and nearly 90 per cent felt it supported a desirable and active way of life. The vast majority thought the Reef is an economic asset (96 per cent); supports a variety of fish and corals (about 96 per cent respectively) and enables environmental appreciation through scientific discoveries (nearly 90 per cent).[785] The strong cultural and economic connection to the Reef among local residents is evidenced by the Reef supporting thousands of jobs in the tourism, fishing and research industries, both directly and indirectly (Section 5.1).[846]

The Reef attracts tourists from all over the world. Tourism on the Reef occurs because of, and contributes to, the Reef's ongoing social significance, which is part of its outstanding universal value. In 2017, about 1800 domestic and international tourists participated in a survey; most felt strong stewardship for the Reef and the environment. The majority of tourists (83 per cent) indicated they "would like to do more to help protect the Great Barrier Reef", and 81 per cent felt a sense of personal responsibility to protect the Reef.[785.] Ratings for different values associated with the Reef (including its biodiversity, scientific heritage, lifestyle and international icon values) were higher in 2017 than those reported in 2013. However, tourists' ratings of optimism for the Reef's future fell significantly.[847] Climate change, pollution and tourism were perceived as the three most serious threats to the Reef by tourists. Among international tourists surveyed in 2017, 78 per cent indicated belief that "climate change is an immediate threat requiring action". Among domestic tourists, this proportion was 67 per cent.

Other heritage values of the Region have social significance to the community. For example, the shipwreck SS *Gothenburg* located near Cape Upstart, near Townsville, has connection with three Australian communities, including Darwin, Adelaide and Queensland. Of the 125 people on board, 106 drowned, including all women and children.[848] However, contemporary evidence about the condition of the social significance of most heritage values, is lacking. Enquiries into the human dimensions of the Reef have notably extended knowledge of some social elements since 2014.

4.5.2 Aesthetic heritage values

The Reef is still strongly associated with beauty, but it is also perceived as being in danger and under threat.[844] Enquiries into the human dimensions of the Reef continue to uncover the extent and nature of peoples' relationships with the Reef, the Reef attributes they value[783] and trigger points at which people feel change and/or damage to the Region is too great.[785,849]

Spectacular scenery and seascapes contribute to the aesthetic appeal of the Region

In 2017, about 1900 local residents were surveyed. The relationship between how proud people are of the Reef as a World Heritage Area (Section 4.5.1) and the importance they place on the spectacular aesthetic beauty of the Reef was evident in the majority of those surveyed (95 per cent).[783,785] As an indicator, the value people place on the aesthetic beauty of a location may be a reason people are motivated to take care of natural places.[783] A linked analysis in 2019 explored the community's level of ecological grief and emotional response to disturbances like coral bleaching.[850,851,852] The results suggested around half of all residents, tourists and tourism operators, and around a quarter of fishers felt a strong sense of grief related to Reef disturbances caused by mass coral bleaching in 2016 and 2017.

The aesthetic heritage values of the Region cover land and sea — seascapes (fish, coral structure), island vistas and coastal landscapes. While new information is available on community perceptions such as "a coral reef without fish is like a playground without the laughter"[783], evidence on the current condition of the tangible elements of aesthetic heritage values is lacking.

Island vistas have legacy impacts from, and continue to be modified by, coastal and island development. Additionally, numerous severe weather events since 2014 have damaged these land-based backdrops. Few contemporary studies have considered island vistas and other elements of the Reef's aesthetic heritage value, making it difficult to determine their current condition.

The emerging social-ecological field continues to expand methodologies to improve techniques in monitoring aesthetic heritage values, using potential indicators[783] and computations[853] of aesthetic value. However, ongoing examination of which locations or biophysical elements are the most important to the Reef's spectacular seascapes and scenery, remains an information gap. Evidence about the condition of the aesthetic heritage values of the Region is inferred from the condition of the Reef's natural heritage values assessed in Chapters 2 and 3.

4.5.3 Scientific heritage values

Scientific heritage value is not well-defined. However, in general terms it is a place's potential to yield information that will contribute to the scientific understanding of the place's natural history.[841] When coupled with the meaning of 'heritage' — being 'our legacy from the past, what we live with today, and what we pass on to future generations'[854] — the scientific heritage value of the Reef encompasses human knowledge of the land and sea.

Scientific discoveries are critical to understanding and preservation of a place's natural and cultural history

The history of the current Great Barrier Reef dates back at least 450,000 years. Human knowledge of the land and sea pre-dates European occupation. Through the Reef's Traditional Owner history, knowledge is preserved in stories and songlines that have been passed down through generations. The Reef's modern scientific legacy (post-European arrival) began with early European voyages to a great south land, such as the expedition of Endeavour in 1770 with British botanist Joseph Banks. Many centuries later, the first contemporary detailed scientific study of the Reef occurred at Low Isles in 1928–1929.[855] In the 21st century, the marine science research and management community provides a measure of Australia's focus on transmitting the scientific heritage value of the Region to future generations. The Reef's prominence through long-term studies and scientific literature is strong. Between 2014 and early 2019, around 2000 scientific journal articles about coral and social values in the Great Barrier Reef were published, and citations of these number in the tens of thousands.[856]

A 2017 survey quantified society's perception of the importance of the Reef's scientific heritage value.[785] Tourists and local residents said they valued the Reef because they can learn about the environment through scientific discoveries (90 and 89 per cent, respectively). Those surveyed placed a strong emphasis on the aesthetic beauty of the Reef (Section 4.5.2), which is intertwined with the need for ongoing scientific evidence about the Reef. People's desire to preserve and understand the Reef and its spectacular scenery continues to inspire scientific exploration. As a result, the condition of the Reef's scientific heritage value continues to improve.

4.6 Assessment summary — Heritage values

Paragraph 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.

The assessment of the Reef's heritage values has been considered against their inherent components and attributes, namely:

- natural heritage values – world heritage value and national heritage value
- Indigenous heritage values
- historic heritage values – Commonwealth heritage values and other historic heritage values
- other heritage values.

Since 2014, the assessment of historic lightstations has been refined. The Commonwealth heritage places were, and continue to be, assessed under the Commonwealth heritage values (Section 4.6.3). Other historic lightstations are assessed separately in Section 4.6.4.

4.6.1 Natural heritage values — world heritage value and national heritage value

The assessment statements for Section 4.6.1 regarding natural heritage values are standalone and relevant to the assessment of the world heritage and national heritage values only.

Grading statements — natural heritage values				
🟩 **Very good** 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.	🟩 **Good** 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.	🟧 **Poor** 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 outstanding universal value.	🟥 **Very poor** Loss or alteration of most elements necessary to maintain the outstanding universal value has occurred, causing a major loss of outstanding universal value.	☐☐ **Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report	
↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟩	🟩↓🟧			**Natural heritage values – world heritage value and national heritage value** The Reef's world heritage and national heritage value represents the outstanding universal value of the Region. Outstanding universal value remains, however, the grade is borderline with poor because the condition of the property has deteriorated to varying extents with respect to criteria vii, viii, ix and x. While the property remains whole and intact, ecosystem resilience is deteriorating and the property's size is becoming less effective as a buffer against these disturbances.
	🟩	🟩↓🟧	◐	◐	**Natural beauty and natural phenomena:** At a broad scale, the Region retains much of its spectacular scenery. However, its natural beauty is being affected in some areas (for example, by poor inshore water quality). Components of natural phenomena, such as turtle breeding, whale migration and coral spawning, continue but these elements (criterion vii) are being increasingly challenged by climate change, resulting in the condition being good borderline poor. Much of the evidence is inferred from the assessments in Chapters 2 and 3.
	🟦	🟩↓	◐	◐	**Major stages of the Earth's evolutionary history:** The Reef's ability to regenerate and grow over millennia following periods of climatic and sea-level change is well documented. However, new evidence has identified that some alteration to processes that influence reef formation, and maintain sediment accumulation on reefs and islands has occurred. This alteration is intensifying in a negative way due to climate change (criterion viii).
	🟩	🟩↓🟧	◐	◐	**Ecological and biological processes:** Overall, some ecological and biological processes (criterion ix) remain in good condition. However, many ecological processes have deteriorated since 2014 due to the combined effects of climate change and inshore land-based run-off. As a result, the condition is considered good borderline poor.
	🟩	🟧↓	◐	◐	**Habitats for conservation of biodiversity:** The property contains a diverse range of habitats (criterion x), many of which are under pressure. Overall, significant habitat reduction and alteration in a number of areas has led to persistent and substantial effects on populations of some dependent species.
	🟩	🟩↓🟧	◐	◐	**Integrity:** While the property remains whole and intact, its integrity is deteriorating. An altered disturbance regime due to climate change has impaired the resilience of the ecosystem resulting in the condition being good borderline poor. The property's size is becoming less effective as a buffer against Reef-wide disturbances.
	🟩				**Natural heritage values:** This component has been absorbed into the assessment of the processes and habitats criteria.

4.6.2 Indigenous heritage values

A series of statements apply to Indigenous, historic and other heritage values, standardising the allocation of grades for all components and attributes examined in the assessment, as well as the grade for the criterion.

Grading statements — Indigenous, historic and other heritage values

🟦 **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.

☐☐ **Borderline**
Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟥	🟥 ↔			**Indigenous heritage values:** Aboriginal and Torres Strait Islander peoples are increasingly reasserting their role in sea country management and protection of Indigenous heritage. The condition and trend of Indigenous heritage values are tied closely to the condition of natural heritage values. The condition of many values remains limited.
	🟩	🟩 ↔	○	○	**Cultural practices, observances, customs and lore:** Loss of Indigenous knowledge is a threat to this component. It is assumed that knowledge transfer is being maintained across the Region, supported by the expansion in land and sea management and cultural activities.
	🟥	🟥 ↔	○	○	**Sacred sites, sites of particular significance and places important for cultural tradition:** The locations of sacred sites are not widely known outside Traditional Owner groups, but the Keppel island region is well documented. Only a very small portion of the Region has dated archaeological sites, contributing to a lack of understanding and recognition of these important areas in management frameworks.
	🟥	🟥 ↔	○	○	**Stories, songlines, totems and languages:** The location-based importance of this component, which can span land and sea, means other uses and pressures can break, damage or displace these values. This value is reliant on healthy populations of totemic species, some of which are in poor condition. The condition of this component is not well understood by managers and is inferred to be poor.
	🟥	🟥 ↔	○	○	**Indigenous structures, technology, tools and archaeology:** The location-based importance of this component, which can span land and sea, means other uses and pressures can break, damage or displace these values. Some heritage components have been documented on and around islands, but limited monitoring of their condition occurs.

4.6.3 Historic heritage values — Commonwealth heritage values

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟩	🟩 ↔			**Commonwealth heritage values:** The five places in the Region included on the Commonwealth Heritage List retain the values for which they were listed. The condition and trend of most places are based on limited published evidence. However, the inference from managers is the properties retain their integrity and are in good condition.
	🟩	🟩 ↑	●	◐	**Processes:** The five Commonwealth heritage places in the Region remain *in situ*. While published condition data are limited, managers are more confident than in 2014 that the heritage values are well maintained and retain a high degree of integrity. For this reason, the grade has improved.
	🟩	🟩 ↔	◐	◐	**Rarity:** The rare architectural features and location of the Lady Elliot Island and North Reef lightstations are maintained. The Shoalwater Bay Military Training Area continues to support threatened species listed as rare attributes, even though some species are deteriorating.
	🟩	🟩 ↔	◐	◐	**Research:** Research and monitoring of the natural environment continues to expand scientific knowledge about the Shoalwater Bay Military Training Area. Condition data are well documented.
	🟩	🟩 ↔	◐	◐	**Characteristic value:** The Dent Island and Lady Elliot Island lightstations are in good condition as a result of ongoing management. Condition data are not systematically published, however, maintenance programs are recorded.
	🟩	🟩 ↔	◐	◐	**Aesthetic characteristics:** The aesthetic characteristics of the Lady Elliot Island lightstation remains in good condition following ongoing maintenance and management. Condition and trend data are not published.
	🟩	🟩 ↔	◐	◐	**Technical achievement:** The technical attributes of the Shoalwater Bay Military Training Area, and the Lady Elliot Island and North Reef lightstations have not been modified. Condition data are not systematically published.
	🟩	🟩 ↔	◐	○	**Indigenous tradition:** Low Island retains its importance as part of the sea country of the Kuku Yalanji and Yirrganydji Traditional Owner groups. No new published data are available on Indigenous traditions, and so the trend since 2014 is inferred to be stable.

4.6.4 Historic heritage values — other

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟩	🟥 –			**Historic heritage values:** Many historic heritage components have not been systematically identified, resulting in an inferred stable trend for several components. Further investigation since 2014 has uncovered a lack of evidence on condition and trend across most components, and the grade has been updated to reflect this.
	🟩	🟩 ↔	◐	◐	**Commonwealth lightstations:** The values of the four lightstations in the Region included on the Commonwealth Heritage List have been retained and are in good condition.
		🟥	◐		**Other historic lightstations and lighthouses:** The former Pine Islet lightstation is the only lightstation attribute located in the Region that is not identified on the Commonwealth Heritage List. The site is derelict; the lighthouse was relocated in 1995. Condition reporting on aids to navigation is data deficient.
	🟥	🟥 ↔	◐	○	**Historic voyages and shipwrecks:** The six historic shipwrecks in the Region are well recorded and in good but naturally declining condition. However, limited progress has been made on systematically recording the majority of other relics.
	🟥	🟥 ↔	◐	○	**World War II features and sites:** Many of these relics have not been systematically identified. Since 2014, two Catalina aircraft wrecks have been protected by special management areas. Site expeditions in this period provide some baseline, condition and trend data.
	🟥	🟥 ↔	○	○	**Other places of historic significance:** Little change has occurred for this component. Broad historic heritage values have not been systematically identified. Condition is not well understood.

4.6.5 Other heritage values

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟩	🟩 –			**Other heritage values:** The Region's scientific heritage value is escalating. The Australian people's concern about the declining condition of the Reef is an emerging observation, as their connection to its environment and natural beauty continues to be strong.
	🟩	🟩 ↔	●	◐	**Social heritage values:** The inherited pattern of cultural activity present in the communities that value the Reef is embedded in the way they access, use or think about the Reef. New studies show the socio-economic worth of the Region supports strong social heritage values.
	🟩	🟩 ↓	◐	○	**Aesthetic heritage values:** Aesthetic beauty is closely aligned to the condition of the ecosystem. Strong evidence has established that several disturbances have damaged parts of the Reef's naturalness. Widespread and localised impacts are also inferred to have diminished some of the Region's aesthetic heritage values.
	🟩	🟩 ↑	●	●	**Scientific heritage values:** The long history of Traditional Owners living on, and researchers studying, the Reef is significant. The Reef's prominence in long-term scientific studies continues to increase.

4.7 Overall summary of heritage values

The Great Barrier Reef's heritage values are assessed against natural (world heritage and national heritage), Indigenous, historic (Commonwealth and other) and other heritage (social, aesthetic and scientific) values.

The Great Barrier Reef remains whole and intact and maintains many of the elements that make up its outstanding universal value, as recognised in its world heritage listing. However, significant components that underpin all four natural world heritage criteria for which the World Heritage Area was inscribed in 1981 have deteriorated since its inscription. One criterion — habitats for the conservation of biodiversity — is assessed as poor, which aligns with the assessment findings in Chapter 2. Given that the impacts from climate change are accelerating, the overall assessment of the Reef's world heritage and national heritage values is good, borderline poor.

> *Overall, human-induced climate change is challenging the integrity of the World Heritage Area; its size is becoming a less effective buffer against broadscale impacts*

Indigenous heritage includes tangible and intangible heritage and is interlinked with the condition of the Reef's natural components. The effects of acute and chronic disturbances in the past five years have affected the condition of the Region's Indigenous heritage value, some of which is irreplaceable (for example, songlines). For this reason, material and non-material Indigenous heritage is graded as being in poor condition overall with a stable trend. However, the limited evidence available in both 2014 and 2019 means the confidence in both grade and trend is rated as inferred. A noteworthy achievement in this space was the release of the Marine Park Authority's 2019 *Aboriginal and Torres Strait Islander Heritage Strategy*.

> *Indigenous heritage includes tangible and intangible heritage and is interlinked with the condition of the Reef's natural components*

The historic heritage values of the five properties in the Region listed on the Commonwealth Heritage List are graded as good, having been identified and included in a relevant inventory. Yet, the condition and trend of most places are based on limited published evidence. The inference by managers is, however, that the properties retain their integrity and are in good condition.

Other historic heritage components (other lightstations, shipwrecks, aircraft wrecks and other places of historic significance) are graded overall as poor. Published condition and trend data are lacking for most sites, so confidence in the grade and trend is limited or inferred. Positive progress has been made towards gathering evidence on shipwrecks and aircraft wrecks. The significant discovery in late 2018 of the precise location of the wreck of the *Martha Ridgway* increased the baseline data for this component.

> *The significance of the World Heritage Area still transcends national boundaries and remains a source of pride for the Australian public broadly*

Other heritage values, including social, aesthetic and scientific, are graded overall as good. The significance of the World Heritage Area still transcends national boundaries and remains a source of pride for the Australian public broadly. Significant progress has been made since 2014 in understanding the human dimensions of the Reef, focusing on societal attitudes and how people value the Reef. The social heritage value of the Region is considered to be in good condition.

A 2017 survey of approximately 3900 people living close to, or deriving benefit from, the Reef (local and national residents, tourists, tourism operators and commercial fishers) highlighted the wider community's concern about the declining condition of the Reef, as their connection to its environment and natural beauty continues to strengthen.[847,857]

As people's concerns about the declining health of the Reef increase, the Region's scientific heritage value continues to grow. The connection between emerging science and the natural heritage value of the Region provides adequate evidence to assess scientific heritage value.

The Reef is still strongly associated with beauty, but is also perceived as being significantly under threat. © Matt Curnock 2017

CHAPTER 5

COMMERCIAL AND NON-COMMERCIAL USE

« *Researchers trialing methods of larval replenishment on coral reefs.* © GBRMPA

COMMERCIAL AND NON-COMMERCIAL USE

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

5.1 Background

The Region has been used for tens of thousands of years by Traditional Owners. Since European settlement, use of the Region's ecosystem has increased through a combination of direct commercial and non-commercial uses (Reef-dependent uses) (Figure 5.1 and Table 5.1). The Region also supports non-Reef-dependent uses that require access through (or to) the area, but do not directly use the natural heritage values of the Region.

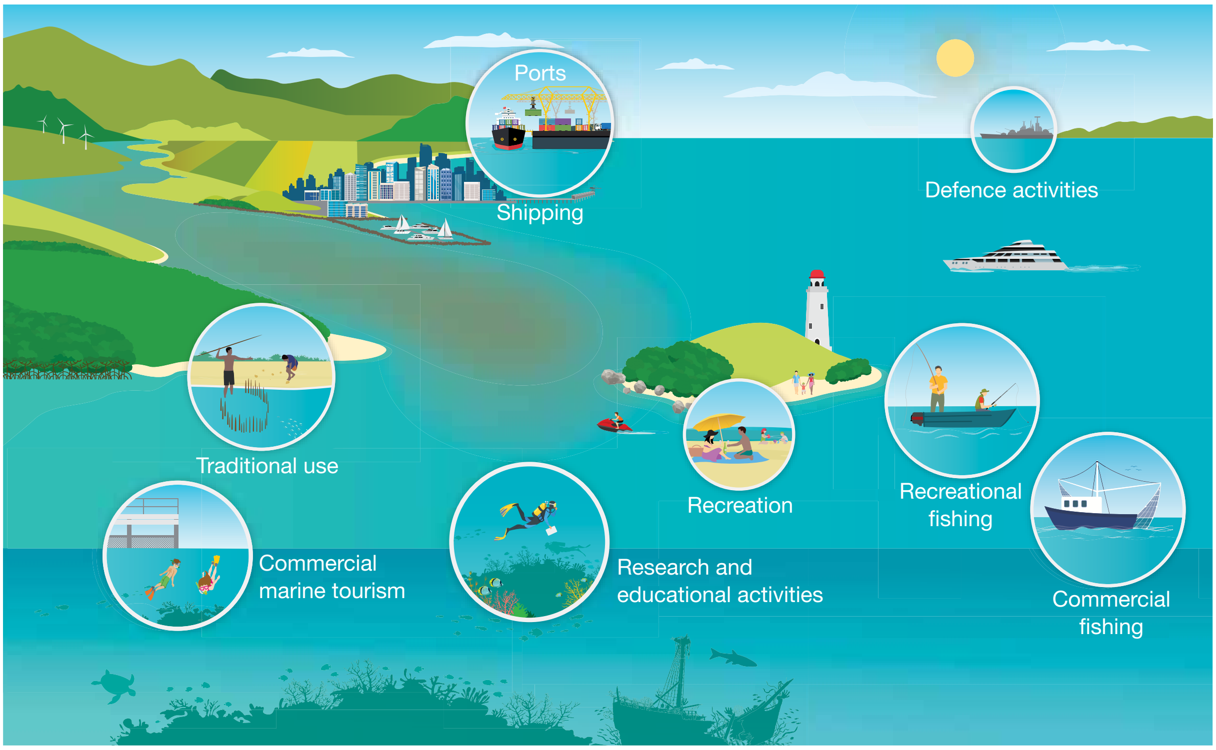


Figure 5.1 Commercial and non-commercial uses
A range of uses occur in the Region; some depend directly on the Reef's natural heritage values and resources.

This assessment of commercial and non-commercial uses examines the current condition and trend of the major uses of the Region and forms the basis for the Chapter 6 assessment of direct use, a factor that influences the Region's values (Section 6.6). The assessment is based on two assessment criteria:

- economic and social benefits of use
- impacts of use on the Region's values.

For more than 40 years, implementation of government management plans and policies have had to balance the protection of the Region against the needs of communities and industries that depend on the Reef for traditional use, social and cultural purposes, and livelihoods. Factors that influence the Region (Chapter 6) have changed and intensified over the years, making this management balance more challenging. Management has been, and continues to be, based on the best available scientific information and intergenerational knowledge. Chapter 7 assesses the effectiveness of the management tools in more detail.

Commercial and non-commercial uses collectively form an important part of the social and economic fabric that supports the adjacent communities in the Catchment and the broader Australian and international communities. The economic and social benefits of each commercial and non-commercial use is considered in terms of its benefit to the community and the natural ecosystem more broadly. All commercial and non-commercial uses, Reef-dependent or not, have the potential to conflict with the long-term protection, conservation and function of the Reef's natural heritage values. Therefore, management of these uses is factored into the assessment of the potential impacts of these uses.

Tourism, fishing, other recreational uses and scientific activities contribute significant benefits to the Australian economy (Table 5.2). The current (2015–16) estimated total contribution of the Reef to the Australian economy is $6390 million (or $6.4 billion) per annum, an increase of about 14 per cent since 2011–12.[846] Tourism and recreational uses have increased their value-added contribution, while commercial fishing has remained relatively stable since the last reporting period. In 2015–16, the Reef supported an estimated total national employment of 64,000 full-time equivalent positions, down from 69,000 in 2011–12[858] (Figure 5.2). This reduction in job figures is assumed to be a reflection of various changes in technology and national economic drivers, rather than significant job losses.[846] Across the various activities in the Region, scientific research (in combination with Reef management) has experienced the strongest value-added growth since 2011–12, with an estimated increase in employment of about 10 per cent. Comparable economic estimates for all commercial and non-commercial uses of the Region over time remain a knowledge gap.

Table 5.1 Commercial and non-commercial uses of the Great Barrier Reef

Reef-dependent uses	Non-Reef-dependent uses
• Commercial marine tourism • Fishing (commercial and recreational) • Recreation (not including fishing) • Research and educational activities • Traditional use of marine resources	• Defence activities • Ports • Shipping

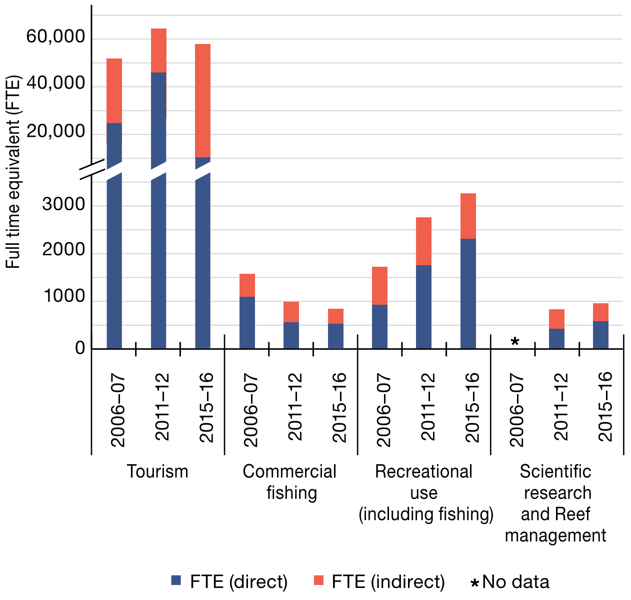


Figure 5.2 National employment levels within some Reef-dependent activities, 2006–07 to 2015–16
Employment numbers are based on direct and indirect full-time equivalent (FTE) employment generated by each activity. Indirect employment estimates include the contribution from support and ancillary goods and services generated by the direct use. Source: Access Economics 2008[859], Deloitte Access Economics 2013[858] and 2017[846]

A cruise ship at anchor on the Great Barrier Reef. © GBRMPA

Table 5.2 Economic contributions to the Australian economy from Reef-dependent activities, 2006–07 to 2015–16

Value-added refers to the output after deducting the value of inputs.

Source: Access Economics 2008[859], Deloitte Access Economics 2013[858] and 2017[846]

Activity	Australian total value-added ($million)			
	2006–07	2011–12	2015–16	Change since 2011–12 (per cent)
Tourism	$5117	$5176	$5700	+10
Commercial fishing and aquaculture	$139	$160	$162	+1
Recreational use (including fishing)	$153	$244	$346	+42
Scientific research and Reef management	-	$98	$182	+86
Total contribution	$5409	$5678	$6390	+13

5.2 Commercial marine tourism

5.2.1 Current condition and trends of commercial marine tourism

Commercial marine tourism is the largest Reef-dependent industry within the Region, contributing significantly to the economy and providing access for more than two million tourists each year. The most common tourism programs on the Reef include vessel-based day trips to reefs, islands, cays and pontoons. From 2011 to 2016, tourism visitation steadily increased from the low experienced during the global financial crisis (Figure 5.3). A slight decrease in visitation in 2017 to approximately 2,240,000 visitor days has continued with a marginal increase in 2018.

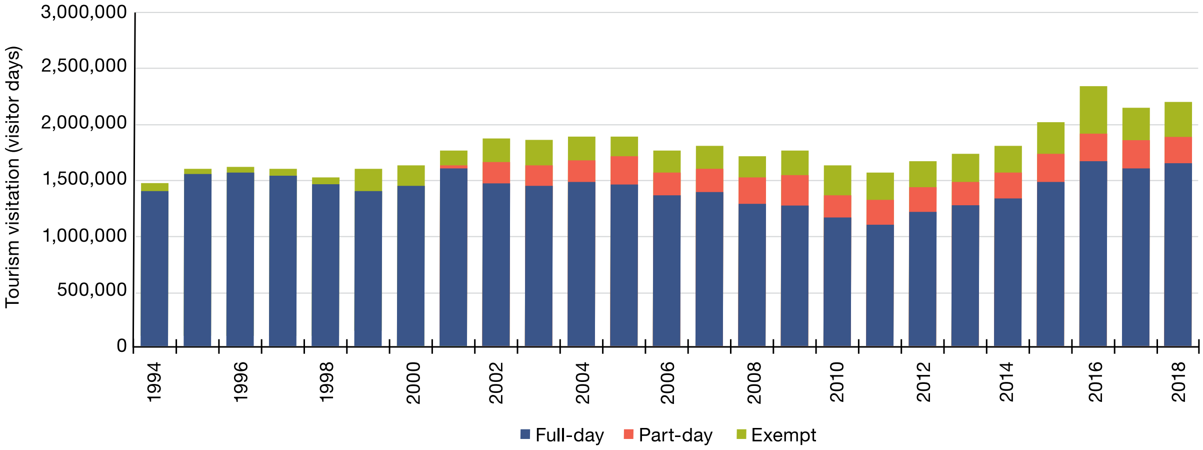


Figure 5.3 Number of tourism visitor days, 1994–2018

A 'visitor day' is a visit by one tourist for one day. For overnight visits, each day is counted separately (for example, a three-day visit by a tourist to the Great Barrier Reef Marine Park is counted as three visitor days). A part-day visit refers to visitors who take a trip of less than three hours. 'Exempt' refers to visitors who are not required to pay the environmental management charge (such as young children, people on trade familiarisation and transfer passengers) as well as those who have already paid the environmental management charge on that day for another tour or who are on their fourth and subsequent days of a trip. These tourism visitor day statistics do not include stand-alone coral viewing activities or scenic flights. Source: GBRMPA 2019[860]

Within the Region, tourism is concentrated in about seven per cent of the area. On average, 86 per cent of tourism visits occur within waters adjacent to Cairns, Port Douglas and the Whitsundays. These areas have plans of management to manage high visitation (Figure 5.4). Tourism in these areas is concentrated around tourism pontoons, popular islands and beaches.

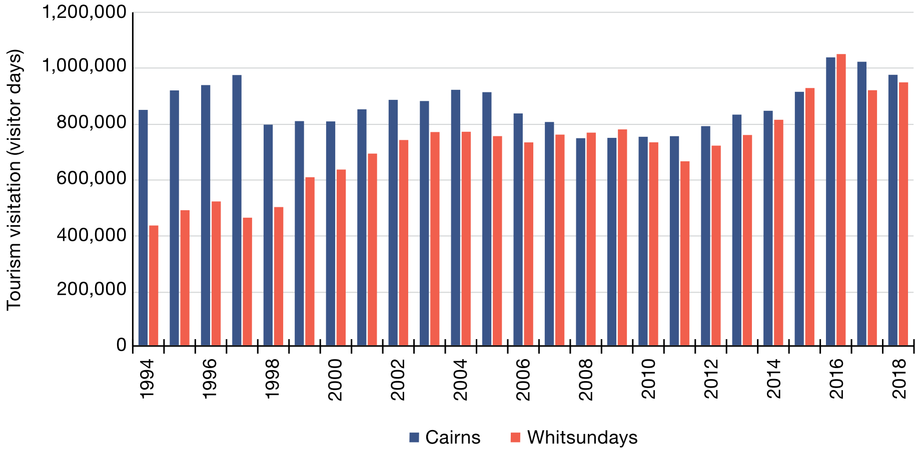


Figure 5.4 Total visitation to the two high-use plan of management areas, Cairns and the Whitsundays, 1994–2018
Source: GBRMPA 2019[860]

Record levels of tourism visitation to the Reef have occurred since 2014

Since 2014, Cairns and the Whitsundays have remained the highest use areas for marine tourism. Reef health is critically important to the stability and value of the Reef tourism industry.[861] Between 2016 and 2018, tourism visitation in the Cairns area slightly decreased (five per cent). Tourism visitation also declined in the Whitsundays in 2017, to a greater extent (12 per cent), but in contrast to Cairns, visitation to the Whitsundays increased in 2018 (Figure 5.4).

The decline in visitation and changes in tourism use around the Whitsundays were probably a result of damaged resorts that had to close, reduced water quality and damage to reef ecosystems following cyclone Debbie, which made landfall in Airlie Beach in March 2017. Media coverage of the back-to-back bleaching events around this time may have also affected travel plans. In response to the underwater damage, some tourism activity appears to have shifted to more island-based activities, while damaged fringing reefs recover.

Between 2014 and 2017, approximately 66 per cent of tourism visitor days in the Region were spent by visitors doing activities run by the 25 most active operators. This proportion is consistent with the previous Outlook Report.

Management Marine tourism in the Region is well established with planning, policy and permit systems in place. The *Great Barrier Reef Marine Park Zoning Plan 2003* (Zoning Plan)[862] and the complementary Queensland Government zoning plan[863] list activities that require permission and those that are allowed as of right. Commercial marine tourism requires permission in every case and can be conducted in almost all zones (except Preservation Zones) of the Marine Park and several other restricted areas.

Applications for permission to conduct tourist programs are jointly assessed and managed by the Marine Park Authority and Queensland Parks and Wildlife Service. In high-use tourism areas within the Marine Park, an added layer of planning complements the Zoning Plan rules, including statutory plans of management for the Cairns, Hinchinbrook and Whitsunday planning areas. These location-based plans of management manage cumulative use, including by capping the number of tourism operations and defining maximum group and vessel sizes at specific locations.

Tourism activities at Hardy Reef off the Whitsundays.
© Matt Curnock

Of the numerous policies and guidelines currently approved by the Marine Park Authority, just over half directly relate to tourism management. In 2017, the Marine Park Authority updated the permissions system policy and implemented further guidelines to provide transparency and certainty about how permits are considered and assessed, including for tourism. An established Tourism Reef Advisory Committee continues to inform the development of policy and strategic direction in the management of the Marine Park. One of the committee's key roles is to advise the Marine Park Authority Board about actions that can be taken to address the risks to the Marine Park identified in the Outlook Report.

In response to cyclone Debbie, managing agencies initiated the largest ever post-cyclone clean-up. Whitehaven Beach, on Whitsunday Island, was re-profiled, and visitor infrastructure was increased and upgraded in this area. This investment supported ongoing presentation of values to visitors and increased recovery of island beaches. The Australian and Queensland governments also provided significant funding through the Tourism Recovery Fund to facilitate tourism recovery following cyclone Debbie. The Queensland Government committed an extra $25 million towards a Great Barrier Reef Island Resorts Rejuvenation Program. This program promotes adopting renewable energy technologies, improved water and waste infrastructure, and conservation and environmental protections against weather events.

The Marine Park Authority's High Standard Tourism Operator program has been in place since 2004. Tourism operators who are independently eco-certified are invited to become part of the program, which lets them apply for longer-term 20-year permits. Sixty four operators were certified as high standard as at December 2018, an improvement from 44 in 2009 (45 per cent increase).

Auditing and reporting are undertaken to make sure high standard tourism operators are meeting certification requirements. Following audits in 2015, it was determined that the level of interpretive content delivered by tourism guides could be improved to better present the values of the World Heritage Area and how it is managed.

To address this gap, the Marine Park Authority launched the Reef Discovery Course in 2018. It is a comprehensive online training course made freely available to staff within the Reef tourism industry. This course aims to increase knowledge of areas such as biology, ecology, geology, heritage and management, and make sure interpretation is accurate.

In 2018, the Marine Park Authority also established the Master Reef Guide program in partnership with Tourism and Events Queensland and the Association of Marine Park Tourism Operators. The program aims to train guides to provide up-to-date information on the Reef, the World Heritage Area and what visitors can do to protect these places. Twenty-six Master Reef Guides had completed the training course as at April 2019.

5.2.2 Benefits of commercial marine tourism

The Reef is an iconic tourism destination

The Reef continues to be recognised locally, nationally and internationally as an iconic nature-based tourism experience. Benefits to people can be cultural, social or economic, and they can be linked to wellbeing and a sense of identity.[785] Commercial marine tourism delivers benefits to both tourists and tourism operators. The environment may also benefit (albeit to a lesser extent), because strong cultural connections with the environment can empower stewardship and engagement in environmental protection.[785] Some tourism operators have increased stewardship at their local sites through adhering to responsible reef practices, practising small-scale permitted coral gardening, and delivering high quality interpretation about the Reef by accredited Master Reef Guides.

Commercial marine tourism contributes significantly to the economy and the estimated icon value of the Reef. In 2015–16, tourism was the most prominent direct use of the Region, generating $2.4 billion (value-added) for Catchment communities.[846] More recent analyses of Reef-dependent and Reef-associated industry value have not been undertaken, and remain a knowledge gap. In the year ending December 2018, international visitation to Queensland reached approximately 2.8 million, the highest visitation recorded since reporting began in 2005, representing a 2.3 per cent increase from 2017. Of this total visitation to Queensland, approximately 51 per cent (1.43 million) occurred in tourism regions adjacent to the Reef.[864]

Culturally, the commercial marine tourism industry benefits tourists by providing access to the Reef and islands, and more broadly presenting the values of the World Heritage Area. Approximately half of the 1800 or so tourists surveyed in 2013 and 2017 felt the Reef contributed to their quality of life and wellbeing.[785] Tourists also derived benefits from the Reef through the different ways they value it. Ninety-five per cent said they valued the Reef because it supported a variety of life, such as fishes and corals. The status of the Reef as a World Heritage Area was also a recognised benefit. Over 65 per cent of tourists stated they valued the Reef for its cultural heritage because it provided a place where people can continue to pass down their wisdom, traditions and way of life.[785]

From a wellbeing perspective, 88 per cent of tourists surveyed in 2017 thought the Reef supported a desirable and active way of life. Commercial marine tourism operators also derive social benefits from the Reef with 89 per cent feeling that the Reef contributed to their quality of life and wellbeing.[785]

The strong connection both tourists and tourism operators feel to the Reef translated into positive intentions to help with environmental issues. For example, in 2017, tourists visiting the Reef indicated strong aspirations to do more to help the Reef, with 62 per cent believing they had personal capacity to make a difference.[785] Eighty-five per cent of tourism operators interviewed aspired to do more to help protect the Reef, and 68 per cent thought climate change was an immediate threat.[785]

While most tourists (approximately 80 per cent) were highly satisfied with their Reef experience, tourists interviewed in 2017 thought the condition of the Reef had deteriorated since 2013. The scores with the greatest decline related to a perception of deteriorated reef condition by international tourists. In contrast to the tourists' perception of deterioration, Reef tourism businesses remained highly optimistic about the future.[785,847] The value tourists place on the Reef and their desire to learn more about its condition and help protect it has increased significantly over time.[847]

5.2.3 Impacts of commercial marine tourism

Commercial marine tourism activities can pose threats to ecosystem and heritage values. The most significant of these include: incompatible uses (where tourism use may displace or affect another user group, such as Traditional Owners or recreational users); groundings of vessels; emissions (both from air travel and vessel operations); and, in some locations, marine debris and discharge of sewage.

Commercial marine tourism can leave a direct or indirect footprint on the values of the Region. Direct effects include damage to coral by snorkelling tourists and the footprint left by concrete mooring blocks associated with tourism pontoons. Indirect effects are harder to measure and can include displacement of other users by tourism use and changes in behaviour of animals that are fed or harassed at tourism sites.

Globally, tourism is responsible for five per cent of the world's fossil fuel consumption and associated carbon emissions.[865] Given the large distance of mid and outer-shelf reefs from the Queensland mainland, fuel consumption in the Reef tourism industry is likely to be far greater than at other locations where reefs are in closer proximity (for example, Ningaloo, Western Australia). The Reef (like Australia) is also typically a long-haul destination for visitors from most countries, so carbon emissions associated with international visitation are higher than those for other tourist destinations. An integral part of the assessment for the High Standard Tourism Operator program is providing evidence that the tourism operation is dedicated to reducing carbon emissions and committed to sustainable practices that address climate change.

Tourism use and associated impacts mainly occur in a few high-use areas

High-use areas offshore from Cairns, Port Douglas and the Whitsundays may each receive 200 to 400 tourists per day. Concentrated snorkelling and diving in these areas is likely to cause some level of direct and indirect damage to ecosystem and heritage values. Site-specific tourism operations mitigate impacts through guided snorkel tours, trails and resting stations that reduce contact with corals. **Physical damage** to reefs and shoals can be caused by the grounding and, in some cases, sinking of tourism vessels in the Region. These **groundings** are only a small proportion of the total vessels operating in the Marine Park on any given day (Section 5.5.3 Figure 5.18). Following the global financial crisis, reduced profitability across the industry increased the potential risks associated with maintaining tourism-related structures, such as pontoons, jetties, underwater observatories and moorings in the Region. An increased focus on permit compliance and auditing by the Marine Park Authority since 2016 found only low levels of non-compliance for tourism pontoons.

Established tourism operations at set locations have the **potential to displace** other users. A 2017 survey found that people in the Fitzroy and Mackay–Whitsunday regions felt they did not have fair access to the Reef compared with other users.[785] In contrast, people in the Wet Tropics and Burnett–Mary regions felt their access was equitable. The areas with the greatest feeling of equity were also sites within the Reef that either have restrictions on tourism use in high-value recreation sites (for example, Vlasoff Cay off Cairns), or have site-specific plans that attempt to balance recreational and tourism use in some areas (for example, Lady Musgrave Island).

Sewage discharge from vessels (both commercial and recreational) can increase nutrients in the water, reduce water quality and damage habitats. Within the Region, macerated sewage must be discharged from vessels at least one nautical mile (1.8 kilometers) seaward from the nearest reef, island, mainland or aquaculture facility, and this does not require a permit. There are few land-based sewage pump-out facilities adjacent to the Region, with only five fixed onshore pump-out facilities registered.[866] Discharging sewage sludge at sea that was loaded to a vessel from a tourism pontoon or other source requires a permit under the *Environment Protection (Sea Dumping) Act 1981* (Cth). Since 2014, three permits allowing sea dumping of sewage have been assessed and approved. This type of permit enables the tourism operator to remove sewage and grey water from their pontoons and discharge it, provided it is more than 500 metres from a reef. Volumes per year range from 13,000 litres for a small pontoon up to 227,000 litres for a larger pontoon. The sewage is discharged while the vessel is underway to increase dilution.

Although a considerable number of **offences** by tourism operators are recorded each year, particularly from the Cairns and Whitsunday planning areas, the environmental impact of these is relatively low compared with other non-compliant activities.[867] Offences by tourism operations typically include breaching of plans of management, failing to comply with the conditions of their Marine Parks permit, grounding vessels on coral, charter fishing in Marine National Park no-take zones, anchoring in no-anchoring areas, unpermitted or non-compliant moorings and approaching too close to whales.[868]

Emerging impacts from tourism activities include: installation of underwater infrastructure (for example, underwater art installations and small-scale reef restoration activities) that are unplanned or poorly financed; disturbance of wildlife and tourists by drones; and increased marine debris (Section 6.5.1).

5.3 Defence activities

5.3.1 Current condition and trends of defence activities

The Australian Defence Force has operated and trained in the Region for more than 100 years. Australian Navy, Army and Air Force bases at Cairns and Townsville serve as key platforms for defence operational activities in the Region. Training activities are regularly undertaken in designated areas, which cover less than four per cent of the Region (Figure 5.5).

Management Defence activities are allowed under the Zoning Plan, and management of the environmental impacts in the Region is undertaken by the Australian Department of Defence in collaboration with the Marine Park Authority and Queensland Government. Other management tools for defence activities include environmental management plans and a strategic environmental assessment for defence activities.[869,870] All operational and training defence activities are managed directly by the Department of Defence, including the conduct of training activities by visiting international defence forces. Many defence activities are conducted with dedicated observers, who may collect data on marine wildlife sightings or delay activities, if required, to avoid or minimise impacts on the environment.[871]

Figure 5.5 Defence training sites in the Region

The Australian Defence Force undertakes training in designated areas within the Region, shown in blue. The Townsville Star and Shoalwater Bay Defence training areas are some of Australia's largest.

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. The economic benefits of most Defence Force activities to the coastal communities adjacent to the Region are not quantified. Periodic visits from international naval ships to the ports of Cairns and Townsville generate short-term economic benefits.[872]

Defence operational activities directly and indirectly support management objectives for the Region through hydrographic surveys, and fishery and border protection patrols. The management agreement between Defence and the Marine Park Authority supports cooperative research programs relevant to environmental management of the Region and adjacent Defence estates.[873] Examples of cooperative research include: collaboration on surveys to detect marine pest incursions; environmental baseline studies; studying the impacts of noise; and developing mitigation strategies regarding waste discharge and wildlife interactions with defence activities. During the acquisition of new land or planning for new development and major activities, the Department of Defence assesses natural, Indigenous and historic heritage values on its estate. Heritage assessments can include consultation with Traditional Owners, who may also participate in monitoring and remediation works.[874]

> *Defence undertakes hydrographic surveys and patrols (for fishery and border protection) that support management of the Region*

In 1965, the Department of Defence acquired the Shoalwater Bay Training Area land. Since then, it has assisted in regenerating degraded areas to a relatively natural state through active land management and excluding grazing and coastal development pressures. In December 2016, Defence partnered with the Marine Park Authority and the Fitzroy Basin Association to reduce the number of feral pigs at the Shoalwater Bay Training Area.[875]

5.3.3 Impacts of defence activities

Defence activities occur in some sensitive areas

While modern defence training activities are well managed and have negligible impacts on the Reef, defence activities are predicted to intensify in the Region[876], coinciding with a decline in the Region's ecosystem health. By their nature, defence activities pose threats to the Region that must be continually monitored and managed, particularly in sensitive areas, such as Shoalwater Bay. 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. The implementation of mitigation measures results in reduced, or rare, incidents causing harm to the habitats and species of the Region. Balancing Defence training requirements with conservation of critical environmental values will remain a significant challenge for managing agencies and Defence. For example, a satellite-tracking study conducted at Triangular Island (in Shoalwater Bay) in 2014 monitored noise impacts on turtles. The study found that the underwater noise and vibrations associated with large explosive detonations did not result in displacement or disturbance to behaviours by resident foraging green turtles. The turtles continued to display strong site fidelity, irrespective of whether they were foraging a few hundred metres from the detonation area or kilometres away.[877]

A range of legacy impacts associated with past defence activities continue. The most significant is the presence of large amounts of **unexploded ordnance** (shells, missiles and bombs) and chemical warfare agents that were deliberately dumped at sea at the end of World War II.[878,879]

In 2004, Defence began phasing out the use of firefighting foams containing specific active ingredients, particularly per and poly-fluoroalkyl substances (PFAS) (Section 6.5). These **chemicals** are environmentally persistent and can cause liver toxicity, tumours and reproductive effects in animals. Current evidence is unclear whether these chemicals cause adverse health effects in humans.[880,881] One of four identified PFAS investigation sites in Queensland includes coastal wetlands and beaches surrounding RAAF Base, Townsville. A risk assessment has begun based on the initial findings of the detailed site investigation.[882]

Amphibious landing at Freshwater Beach, Exercise Talisman Sabre 2017. © Department of Defence (Cth)

5.4 Fishing

Fishing is the largest extractive use of the Region and comprises a range of fishing activities targeting a variety of species, including fishes, crabs and prawns. For the purposes of this report, the term 'fishing' includes recreational, charter and commercial fisheries. Fishing activities associated with traditional use are considered in Section 5.9. About two thirds of the Marine Park is available to most types of fishing.

Fishing continues to be an important use of the Region

At present, no marine-based aquaculture operations are underway in the Region, although permission has been granted for a small pearl oyster facility to be established at Albany Island, Cape York. Some land-based aquaculture operations exist in the Catchment (Section 6.4.1).

5.4.1 Current condition and trends of fishing

Recreational fishing Fishing remains one of the most popular recreational activities on the Reef. Even though more than half of Queensland's recreational fishers live in the south-east of the state, the highest participation rates (up to 30 per cent of the residential population) are in regional areas.[883] The most recent telephone survey data available[883] indicate that in 2013–14 the Gladstone residential region had the highest level of boat ownership among fishing households (70 per cent), followed by the Mackay–Whitsunday residential region (67 per cent). During the 2013–14 period, Queensland residents fished for approximately 2.5 million days, similar to the 2.6 million days estimate in 2010–11. Participation rates reduced slightly over that period from 17 per cent to 15 per cent.

TOP THREE SPECIES KEPT IN 2016

	Common coral trout	Spanish mackerel	Mangrove jack	Barred javelin	Pikey bream	School mackerel	Sand whiting	King threadfin
Cairns	●	●	●					
Hinchinbrook	●			●	●			
Townsville		●		●		●		
Mackay				●	●		●	
Rockhampton		●				●		●

Figure 5.6 Top three species caught and kept by recreational fishers during a 12-month period (November 2015 to October 2016) *This infographic highlights regional variation in the fish species most commonly harvested by recreational fishers, using data gathered through surveys conducted at boat ramps.* Source: Department of Agriculture and Fisheries (Qld) 2017[884]

For recreational fishing in the Region's estuary and ocean waters in 2013–14, tropical snapper, emperor, coral trout, cod and grouper were the most caught finfish species groups.[883] Large numbers of invertebrate species, including crabs, were also taken. Target species vary among locations (Figure 5.6).[883,884]

Charter fishing Operators take paying customers on boat trips to fish recreationally as visitors on a tourism vessel. For the year 2016–17, 96 active charter fishing licencees reported catch from within the Marine Park. The annual charter fishery effort (fishing days) within the Marine Park declined overall from 2008 to 2018, with a slight upward trend for 2016 to 2018.[885] Catch also increased somewhat for 2016 to 2018, but remained lower than historical levels (Figure 5.7).

Species of importance to the charter fishery differ by location. Overall, coral trout, redthroat emperor, mackerel and tropical snapper make up the greatest proportion of catch reported

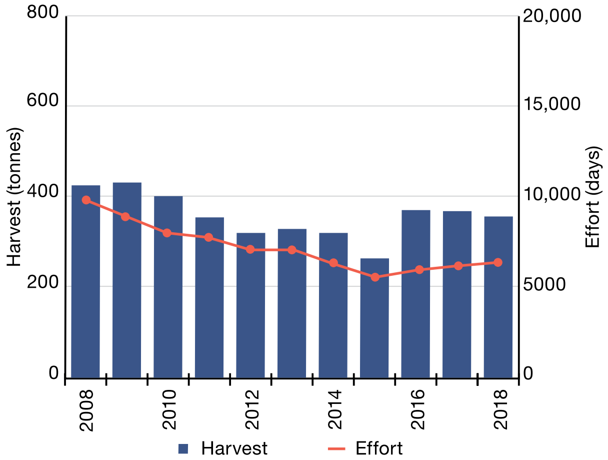


Figure 5.7 Charter fishing total catch and effort in the Great Barrier Reef, 2008–2018
Source: Department of Agriculture and Fisheries (Qld) 2019[885]

by charter fishers within the Marine Park. These are highly prized recreational and targeted commercial species. Some concerns exist regarding aspects of the completeness and accuracy of data reported through commercial and charter logbooks, as there is no independent validation program.[886,887]

Commercial fishing Trawl, net, line and pot remain the most significant commercial fishing methods in use in the Region (Table 5.3). In 2017, the commercial harvest (retained catch) of fisheries product in the Region was about 7600 tonnes, not including marine aquarium fish or coral. Of this, around 96 per cent came from the four main fishing methods. The largest change in the past 10 years has been in the net fishery sector, as a result of licence buybacks.[888,889,890,891] The 2017 harvest was 57 per cent (1331 tonnes) lower than the harvest in 2007 (Table 5.3 and Figure 5.8). New management arrangements for all commercial (and recreational) fisheries in the Region are currently being developed, as part of the implementation of the Queensland Sustainable Fisheries Strategy 2017–2027 (Sustainable Fisheries Strategy).[892]

Table 5.3 Commercial harvest in the Great Barrier Reef by fishery in 2007, 2012 and 2017

Data are accurate at the point of extraction from QFish and other databases. Differences to 2007 and 2012 figures reported in the 2014 Outlook Report generally result from subsequent database corrections or the use of QFish's new Reef data extraction boundaries. For instance, the mud and blue swimmer crab harvest figures now include animals caught in rivers and creeks.

Source: Department of Agriculture and Fisheries (Qld) 2018[885]

Fishing method	Fishery	Commercial harvest (retained catch)			Main target species in the Region
		2007 (tonnes)	2012 (tonnes)	2017 (tonnes)	
Trawl	Otter trawl	3333	3426	3637	Prawns, scallops, bugs, squids
	Beam trawl	70	33	21	Prawns
Net (mainly large mesh net)	East Coast Inshore (principally)	2341	1697	1010	Barramundi, sharks, grey mackerel, threadfin salmons, sea mullet, whiting
Hook and line	Coral Reef Finfish and Spanish Mackerel (principally), and hook and line component of East Coast Inshore	2122	1746	1845	Coral trouts, cods, emperors, tropical snappers, Spanish mackerel, other mackerels, sharks
Pot	Mud crab, blue swimmer crab - pot	601	893	667	Mud crab, blue swimmer crab
	Spanner crab - dillies	526	205	132	Spanner crab
Hand-based collection (harvest)	Coral	106	85	20	'Live rock' and potentially hundreds of species of coral
	Marine aquarium fish	179,948 fish	146,650 fish	90,360 fish	Potentially hundreds of species, mostly damselfish, anemone fish, wrasses, angel fish
	Tropical rock lobster	238	154	185	Tropical rock lobster
	Trochus	141	16	0	Trochus
	Sea cucumber	252	379	262	White teatfish, blackfish, curryfish

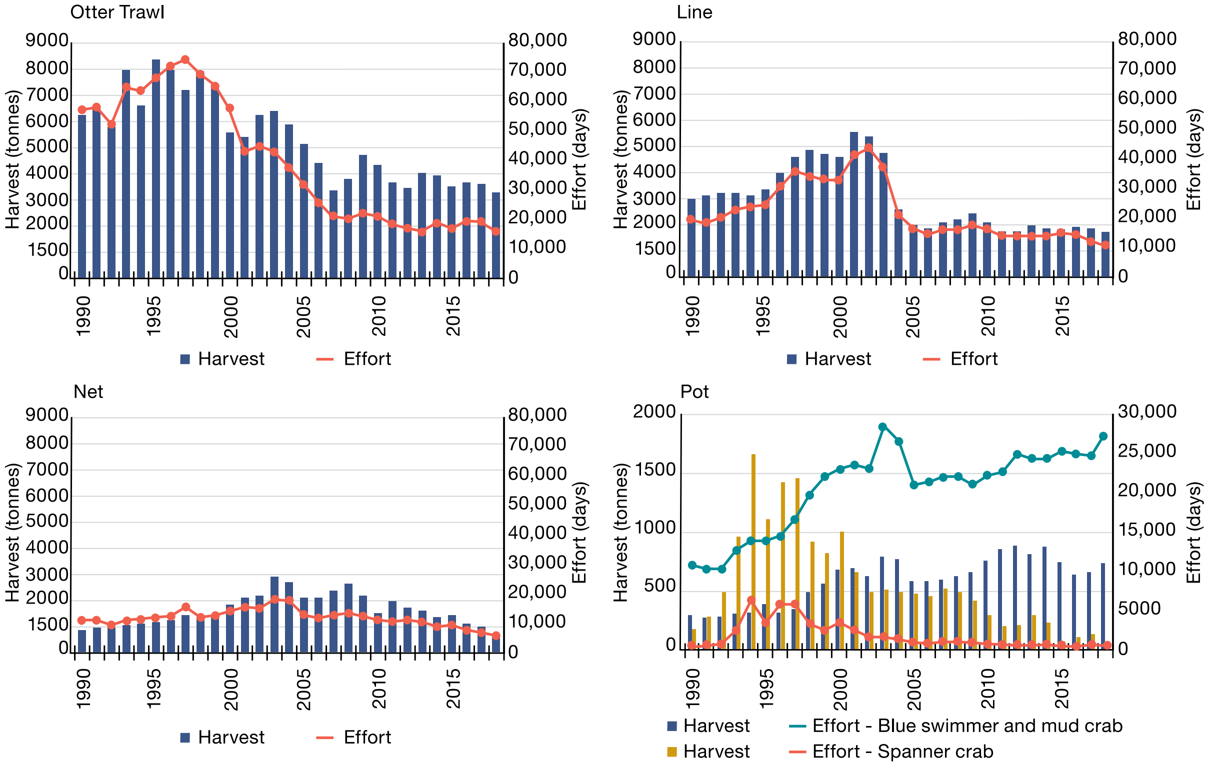


Figure 5.8 Commercial fisheries harvest and effort in the Great Barrier Reef, 1990–2018
Annual harvest and fishing effort for the four major fisheries (otter trawl, net, line, and pot) from 1990 to 2018. Data are based on commercial fisher logbook records. Effort is expressed in fishing days. A day of 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 and Fisheries (Qld) 2019[885]

Trawler off Low Isles in the north of the Region. © GBRMPA, photographer: Pine Creek Pictures

There are two basic types of trawling: otter trawling and beam trawling. The otter trawl fishery, which operates in more open waters is by far the larger, accounting for most of the total harvest taken each year (Table 5.3 and Figure 5.8). The **East Coast Otter Trawl Fishery** is the largest fishery in Queensland, both in terms of the volume of product caught and the economic value of the product.

Within the Region, trawl fishing is currently allowed in all General Use Zones (with some additional spatial restrictions), totalling 34 per cent (118,488 square kilometres) of the World Heritage Area.[893] In 2017, the total area of fisheries reporting grids (excluding where trawling is not allowed) for which otter and beam trawl harvest was recorded equaled approximately 30 per cent (106,629 square kilometres) of the World Heritage Area. Some areas in the Region, particularly deep areas (down to about 250 metres) of the outer southern Reef, have among the highest trawl footprints and effort intensity in Australia.[894]

Since 2014, the state of saucer scallops in Queensland has come under increased focus. Standardised trawl harvest rates of saucer scallops from January 2015 to April 2016 were the lowest in the 39-year record. Estimates of spawning stock in 2015 were potentially as low as five to six per cent of 1977 levels, when the fishery was in its early development. By 2016, profitability in the scallop fishery relied on the value of a co-caught species (Moreton Bay bugs).[113] The 2016 stock status assessment concluded that the saucer scallop fishery was recruitment overfished.[895,896] The classification system[897] has since changed and the 2018 assessment gives the status as depleted.[898] The 2017 fishery-independent scallop survey (sampling in October 2017) indicated very low abundance of scallop compared to previous survey years and concluded the stock's likely biomass remains very low.[899] In December 2016, legislative changes were made to keep all scallop replenishment areas permanently closed from January 2017 and introduce winter closure (1 May to 31 October) on all east coast saucer scallop harvesting to protect the spawning stock over the winter months.[900] Further management arrangements may be required to recover the stocks and make sure overfishing does not continue.[901]

The **East Coast Inshore Fishery** is complex, covering various target species and multiple types of commercial gear. In the Region, the main gear types are mesh net, bait net and line. Many of the species targeted by commercial fishers are also targeted by recreational fishers, including bream, flathead, whiting, barramundi, jewfish, threadfin salmons and trevally.

Commercial effort in the East Coast Inshore Fishery has been reduced in the last five years with the removal of 120 large mesh net licences. There is limited information on a range of species within this fishery, including for many that have an undefined stock status.[902] There are serious sustainability concerns for black jewfish.[903,904] The commercial catch of black jewfish has increased ten-fold, reaching 95.5 tonnes for the 2018–19 year by the end of December 2018[885] due to the high economic value of the species' swim bladders (up to $920 per kilogram). The annual historical average for commercial harvest of this species is 16 tonnes. Fisheries Queensland is implementing management actions to address unsustainable harvest of black jewfish, including changes to the commercial fishing reporting requirements that took effect in April and May 2019.[904] The total allowable commercial catch for sharks and rays constrain the amount of hammerhead shark that fishers can harvest (including under a new management arrangement that began on 1 January 2018). However, they do not constrain harvest at a species level for other shark and ray species. This situation may be significant for species, such as pigeye shark, where fishing mortality estimates are relatively high and harvest rates may have been unsustainable in the past.[905,906]

Live coral trout harvested by line fishing. © GBRMPA

In the **Spanish Mackerel Fishery** (a line-only fishery) almost one third of the total commercial harvest is taken from a very small area off the coast of Townsville and most of this is during the spring months.[907,908] Following a substantial reduction in effort associated with the fisheries management and Marine Park zoning changes in 2004, fishing effort has since increased from around 9000 to 13,500 tender vessel days, with fishing effort almost doubling on the main fishing grounds off Townsville over the past eight years.[907,908] The most recent stock assessment for Spanish mackerel suggests the current harvest level for the east coast stock is sustainable.[909,910] However, only about half of the total allowable commercial catch (574.6 tonnes) has been harvested in recent years. If the total allowable commercial catch was to be largely used, and current or increased charter and recreational harvests continued, then the biomass of the Spanish mackerel population may decline.[909] The risks from fishing spawning aggregations are also a critical consideration.[909] The spatial and temporal distribution of spawning aggregations has contracted in the Region, with one aggregation in Cairns now commercially extirpated.[15,16] Current catch rates at spawning aggregations are up to 90 per cent lower than those reported in the early 1900s[15] (Section 2.2.2).

There are concerns for the two most important species harvested by the **Rocky Reef Fishery**: Australian snapper and pearl perch. While some take of these species occurs in the Region, most of the harvest has historically occurred further south. However, commercial and recreational catches have been declining and there may be related movement of additional fishing effort into the Region.

Concerns exist for some species harvested by commercial and recreational fishers

The Queensland component of the east-coast stock of Australian snapper is recruitment overfished[911,912] and its status was assessed as depleted in 2018.[909,913] The Queensland fishery appears to have relatively few older fish and fishery-independent data (2007–2015) show a decrease in relative catch rates of 57 per cent since 2014 and 94 per cent since 2011.[914] Also, commercial, recreational and charter sector data for Queensland all show harvest declines to historic lows during the period 2007 to 2015.[907,915,916] The current level of fishing pressure is thought to be too high to allow recovery of the Queensland component of the stock.[911,914] Geographically, commercial harvests have increased at the northern extent of the fishery within the Region (particularly the Swain Reefs area) and further offshore, potentially in response to declining catches and catch rates in areas south of the Region.[912]

The east coast pearl perch stock is classified as depleted and considered recruitment impaired.[917] Commercial harvest rates declined by about 40 per cent between 2006 and 2014.[895,918,919] A similar decline also occurred in the charter and recreational fishing sectors.[919] Commercial harvest in 2016–17 was about 17 tonnes, continuing around five years of historically low harvest levels.[885] From 2012 to 2017, the proportion of the total harvest taken from within the Region increased from around 27 per cent to around 52 per cent. Fishing effort, measured as days when pearl perch are landed, also increased in the Region, from 295 fishing days in 2012 to 578 days in 2017. Collectively, these indicators suggest fishing pressure is increasing on pearl perch within the Region as harvests in southern Queensland decline.

The commercial component of the **Coral Reef Finfish Fishery** operates predominantly in the Marine Park using only line fishing. The majority of catch is from the commercial sector, targeting coral trout (Section 8.3.4 and Figure 5.9) for live export. However, the fishery also includes substantial recreational and charter fishing sector effort. All three sectors target coral trout, emperor and tropical snapper species and around 120 other fish species are also taken. The annual total allowable commercial catch for coral trout has been significantly reduced over time. In 2004, it was set at 1350 tonnes and by 2015 was constrained to a record low of 917 tonnes. Since then, the total allowable commercial catch has slowly increased, to 1163 tonnes for the 2018–19 season (Figure 5.9). Total allowable commercial catch levels for red throat emperor (611 tonnes) and 'other species' (956 tonnes) have not changed since 2004 because decision rules are not yet[892,920] in place for adjusting the total allowable commercial catch for these species. Some species within the 'other species' category are more at risk of over-exploitation than others and there is potential for their excessive harvest within the total allowable commercial catch.[288,921]

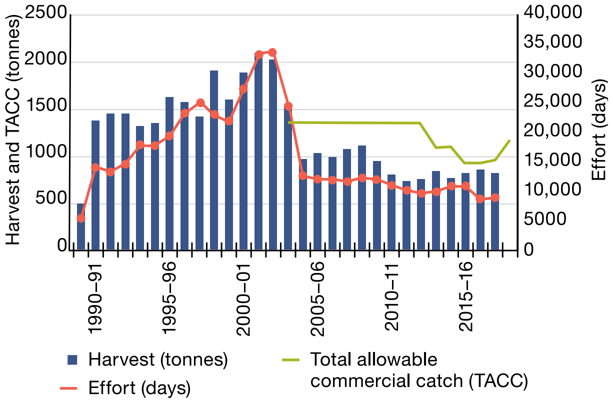


Figure 5.9 Commercial coral trout line fishing harvest and effort in the Great Barrier Reef, 1989–90 to 2017–18
Data only includes coral trout caught by line fishing. Effort is expressed in fishing days (primary vessel). Source: Department of Agriculture and Fisheries (Qld) 2019[885]

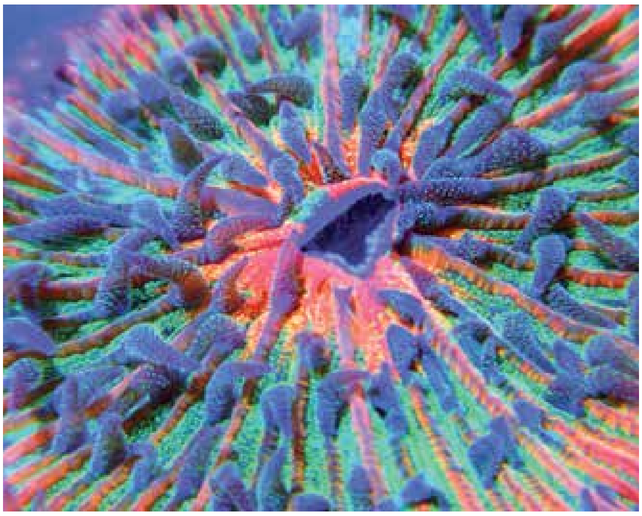
Several **crab species** (Figure 5.8) are commercially and recreationally targeted in the Region. Mud crabs are an important species for fishers throughout the Region. Blue swimmer and spanner crabs are mostly harvested south of the Region (about 95 per cent of the total reported commercial pot harvest), and are taken in relatively small numbers in the southern areas of the Region. In 2016, the status of all three species was assessed as sustainable.[922,923,924]

Protection of all female mud and blue swimmer crabs and size limits that protect immature males strongly contributes to sustainability.[922,923] However, catches in the mud crab fishery have been declining over recent years and many commercial fishers state that current catch rates are no longer economically viable.[925] The commercial harvest of blue swimmer crabs in Queensland in recent years has been about one quarter of that harvested in 2003 and 2004, and the most recent stock assessment noted that significant reductions in fishing effort are required to make sure stocks are sustainable and promote an optimum economic yield.[925] These stocks are under considerable pressure and there is concern about overcapacity, competition, localised depletion and reduced recreational fishing satisfaction.[925] Reports of black-marketing due to the high value of mud crab are increasing.[925]

Depletion is also an issue for the spanner crab fishery[926], particularly as spanner crabs are longer lived and slower growing than most other commercial crab species. In 2015–16, the total allowable commercial catch for the main fishing area was 1631 tonnes[927], but it was reduced by almost 50 per cent for 2018–19 (to 847 tonnes) in response to declining catch rates in recent years.[924,928,929] The 2018 stock status assessment classifies spanner crabs as depleting.[895,930]

The main commercial **dive-based harvest fisheries** operating within the Region are the sea cucumber fishery, coral fishery, marine aquarium fish fishery and the tropical rock lobster fishery. In the east coast Queensland sea cucumber fishery, currently 18 commercial harvest licences (all owned by two operators) are authorised to take sea cucumber by hand using scuba or surface-supplied air. Total harvest for the fishery has remained relatively stable over the last decade (Table 5.3).[931] The stock status for the two main commercially caught species, white teatfish and burrowing blackfish, are rated as sustainable.[895] However, all other sea cucumber species are grouped under the fixed total allowable commercial catch for 'other species'. This does not allow the total allowable commercial catch to be adjusted at the species level to ensure commercially significant species that are sensitive to localised fishing pressure are harvested sustainably.[932] The exception is black teatfish, for which there is currently (Section 8.3.3) a total allowable commercial catch of zero tonnes within the fishery's total allowable commercial catch.[2,928]

The reporting requirements and quota rules for the coral fishery have changed since the 2014 Outlook Report. A total of 59 commercial harvest licences are currently authorised for Queensland.[928] No stock assessments are in place due to the large number of species harvested. The average amount of product harvested under the Queensland coral fishery has increased over the past 14 years (Table 5.3 and Figure 5.10). In 2016–17, 48 per cent of the 'specialty coral' and 37 per cent of the 'other coral' allowances were used by fishers.[933] The wildlife trade operation assessment for the fishery, which allows for export, suggests impacts are likely to be low.[934]



The coral fishery supplies marine aquarium enthusiasts with attractive specimens like this Fungia species. © Cairns Marine

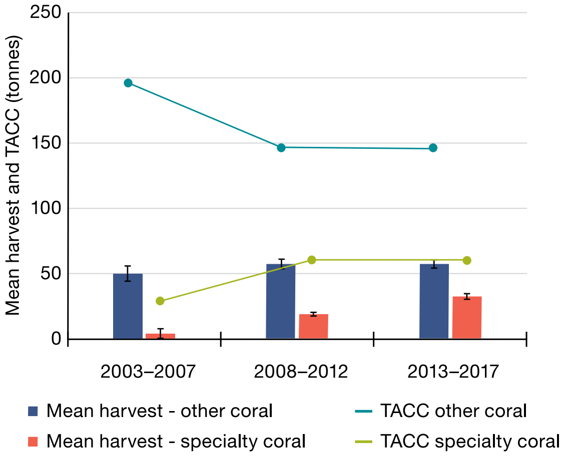


Figure 5.10 Average annual product harvested in the coral fishery in the Great Barrier Reef for three 5-year periods 2003–2007, 2008–2012, 2013–2017
Coral harvest weights are based on unloads recorded via the quota monitoring system rather than logbook data because, since the start of the 2015–16 quota season, fishers log the number of pieces of coral rather than weight. For each period, harvest is shown as a mean +/- standard error. Note that the total allowable commercial catch (TACC) shown for the 2003 to 2007 period applies to 2003 to 2005 only. During 2006 and 2007, TACC was at the level shown for 2008 to 2012. Source: Department of Agriculture and Fisheries (Qld) 2018 and 2019[885,928,933]

The marine aquarium fish fishery collects a wide variety of fish and invertebrates for the live aquarium trade, most of which is exported. As is the case for the coral fishery, stock assessments are not conducted due to the high number of species harvested and the impact has been assessed as likely to be low.[935] Currently, 42 licences are authorised, with 21 of those reporting catch in 2017 and the rest inactive. Collection is carried out using scuba or surface-supplied air with hand-held fishing gear, including lines, small nets and herding devices. Both effort and catch have substantially reduced in 2017 compared with historical levels (Table 5.3 and Figure 5.11). This decline may be partly related to international market demand, as many species are now grown in aquaculture facilities.

The harlequin tuskfish is a popular aquarium fish due to its bright colours and striking patterns. © Cairns Marine, photographer: Phil Woodhead

The tropical rock lobster fishery predominantly supplies a live export market. Collection is by hand, in reef waters to a depth of 25 metres. The commercial fishery in the Region is restricted to operating north of latitude 14 degrees south (around Princess Charlotte Bay). Recreational take in the Region is small. Although 28 commercial licences are authorised, only nine licence-holders hold quota. The stock was classified in 2018 as sustainable[895] and 95 and 83 per cent of the total allowable commercial catch was harvested in 2017 and 2018 respectively (Figure 5.12).

Since 1962, the **Queensland shark control program** has been implemented under the *Fisheries Act 1994* (Qld) (as amended) to reduce the risk of shark attacks on bathers at popular swimming locations by targeting the removal of sharks identified as posing a risk to swimmers. For this reason, the extraction and other impacts of the methods used are included in the fishing assessment.

Since the 2014 Outlook Report, all five remaining nets have been removed from the Marine Park and replaced with drumlines. A maximum of 173 drumlines can be set in the Marine Park at any one time. In the Region (outside the Marine Park) two nets remain at Harbour Beach, Mackay. From 2014 to 2017, 1251 sharks of targeted species were taken from within the Region under the program. A further 232 sharks of non-target species were also caught, with approximately 36 per cent released alive.[936] None of the sharks are considered retained take. Evidence from the program indicates that once nets are replaced with drumlines the number of species caught decreases and the percentage released alive increases.[937]

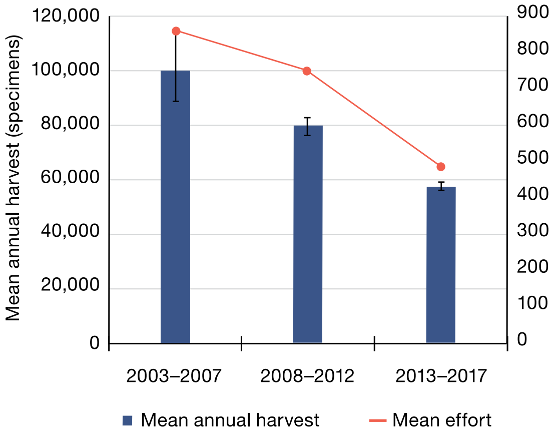


Figure 5.11 Marine aquarium fishery harvest and effort in the Great Barrier Reef for three 5-year periods 2003–2007, 2008–2012, 2013–2017
Harvest is expressed as the number of individual specimens and effort is expressed in fishing days (of primary vessel). For each period, harvest is shown as a mean +/- standard error.
Source: Department of Agriculture and Fisheries (Qld) 2019[885]

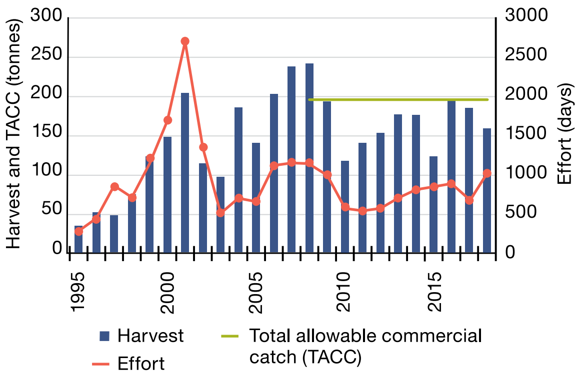


Figure 5.12 Tropical rock lobster fishery harvest and effort in the Great Barrier Reef, 1995–2018
Harvest and total allowable commercial catch (TACC) are expressed in tonnes; effort is expressed in fishing days.
Source: Department of Agriculture and Fisheries (Qld) 2019[885]

Management The Australian and Queensland governments, in aiming for ecologically sustainable fishing in the Region, take an integrated and collaborative approach to fisheries management.[938] Statewide fishery management arrangements are applied under the *Fisheries Act 1994 (Qld)*, and the Australian and Queensland governments work cooperatively in the Region through the Reef Joint Field Management Program, including to conduct fisheries-related surveillance and other enforcement activities. The Zoning Plan and *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004* apply to all fishing activities in the Great Barrier Reef Marine Park, and specify areas that can be fished and the type of fishing that can be undertaken. Subject to meeting the overarching objective of the *Great Barrier Reef Marine Park Act 1975*, namely long-term protection and conservation, the Offshore Constitutional Settlement[939] provides for the Queensland Government to have lead responsibility for fisheries management within the Region.

Ensuring ecological sustainability is crucial

As in many other regions and jurisdictions[940], allocation of fisheries resources is an ongoing source of conflict between the commercial and recreational sectors within the Region. In November 2015, three net-free fishing zones prohibiting commercial net fishing were introduced to improve recreational and charter fishing opportunities near Cairns, Mackay and Rockhampton and reduce interactions with species of conservation concern.[941] Surveys conducted in 2015 and 2016 showed recreational fishers were satisfied with their fishing experience in the net-free zones and expected further improvements over time.[942,943]

Recreational fishers in Queensland do not require a fishing licence.[944] Recreational fish size, take, possession and gear limits apply in tidal waters and the sale of any fish caught recreationally is prohibited. Seasonal closures also apply for some species. Guidance on best-practice release techniques for line-caught fish is available.[945] Improved monitoring for recreational fishing is needed to address information gaps.[892]

For commercial fishing activities, direct management arrangements include licences for all operators, total allowable commercial catches for some species, fish size and possession limits, restrictions on fishing apparatus, closed areas and seasonal closures.[946] The management arrangements for most commercial fisheries in the Region are accredited for export approval against the guidelines for the ecologically sustainable management of fisheries[947] under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). Commercial harvest fisheries and all developmental fisheries also require Marine Parks permits. Currently, fisheries managed solely under a total allowable commercial catch system may be more at risk of exceeding harvest limits than those managed under individual transferable quotas[948] because the latter have more robust reporting requirements.

Fishing practices and management continue to improve

Since 2014, some legislated changes for the East Coast Otter Trawl Fishery have been implemented to improve environmental outcomes for the fishery. In 2015, mandatory use of improved bycatch reduction devices began, to help reduce the substantial incidental capture of sea snakes and other bycatch species. Further changes were also made to improve turtle excluder devices (mandatory in the fishery for over a decade) and trawl spikes became prohibited.[949,950,951] Ways to address some remaining environmental risks to species and habitats are being considered in the current fishery reform process, noting trawl fishing effort is a key driver of ecological risk.[952,953]

Boat ramps, including this one at Yorkey's Knob, Cairns, provide recreational fishers access to the Region.
© GBRMPA 2012. photographer: Pine Creek Pictures

Legislative adjustments have been made regarding hammerhead sharks, in recognition of declines in some species.[954,955,956,957,958,959] New Queensland fisheries regulations came into effect on 1 January 2018 to strengthen the management controls around hammerhead sharks. When the scalloped hammerhead became listed as 'conservation dependent' under Commonwealth legislation in March 2018, the Marine Park regulations were amended to recognise this listing and enable management consistency and continued take.[954]

Concerns remain regarding some aspects of current fisheries management. For example, current management arrangements for the Coral Reef Finfish Fishery do not enable responses to changes in species status at a stock level or regional scale. There is no independent validation of fishers' logbook reporting, following cessation of the independent fishery observer program (for all fisheries) in 2013.[960] It is also recognised that the fishery's current 'other species' category does not adequately constrain harvest of species considered to be at high risk, including red emperor and saddle-tail snapper.[921,961] Historically, monitoring of these species, including fishery discards, has not been strong. However, recent commitments[962] have included initiation of improvements to biological monitoring for a number of fishes within the 'other species' category.

While fishing practices and management continue to improve, ensuring ecological sustainability is critical. As outlined above, information remains limited in some areas and sustainability concerns exist for some species. Of major significance since the 2014 Outlook Report is the development of the *Queensland Sustainable Fisheries Strategy 2017–2027*.[892] Work towards implementing the strategy has commenced with actions identified across 10 reform areas (Box 6).

BOX 6

Queensland Sustainable Fisheries Strategy 2017–2027

In June 2017, the Queensland Government released the *Sustainable Fisheries Strategy 2017–2027*[892], paving the way for Queensland to have a world-class fisheries management system that makes sure fish stocks are healthy and supports Queensland jobs. The strategy identifies 10 areas for reform and commits to a range of important initiatives, including:

- setting a target of 60 per cent virgin biomass for all stocks by 2027 — a critically important contribution to a healthy marine ecosystem and ecologically resilient Great Barrier Reef
- installing vessel-tracking units on all commercial boats by 2020, with a priority to have them on net, line and crab boats by the end of 2018 (Section 5.4.3 Box 7)
- developing a harvest strategy for each specific fishery — these (and future ecological risk assessments) should explicitly consider and respond to all high risks relating to fishing, particularly the very high risk of incidental catch of species of conservation concern identified by the 2014 and current Outlook Reports
- modernising Queensland's fisheries laws, including introducing stronger compliance powers and penalties for serious offences, such as seafood black-marketing
- boosting engagement and field presence — achievements so far include establishing new fishery working groups and an expert panel, employing 20 new compliance officers and reopening the Queensland Boating and Fisheries Patrol office in Gladstone
- rolling out new biological monitoring and implementing of a data validation plan that aims to improve commercial and charter logbook information.

Ensuring fisheries are ecologically sustainable is important for maintaining a healthy and resilient Great Barrier Reef. The Queensland Department of Agriculture and Fisheries will continue to publish regular progress reports on the Sustainable Fisheries Strategy.[892,963,964]

5.4.2 Benefits of fishing

Fishing is important socially and economically

Commercial fishing is an important source of income for Queensland coastal communities and plays a vital role in Australia's seafood industry.[846] In 2015–16, the total value of commercial fishing in the Region was estimated to be $104 million.[846] In 2015–16, the Region's commercial fishing, together with the land-based aquaculture industry, value-added an estimated $162 million to the national economy and generated the equivalent of 814 full-time jobs Australia-wide.[846]

The gross value product forecast for Queensland-wide commercial and recreational fisheries combined for 2018–19 is $275 million ($181 and $94 million, respectively).[965] The commercial and recreational fishing figures are three and five per cent greater, respectively, than the average for the previous five years. Inshore fisheries are believed to produce economic benefits to local communities beyond their immediate gross value product.[966] Concurrent implementation of no-take zones and fisheries harvest controls, including reduced effort, have enhanced the benefits to both fish populations and fisheries. For example, commercial fisheries' catch data and population biomass observations for coral trout indicate the species responded positively following important management changes in 2004 (Section 8.3.4).[967]

Commercial fishers continue to have a high attachment to their industry and most have been involved for more than 30 years. Commercial fishers' level of optimism about their business in the Reef was higher in 2017 than 2013.[968] Generally, fishers rely heavily on the industry, with most receiving about 65 per cent of their income from the Region.[969] Commercial fishers have high personal connection to the Reef and state they have strong appreciation for the biodiversity, aesthetic and lifestyle benefits it provides. They consider they would be personally affected if the Reef's health declined.[969]

Fishing is one of the most popular recreational pastimes in the Region, generating somewhere between $70 and $311 million in expenditure on recreational fishing and related equipment in 2015–16.[846] People enjoy recreational fishing for the opportunity to catch fresh local seafood and for appreciating the Region's natural beauty, wildlife watching, outdoor physical activity, relaxation, and spending time with family and friends.[970] Recreational fishers also identify environmental and wellbeing benefits, including fostering respect and connection with the environment, understanding food sources, building relationships, and enhancing community cohesion.[970] In terms of appreciation of lifestyle, biodiversity and aesthetics, and pride in its World Heritage Area status, local residents (including recreational fishers) show higher levels of dependency on the Reef than commercial fishers and tourism operators.[969]

Recreational fisher with a bar-cheeked coral trout. © Henriette van den Heever 2016

5.4.3 Impacts of fishing

Fishing removes biomass from the Region and, when harvest is not conducted in an ecologically sustainable way, it can affect the abundance of targeted species locally and at a population level. Declines in populations of culturally-significant species affected by fishing can have flow-on implications for the Region's Indigenous heritage values (Section 4.3), such as cultural practices, observances, lore, stories, songlines and sites.[971] The status of some targeted species is cause for community and scientific concerns.[909,911,933,972]

Illegal fishing continues to add pressure to an already deteriorating system

Predators, such as coral trout, emperors, mackerel and sharks make up about 40 per cent of the total commercial retained catch (Figure 5.13) and the majority of the recreational fishing catch.[883] Reductions in predator populations can have long-term effects on marine systems, including direct and indirect effects on the food chain[176,605] (Section 3.4.5). For example, predator abundance and behaviour changes can alter food webs and result in flow-on effects for herbivore populations that moderate algal cover on coral reefs.[607,973,974]

Some predatory species are subject to considerable fishing effort and data limitations hamper some fisheries assessments. The Queensland component of the east coast stock of Australian snapper is considered depleted as are pearl perch.[911,913,917] Black jewfish have been subjected to significantly increased levels of harvest in recent years because of the high value of their swim bladders.[975] This predatory species is vulnerable to overfishing if catch limits are not in place. Also of concern, the stock status for cobia and mangrove jack were downgraded in 2017 from sustainably fished to undefined. Approximately 40 per cent of the more than 60 Queensland east coast fisheries resources that have been assessed are currently classified as undefined, including commercially and recreationally important jewfish, barred javelin and some emperors.[895]

Some sharks and rays are at higher risk from fishing than others.[147,288,297,906,951,952] The 2015 stock assessment of whaler and hammerhead sharks in Queensland found the quota and catch rates of these sharks were sustainable.[976] However, the 2015 stock assessment remains uncertain due to data limitations around species composition and discards.[977] Sharks and rays are discarded in the trawl fishery, but mortality and health impacts are still a concern.[978,979,980,981] The equipment used in the Queensland shark control program extracts targeted sharks and also interacts with other species, including some species of conservation concern. From 2014 to 2017, 16 individuals of protected species, including two crocodiles, five marine turtles, six Queensland groper, two manta rays, and one dolphin, were incidentally caught on shark control program gear within the Region; 11 of these (68 per cent) were released alive.[885] Some species targeted under the program[982] are protected, including the white shark, longfin mako, shortfin mako, school shark and silky whaler.[983] Some of these species have not been caught in the Region since the early 2000s, and others may be unlikely to be caught due to their pelagic nature.[937]

Particle feeders (such as prawns and scallops) account for over half of the weight of the total retained commercial catch across the Region's four main fishery types (Figure 5.13). Overharvesting can cause population declines. Potential flow-on effects of extraction include damage to other particle feeders, such as sponges, and changes to other ecosystem processes (for example, to predation through changed feeding opportunities).[176] The 2012 ecological risk assessment for the East Coast Otter Trawl Fishery assessed trawling as generally low risk for non-target particle feeders at the Reef scale.[176]

In addition to extracting retained catch, fishing also causes death, injury and stress of **discarded species**. For example, post-trawl survival analysis for two small elasmobranch (shark and ray) species caught incidentally in the Region's prawn fisheries found lowered survival with increased time on deck and differences in capture and release resilience.[979] Preliminary analysis for the Region in the 2009 Outlook Report suggested non-retained catch (discards and bycatch) by commercial fisheries is likely to be significantly higher than the retained catch, with the trawl fishery responsible for most of the non-retained catch.[1] Discards from the Queensland East Coast Otter Trawl Fishery declined by around one third between 1988 and 2014. However, this decrease was primarily due to concurrent reductions in fishing effort over this period.[951] Knowledge about the amount of non-retained commercial catch in the Reef has not improved and uncertainty remains high.

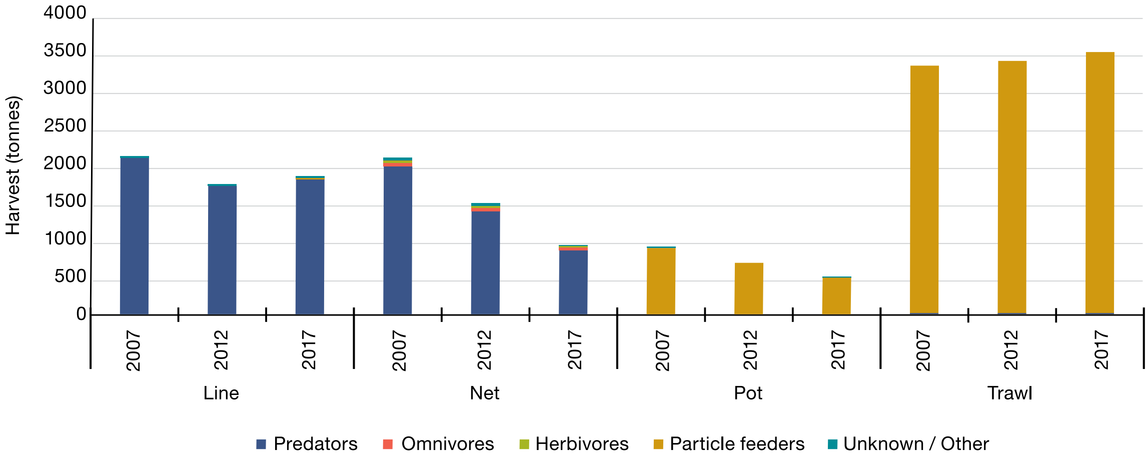


Figure 5.13 Ecological groups retained by major commercial fisheries in the Great Barrier Reef in 2007, 2012 and 2017 *Predators and particle feeders make up the majority of the harvest retained by commercial fishing in the Region. Particle feeders includes species that are primarily filter feeders, detritivores and scavengers. Data are for commercial retained catch only. Discarded catch and bycatch are not included.* Source: Department of Agriculture and Fisheries (Qld) 2019[885]

Table 5.4 Estimated proportion of marine species catch released by recreational fishers in Queensland over a 12-month period

Catch was recorded between 1 November 2013 and 31 October 2014. Source: Department of Agriculture and Fisheries (Qld) 2015[883]

Proportion of catch released (per species)			
0–25 %	25–50 %	51–75 %	76–100 %
• Garfish • Herring and pilchard • Mullet • Prawn • Yabby (marine)	• Cobia • Coral trout • Finfish (other) • Mackerel • Parrotfish • Tailor • Threadfin and Australian salmon • Whiting	• Bream • Emperor • Flathead • Javelin • Jewfish • Pearl perch • Pike • Morwong and sweetlip • Snapper • Trevally and amberjack • Tropical snapper and sea perch • Wrasse	• Barramundi • Catfish • Cod and Queensland grouper • Crab • Shark and ray • Non-fish (marine reptiles)

Recreational fishers generally release a significant proportion of their catch due to catch-and-release practices or the catch being undesirable, too small or outside the legal size limit. For a large number of species, more than half of the catch is released (Table 5.4). Sharks and rays are not generally targeted by recreational fishers; an estimated 90 per cent are released because they are unwanted.[883] Catch-and-release practices presume the fish is likely to resume normal behaviour and survive.[984] However, stress or injury from fishing interactions can lead to post-release mortality and behavioural impairments can increase the released fish's susceptibility to predation.[985] Recreational fishing can be a significant pressure on coastal fish stocks, with recreational harvest exceeding commercial harvest for some species.[883,986]

Incidental capture, entanglement and death of **species of conservation concern** as a result of commercial fishing continues to have a major ecological impact on the Region's values. It is important to consider the interactions additively across multiple fisheries.[340] For species of conservation concern, such as inshore dolphins, dugongs, sawfishes and some marine turtles, loss of even small numbers of individuals may have a substantial effect on population status, resilience and rate of recovery from past impacts.[292,308,401,404,987] Despite mandatory reporting of these incidents, many interactions go unreported, so the magnitude of the impact is underestimated.[988]

Fish **spawning aggregations** are recognised as a natural phenomenon that contributes to the Reef's outstanding universal value.[307] They are protected to some extent by the current zoning arrangements. However, other than for barramundi, spawning aggregations of inshore species (for example, golden snapper and black jewfish) are not protected by seasonal closure periods. Loss of fish spawning aggregations leads to declines in fish populations through reduced recruitment, with negative ecological consequences.[989]

Physical damage to the seabed and reef habitats occurs as a result of some fishing activities. Line fishing gear can cause direct physical damage to live coral tissue and coral colonies, and contribute to increased coral disease.[990] Physical damage to reefs and shoals can be caused by the grounding (and in some cases sinking) of commercial and recreational fishing vessels in the Region (Figure 5.18). Use of electric outboard motors with automatic positioning system capability (an alternative to physical anchoring) in the commercial and recreational fishing sectors is estimated to have risen since 2014, based on anecdotal reports. Trawling has physical impacts on habitats in the Region and can remove or damage seabed plants and animals. While risk for seabed biodiversity has been reduced by trawl management actions[114], some concerns remain. For example, an area in the southern Reef has been identified as being among the national hotspots for risk from trawling and is the area at highest potential risk within the Region.[110,894] High trawling effort levels and a poor understanding of the habitat in this area contribute to the risk. At-risk long-lived deep-water elasmobranch species are known to occur in this area, and to be taken and killed in trawl bycatch.[147] Further information on the risk to these species is needed.[147] The impacts of trawling on upper continental slope habitats must also be better understood.

Discarded fishing line and loss of fishing gear contributes to **marine debris** (Section 6.5.1), causing entanglement and ingestion by marine species.[337,991]

Illegal recreational fishing in the Region is of increasing concern. The number of reported offences has averaged around 500 each year since 2012–13, with a trend of gradual increase to the 653 reported offences in 2017–18. Illegal recreational fishing accounts for approximately 55 per cent of the 1189 fishing and non-fishing possible offences reported in 2017–18.[868] The increasing trend in non-compliance reports may reflect improved surveillance efforts and technologies, such as new high-speed patrol vessels armed with technology for detection at night. Rate of change in recreational fishing effort (and therefore, likelihood of offences) is not well known, but is generally expected to correlate with population growth in the Catchment and long-term increases in recreational vessel registrations (Section 5.5.1).

Understanding of the spatial and behavioural patterns of fishers is growing, and indicates poaching is more likely to occur at some locations than others.[992,993,994] In 2017, 50 per cent of all reported poaching occurred in just ten no-take zones.[993] Similarly, over the period 2010 to 2018 most poaching in no-take zones was concentrated in just 20 per cent of those zones.[993] Reported offences tended to occur in no-take zones that also attracted high levels of legitimate activity, a finding that provides insight into the opportunity factors that increase the risk of poaching.[993]

While the majority of recreational fishers consider poaching to be personally and socially unacceptable[995], the use of different social survey techniques has found that between three and 18 per cent of recreational fishers will admit to having fished in no-take Marine Park zones during the past year.[992,996] In the Palm Island and Whitsundays areas, accumulation rates of derelict fishing gear entangled on reefs suggests some no-take zones are subject to levels of fishing pressure similar to those in areas legally open to fishing.[992] Even low levels of poaching can have substantial impacts on fish populations and ecosystem health.[297,997]

The number of **commercial fishing offences** in the Region has fluctuated but shows a declining trend over recent years — from almost 100 reported in 2014–15 to around 40 in 2017–18. Commercial line fishing offences, including fishing dories unattached from their primary vessel in no-take zones, were the most frequent non-compliant activity over that period (despite considerable variability between years). Offences in other commercial fisheries are generally less frequent and include illegal activity in the net, trawl, crab, lobster and coral fisheries. Some commercial and recreational fishers employ counter-surveillance tactics to avoid detection of their illegal activity. Therefore, the actual extent of illegal fishing by both sectors is considered to be much greater than the number of detected offences suggest. The expansion of commercial fishing vessel tracking under the *Queensland Sustainable Fishing Strategy 2017–2027* to include line, net and crab fisheries from 1 January 2019 and all fisheries by the end of 2020 (Box 7) is expected to substantially improve commercial fishing compliance rates and the efficiency and efficacy of the multi-agency surveillance program.

BOX 7

Expanding use of vessel tracking technology in fisheries management

No-take zones offer a range of benefits (Section 7.3.3 Box 11), including rebuilding of depleted fish populations[998] and faster recovery of fish and coral communities following cyclones and coral bleaching.[756] However, many commercial, charter and recreational fishers continue to operate in contravention of the *Great Barrier Reef Zoning Plan 2003* (for example, fishing illegally). Given cumulative pressures are affecting the Reef's resilience, the benefits of protecting no-take zones by enhancing compliance are now more important than ever.

Electronic vessel tracking (also known as vessel monitoring systems or VMS) has been widely adopted in Australia and around the world, and is used very successfully as a means to monitor commercial fishing vessel activity. The vessel tracking units fitted to vessels transmit regular positional information via a satellite network to a computer system. The positional information can then be displayed and analysed.

Vessel tracking became mandatory in the Queensland East Coast Otter Trawl fishery in 2001. Monitoring and analysis of vessel tracking data led to a number of successful prosecutions and significantly reduced the number of instances of vessels fishing within no-take zones. The *Queensland Sustainable Fisheries Strategy 2017–2027* was released in June 2017. Its reform commitments included an expansion of vessel tracking to all commercial fisheries by 2020, including installing vessel tracking units in the net, line and crab fisheries (including tenders and dories) by the end of 2018.[892] Implementing this component of the strategy led to a legal requirement for vessel tracking in these fisheries coming into effect on 1 January 2019.[999] Improved compliance with Marine Park zoning is expected as a result.

5.5 Recreation (not including fishing)

5.5.1 Current condition and trends of recreation

The Reef is vital to the wellbeing of Queensland's coastal communities[1000,1001] and an important contributor to the wellbeing of other Australians[843] and the broader international community. Aside from commercial operations and tourism, people use the Region for a wide range of recreational activities, including relaxation, stress reduction through access to natural settings, and exercise through snorkelling, boating and diving (Figure 5.14). The benefits recreational users derive from the Region are a critical part of their lifestyle and, as a result, many local residents are attached to, and depend on, the Reef.[783,851]

Recreational use continues to grow in the Region

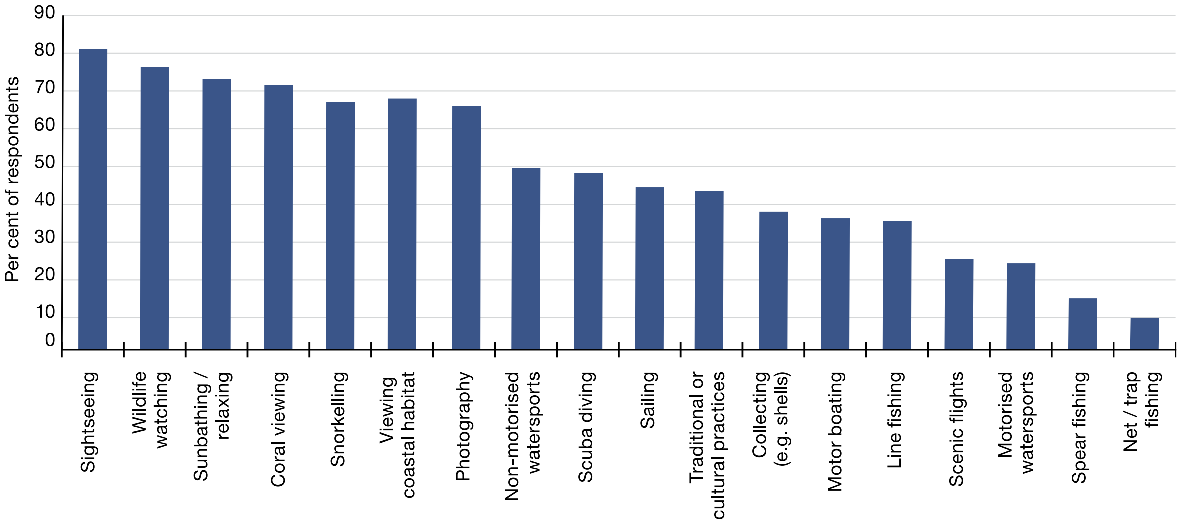


Figure 5.14 The most important activities contributing to coastal residents' use and enjoyment of the Region
Responses from 1933 residents. Activities were not rated exclusively. Source: Marshall *et al.* 2019[785]

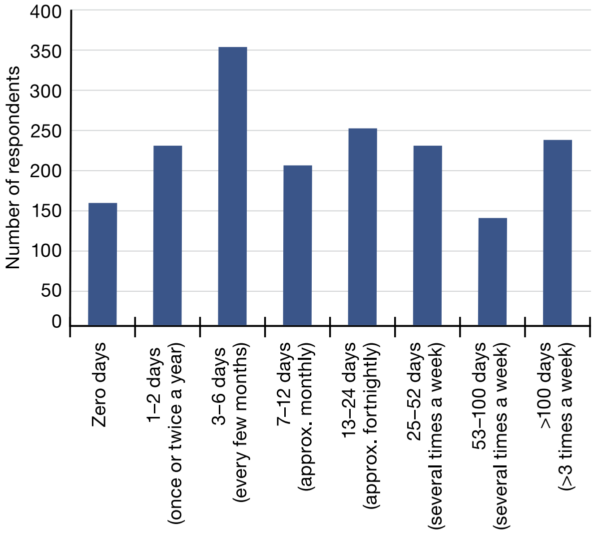


Figure 5.15 Number of days residents visited the Reef in a 12-month period
Responses from 1933 residents. Source: Marshall *et al.* 2019[785]

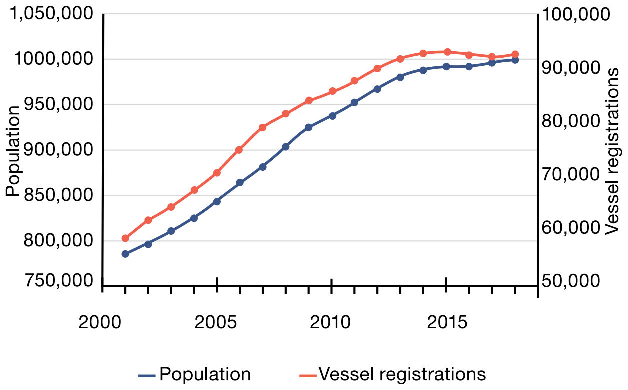


Figure 5.16 Number of recreational vessels registered and population in the Catchment, 2001–2018
Source: Department of Transport and Main Roads (Qld) 2018[1004], Queensland Government Statistician's Office 2018[1005], adopted from Hughes *et al.* 2015[1006]

The Reef is an extremely well-accessed resource. Local residents spend a significant portion of their leisure time along the Reef coastline, primarily along its beaches.[785] In 2013, over 40 per cent of local residents (from 3181 residents surveyed) indicated that they lived in the Catchment because of the Reef.[851]

Residents of the Region spend from one to more than 100 days on the Reef per year, with short multi-day trips being the most common (Figure 5.15).[785] People mostly travel less than 10 kilometres from land to access the Reef (39 per cent), while 32 per cent of people travel 10–50 kilometres.[785] Residents have high aspirations to protect the Reef and would like to do more to protect it (such as improving water quality). But they felt their capacity to do so was low to moderate because they lacked the necessary knowledge, skills, time and/or opportunity.[785]

Infrastructure supports managed recreational access to islands in the Region.
© Matt Curnock

Population growth and economic development will increase the demand for recreational activities within the Region (Section 6.2).[1002] The Queensland coastal population is growing rapidly, with the state population expected to nearly double from 4.7 million (in 2015) to 8.2 million by 2050.[1003] The number of recreational vessel registrations in 2014–2018 is the highest recorded (Figure 5.16).

Management A number of Australian and Queensland government agencies are responsible for managing recreational use. Recreational use (not including fishing) is one of the major direct uses in the Region.[1007] Recreational activities can be undertaken in almost all parts of the Region; exceptions are the Preservation Zones (which cover less than two per cent of the Marine Park), and Restricted Access Areas.

The Zoning Plan and plans of management (for the Cairns, Hinchinbrook and Whitsundays areas) help to manage multiple uses. These management tools aim to protect the environment while providing for a range of uses, particularly in high-use areas. The plans of management cap the number of tourism operations and define maximum group and vessel sizes at specific locations, and where motorised water-sports can take place. These approaches were developed in part to better provide for recreational use in these areas.

Since 2014, management initiatives have increased the number of reef protection markers (which show no-anchoring areas) and public access moorings in the Region (Figure 5.17). These management initiatives continue to protect coral communities under threat from recreational boating damage by raising awareness and influencing the distribution of recreational activities within the Region.

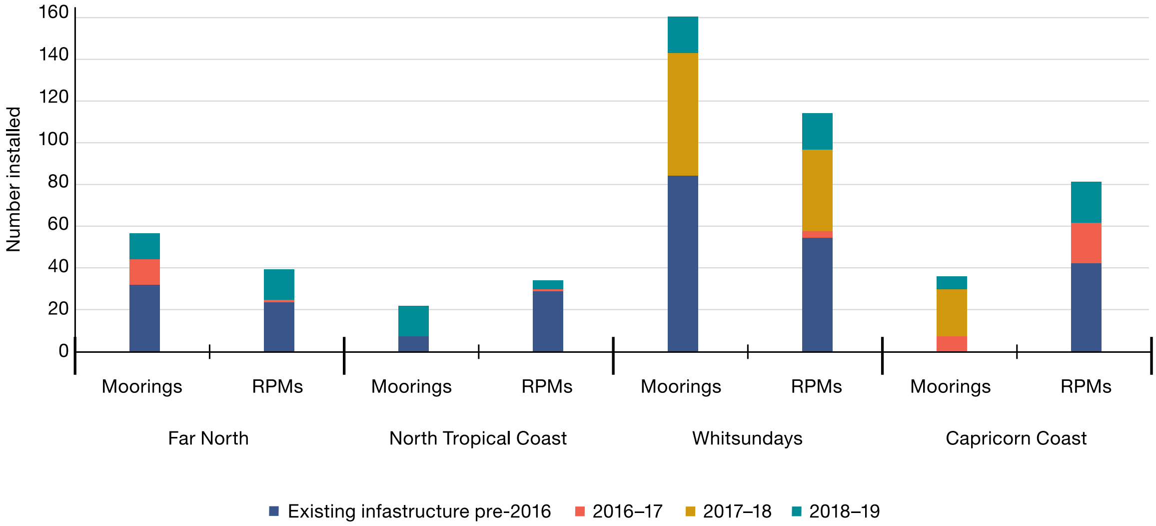


Figure 5.17 Investment in reef protection markers (RPMs) and public moorings within the Region, 2016–17 to 2018–19
Source: Queensland Parks and Wildlife Service 2019[1008]

In 2017, local residents were moderately confident in, and supportive of, Reef management approaches (48 per cent). They were also generally supportive of the rules, regulations and governance in place[785], although less so than in 2013.[1009] Only 24 per cent of local residents in 2017 believed that enough was being done to effectively manage the Reef.[785] Twenty-seven per cent of residents felt that they did not have fair access to the Reef compared with other user groups. Only about one third of residents felt that future generations had been adequately considered in the management of the Reef.[785]

5.5.2 Benefits of recreation

Residents feel the Reef contributes to their quality of life and wellbeing

The Reef provides constantly evolving opportunities for people to engage with it. This allows them to develop a sense of identity based on living within the Region, pride in the World Heritage Area and an appreciation of its outstanding natural beauty and biodiversity. The recreational and lifestyle opportunities provided, mean that people develop a distinct culture that depends on the Reef.[783] This cultural relationship defines who they are as a community and provides a day-to-day sense of meaning and feeling of belonging, which are critical for emotional and mental wellbeing.[852] Survey results suggest that the cultural value of the Reef has significantly increased for residents since 2013 despite the loss of corals from climate change.[1009]

Recreational activities support an active way of life and wellbeing.
© Ross Miller 2019

The Reef's outstanding universal value, encapsulated by its biophysical and natural heritage value, is one of the primary reasons why people visit the Reef for recreational purposes. As well as being a key part of people's identity in the Region and more broadly, as an Australian, the Reef is woven into the society of coastal communities and generates significant regional economic value.[783] Economic value of the Reef was the most important value identified by residents in 2017.[1009] Quantifying and monitoring recreational use of the Reef in terms of numbers of people and locations is difficult, although it was estimated that the Reef received 3.9 million visits in 2016.[846] Gaps remain in our understanding of trends and locations of recreational use in the Region.

In 2017, 81 per cent of residents stated that the Reef contributed to their quality of life and wellbeing, and the majority loved that they live beside the Reef. However, only 48 per cent were optimistic about its future.[785] Declines in Reef condition are interlinked with human wellbeing.[843,850,1010] Most users have a strong positive association with the Region believing that the Reef makes them feel better physically and/or mentally.[785] Conversely, depression and anxiety are feelings that have been linked to environmental decline.[1011] The Reef is highly valued by residents of the Region for its beauty, the seafood and lifestyle it provides, and by Traditional Owners for its rich Indigenous heritage and spiritual importance.

In 2015–16, recreational activities (including recreational fishing) was one of the prominent direct uses of the Region, generating $346 million (value-added) to the Australian economy, a 41 per cent increase on the $244 million (value-added) estimate for these activities in 2011–12 (Section 5.1 Table 5.2).[846] In Australia, recreational activities generated the equivalent of 3200 full-time jobs, approximately 20 per cent higher than the 2011–12 estimate of 2700.[846] The greatest contribution associated with recreational activity is attributed to expenditure on equipment, including the purchase of boats and repair of recreational equipment.

Recreational users contribute to the long-term protection and management of the Region's values by collecting valuable information on Reef condition, marine animals and incidents through programs, such as Eye on the Reef, Reef Guardians and the Strandings Hotline. These community-based programs are built to empower people to understand trends in condition and reduce threats to the Region. For example, more then 4000 people were involved in the marine debris project between 2014 and 2016.[316]

5.5.3 Impacts of recreation

Most recreational impacts are concentrated around major population centres

Few studies have investigated the impact of recreational uses (excluding fishing) on the Region, probably because it is not regulated by any permit system and recreational users can be transient. Recreational uses can affect the Reef through direct localised impacts, such as **anchor damage**, litter, vessel groundings, handling marine organisms (such as sea stars), **boat strikes** on marine organisms, **disturbance of shipwrecks** and other heritage sites, disturbance by personal drones of wildlife and human enjoyment[1012], **damage to corals** from snorkelling and diving fins, and negative **interactions between different users** especially in relation to vessel, speed and noise (for example, jet skis).[785,1007,1013] Indirect impacts include encroachment of structures on the Region, such as those that provide access and facilities for recreational users (for example, boat ramps and moorings). Most impacts are minimal and concentrated around major population centres. However, given the sheer number of recreational users in the Region, the cumulative effect of many small impacts concentrated in certain areas can be significant.

Recreational activity in the Marine Park can be influenced by the state of the ecosystem, weather, water quality, access, socio-demographic factors, visual amenity, social interaction, and health and wellbeing of individuals.[843,1014] The current and future implications of climate change, poor water quality and coastal development on the values of the Reef are key sources of uncertainty and community concern.[843] In 2017, residents' knowledge of the current ecological predicament of the Reef was higher than in 2013, with residents' understanding of climate change increasing from 53 per cent in 2013 to 68 per cent in 2017.[1009]

Underwater reefscape view of diver on Patches 3 Reef.
© Matt Curnock 2018

Impacts from recreational users are predominantly managed by public education and public infrastructure, such as signage. Because of the vast size of the Marine Park, management focuses heavily on ensuring users are aware of the impacts of their activities, thereby fostering self-management. Providing information about threats caused by recreational activities, and how they can be managed, plays a major part in managing recreational use and encouraging stewardship through responsible reef practices. Well-known avenues for providing information include zoning maps, mobile phone apps and signage.

Recreational users may interrupt the connection Traditional Owners have to their sea country by **removing or damaging significant artefacts** or sites of cultural significance (whether intentional or unintentional).[1007] High recreational use in culturally significant areas can also displace Traditional Owners by preventing them from accessing these sites and practising their culture (Chapter 9).

Damage to the environment from tourism, commercial fishing and recreational vessels does occur in the Region due to accidental **groundings**, human error and severe weather. The number of incidents from tourism and recreational vessels are likely to rise with increasing visitation. From 2013 to 2018, recreational vessel groundings were more common than either tourism or commercial fishing vessel groundings (Figure 5.18). The spike in recreational vessel incidents in 2017 is probably due to cyclone Debbie resulting in vessels being washed up on nearby islands, fringing reefs and the coast. It is assumed that the number of incidents occurring in the Region are higher than what is reported to managing agencies.

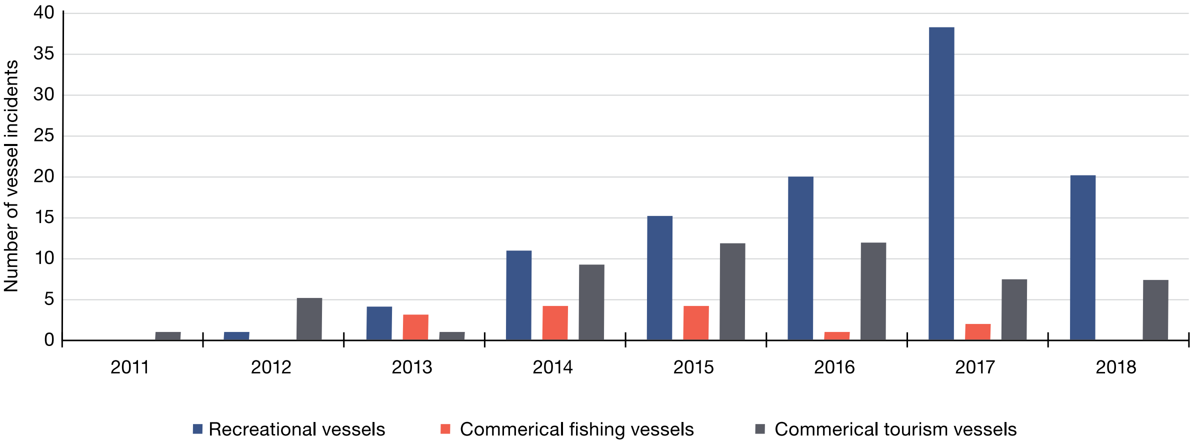


Figure 5.18 Number of groundings of recreational, commercial fishing and commercial tourism vessels in the Marine Park, 2011–2018
Recreational vessels include recreational yacht, sail and powerboats. Commercial fishing vessels include foreign fishing vessels. Commercial tourism vessels include tourist and charter vessels. It is unknown how many recreational vessels are active in the Region per day or year. These groundings are only a small proportion of the total vessels that operate in the Marine Park on any given day. Total vessel registration numbers for Queensland are shown in Figure 5.16. Source: GBRMPA 2019[1015]

The majority of vessel access to the Region is via public launch facilities (such as boat ramps) maintained by local and state governments. Construction and maintenance of launch facilities can directly affect the Region through clearing of coastal habitats, dredging and disposal (capital and maintenance). Encroachment of permanent human-made structures in the marine environment can also affect the aesthetic value of the area. Up-to-date data are lacking on the extent of this infrastructure (within or adjacent to the Region) and its impact on the Region. Infrastructure continues to be upgraded, and new infrastructure built, to keep up with demand for this ongoing direct use of the Region.

Introduced species, including weeds, marine pests or feral animals brought into the Region by recreational users, pose a threat to the Region (Section 3.6.3). For example, international yachts entering the Region are a high-risk vector. Other disturbances from recreational use include oil and chemical spills, sewage discharge and disturbance of wildlife, particularly on beaches and islands.[1007]

5.6 Research and educational activities

5.6.1 Current condition and trends of research and educational activities

The Region is highly valued for research and educational activities

The Reef is of strong scientific interest due to its high biological and ecological diversity, geomorphology, and Indigenous heritage value and social value. Scientific research has made, and continues to make, a critical contribution to the way the Region is understood, managed and used.[2,6,24]

Research on reef restoration and adaptation has increased rapidly since 2014 and will continue to grow. Interest has increased in undertaking localised pilot studies for restoration activities based on techniques used internationally.[1016] For example, some non-profit organisations and tourism operators are investing in coral nursery and propagation studies in an effort to help high-value tourism sites recover from tropical cyclone damage and recent mass coral bleaching events. The response of coral reefs to climate change has continued to be an important area of active research, its pertinence highlighted by the significant temperature-related damage to coral reef habitat across much of the Region in the summers of 2015–16 and 2016–17. It has generated new insights into the relationship between heat exposure, bleaching and coral mortality, as well as shifts in coral assemblages and the resilience of recruitment processes.[88,91,96,141,501]

A network of six island research stations located at Lizard Island, Low Isles, Green Island, Orpheus Island, Heron Island and One Tree Island continue to be integral to the conduct of research activities on the Reef. Scientific Research Zones around these stations are intended to provide areas for research and education, generally free from extractive activities of other users.

The majority of permitted educational activities are focused on learning about the natural and cultural values within the Marine Park and associated field research methodologies. These educational programs are generally based at the island research stations; more than 60 per cent of the education permits issued between July 2014 and March 2018 were for education classes visiting the Heron Island Research Station.[1017] Permitted educational activities also include courses for recreation or professional activities, such as sail training or occupational dive certification.[1018]

Management The Zoning Plan and the Marine Park regulations set out the way in which research and educational activities are managed. Limited impact research may be conducted by accredited research institutions in accordance with the zoning plan and the Marine Park regulations. All other research and educational activities are managed through permits issued jointly by the Marine Park Authority and the Queensland Parks and Wildlife Service.[1018] The *Guidelines for Managing Research in the Great Barrier Reef Marine Park*[1019] complement the statutory framework by providing further definitions, examples and best environmental practice guidance for researchers, particularly when conducting extractive research. Additional guidance (developed in the last few years) is provided by the *Guidelines: Permit applications for restoration/adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park*.[24,1020]

Scientific monitoring and question-driven research for key processes, habitats, species and use patterns, particularly when maintained long-term, enable early detection of trends and changes in a range of the Reef's values and factors affecting them. The *Reef 2050 Integrated Monitoring and Reporting Program*[1021] is being developed to inform management of the Reef and to track the progress of the Australian and Queensland governments' long-term plan (Reef 2050 Plan) to protect the Reef (Section 7.4.3 and Section 10.3 Box 16). This initiative will help refine existing monitoring and research and improve adaptive management.

5.6.2 Benefits of research and educational activities

Research and monitoring of the Reef contribute to global knowledge about individual species, coral reef systems and tropical marine ecology. For example, research within the Region has contributed significantly to climate change science, including advancing understanding of the resilience and adaptation potential of habitats, species and human communities.[163,219,501,850,1022,1023,1024,1025] Improved understanding of the Region's values and how components interact and respond to changing conditions contributes to its protection and management.

Research underpins management of the Region and has economic, social and cultural benefits

Targeted and applied research provides information that helps managers assess the outcomes of various management initiatives, including the effectiveness and potential impacts of innovative reef intervention actions. A significant policy shift is being progressed in terms of increasing use of deliberate and pro-active intervention approaches to restoration and adaptation, rather than relying solely on supporting a resilient ecosystem and allowing natural recovery after disturbance.[24,1020] The first phase of a multi-agency reef restoration and adaptation research and development program, led by the Australian Institute of Marine Science, is underway.[1026] The program aims to investigate options to support the Reef using cost-effective and scalable prevention and repair interventions, including both engineering and biological approaches.

Knowledge derived from research related to the Region also supports management in many other ways, including advancing understanding of resilience components and cumulative impacts, refining modelling used to predict Reef processes (including hydrodynamics and biogeochemistry), and improving efficiency and effectiveness of crown-of-thorns starfish control measures.[88,423,757,758,1027,1028,1029,1030]

A range of academic institutions and government agencies undertake research on the Reef, providing income and employment in regional communities. A recent study suggested scientific research and Reef management was worth an estimated $182 million to the Australian economy in 2015–16.[846] This represents a doubling in both value-added economic contributions and full-time employment in this sector since 2011–12 (Section 5.1 Table 5.2).

5.6.3 Impacts of research and educational activities

Research and educational activities can affect ecosystem and heritage values. These impacts are generally minor or locally constrained, given current management arrangements. Little is known about the cumulative impacts of research and educational activities undertaken in the Region. 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. Over 70 per cent of all research permits granted between July 2014 and January 2018 include access to at least one of the Scientific Research Zones, with the majority of these programs basing their fieldwork at Lizard Island, Orpheus Island or Heron Island research station.[1017] Impacts are managed, in part, through the local management of research station directors. Directors have the mandate to influence the spread of activities in space and time so as to reduce conflicts and minimise local depletion. The Marine Park Authority's new online reporting portal has improved access to information on permitted research take (for example, numbers of specimens collected).

Research and educational activities are often concentrated around research stations

5.7 Ports

Twelve ports are located in the Region (Figure 5.20) and are within the World Heritage Area. Of these, only the ports of Cooktown and Quintell Beach in Cape York are located wholly within the Marine Park (Box 8). Port development can be described as in-water areas (maritime port infrastructure) or areas above low water mark (land-based port infrastructure). While port activities will continue to have localised adverse impacts on the marine environment, changes to the regulatory framework have reduced the potential for impacts from capital dredging and associated disposal of dredge material in the Region. These regulatory changes, in conjunction with a cooperative approach to managing the impacts of port development and changed market conditions, have seen a reduction in maritime port development activities (in-water areas) since 2014.

Ports form an integral part of the maritime supply chain supporting industries, trade and local communities. Maritime port infrastructure, including shipping lanes, channels and berths, are critical to the ongoing operation of many trade industries. In the same way that roads and rail must be maintained, the upkeep of maritime port infrastructure is essential for the efficient flow of trade.[1031]

BOX 8

What is a port?

The limits of the Region's 12 ports (Figure 5.20) are defined by the *Transport Infrastructure (Ports) Regulation 2016* (Qld). Multiple jurisdictions regulate port operations, making port governance complex. **Port exclusion areas** (operational areas) exclude port areas from the Great Barrier Reef Marine Park. Ten of the 12 ports (all except Cooktown and Quintell Beach) have exclusion areas. The operational areas of the priority ports are located outside the Commonwealth and state marine parks. The ports at Cape Flattery, Lucinda and Port Alma (Rockhampton) have small parts of their operational areas in the state marine park.

Port management involves inter-connected jurisdictions, each with their own definitions and key concepts. Four ports are **priority ports** under the *Sustainable Ports Development Act 2015* (Qld) (the Ports Act) — Gladstone, Mackay/Hay Point, Abbot Point and Townsville. The ports of Mackay and Hay Point are referred to as one priority port; the Port of Cairns is not a priority port but is considered under the Ports Act. The **major trading ports** are the ports of Gladstone, Mackay, Hay Point, Abbot Point, Townsville and Cairns. Smaller trading ports are community or **minor ports**.

5.7.1 Current condition and trends of ports

The current condition of ports is measured by the trend in port-related activities that influence the values of the Region (such as dredging and dredge material disposal and the location of that disposal) and the level of activity generated (trade throughput).

Dredging and disposal at ports has a long history, with dredging first occurring at Townsville and Cairns in the early 1880s.[1032] This activity remains an essential operational requirement at all ports in the Region[1033] and is undertaken in two forms: capital and maintenance dredging. Capital dredging creates new, or improves existing, channels and berths to accommodate increased traffic and larger ships (Section 5.8).[1034] In contrast, maintenance dredging involves removing the build-up of mainly fine sediments that accumulate in existing channels and berths.[1035] Once marine sediments are dredged, the material is either disposed of at sea in offshore disposal areas or beneficially reused (for example, in land reclamation, beach nourishment or restoration purposes).[1036]

The volume of sea disposal of capital dredge material across the ports in the World Heritage Area has reduced significantly since the last Outlook Report (Figure 5.19). In 2013, the annual combined capital and maintenance dredge material disposed of in the World Heritage Area was about 1.7 million cubic metres. At that time, a further 30+ million cubic metres was proposed for marine disposal.[2] However, limited sea disposal of capital dredge material has actually occurred since 2013. The average annual total for combined capital and maintenance dredging disposal in the World Heritage Area was 1.5 million cubic metres for 2013 to 2016.

All ports require maintenance dredging. However, some ports have greater maintenance dredging requirements as a result of local port characteristics (for example, a shallow harbour). The ports of Cairns and Townsville are both shallow harbours, and have higher levels of sedimentation due to natural sediment transportation and coastal storm events.[1034] Maintenance dredging across the Region was limited in 2015 and 2016; some maintenance dredging occurred in Cairns, Townsville and Gladstone between 2014 and 2017 (Figure 5.20).

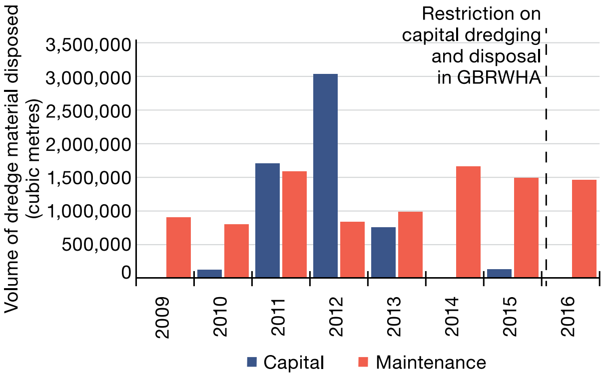
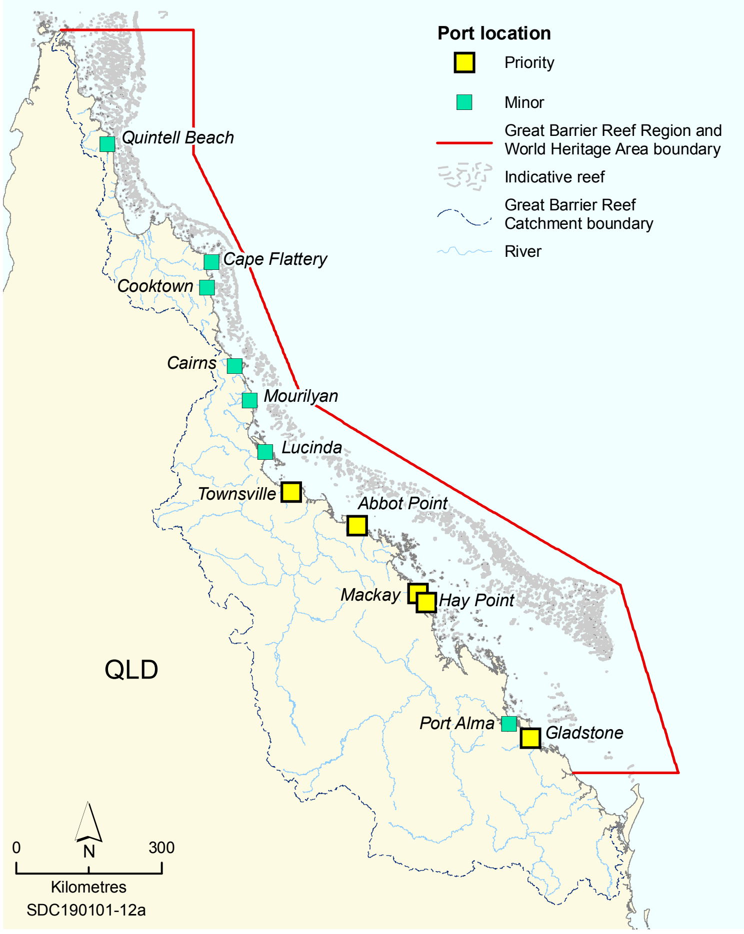


Figure 5.19 Dredge material disposal (capital and maintenance) in the Great Barrier Reef World Heritage Area, 2009 to 2016
The data shown include permitted works issued under the Environment Protection (Sea Dumping) Act 1981 (Cth) and do not include dredge campaigns in internal waters. Ports are the largest contributors; smaller volumes originate from other marine access facilities. Disposal within port limits (including port exclusion areas) is included. Commonwealth and Queensland regulatory changes in 2015 combined to impose restrictions on capital dredging and disposal in the World Heritage Area. The data inform annual reports to the International Maritime Organization[1037].
Source: Department of Environment and Energy 2018[1038]

Aerial view of the Port of Townsville and the Ross River.
© Matt Curnock 2019



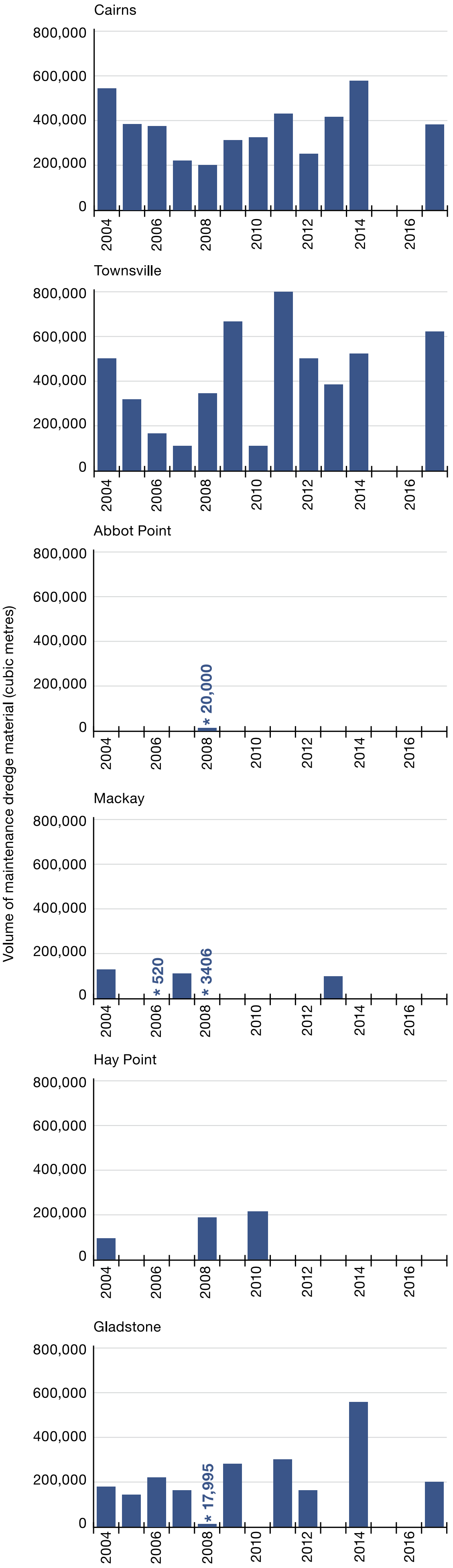


Figure 5.20 Maintenance dredge volumes in the Great Barrier Reef World Heritage Area, 2004 to 2017

The map shows the 12 ports in the Region. The graphs show volumes of material dredged for maintenance purposes at the six major trading ports. Asterisks with numbers are used to show data when bars are small and difficult to discern. Source: Department of Transport and Main Roads 2018[1034], Queensland Ports Association 2017[1039] and 2018[1040]

Port of Townsville receiving a ship for unloading. © GBRMPA

Approved sea disposal areas (or dredge material placement areas) offshore from ports in the Region cover approximately 66 square kilometres (or less than 0.02 per cent of the Region). About half of these areas are in the Marine Park (that is, adjacent to the ports of Cooktown, Cairns, Abbot Point and Hay Point) and include sea disposal areas located near the marine access facilities at Port Douglas and Rosslyn Bay. Since 2014, only maintenance dredge material has been relocated to these sea disposal areas. While some data are available (mainly in reports associated with statutory environmental impact assessments), condition and trend data on the retentive capacity and impacts on adjacent habitats are not collected and collated across all ports in the Region.

Since 2014, sea disposal of capital dredge material has been reduced

Land reclamation occurs when an area is restricted from tidal influence and converted into land above the high water mark. While land reclamation has occurred in the Region since European settlement for port and other purposes, the extent is difficult to quantify. A reclamation area can be filled with dredged material or other fill. It is not known how much dredge material from the Region's 12 ports has been disposed on land or used beneficially (for beach nourishment or environmental restoration purposes) since 2014.

Management Before 2014, port development and operations in the Region were in the national and international spotlight, with the UNESCO World Heritage Committee recommending threats from ports be avoided by prohibiting development within and adjoining the World Heritage Area.[1041] Significant management changes have since taken place, and the effectiveness of these changes is addressed in Chapter 7. In June 2015, the Marine Park regulations were amended to prohibit sea disposal (greater than 15,000 cubic metres) of capital dredge material in the Marine Park. Also, in November 2015, the Queensland Government enacted the *Sustainable Ports Development Act 2015* (Qld) (the Ports Act) to provide for the protection of the World Heritage Area through managing port-related development in and adjacent to the area.[1041,1042] The Ports Act applies to all 12 ports in the Region; it prohibits sea disposal of capital dredge material and restricts capital dredging in the World Heritage Area, subject to exceptions.

Priority port master planning is also a substantial management initiative under the Ports Act. The master plan for the Port of Gladstone was the first to be released in late 2018. It provides strategic direction for future development, including widening and deepening of shipping channels.[1043] The Port of Townsville released its draft master plan in late 2018.[1044] In 2016, the Queensland Government adopted the *Maintenance Dredging Strategy for Great Barrier Reef World Heritage Area Ports*[1034], which sets out a framework to monitor maintenance dredging and disposal volumes at all ports.

Regulatory controls provide avoidance and mitigation measures to reduce the scale of impacts from dredging, disposal and sedimentation. Managers also apply mitigation measures, such as environmental windows (periods of go-slow or, in some cases, no dredging).[1045] Such measures aim to minimise impacts during periods of coral spawning, seagrass recruitment[1046], and turtle breeding, and immediately following severe weather events.[1034,1047]

5.7.2 Benefits of ports

Combined trade throughput at the priority ports exceeded 262 million tonnes in 2016–17

Ports provide critical support services and help maintain and grow the economy. Ports enable the export of agricultural and mineral commodities and the import of goods, such as fuel, cars and household items that support regional communities. Combined trade throughput at the priority ports in the Region (Townsville, Abbot Point, Hay Point/Mackay and Gladstone) exceeded 262 million tonnes in 2016–17. This trade represents a 3.4 per cent decrease from the previous year.[1048] The Port of Gladstone experienced steady growth since 2014 (3.6 per cent), exceeding 120 million tonnes of total trade throughput in 2016–17. In the same period, the steepest decline in total trade throughput was observed at the Port of Townsville (about 25 per cent reduction).

Historical growth in throughput and marine access at ports (including cruise ships and defence vessels) helped drive the Queensland economy and led to the development and growth of adjacent towns. This growth has increased the demand for goods, employment and infrastructure to service the expanding population.[1049] While comprehensive data on direct and indirect employment across all ports in the Region are not available, in 2016–17 it was estimated that the priority ports generated employment of 960 full-time equivalent jobs. This number represents a 0.6 per cent increase from the previous year.[1048,1050]

James Cook University's Seagrass Ecology Group at Abbot Point conducting annual seagrass monitoring funded by North Queensland Bulk Ports. © JCU Seagrass Ecology Group, Cairns

A further indicator of the economic stimulus generated by ports is the scale of capital works they undertake. Across the priority ports since 2014, such works include:

- Townsville — construction of the $40.7 million Berth 4 upgrade project, completed in early 2018[1051]
- Gladstone — completion of the $29.5 million Stage 1A East Shores precinct in 2014, with Stage 1B expected to begin in 2019.[1052]

Ports sustain jobs indirectly through ongoing industrialisation and commerce in their local communities, sometimes reaching well beyond the local area of the port. Between 2011 and 2016, the greatest population increases adjacent to priority ports were in Townsville and Gladstone, which grew by about seven and four per cent, respectively.[1053,1054] Economic prosperity in the catchments' surrounding ports has driven the development of other support infrastructure, such as railways, roads and power networks.

The contribution made by ports towards long-term monitoring programs for seagrass, coral, benthic communities and water quality, provides a benefit by expanding the scientific knowledge of the Region. Recognition and partnerships with Traditional Owners has also improved in some locations.[1055]

5.7.3 Impacts of ports

The operation and expansion of ports exert a mix of pressures on the environment.[1056] These pressures range from direct removal of habitat (by dredging the seafloor) through to indirect environmental impacts, such as intermittent noise pollution (from a concentration of ships, dredging, pile driving or constructing revetment walls). Dust, cargo and pollutant spills, and light pollution from port infrastructure can all affect the marine environment and are monitored and managed within port areas.

Impacts from ports are generally localised

Dredging activities (**dredging** and **disposal of dredge material**) affect the values of the Region. Disposal of capital dredge material at sea is an activity with potential to harm the marine environment.[1032] However, regulatory changes since 2014 have reduced current direct threats associated with this activity (Sections 5.7 and 7.3.4). Limited capital dredging may still be permitted at priority ports in some circumstances, and small-scale capital dredge disposal (up to 15,000 cubic metres) can be dumped in the Region.[1057] Further, sea disposal of maintenance dredge material and reclamation remain activities that can be permitted.

The intensity of impacts from dredging and disposal are affected by: the type of dredging undertaken (capital or maintenance); the volume of material dredged or dumped; local sediment and benthic characteristics (such as the depth of the harbour); prevailing winds and currents; extreme weather events; and the configuration of port infrastructure. These characteristics can influence the spatial and temporal scale of the impacts. Understanding how these factors interact is key to managing the impacts of maritime port development.

Increased suspended sediment concentrations from dredging activities can have broad impacts: increased turbidity may smother organisms that live on the bottom (such as corals[1058,1059] and seagrasses[60,517]) and reduce light availability.[1060,1061] The effects on mobile species in the marine environment from increased turbidity and reduced light is an ongoing concern.[1047,1062,1063] These effects can occur as a result of active dredging, and also because of natural resuspension of existing sediments over time, which can affect adjacent habitats and species.[1061] In combination, consideration of local environmental conditions[1064], regulations and mitigation measures are intended to reduce the magnitude of impacts from dredging and disposal activities.

In some locations, sea disposal is more viable than land-based disposal.[1065,1066] Factors that contribute to the viability of a dredge material placement area include local hydrodynamics, the retentive nature of the marine environment, distance from sensitive areas, jurisdiction and cost-benefit considerations.[1067] Because sea disposal sites are situated in the active coastal sedimentary system, the material will gradually reassimilate.[1035]

Impacts from dredging are estimated to be localised, with contemporary modelling in Australia suggesting dredge-related turbidity and associated impacts may be restricted to within 0.5 to five kilometres of a dredging site.[1061,1068] Until recently, it has been difficult to identify the origins of suspended sediments present in the Region, such as distinguishing sediments from dredging activities and river inflows (Section 3.2.4)[43,467,473] from background sediments and the influence of local hydrodynamics[1046,1068,1069]. Understanding the relationship is an expanding field.[1035,1070]

Reclamation and land-based disposal are alternatives to sea disposal of dredge material. Environmental impacts will, in the main, be transferred from the marine ecosystem to the land or adjacent waters, or the Catchment. The impacts on the marine environment from land-based disposal of dredge material can be more readily managed, observed and mitigated than the impacts of easily dispersed sediment in the water column.[1032,1065,1071] Associated impacts on intertidal and coastal ecosystems above low water mark are assessed in Section 3.5. Weighing up the degree of impacts from each type of disposal method requires a site-specific assessment.[1070,1071,1072] Land-based disposal is often not the preferred option for disposing of dredge material from port development for a range of reasons. For example the sediment from maintenance dredging is generally too fine or poor in quality for the construction of

Curtis Island, Port of Gladstone. © Aerial Media Gladstone 2019

land.[1032,1067,1073] Fine dredged sediments can also remain highly unstable when on land, potentially re-entering waterways through run-off and seepage through armour walls.[1032,1065,1074] The total extent of reclamation (legacy and current) and land-based disposal across the Region, remains a knowledge gap.

Other impacts, such as heavy metal **contamination**[1075], marine debris and impacts on the Region's aesthetic values can also result from port operations and associated shipping (Section 5.8). Coal and coal seam gas exports have historically been and remain the largest driver of port expansion in the Region. Direct impacts continue to occur from coal dust contamination, which escapes as coal is transferred between train and ship, and large coal rocks dislodged from ships during adverse weather. Hydrocarbon markers from coal have been identified up to 180 metres offshore from Mackay,[1076] with concentrations of coal dust higher in inshore sediments and decreasing offshore.[1075,1077] Coal particles have the potential to affect corals, fishes and seagrasses through light limitation, direct smothering and reduced feeding efficiency.[1078,1079] However, some knowledge gaps remain regarding the effects of coal contamination on marine organisms *in situ*.

Noise pollution can be created by various port activities above and below water. Since 2014, observations have demonstrated that juvenile fishes may suffer lethal impacts from noise pollution associated with port activities, such as pile driving.[1047] **Light pollution** produced by port infrastructure, shipping (Section 5.8), marine tourism (Section 5.2) and coastal development (including island resorts; Section 6.4) can interrupt the navigation ability of marine species and influence ecological processes, such as predation and recruitment.[1080] For example, bright lights can disrupt the sea-finding ability of turtle hatchlings[1081], with glow from port infrastructure on Curtis Island (near Gladstone)[327] potentially affecting turtles some 15 kilometres away.[1081]

Ports are an established use of the Region and, as with any other use, their presence and ongoing operation continue to pose a range of threats to habitats and species. Some impacts associated with the operation of the 12 ports in the Region have been reduced since 2009, while others persist. Of the impacts that remain, some could not be mitigated even with significant additional intervention (for example, effects on aesthetic values or permanent removal of intertidal and inshore marine habitats).

5.8 Shipping

5.8.1 Current condition and trends of shipping

In this report, shipping includes vessels greater than 50 metres in overall length, including cruise ships and large recreational or commercial superyachts. Shipping also includes vessels carrying specialised product regardless of length (for example, oil tankers and chemical or liquefied gas carriers). While cruise ships are a commercial marine tourism use, their size and management are more aligned to shipping in this chapter than commercial marine tourism (Section 5.2). Shipping within Torres Strait, which is outside the Region, does not form part of this assessment, unless relevant to the Region (for example, where ships enter the northern part of the Region).

Given Australia is an island nation, shipping provides a critical servicing role and supports the economy through both imports and exports. Compared with other areas around Australia (and internationally), shipping traffic through the Region is relatively limited. In Singapore, more than 130,000 ships are processed annually[1082], compared to approximately 3000 individual ships that transit the Region annually (Figure 5.22).[1083] Around 11,000 voyages were made through the Region in 2018, with some ships stopping over at major and minor ports.

In 2014, a projected 250 per cent increase in shipping traffic through the Region was predicted to eventuate over the next 20

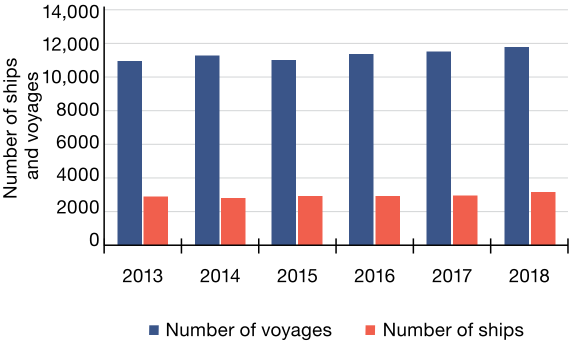


Figure 5.21 Ships visiting the Region, 2013–2018
Total number of ships visiting the Region per calendar year and the total number of voyages made by those ships. The ships include coal carriers, bulk carriers, container carriers, vehicle carriers, general cargo ships, tankers, liquefied natural gas ships, cruise ships and superyachts >50 metres (fishing, other tourism and recreational vessels are not included). Ships using the Great North East Channel are excluded, as these generally cross Torres Strait without entering the Region.
Source: Maritime Safety Queensland 2018[1085]

years. Based on port industry forecasts in 2012, approximately 5800 ships were expected to dock at Reef ports in 2017.[1084] However, Queensland port throughput in 2016–17 had decreased by 0.9 per cent from the previous year, with a 6.3 per cent decrease in coal exports on the previous year.[1048] While the rate of shipping growth projected in 2014 has not eventuated, ship voyages through the Region are slowly increasing (Figure 5.21).[1085,1086]

Ships may transit the Reef using the shallower inner route, or transit around the outer barrier reef using the outer route. In 2014, a two-way shipping route in the Great Barrier Reef and Torres Strait was formalised by the International Maritime Organization to encourage shipping traffic to use established lanes and separate northbound and southbound traffic. Ships that transit the Reef enter using one of six major shipping channels (or passages) (Figure 5.22). The Prince of Wales Channel, which enters at the tip of Cape York, is the busiest, followed by the inner route, which enters to the north of Cooktown.[1085] Fewer ships enter the Reef through the Whitsunday and Grafton passages.

The number of ships entering the Reef through the northern two channels decreased from 2014 to 2017, but increased slightly in 2018 (Figure 5.23). Hydrographers Passage and Palm Passage, offshore Townsville, have seen the greatest increase in shipping traffic since 2013.

The shorter and shallower inner route is favoured by most vessels with shallower draught (less than 12.2 metres) or larger unladen ships returning without cargo, which sit higher in the water.[1089] In the outer route, there is no restriction on the draught of ships (hull depth) as water depth can extend to more than 1000 metres.[134,135] There is a global trend towards longer ships with deeper drafts.[1086] This may result in a net reduction in the number of small ships transiting the inner route of the Region. Since 2013, the average ship length has increased by approximately 20 metres (from 196 metres to 214 metres in 2018).[1085] This will have flow-on effects to shipping lanes and future port infrastructure requirements.[1043,1044] Older vessels, which are more expensive to operate, are being retired.

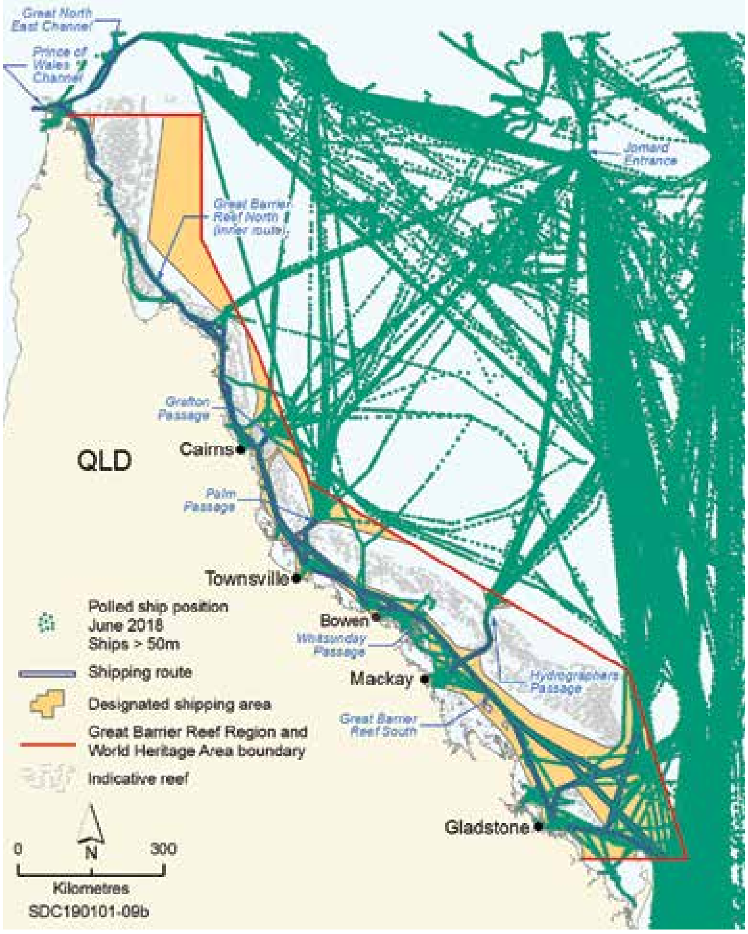


Figure 5.22 Major shipping channels and ship movement patterns over a 30-day period, June 2018
Ship positions (polled by satellite) for the selected period are similar for different times of the year and have been chosen to illustrate general shipping patterns within and outside the Region. Source: Australian Maritime Safety Authority (Cth) 2018.[1087] The data have been used in the Outlook Report with the permission of the Australian Maritime Safety Authority (AMSA). However AMSA have not evaluated the data as altered and incorporated within the Outlook Report, and therefore, gives no warranty regarding its accuracy, completeness, currency or suitability for any particular purpose.

Liquefied natural gas (LNG) production is expected to reach full capacity in 2018–19, which may result in an increase in the size of LNG ships visiting Australia.[1089] In April 2018, the International Maritime Organization adopted an initial strategy to reduce greenhouse gas emissions from international shipping. Under this strategy, international ships are urged to reduce carbon emissions by 40 per cent by 2030 (compared to 2008 emission levels), pursuing efforts towards a 70 per cent reduction by 2050.[1090] In addition, mandatory energy efficiency measures to reduce greenhouse gas emissions have been adopted under international regulations since 2013.[1091] This will mean that ships transiting the Region in future are more energy efficient.

While cruise ships comprise a minor component of the commercial ships transiting the Region, the number visiting the Region has increased gradually since 2015. Cruise ships are getting larger and carrying more passengers. With a cruise ship terminal being developed in Brisbane, growth in traffic along the Region's coastline is expected to increase from 2020.[1086] Cruise ships can transit through the Region via the designated shipping area, and they have the option of port stopovers (Cairns and offshore Whitsundays being the most common) or anchoring within designated cruise ship anchorages. The number of cruise ship bookings to designated anchorages in 2018 exceeded the previous four years and was the second highest on record since the booking system began in 2012 (Figure 5.24). Areas between Townsville and the Whitsundays have consistently received the highest level of cruise ship activity, concentrating around the Whitsundays.

Superyachts greater than 50 metres in length also visit the Region, with the majority being private, high-value luxury vessels rather than commercially operated. Given the size of these vessels, the threats they pose and the management actions applied are similar to other shipping in the Region. Once superyachts reach 50 metres or more they are required to participate in the Great Barrier Reef and Torres Strait Vessel Traffic Service (see below), and vessels over 70 metres require a ship pilot to be on-board within compulsory pilotage areas. Superyacht numbers are likely to increase in the future, underpinned by an increasing number based in the Asia-Pacific region and by recovering cruising and charter activity across the international market.[1093]

Cruise ships are getting larger, carrying more passengers and increasing in number

Management The Reef is designated as a Particularly Sensitive Sea Area by the International Maritime Organization, and shipping is closely managed by multiple government agencies. Since 2014, shipping management has been coordinated and strengthened by implementation of the *North-East Shipping Management Plan*, revised in 2019.[1086] The plan sets out protective measures to further reduce some of the environmental impacts from shipping activities (Section 5.8.3). These protective measures include further investigation of the impact of ship anchorages, resuspension of sediment generated from ship propellers and habitat restoration techniques following damage from a ship grounding.

Ships are restricted to areas of operation in the Region based on the Zoning Plan and designated shipping areas. For ships over 70 metres, such as loaded oil tankers, chemical carriers and liquefied gas carriers (irrespective of length), pilotage is compulsory for the inner route, Hydrographers Passage and within the Whitsundays (Figure 5.22). Pilots, are licenced by the Australian Maritime Safety Authority to help ships safely navigate through the Region. A new two-way route along the length of the Torres Strait and Great Barrier Reef was approved by the International Maritime Organization in 2014. This, coupled with an upgrade to emergency towage capability in the Region and Coral Sea, has improved response strategies and reduced the risk of a potential shipping incident.[1086]

The Queensland Government is the vessel traffic services authority for Queensland and operates five vessel tracking centres for Queensland ports and surrounding waterways. The operation of the Great Barrier Reef and Torres Strait Vessel Traffic Service (established in 2004) provides 24-hour tracking and monitoring of all shipping traffic in the Great Barrier Reef and Torres Strait regions. This service can divert ships if there is a possible traffic conflict, intervene to prevent a maritime incident, monitor maritime incidents and support effective response (Chapter 7).

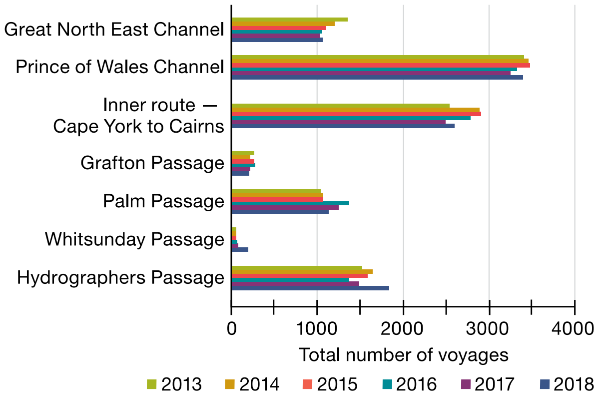


Figure 5.23 Ship voyages through Great Barrier Reef entry passages and the inner route, 2013–2018
Total number of ship voyages passing through the six main entry passages (channels) to the Reef and along the inner designated shipping route. The ships undertaking voyages include coal carriers, bulk carriers, container carriers, vehicle carriers, general cargo ships, tankers, cruise ships and superyachts (fishing, other tourism and recreational vessels are not included). Source: Australian Maritime Safety Authority (Cth) 2018[1088]

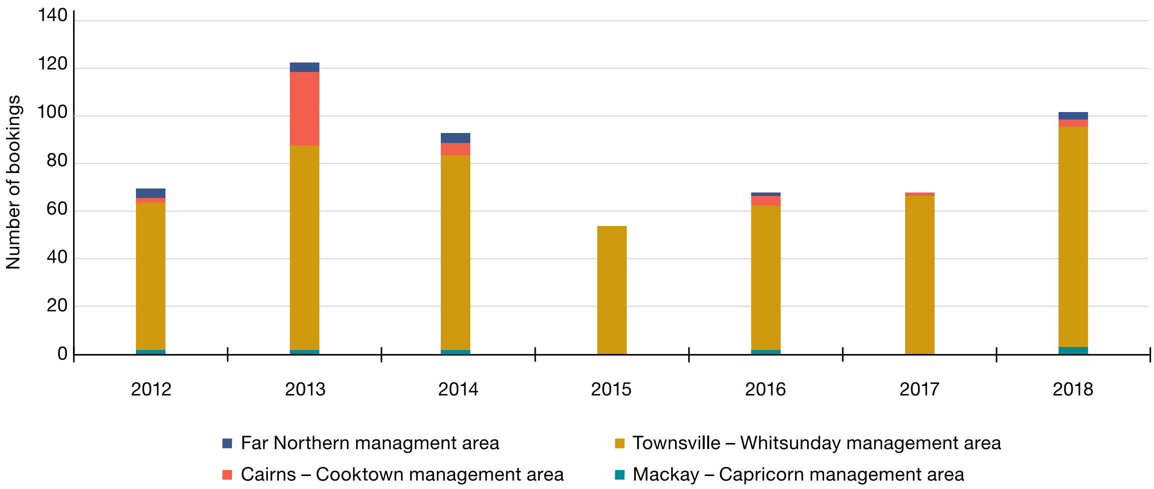


Figure 5.24 Cruise ship anchorage bookings, 2012–2018
Total number of bookings by cruise ships to designated anchorages within the four Marine Park management areas.
Source: GBRMPA 2018[1092]

Ship safety within ports has improved with an increased number of marine surveyors who undertake ship inspections while vessels are in port. Between 2014 and 2017, approximately 5000 inspections were undertaken for 25,785 ship arrivals at ports in the Region.[1088] Many ships visit the same port regularly and most inspection activity occurs in the larger, busier ports, such as Brisbane, Gladstone and Hay Point, which accounted for 81 per cent of all inspections between 2014 and 2017.[1088] Ship safety inspection statistics indicate the standard of shipping arriving in Australian ports continues to improve. This is demonstrated by the steady reduction in the detention rates of unsafe ships from 2011 (nine per cent) to 2017 (five per cent). The average number of deficiencies in ship safety identified per inspection has also remained at a low of 2.3.

The Australian Maritime Safety Authority's safety regulation responsibilities were extended in 2013 to include all foreign ships visiting Australian ports, regardless of the nature or route of the voyages involved. Since July 2013, foreign-flag ships that could previously operate 'intrastate' under Queensland jurisdiction have become subject to the state port control regime implemented by the Australian Maritime Safety Authority. This ensures a consistent standard is applied to all foreign-flag ships using regional ports. Since 2014, the Australian Maritime Safety Authority has issued 13 directions to 12 ships to prevent them from accessing Australian ports owing to repeated breaches.

Ships visiting ports to load and unload cargo may need to anchor near a port to wait for a scheduled berth. Established anchorages are designated adjacent to Cairns, Townsville, Hay Point, Abbot Point and Gladstone ports. Some anchorage areas do not have designated anchorage points (for example, Abbot Point) and there is no single state regulator for designating and approving anchorages, nor are there standard processes to follow.[1094] The total designated anchorage area for all the five ports combined is 2881 square kilometres (less than one per cent of the Region).[1075] Hay Point coal port has the largest and busiest anchorage within the Region, with 100 anchorages, but the number of ships waiting at anchor is generally under half of this.

Bookings to designated cruise ship anchorages aim to provide an uncongested safe anchorage in places where the seafloor is mostly sand with limited habitat structure and the values of desirable locations can be presented to tourists (for example, around the Whitsunday and Hinchinbrook islands). Access to locations by the support tender vessels that service cruise ships are also managed closely, restricting the number of visits by group size and vessel size in high-use locations. Superyachts greater than 50 metres are also required to book to these designated anchorages.

Ships (including cruise ships) accumulate waste during transit in the form of waste water (oily water, sewage, grey water and waste water associated with on-board equipment) and garbage (for example, food waste and plastics).

A liquified natural gas transport ship moving through the Region. © GBRMPA

Australia is party to Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL)[1095], which regulates garbage pollution from ships. Discharge of plastic into the sea has been prohibited under MARPOL Annex V since 1988, and discharge of all types of garbage into the sea, with very limited exceptions (not related to plastics), has been prohibited since 2013. The 2018 *Threat Abatement Plan for the Impacts of Marine Debris on the vertebrate wildlife of Australia's coasts and oceans*[1096] identifies the need to continue to address the management of ships' waste and the role technology can play in managing waste (for example, shipboard gasification waste-to-energy systems).

Sewage discharges in the Region need to be in accordance with Annex IV of MARPOL[1097] or, for domestic voyages, in accordance with requirements of Marine Park regulations for both treated and untreated sewage. Grey water may be discharged within the Marine Park, but it must be as far as practicable from reefs and islands.

MARPOL obliges ports make available adequate garbage-reception facilities that meet the needs of the ships calling at the port. In Queensland, ships are charged an extra cost in some ports to dispose of their garbage, rather than it being included in their berthing fee. The Australian Maritime Safety Authority works closely with ports to identify, and rectify, any alleged inadequacies with garbage-reception facilities in ports. In 2018, Hay Point trialled recycling certain garbage types from visiting international ships and found it to be feasible.[1086] The provision of recycling facilities encourages proper disposal and reduces the incentive to dispose at sea to avoid waste disposal fees in port. Unreasonable costs associated with garbage disposal in port has the potential to increase the likelihood of at-sea disposal, contributing to marine debris impacts.

5.8.2 Benefits of shipping

Ships that visit ports within the Reef provide important services to communities adjacent to the Region, transporting cargo as well as supporting tourism. International exports of goods from Queensland increased $12.4 billion to $83 billion between February 2018 and February 2019.[1098] The largest value increase in commodity exports was recorded in thermal and coking coal. In 2015, thermal coal exports experienced a decrease, however since that time exports have increased, valued at $35.8 billion between February 2018 and February 2019.[1098] In general, these fluctuations are caused by price, rather than by volume (which has been stable for the past three years).

The economic activity generated by shipping traffic provides a range of social and economic benefits to communities in the Region's Catchment and beyond. Each year, ships and their cargo are processed at ports, with the major trading ports (Box 8) processing over 3000 ships per year (Figure 5.25). Hay Point, one of the largest coal export ports in the world, has loaded approximately 1200 ships each year since 2014. There is currently no reliable estimate of the level of economic contribution (both direct and value-added) from shipping within the Reef. Nor is there an estimate of the economic benefit shipping receives from an intact barrier reef that provides some protection from oceanic swells.

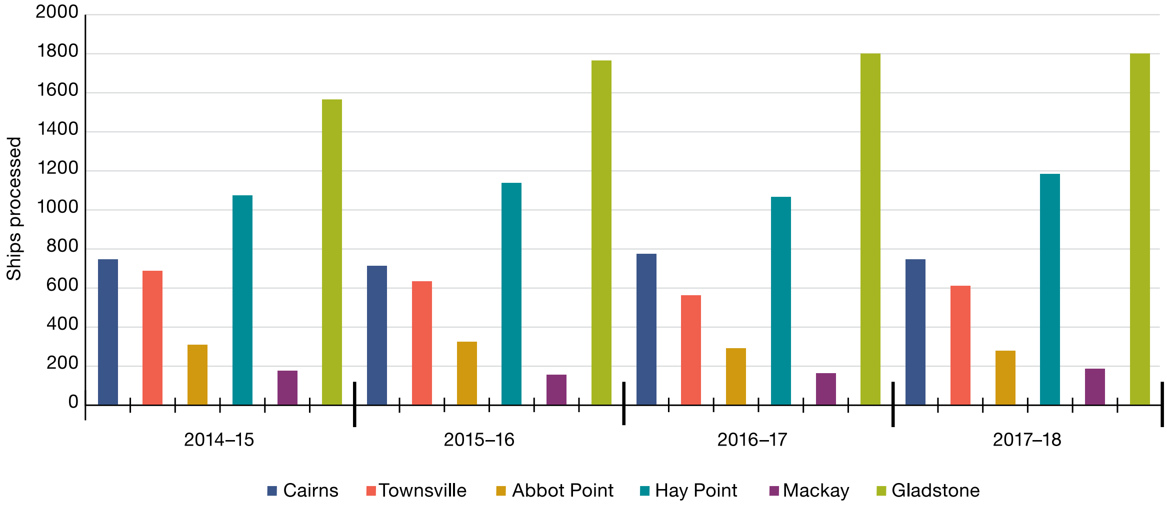


Figure 5.25 Ships processed by major trading ports within the Region
For the ports of Abbot Point and Hay Point only bulk carriers are reported. For the Port of Cairns the ships include bulk carriers and general cargo. All other ports refer to ships or vessels as a total number in annual reports. Source: Ports North[1099], Port of Townsville Limited[1100], Gladstone Port Corporation[1101], North Queensland Bulk Port Corporation[1102]

Cruise ship and superyacht activities bring potential economic benefits to the local tourism and recreation industries, resorts and mainland townships. Cruise ships provide an important platform for presenting the Region's values to both national and international visitors. Cruise tourism contributed $35 million to the Catchment in 2011–12.[858] While an updated analysis of the economic contribution from the Reef cruise ship industry has not been undertaken, there has been a 10 per cent per annum increase in cruise shipping within Queensland over the past five years. This contributed $501 million dollars to the Queensland economy in 2017–18.[1103] Cairns and the Whitsundays continue to be the most popular cruise ship ports within the Region with a small amount of growth occurring in Gladstone, while Townsville also grew from four ships in 2014–15 to eight in 2017–18[1103] (Figure 5.24).

5.8.3 Impacts of shipping

To date, the impacts of shipping have mainly been caused by physical damage and pollution from toxic antifoulant paint as a result of ship groundings, oil spills, resuspension of sediments from propeller wash, damage to the seafloor from ship anchoring[1104], illegal discharge of garbage (food waste and plastics), light pollution (ships at anchor) and underwater ship-generated noise. Whales being struck by ships is an added impact, with approximately 15 per cent of whale strikes reported to the International Whaling Commission occurring in Australian waters (547 total reported worldwide up to 2010)[392]. While the data are not specific to the Region, the number of whale strikes has increased since 1874 (when reporting began), with the majority of strikes since 1997 being concentrated on the east coast.[392] The risk of **whale strike** increases during the whale migration season and may increase further if an increase in shipping, ship size and other large vessel traffic is coupled with an exponentially increasing humpback whale population (Section 2.4.14). Some risk of whale strike has been reduced through a notification procedure implemented by Marine Safety Queensland, whereby ships are notified when a whale is in one of the port shipping channels and ship movements can be delayed to reduce the chances of whale strike.

Illegal discharge of garbage can reduce water quality and, depending on the type of garbage, create entanglement and ingestion hazards for marine and island species. Since 2014, seven shipping companies and their masters were found guilty of discharging garbage into the sea and were fined, with fines ranging from approximately $3000 to $20,000.[1105,1106]

Antifouling paints are applied to ships to reduce the growth of marine organisms that build up on the hull and reduce ship speed. The paints can contain metal pigments, such as copper, iron or zinc, and biocides that deter growth of fouling organisms.[1075] These compounds have been detected in water and sediment samples within the Region's ecosystem[1075], and concentrations are much higher in ports and near **ship groundings**.[1075]

Shipping incidents include those that have the potential to cause significant environmental harm (such as a near miss) and those that cause environmental harm. A near miss may occur when a vessel becomes disabled, almost runs aground, and requires assistance. It may be the result of mechanical breakdown, negligence or weather. Some near misses have resulted in ships coming very close to sensitive habitats. Twenty incidents have been reported in the Region since 2014[834,1015], comprising groundings, near misses and instances of two ships, or a ship and another vessel, coming into close quarters with one another. The majority occurred in the north, between Cairns and the tip of Cape York (Figure 5.27). Seven close-quarter interactions involved smaller vessels, such as fishing vessels, nearly colliding with ships. Two actual collisions involving ships and commercial fishing vessels have occurred since 2014 (Figure 5.26). No ship groundings on sensitive habitats have been recorded since 2010, when the ship *Shen Neng I* ran aground on Douglas Shoal. However, in 2018, a ship ran aground on mud in the Gladstone Channel following mechanical failure; it was assisted by tugs back into the channel.

Given advances in technology and the level of monitoring of shipping traffic in the Region, near misses should be rare. However, human error and mechanical breakdowns are always a possibility. The most serious of these involved the *Chengyang Eminence* in November 2014 north of Cooktown, while transiting with a Reef pilot on board. The newly built 225-metre bulk carrier's steering gear failed, bringing it to within one vessel length of the reef edge. Significant environmental harm was avoided in that case.

Queensland Parks and Wildlife Service ranger investigating oil spill remains following the Cape Upstart Oil Spill in 2015. © GBRMPA 2015

Since 2014, five **oil spills** have been reported from ships. Four of these were minor and involved small amounts of diesel (estimated to be less than 100 litres). For most of these minor spills, sheens of oil on the water or oil patties on a beach were observed, but could not be linked to a particular ship. In 2015, a moderate-sized oil spill occurred around Cape Upstart (central Great Barrier Reef) that resulted in up to 15 tonnes of oil washing up on beaches from Townsville to Dunk Island, across a distance of approximately 150 kilometres.

Disturbance from ships anchoring is a chronic impact that is more prevalent close to ports and within designated anchorages. An analysis of the impact of ship anchorages and their management in the Reef was

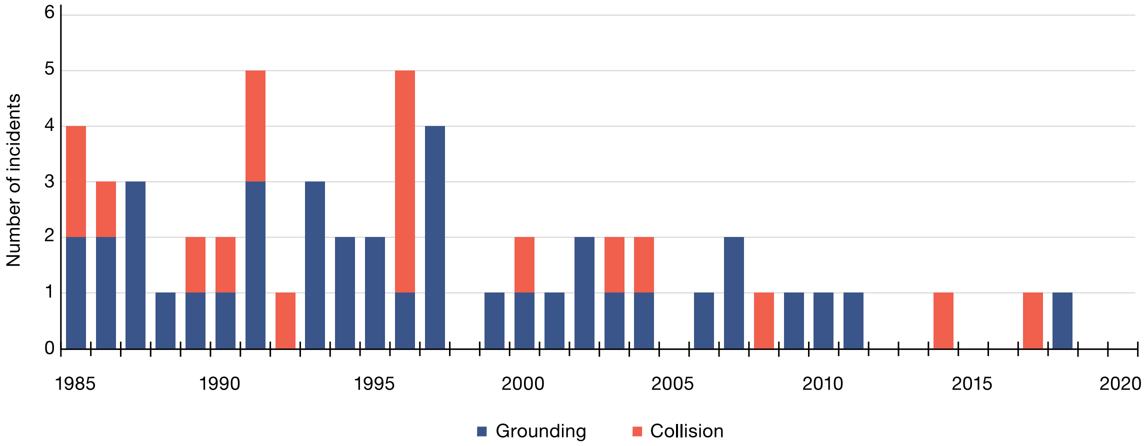


Figure 5.26 Ship groundings and collisions, 1985–2018
Bars represent groundings and collisions reported to the Marine Park Authority, Maritime Safety Queensland and Australian Maritime Safety Authority involving ships within the World Heritage Area. All collisions reported were between ships and smaller vessels, rather than between two ships. Groundings include those within designated port areas. Annual total numbers of ships visiting the Region from 2013 to 2018 are shown in Figure 5.21. Source: GBRMPA 2019[1015]

undertaken in 2013[1104], with no equivalent study undertaken since that time. A reduction in aesthetic values from ship anchoring was rated as a high risk in 2013[1104] and it is likely to remain at that level given shipping traffic has been maintained at similar levels. Additional impacts of ships at anchor include light pollution and interference with species behaviour, marine pest introduction and noise.[1104]

Ship anchoring occurs on a daily basis in the Region. Deployment of a ship's anchor resuspends sediments, creating plumes that reduce water clarity and light penetration.[1094] This sediment can directly smother benthic organisms[1032] or clog fish gills[1047]. Indirect effects may be caused by low visibility conditions, which deter some species of fish[1047] resulting in shifted fish distributions and probable flow-on effects to food chain dynamics. Cruise ships are fewer in number than coal and container ships (trade ships) and generally anchor in different locations. Cruise ships may anchor for nature experiences and shore-based activities, adjacent to islands and the mainland, resulting in similar direct and indirect anchor damage impacts as trade ships (albeit to a lesser extent).

International ships can introduce unwanted **pests and diseases** to Australia through biofouling and in ballast water. The *Biosecurity Act 2015* (Cth) prescribes how ballast water should be managed within Australian waters. National biofouling management guidelines[1108] are available to help vessel operators manage and control biofouling threats to the Great Barrier Reef. The potential impact of introduced marine species transported by ships into ports within the Region is discussed in Section 3.6.3.

Shipping is one of the means by which marine debris enters the Region. Chronic exposure to

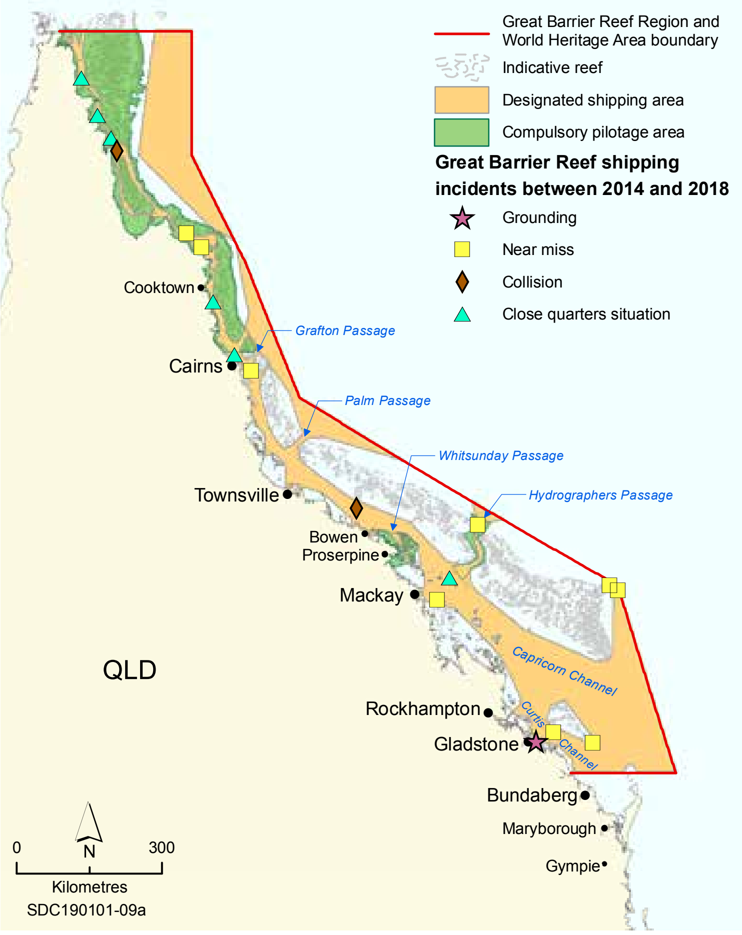


Figure 5.27 Location of shipping incidents, 2014–2018
A shipping incident is defined to include groundings and near misses for ships >50 metres; and collisions and close quarters between ships, or ships and vessels <50 metres. The designated shipping area and areas where a pilot is required to assist the ship to transit the Region are also marked.
Source: Maritime Safety Queensland 2018[1107] and GBRMPA 2018[1015]

marine-based sources of debris on the Reef is most likely in areas frequented by ships and smaller vessels, primarily in ports and marinas, at anchorage areas, at moorings and, to a lesser extent, along shipping lanes.[1075] A regional-scale analysis of marine debris collected by citizen scientists found that collections adjacent to Mackay in the central Reef had the highest proportion of ship-sourced marine debris (accounting for approximately three per cent) (Section 6.5.1 Figure 6.10). Overall, shipping was not found to be the dominant source of marine debris across the Region (accounting for two per cent on average). On average, plastic remnants from other unidentified sources and garbage washed ashore (from undefined oceanic sources) were the most dominant sources (46 per cent and 32 per cent respectively) (Section 6.5.1).

BOX 9

Remediation of Douglas Shoal following 2010 ship grounding

In April 2010, the Chinese-registered coal carrier *Shen Neng I* ran aground on Douglas Shoal in the Great Barrier Reef, near Heron Island. The vessel was grounded for nine days, damaging an estimated 42 hectares of habitat and producing the largest ship-grounding scar ever recorded on the Great Barrier Reef. The 2014 Outlook Report outlined the details of the 2010 *Shen Neng I* incident.

Following the incident, there was no immediate access to the resources needed for clean-up or restoration of the area. In late 2016, the Marine Park Authority negotiated an out-of-court settlement with the ship's owners and insurers, resulting in $35 million being allocated to clean up the site. Surveys and planning are now underway to determine how best to address the three types of damage caused by the ship: toxic antifouling paint particles, unconsolidated rubble and crushed habitat. All three types of damage hinder natural recovery of the site by making it difficult for plants and animals to re-establish. Damaged areas are still visible on satellite images more than nine years after the incident. Monitoring will be focused on assessing the effectiveness of different remediation and restoration methods to support recovery. This will give Reef managers critical knowledge about how best to respond to any future shipping incidents or other events that physically damage the reef, such as cyclones.

Diver surveying an area of gouged reef immediately after the Shen Neng I grounding incident in 2010. © GBRMPA

Ships anchored north of the Port of Abbot Point, February 2019. © Matt Curnock

5.9 Traditional use of marine resources

5.9.1 Current condition and trends of traditional use of marine resources

More than 70 Traditional Owner clan groups maintain connection to sea country within the Region. Traditional use of marine resources is important to Traditional Owners and continues long-established Indigenous heritage traditions. Traditional use of marine resources is broad, and includes undertaking of lawful activities, as part of Aboriginal and Torres Strait Islander peoples' customs or traditions for the purposes of satisfying personal, domestic or communal needs. It includes fishing, collecting (for example, shellfish), hunting (or harvesting), and looking after Indigenous heritage places. Many Aboriginal and Torres Strait Islanders undertake traditional use of marine resources to practise 'living maritime culture', provide traditional food for families and educate younger generations about traditional rules and protocols.

About 25 per cent of the Region's coastline is covered by Traditional Owner agreements

Aboriginal people and Torres Strait Islanders have used the Region's marine resources for thousands of years.[107] Significant advances have been made since 2014 in Traditional Owner-led and partnered monitoring and natural resource management programs relevant to traditional use in the Region, including:

- seagrass surveys
- Reef health surveys and crown-of-thorns starfish control
- marine debris clean-up programs[1109]
- compliance training and increasing participation in compliance patrols on sea country.[1110]

With the release of the Reef 2050 Plan[9], and continuation of the Land and Sea Country Partnerships Program initiatives (managed by the Marine Park Authority), there has been an increased focus on collaborative management and monitoring (Section 7.3.8). Since 2014, while coordinated monitoring of species and habitats (seagrasses, oyster beds and marine megafauna) has continued to expand, limited data have been collated on traditional use. As development of cultural protocols and ongoing investment in monitoring advances, information on the trends in traditional use will be better understood.

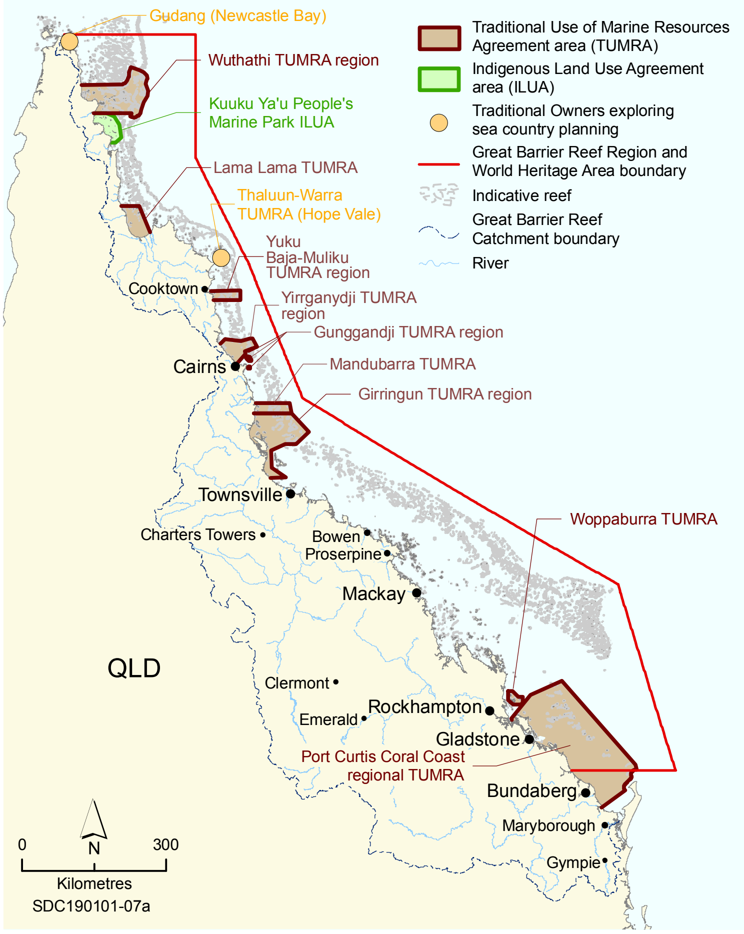


Figure 5.28 Areas of the Great Barrier Reef covered by accredited Traditional Owner agreements, 2018
Some Traditional Owners of the Great Barrier Reef have formalised their aspirations for sea country through Traditional Use of Marine Resource Agreements and Indigenous Land Use Agreements.

Management Traditional use within the Region is managed collaboratively with Traditional Owners. Legislation that governs the Great Barrier Reef Marine Park (Commonwealth) and the Great Barrier Reef Coast Marine Parks (Queensland), provides for the cooperative involvement of Aboriginal communities and partnerships with Traditional Owners in the sustainable management of marine resources through Traditional Use of Marine Resources Agreements. Through the agreement process, Traditional Owners agree on complex matters, such as maritime estates (where lore governs boundaries), protocols, sea country planning, harvest areas, community permits, compliance plans (including addressing unauthorised practices, such as poaching), and Indigenous heritage management. Twenty five per cent of the Region's coastline is covered by Traditional Owner agreements (a small increase of about 0.4 per cent since 2014). Accredited Traditional Owner agreements cover approximately 46,808 square kilometres of the Region (Figure 5.28) comprising nine Traditional Use of Marine Resources Agreement and one Indigenous Land Use Agreement (a voluntary agreement between a native title group and others about the use of land and waters). The Mandubarra Traditional Use of Marine Resources Agreement, accredited for the first time in 2018, covers a sea country area to the south of Innisfail.

Most Traditional Owner groups along the mainland coast of the Region continue to exercise their native title rights, including hunting or collecting under section 211 of the *Native Title Act 1993* (Cth). Many Traditional Owner groups with an accredited agreement, have set a voluntary moratorium on the harvest of turtles and dugongs. For those agreements that include hunting, harvest limits have been negotiated and formally assessed for sustainability prior to an accreditation decision. The accredited agreements enable groups to manage traditional harvest sustainably through a process of permitting, monitoring, recording and supporting compliance actions.

In the Torres Strait a large proportion of the high density dugong habitat is not hunted by Traditional Owners.[1111] This is because traditional use is geographically constrained by culturally-based Turtle and Dugong Hunting Management Plans, the socio-economic status of some Traditional Owners, where people live, access points (such as boat ramps) and the high price of fuel. It is likely that a similar pattern of use exists within the Region, however this analysis has not been completed on a broad scale and remains challenging.

Marine Park Authority compliance officer mentoring a Traditional Owner ranger/Marine Park inspector on pre-surveillance equipment checks. © GBRMPA

Since 2011, the urban coast dugong population and southern green turtle populations are showing signs of recovery, largely due to movements back into 'hotspot areas' with recovering seagrass meadows, including Hinchinbrook Island, Cleveland Bay (Townsville) and Shoalwater Bay.[413] However, turtle and dugong population sizes are much less than in 1981 when the World Heritage Area was declared. Scientists consider that the traditional harvest of large juvenile green turtles is more sustainable than the harvest of adult females. Given that the urban coast dugong population is much less than the southern green turtle stock, traditional harvest of dugongs requires more careful consideration in traditional use agreements. Many Traditional Owner groups recognise this and have placed voluntary moratoria on hunting after extreme weather events.

The types of impacts that affect the practice of traditional use of marine resources have not changed markedly since 2014. However, a greater emphasis is now being placed on the impacts from climate change to sea country management, in particular, how changing weather patterns may affect traditional gathering and customs.[1112]

Since 2014, focus has increased on the delivery of compliance training to Indigenous rangers that work in and adjacent to the Region. Forty nine Indigenous Rangers were trained over three years (28 in 2016 and 21 in 2019). Seventeen Indigenous rangers from the first training intake were then appointed specific Marine Park inspector powers under the *Great Barrier Reef Marine Park Act 1975* (Cth). They now form part of the wider Reef compliance program, and support the management of sea country and Zoning Plan compliance (particularly in remote areas). This short term program is on track to train 75 rangers in total by June 2020, supporting Indigenous people to combine traditional knowledge with conservation training to protect and manage their land, sea and culture.

The Marine Park Authority Board includes a representative specialising in Indigenous matters relevant to the Marine Park. An update to the legislation governing the Region[1113], identifies this membership as an ongoing requirement. An established Indigenous Reef Advisory Committee continues to provide the Marine Park Authority with strategic advice to build a greater understanding of Traditional Owner issues within Marine Park management. An Indigenous representative also forms part of the Marine Park Authority's Tourism Reef Advisory Committee. A key role for these committees is to advise the Marine Park Authority Board in relation to actions that can be taken to address threats to the Marine Park identified in the Outlook Report.

5.9.2 Benefits of traditional use of marine resources

The continuing sea country management and custodianship of the Great Barrier Reef by Traditional Owners are important components of the natural and Indigenous heritage value of the Region. Traditional use, and the area-based agreements that support it, plays a constructive role in managing biodiversity and sustaining Indigenous heritage.[1114]

While gaps remain in our knowledge of the total economic worth of traditional use of marine resources, investment in Traditional Owner-led management actions under the Reef 2050 Plan continues to expand. Investment in accredited Traditional Use of Marine Resources Agreements helps to conserve and protect significant species, habitats and ecosystems; restore and maintain waterways and coastal environments; protect world heritage areas (Great Barrier Reef and Wet Tropics); and continue to refine Traditional Owner skillsets, knowledge and engagement in natural and Indigenous resource management. A 2016 study analysed the social return on investment resulting from funded Indigenous governance systems. It found that, for every $1 invested, an equivalent of approximately $2.20 of social, economic, cultural and environmental value is generated for communities and stakeholders.[1115] Traditional Owners are involved in the design and delivery of mitigation strategies for a range of threats to turtles and dugongs (for example, the Nest to Ocean Turtle Protection Program that protects turtle nests from terrestrial predators).

Reef Joint Field Management Program and Indigenous rangers assessing green turtle nests, Raine Island 2018.
© Queensland Parks and Wildlife Service, photographer: Andy Dunstan

While Traditional Owners have Native Title rights to fish and collect, including the harvest of turtles and dugongs, they consider the latest science and traditional lore and custom when considering harvest of these species in their sea country, and voluntarily adjust these figures according to the health of the ecosystem. Traditional Owners hold many spiritual and economic connections to the Region. Establishing effective partnerships helps protect the natural and Indigenous heritage value, conserve biodiversity and enhance the resilience of the Reef.

5.9.3 Impacts of traditional use of marine resources

Traditional use includes fishing and collecting a wide range of plants and animals. Impacts from traditional use can occur when the harvest is unsustainable; this is more likely when the plants or animals taken are already threatened and in low numbers. Green turtles and dugongs have been, and remain, at risk from many human-related activities (Sections 2.4.10 and 2.4.16). Within the Region, the Australian Government's *Marine Turtle Recovery Plan 2017–2027*[308] found climate change, marine debris ingestion and habitat modification (in the southern part of the Region) were the highest risks to marine turtles – and Indigenous harvest was assessed as moderate. Specifically, Indigenous use was a high risk for three turtle populations (all of which are outside the Region), with egg harvest the primary risk within the Region. Scientific modelling of dugong populations in Torres Strait concluded that traditional use of green turtles and dugongs is sustainable.[811,1111,1116] An equivalent understanding of the level take of turtles and dugongs across the entire Region remains a knowledge gap.

Nominated levels of traditional harvest under all accredited Traditional Use of Marine Resources Agreements are assessed by the managing agencies against the most recent research at the time of application, to make sure accredited harvest limits are sustainable. The sustainability of limits is reviewed to encompass the spatial scale of the agreement area and the estimated population status of the regional populations of marine turtles and dugongs likely to reside in, or use, an area. To make sure traditional use remains a low risk, well-designed monitoring in partnership with Traditional Owner groups is required. The ongoing development and revision of management policies and agreements in response to monitoring outcomes will also reduce potential threats.

Reductions in populations of species (particularly those with cultural significance, like turtles and dugongs) from **illegal fishing and poaching** is not considered legal traditional use. Illegal fishing and poaching in this sense becomes an impact on the traditional use of the Region's marine resources. Poaching in this context involves people hunting in areas outside their traditional sea country and without the customary approval or permission of the relevant Traditional Owners. Traditional Owners hunting for commercial purposes (that is, to sell the meat) is also considered to be illegal take. In 2016–17, the Australian Criminal Intelligence Commission undertook an investigation into illegal poaching and the transportation and trade of turtle and dugong meat in Far North Queensland and Torres Strait. The investigation found that the poaching and sale of meat was minimal and usually opportunistic, and that there was no substantive evidence to suggest an organised commercial trade existed in Queensland or the Torres Strait.[1117]

5.10 Assessment summary — Commercial and non-commercial use

Paragraph 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

Grading statements — economic and social benefits of use

🟩	🟨	🟧	🟥	☐☐
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.	**Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟩 ↔	🟩 ↔			**Economic and social benefits of use:** Economic and social benefits to the Region continue to be in very good or good condition. Commercial and non-commercial use continue to contribute to the Region's economy. The social benefits of fishing and recreation contribute significantly to health and wellbeing. The Reef is of major importance to Traditional Owners.
🟩	🟩 ↔	🟩 ↔	●	●	**Commercial marine tourism:** Tourism continues to make significant contributions to the social and economic value of the Reef. Although recent disturbances impacted visitor numbers in Cairns and the Whitsundays, visitation is slowly increasing.
🟨	🟨 ↔	🟨 ↔	●	●	**Defence activities:** Periodic visits from Australian and international forces generate short-term economic benefits to the Region. Defence supports cooperative research and management programs in the Region and adjacent estates.
🟨	🟨 ↔	🟨 ↔	●	●	**Fishing:** The economic contribution of commercial and recreational fishing increased slightly. Commercial fishers have a high personal connection with the Region. People enjoy recreational fishing for a variety of reasons.
🟩	🟩 ↔	🟩 ↔	○	○	**Recreation (not including fishing):** Continued growth in population and economics will increase the demand for recreational activities within the Region. Recreational use of the Region is vital to the wellbeing of Queensland's coastal communities.
🟩	🟩 ↔	🟩 ↑	●	●	**Research and educational activities:** Knowledge derived from research related to the Region continues to support management. Contributions to the economy have increased since 2011–12. Research into intervention and restoration activities is increasing.
	🟩	🟩 ↔	●	●	**Ports:** The four priority ports adjacent to the Region provide significant economic and social benefit to the Queensland and national economies. Employment statistics remain a data gap.
	🟩	🟩 ↔	●	◐	**Shipping:** The total number of ships processed through the major trading ports has remained relatively stable since 2014. Cruise shipping had the greatest growth. There is currently no reliable estimate of the level of economic contribution (both direct and value-added) from shipping within the Region.
🟩	🟩 ↔	🟩 ↔	○	○	**Traditional use of marine resources:** Traditional ownership continues to provide and receive environmental, social and cultural benefits for Traditional Owners. Since 2014, the proportion of the Region's coastline under Traditional Use of Marine Resources Agreements has increased to 25 per cent.

5.10.2 Impacts of use on the Region's values

Grading statements — impacts of use

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

🟧 **Low impact**
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.

🟥 **High impact**
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.

🟪 **Very high impact**
The impacts of use are widespread, to the extent that ecosystem function and heritage values are severely compromised.

☐☐ **Borderline**
Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟧	🟥 ↑	🟥 ↔			**Impacts of use on the Region's values:** The observed impacts from direct use of the Region are mainly localised. However, collectively, the impacts of this use are obvious (to varying degrees) in many locations. Fishing is a high-impact use occurring throughout the Region and some aspects remain a concern. Marine incidents involving small vessels have increased. As the population increases, use of the Region and associated impacts are likely to increase. The cumulative effects of direct use of the Region coupled with a deterioration of its natural and heritage values amplifies the identified impacts.
🟨	🟨 ↔	🟨 ↔	●	●	**Commercial marine tourism:** While marine tourism extends throughout the Region, its impacts are generally localised to a few intensively managed areas. Impacts from cumulative use will amplify as natural values deteriorate. Vessel incidents and infrastructure damage spike after extreme events and cause localised damage to values.
🟨	🟨 ↔	🟨 ↔	●	●	**Defence activities:** Defence activities have localised impacts on the Region. Balancing the Defence requirements for training with conservation of critical environmental values will remain a significant challenge in the future.
🟥	🟥 ↔	🟥 ↔	◐	◐	**Fishing:** Fishing occurs in most parts of the Region. The extraction of biomass, interaction of animals with fishing equipment, and discarded catch are ongoing pressures from fishing. Illegal fishing and poaching remain strong concerns. Fisheries management is improving but reforms are yet to be fully implemented and information gaps remain.
🟧	🟧 ↔	🟧 ↑	○	○	**Recreation (not including fishing):** Few studies have investigated the impact of recreational uses (excluding fishing) in the Marine Park. Impacts are mainly in the inshore areas around major population centres. Localised damage to habitats by small recreational vessels may be more common than reported.
🟨	🟨 ↔	🟨 ↔	◐	◐	**Research and educational activities:** Understanding of cumulative effects of the minor impacts associated with research and educational activities is limited. Activity is often concentrated around research stations.
	🟥	🟧🟥 ↓	●	◐	**Ports:** Many threats from port activities (maintenance dredging and associated disposal of dredge material, artificial light from port infrastructure, noise and other pollution) remain and cause impacts at a localised scale. However, threats associated with capital dredging and associated disposal have decreased since 2014, resulting in the impact grade being considered borderline with low impact.
	🟧	🟧 ↔	◐	◐	**Shipping:** Ships are getting larger. The number of shipping incidents has remained relatively stable. Other impacts caused by ships, such as resuspension of sediments from propeller wash, anchoring, light and noise pollution (from ships at anchor) and whale strike remain ongoing threats.
🟥	🟨 ↓	🟨 ↔	◐	◐	**Traditional use of marine resources:** Traditional harvest, fishing and collecting involve a range of marine species (some of conservation concern). Within Traditional Use of Marine Resource Agreement areas, harvest is limited and considered sustainable. Region-wide level of Traditional harvest remains a knowledge gap, but is considered to cause minimal impact compared with other threats.

5.11 Overall summary of commercial and non-commercial use

The Great Barrier Reef contributes significantly to the Australian economy and the wellbeing and lifestyle of the communities that depend on the Reef for traditional use, social and cultural purposes, and livelihoods. The economic and social benefits of commercial and non-commercial use are rated overall as very good.

Use of the Region continues to provide significant economic and social benefits

The observed impacts from direct use of the Region are mainly localised and rated overall as high impact. However, collectively, the impacts of this use are obvious (to varying degrees) in many locations. Fishing is a high-impact activity occurring throughout the Region and some aspects remain a concern. Marine incidents involving small vessels have increased. As the population increases use of the Region and associated impacts are likely to increase. The cumulative effects of direct use of the Region coupled with a deterioration of its natural and heritage values amplifies the identified impacts.

Commercial marine tourism continues to be the most economically significant use of the Reef. Record levels of tourism visitation occurred in 2016 despite coral bleaching events. However, visitation declined in some areas, particularly in the Whitsundays in 2017 following cyclone Debbie. Impacts of commercial marine tourism are generally localised around intensively visited areas.

Cumulative effects of direct use of the Region coupled with a deterioration of its natural and heritage values amplifies identified impacts

Defence activities in the Region directly contribute to Australia's defence capacity and generate economic benefits to the Region. Defence continue to deliver and support environmental monitoring and management. Recreational and commercial fishing continue to be important social and economic direct uses of the Region. Fisheries management and practices continue to improve, with the most significant change being the development of the Queensland Sustainable Fisheries Strategy 2017–2027. Some knowledge gaps and sustainability concerns for some species still exist. Illegal fishing and poaching continue to cause concern.

The Region provides opportunities for many recreation activities beyond fishing. Continued population growth and economic wealth will increase the demand for recreational activities in the Region. Most recreational impacts are minimal (with cumulative impacts largely unknown) and concentrated around major population centres. Research underpins management of the Region and has broad and growing economic and social benefits. Research and educational activities are often concentrated around research stations; there is potential for localised cumulative effects.

Population growth will increase the demand for recreational activities in the Region

Ports provide significant economic and social benefits to the Region. Since 2014, the combined effect of regulatory changes, a cooperative approach to managing the impacts of port development and changed market conditions have seen some of the threats from ports reduce. Localised impacts from ports remain, predominantly from maintenance dredging and associated disposal of dredge material, artificial light from port infrastructure, noise and other pollution.

Some impacts from direct use have been reduced (particularly for ports); room for further improvement remains

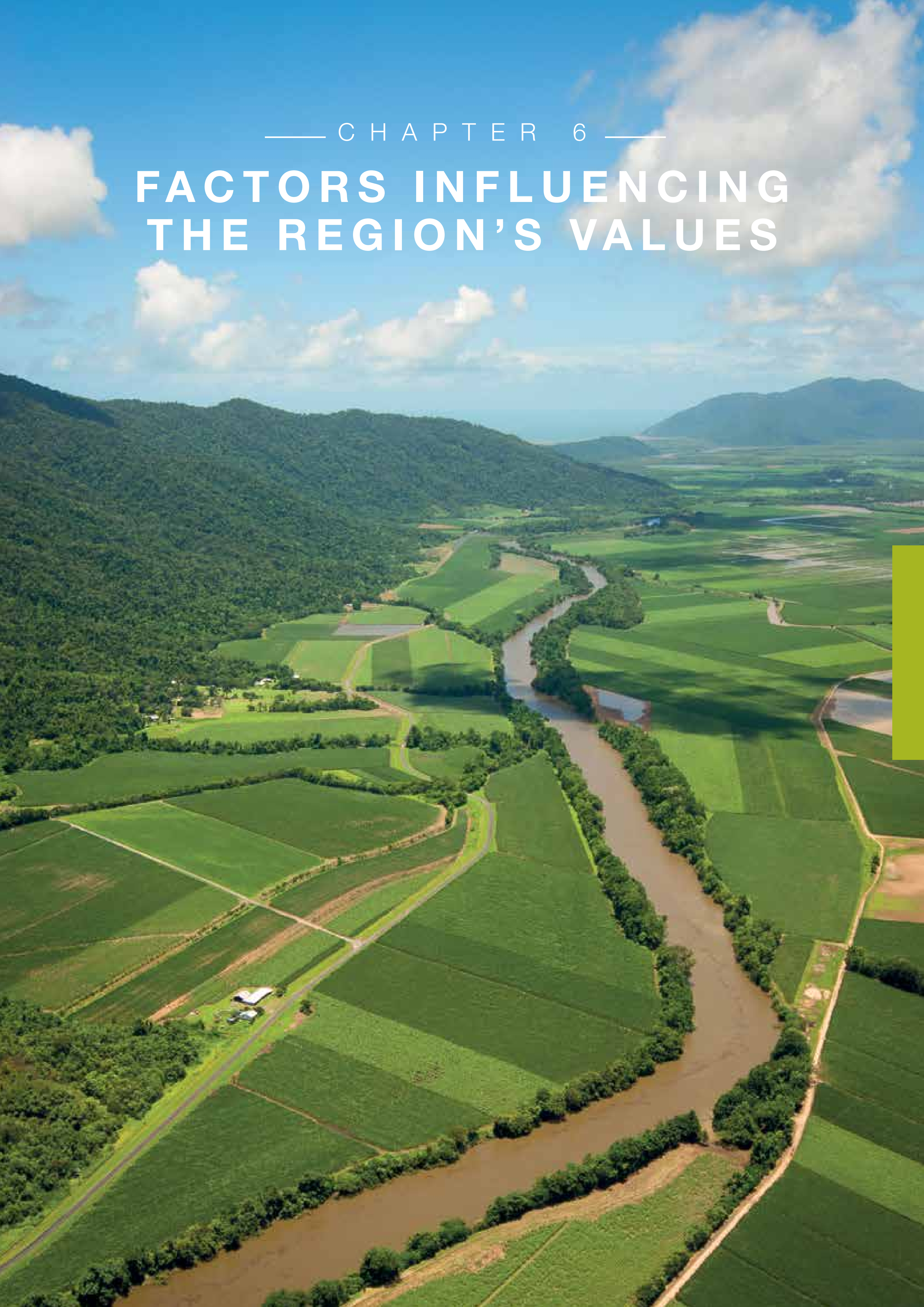
The number of ships travelling through the Region has remained stable since 2014, except for cruise ships which have continued to increase. Ships are getting bigger, which will increase associated pressures, such as anchoring impacts on benthos and sediment suspension from propeller wash, particularly within the shallow inner route. Shipping safety is well regulated in the Region, and the impacts, being generally known and managed. However, threats remain from ship propellers resuspending sediments, which can affect organisms, water clarity and community benefits. Vessel strikes, light and noise pollution remain ongoing threats that are not well understood.

Managing agencies continue to work with Traditional Owners to protect Indigenous heritage values, conserve biodiversity, enhance the resilience of the Reef, and maintain connection to land and sea country. In 2018, nine Traditional Use of Marine Resources Agreements and one Indigenous Land Use Agreement were in place, an increase of two agreements since 2014. Combined, these agreements cover approximately 25 per cent of the Region's coastline.

Diving for tropical rock lobster using surface-supplied air. © GBRMPA

CHAPTER 6

FACTORS INFLUENCING THE REGION'S VALUES



« *Sugarcane cultivation along the Mulgrave River.* © Dieter Tracey 2015

FACTORS INFLUENCING THE REGION'S VALUES

'an assessment of the factors influencing the current and projected future environmental, economic and social values …' of the Great Barrier Reef Region, s 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, paragraph 116A(2)(e) of the *Great Barrier Reef Marine Park Regulations 1983*

6.1 Background

The Region comprises a diverse range of natural values (ecosystems, habitats, species and processes) and Indigenous and historic heritage values described in Chapters 2 to 4. The condition of these values determines the health of the Region and the quality of the social and economic benefits (for example, income, appreciation and enjoyment) the community derives from the Region.

Several major factors influence the Reef's values. The four factors assessed in previous Outlook Reports remain the primary factors influencing the Region: climate change, coastal development, land-based run-off and direct use. This chapter considers the trend of each influencing factor, as well as the Region's vulnerability to those factors. Any impacts the factors have on the Region's outstanding universal value (including natural, Indigenous and historic heritage value) and the benefits derived from those values, provide a basis for predicting future risks to the Region and its long-term outlook (Chapters 9 and 10).

While direct uses occur in the Region, the other three main influencing factors are largely external to the Region. All four factors are, in turn, affected by broader drivers of change (economic growth, population growth, technological development and societal attitudes) that affect how society functions, matures and interacts with the environment (Figure 6.1).

The assessment is based on four assessment criteria:

- impacts on ecological values
- impacts on heritage values
- impacts on economic values
- impacts on social values.

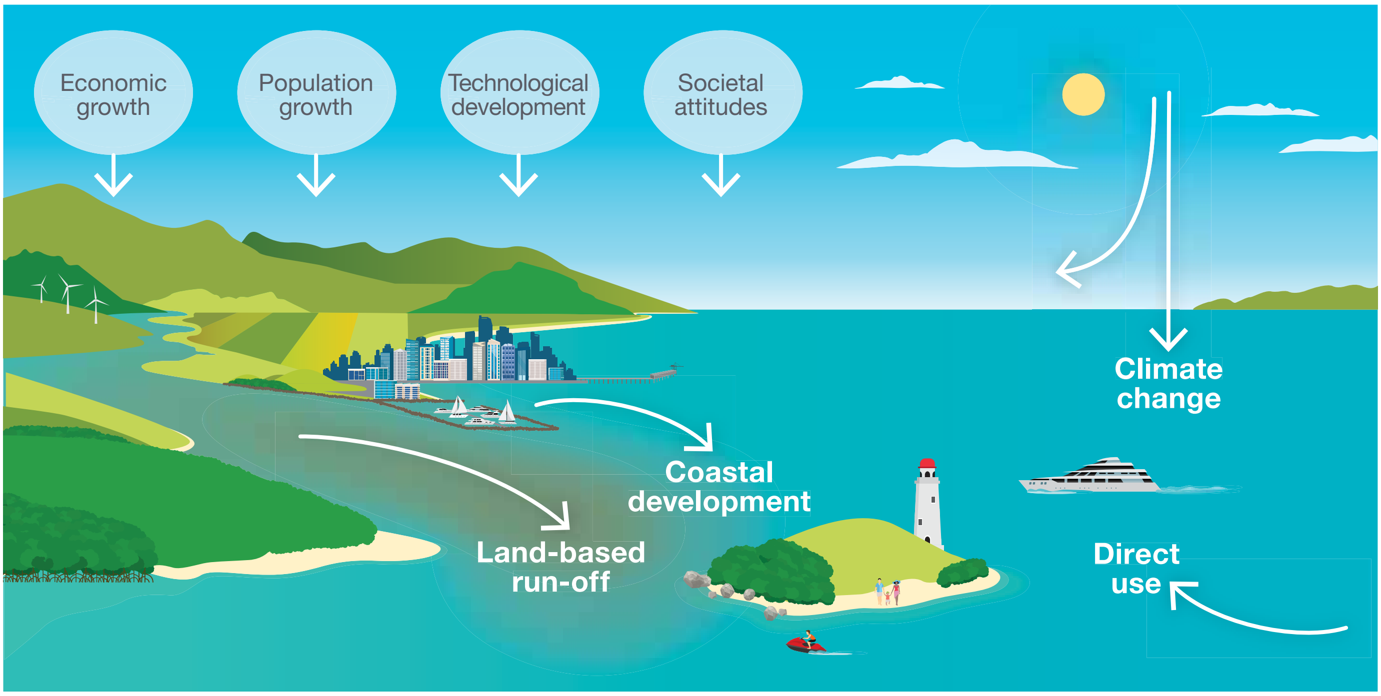


Figure 6.1 Factors influencing the Region's values and drivers of change
The Region's values are influenced by four main factors: climate change, coastal development, land-based run-off and direct use. These are, in turn, affected by broader drivers of change, including economic and population growth, technological development and societal attitudes.

6.2 Drivers of change

Drivers are underlying causes of change in society and ecosystems. The Reef is currently undergoing significant social, economic and environmental change.[969] Drivers affect how society functions and interacts with the built and natural environment, and can act independently or in combination.[1011] Economic and population growth, technological developments and societal attitudes are key drivers and affect the nature and intensity of the four primary factors influencing the Region (climate change, coastal development, land-based run-off and direct use) (Figure 6.1). Drivers lead to challenges for the environment but also benefits, particularly through technological development and societal changes.[1118]

6.2.1 Economic growth

Queensland's economy is driven primarily by tourism, agriculture, resources (mining), construction, manufacturing and services.[1119] It has maintained an average annual growth rate of 2.4 per cent over the last decade (Figure 6.2).[1119] The value of Queensland's economic activity is trending upwards, although growth slowed between 2008 and 2011 (Figure 6.3). The underlying trends driving the Queensland economy (Figure 6.3) have been the housing boom (2004–05 to 2007–08), the coal mining boom (2004–05 to 2008–09), the global financial crisis (2007–08), a cluster of natural disasters (for example, cyclone Yasi and associated floods) (2009–10 to 2011–12), and expanding investment in liquefied natural gas (2012–13 to 2014–15).[1120]

A significant proportion of Queensland's economic activity takes place in the Region and its Catchment

In 2016–17, Queensland recorded economic growth of 1.8 per cent, with the health care and social assistance industry the largest contributor. From 2020–21, the state's economy is predicted to grow by an estimated 2.75 per cent per annum.[1120]

A significant proportion of Queensland's economic activity takes place within the Region and its Catchment. More than 90 per cent of Queensland's saleable coal is exported overseas[1121] from ports within the Region and shipped through the Region. The state's export trade is dominated by mining (64 per cent) and agriculture.[1121] Mining experienced a reduction in 2010–11, but has grown strongly over subsequent years, contributing six per cent to the state's economy in 2015–16 and 2016–17.[1119] Construction activity (engineering, residential and non-residential) contributed eight per cent annually to the Queensland economy between 2015 and 2017.[1119] A boom in liquefied natural gas exports began in 2015–16 and is projected to continue, reaching peak production in 2018–19.[1120,1122]

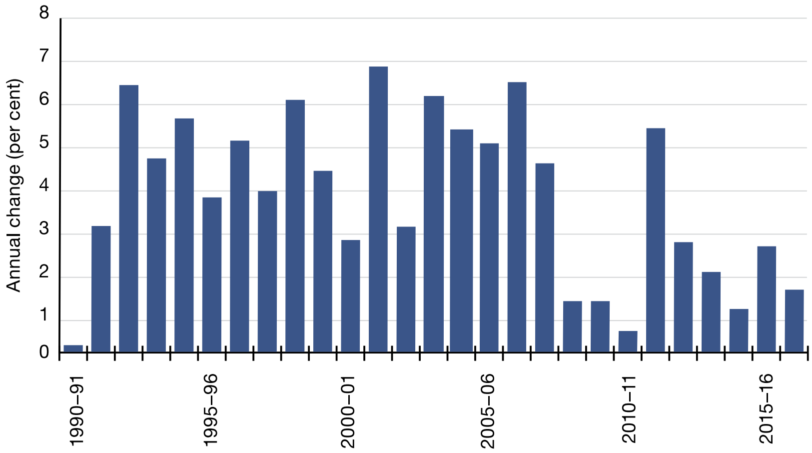


Figure 6.2 Economic growth in Queensland, 1990–91 to 2016–17
Annual percentage change in the Queensland gross state product (chain volume measure) for financial years. Source: Australian Bureau of Statistics 2018[1119]

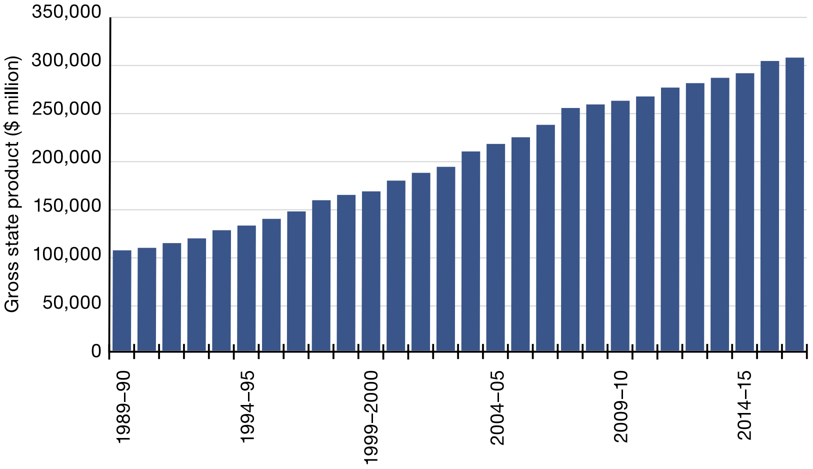


Figure 6.3 Economic activity in Queensland, 1989–90 to 2016–17
Total economic activity in Queensland based on gross state product (chain volume measure) for financial years. Source: Australian Bureau of Statistics 2018[1119]

Since 2010–11, production in the agriculture, forestry and fishing industries has grown steadily. Between 2015–16 and 2017–18 agriculture, forestry and fishing contributed three per cent annually to the Queensland economy, with operations in the Catchment contributing a large component.[1119] In 2016–17, the gross value of agricultural production in Queensland was $14 billion, with approximately half derived from agriculture within the Catchment.[1123] Most of the production value in the Catchment in 2016–17 came from cattle and sugarcane, which accounted for 35 per cent and 22 per cent respectively.[1123] The greatest agricultural output in that period came from the Fitzroy region, mostly from cattle.[1123]

Cattle graze about 320,000 square kilometres of the 480,000 square kilometres in the Catchment (or 67 per cent).[1123] Given its dominance and sensitivity to severe weather, such as droughts and floods, the economic activity of this industry, and thus the Region, can change rapidly.[1119,1121]

Tourism is the Reef's largest economic activity (Section 5.2). In 2016–17, Queensland tourism contributed $11.7 billion (approximately four per cent) to the state economy and areas adjacent to the Reef directly contributed $3.2 billion.[1124] Domestic visitors account for 89 per cent of overnight visitation to Queensland.[1124] The economic contribution of international tourism in Queensland grew from $2.3 billion in 2006–07 to $3.3 billion in 2016–17.[1125] Visitors to the Reef over the last decade have increased in almost all natural resource management regions.[1123] The Mackay–Whitsunday region is an exception, experiencing a slump of 26 per cent between 2006 and 2016, attributed to a decline in domestic visitor numbers.[1123] By comparison, tourism expenditure is far higher in the Wet Tropics region compared with any other, primarily due to Cairns being the point of origin for most visitors to the Reef and the primary destination of international visitors.

6.2.2 Population growth

Population growth is one of the main drivers presenting a challenge to the environmental integrity of the Region. The increasing number of people living close to the coast is a key human-induced pressure on the Reef, primarily due to coastal development and recreational fishing.

Annual population growth within the Catchment is forecast to be 1.1 per cent per year until 2041

In June 2018, the Catchment population was approximately one million with an annual growth rate of 0.3 per cent since 2013.[1126] The Catchment population is expected to climb to 1.32 million by 2041, an increase of 1.1 per cent per year.[1126] Townsville is expected to have the largest population growth to more than 282,000.[1126] Note, these population figures are smaller than those given in the 2014 Outlook Report because they no longer include some local government areas outside the Region.

Employment and lifestyle opportunities in the Region and Catchment influence population growth. The growth of coastal communities generates a variety of impacts, including increased recreational fishing (Section 5.4) and other direct uses of the Region (Section 6.6), coastal development (Section 6.4), and pollution[1127] (land-based run-off; Section 6.5). Coastal infrastructure (roads, marinas and boat ramps), housing development and the demand for more urban support services will inevitably increase with an expanding population.[1126]

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 development can drive both positive and negative changes.[1118] Advances in technology have changed knowledge, management and use of the Region, and in some instances have helped reduce environmental impacts.

Global cooperation across various industries and sectors is required in order to mitigate the effects of climate change. Technological developments are advancing the production of clean energy goods and services. For example, they assist in reducing emissions from food production (sustainable bio-based feedstocks, water saving irrigation), waste disposal (capturing methane biogas), transport (electric super highways, biofuel) and support renewable energy production.[1128,1129] Carbon capture, utilisation and storage is still in early stages of development, and is being addressed by governments at different rates around the world.[1130]

Advances in technology can both reduce and increase environmental impacts

The most significant technological development in terms of reducing greenhouse gas emissions is large-scale deployment of renewable energy. Queensland is the leading state in planned, large-scale renewable energy projects.[1131] Continuing advances in, and expansion of, renewable energy are occurring adjacent to the Reef[1132], and will reduce emissions of greenhouse gases[1131,1133] in the local energy sector. Technological development, innovation and social buy-in will be driving forces in improving energy efficiency and uptake of renewable energy.

The potential of assisted evolution technologies to enhance the resilience of corals to future sea temperature increases by accelerating natural adaptation is being explored.[1134] Additionally, novel techniques, such as assisted gene flow and hybridisation, are being investigated for their potential to enhance the thermal tolerance, growth and reproduction of corals.[1026]

Underwater and above water surveillance technologies have also advanced. Research and development have produced autonomous underwater robots (remotely operated vehicles), which are being tested to determine their use in surveying large areas of reef environments. This will allow crown-of-thorns starfish to be detected over wide areas and injected as a control measure.[1135] This technology may increase data collection capacity, particularly at greater depths and at night, when scuba diving is a higher risk activity.

Above the water, the adoption of drone technology for compliance is proving a cost-effective and efficient method of surveying and monitoring large spatial areas. Drone use will continue to expand, and their decreasing cost and GPS capabilities will see them becoming a primary cultural monitoring and mapping tool. Drones are already used to enforce compliance within the Reef and are used by Traditional Owners to monitor their sea country and record cultural heritage. Use of personal drones is also likely to continue to increase among people using the Region for activities, including recreation, tourism and recreational fishing. This is likely to increase risks associated with public appreciation and wildlife disturbance.

6.2.4 Societal attitudes

Understanding societal attitudes is essential for long-term planning and evaluation of management decisions.[1136] These attitudes are shaped by culture, social norms, values, information, misinformation, circumstances and personal experiences.[1011] By feeding into planning and management, societal attitudes can drive change.[1011] In 2013, residents perceived that shipping, water quality and fishing were the major threats to the Reef. By 2017, this perception had shifted to focus on pollution, climate change and coral bleaching.[785] Other aspects, such as how individuals identify and use the Reef, can also influence their attitude towards the Reef.[969,1011] How attitudes change over time can be affected by the extent of society's knowledge about the Reef, and the source of that knowledge varies.[969,1011] Word of mouth, print and social media play a persuasive role in informing the public's view about the Reef.[1011]

The understanding of societal attitudes is essential for sustainable use of the Region and long-term planning

Results from the Social and Economic Long-Term Monitoring Program (SELTMP)[785] offer some insights into the human dimensions of the Reef. Participants' responses highlighted the importance of the Reef's exceptional natural beauty and superlative natural phenomena to visitors and stakeholders.[785] A prevailing social expectation is that the Reef will remain beautiful and a relatively natural place to live, work and recreate.[969] However, these values are subject to growing pressures and the survey results indicate that the community does not believe enough is being done to prevent ongoing threats to the Reefs especially threats from climate change (Section 4.5.1).[785] Some Reef stakeholders feel climate change is an immediate threat requiring urgent attention, but that opinion is more common among people from the tourism industry (68 per cent) than the commercial fishing industry (27 per cent).[785]

Stakeholders who rely on the Reef for recreational and economic opportunities will experience greater disruption than other stakeholders as the Reef ecosystem changes.[1137] Tourism industry profit and viability can also be affected by publicity about the decline of Reef health.[1138]

Traditional Owners who are more culturally and socially connected to, and dependent on, the Reef than other groups, will experience widespread adverse consequences from declining Reef health.[969] Aboriginal and Torres Strait Islander people value the Reef as a place where people can continue to pass down wisdom, traditions and a way of life (Section 4.3). As custodians and users of the Reef, Traditional Owner groups have the longest connection to their sea country, integrating nature, heritage and Indigenous culture.[1011]

6.3 Climate change

Climate change due to human activities is a global issue that affects terrestrial, wetland, freshwater, marine and coastal ecosystems and the services they provide. Climate change is the most pervasive and persistent influence on the Region. The most immediate and priority current threat from climate change is thermal extremes that cause mass mortality of corals and other organisms. Effects from sea-level rise and ocean acidification are slowly increasing, but are not having nearly the same immediate and Region-wide impact as increases in sea temperature.

Great Barrier Reef waters have already warmed by more than 0.8 degrees Celsius since 1880 due to anthropogenic climate change, with severe impacts already being observed in the Region

In 2016 and 2017, the Region underwent two consecutive summers of mass coral bleaching, resulting in the loss of at least 30 per cent of the Region's shallow-water coral cover (Section 2.3.5). These events are directly attributed to warmer-than-average sea temperatures due to climate change.[1139] The present-day frequency and severity of climate change-related impacts are increasing and interacting with the other key threats (Sections 6.4 to 6.6), compounding their effects.

Of the four main factors influencing the Region's values in the 2014 Outlook Report, climate change was assessed as having the highest negative impact, with impacts on natural and heritage values expected to increase. In the past four years, many worst-case scenario climate change predictions made over 30 years ago[1140] have now been realised[141], and our understanding of the future conditions of ecosystems in the Region has grown considerably.

6.3.1 Trends in climate change

Human activities have already caused approximately one degree Celsius of global warming above pre-industrial levels, with a likely range of 0.8 degrees Celsius to 1.2 degrees Celsius.[1141] Warming is generally higher over land than over the ocean, but recent evidence suggests oceans are heating up about 40 per cent faster than previously estimated[502] and the pace of change is accelerating at an unprecedented rate[452] (Figure 6.4). Both the magnitude and rate of these changes exceed the extent of natural variation over the last millennium and over glacial-interglacial time scales.[1142,1143,1144] The extent to which the climate will change in coming decades depends on current and future greenhouse gas emissions.

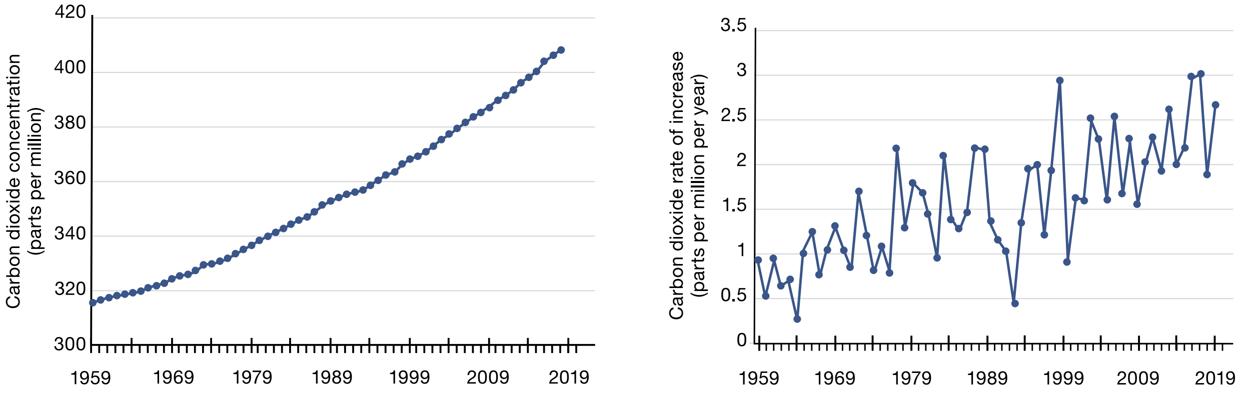


Figure 6.4 Changes in global atmospheric carbon dioxide concentrations
Global carbon dioxide concentrations in the atmosphere have been rising. Both global carbon dioxide concentrations (left) and the annual mean carbon dioxide rate of increase (right) rose steadily between 1959 and mid-2018. Trends shown are based on globally averaged marine surface data. Source: Dlugokencky and Tans 2019[1145]

In 2015, the *Paris Climate Change Agreement* established the goal of holding the increase in the global average temperature to well below two degrees Celsius above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 degrees Celsius.[1146] These aspirational constraints include the warming that has already occurred to date, which in 2017 was approximately one degree Celsius above pre-industrial levels and is currently increasing at 0.2 degrees Celsius per decade.[487] At current rates of warming, global mean temperature would reach 1.5 degrees Celsius between 2030 and 2052.[1141,1147,1148] There is also a very high risk of exceeding 1.5 degrees Celsius and approaching two degrees Celsius by 2065.[487] Warming of 1.5 degrees Celsius would have serious implications for many ecosystems; warming of two degrees Celsius would result in a completely new climate regime under which many ecosystems would undergo irreversible change.[562,1149,1150]

A number of long-term changes in the climate system are already occurring in Australia, such as an increase in mean air and **sea surface temperatures**. Warming over Australia is expected to be slightly greater than the global average[452] (Figure 6.5). In Australia, the best case scenario for halting emissions (referred to as RCP 2.6) would equate to average warming of between 0.6 degrees Celsius and 1.7 degrees Celsius by 2090 (relative to a baseline of average temperatures between 1986 and 2005). Under the worst case scenario (referred to as RCP 8.5), warming would range from 2.8 degrees Celsius to 5.1 degrees Celsius over the same period.[1151] The average air temperature in Australia has already increased by around one degree Celsius since 1910[1151], with severe impacts already being observed in the Region. It is almost certain that the Region will warm by at least another 0.5 degrees Celsius (Section 9.3.2).

From 1925 to 2016, global average marine heatwave frequency and duration increased, resulting in a 54 per cent increase in annual marine heatwave days globally.[1152] In Australia, above-average annual sea surface temperatures have been observed every year since 1994 and have been persistently high in recent years.[1153] Sea surface temperatures in the Australian region have warmed by around 1.0 degree celcius since 1910[452], with the Reef warming by 0.8 degrees in the same period (Figure 6.6).[501] Since 2014, some of the hottest sea surface temperatures ever recorded in the Region's waters occurred in February–March 2016.[165] This marine heatwave was 175 times more likely to occur under the influence of climate change[1154] than without climate change. A second marine heatwave occurred in the 2016–17 summer, with a larger area of the Reef exposed to higher than average sea surface temperatures.[1153] In the future, the chance of a marine heatwave occurring in any given year will be double that of today, if warming reaches 1.5 degrees Celsius and triple if warming reaches two degrees Celsius.[1139]

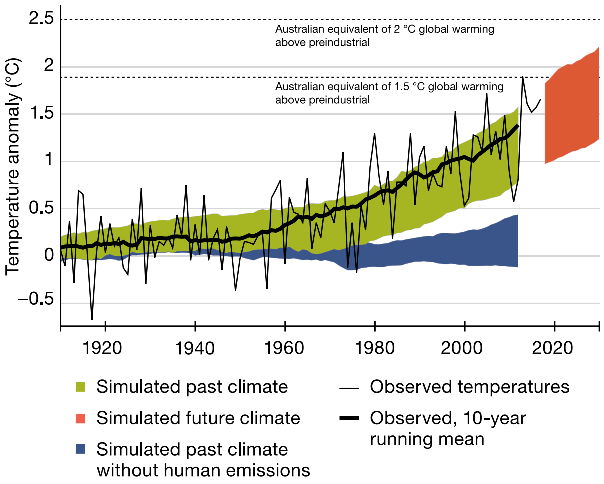


Figure 6.5 Australia's average annual temperature relative to the 1861–1900 period
The thin black line represents Australian temperature observations since 1910, with the bold black line the ten year running mean. The shaded bands are the 10 to 90 per cent range of the 20-year running mean temperatures simulated from the latest generation of global climate models. The green band shows simulations that include observed conditions of greenhouse gases, aerosols, solar input and volcanoes; the blue band shows simulations of observed conditions but not including human emissions of greenhouse gases or aerosols; the red band shows simulations projecting forward into the future (all emissions scenarios are included). Warming over Australia is expected to be slightly higher than the global average. The dotted lines represent the Australian equivalent of the global warming thresholds of 1.5 °C and 2 °C above preindustrial levels, which are used to inform possible risks and responses for coming decades. Source: CSIRO and Bureau of Meteorology 2018[452]

Changes to temperature extremes often lead to greater impacts than changes to the mean climate. For example, it is estimated that by 2090 under the worst-case scenario (RCP 8.5), Cairns would experience 48 days per year of air temperatures exceeding 35 degrees Celsius, a dramatic rise from the current three days per year.[485,1156] The frequency and severity of extreme events, such as heat waves, are critical and have important consequences for the Region's values.

Heatwaves are becoming hotter, lasting longer and occurring more often, affecting both terrestrial and marine environments

As the ocean continues to warm and land-based ice starts to melt, the pace of global **sea-level rise** will accelerate.[485] Although mitigation of greenhouse gas emissions might reduce the overall magnitude of sea-level rise in the long-term, the Earth is already locked into significant sea-level rise this century, regardless of what future emission scenario is followed, due to the lag effects in ocean warming and ice-melt.[1157,1158] Projections for global sea-level rise by 2090 range from 0.6 to 0.86 metres and strongly depend on current and future emissions. However, sea-level rise is currently tracking toward the worst-case scenario (RCP 8.5) of up to 0.86 metres.[1151,1159]

The fastest sea-level rises are being recorded in Australia's northern areas.[486] Since 1993, the average rate of sea-level rise in the Region was between five and seven millimetres per year (and in some locations up to 12 millimetres per year[486]), well above the global average of 3.2 millimetres per year[1160]. Sea-level rise directly threatens low-lying habitats within the Region, such as islands, beaches and coastlines (Chapter 2). As average sea level continues to rise, the height of extreme sea-level events (such as storm surges during tropical cyclones) will also increase, causing increasingly severe impacts on coastal communities, infrastructure and coastal habitats.

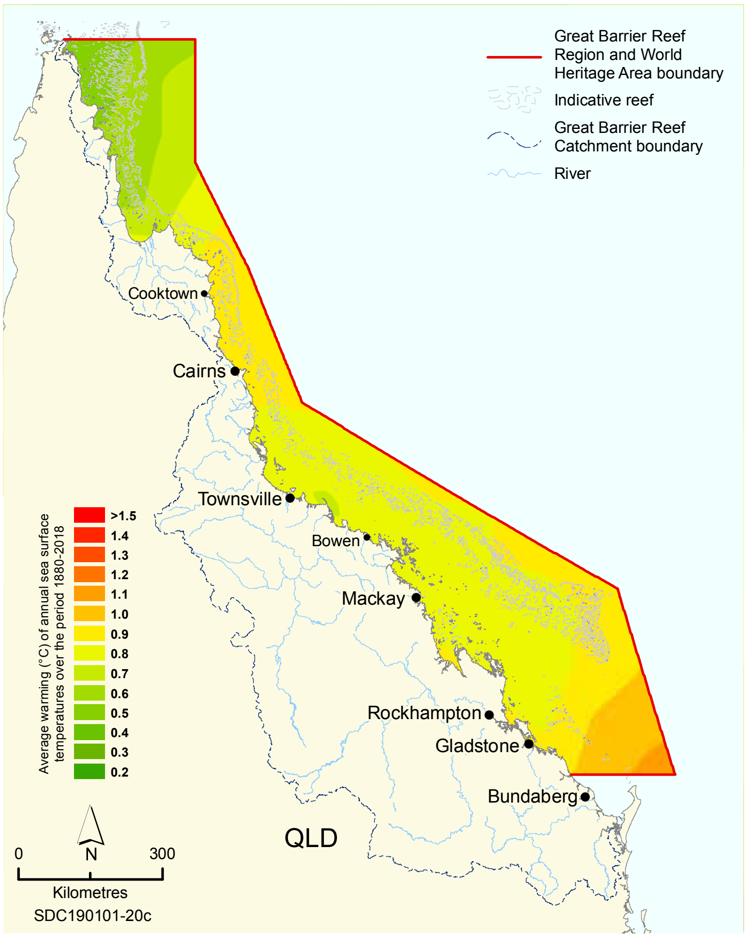


Figure 6.6 Average warming of annual sea surface temperature between 1880 and 2018 for the Great Barrier Reef
Annual sea surface temperature (SST) was extracted from the Met Office Hadley Centre for Climate Prediction and Research (HadISST1 data set) for 1-degree latitude x 1-degree longitude grid boxes for the Region.
Source: Rayner *et al.* 2003[1155]

The ocean provides a critical service to both ecological communities and human society by strongly regulating the climate system, particularly through the absorption of carbon dioxide. Without this service, the amount of global warming to date would have been considerably higher. However, increased carbon dioxide in the ocean alters its **ocean chemistry**. Since the beginning of the Industrial Revolution, the ocean has absorbed roughly one third of the anthropogenic carbon dioxide emissions.[1161] In response, **ocean pH** has decreased close to 0.1 units since the pre-industrial period (Section 3.3.2). The increase in carbon dioxide has also reduced the concentration of carbonate ions in the ocean by 30 per cent[545,1162]; at a rate at least 10 times faster than any concentration change within the last 65 million years[1163].

In the Region, the rate and magnitude of increases of carbon dioxide concentrations are more significant on inshore reefs (those within 10 kilometres of the coast) than reefs further offshore.[162,163,164] In the past 30 years, carbon dioxide concentrations on these inshore reefs have increased at a rate up to three times higher than atmospheric values, suggesting that the Region's inshore coral reefs are more vulnerable to ocean acidification and have less buffering capacity compared to mid- and outer-shelf reefs.[162] However, the effects of this may currently be negligible compared to the observed, severe impact of ocean warming on the Reef.

Global atmospheric and ocean circulation patterns and rising temperatures influence **ocean currents** (Section 3.2.1). The major current in the Region, the East Australian Current, has become one of the fastest warming currents in the world, warming two to three times faster than the global average ocean warming rate.[427] This has led to two major changes in the current's properties: the amount of water it transports southward and the frequency of eddy formation. The East Australian Current has already advanced beyond its normal southern boundary, about 350 kilometres off the coast of New South Wales and this trend is expected to continue.[427]

Although current projections suggest the frequency of **tropical cyclones** is most likely to remain stable or even decrease[56,1164,1165], cyclone intensity is expected to increase (Section 3.2.2)[55,56]. As a result, a marked increase in the frequency of the most intense cyclones (categories 4 and 5) is projected.[1164,1166,1167] Since 1975, the proportion of intense tropical cyclones has increased 25–30 per cent, corresponding to the observed one degree Celsius of global warming.[1167] Modelled projections have indicated that relative to pre-industrial conditions, cyclones in northeast Australia will have both higher wind speeds (by 5–10 per cent on average) and heavier rainfall (by up to 27 per cent for average hourly rainfall rates) under worst-case scenario (RCP 8.5) future climate change.[1168] To date, climate change has not significantly influenced cyclone wind speeds but has significantly enhanced rainfall by 4–9 per cent.[1169] The forward speed of tropical cyclones over Australia has slowed by 22 per cent since 1946, increasing the potential for higher total rainfalls as cyclones remain over certain locations for longer periods.[453]

Rainfall variability is strongly related to changes in sea surface temperatures across the Pacific Ocean associated with El Niño–Southern Oscillation.[1170] However, as the influence of climate change strengthens, the intensity of heavy rainfall events is projected to increase in the Region.[1156] This has already occurred on a global scale; approximately 20 per cent of global heavy rainfall events over land are attributable to the observed temperature increase since pre-industrial times.[1171] Australian weather station records show that a higher proportion of total annual rainfall in recent decades, compared with earlier, has come from heavy rain days.[452] For heavy rain days, total rainfall is expected to increase by around seven per cent for each degree of warming, whereas for short-duration rainfall events, observations in Australia generally show a larger than seven per cent increase per degree of warming.[452] More intense rainfall will increase the likelihood of severe floods and subsequent large freshwater inflows to the marine environment (Section 3.2.3), increasing turbidity and sedimentation (Section 3.2.4) that can damage inshore coral reefs and seagrass meadows. Based on analyses of coral cores, extreme flood events are now occurring more frequently than in the past and fresh water is extending further out to mid-shelf areas of the Reef more often.[457]

The El Niño–Southern Oscillation is the most important driver of inter-annual climate variability in the Region, associated with a sustained period (many months) of warming (El Niño) or cooling (La Niña) in the central and eastern tropical Pacific.[1156] During an El Niño event, the prevailing trade winds that blow from east to west across the Pacific Ocean weaken or even reverse, and the eastern tropical sea surface temperatures warm. The opposite occurs during a La Niña event.

Extreme El Niño events result in the centre of Pacific rainfall moving eastward, away from the Australian coast towards South America. The common result is intense droughts across eastern Australia[1172] and unusually warm late summer sea surface temperatures in the Region[459]. Extreme El Niño events have occurred in the Region in 1982–83, 1997–98 and 2015–16 coinciding with worldwide climate extremes and are predicted to increase in frequency due to climate change.[1173] Compared to the past four centuries, Eastern Pacific El Niño events over the last 30 years have been fewer, but more intense.[1174] Additionally, the link between El Niño and coral bleaching has weakened, because La Niña sea surface temperatures today are warmer than they were during El Niños 30 years ago, due to global heating.[99] Two of the four mass bleaching events on the Reef have occurred during El Niño phases of El Niño–Southern Oscillation cycles (1998 and 2016) and two have not (2002 and 2017).[88] Even if global warming is limited to 1.5 degrees Celsius, the risk of extreme El Niño events is predicted to increase from around five events per 100 years to at least 10 events per 100 years by 2050 (based on the lowest emissions scenario RCP2.6).[1172] During extreme La Niña events, the Australian summer monsoon is more vigorous than usual, with more tropical cyclone activity in the Region. This results in above-average rainfall and river flows, as happened in 2010–11. The extreme rainfall of that summer season was exacerbated by warmer sea surface temperatures around tropical Australia.[1175] The frequency of such extreme La Niña events are also projected to increase in a warmer world.[1176]

The extreme rainfall event in early 2019 resulted in widespread flooding, inundating homes, businesses and local sports clubs, such as the Townsville and James Cook University Rowing Club. © Chloe Schauble

6.3.2 Vulnerability of the ecosystem to climate change

The Region is particularly vulnerable to the pervasive influence of a rapidly changing climate.[1150] The primary concern is impacts on habitat-forming species, such as corals, seagrasses and mangroves, in the Region. Severe impacts that reduce the abundance or condition of habitats have flow-on effects to dependent species and communities in the Region.[1177,1178,1179]

Increasing temperatures are threatening most species and habitats in the Region

Coral reefs and coral-dependent species are the most vulnerable to **sea temperature increases**[1180] (Figure 6.7), as evidenced by the 2016 and 2017 mass bleaching events (Sections 2.3.5 and 2.4.4). Cascading effects have already resulted in the decline of coral-associated fish and invertebrates.[244,273] As the climate continues to change, the capacity of hard corals to survive, grow and reproduce is increasingly compromised[96], with resulting consequences for other species dependent on coral reefs (Section 2.3.5).

Seagrass meadows are less vulnerable to temperature increases than are coral reefs (Figure 6.7).[1181,1182] However, extreme water temperatures (greater than 40 degrees Celsius) can be fatal to seagrasses.[1181,1183] Recent evidence has linked seagrass decline in Western Australia[1184] and more than 7400 hectares of mangrove dieback in the Gulf of Carpentaria[1185] to severe marine heatwaves due to global warming. Severe cyclones Ita (2014) and Nathan (2015) resulted in 400–600 hectares of mangrove forest dieback near the Starcke River, Cape York.[52] These mortality events highlight the susceptibility of these ecosystems to the effects of climate change. Loss of seagrasses and mangroves will potentially release stored carbon back into the atmosphere, contributing to further rises in atmospheric carbon dioxide concentrations.[51,61] Projections of the future distribution of seagrasses suggest a poleward shift due to increasing sea water temperatures.[1186]

Bleached hard and soft corals at Low Isles, March 2017.
© Jenni Fox 2017

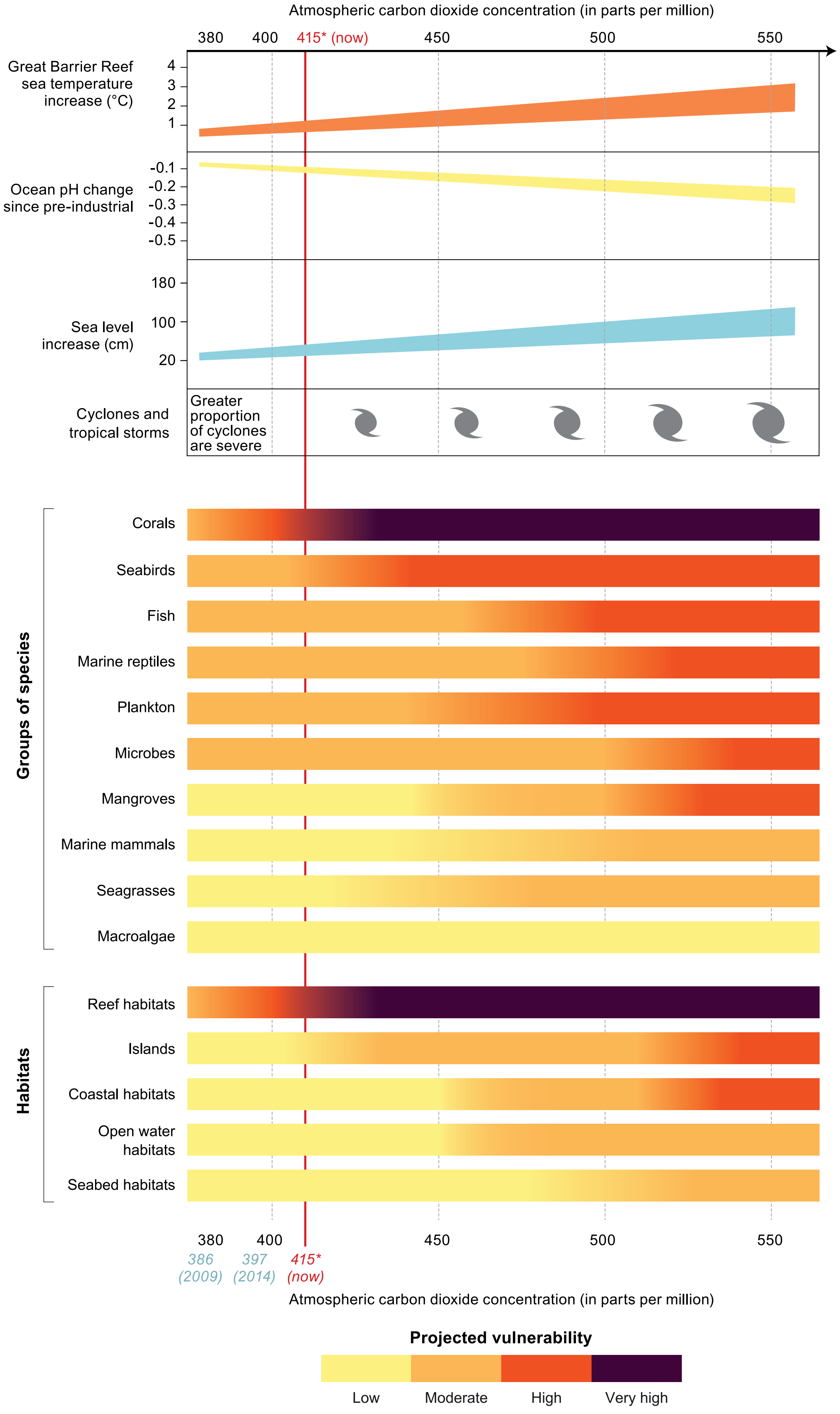
Calcifying organisms, including corals, echinoderms and algae, are most vulnerable to **ocean acidification**.[231,508,1187] Even relatively small decreases in ocean pH reduce the capacity of corals to build skeletons, which in turn reduces their capacity to create habitat.[1188,1189] As ocean acidification rates are highest on inshore reefs, which account for approximately 20 per cent of the total number of reefs in the Great Barrier Reef, the rapid decline of these inshore reefs is of great concern.[162] When calcifying organisms are weakened they are less able to resist and recover from physical damage caused by tropical cyclones.[1190]

Since 1975, a 27–49 per cent decrease in net calcification by the coral community has been observed on Lizard Island reefs.[1191] Another study demonstrated that net community calcification under pre-industrial conditions was significantly higher than it is today.[1192] This may indicate that ocean acidification could already be impairing coral reef growth. Over 55 million years ago, under high atmospheric concentrations of carbon dioxide, a reduction in calcification occurred.[105,1193,1194] It took tens of thousands of years for those changes to reverse[543], which means the emerging risks associated with ocean acidification will be essentially irreversible on human timescales.[1195]

Sea-level rise is projected to place significant pressure on coral reefs[488], mangrove forests[1185] and seagrasses[47], as well as on salt marshes and islands.[1196] For these habitats to persist, growth must keep pace with sea-level rise, however few coral reefs have the capacity to do this.[488] More frequent coastal inundation will lead to hyper-salinisation of coastal habitats and shifts in intertidal species distributions.[510]

Most marine organisms are ectotherms and are unable to regulate their body temperature. Increases in temperature affect their performance and fitness.[1197,1198] Temperature impacts due to global warming are evident on many species in the Region (Section 2.4), with mass mortality of fish and invertebrates in shallow northern reef lagoons in 2016.[90] Temperature experiments involving coral trout found declines in survivorship, metabolism and swimming activity with relatively moderate increases in temperature[277,1023,1199] (Section 2.4.7). Feminisation of green turtle hatchlings originating from Raine Island nesting beaches has been an ongoing trend for more than two decades, due to increasing sand temperatures caused by global warming (Section 2.4.10).[319] Thermal stress reduces reproductive rates and alters behaviour in crustaceans (Section 2.4.5).[243,636] Although the sub-lethal effects of temperature are often inconspicuous, they can potentially de-stabilise how the ecosystem operates.[243,636,1200]

Indirect effects of increasing temperatures are also a concern for the Region. Latitudinal shifts in species distributions and changes in the timing of biological events have already been shown for a number of plankton, bony fish and invertebrate species in response to temperature increases.[1201] Effects of increased sea surface temperatures, such as changes in timing of breeding and body size of breeding adults and loss of adequate food supplies, have been observed in many bird populations within the Region.[361,1202,1203,1204]



* For the first time since human existence, the planet's atmosphere has reached 415ppm

Figure 6.7 Projected vulnerabilities of components of the Reef ecosystem to climate change
Vulnerability differs for a number of ecosystem components and depends on total atmospheric carbon dioxide concentrations. Changes in sea temperatures, ocean pH and sea level are indicative only, based on the latest climate projections.
Source: Adapted from values presented in Gattuso *et al.* 2015[1159] and Hoegh-Guldberg *et al.* 2018[487]

As the East Australian Current strengthens and moves warmer water further south, some tropical species are expanding southwards along the southeast coast of Australia.[1205,1206] As southern waters continue to warm, particularly during winter, these species may persist and establish new populations, representing a range expansion and the tropicalisation of temperate marine ecosystems.[691,1207] Different species compositions could result in a reorganisation of ecosystem functions, particularly if displaced species are habitat-forming and lose their dominant position in the ecosystem.[1208,1209] Overall, range shifts and changes in the timing of biological events can desynchronise ecological interactions and thereby threaten ecosystem function.

The Region's key habitats, such as coral reefs, seagrass meadows and mangroves, have a natural resilience against acute physical disturbances, such as tropical cyclones, intense rainfall, freshwater flood plumes and heatwaves. However, climate change is exacerbating both acute and chronic disturbances in the Region, shrinking recovery windows and overwhelming resilience capability.[99,439,1152,1172] In the past four decades, warming due to climate change has resulted in a five-fold increase in severe coral bleaching events globally[99], and it will amplify the effects of other influencing factors, such as direct use, coastal development and land-based run-off (Sections 6.4 and 6.5).

6.3.3 Implications of climate change for regional communities

The threat of climate change is particularly pronounced for Reef-reliant communities

Climate change is the primary driver increasing threats to communities living in, or adjacent to, the Region, through an increase in climate extremes (record-breaking temperatures, floods and droughts) and declining Reef condition. This then affects health and wellbeing, food security and economic benefits. The ecological and economic benefits regional communities derive from the Region are diverse, and include income from fisheries and tourism, coastal protection, habitat provision for valuable species and cultural values.[1210] Climate change has already reduced fisheries productivity[1211], positive tourism experiences[1212], and coastal protection by mangroves, seagrasses and coral reefs.[1213,1214] For example, it is estimated that global marine fisheries catches will decline by three million metric tonnes for every degree Celsius of global warming, with serious regional impacts.[1215] Human health will also be affected by climate change, through increased disease outbreaks[1216], heat stress[1217] and reduced food security.[1218]

The vulnerability of reef-reliant industries largely depends on their exposure and sensitivity to the associated impacts, as well as their ability to anticipate and adapt to change. Surveys indicate people in the tourism industry are very concerned about the impacts of climate change on their businesses and livelihoods. Approximately one third of commercial fishers surveyed expressed similar concern, but many others still felt they needed more evidence to be convinced of the problem[785] (Section 6.2.3). Building stronger and more resilient communities will be critical for the future sustainability of reef-reliant industries.[24] Actions taken to improve community knowledge of climate change will enable communities to better prepare for, and mitigate, the impacts of climate change.

6.4 Coastal development in the Catchment

New and legacy barriers to the flow and modification of coastal ecosystems continue to affect Reef health

Coastal development includes all development activities, construction and land uses along the coastline as well as inland areas within the Catchment and development on islands (Section 2.3.1). The broad range of intensive land use in the Catchment exerts individual and cumulative pressures on coastal and inshore ecosystems.[718] It is broadly accepted that to support the condition and resilience of the marine ecosystem, priorities must continue to focus on reducing agricultural sources of pollutants from contributing land uses.[462,1219] Using land for agriculture is an aspect of coastal development. Trends in agricultural land management practices that affect water quality are examined in the land-based run-off section of this report (Section 6.5).

Approximately one million people live in the Catchment.[1126] In 2016, an estimated 885,000 people were living in the 18 local government areas with direct coastline access to the Region[1054,1220], approximately four per cent more than in 2011. Around 4100 new dwellings were constructed in these local government areas between 2014 and 2017, representing a slower housing market of approximately eight per cent in the same period. Population growth drives coastal development, concentrating mainly around urban areas. In turn, infrastructure demands intensify (for example, more roads and larger stormwater networks) and expansion into previously remote areas of the Catchment may occur (for example, Cape York). Pressure to produce and export food will also drive demand for agricultural land in the Catchment. Since 2014, the greatest expansion of any land use in the Catchment has been in conservation and natural environments, including wetlands (Figure 6.8). The expansion has specifically involved the conversion of one land use to another, and occurred predominantly in the Cape York and Mackay–Whitsunday natural resource management (NRM) regions.

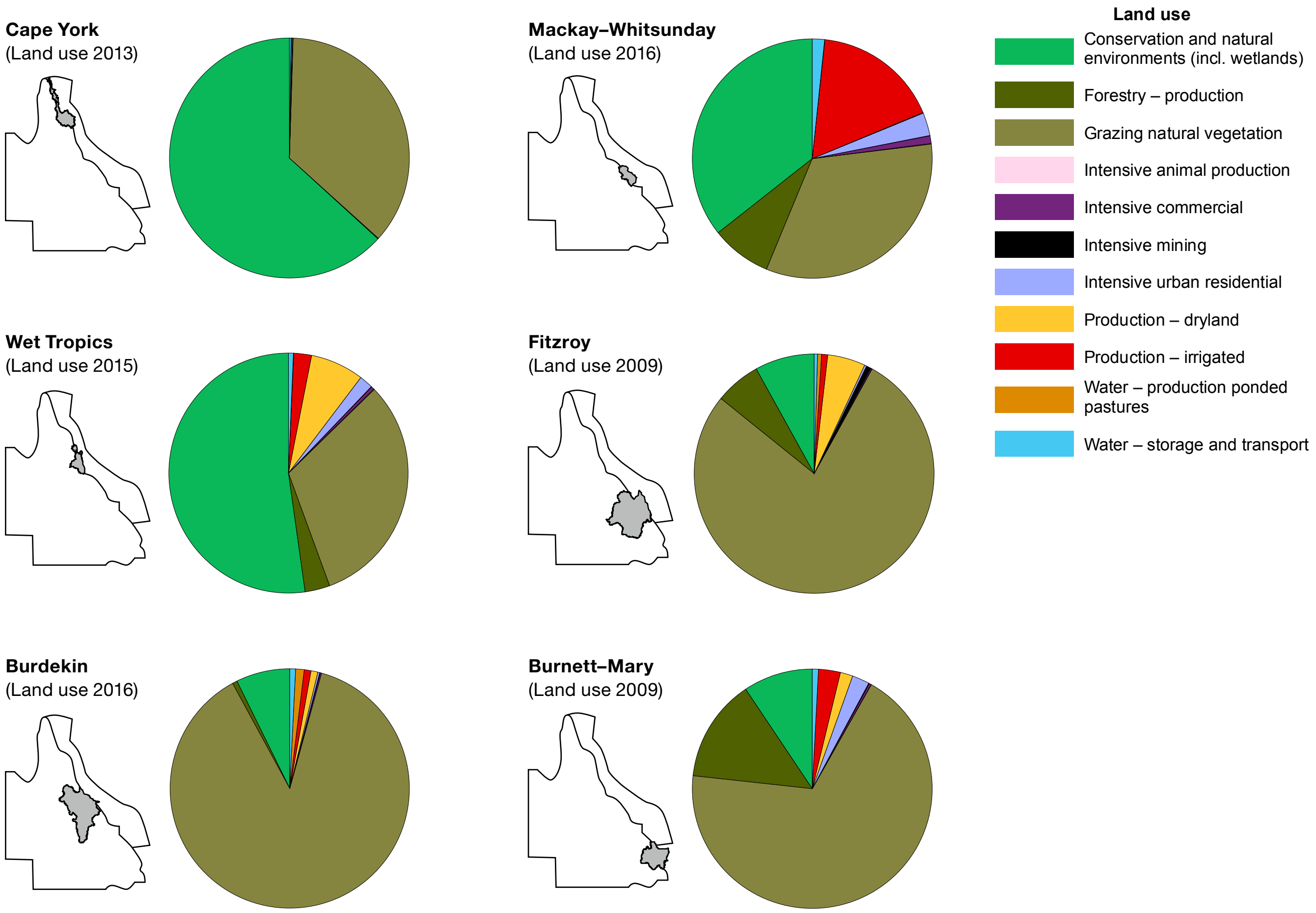


Figure 6.8 Proportion of land uses in the Catchment
Catchment land uses are grouped according to similarities in the ecological functions they provide to the Reef. The graphs identify the latest data capture between 2009 and 2016 for each natural resource management region. Source: Adapted from Department of Science, Information Technology, Innovation and the Arts (Qld)[1221]

6.4.1 Trends in coastal development

Agriculture Most land in the Catchment (about 72 per cent) supports some form of agricultural use (grazing, dryland or irrigated production and intensive animal production).[1221] As with other sectors of the Queensland economy, the primary industry sector has experienced growth in the value of production since 2014. In 2017–18, the total value of Queensland's primary industry commodities (combined gross value of production and first-stage processing) was forecast to be $19.45 billion — nine per cent greater than the average for the previous five years.[1222]

Most land in the Catchment supports some form of agricultural use

© Department of Environment and Science (Qld)

Agriculture is the main pollutant source affecting the condition of the marine ecosystem, via land-based run-off from the Catchment (Section 6.5).[527] Diffuse source pollution (not from a single discharge point) is run-off from agricultural land uses. The magnitude of the threats to the Region from poor water quality are influenced by activities, soil type and topography in the Catchment. Relevant activities include modifying coastal ecosystems (Section 3.5); the construction of barriers to flow (such as roads, rail lines, ponded pastures and weirs); and subsequent agricultural land practices (such as fertiliser use, irrigation and crop-rotation). New and legacy vegetation clearing and infrastructure, such as ponded pastures, continue to be significant human-induced threats to the Reef.[9,1219,1223] How the land can be managed to minimise the threat is considered in the assessment of land-based run-off in Section 6.5.

Mining and resources Queensland's richest resource provinces are located within the Catchment. The resource sector contributed $29.1 billion (including direct spending on royalties, tax and wages) to Queensland's economy in 2017–18.[1224] Coal mining was the largest contributor, accounting for approximately $19.9 billion (68.3 per cent of the total spending). While coal exploration activities in Queensland have declined (with a 25 per cent drop in granted exploration tenure in 2015–16 compared with the previous year), new projects are still in progress.[1225] Statewide coal production (coking and thermal net output) remained generally steady between 2014–15 and 2016–17 at approximately 240 million tonnes per annum.[1224]

Urban run-off is a lower threat than run-off from other major land uses

Urban and industrial development Urban and industrial development occupies a small proportion of the Catchment (less than 0.7 per cent) and minimal expansion has occurred since 2014.[1221] Population growth exerts pressure to develop land, construct new or upgrade infrastructure (such as roads and utilities, which impede flow) and encroach on coastal and inshore ecosystems.[1226] Gaps remain in our understanding of cumulative impacts from new and legacy development. Given the established regulatory framework for urban and industrial development, the impact of urban run-off (or point source pollution channelled to a single discharge point; Section 6.5) on water quality and Reef condition is considered localised and a lower threat than run-off from other major land uses. Instead, the influences of agriculture (particularly cane farming and cattle grazing land management practices) continue to be the focus of ongoing water quality management.[462] In 2018, urban, industrial and public lands were incorporated into new water quality targets.[527] The increasing impact of land-based marine debris is an emerging concern for Australian residents[785] (Section 6.5). The extent of artificial light pollution from coastal development (urban areas, industry, ports, marinas and ships in anchorages) remains a data gap.

Sewage treatment plants An example of point source pollution is sewage treatment plants. These facilities have been progressively upgraded over the last 25 years.[9] In 2017, an industry analysis estimated that 76 sewage treatment plants were located within 50 kilometres of the coastline.[1227] Of these, 27 had achieved best practice for the reduction of nitrogen and phosphorus loads to the Region ('tertiary' treatment standard). Achieving this standard may not always be feasible in some locations.[1219,1227] Overall, the contribution of sewage treatment plants to anthropogenic nutrient loads to the Region is minor[467], however, comprehensive evidence about these facilities is limited.[1223]

Barriers to flow Waterways within the Catchment have been affected by barriers to flow since European settlement. Structures of all sizes that impede water flow have an influence on waterway condition and function. Data are limited on the extent of these structures across the Catchment, however, statistics are available for the Mackay–Whitsunday and Wet Tropics NRM regions. River basin assessments for 2013–14 in the Mackay–Whitsunday region consider barrier density on freshwater waterways, estuary barrier density and in-stream habitat modification.[1228,1229,1230] For example, overall the Plane River rates poorly and the Don River is considered good. The Wet Tropics analysis from 2015–16 continues to evolve, and several indicators have not yet been developed or monitored.[1231] However, the Wet Tropics region had more waterways free of barriers in 2015–16 than the Mackay–Whitsunday region in 2013–14.

Tidal works Sea walls, groynes and reclamation are tidal works that present barriers to flow. The Region is susceptible to impacts from tidal works mainly near built-up areas. Tidal works have occurred in, and adjacent to, the Region since European settlement. While quantifiable extent data are available for some works, comprehensive data on all tidal works and their cumulative impacts are lacking. A recent study estimated nine per cent of the Region's mainland shoreline has been modified by engineered structures.[1232] Most structures occur in marina and port developments, with 60 per cent located within the lower three kilometres of estuaries.

Linear infrastructure Privately and publicly owned roads, rail and tracks are types of linear infrastructure that present barriers to flow. They are not confined to built-up areas and are present across the Catchment. New or upgraded roads make marine and coastal areas more accessible and can increase direct use of the Reef. Erosion from linear infrastructure has been identified as a significant sediment source within particular parts of the Catchment[467] and a vector for pests and weeds into remote coastal ecosystems. For example, in the Normanby–Stewart catchment of Cape York, linear road infrastructure represents the largest direct human-induced disturbance of all intensive land uses in this area.[1233] Access to quantitative data on the state of existing linear infrastructure remains a challenge for condition and trend reporting.

Linear road infrastructure represents the largest anthropogenic disturbance in some areas of the Catchment

Aquaculture Aquaculture is a comparatively minor land use in the Catchment, covering an estimated 30 square kilometres. However, six land-based aquaculture development areas identified in the Catchment are proposed to promote the growth of this sector.[1234,1235,1236] Since 2014, the statewide production value has been varied but overall it has declined (less than five per cent, from $120 million in 2014–15 to $114 million in 2017–18).[1237] No marine-based aquaculture facilities are currently operating in the Region.

Port development Port development undertaken directly in the Region is described and assessed in Section 5.5. Land-based aspects of port activities (above low water mark, including reclamation) form part of the coastal development assessment. However, coordinated data on the extent of new and legacy port reclamation remains a data gap. New reclamation is thought to be minimal since 2014. Point source pollutants from ports are regulated and impacts on the Region are largely localised. However, coordinated data across all ports in the Region are limited.

Marine access infrastructure Marine access infrastructure and launch facilities (boat ramps, pontoons and marinas on islands, in rivers and on the mainland coast) support local, recreational and tourism access to the Region. While some of these facilities are outside the Region, impacts from dredging and disposal of these facilities may flow into and affect the Region. The threat is assumed to be minimal and localised, given the small volumes and permit conditions. Since 2014, approximately 323,000 cubic metres of material in total was dredged (capital and maintenance) at these facilitates in and adjacent the Region.[1238]

Island development Development on some of the Region's islands supports permanent residential populations and tourism resorts. The principal residential islands include Palm Island and Magnetic Island, with stable populations of about 2400 and 2300, respectively.[1054] Islands of the Reef form part of the property's outstanding universal value. The property's aesthetic heritage value has been affected by a number of deteriorating island destinations on state-owned land (including national parks).[1239] While many island resorts have remained closed following cyclones in 2011 and 2017, Daydream Island Resort reopened in early 2019. At the time of writing, a proposed redevelopment on Great Keppel Island had not progressed and a proposal at Lindeman Island was amended, removing marine infrastructure elements. A development at Hummock Hill near Gladstone, approved in 2018, also amended its plans to remove marine infrastructure.

Deteriorated island resort infrastructure affects aesthetic heritage values

6.4.2 Vulnerability of the ecosystem to coastal development

The Region's ecosystem remains vulnerable to the effects of legacy, current and future coastal development, as well as cumulative impacts. The primary pressure from coastal development is from agricultural land use. By comparison, pressure from urban, industrial and mining development is minor. Modifying coastal ecosystems and barriers to flow increases the risk posed by poor water quality entering the Region.

The Region's ecosystem remains vulnerable to the effects of legacy, current and future coastal development

Modifying coastal ecosystems for coastal development limits their ability to provide ecosystem function and services that benefit the values of the Reef[102] (Section 3.5). For example, modifying wetlands can limit their effectiveness in absorbing and transforming pollutants, slowing overland flow and providing nurseries for freshwater and marine species.[43,102,707,719] Intact coastal ecosystems can prevent major erosive processes (like gully erosion) and abundant ground cover may decrease sediment and nutrient loads entering the Region.[467] As an indicator of modification, between 2015–16 and 2017–18, the Catchment accounted for a consistently high proportion (about 38–47 per cent) of woody vegetation clearing in the state (Section 3.5 Figure 3.12).[703,704]

Land-based pollutants from the Cape York NRM region are not recognised as posing a high threat to coastal or marine ecosystems.[1240] Even so, proactive management actions are being taken. For example, in 2016 the Queensland Government purchased Springvale Station (a 560 square kilometre cattle property) with an aim to reduce sediment into the Normanby River catchment. The property is in the state's protected area estate and contributes to the 73 per cent of area added to conservation and natural land use across the Catchment.[1233,1241] Data are not yet available on the performance of the remediation activities on Springvale Station (such as destocking and erosion management[1242]; Figure 6.9) or any improvements in water quality entering Princess Charlotte Bay. By contrast, the Cape York region falls within the 20-year plan to invest and support economic expansion of northern Australia.[1243] This initiative may result in expansive new barriers to flow and further modification of coastal ecosystems in this area.

Agricultural land use is the primary pressure on the Reef from coastal development

Barriers to flow, such as tidal barrages and tidal works, have historically been installed to prevent the ingress of saline tidal waters and often to provide road access to the foreshore. As a result ponded pastures are created, impounding fresh water or forming an area to expand cropping and grazing land (Section 3.5.1). Where barriers reduce freshwater flow and connectivity between marine and freshwater systems, fisheries productivity can be reduced.[1244,1245,1246] Long-standing legislative arrangements mean the Region's exposure to impacts from new ponded pastures infrastructure should be limited.[712,713]

Figure 6.9 Gully erosion, West Normanby River catchment, Springvale Station © Kerry Trapnell 2017

Barriers to flow have been linked to the mobilisation of acid sulfate soils. Activities that may disturb **acid sulfate soils** have been regulated in Queensland since the early 2000s, reducing the exposure of the Region to such impacts. Acid, metals and other contaminants in these soils can affect many species at a local scale, both immediately and through accumulation in the food chain. This occurred in the Trinity Inlet (Cairns) where a seven kilometre bund wall was constructed in the 1970s to enable sugar cane production.

The Queensland Government purchased and created the East Trinity Environmental Reserve in 2000, undertaking active remediation. By 2016, the area returned to a functioning mangrove ecosystem and wildlife habitat.[1247,1248]

Tidal works, such as foreshore seawalls and groynes outside, and encroaching on, the Region, can affect inshore marine habitats by altering local marine hydrology, permanently removing inshore marine habitats and diminishing local aesthetic attributes. The presence of **artificial light** adjacent to the Region is an inferred increasing risk as regional communities expand in the coastal zone. It is known that emerging marine turtle hatchlings have a reduced ability to find the sea in the presence of artificial light (Section 2.4.10).[331]

Mining and other resource activities cover a comparatively very small proportion of the Catchment, but they can expose the Region to impacts that are hard to reverse. Contaminated tailing water flowing into the Region or water table is a current and future threat. Threats are regulated through new environmental protection legislation.[1249,1250,1251] Resource-based activities can affect the Region's natural, Indigenous and historic heritage value in two main ways.[1252,1253] Firstly, the historical export of resources and agriculture has been the major driver of port, linear infrastructure and urban expansion along the Region's coast. Secondly, continued global use of fossil fuels is the primary driver of climate change and ocean warming (Section 6.3).

Atmospheric pollution (excluding the contribution to climate change of gases, such as carbon dioxide) is not currently a significant threat to the condition of the Reef. While some recent studies have considered the impacts of pollutants like coal dust particles on the Reef (Section 5.7)[1078,1079], limited data are available for other atmospheric pollutants.

6.4.3 Implications of coastal development for regional communities

Coastal development occurs in areas of the Catchment where the bulk of the population reside. While rural areas have low populations, coastal development in the form of agriculture (specifically grazing) is the dominant land use in the Catchment and is the primary source of poor water quality entering the Region. As such, human-induced land-based run-off remains one of the greatest impacts and threats to the Reef — and one of the most manageable.

Implications of coastal development cannot be considered in isolation from other influencing factors

In urban areas and small communities, coastal development provides broad economic and social benefits via employment, economic activity, housing and places for recreation. While some data and monitoring gaps exist, urban activities are considered well regulated and their impacts on the Region are largely minor and localised.[462,1219] However, modifying coastal ecosystems for further urban or agricultural development remains a threat to the condition of the Region. The pressure exerted by modifying coastal ecosystems is more pronounced in rural areas, resulting in poor water quality entering the marine environment.[1219] Poor water quality more broadly can affect the economic and social benefits regional communities derive from the Region (Section 6.5.3). The effects of climate change (Section 6.3) are likely to amplify the effects of coastal development (urban, industrial and rural) on the Region. The implications of coastal development, therefore, cannot be considered in isolation.

6.5 Land-based run-off

Land-based run-off comprises freshwater flow (Section 3.2.3) from the terrestrial environment and what is carried with it into receiving waterbodies, including sediments, nutrients, pesticides and other pollutants (Sections 3.2.4 and 3.3.1). Land-based run-off can be both point source and diffuse source. A point source is a single, identifiable, discharge point, such as a pipe. Diffuse sources are inputs occurring over a wide area, not easily attributed to a single source, such as land-based run-off.

As water flows through the Catchment to the marine environment, the uses of the land it passes through and over have a strong influence on its volume, velocity and quality. Activities, such as the application of fertilisers, livestock management, pest control, stormwater and sewage management, aquaculture, mining and fracking, and earthworks can all affect the resulting water quality.[1254]

Diffuse source land-based run-off occurs naturally and has always delivered sediments and nutrients to the Region. However, changes in land use within the Catchment since European settlement have increased the loads of sediments, nutrients and other pollutants (including pesticides, herbicides, heavy metals and plastics) entering the Region. The expansion of Catchment development (particularly agriculture) has been a primary contributing factor (Section 6.4).

The 2017 Scientific Consensus Statement determined that *'current initiatives will not meet the water quality targets'* and *'progress towards water quality targets has been slow'*.[462,1223] The *Reef Water Quality Protection Plan 2013*[720] was updated in 2017, and transitioned into the *Reef 2050 Water Quality Improvement Plan 2017–2022* (Reef 2050 WQIP).[527]

The Reef 2050 WQIP was released in 2018. Actions and progress towards Reef 2050 WQIP targets are assessed annually. The whole-of-Reef water quality targets in the Reef 2050 WQIP to be achieved by 2025, include:

- at least 60 per cent reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads
- at least 20 per cent reduction in anthropogenic end-of-catchment particulate nutrient loads
- at least 25 per cent reduction in anthropogenic end-of-catchment fine sediment (less than 16 micrometres) loads
- protect at least 99 per cent of aquatic species at the end-of-catchments.[527]

6.5.1 Trends in land-based run-off

Freshwater flowing from the Catchment is the main mechanism for transporting pollutants into the Region. The condition and trend of specific pollutant loads and water quality parameters most relevant to land-based run-off (nutrients, sediments, pesticides and other pollutants) are detailed below. Freshwater inflow, nutrient cycling, sediment exposure and salinity are discussed in Chapter 3.

Since 2014–15, annual freshwater discharge to the Region has been below the long-term median due to below-average rainfall (Section 3.2.3). As a result, annually monitored sediment, nutrient and pesticide loads discharged into the Region have been relatively low, particularly in comparison to the previous Outlook reporting period, in which several large-scale floods influenced the Region.[469] However, extreme rainfall and flooding occurred between the Cape York and Mackay–Whitsunday regions in February 2019 (Section 3.2.3). Research into the impacts of this large freshwater flow is underway but results fall outside this reporting period.

Catchment modelling is used to estimate the long-term annual average load reductions expected as a result of the reported adoption of improved land management practices (Box 10 and Figure 6.12). This modelling factors in significant inter-annual variability of climate conditions when assessing improvements. Although the models used involve certain assumptions and limitations[1255,1256], they draw on the best available science and the information produced is generally well regarded. Modelled results for 2014–2017 indicate that Region-wide progress in load reductions ranged from very poor to good, depending on the pollutant being measured.[463] The rate of progress slowed for all pollutants after 2013 compared with the improvement rate between 2008 and 2013.[1219]

It takes a significant period of time for improved land practices to influence the condition of inshore ecosystems

After 15 years of monitoring, it is still not clear whether reduced land-derived pollutant loads have made a measureable change in the trend of land-based run-off in the Region.[155] The lack of certainty is due to most parameters fluctuating over the monitoring period and annual variation in rainfall and run-off.[463,469,1257] Sufficient time series are required to differentiate annual variation from long-term trend in the quality of the receiving water.[462,469,472] In addition, it can take a long time for improvements in land management practice to show up as measured improvements in the water. The time lag can be years (for pesticides) to decades (for nutrients and sediments).[472,1258] For instance, it has been estimated it will take 50 years to detect load reductions at the end-of-catchments of both the Burdekin and Tully rivers.[1258] The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program is designed and adapted frequently to specifically detect changes well within these timeframes and inform management actions as needed.

Overseas studies have detected measurable reductions in river pollutant loads and associated coastal water quality and ecosystem condition, ranging between eight to 20 years for nutrients and 28 years for sediments.[1259] The small improvement in trend of water quality entering the Region suggests that Catchment land use changes have not yet been implemented at a sufficient scale or timeframe to result in a measurable difference. Confounding factors, including extreme weather events, also complicate this process.

Nutrients Nutrients occur naturally in the environment in relatively low concentrations. They include dissolved inorganic and organic nutrients (such as nitrogen, phosphorus and carbon) and particulate nitrogen and phosphorus (Section 3.3.1).[467] Modelling indicates that total nitrogen loads exported to the Region via land-based run-off have more than doubled since European settlement, from approximately 20,000 to 46,500 tonnes per year. This ranges from 1.2-fold to 4.7-fold increases for individual catchments. The largest nutrient loads come from the Wet Tropics (46 per cent) and Burdekin (21 per cent) regions.[467] This is largely due to land use changes in the Catchment, particularly fertiliser use in agriculture (predominantly sugarcane).[43,154,467,537,1260] Urban areas also contribute small amounts of nutrients to the Region, such as through wastewater discharges, which are important at a local scale.[467]

Nutrient concentrations across the length and width of the Region are highly variable; they are affected by the proximity of rivers, water circulation patterns and upstream land use. Concentrations of chlorophyll-*a* (an indicator of nutrient enrichment) across the Region hover near, or slightly above, the annual Great Barrier Reef Water Quality Guideline[1261] values, except in the Mackay–Whitsunday region where chlorophyll-*a* concentrations have exceeded guideline values since monitoring began in 2005 (Section 3.3.1).[155] All monitored inshore regions show increased concentrations of dissolved organic carbon since 2005, suggesting biogeochemical cycling is changing.[155,469]

Catchment modelling indicates very poor progress against nutrient reduction targets

Models suggest that investments to improve agricultural land management practices from 2009 to 2016 reduced the dissolved inorganic nitrogen load leaving the Catchment by 20.9 per cent. Reduced levels of chronic environmental stress are expected to follow for the Region's inshore ecosystems.[461,1262,1263] However, the lag between improved practices and environmental benefits is likely to mean that nutrient concentrations will continue to affect the ecosystem for years to decades.[43,167,470,1259] Current Catchment modelling reports very poor progress towards the dissolved inorganic nitrogen target of 60 per cent reduction for the whole Reef by 2025 under the Reef 2050 WQIP.[527] From 2009 to 2018, load reduction was only 21.2 per cent.[1264]

The largest loads of particulate nitrogen originate from the Wet Tropics (27 per cent) and Fitzroy (20 per cent) regions.[467] Particulate nitrogen primarily comes from land used for grazing.[467] As at June 2018, overall progress against the new Reef 2050 WQIP target of 20 per cent reduction by 2025[527] was 13 per cent.[1264] Particulate and dissolved organic nutrients are a major contributor of loads to the Region, but understanding of their sources and transformations remains a significant knowledge gap.[467]

Phosphorus often binds to sediments, particularly fine sediment, which may cause it to be more readily available once in the marine environment.[467] Modelling estimates that the Region's particulate phosphorus loads have increased 2.9-fold from pre-development conditions (with increases ranging from 1.2-fold to 5.3-fold for individual catchments).[467] The largest phosphorus loads come from the Fitzroy (33 per cent) and Burdekin (22 per cent) regions.[467] In the Wet Tropics and Mackay–Whitsunday regions, the main source of phosphorus is sugarcane farming. Grazing activities contribute the most in other regions. Cape York is the exception, contributing minimal anthropogenic phosphorus.[467] The Reef 2050 WQIP target for particulate phosphorus is a 20 per cent reduction in loads[527] entering the Reef by 2025. As at June 2018, a reduction of 16.2 per cent had been achieved.[1264]

Sediments Since European settlement, fine sediments entering the Reef lagoon are estimated to have increased five-fold, and in some regions up to eight-fold.[154,467] Land use south of Port Douglas is generally more intensive and adjacent inshore marine areas are more frequently exposed to greater sediment loads than those further north.[463]

Catchment modelling indicates moderate progress against suspended sediment reduction targets

The Burdekin region is the major contributor (approximately 40 per cent) of the total anthropogenic sediment load to the Region, followed by the Fitzroy (18 per cent), Wet Tropics and Burnett–Mary regions (15 per cent each).[467] The main sources of sediment loads from land are from grazing lands, erosion on hillslopes and sub-surface erosion from gully and streambank.[467] Sediments from urban areas can be important at local scales.[467]

Sediment loads are exacerbated by highly variable rainfall patterns across the various river catchments.[153,467,473] Sediments delivered from flood plumes settle relatively close to river mouths (within 50 kilometres).[470,471] However, fine sediment is carried further in suspension.[467,472] Delivery and resuspension of new sediments from run-off and dredging, and resuspension of existing sediments, combine to affect water quality condition.[467,471,475] Concentrations of total suspended solids in the marine area are either below or at the annual Great Barrier Reef Water Quality Guideline values in the Johnstone–Russell–Mulgrave sub-region (Wet Tropics) and Burdekin region.[155,1261] However, in the Tully–Herbert sub-region (Wet Tropics) and Mackay–Whitsunday region, concentrations are either on or slightly above guideline values.[155] Water clarity has decreased in the Mackay–Whitsunday region since monitoring began in 2005.[155,469]

A key target of the Reef 2050 WQIP is to achieve a 25 per cent reduction in sediment loads entering the Region as a result of human activities by 2025.[527] Overall progress, as of June 2018, shows a reduction of 14.4 per cent.[1264] A significant lag time is likely before reductions in suspended sediment load in the Region will be measurable and water quality improvements are ecologically significant; sediment effects will continue for years or decades.[43,167,470,1258,1259] In addition, sediment exposure is expected to increase with the predicted increase in severity of extreme weather events due to a changing climate.[43]

Turbid river plume emerging from the Mulgrave–Russell river system, February 2015. © Dieter Tracey

Pesticides Pesticides, including herbicides, insecticides and fungicides, are used to control pests and weeds in agricultural and urban environments. These compounds were absent from the Region's environment before European settlement.[1265,1266,1267]

The current pesticide target aims to protect at least 99 per cent of aquatic species from all pesticides, as measured at the end-of-catchments. To date, pesticide reduction has mainly focused on reducing the loads of five photosystem II (PSII) herbicides (ametryn, atrazine, diuron, hexazinone and tebuthiuron).[1268] However, with advances in understanding of the toxicity of a broader range of pesticides, the assessment has expanded to 22 pesticides (PSII herbicides, other herbicides and insecticides) with a focus on reducing concentrations (that directly relate to species protection) rather than loads of pesticides.[1268]

Sugarcane cropping contributes more than 95 per cent of the total load of photosystem II (PSII) herbicides entering the Region

Up to 56 different types of pesticides and pesticide metabolites have been detected in the Region's freshwater, estuarine, wetland and marine ecosystems.[1269] These most often occur in mixtures and can have a joint toxic impact on organisms (Section 6.5.2). Since 2009, there is no clear reduction in nearshore marine pesticide concentrations linked to improved land management practices.[1254,1270] Diuron, atrazine and hexazinone are the most consistently detected and abundant PSII herbicides at most sites, reflecting land use in sugarcane, horticulture and grain cropping industries.[1268] The concentrations of pesticides in marine waters in the Region remains generally low.[1268] The highest pesticide concentrations are generally found at the Mackay–Whitsunday sites (Round Top Island).[1268] The spatial pattern of pesticide concentrations in the marine environment reflects the dominant land use in the adjacent Catchment, and highest concentrations are found closest to the source.[1269] Sugarcane cropping contributes more than 95 per cent of the total load of PSII herbicides entering the Region and is the dominant land use in the Wet Tropics.[1269] The cumulative effects of long-term exposure to the mixture of pesticides is not well understood, and there is the potential that exposure may reduce resilience of inshore seagrass and coral habitats.[1268,1270,1271]

Marine debris Marine debris, in particular plastic, causes environmental, economic, aesthetic and human health impacts.[36,159,467,580] The most common marine debris found in the Region are plastic remnants (including lids, wrap and containers), rope and net scraps, cigarette butts and rubber footwear.[42,1272]

Plastic remnants dominated marine debris loads collected in more than 261 beach clean-ups within the Region in 2017.[37] However, single-use plastics only constituted a small proportion (approximately one to two per cent) of the overall marine debris collected.[37] The three most prevalent types of single-use plastic were plastic drink bottles, plastic bags and straws (Figure 6.10). More single-use plastic items were found washed up on islands than at coastal or inland locations.[1273]

Global plastic use has increased twenty-fold since the 1960s and is expected to double again in the next 20 years[1274], so the potential for global environmental harm is significant. The distribution and volume of marine debris are highly influenced by the amount washed into the Region, its size and buoyancy, and the effects of currents, winds and the shape of the coastline and offshore islands. Marine debris enters the Region from the Catchment (from industrial and urban sources) and from local and international ocean-based activities (ship-sourced waste, abandoned fishing gear from recreational and commercial fisheries, and recreational uses and tourism).[43,1275] The distance marine debris travels depends on its source and weight. Marine debris from rivers in the Region is estimated to travel an average of 19 kilometres from its source, whereas marine debris from shipping is estimated to travel approximately 225 kilometres.[36] Predicting plastic movement can be difficult given the uncertainty around how a diverse range of particles will respond to hydrodynamics and wind. Understanding and quantifying the source and volume of marine debris in the Region is improving, but remains a significant knowledge gap that requires ongoing effort.[43]

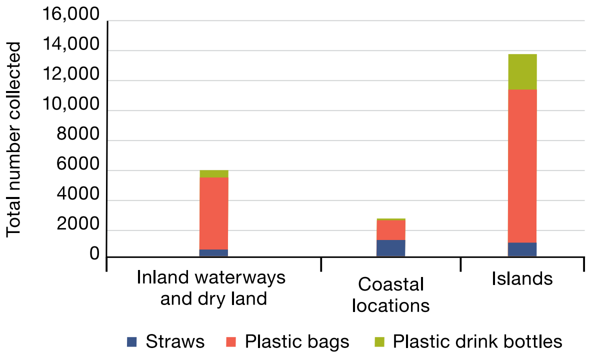


Figure 6.10 Three of the most prevalent types of single-use plastic collected from across the Region, 2017
The data represents 134 coastal beach, 92 island and 35 waterway and dry land clean-ups. Source: Australian Marine Debris Initiative 2018[37] GBRMPA acknowledges the Australian Marine Debris Initiative and the community organisations and individuals involved in the collection and provision of data used in this report.

The type of marine debris washing up on coastlines and islands across the Region between 2014 and 2018 differed from north to south and from the coastline out to islands (Figure 6.11).[37] Over that time, marine debris initiatives recorded 6645 clean-up days (recorded by the Tangaroa Blue Foundation 2018), which is likely to be an underestimate, especially for activities in isolated areas.[37] Plastic remnants (hard plastic and film fragments) were the most prevalent marine debris type in 2014-2018 in all regions, on both the coast and islands.[37] Less local litter originates from the Cape York coast in the northern sector compared with the more populated central (adjacent to Townsville) and southern (adjacent to Bundaberg) sectors.[37]

At a smaller scale, a separate study on islands in the Capricorn Bunker Group (offshore Gladstone), found marine debris had probably come from local sources, such as tourism and fishing.[1276] Cape York and the Wet Tropics received the highest proportion of garbage being washed ashore from sources at sea (for example, from South East Asian sources).[42,43] Cape York's exposure to both oceanic sources and local shipping activity is of particular concern.[43] Debris sourced from shipping and recreational fishing over this same time period was relatively low in all other areas.

Other pollutants Other pollutants, including metals and metalloids, antifouling paints, pharmaceuticals and personal care products (such as cosmetics and soaps) can be found in the Region.[1240] Chronic contamination from antifouling paints and exposure to personal care products have been assessed as a risk in regions south of Cape York.[1240] These pollutants are associated with land-based run-off and high levels of human occupation locally and globally.[43,1075] Pharmaceuticals and personal care products have been found in treated sewage (for example, paracetamol in the Fitzroy region)[1277,1278], although monitoring information on spatial and temporal variation of these pollutants is limited.[1075]

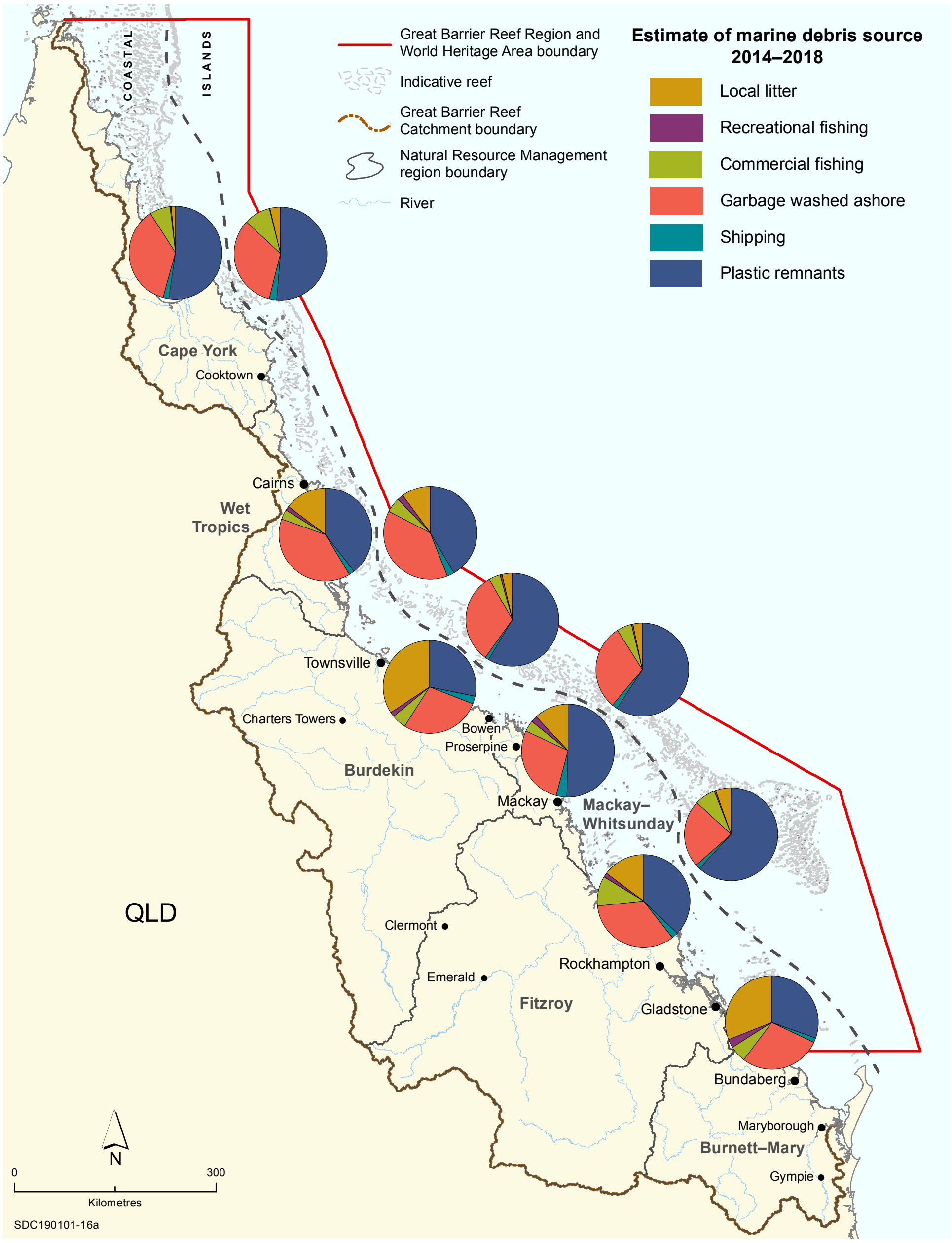


Figure 6.11 Estimate of the main source of marine debris, 2014 to 2018
Data shown cover marine debris collected from coastlines and islands adjacent to six natural resource management regions from 2014 to 2018. Plastic remnants are from unidentified sources.
Source: Australian Marine Debris Initiative[37] GBRMPA acknowledges the Australian Marine Debris Initiative and the community organisations and individuals involved in the collection and provision of data used in this report.

Although artificial chemicals were expected to be in very low concentration, a test of inshore areas in 2016–17 detected eight pharmaceuticals, two personal care products, one illicit drug, 13 endogenous chemicals, two fungicides and one herbicide metabolite.[1270] The cumulative effects of the mixture of chemicals are unknown and little monitoring information exists for non-agricultural chemical pollutants.[1270]

Metals and metalloids naturally occur in rock and soils, and can enter the marine environment via weathering, erosion and atmospheric deposition. Human activities have increased concentrations entering the marine environment through run-off and point-source discharge from most land uses in the Catchment, such as from mines and ports.[1279] Most studies have been conducted in and around ports, including Gladstone, Hay Point, Abbot Point, Townsville, and Cairns. Concentrations in these areas are relatively low, although water quality guidelines were exceeded in some instances.[1279,1280] Metals and metalloids accumulate and remain in the system for years to decades.[1279,1280] Mines within the Catchment have released metals and metalloids into the Region, including arsenic (associated with tin mining) and mercury (associated with past gold mining).[1279] Disposal of waste water from contemporary mining and refining activities continues to pose a risk to the Region, particularly after high-rainfall events.[1279]

Per- and poly-fluoroalkyl substances (PFAS) are artificial chemicals used widely and mass produced since the 1950s.[1281,1282] These chemicals are now considered possibly damaging to human health and the environment. Historically in Australia, PFAS were used in high volumes in firefighting foams and in waterproofing and stain-resistance treatments for products, such as textiles, carpet and paper. Because PFAS help reduce friction, they are also used in a variety of other industries, including aerospace, automotive, building and construction, and electronics.[1283,1284,1285,1286]

Firefighting foams containing PFAS as active ingredients are used extensively worldwide and within Australia, including at Defence bases, ports and other industries for both emergency firefighting and training. Past practices have resulted in high levels of PFAS contaminating the environment, particularly near firefighting training sites.[1284] As landfills and wastewater treatment plants consolidate waste containing PFAS from a broad range of industrial, commercial and consumer products, they are also potential point sources for PFAS emissions.[1283] PFAS can enter the ocean from a variety of sources, including contaminated rivers, groundwater and effluent, where they will persist and become part of the food chain.[1287] In 2004, the Department of Defence began phasing out the use of firefighting foams containing PFAS.[1284] More recently, high concentrations of PFAS have been found in the Catchment around the Townsville RAAF base[1288], and the ports of Gladstone and Townsville.[1289,1290] Low levels have been found in the Port of Mackay.[1291] The distribution and effects of PFAS in the marine environment are not well understood.

View towards the junction of the Russell and Mulgrave rivers over flooded sugarcane fields. © Dieter Tracey

BOX 10

Agricultural land management practices

While agricultural land use is a type of coastal development, agricultural land management practices form part of the assessment of land-based run-off. Several initiatives have been established to drive and encourage best practice agricultural land management throughout the Catchment.[527,1292,1293,1294] In March 2019, strengthened Reef protection regulations were proposed.[1295,1296] 'Best practice' is not a regulated standard; it varies across industry sectors and is reported using industry-specific management practice frameworks[1297,1298] or an alternative benchmark applied independently by industry. Rationalising the varying definitions, targets and measurements of best practice from different programs applying agricultural land management practices is difficult.[1295,1299]

After a period of early uptake, the rate of adoption of agricultural best practice has slowed. This is partially a consequence of modified targets but also reflects improved measurement frameworks.[462,1297,1298] Evidence from farm trials suggests that sustainable agricultural practice improves productivity, increases profitability and protects the Reef.[1295] Over several years, the targets for measuring the uptake of best practice have evolved from measuring the number of landholders who adopted improved management practice[1300] to measuring the total land area managed using best management practice systems.[527,720]

In mid-2018, the Reef 2050 WQIP introduced new land and catchment management targets, as part of the five-year review and update process.[527] Since monitoring began in 2009, industry sector adoption of best management practices has been observed in some NRM regions (for example, grazing in Cape York).[1264] Changes to how the data are assessed have occurred as part of improvements in program evaluation. The changes mean data from 2016 onwards cannot be compared with previous years. However, the new data for 2016 provide a more accurate benchmark against which to measure future progress. Overall, progress against the new Reef 2050 WQIP targets remains slow (Figure 6.12).[1264] Further improvement will depend on increasing commitment by land managers to make long-term changes in agricultural land management practices.[707,1257,1301] The effectiveness of management tools to address potential impacts from land-based run-off and coastal development is discussed further in Chapter 7.

Cattle grazing is one of the key agricultural land uses in the Catchment. © Department of Environment and Science (Qld) 2013

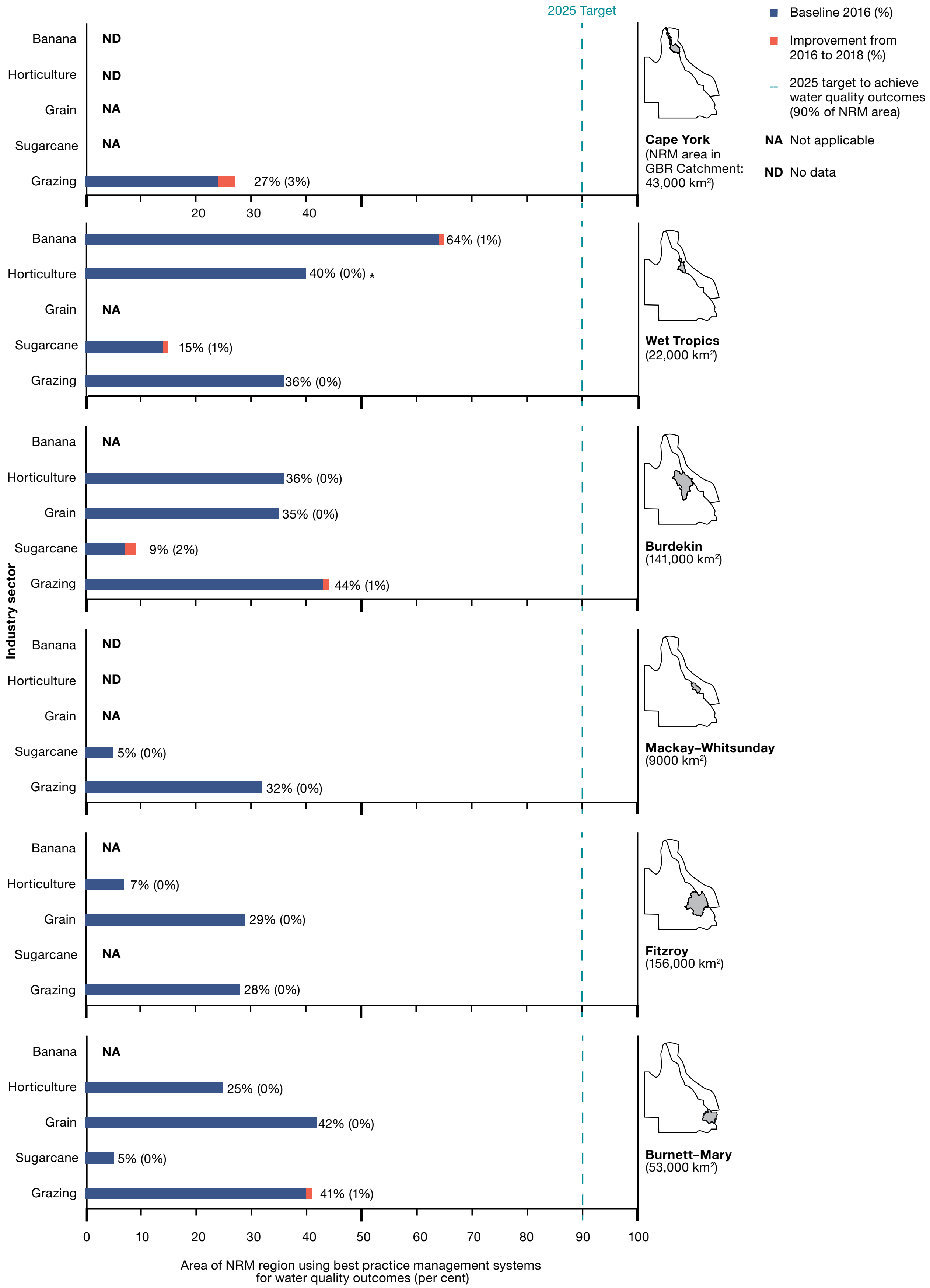


Figure 6.12 Proportion of area managed using best management agricultural practice systems in the Catchment, 2016–2018
Monitoring agricultural land management practices began in 2009; the baseline was reset in 2013 and again in 2016 to align with the next reporting period. New land and catchment management targets were introduced in mid-2018 to achieve water quality targets by 2025.[527] *The dotted blue line represents the Reef 2050 WQIP target for 2025. The percentage shows the proportion of land under best management agricultural practice systems as of 30 June 2018 (percentage point increase since 2016 is included in brackets). (*) Indicates significant new data capture since 2016.* Source: Commonwealth of Australia and State of Queensland[1264]

6.5.2 Vulnerability of the ecosystem to land-based run-off

Thirty-five major river catchments drain into the Region, with varying flow frequency and intensity. The greatest water quality risks to the Region and its coastal ecosystems are land-derived inputs from nutrients, fine sediments and pesticides.[1240] Mid-shelf and offshore areas are less influenced by land-based run-off because of their distance from river mouths. The water quality in these areas is considered generally in better condition.[43,469] However, in some locations between Lizard Island and Townsville, mid-shelf reefs are affected by land-based run-off, which are adjacent to regions that have a high dissolved inorganic nutrient load.[1240] In contrast, inshore areas are highly influenced and degraded by land-based run-off[43,1302] (for example, coral resilience is lowered due to poor water quality).[1303]

Following periods of comparatively low sediment, nutrient and pesticide loads, inshore ecosystems have demonstrated some ability to improve, provided they do not experience extra stresses. The observed recovery of seagrass meadows in inshore areas between 2012 and 2018 for example, was partly due to an absence of severe cyclones and below-average rainfall and freshwater discharge.[462,463] In the Mackay–Whitsunday region, inshore coral condition improved significantly in 2015–16, similar to levels when monitoring first began in 2005–06, highlighting the recovery potential of these reefs. However, after cyclone Debbie impacted this area in 2017, the recovery gains were reversed and coral condition decreased.[193] Recovery of these corals is likely to take several decades even if future agricultural inputs are eliminated.[1304] Future recovery of inshore ecosystems will depend on a number of factors, including good water quality, sufficient recruitment, regrowth of surviving corals, and a suitable recovery window free from other major stressors, especially thermal extremes.

Understanding the exposure of the Region's ecosystems to pollutants in land-based run-off is important for identifying the most vulnerable areas.[469] Of the six NRM regions in the Catchment, the inshore areas adjacent to the Cape York region are considered the least affected by land-based activities. The other five NRM regions are more developed (80 per cent used for agriculture[1305]) and contribute high pollutant loads to the Region through river discharges.[707] Best practice land management has been identified as the activity having the greatest potential to improve water quality entering the Region.[462]

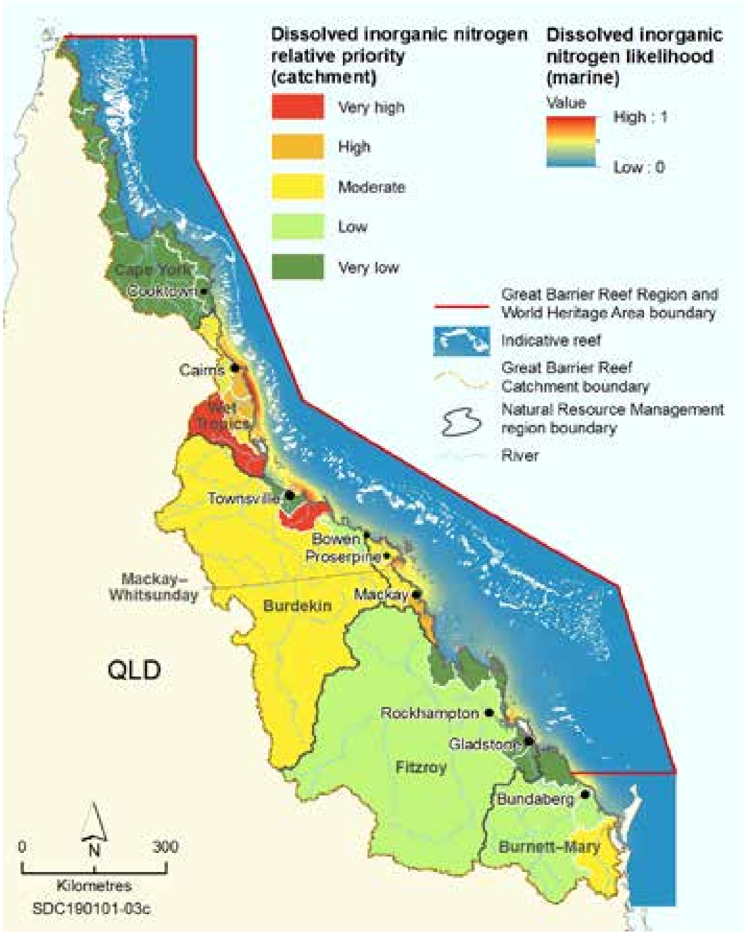


Figure 6.13 Relative catchment priorities and likelihood of exposure of Reef ecosystems to dissolved inorganic nitrogen
Assessment of the relative priority of each of the Region's 35 catchments according to their contribution to the modelled likelihood of exposure of Reef ecosystems to anthropogenic dissolved inorganic nitrogen (illustrated by shading in marine areas). Source: James Cook University adapted from Waterhouse *et al*. 2017[1240]

Understanding the impacts from multiple pollutant sources is critical to protecting the Region's values. Depending on the pollutant (nutrients, sediment and pesticides), different areas in the Region are subject to high anthropogenic loads (Figure 6.13, Figure 6.14, Figure 6.15). Areas adjacent to the Wet Tropics, Burdekin and Mackay–Whitsunday NRM regions are of particular concern, given high modelled loads of dissolved inorganic nutrients and suspended sediments. That makes the species, habitats, ecological processes, and community benefits in those regions particularly vulnerable to land-based run-off.

All ecosystems and species in the Region require some nutrients to facilitate growth, either through direct ingestion or absorption.[1223] However, **increased nutrients** from land-based run-off can overwhelm natural processes and negatively affect Reef ecosystems.[537] Dissolved inorganic nutrients (and fine particles) can travel large distances[43,458,537] during high-flow river discharge events (Figure 6.13), where they become available to phytoplankton, bacteria, macroalgae and seagrasses further offshore.[59,537,1306] Elevated concentrations of dissolved inorganic nutrients within the water column, derived from land-based run-off and offshore upwelling within the Reef system, can fuel the abundance of some phytoplankton species and benefit crown-of-thorns starfish larvae.[757,1307] (Section 3.6.2) This effect on larval food supply may be one of the factors that influence **outbreaks of crown-of-thorns starfish**, along with the availability of coral cover, abundance of predators, and connectivity (Section 3.6.2). Increases in dissolved inorganic nutrients can also increase benthic algae growth, potentially increasing competition with corals for

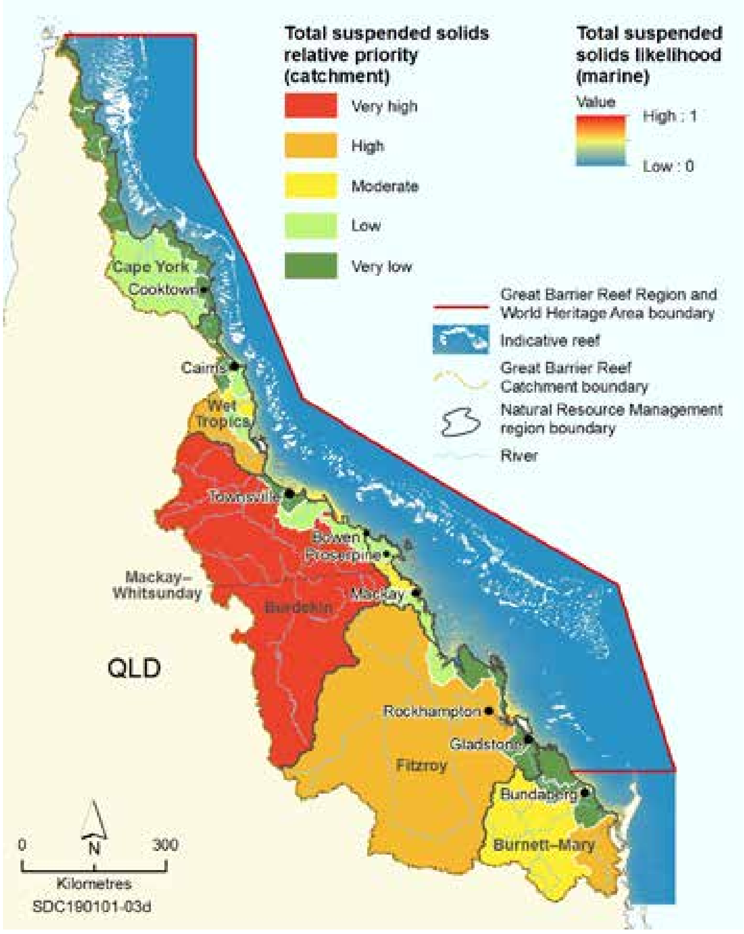


Figure 6.14 Relative catchment priorities and likelihood of exposure of Reef ecosystems to total suspended solids
Assessment of the relative priority of each of the Reef's 35 catchments according to their contribution to the modelled likelihood of exposure of Reef ecosystems to anthropogenic total suspended solids (illustrated by shading in marine areas). Source: James Cook University adapted from Waterhouse *et al.* 2017[1240]

space.[43,59,158,1308] Dissolved inorganic nutrients may also exacerbate the effect of other stressors, such as high temperature anomalies and increase the susceptibility of hard corals to bleaching and disease.[537,539,540] The effects of high levels of dissolved inorganic nutrients (including sediments binding) on seagrasses vary. Initially seagrass growth is promoted[70], but light availability may decline with increased growth of phytoplankton in the water column and epiphytes that coat seagrass.[1240]

The receiving waters and ecosystems in the Wet Tropics region and, to a lesser extent, the Burdekin and Mackay–Whitsunday regions, are the most likely to experience high levels of dissolved inorganic nutrients (Figure 6.13). The basins that deliver the greatest contribution of loads to these areas and are, therefore, a high priority for management are the Herbert, Haughton, Mulgrave–Russell, Johnstone, Tully and Plane catchments (Figure 6.13).[1240]

Suspended **sediment in run-off** entering the Region can have far-reaching effects on Reef ecosystems, particularly following extreme weather events. Fine sediments are of most concern for areas with shallow seagrass meadows and inshore coral reefs, because they are lighter, remain suspended for longer, travel further and are resuspended with winds and tides.[1240] These factors perpetuate the impact of fine sediments over long periods. Sediments reduce light availability required for photosynthesis, essential for food chain dynamics and the growth of corals and seagrass meadows.[43,153,473] High concentrations of suspended sediments from dredging and natural resuspension events can negatively affect coral spawning events and coral settlement, which generally occur from October to December.[1309]

Coral reproduction is also highly vulnerable to suspended sediments, which can entangle and entrap small coral spawn and also reduce their settlement success.[1309,1310] Fine sediments can settle and build up on benthic turfing algae, deterring herbivores from grazing.[603,1311] Adult corals can also die or be partially smothered from high levels of sediment exposure.[514] Turbid waters can also affect fish species, doubling larvae development time[1312], reducing growth rates[1313], reducing the ability to find suitable habitat[1314], changing predator–prey interactions[477,1315], and damaging gill structure.[1063,1316] Mangroves and wetlands are also vulnerable to pressures from increased sediments along with other pollutants and nutrients, affecting biodiversity and their ability to provide ecosystem services to the Reef.[473]

The likelihood of exposure of marine habitats to fine sediment is greatest in receiving waters adjacent to the Burdekin and Fitzroy regions (Figure 6.14).[1240] The catchments that deliver the greatest contribution of loads to these areas and are, therefore, higher priority for management are the Burdekin, Herbert, Fitzroy and Burnett–Mary catchments (Figure 6.14).[1240]

Pesticide run-off poses a toxicity risk to freshwater ecosystems in the Catchment and some inshore coastal habitats, particularly within the southern Mackay–Whitsunday and the lower Burdekin regions, where the highest end-of-catchment concentrations occur (Figure 6.15).[254,462,1254,1317,1318] Potential impacts from pesticides include: reduced growth as a result of photosynthetic inhibition in seagrass, coral and algae; reduced fertilisation and metamorphosis in invertebrates[473,1269]; disruption of ecological processes, such as nutrient cycling and recruitment[1254,1271,1319]; and potential endocrine disruption in fish.[1320,1321,1322]

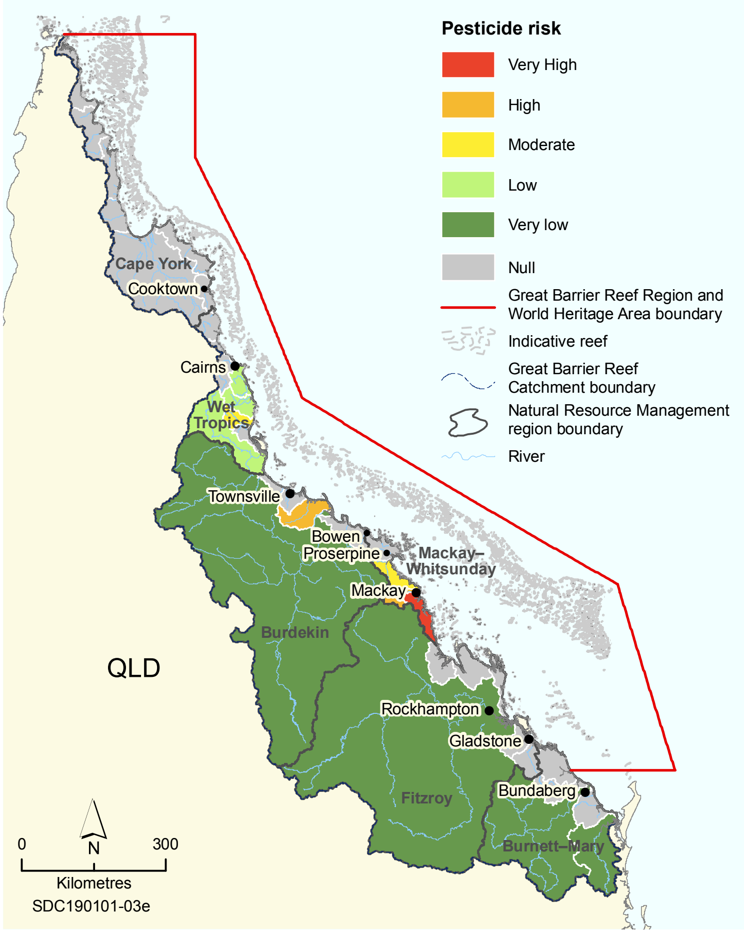


Figure 6.15 The risk of pesticides to freshwater and estuarine ecosystems
Assessment of the risk of pesticides to freshwater and estuarine ecosystems for each of the Reef's 35 catchments. Assessment was not conducted in catchment areas shaded grey due to limited or no data availability. Pesticides are important at different scales and different locations in the Region and the risk differs between the individual pollutants, source catchments and the distance from the coast. Source: James Cook University adapted from Waterhouse *et al.* 2017[1223]

Pesticides used today have shorter half-lives (that is, they breakdown faster) than those used in the past (for example, DDT).[473,1269] However, they can still persist (and accumulate) in the marine environment for a significant period, ranging from a month to nine years.[1323] Low concentrations of pesticides have been detected in offshore sediments.[1269] The potential impact of pesticides on ecosystems and species in the Region is not well understood.

Due to its high use, the herbicide diuron dominates toxic-load assessments and has been shown to reduce the productivity and photosynthetic efficiency of marine plants and corals.[43,1324] Alternative herbicides (including 2,4-D and glyphosate) were expected to cause less environmental harm than PSII herbicides.[1325] However, several studies have found that some alternative herbicides pose a similar risk to the environment as PSII herbicides.[1254,1266,1267,1269] The frequency of alternative herbicides at greater concentrations than PSII herbicides have been observed in the Wet Tropics.[1254]

Except for a few specific locations, concentrations of pesticides in the Region are below levels expected to cause significant risk to marine organisms.[1254] However, the effect of ongoing low-level pesticide exposure on the inshore Reef area remains a key knowledge gap.[472] The threat from pesticides is likely to be higher in some regions than others, especially when present in combination with other pollutants and stressors (for example, thermal stress).[473,1254,1269] The cumulative effects of multiple pollutants and stressors on ecosystem health remain poorly understood.[473,1254,1269]

Other pollutants (in particular, marine debris and specifically single-use plastic) are likely to be more widespread than previously reported, due to the continual breaking up of macroplastics into microplastics. The impact of plastic marine debris can persist and amplify when it degrades over time to create microplastics (plastics smaller than five millimetres long). These smaller plastic particles can be ingested by marine organisms, accumulate through the food chain and have the potential to affect human health.[43,159,444,1326,1327]

Marine debris can enter the Region via **terrestrial discharge** of stormwater. It has the potential to affect a wide range of species and habitats, including but not limited to marine turtles, fish, cetaceans, dugongs, seabirds, corals, microorganisms and invertebrates through direct entanglement or by being mistaken for food.[43,1275,1327,1328,1329,1330] For example, on Heron Island, 21 per cent of wedge-tailed shearwater chicks were fed plastic fragments by their parents.[365] Furthermore, 52 per cent of marine turtles may have ingested debris[1331] with the youngest turtles being the most susceptible to plastic pollution.[336] Loggerhead turtle hatchlings travelling down the East Australian Current and feeding at the surface are more likely than adults turtles to be exposed to, and ingest, floating macroplastics (such as plastic bottles and take-away container fragments).[336,649,1331,1332] Ingested marine debris can result in digestive blockages, toxin absorption and death.[1275,1333] There is growing concern about microplastic accumulation on nesting sites and the negative affects it can have on incubating environments for marine turtles.[1096] Recent evidence indicates low concentrations of microplastic particles have been found in corals within the Region.[159] Corals that come into contact with marine debris are 20 times more susceptible to disease, although this is minimal in the Region.[580] Debris can also block out light and smother coral.[36,43] Microorganisms and invertebrates have been detected on floating plastic in the Region, highlighting a dispersal pathway for invasive species.[36,43,1328,1334]

Metals and metalloids have been detected in the water, sediment and biota of marine ecosystems in the Region.[43,1279] They can exert toxic and sub-lethal effects on marine species, which include impairing fertilisation of corals and entering the food web by being absorbed by microorganisms and ingested by filter feeders (oysters and mussels) and fish.[1279,1335] Elevated levels of metals and metalloids in green turtles can cause acute inflammation and liver dysfunction.[1336,1337] The longer term effects of bioaccumulation within the ecosystem are not well understood.[43]

Some compounds in PFASs are highly persistent and therefore tend to bioaccumulate in organisms and move up the food chain. Some PFASs are known to have impacts on the environment (affecting offspring, survival and growth of freshwater fish and invertebrates)[1338,1339] and human health (such as PFOS).[1281,1284,1288,1340] Though PFAS are being phased out, they are expected to persist in the environment for long periods of time.[1284] The deep ocean is a potential sink for PFAS, which can be released through resuspension.[1288,1341] More research is required to determine the potential consequences of long-term exposure to aquatic organisms and the risk to human health.[880]

6.5.3 Implications of land-based run-off for regional communities

Australians regard the Reef as a significant contributor to their national identity and in many cases place more value on that aspect than its economic values.[1299] A survey of stakeholders in 2017, concluded the Reef is highly valued for a range of socio-economic reasons, including that it supports a variety of life (fish and coral reefs), has aesthetic beauty and is a World Heritage Area (Section 4.5.1).[785] Pollution of marine and island environments in the Region from land-based run-off and degradation of ecosystems reduces heritage and natural values and threatens Reef-dependent industries, especially marine tourism. It can also affect people personally though their health and wellbeing, personal connections, and enjoyment and appreciation of the Reef. Catchment residents surveyed in 2017 rated pollution as one of the greatest threats to the Reef.[785] Similarly, 1545 Catchment residents surveyed in 2015 found they placed great importance on seeing no visible rubbish on beaches and islands.[849]

Reef-dependent industries are affected when poor water quality degrades ecosystems

Observed reduction in water clarity has been greatest in regions with the highest nutrient and sediment loads adjacent to the most intense agricultural land use.[158] Poor water clarity affects visitor experiences through reduced underwater visibility and diver safety.[1342] Reduced water clarity may also indirectly reduce economic return, through a decrease in expenditure by divers and snorkellers.[1343] Local businesses are most supportive of initiatives to improve water quality in areas that have high levels of use and are also affected by agriculture, such as the Whitsundays. Government and community members, particularly farmers, have invested significantly in reducing the input of excess nutrients, sediment and pesticides from broadscale agriculture into the Region. Many actions to improve coastal habitats, minimise erosion and improve the efficiency of fertiliser applications on farms can improve the quality of water entering the Region.[707] Within urban areas, actions by local governments and schools to revegetate terrestrial habitats and reduce waste entering waterways are contributing to improved water quality entering the Region.

6.6 Direct use

Direct use of the Region includes commercial marine tourism, defence activities, fishing, recreation, research and educational activities, ports, shipping and the traditional use of marine resources. The current and projected trends in direct use are based on the relevant sections in Chapter 5. The analysis of the vulnerability of the Region's values to ongoing direct use as a whole (Section 6.6.2), and its implications for regional communities, align with the evidence and assessments presented in Chapters 2 to 5.

6.6.1 Trends in direct use

Commercial marine tourism remains the highest contributing Reef-dependent industry to the Region's economy (Section 5.2). Since 2014, the number of visitors to the Region has generally increased. The Marine Park Authority's high standard tourism program remains in place, although uptake has slowed. Interpretive products about the Region's values and training for Reef tourism guides have increased.

Declining ecosystem condition reduces the benefits Reef-dependent industries and people derive from the Reef

Defence activities, specifically training, are expected to be maintained or increase in frequency and intensity (Section 5.3). While modern defence training activities have negligible impacts on the Region, balancing defence activities with conservation in sensitive habitats remains a high priority. As cumulative stressors increase, the risk of not achieving appropriate balance will increase.

Amphibious landing as part of defence training exercises.
© Department of Defence (Cth) 2017

Fishing is the largest extractive use of the Region (Section 5.4). Trawl, net, line and pot remain the most significant commercial fishing methods. Recreational fishing remains one of the most popular activities on the Reef and in estuaries. Some species continue to be a concern and information remains limited for some species. Illegal fishing (recreational and commercial) persists as an issue. No-take zones are exhibiting a variety of benefits for fisheries' sustainability and ecosystem health. Given this, and the growing pressure on the Reef's ecosystem generally, fishers' compliance with zoning requirements is increasingly important. The expansion of vessel tracking systems into more commercial sectors is expected to substantially improve commercial fishing compliance rates.

Recreational use (not including fishing) is one of the major direct uses of the Region. It encompasses short trips to the beach through to longer journeys to the Reef (Section 5.5). Between 2014 and 2018, the number of recreational vessel registrations in the Catchment was the highest recorded. The broad cultural value of the Reef has significantly increased for residents since 2013, despite coral condition decreasing.[1009]

Research and educational activities occur in many parts of the Region, often around research stations. Understanding of cumulative effects of the impacts associated with research and educational activities remains limited (Section 5.6). Since 2014, research on the effects of climate change, reef restoration technologies and socio-ecological connections in response to multiple stressors (such as crown-of-thorns starfish predation and mass coral bleaching) has continued to grow.

Ports in the Region have experienced mixed economic outputs since 2014, with a minor decline in combined trade throughput at the priority ports in 2016–17 (Section 5.7). While port operations and their impacts have remained constant since 2014, regulatory changes for ports in 2015 have reduced some threats and increased management effort. Port maritime development has slowed since that time.

Shipping traffic through the Region is relatively limited compared with busier international locations (Section 5.8), although the number of cruise ships transiting the Region is increasing. Advances in technology, regulation, inspections and the level of monitoring of shipping traffic have improved shipping safety. Shipping and its impacts in the Region have remained constant since 2014. However, knowledge and management gaps remain around the impact of ship anchoring, resuspension of sediments from ship propellers and light pollution from ships at anchor.

Traditional use of marine resources is a key part of the Reef's Indigenous culture and the ongoing connection of Traditional Owners to their land and sea country (Section 5.9). Since 2014, new Traditional Use of Marine Resource Agreements have been accredited bringing the cumulative area covered by these agreements to approximately a quarter of the Region's coastline.

6.6.2 Vulnerability of the ecosystem to direct use

The eight identified direct uses of the Region expose the Reef's values to a variety of impacts at a local scale and cumulatively. When coupled with the highest and most immediate threats to the Reef (such as sea temperature increase and altered weather patterns), the impact of direct use is amplified. Some activities (tourism, defence, ports and research) tend to be localised, while other uses (fishing, recreational use and shipping) are more widespread. The effectiveness of the current management tools for the main types of direct use in, and adjacent to, the Region are assessed in Chapter 7.

Damage from direct use can be permanent or temporary. Permanent change is usually a result of modifications to coastline and island habitats from coastal development, or port and marine infrastructure activities. By contrast, direct use impacts that can kill and injure coral, such as anchoring, are usually temporary and smaller in scale. Damaged areas can return to a pre-disturbance state if recovery times are adequate. Handling and manipulation of benthic organisms can lead to localised damage to the reef structure and increase the prevalence of **outbreaks of disease**.[1344]

Commercial marine tourism, fishing and recreation activities in some locations may interact with other uses — **incompatible uses** (with incompatible values) can affect or displace another user group. Displacement concerns have been raised between commercial marine tourism and Traditional Owners, as well as resource allocation between recreational and commercial fishers.

Legacy defence activities, such as unexploded ordinance, and other activities in the Catchment and Region involving PFAS, continue to be detected in, and adjacent to, the Region. The impact of PFAS chemicals on plant and animal communities is still unknown. **Marine debris** is a threatening process for wildlife[1096] and an emerging threat to the Region as the global human population increases (Section 6.2.1). Direct uses have the potential to add marine debris to coastal, island and marine habitats. A comprehensive understanding of the quantity of, and ecological effects from, microplastics in the Region is lacking (Section 6.5).

Marine debris clean up by Tangaroa Blue.
© GBRMPA, photographer: Christian Miller

The number of reported **vessel strikes** on species of conservation concern is generally low.[1015] Surface-breathing marine animals (such as marine turtles, dugongs, dolphins and whales) are most often struck by vessels, with the collision often resulting in injury or death. Population growth in regional communities is a driver of human-induced impacts on the Region. More vessel use, larger ships and expansion of direct use activities are likely to increase **wildlife disturbance** across the Region.

Even though procedural controls are in place to respond to **oil spills** and some **chemical spills**, the Region remains vulnerable to **vessel groundings** and large spills of other foreign material (diesel and other cargo). For example, large volumes of sugar released into a coral reef environment could make the water anoxic (devoid of oxygen) affecting a large number of species. Shipping (and other vessels greater than 50 metres in overall length), international fishing and recreational vessels (predominantly yachts) are vectors for introduced **exotic species**. If introduced and persistent, introduced species can have widespread effects on the ecosystem. While limited pest incursions have occurred at ports and marinas since 2014, islands remain vulnerable to pest incursions.

Dredging and **disposal of dredge material** in inshore areas contribute to sedimentation by disrupting and resuspending sediments. A growing shipping fleet and increased coastal development (including from ports) continues to intensify the intrusion of artificial light into the Region. The effect of **artificial light** on marine turtles is well known[331,332,1345], and exposure has increased since 2014.

Fishing is the single largest extractive activity in the Region. Target and non-target species from various trophic levels are directly removed from the ecosystem. Indirectly, other species and habitats may also be affected through anchor damage and **damage to the seafloor** (from trawling). Across the range of threats and impacts from fishing, **incidental catch of species of conservation concern** (dugongs, inshore dolphins and some species of sea snakes, marine turtles, sharks and rays) still persists. Dugong and green turtle populations are still depleted following past commercial harvesting and are further threatened by climate change. These species remain at risk of entanglement and drowning when they interact with legal fishing gear, or **illegal fishing and poaching**. Illegal fishing in no-take zones and harvest of fish smaller or larger than relevant size limits can be perceived by fishers as a one-off, short-term impact. However, illegal fishing can have long-term impacts on biodiversity given some species take many years to reach sexual maturity (Section 8.3.4).

Climate change, habitat loss and delayed recovery of critical fisheries habitats make the ecosystem more vulnerable to direct effects from fishing and other direct use. Conversely, deterioration of habitat that fisheries species rely upon will increase the vulnerability of the fishing industry through reduced catches, increased disease prevalence and a potential shift in fisheries species. This social-ecological vulnerability also applies to all other Reef-dependent uses.

6.6.3 Implications of direct use for regional communities

The Region is not a pristine ecosystem and it exists in a dynamic state.[781] The dynamic state involves interactions with people and how they use the Region's natural heritage values and connect with Indigenous heritage values. Since European settlement, use of the Region has changed and intensified.

For uses that depend on the Reef, the condition of the ecosystem remains fundamental to the longevity of their various industries, economic prosperity and social wellbeing. The social and economic implications flowing from the unprecedented back-to-back coral bleaching events in 2016 and 2017 and several cyclones since 2015 are partly known. The social-ecological implications are particularly obvious where the damage to the environment or resort infrastructure affected tourists' choice of destination. However, the indirect effects are not yet fully known. The direct economic cost of climate change and ecosystem disturbance on Reef-dependent communities has not been fully quantified and remains a knowledge gap.

Recreational use provides enjoyment and social benefits.
© GBRMPA, photographer: Pine Creek Pictures

Non-Reef-dependent uses (defence activities, ports and shipping), which are not directly connected to the Region's natural values, are affected by external factors. The economic significance of ports and shipping is largely driven by global and domestic demand for resources and commodities. As an interconnected system, however, changes to the climate that affect the health and usability of the Region are likely to affect the suitability of the Reef as a transit corridor for ships.

6.7 Vulnerability of heritage values to influencing factors

Of the four main factors influencing the Region (climate change, coastal development, land-based run-off and direct use), climate change remains the greatest threat to the Region's heritage values. The outstanding universal value of the Reef and how Traditional Owners interact with the natural environment, are highly vulnerable to the factors influencing the Region.

Pressures exerted on the Region's natural heritage value (ecological and biological processes and habitats assessed in Chapters 2 and 3) equally apply pressure on the Region's Indigenous heritage value. Therefore, even the slightest change in the Region's processes or habitats may have far-reaching consequences on the natural and Indigenous heritage value of the Region. While the impacts of climate change have been assessed for many of Australia's world heritage properties, including the Reef (Sections 6.3 and 7.3.9), limited adaptive planning has been undertaken for other Indigenous and historic heritage places in the Region.[1346] Spatial and temporal impacts of climate change vary between places and properties, so each will have different vulnerabilities and adaptive capacity. Adaptive responses can ameliorate risk by early identification of specific impacts and instigation of targeted conservation measures.[1347] Broad social and cultural values of Traditional Owners, regional communities and Reef users will make an important contribution to developing vulnerability assessments and interventions.[1348]

The cultural sensitivity of some Indigenous heritage values and the vast geographical expanse of the Region make investigation, monitoring and management of these values difficult. Island and mangrove systems are highly valued by Traditional Owners and some Indigenous cultural sites, such as middens, are still recovering from several recent severe cyclones (Section 4.3). Some traditionally valued species (marine turtles and dugong) remain under pressure from climate change, habitat loss and degradation, fishing-associated impacts[811], and marine debris. Conversely, humpback whales, which are important to the Woppaburra Traditional Owners, are recovering strongly but remain at risk from wildlife disturbance (people approaching too close) and vessel strike. Direct use of the Region may restrict Traditional Owners' access to country, which may **fragment cultural knowledge** and reduce the capacity of Traditional Owners to pass on their culture (a **foundational capacity gap**). Without access and connection to country, Traditional Owner groups cannot manage their land and sea country. Distance and separation from country may also result in loss and fragmentation of knowledge of tangible and intangible Indigenous heritage values.

An inherently difficult aspect of maintaining resilience of historic heritage values, is identifying and protecting sites, and monitoring their condition and integrity. Where heritage values are known (for example, lightstations), ongoing maintenance reduces the asset's vulnerability. Historic heritage values (lightstations, shipwrecks and aircraft wrecks) continue to be vulnerable to natural degradation, severe weather events and illegal activities. The location of heritage values can influence their vulnerability and resilience.[1348] Under predicted climate change scenarios, sea-level rise (Section 3.2.5) will endanger Indigenous and historic heritage components situated at or just above sea level in intertidal areas and on Commonwealth islands.

Indigenous and historic heritage is irreplaceable, therefore, where possible, impacts should be avoided or mitigated.[1349] Irreversible damage or loss of Indigenous and historic heritage values can arise from direct use (for example, through intentional or unintentional removal of, or damage to, significant artefacts or sites of Indigenous significance).[1007] **Inappropriate behaviour** or presence of people at certain sites can also affect Indigenous heritage values. Poor water quality, coupled with climate change impacts, natural processes and encroaching coastal development (ports, marinas, revetment walls) will place pressure on inshore and coastal natural and Indigenous heritage values. Overall, a changing climate is imposing strong current and predicted impacts on all the Region's heritage values.

Many heritage values are vulnerability to the same threats as the ecosystem. Sediment laden water affects habitats of culturally significant species. © Matt Curnock 2019

6.8 Assessment summary — Factors influencing the Region's values

Paragraph 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.

Paragraph 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.

Grades for all components and attributes examined in the assessment, as well as the grade for the criterion, are allocated according to the statements in the table below.

6.8.1 Impacts on ecological values

Grading statements — impacts on ecological, heritage, economic and social values

🟨	🟧	🟥	🟪	☐☐
Very low impact Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's ecological, heritage, economic or 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 ecological, heritage, economic or social values.	**High impact** Current and predicted future impacts are likely to significantly affect the Region's ecological, heritage, economic or social values. Concern about serious ecosystem, heritage, economic or social 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, heritage, economic or social values. Widespread and serious ecosystem, heritage, economic or social effects likely within next 10–20 years.	**Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟥	🟥 ↑ ↑	🟪 ↑ ↑			**Impact on ecological values:** Climate change has had a widespread effect on ecological values fundamental to the Region's identity. High coral mortality due to thermal bleaching events has transformed the Reef. Evidence of cascading effects of coral loss on fish and invertebrate abundance and diversity are emerging. Negative impacts on ecological values, associated with coastal development, land-based run-off and direct use are being amplified under the strong signal of climate change.
🟪	🟪 ↑ ↑	🟪 ↑ ↑	●	●	**Climate change:** Climate change has had far-reaching effects on the Reef, with record-breaking sea surface temperatures resulting in widespread mortality of shallow-water corals. Flow-on effects to dependent species, habitats and heritage values are also occurring. Impacts of climate change are becoming more severe and widespread.
🟥	🟥 ↑ ↑	🟥 ↔ ↑	◐	◐	**Coastal development:** The extent of new coastal development has been minor, although the impact of legacy development remains high. Projected future populations will increase development pressure on the Region. Economic expansion in northern Australia will intensify access to currently remote parts of the Catchment.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟥	🟥 ↓ ↓	🟥 ↔ ↓	●	●	**Land-based run-off:** Poor water quality continues to affect inshore areas. The rate of reduction of pollutant loads has been slow as a result of modest improvements in agricultural land management.
🟧	🟧 ↑ ↑	🟥 ↑ ↑	◐	◐	**Direct use:** The cumulative effects of extraction and damage to the Reef by direct use, coupled with smaller recovery windows, erode ecosystem resilience. More frequent acute disturbances (cyclones, flood plumes, coral bleaching) will exert more pressure on a degraded system.

6.8.2 Impacts on heritage values

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟥 ↑	🟥 ↔ ↑			**Impact on heritage values:** The Region's natural heritage value is already impacted by climate change, transforming the reefscape through reductions in species and habitats and altered ecological processes. This status, coupled with Traditional Owners' connection to sea country, places Indigenous heritage values of the Region under growing pressure. Historic heritage values remain vulnerable to a changing climate and impacts from human interaction.
	🟪 ↑	🟪 ↑ ↑	◐	◐	**Climate change:** The interconnectedness of the natural and Indigenous heritage values exacerbates the vulnerability of the Region to the impacts of a changing climate. Some Indigenous and historic heritage values are irreplaceable if lost or damaged. Historic heritage components remain exposed to altered weather patterns.
	🟥 ↑	🟥 ↔ ↑	◐	◐	**Coastal development:** Encroachment from coastal development into the Region (ports, marinas, revetment walls) will place pressure on inshore and coastal natural and Indigenous heritage values. Altered weather patterns resulting from increased global emissions are a major threat to heritage values.
	🟥 ↓	🟥 ↔ ↓	◐	○	**Land-based run-off:** Culturally significant species (dugongs, marine turtles) that rely on inshore seagrass continue to be vulnerable to land-based run-off. A changing climate is imposing strong current and predicted impacts on natural and Indigenous heritage values.
	🟧 ↑	🟧 − −	◐	◐	**Direct use:** Direct use has limited impacts on historic heritage values, except shipwrecks that can be damaged by various activities. Even though many threats associated with direct use are generally well managed, an imbalance persists between traditional use and ecological and economic benefits to the Region.

6.8.3 Impacts on economic values

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟥	🟥 ↑ ↑	🟥 ↔ −			**Impact on economic values:** The economic value of Reef-dependent uses relies on a healthy Reef ecosystem. For non-Reef-dependent uses, economic value is aligned with market forces and population growth in the Catchment. Effects of ecological declines may become apparent over the next few years.
🟥	🟥 ↑ ↑	🟥 ↑ ↑	●	●	**Climate change:** Climate change effects on the Regions' natural heritage are expected to have major economic consequences for Reef-dependent industries, including tourism and fisheries. Economic effects of climate change may lag behind ecological effects and to date the full impact of ecological damage sustained since 2014 has not yet been fully realised. The loss of coastal protection as the Reef degrades and more frequent severe weather occurs poses a significant economic and social risk to the Queensland community.
🟧	🟧 − −	🟧 − −	◐	◐	**Coastal development:** Population growth, poorly managed land use, development and infrastructure in the Catchment may affect the marine ecosystem. Indirectly, this would place pressure on the profitability of Reef-dependent uses.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟥	🟥 ↓ ↓	🟥 ↔ ↓	◐	◐	**Land-based run-off:** The Region is vulnerable to the effects of poor water quality. Resulting declines in ecosystem health will affect the economic growth of Reef-dependent industries. However, if practice change continues impacts may decrease in future.
🟨	🟨 ↔ ↓	🟨 ↔ −	●	◐	**Direct use:** Direct use of the Region continues to be a significant contributor to regional and national economies. Visitation showed minor declines coinciding with severe cyclones, but by 2018 was showing signs of recovery. Future economic value of many Reef-dependent activities is intrinsically linked to the condition of the Reef.

6.8.4 Impacts on social values

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟧	🟧 ↑ ↑	🟧 ↑ ↑			**Impact on social values:** Ecosystem decline as a result of climate change and land-based run-off will affect community health, wellbeing and enjoyment derived from the Region. An increased concern for the Region and its ecosystems has been recorded. However, across the broad spectrum of influencing factors, evidence is limited about the effect of disturbances on social values.
🟥	🟥 ↑ ↑	🟪 ↑ ↑	◐	◐	**Climate change:** Climate-related changes to the ecosystem have affected patterns of use of the Reef and visitor satisfaction. People's awareness of the current and future effects of climate change is increasing their concern about the ecosystem. The loss of coastal protection will have effects on social values. The vulnerability of Reef-dependent individuals and businesses depends on their ability to anticipate and adapt to change.
🟧	🟧 ↔ ↔	🟧 ↔ −	◐	◐	**Coastal development:** Coastal development provides broad economic and social benefits to regional communities adjacent the Region through employment, commerce and places for recreation. Expansion into remote parts of the Catchment may provide social benefit from further access to the Region.
🟧	🟧 ↓ ↓	🟧 ↔ ↓	◐	◐	**Land-based run-off:** Ecosystem declines from poor water quality, particularly in inshore areas, can affect wellbeing and enjoyment of stakeholders through degraded aesthetics.
🟧	🟧 ↔ ↔	🟧 ↔ ↔	◐	◐	**Direct use:** The Reef continues to be valued by national and international communities. Employment opportunities, knowledge, recreation and access contribute to the social benefits derived from the Reef. Traditional Owners' connections to land and sea country are fundamental to the Indigenous cultural values of the Region.

6.9 Overall summary of factors influencing the Region's values

The Reef is undergoing significant social, economic and environmental change. The main drivers increasing pressure on the Reef's values are economic and population growth; management will become more challenging if growth outpaces the implementation of protective management measures (such as setting limits on use of sensitive locations). Drivers of change can also positively affect the Region's values. For example, technological developments (another key driver) can lead to changed behaviours, such as use of renewable energy.

The Reef is undergoing significant social, economic and environmental change

Influenced by these underlying drivers of change, climate change, coastal development, land-based run-off and direct use are the major factors affecting the Region's values. Each of these factors is assessed in terms of its impact on ecological, heritage, economic and social values. Understanding of the current condition and trend of these factors has improved since 2014.

Of the four major factors, climate change is having the greatest impact on the Region's values, and the signals of climate change, such as increasing water temperatures, are accelerating. Furthermore, climate change will amplify the impacts of other threats. The impacts of climate change will become more frequent, severe and widespread. The resultant trend is one of increasing cumulative effects on the Region's ecological, heritage, economic and social values. For example, two consecutive years of mass coral bleaching caused the loss of at least 30 per cent of the Region's shallow-water coral cover, and this is having cascading effects on coral-dependent species.

Overwhelmingly, climate change is the primary factor affecting the Reef, and its influence is increasing faster than previously predicted

Coastal development has a high impact on ecological and heritage values. Legacy effects of past coastal development, primarily agricultural land uses, mining and urban development, are still significantly affecting coastal ecosystems adjacent to the Reef. The future trend is increasing, and existing and further modifications to coastal ecosystems and barriers to flow will encroach further upon natural and heritage values in the future.

Land-based run-off from agriculture in the Catchment remains the greatest contributor to poor water quality in the inshore area

The Region continues to be vulnerable to exposure to pollutants (mainly sediments, nutrients and pesticides) transported from land-based run-off resulting from unsustainable agricultural land management practices. Land-based run-off can seriously threaten the Region's natural and Indigenous heritage values and, therefore, the success of Reef-dependent industries such as commercial fishing and marine tourism. Poor water quality can also affect social attributes, such as people's health and wellbeing, personal connections, enjoyment and appreciation of the Reef.

Cumulative impacts to ecological values from the factors influencing the Region's values are amplified under the strong signal of climate change

Across the multitude of direct uses of the Region, the Reef's values are exposed to a variety of pressures, including local and widespread impacts. The cumulative effects of multiple direct uses occurring in one location, coupled with broad influences of climate change, remain a significant issue and management challenge. Knowledge and understanding has continued to improve for marine debris and its impacts on species and ecosystems. It is essential that management actions that effectively address direct use impacts and maintain resilience continue, in particular, effective spatial planning, compliance and crown-of-thorns starfish control.

Some structures within waterways provide mechanisms to assist fish to move upstream.
© GBRMPA 2016, photographer: Through the Looking Glass Studio

CHAPTER 7

EXISTING PROTECTION AND MANAGEMENT

« *Diver culling crown-of-thorns starfish* © GBRMPA 2013

EXISTING PROTECTION AND MANAGEMENT

'an assessment of the existing measures to protect and manage the ecosystem …' within the Great Barrier Reef Region, s 54(3)(f) of the *Great Barrier Reef Marine Park Act 1975*

'an assessment of the existing measures to protect and manage the relevant heritage values …' of the Great Barrier Reef Region, paragraph 116A(2)(d) of the *Great Barrier Reef Marine Park Regulations 1983*

7.1 Background

Protection and management of the Region is a partnership between many government agencies, Traditional Owners, stakeholders and community members, with influencing activities occurring within and adjacent to the Region. An understanding of management effectiveness for these activities is an important component in determining the probable resilience of the Region's ecosystem and heritage values. Management effectiveness also contributes to an assessment of the major risks that remain after management actions are considered; the assessment informs future adaptive management options to strengthen and improve the outlook for the Reef.

The effectiveness of existing measures to protect and manage the Region's ecosystem was independently assessed in the 2009 Outlook Report and the 2014 Outlook Report. An assessment has been completed for the 2019 Outlook Report to compare management effectiveness over time and highlight areas that have been strengthened and those that have weakened. This assessment was undertaken by five independent reviewers.[5] Their assessment considered the effectiveness of management actions undertaken by all government agencies and other parties that play a role in protection and management of the Region.

The full report of the independent assessors1 is available on the Great Barrier Reef Marine Park Authority's (Marine Park Authority's) website (www.gbrmpa.gov.au). A separate high-level assessment, the Reef 2050 Insights Report[2], provides insights into the effectiveness of the contributions of the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan). It is also available on the Marine Park Authority's website.

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). The Australian Constitution does not expressly regulate natural resource management and environment protection. These matters are regulated by the Queensland government. The Reef and Australia's world and national heritage properties are protected through Commonwealth legislation under other Constitutional powers.

The Great Barrier Reef Marine Park Act 1975 (Cth) (the Act) is the primary legislation dedicated to the long-term protection of the environment, biodiversity and heritage values of the Region. It established the Marine Park Authority and governs its operations. The Marine Park Authority manages the Great Barrier Reef Marine Park (Figure 7.1) 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 and the Commonwealth Coral Sea Marine Park, which extends from the outer boundary.

Both the Australian and Queensland governments have direct legislative responsibilities within the Region

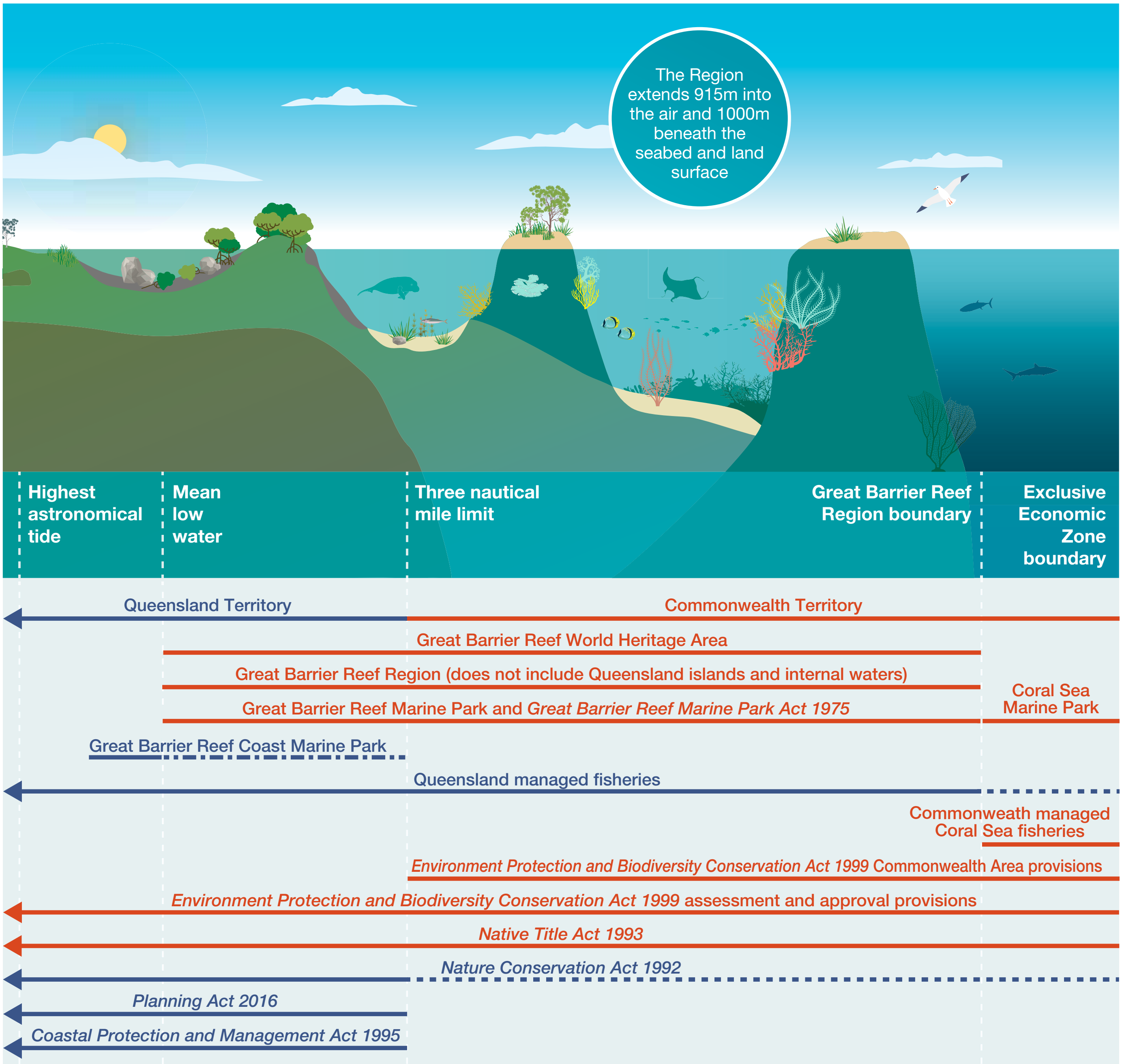


Figure 7.1 Jurisdictional boundaries

The Region encompasses both Commonwealth (red) and Queensland (blue) jurisdictions. Queensland territory extends from the land to the three nautical mile limit. A Commonwealth and state intergovernmental agreement to jointly manage marine parks and island national parks ensures integrated field management of the Great Barrier Reef Marine Park and the abutting Great Barrier Reef Coast Marine Park. The dashed line indicates that the latter marine park includes the Queensland-owned islands that lie within the Region. The dotted lines indicate the possible extent of the relevant legislation or jurisdiction (for example, depending on species or fishery). Fisheries management within the Region is regulated by the Queensland Government. The assessment and approval provisions of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) apply throughout the Region. However, its Commonwealth reserve provisions apply only in the Coral Sea Marine Park.

To ensure a cooperative approach, the Australian and Queensland governments work in partnership through the *Great Barrier Reef Intergovernmental Agreement 2015*[938] to protect and manage the Region. The responsible government agencies (Marine Park Authority and Queensland Parks and Wildlife Services) have a close working relationship, resulting in joint management on many issues within the Marine Park, the adjacent Queensland Great Barrier Reef Coast Marine Park and Queensland island national parks.

Since the 2014 Outlook Report, the roles and responsibilities for the long-term protection of the Great Barrier Reef World Heritage Area (World Heritage Area) and the Region have been focused and guided under the overarching Reef 2050 Plan.[9] This plan helps respond to findings of the 2014 Outlook Report and provides management direction to 2050.[9] The Reef 2050 Plan forms a new addendum to the Great Barrier Reef Intergovernmental Agreement 2015.

Protection and management responsibilities outside the Region Many of the threats to the Region's ecosystem (natural heritage value) and heritage values (Indigenous, historic and other) arise outside its boundaries (such as climate change, coastal development and Catchment land use practices). Australian, Queensland and local government agencies have mixed regulatory responsibilities for these matters.

The Australian Government has national and international responsibilities in relation to environment and heritage protection for the World Heritage Area. Actions having, or likely to have, a significant impact on matters of national environmental significance (including the Marine Park and the World Heritage Area), whether they are undertaken in or outside the Region, are regulated under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (the EPBC Act). The Queensland Government is responsible for natural resource management and land use for Queensland's islands, coast and hinterland, including through the *Planning Act 2016* (Qld), *Coastal Protection and Management Act 1995* (Qld) and *Nature Conservation Act 1992* (Qld).

Partners in management Many government agencies, Traditional Owners, stakeholders and individuals directly participate in protection and management activities within the Region and the adjacent Catchment (Table 7.1).

Table 7.1 Partners in the management of the Region

Australian Government	The **Great Barrier Reef Marine Park Authority** is the primary agency dedicated to protection of the Region, and is responsible for implementing the Great Barrier Reef Marine Park Act and contributing to reporting on the state of the World Heritage Area
	The **Department of the Environment and Energy** is responsible for implementing the EPBC Act and coordinating reporting on the state of the World Heritage Area
	Australian Maritime Safety Authority is responsible for maritime safety including environmental considerations and search and rescue
	Maritime Border Command provides aerial surveillance of the Region
	Parks Australia manages the adjacent Coral Sea Marine Park, for which a management plan came into effect on 1 July 2018
Queensland Government	The **Queensland Parks and Wildlife Service** is responsible for day-to-day joint field management of the Marine Parks and Islands with the Marine Park Authority
	The **Department of Environment and Science** is the lead agency on environmental management matters in intertidal areas, Queensland internal waters and the Catchment
	Maritime Safety Queensland is responsible for the protection of Queensland's waterways and the people who use them
	Department of Agriculture and Fisheries and **Queensland Boating and Fisheries Patrol** manage and enforce fisheries and transport legislation
Partners	**Traditional Owners** work to protect cultural and heritage values, conserve biodiversity and enhance the resilience of their land and sea country
	Researchers and **research institutions** provide training, public outreach and scientific evidence to inform policy reform, improved governance and adaptive management through formal and informal channels
	Local governments, industry groups (for example, ports and shipping), **regional natural resource management bodies, advisory committees** and the **community** are involved in actions to minimise impacts, address threats and improve outcomes for the Region

7.1.2 Focus of management

Activities to protect and manage the Reef focus on 14 broad management topics across three areas:

Managing direct use

- commercial marine tourism
- defence activities
- fishing
- ports
- recreation (not including fishing)
- research 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 form the basis of the assessment of existing measures to protect and manage the Region's ecosystem and heritage values. Additionally, three main management approaches are examined: environmental regulation; engagement; and knowledge, integration and innovation.

A researcher conducting a coral health survey along a marked transect. © Tane Sinclair-Taylor

7.1.3 Scale and complexity

The 14 management topics assessed vary in scale and complexity (Table 7.2). The assessment of effectiveness for each management topic has not been weighted to take into account differences in scale and complexity between topics. Inter-relationships between management topics often manifest with cumulative effect, creating additional management challenges. This complexity is further analysed in the risks chapter (Chapter 9) and addressed in the long-term outlook chapter (Chapter 10).

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, but limited to Catchment areas and mainly inshore waters	Major	Major	Major
Land-based run-off	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

7.1.4 Management approaches and tools

Three main management approaches are used to protect and manage the Region:

- **Environmental regulation**: management tools, such as regulations, zoning plans, management plans, permits and licences, and compliance actions (audits, infringement notices and prosecutions) are used to establish and enforce the environmental standards necessary to protect and manage the Reef.
- **Engagement**: management agencies work with Traditional Owners, scientists, the community, industry and local government to strengthen knowledge, ensure fit-for-purpose management and influence actions that will help improve the outlook for the Region.
- **Knowledge, integration and innovation**: effective management is based on the best available science and draws on traditional ecological knowledge and information from the wider community. It is informed by the results of ongoing monitoring.

Each of these approaches is explicitly assessed in Section 7.4. Many management tools are used to address a number of topics and each topic is addressed by a combination of tools (Table 7.3). The effectiveness of all of the relevant tools has been assessed for each management topic.

Table 7.3 Management tools used to address the broad management topics

Management tools	Direct uses								External factors			Values		
	Commercial marine tourism	Defence activities	Fishing	Ports	Recreation (not including fishing)	Research 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 actions	●	●	●	●	●	●	●	●		●	●	●	●	●
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

To ensure the assessment of existing measures to protect and manage the Region’s ecosystem (natural heritage value) and heritage values (Indigenous, historic and other) was independent, the Marine Park Authority engaged five external independent assessors through an open tender process to jointly undertake the assessment. These assessors have expertise in protected area management, defence, ports, shipping, monitoring and evaluation, public policy and governance. The full report[5], including the evidence assessed to inform grades, has been summarised in Sections 7.3 to 7.5. These sections were reviewed by the independent assessors to make sure they are a transparent and fair reflection of their findings.

The effectiveness of protection and management measures was independently assessed

Since 2014, the Reef 2050 Plan[9] has been a key driver of actions. The related Reef 2050 Insights Report considers the Reef 2050 Plan's strengths, weaknesses and contribution to the effective management of the Region.[8]

7.2.1 Scope

The scope and methods for this assessment are consistent with the 2009 and 2014 Outlook Reports. The assessment considers 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 management responsibilities of the Marine Park Authority.

Management actions both inside and outside the Region are examined to the extent they are relevant to, and influence protection and management of, the Region's ecosystem and heritage values. In relation to the global issue of climate change, the assessment primarily considered measures undertaken by managing agencies specifically to protect and manage the Region. Given the unprecedented back-to-back coral bleaching events, and other climate-driven pressures, this assessment also broadly considers state, national and global climate change initiatives that are relevant to the values of the Region.

7.2.2 Assessment method

The International Union for the Conservation of Nature and Natural Resources (IUCN) has developed a framework for assessing management effectiveness of protected areas, which has been applied around the world.[1350] The 2019 Outlook Report assessment consistently applies this framework. This framework is based on a management cycle in which management is continuously evaluated and refined (Figure 7.2).

The assessment was based on the six elements of the management cycle:

- understanding context
- planning
- financial, staffing and information inputs
- management systems and processes
- delivery of outputs
- achievement of outcomes.

The independent assessment examined the six elements of the management cycle for each management topic outlined in Section 7.1.2 above. This framework specifies that effective management needs to be underpinned by a thorough understanding of the specific conditions related to protected areas, be carefully planned and implemented, and include regular monitoring, leading to changes in management as required.

For each management topic, the independent assessors considered evidence provided by managing agencies against 49 indicators to assess effectiveness at each stage of the management cycle (Appendix 5). 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).

The independent assessment of management effectiveness is examined around the six elements of the management cycle

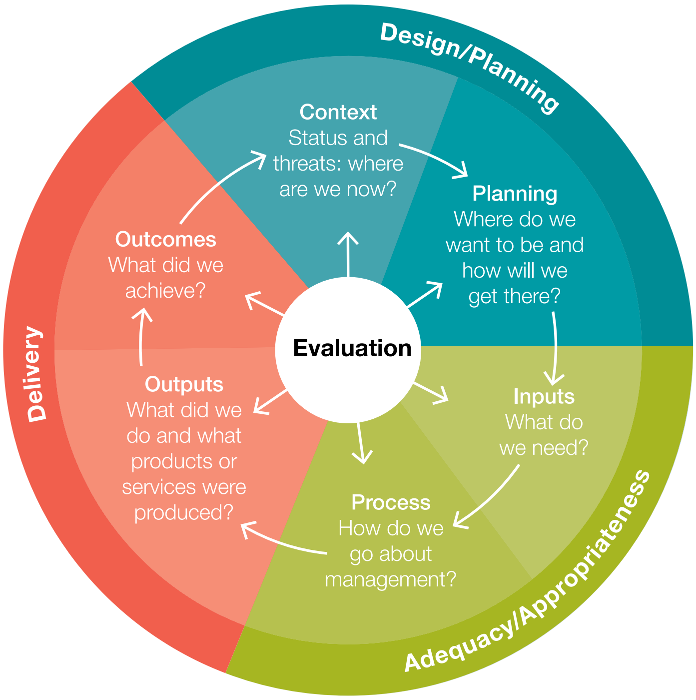


Figure 7.2 Framework for assessing management effectiveness of protected areas
Effective management is a closed loop where issues are considered, plans are made, resources are expended, processes are followed, and products and services are delivered, all leading to outcomes that address the issues. Source: Adapted from Hockings *et al.* 2006[1350]

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. To refine existing methodology without affecting comparability, the independent assessors introduced another step based on an innovation developed as part of the IUCN Green List of Protected and Conserved Areas Programme. This involved specifying ‘means of verifying’ each indicator, which identifies the most relevant types of evidence needed to appropriately assess each indicator.

The independent assessors also sought extra information from relevant research papers, semi-structured stakeholder interviews, workshops with managing agencies and other source documents. The assessment was based on documentation available and advice provided before the end of September 2018. Where necessary, information has been updated after this date with the consent of the independent assessors, but only where the new information involved a substantial change in management.

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 of the 14 broad management topics by the five expert assessors.[5]

Managing direct use

7.3.1 Commercial marine tourism

In terms of economic value and employment, tourism is recognised as the most significant direct use of the Region.[846] Both the Australian and Queensland governments recognise the importance of the Region to tourism. Marine tourism activities are considered to be a comparatively low risk to the Reef’s values when considered across the entire Region. However, at a local scale, marine tourism activities can affect the environment and heritage values and displace other users (for example, through congestion at particular high-use sites).

To address risks associated with marine tourism, the Marine Park Authority and the Queensland Parks and Wildlife Service jointly manage use and access through permits, management plans and compliance operations. A comprehensive suite of management tools, complemented by strong industry partnerships, continues to contribute to a sustainable tourism sector in the Region.

A comprehensive suite of management tools, complemented by strong industry partnerships, contribute to the sustainable management of tourism activities

The strongest improvements in management over the past five years have involved revised planning and permit processes and better material informing tourists about the Reef and its values. For example, in 2017, the amended *Whitsundays Plan of Management 1998* increased protection of sensitive seabird nesting areas, increased flexibility to accommodate low or no-impact activities, improved recognition of the importance of the area to Traditional Owners and increased flexibility for some tourism activities, such as motorised water sports at established locations.

In 2017, permission processes in the Marine Park regulations were reviewed. New assessment guidelines and policies under a strengthening permissions systems project were completed by the Marine Park Authority with a view to improving consistency and transparency in decision-making. The Marine Park Authority is meeting the service level standards for processing applications for permissions it developed and set out in the permission system service charter.[1351] Local-scale issues, such as damage to coral (from anchoring and fin damage from tourists snorkelling or diving) and disturbance of marine wildlife (through feeding, touching, noise and crowding) have been reduced through regulation, communication of responsible reef practices, and increased provision of reef protection infrastructure, such as public moorings.

The impact of climate change (causing unprecedented mass mortality of corals in 2016 and 2017), poor water quality and severe weather on particular tourism sites, has increased dramatically since 2014. The tourism industry and managing agencies need to make sure future management and use of the Region are sustainable, adaptable and flexible. This is especially important for addressing potential issues, such as congestion, if some sites become unviable for tourism purposes following disturbances. The Marine Park Authority’s *Marine Tourism Contingency Plan 2014*[1352] provides some flexibility for tourism operators to relocate following damage at particular sites (for example, after cyclone Debbie in 2017).

The Marine Park Authority has invested additional resources in the enforcement of permissions. This includes making sure permitted structures are well-maintained to reduce risks to the Region’s values (for example, in 2016–17, all nine tourism pontoons were audited and no significant issues were found).

Stakeholders are well known by managing agencies and are proactively engaged through meetings, training programs and advisory committees. Managing agencies leverage better practices from the tourism industry through a High Standard Tourism Operator Program. Eligible operators are accredited on the basis of their operations being ecologically sustainable and culturally appropriate, including presenting the values of the Region to a high standard. The number of independently certified high standard tourism operations has steadily increased from 19 operators in 2004 to 69 in 2017. These operations carry approximately 63 per cent of tourists visiting the Reef.

In 2015, the Marine Park Authority commissioned an independent audit of certified high standard tourism operators to determine the level of compliance with certification requirements. The audit identified fundamental strengths and positive experiences and also significant gaps relating to how the world heritage values were presented in interpretive content and education. The Master Reef Guides program and Reef Discovery Training course have been developed by the Marine Park Authority in partnership with the tourism industry to address this deficiency.

Context and planning are identified as areas that require strengthening. No systematic monitoring system is in place to assess the effectiveness of plans of management. The *Cairns Area Plan of Management 1998* and the *Hinchinbrook Plan of Management 2004* are both overdue for review – the Cairns plan was last amended in 2008 and the Hinchinbrook plan has not been amended since it was created in 2004. The delayed review of these plans is in part due to the low risk nature of marine tourism compared to other activities, such as crown-of-thorns starfish control. Since 2016, these plan of management areas have been affected by multiple stressors, such as mass coral bleaching and several severe cyclones. Some understanding of how impacted habitats have affected enjoyment of, and accessibility to, the Reef by visitors and the reef-based tourism industry exists, but is limited. To make sure the plans remain fit for purpose in the face of increasing cumulative impacts and a changing environment, the future needs of these areas should be considered through a risk-based planning approach.

The value that tourism visitors put on the Region is indicative of its national and international importance. The effective management of marine tourism in the Region is based on strong partnerships with the industry and a strong joint management approach between the Marine Park Authority and the Queensland Parks and Wildlife Service.

7.3.2 Defence activities

Activities undertaken by the Department of Defence in the Region continue to be managed effectively. Close cooperation exists between Defence, the Marine Park Authority and other agencies, particularly relating to the management cycles for major exercises using the Shoalwater Bay Military Training Area. Any impacts identified through day-to-day management of exercises were localised and short-term, and all incidents were considered to be well managed.

The management framework for defence activities continues to deliver effective environmental monitoring and management, commensurate with the low level of evident risks

Defence has a mature environmental management system in place that has operated very effectively for many years. The memorandum of understanding between Defence and the Marine Park Authority continues to underpin strong working relationships and information sharing, and instils a high level of confidence that defence activities are environmentally sustainable in the Region.

Defence continues to demonstrate a strong commitment to minimising its impacts, including implementing strict controls in sensitive habitats. For example, as part of the Talisman Sabre exercise in 2017, amphibious landing activities occurred at Stanage Bay rather than within the Shoalwater Bay Military Training Area. Stanage Bay offered deeper water access and thus reduced the potential impacts on seagrass beds important for dugongs and green turtles. The decision to use Stanage Bay recognised pressures on the Region from other threats, particularly coral bleaching impacts associated with climate change and storm events.

Shoalwater Bay remains a relatively large and intact natural area that is an increasingly important refuge for species (for example, dugongs and birdlife) whose distribution are contracting in response to other pressures, such as coastal development and climate change. Balancing the Defence requirements for training with conservation of critical environmental values will remain a significant challenge for managing agencies and Defence.

Defence continues to play an effective role in response to reports of legacy unexploded ordnance. Since the 2014 Outlook Report, some improvements have been made to the publicly available information about management of unexploded ordnance, explosive ordnance waste, and a wide range of dumped war materials. Web-based mapping tools now cover some of the known marine areas where contamination is likely to exist outside existing Defence training areas. This information is useful for managers making decisions about permitted uses in areas that might be affected by discarded or misfired ordnance. Almost no information is available on the presence or effects of ordnance contamination on the Reef. An exception is the World War II dump site at John Brewer Reef, offshore from Townsville, where extensive surveys have been undertaken since the discovery of dumped ordnance in 1988. As noted in the 2014 Outlook Report, Defence continues to treat hazards arising from unexploded ordnance contamination completely differently to all other forms of hazardous material contamination of the environment. It is a specific shortcoming that the Commonwealth policy on the management of land in Australia affected by unexploded ordnance does not clearly consider environmental contamination risks.

7.3.3 Fishing

Fishing is the principal extractive use of the Reef. Viable commercial fishing industries and recreational fishing depend on a healthy ecosystem. Management of fishing, and the aquatic environment on which it depends, is shared between the Australian and Queensland governments. The primary management tool for commercial and recreational fishing is the *Fisheries Act 1994* (Qld) and associated fisheries regulations. These require licensing of commercial fishing and establish fishing gear limitations, size and possession limits, spatial and temporal fishery closures and total allowable commercial catch limits. Also, the Queensland Boating and Fisheries Patrol and the Reef Joint Field Management Program carry out a comprehensive compliance program. These programs have been strengthened over the past five years, particularly in relation to recreational fishing. The Reef Joint Field Management Program is on track to double in size by 2021, further improving capacity for compliance and enforcement.

The most significant change in management of fishing in the Region since 2014 is the development of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Sustainable Fisheries Strategy).[892] This strategy covers both commercial and recreational fishing and commits to 10 major reform areas, including improved monitoring, research, environmental risk assessments and fish stock management. Delivery of this plan and associated investment have resulted in an increased management effectiveness grade for planning and inputs (Table 7.4). For example, in 2017–18 an extra 16 Queensland Boating and Fisheries Patrol compliance officers were appointed in the Region and 11 other full-time equivalent staff were recruited to support implementation of the strategy.

Illegal fishing is considered one of the greatest risks to targeted stocks and the sustainability of legal fishing. Fisheries compliance measures have increased since 2014, with Vessel Monitoring Systems (Section 5.4.3 Box 7) to be operational on all commercial vessels by 2020 and the Marine Park Authority making greater use of legislation to restrict activities of repeat offenders.

Recreational fishing in no-take areas, primarily Marine National Park (Green) Zones continues to be the most common offence in the Marine Park, undermining the health of the ecosystem. Each year since 2014–15, the Reef Joint Field Management Program has recorded more than 500 offences per year involving recreational fishing in the Marine Park. The number of offences has been gradually increasing with 653 reported in 2017–18. This increase is partly due to improved surveillance focussed on recreational fishing, but also reflects increased illegal activity. Recent research to understand why people fish in no-take zones has determined that the primary drivers of intentional illegal activity are fishers' perceptions of better fishing, the beliefs they will not get caught and that others are doing the same.[992,995] This information is being used to inform and refine compliance plans and strategies to target illegal recreational fishing. Notably, the vast majority of fishers (98 per cent) have high regard for the legitimacy of management and believe that illegal fishing is socially unacceptable.[995]

The Queensland Sustainable Fisheries Strategy 2017–2027 represents a significant change in fisheries management

Ecosystem effects and cumulative impacts of recreational fishing are concentrated in inshore areas close to major population centres. Increasing numbers of recreational fishers will increase the pressure on particular species and locations, but these impacts are largely unquantified.

While managers have a good understanding of the values of the Region with respect to fishing, the effect of ecosystem degradation on fisheries productivity is less understood. For example, the condition and trend of habitats that support fisheries have diminished following multiple wide-scale impacts (bleaching, cyclones). Fisheries are likely to experience lag effects of those impacts in the next few years (Sections 2.4.7 and 8.3.4).

There is good understanding of commercial fisheries' effort and harvest information. The Queensland Department of Agriculture and Fisheries assesses the stock status of important Queensland fish species each year. While some of the cumulative impacts associated with commercial fishing are known, information gaps exist, especially with respect to the impact of the coral bleaching events on fish stocks and the impact of fishing activities on Reef ecosystems. In addition, the sustainability of pearl perch, which has been classified as depleted, is of concern. There are also concerns about large declines in spawning aggregations and catch rates for Spanish mackerel[15,16], and evidence of major declines in catch rates for the Queensland component of the snapper stock[1353].

Management agencies engage with key fishing stakeholders to promote stewardship and influence good management practices. The Marine Park Authority's Local Marine Advisory Committees are used to gauge community views on Reef matters and provide a conduit for managers. However, these committees generally lack commercial fishers as members due to their job requirements. Significant public consultation with stakeholders was undertaken as part of the development of the Sustainable Fisheries Strategy.[892] A Sustainable Fisheries Expert Panel was established in July 2018 and stakeholder-based fishery working groups were formed, which include Marine Park Authority representatives. These working groups are effective partnerships that will achieve the outcomes required.

Actions associated with the Sustainable Fisheries Strategy, which has been in place since June 2017, are on track. The strategy provides a clear program of work and an opportunity to introduce best practice standards. It is responsible for the improved management effectiveness scores for fishing (Section 7.6). Implementation of the strategy and the improved compliance measures provides the opportunity for improved and effective future management of fisheries.

Benefits of zoning and importance of compliance

Since the rezoning of the Great Barrier Reef Marine Park in 2004, a growing body of research has reported important ecosystem benefits arising from the expansion of no-take zones.[1354] As the Reef faces a range of pressures and impacts that threaten its health and future, no-take zoning and user compliance is more important than ever. However, during the 2016 and 2017 bleaching, zoning did not protect reefs from extreme temperatures due to climate change.[141]

Reefs in no-take and no-entry zones have a greater density and biomass of fishes targeted by fishers than reefs in zones open to fishing.[613,998,1355,1356] A wider ecosystem and fisheries benefit of this protection comes from the spread of targeted fish larvae out of no-take zones, and the 'spillover' contribution to stocks in areas open to fishing.[618,619] Fish in no-take zones are larger and more numerous, and may make a considerable contribution to sustaining populations in fished areas.[618,619] This spillover effect is important in educating fishers about the importance of compliance because it demonstrates the benefits they gain personally from no-take areas and encourages them to report non-compliance.

Other ecosystem benefits of no-take zones in the Reef include lower levels of coral disease (potentially as a result of reduced damage to coral tissue from fishing activity[990]) and fewer and less severe crown-of-thorns starfish outbreaks (potentially due to increasing densities of predators of young starfish[762]). Long-term monitoring data has indicated that reefs in no-take zones have a more stable community structure. Whether these findings remain following broadscale coral mortality from back-to-back bleaching events remains to be seen. However, research has shown that the magnitude of disturbance from impacts, such as a single coral bleaching event, crown-of-thorns starfish outbreaks, coral disease and cyclones, was 30 per cent lower in no-take zones, and reefs recovered 20 per cent faster than nearby reefs that are open to fishing.[756]

The differences in fish biomass between no-take zones and zones open to fishing[613,998,1355,1356] suggests that most users comply with zoning. However, non-compliance remains a significant problem with 500–600 zoning offences involving recreational and commercial fishing recorded by the Marine Park Authority each year.

Lost fishing lines have been recorded in substantial quantities in no-take zones[1357] and social surveys estimated that three to 18 per cent of recreational fishers fished in a no-take zone during the preceding year.[992,996] Illegal fishing in no-take zones can reduce targeted fish densities significantly[1358] and is limiting the full potential of the ecological and fishery benefits of the Zoning Plan.

There is strong evidence for the importance and effectiveness of the Zoning Plan in maintaining ecosystem health and supporting the Reef's resilience and recovery. These, and perhaps other as yet unidentified benefits, may be crucial to the Reef's long-term health and survival. Minimising the impacts of illegal fishing and other zoning non-compliance is vital, and the recent funding and technology-related enhancements to compliance and enforcement capability in the Marine Park are an important and valuable investment in the future of the Reef.

Marine Park vessel Reef Sentinel — one of the range of vessel and aircraft surveillance platforms used in the multi-agency compliance program for the World Heritage Area. © GBRMPA

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 shipping and 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. The assessment is confined to those aspects of the operation and management of the 12 Reef ports (Section 5.7) that affect the Region's ecosystem and heritage values.

Since 2009, the Marine Park Authority's interest in matters relating to ports adjacent to the Region has been facilitated through a memorandum of understanding with the Queensland Ports Association. This agreement allows for a cooperative approach to Reef-related policy and regulatory matters relevant to Reef ports. Policy and regulatory matters are discussed at regular port forum meetings, which include representatives of all relevant port corporations as well as Australian and Queensland government environmental regulators.

New legislation and management processes are coordinating holistic planning for future port developments

Since the 2014 Outlook Report, port planning and development in the Region have been reinvigorated with significant reforms. The *Sustainable Ports Development Act 2015* (Qld) limits the spatial extent of port development to existing port sites and new Marine Park regulations restrict the disposal of capital dredge material in the Marine Park. Actions under the Reef 2050 Plan[9] related to ports have improved the management of ports and their potential impacts. These include developing a *Maintenance Dredging Strategy for the Great Barrier Reef World Heritage Area*[1034], guidelines for long-term maintenance dredge management plans and the Queensland Ports Strategy.[1041] The Queensland Government has also implemented the statutory port master planning process, including guidelines.

Implementation of the port master planning process is still in its infancy at the time of this management effectiveness review. Therefore, the full effect of this new initiative could not be observed or assessed. Nevertheless, the new mandatory and coordinated approach to port development in the Region is intended to ensure effective recognition and protection of the Reef's outstanding universal value, which will probably be reflected in future management effectiveness evaluations.

In general terms, ports within the Region continue to be well managed. While ports conduct a diverse range and number of monitoring programs, there are gaps in the range, quality and consistency of data collected across ports generally. These gaps also apply to the presentation and availability of collected data, as evidenced by a review of the publicly accessible ports monitoring data (for example, seagrass data). Expanded monitoring and reporting programs focused on known risks have the potential to identify new or emerging threats to the Region. They can also demonstrate the absence of such threats, which may include significant deterioration in sediment quality or the incidence of invasive marine species.

7.3.5 Recreation (not including fishing)

Recreation is defined as an independent visit for enjoyment that is not part of a commercial tourism operation.[1007] Responsibility for managing non-extractive recreation is spread across a variety of Australian and Queensland government agencies. Relevant agencies (the Marine Park Authority, Queensland Parks and Wildlife Service, Queensland Boating and Fisheries Patrol, Maritime Safety Queensland and Queensland Water Police) continue to coordinate effectively to enforce the Commonwealth and Queensland Marine Park Acts, regulations, zoning plans and plans of management.

These management tools are supported by a risk-based compliance and enforcement plan. Stewardship and education programs, such as responsible reef practices, aim to increase sustainable recreational behaviours and support positive stewardship activities undertaken by recreational users. The recently expanded network of public moorings and no-anchoring areas will help reduce impacts of recreation, such as anchor damage in heavily accessed areas, while providing for easier access.

The revised *Whitsundays Plan of Management 1998* provides more anchorages for superyachts, increases water sport opportunities at already established locations and simplifies boundaries to make it easier for users to understand what activities are allowed where. The changes to the plan of management also considered the impacts of cyclone Debbie in March 2017 and the resulting pressure on popular sites.

Work undertaken on the aesthetic values of the Region reported that the cumulative use of recreational users at popular sites had a localised, medium risk of affecting naturalness, solitude and tranquillity.[782] The condition and trend of recreation are discussed in the Marine Park Authority's 2012 *Recreation Management Strategy for the Great Barrier Reef Marine Park* (Recreation Management Strategy)[1007], but information about impacts of recreation on the condition and trend of values as a whole is still lacking. Relevant key risks identified in the risk-based compliance and enforcement plan include vessels approaching whales, disposal of garbage, island national park offences, misuse of public moorings and offence under the plans of management offences (for example, motorised water sports outside designated areas, anchoring in no-anchoring areas or exceeding vessel speed limits).

Limited Marine Park Authority resources have been directly allocated to managing recreation since the development of the Recreation Management Strategy in 2012.[1007] Recreational use is seen as a low risk to the Region, which is supported by the IUCN Outlook report for the Reef.[1359] The lack of an implementation plan or review of the Recreation Management Strategy since it was released reflects the low risk recreation has on Reef values. However, to make sure the Recreation Management Strategy remains fit for purpose in the face of increasing cumulative impacts, a review of the risk assessment within the strategy would strengthen its effectiveness as a planning tool.

Stakeholder engagement with recreational users remains strong. Marine Park Authority and Queensland Parks and Wildlife Service staff across the Region continue to interact with recreational users, particularly through Local Marine Advisory Committees, public engagement and via the Reef Guardian program, which includes schools, councils and fishers. However, the diversity and informality inherent in recreational use continues to make it difficult to engage with most users, and document their values and activities spatially.

7.3.6 Research activities

This evaluation of the effectiveness of management in relation to research activities primarily concentrates on the direct management of research activities in the Region. Management agency interactions with research providers and alignment of research into management is also considered, but to a lesser extent.

Reef managers aim to minimise impacts of research activities through a risk-based permits process

The Reef is known internationally as a premier site in which to conduct scientific studies. The majority of research occurs at the four major research stations at Lizard, Orpheus, One Tree and Heron islands. A wide range of low-intensity research is conducted at other locations.

Researchers who undertake research in the Region, such as the collection of specimens and installation of research equipment, require permits and licences from managing agencies. The Marine Park Authority, Queensland Parks and Wildlife Service and Queensland Department of Agriculture and Fisheries have lead roles in managing research activities. Joint accreditation of research institutions by the Marine Park Authority and Queensland Parks and Wildlife Service also enables low-risk research to occur in particular locations without the need for specific permits. These mechanisms are underpinned by zoning plans, legislation and policy. The Marine Park Authority's policy on *Managing research in the Great Barrier Reef Marine Park*[1360] and the Marine Park regulations were updated in late 2017 to increase consistency and transparency in decision-making and make it easier for researchers to understand permit application requirements.

Researchers are generally required to spread collections across species and locations to reduce impacts. Research station directors help with monitoring and managing the activities of researchers who use those facilities. Research is not considered to have a large or detrimental impact on the Reef ecosystem. However, limited knowledge is readily available on the cumulative collection of samples by researchers. It had been intended that environmental management plans and improved electronic systems would address this. However, since the 2009 Outlook Report, the implementation of environmental management plans adjacent to research stations has continued to be slow and auditing of research permit compliance remains limited. The online submission of research permits and collection reports has been possible since mid-2018. This is expected to help address this weakness and improve permit processing timeframes.

Research is key to assessing and advising on the condition and trend of the values and threats arising from broader environmental and anthropogenic stressors. Numerous science strategies, research partnerships and funding streams are in place to support and influence research priorities so that outcomes can be applied to management of the Region. For example, the Marine Park Authority's *Science Strategy and Information Needs 2014–2019*[6] identifies key research priorities to better inform management of the Reef. Promoting and applying research to understand and address the larger environmental stressors from both a biophysical and socio-economic perspective is a key role for management agencies. The role needs to be maintained and strengthened, particularly in relation to understanding impacts from climate change stressors, reef intervention and restoration activities, and liaison with Traditional Owners about research undertaken on their country.

The flow-on effects to the ecosystem from multiple disturbances are only just beginning to be quantified. The shortening of recovery periods between disturbances is leading managing agencies, researchers and the community to consider, facilitate and deploy more hands-on intervention and restoration activities, some of which are in their infancy on the Reef. A major research effort is now underway (including the Reef Restoration and Adaptation Program) to potentially increase the local abundance of corals.

Inclusion of Traditional Owners in research within their sea country is limited and research results are often not disseminated to Traditional Owners. However, examples of collaboration are increasing. These include: a protocol between the Wuthathi Aboriginal Corporation and Queensland Parks and Wildlife Service to manage permits for research in the Shelburne Bay area in Cape York; new guidelines for Woppaburra Traditional Owner Heritage Assessments in the Keppel islands region; and involvement of Traditional Owners in the development and implementation of research, monitoring and beach restoration at Raine Island.

Multiple managing agencies continue to have representation on major committees relating to research on the Reef. Many of these are coordinated through the overarching Reef 2050 Plan. However, a number of researchers noted decreased engagement from the Marine Park Authority's staff on research priorities, which they attributed to a loss of key staff members at the authority over the past few years. The reduced engagement may also be a consequence of diversified sources of funding for research in the Region, with significant research funds being managed through the Commonwealth Department of the Environment and Energy.

7.3.7 Shipping

In this assessment, the topic of shipping encompasses the movement and operation of ships (greater than 50 metres in length), 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 and impacts of ships while at anchor (for example, illegal discharge of ballast water or effluent).

Agencies with responsibility for managing shipping and shipping safety in the Region (Australian Maritime Safety Authority, Maritime Safety Queensland and, to a lesser extent, the Marine Park Authority) are considered to be generally well equipped to undertake the required tasks. They have effective methods and procedures for planning and implementing appropriate measures to manage shipping activity.

Shipping is generally well regulated and managed within the Region

Shipping safety in the Region is well regulated and effectively managed through an extensive suite of control, risk-reduction and risk-response measures. While shipping incidents, such as loss of propulsion and navigation, and errors, inevitably occur at times, the rate of such incidents and the potential consequences are attenuated to a significant extent by improvements in technology. These include advancing ship design and marine environment protection and safety requirements (for example, protected fuel tanks and electronic aids to navigation), other controls (for example, the vessel tracking system REEFVTS and designated shipping areas) and enforcement and compliance mechanisms (for example, port state control inspections and ship vetting). Since 2012, the coordinated management of shipping has improved markedly through the development and progressive implementation of the 2014 *North-East Shipping Management Plan*.[1361] Actions have included more marine surveyors at ports to ensure effective inspection of ships and upgraded emergency towage capacity in the Region. The plan also identified emergent risks, improved multi-agency coordination, and refined existing management practices. It is enhanced by the parallel implementation of elements of the Reef 2050 Plan related to shipping.

It is critical that control and emergency response arrangements anticipate and respond to changes in shipping activity levels and risk profiles. Planning and processes could be strengthened by improved policies and procedures for restoring and rehabilitating damaged areas following groundings, and improved control, surveillance and monitoring for introduced marine species, particularly in relation to ship biofouling.

In general, single, catastrophic events have been planned for, but chronic, low-level effects have not been adequately considered. There is also particular concern about the cumulative effects of aspects of shipping, such as leaching and loss of biocidal antifouling paints, wake and turbulence effects, animal strikes, and altered light and underwater noise regimes. Aesthetic issues related to shipping in remote areas are less understood than in designated port and anchorage areas. While there has been some progress on the study and management of these issues in recent years, further work is required.

7.3.8 Traditional use of marine resources

The program to develop and implement statutory agreements to sustainably manage traditional use of marine resources remains one of the success stories in management of the Region.[1362] Under the *Native Title Act 1993* (Cth), Aboriginal and Torres Strait Islander peoples from more than 70 Traditional Owner groups along the Reef have rights in relation to the harvest and use of marine resources for traditional uses within their land and sea country. Managers have a good understanding of Commonwealth and state legislation, as well as national and international obligations in relation to biodiversity conservation and the rights of Indigenous peoples.

Traditional Use of Marine Resources Agreements remain one of the management success stories of the Region

At a formal, administrative level, traditional use of marine resources in the Region is primarily managed through Traditional Use of Marine Resources Agreements — formal agreements developed by Traditional Owner groups that are jointly assessed and accredited by the Marine Park Authority and Queensland Government. These agreements promote sustainable use of species, such as dugongs and green turtles. They also incorporate monitoring and management of other species and ecosystems, such as seagrasses, oyster beds and shellfish. Aspiration statements, clear objectives and implementation plans are part of each Traditional Use of Marine Resources Agreement. In 2018, nine Traditional Use of Marine Resources Agreements and one Indigenous Land Use Agreement were in place. This is an increase of two agreements since 2014.

Combined, these agreements cover approximately 25 per cent of the Great Barrier Reef coastline. It is noted that expansion of Traditional Use of Marine Resources Agreements will take time.

While securing Traditional Use of Marine Resources Agreements over the remaining areas of the Region is important, the process cannot be rushed. Appropriate inputs will enable relationships between Traditional Owners and managing agencies to be maintained and strengthened. Sustainable funding announced in 2018 for the Traditional Use of Marine Resources Agreements program, mean that appropriate levels of engagement should be possible with existing Traditional Use of Marine Resources Agreements.

Traditional Use of Marine Resources Agreements also provide mechanisms and support for many other activities conducted by Traditional Owner groups, including monitoring, education, community activities and compliance activities within their land and sea country. Since 2014, investment in Indigenous ranger programs has improved partnership and compliance outcomes for the Region's values. For example, compliance training was delivered to more than 500 Traditional Owners over 2016–17, strengthening enforcement of Traditional Use of Marine Resources Agreements and increasing Marine Park compliance generally. Social, economic and health outcomes have not been formally assessed, but are likely to also be substantial, as are outcomes from the Indigenous ranger program.[1363]

It is clear that impacts from a range of pressures (such as climate change, other users, depletion of megafauna and severe weather) have affected Traditional Owners' use of the marine environment and their ability to continue important cultural practices. For traditional use of marine resources, the management effectiveness grade for context has declined from effective to mostly effective (Table 7.4 in Section 7.6). This decrease is due to the challenges of understanding threats, impacts and current status of the relevant values in times of rapid change, especially due to the impacts of cyclones and climate change (for example, coral bleaching). The cumulative impacts of all other threats, and the ability of species of cultural significance to recover, are not well understood.

The effectiveness of engaging broader stakeholders and local communities is highly variable. In 2015–16, some issues occurred in multiple-use areas where the activities of tourism operators and visitors conflicted with Traditional Owner use of marine resources. Some of these tensions were relieved by the Gunggandji Traditional Use of Marine Resources Agreement signed in June 2016.

Managing external factors

7.3.9 Climate change

The Paris Agreement under the United Nations Framework Convention on Climate Change provides the international framework for actions to mitigate climate change. Nationally determined contributions, which set out countries' actions to limit climate change to well below two degrees Celsius, are not yet sufficient to achieve this goal.[1364] The effectiveness of global actions to mitigate climate change will be the primary determinant of further climate impacts on the Reef.

The Reef 2050 Plan aims to address key threats and boost the health and resilience of the Reef so that it can better cope with the impacts of climate change. Primary responsibility for national responses to climate change rests with the Commonwealth Department of the Environment and Energy. In 2015, the Reef 2050 Plan did not set out to directly address the threat of climate change through its objectives, targets and actions. In mid-2017, the Great Barrier Reef Ministerial Forum brought forward the plan's mid-term review in recognition of the impacts of coral bleaching and future climate projections. The resulting updated Reef 2050 Plan (2018) focuses on additional actions within the Region to address climate change impacts, such as, implementing the *Great Barrier Reef Blueprint for Resilience*.[24] A broader review of targets and objectives will be undertaken in 2020 following release of this 2019 Outlook Report.

Widespread coral bleaching events in 2016 and 2017 have increased attention on climate change as the principal threat to the Reef

Climate policy and mitigation and adaptation programs remain in a state of flux at the national level as made clear in the report of the 2017 Senate inquiry on impacts of climate change on marine fisheries and biodiversity.[1365] Policy dissonance exists within government and society whereby conflicting policies relating to environmental protection and development sit side by side. Many of these conflicts cannot be directly addressed by most Reef 2050 partners as they lie outside the direct management role of agencies limited by statute.

At the time of the 2014 Outlook Report, the Queensland Government's focus and action on climate change had diminished with the disbanding of their Office of Climate Change. Also, significant reductions in staffing and expertise relevant to climate change occurred within the Australian and Queensland governments. Since then, the Queensland Government has released the Queensland Climate Change Response, comprising the *Queensland Climate Transition Strategy*[1366], with a zero net emission target by 2050, and the *Queensland Climate Adaptation Strategy*[1367]. Climate change programs and staffing have been rebuilt. These include specific sectoral strategies and programs for local governments, such as QCoast 2100, which supports local governments to prepare coastal hazard adaptation measures. Under the Queensland Climate Adaptation Strategy are eight sector adaptation plans. The *Biodiversity and Ecosystems Climate Adaptation Plan*[1368] aims to minimise the negative impacts of climate change on Queensland biodiversity and ecosystems through collaboration, planning and on-ground action.[1368] However, governments at all levels continue to exhibit considerable policy dissonance in the strategies they are pursuing for climate change response and economic development.[1369]

With respect to its management activity in the Region, the Marine Park Authority advises other agencies about mitigation of, and adaptation to, climate change and extreme weather. It also undertakes activities to build the resilience of the Region's ecosystems (for example on Raine Island) (Section 2.4.10). While the Marine Park Authority has no jurisdictional responsibility for addressing climate change in the broad sense, it has contributed significantly to developing international best practice for managing responses to climate change and cyclones as they relate to Reef ecosystems. This contribution has been achieved through research, monitoring and partnerships with research institutions, government agencies and stakeholder groups as well as education, community awareness and stakeholder engagement programs. Assessing the effectiveness of the Marine Park Authority and other Reef management agencies in addressing this issue is challenging, as so much depends on the actions of others. This is especially so in regard to the effectiveness of mitigation measures taken at national and international levels and the mitigation and adaptation measures undertaken in adjacent coastal areas by local governments and others.

Alongside other research institutions, the Marine Park Authority plays a key role in facilitating awareness of the impacts from climate change and cyclones on the Region. The Outlook Report continues to emphasise that climate change is the principal long-term threat to the condition of the ecosystem. The Marine Park Authority prepared a vulnerability assessment for the Reef in relation to climate change in 2007 and a strategic plan to address climate change in 2009. The *Climate Change Strategy and Action Plan 2012–2017*[1370] (Climate Change Action Plan) acknowledged the important role the Marine Park Authority plays in informing national and international climate policy and providing knowledge to support effective management of inshore areas. However, implementation of the Climate Change Action Plan was defunded early in its life, and many actions in that plan remain unaddressed or only partially implemented. A number of the actions have been incorporated into annual operational plans or are now included in the sectoral adaptation programs being developed by the Queensland Government. Changes in staffing and organisational structures within the Marine Park Authority have lowered its prominence in addressing climate change. The Marine Park Authority no longer has an identifiable unit focused on climate change responses, although a number of staff across the Marine Park Authority have responsibility for climate policy and responses. In early 2019, the Marine Park Authority released a draft position statement on climate change for targeted consultation. While not completed before the finalisation of the independent reviewers' management effectiveness assessment, its finalisation will provide a clear position on this critical threat.

Management effectiveness of climate change is the weakest topic assessed, with most elements trending down or declining in grade

Work continues on identifying the gaps in available biophysical information. This job has been made larger and more important by bleaching events and the decline in our knowledge of the condition of Reef biota. The Reef 2050 Integrated Monitoring and Reporting Program (RIMReP), when operational, will help to provide critical knowledge within a structured framework. The need to clarify socio-economic implications is being addressed in collaboration with the CSIRO through the Social and Economic Long-Term Monitoring Program, established with National Environmental Research Program Funding in 2011, and the National Environmental Science Program in 2015.

Critical elements of current condition and trend are being monitored by researchers and managers, but knowledge in this area has declined since the bleaching events. Work is also underway with Traditional Owners to apply available traditional knowledge to consider climate change implications, through Traditional Use of Marine Resources Agreements and Sea Country forums.

Community engagement relating to climate change continues through initiatives, such as Eye on the Reef and the Reef Guardian program, which includes schools, councils and fishers. A reef health incident response framework was developed in 2011, in consultation with stakeholders, and continues to be updated as needed.

The Marine Park Authority is just one voice in what is an increasingly crowded policy and management space, with strategies being developed at national, state and local levels. However, the defunded Climate Change Action Plan[1370] represented a significant withdrawal of the Marine Park Authority from a very visible role in planning for, and leading, work on addressing climate change relating to the Region. To some extent, this has shifted its role from being a 'consequence maker' advocating for effective climate mitigation to being a 'consequence taker' responding to climate change impacts with actions to improve Reef resilience as part of an adaptation strategy.

Documents based on the latest scientific research, such as the revised Reef 2050 Plan[9] and *Great Barrier Reef Blueprint for Resilience* (Reef Blueprint)[24] make it clearer that restricting the global temperature increase to 1.5 degrees Celsius or lower is critical to the Reef remaining a functioning ecosystem. The Reef Blueprint, released in late 2017 (Box 12), may mark a resurgence of a more active role by managing agencies in this space, with a focus on building a 'resilience network' of areas within the Region that have the best chance of supporting system-wide resilience and recovery following disturbances. The proposed activities within the Region, such as dramatically enhancing compliance, accelerating actions to address climate change, expanding crown-of-thorns starfish control, protecting key species and locations, and actively restoring local areas, are all desirable, ‘no-regrets’ actions. However, the success of the Reef Blueprint will depend on the extent to which they are able to achieve broader objectives of fostering change at a wider policy, societal and geographic level.

BOX 12

Blueprint for resilience

In May 2017, with the Reef facing unprecedented pressures, the Marine Park Authority convened regional, national and international Reef experts for the first ever Reef Summit. Working with the goal of improving the capacity of corals to resist and recover from climate-related impacts, the summit released the Reef Blueprint.[24]

The Reef Blueprint signals a change in the focus of future management of the Reef. It identifies the 10 most promising initiatives to guide future actions and solutions that can be pursued with partners, developed quickly and applied to large areas (Figure 7.3).

The Reef Blueprint has already contributed to securing unprecedented levels of funding to develop and implement innovative and timely strategies.[1371] It has also helped galvanise collaboration and resilience-building efforts across the Reef community. The on-water and immediate efforts underway include enhancing compliance, crown-of-thorns starfish control, and identifying and protecting a network of resilient coral reef sites.

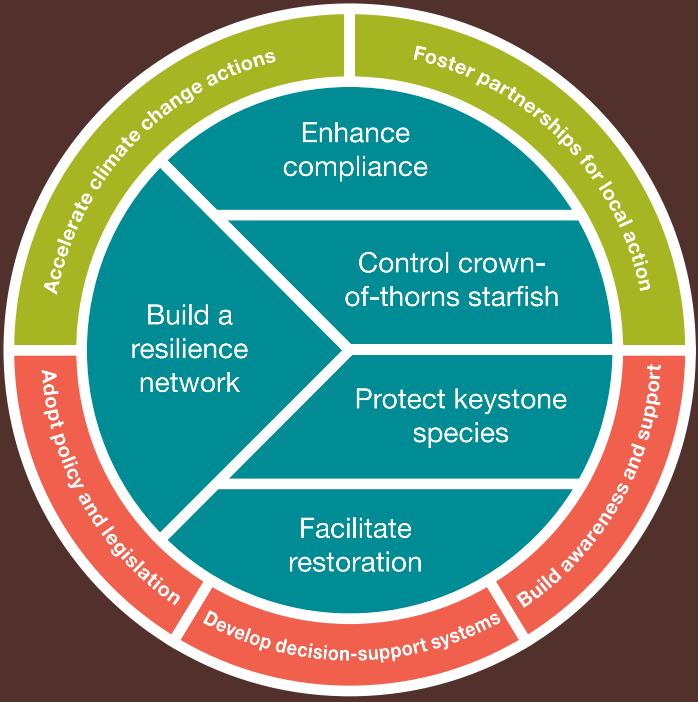


Figure 7.3 Great Barrier Reef Blueprint for Resilience initiatives
Source: GBRMPA 2017[24]

7.3.10 Coastal development

Coastal development includes management of activities undertaken within the 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. Similarly, the management of land-based run-off is considered in Section 7.3.11.

Planning systems to effectively address coastal development have evolved and improved over the past five years

The *Planning Act 2016* (Qld) (the Planning Act) and associated legislation, preserve ecological sustainability as a core principle of planning in Queensland. The planning reform that led to this new Planning Act reinstated coastal land surrender provisions under the *Coastal Protection and Management Act 1995* (Qld) to make sure areas at high risk of coastal erosion remain free from development.

The 2014 *Queensland State Planning Policy*[1372] introduced a coordinated approach to all state interests. The state development assessment provisions were introduced in 2013 to guide Queensland’s assessment of development applications that were likely to affect state interests. These documents were reviewed in 2017[1373] in association with the introduction of the Planning Act. In early 2018, the coastal protection state interest of the State Planning Policy was integrated into the planning schemes of 12 of the 22 coastal local governments in the Catchment.

As part of the planning reform since 2014, the Queensland Government introduced new erosion prone areas in coastal hazard maps. Planning scheme reviews have rezoned some privately owned land in the erosion prone area to 'limited development zone'. This means undeveloped rural and natural areas within the Catchment now have restricted development potential.

Reprofiling of Raine Island turtle nesting beach. © GBRMPA

Development regulations (largely focused on urban areas) regarding coastal development, water quality and protection of wetlands have improved as local governments progressively update their planning schemes. The *Wetlands in the Great Barrier Reef Catchments Management Strategy 2016–21*[1374] outlines an integrated approach to catchment and coastal environment management. The strategy considers the multiple values of wetlands and the role they play in the ecosystem health of the Region. It provides a whole-of-system framework for Catchment management and the protection, maintenance and restoration of wetland systems. Implementing regional water quality improvement plans (such as the *Wet Tropics Water Quality Improvement Plan 2015–2020*) also improves ecosystem function.[1375] Earthworks above a specified scale in wetlands (including earthworks for agricultural activities) were regulated in 2014, and a reduction in the rate of loss of these wetlands in the Catchment has been observed.[43] Pressure from mining-associated coastal development appears to be less than in previous years following a downturn in the mining sector.

While a 45 per cent increase in the rate of clearing of woody vegetation occurred in the Catchment between 2014–15 and 2015–16, the rate of clearing from 2016–17 (166,000 hectares) to 2017–18 (148,000 hectares) decreased.[704] Legislation to reinstate stricter tree clearing was passed by the Queensland Government in 2018. While it is still too early to measure outcomes, this legislative planning tool is expected to reduce the future clearing rate, and the associated increase in adverse impacts on coastal ecosystems.

Legacy issues remain in coastal areas, such as retaining dams that hold significant volumes of toxic water that can leach into the Region. The financial collapse of the Yabulu nickel refinery in Townsville in 2016 highlighted a limitation of the Queensland Government's power to enforce environmentally relevant activity conditions on operators. This issue has recently been addressed by the *Environmental Protection (Chain of Responsibility) Amendment Act 2016* (Qld) that allows the state to enforce environmental and rehabilitation obligations against 'related persons' of companies in financial difficulty.

Stakeholder engagement on coastal ecosystem management continues to play an important role in protecting the Region's values. Coastal ecosystems management is a focus of coastal Reef Guardian councils and schools and is regularly discussed at Local Marine Advisory Committees and Reef Advisory Committees.

For coastal development, the management effectiveness grades for planning, inputs, processes and outputs have improved to a rating of mostly effective (Table 7.4 in Section 7.6). This is a positive sign that the major issues are starting to be addressed. However, the impact of these improvements on the attainment of desired outcomes for coastal development has yet to be demonstrated. The long-term future condition and trend for inshore and coastal ecosystems are very poor if strong cooperative management action is not taken to halt and reverse their decline. The impact of inappropriate coastal development has been highlighted in the Reef 2050 Plan[9] and the 2017 Scientific Consensus Statement.[43,462]

7.3.11 Land-based run-off

Land-based run-off has been recognised as having a significant impact on the values of the Region.[2,462,941,1376] The Queensland Government regulates land-based run-off from industrial, municipal and agricultural sources in the Catchment under the *Environmental Protection Act 1994* (Qld), and the current government is committed to broadening Reef protection regulations to reduce nutrients and sediment pollution.

An unavoidable lag occurs between actions on the ground and better Reef water quality

Planning approaches to address land-based run-off continue to improve. The Reef 2050 Plan includes actions to protect the values, health and resilience of the Region while allowing for ecologically sustainable use. The *Reef 2050 Water Quality Improvement Plan 2017–2022* (Reef 2050 WQIP, previously the Reef Plan)[527] directly aligns with, and is nested within, the Reef 2050 Plan. Since 2014, an understanding of how poor water quality is perceived by, and affects, Reef users has improved. Restrictions on vegetation clearing in the Catchment were reintroduced after 2018 and restrictions on riparian clearing in the Catchment were expanded to the Fitzroy, Burnett–Mary and Cape York NRM regions. Healthy waters management plans are additional legislative tools under the *Environmental Protection (Water) Policy 2009* (Qld). These plans identify management goals and water quality objectives to protect specific environmental values of waterways.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) and the associated Reef Report Card process have continually improved to provide a succinct snapshot of improvements and changes in land management practices and pollutant loads across the Catchment. Nutrients, fine sediments and pesticides are the primary pollutants that pose an ongoing risk to the Reef coastal and marine ecosystems. Significant progress has been made in understanding these pollutants, their delivery from the Catchment and the benefit of improved land management practices on water quality entering the Region.[462] The annual Reef report cards have confirmed the estimated average pollutant loads in land-based run-off have declined since 2014. However, progress from the adoption of improved land management practices continues to be slow. Significant time lags are expected between improved land management practices and condition of the Reef.

Measurable targets, improved accountability and coordinated monitoring, evaluation and reporting are clearly articulated in the Reef 2050 WQIP. The plan includes a diverse set of actions and builds on almost 15 years of effort by governments at all levels, working in partnership with landholders, natural resource managers, industry, researchers and conservation groups. It addresses agricultural land-based sources of water pollution, and added urban, industrial and public lands in 2018. The Reef 2050 WQIP also recognises the importance of people in creating change and includes social, cultural and economic values. The plan sets targets for improving water quality for 35 major river basins flowing to the Reef, for the six NRM regions and the whole Reef. This is an increased level of specificity compared to previous targets. The planning process used sophisticated modelling and other scientific information to make sure the targets are based on what is needed for a healthy Reef.

The *Reef 2050 Plan Investment Framework*[10] identified the investment needed to reduce land-based run-off through improved land management practices, as well as the research and monitoring programs needed to assess effectiveness of the investments. This framework has resulted in significant increases in financial inputs over the past five years. Planning has expanded and continues to be effective. The processes and outputs of the Reef 2050 WQIP continue to improve. However, the 2017 Scientific Consensus Statement highlighted that poor water quality is continuing to degrade Reef health.[1223] On-ground delivery programs are undertaking landscape restoration and habitat repair in areas that pose the greatest risk to the Reef. Change will remain slow while improvements to agricultural land management practices remains voluntary, and the significant time-lag between actions on the ground and better water quality results will be exacerbated. It should be noted that, in February 2019, a bill was introduced into Queensland Parliament to strengthen existing Reef protection regulations.

Coastal ecosystems can benefit from revegetation; these local students are from Mission Beach State School.
© GBRMPA 2014

Managing to protect the Region's values

7.3.12 Biodiversity values

Protection of biodiversity values in the Region is one of the primary objectives for management. The focus on biodiversity was heightened following international attention on the World Heritage Area by UNESCO and the subsequent Strategic Assessments. The outcomes from these assessments strengthened research collaborations and increased understanding of threats to the system, and the state of biodiversity in the Region.

The cumulative and consequential impacts across the Region of back-to-back coral bleaching events in 2016–17, the 10 severe cyclones that have crossed the Region since 2006, and the impacts of crown-of-thorns starfish, have dramatically changed the situation in relation to management of biodiversity in the Region. Reef surveys have documented the extent of damage, recovery and mortality.[440] However, the resulting flow-on effects of coral loss to the broader ecosystem and species are only just beginning to be quantified. Management agencies are now in a space of knowledge uncertainty as research and monitoring strive to keep pace with a rapidly changing system. Although progress has been slow, once implemented, the Reef 2050 Integrated Monitoring and Reporting Program (Section 10.3 Box 16) will consolidate monitoring information and make it more readily available to address this knowledge deficiency.[1377,1378]

The rate at which the system is changing following disturbances makes biodiversity protection a challenge

At a Region-wide scale, the amalgamated Zoning Plan, which came into effect in 2004 and is reflected in the adjacent Queensland Great Barrier Reef Coast Marine Park, is the most significant planning tool to enhance biodiversity protection. To be effective, zoning provisions need to be enforced. Enforcement has significantly improved over recent years with improved compliance monitoring technology, the planned expansion of remote vessel tracking across the commercial fishing fleet, and better targeting of compliance actions based on risk that gives priority to impacts on protected species. Zoning has provided a robust framework for Reef-wide management and is demonstrating positive results.[613,998,1355,1356] However, the zoning provisions only address biodiversity protection at a broad level. Some threats, such as crown-of-thorns starfish outbreaks, are addressed at a local level by other measures (Box 13), but major threats to biodiversity, such as climate change, coastal development and land-based run-off, cannot be addressed directly by either the zoning provisions or individual biodiversity protection measures.

The *Great Barrier Reef Biodiversity Conservation Strategy* (Biodiversity Conservation Strategy)[1379], developed in 2013, has been superseded by the Reef 2050 Plan, which includes a specific theme on biodiversity including targets and outcomes to improve and reduce the pressures. In addition, the Reef Blueprint[24], recommends approaches for better reef management into the future. It emphasises adapting to climate change and promoting actions through a resilience network of areas, to supporting resilience and recovery following disturbances. Although the Reef Blueprint is still in its infancy, some stakeholders question the validity of its approach, especially given the widespread extent

BOX 13

Crown-of-thorns starfish control program

The goal of the Marine Park Authority's crown-of-thorns starfish control program is to protect coral from starfish predation on high-value reefs in the Marine Park. This is achieved by culling starfish to bring their numbers down to ecologically sustainable levels for coral growth and recovery.

The management objectives of the control program progress through different stages (prevention, suppression, containment and protection) as the dynamics of the outbreak progress over time (Figure 7.4). In 2018, the secondary outbreaks that began in 2010 were well underway, and the control program continued to focus on the protection of coral at high-value sites in the Marine Park. Recent research has shown the crown-of-thorns starfish control program to be effective in reducing starfish numbers and improving hard coral cover at sites where culling is regularly carried out.[758,1380]

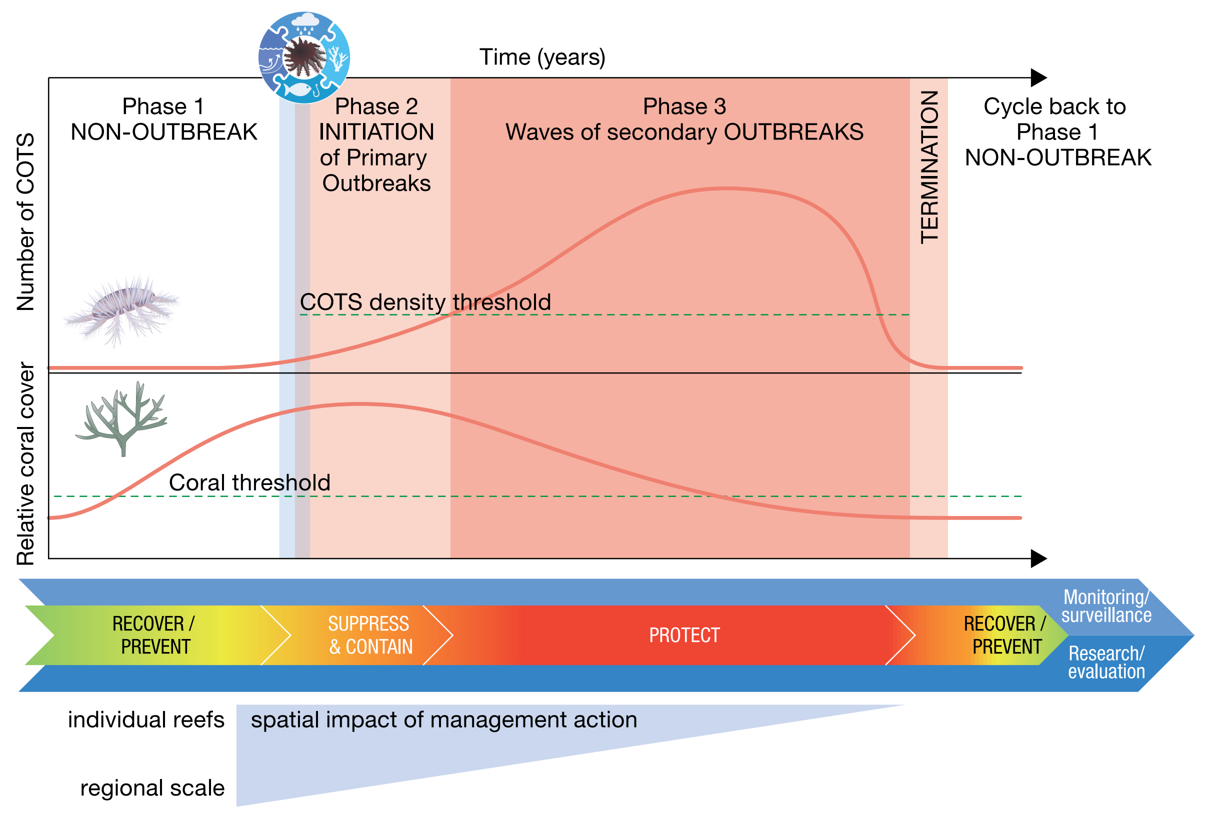


Figure 7.4 Crown-of-thorns starfish (COTS) outbreak cycle and the associated stages of management action
Outbreak management actions for the current outbreak are in the phase 3 protect stage, with the outbreak likely to approach termination in the next few years. Source: GBRMPA (unpublished)[1381]

of coral bleaching across the Region, and the limited dispersal capacity of coral larvae. Others assert it would be a mistake not to pursue this approach and related initiatives, such as the Reef Restoration and Adaptation Program.

Various initiatives have considerably improved the availability and accessibility of relevant Traditional Owner knowledge to managers. Examples include the Indigenous ranger programs and strengthened communications between managers and Indigenous people through the Land and Sea Country Partnership Program.

Major risks and threats to biodiversity protection are well documented and risk assessment and management procedures are in place. Vulnerability assessments specify risks to biodiversity values and recommend mitigation measures. However, the rate at which the system is changing following disturbances makes biodiversity protection a challenge. Managers have little capacity to track the biodiversity outputs and outcomes resulting from management actions in this area.

Culling vessel operations are guided by science and scouting surveys undertaken by cull vessels and the Reef Joint Field Management Program. Outcomes are measured by comparing coral cover and starfish densities at high-value target reefs before culling begins, and then monitoring over time to ensure culling efforts do not cease until starfish densities fall below a threshold needed to support coral recovery.

John Brewer Reef, one of the high value sites prioritised for culling, located 70 kilometres offshore from Townsville, is an important reef for recreational fishing and diving. During the first survey in November 2018, the reef was experiencing a severe outbreak with an average of 3.5 starfish counted per survey (Figure 7.5). Intensive culling operations at this reef began following the initial survey, and over several months a team of trained divers culled more than 20,000 starfish to bring starfish numbers down to levels that minimise their impact on corals. In March 2019, another round of surveys revealed that culling had reduced the severity of the outbreak, with an average of 0.35 starfish counted per survey (Figure 7.5). Hard coral cover was maintained at an average of 31–42 per cent throughout intensive culling operations. This high-value reef will continue to be visited by the control program vessels to further reduce starfish numbers and protect coral.

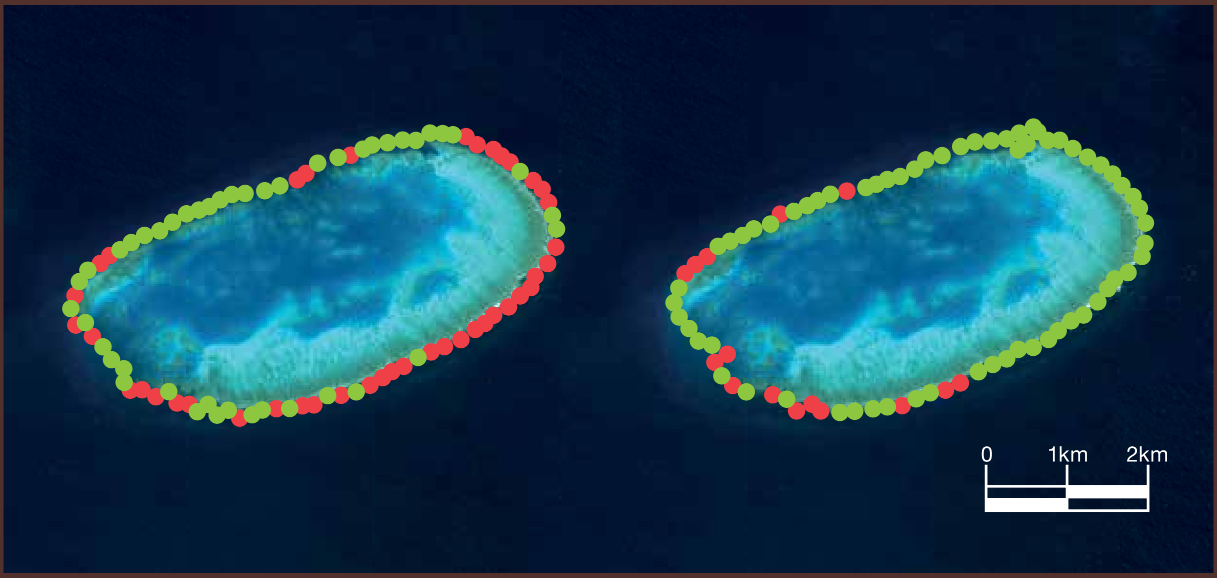


Figure 7.5 Survey data showing progress in COTS control at John Brewer Reef
Each dot represents a two-minute manta tow survey. Green dots indicate surveys where no crown-of-thorns starfish were counted, and red dots indicate they were observed. Left: Initial surveys undertaken November 2018 around the perimeter of John Brewer Reef indicate the reef was in severe outbreak mode, with an average of 3.5 crown-of-thorns starfish per survey. Right: Surveys, repeated in March 2019 during intensive culling, indicated that the reef had shifted from severe outbreak to established outbreak status, with an average of 0.35 crown-of-thorns starfish per survey. Source: GBRMPA Eye on the Reef (unpublished)[735]

7.3.13 Heritage values

In this assessment, the topic of heritage encompasses Indigenous, historic and other heritage values (aesthetic, social and scientific) as set out in Chapter 4. Commonwealth heritage values as well as the Region's world and national heritage value (not including natural heritage values) are also included in the assessment. The effectiveness of measures to protect and manage natural heritage values (an element of world heritage) is considered in the assessment of management to protect biodiversity value (Section 7.3.12) and further set out in Chapters 2 and 3.

Recognition of the Region's heritage value has improved over the last four years, especially in relation to Indigenous heritage values. The 2015 Great Barrier Reef Intergovernmental Agreement includes a commitment to *'ensure that Indigenous traditional cultural practices continue to be recognised in the conservation and management of the Great Barrier Reef'.*[938]

Recognition of the heritage values of the Region has improved over the last four years

The Reef 2050 Plan includes a dedicated heritage theme with associated targets, objectives and actions. This has stimulated further heritage planning and increased engagement of Traditional Owners in protection and management of the Reef. The 2019 *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park*[803] sets out outcomes, objectives and actions for gaining more information and protecting and managing the Region's Indigenous heritage value. There was extensive engagement with more than 20 Traditional Owner groups during its development phase, as well as a program of public consultation.

There is concern that some places of special cultural importance, as well as Indigenous structures, technology, tools and archaeology, have not been systematically identified, and some are deteriorating. Knowledge of Indigenous heritage is held by the Traditional Owners, who decide what knowledge should be shared. In some places, initiatives, such as the Traditional Use of Marine Resources Agreements and Indigenous Land and Sea Ranger programs are helping more Traditional Owners access their sea country and pass on knowledge from Elders to younger people. A good example of Traditional Owner-approved knowledge gathering, storage and application is demonstrated by the Woppaburra Guidelines. The guidelines, adopted in July 2017, map important Indigenous heritage values in the Keppel islands region, which informs permit assessments. Traditional Owners can also use the values mapping for other purposes.

Traditional Owner groups have expressed concern that they are not yet fully recognised as partners in management and that some cultural sites are deteriorating

Planning for Indigenous heritage in the Region is very complex, involving an array of broad and site-specific plans for marine environments and islands. Plans are improving in their recognition of the central role and rights of Indigenous people, but often actions are not specific and lack deadlines. As with other matters, separating heritage plans for state-owned islands and coastal areas from the adjacent reefs makes little sense to Traditional Owners or the public, especially within the World Heritage Area. Traditional Owners have proposed that more Sea Plans or Land and Sea Plans covering traditional sea country should be produced to specifically focus on Indigenous matters across tenures or ownership.[1369]

Reef Joint Field Management Program annual business plans now recognise Indigenous engagement as a standalone high-level strategy with specific targets, performance indicators and activities that promote Indigenous partnerships in heritage management. The program focuses on the implementation and field delivery of agreements, and mentoring, training and empowering Land and Sea Rangers and Indigenous Compliance Officers. It is responsible for protecting both Indigenous and historic heritage values, including story places and other locations of ceremonial and spiritual significance, on island national parks and Commonwealth islands. Protection is typically achieved through education or by enforcing compliance with legislation. If active maintenance or restoration works are necessary, they are undertaken in partnership with Aboriginal and Torres Strait Islander people.

Involvement of Traditional Owners in field management has increased and is yielding benefits in terms of cross-cultural awareness, as well as being of benefit to conservation. However, there is still more work to do. In recent years, Traditional Owners have expressed concern that they are not yet fully recognised as partners in management and that some cultural sites are deteriorating.

Knowledge of the Region's historic heritage remains patchy. The five Commonwealth listed heritage places and six priority shipwrecks are thoroughly understood, but less is known of the remaining shipwrecks and aircraft wrecks in the Region. It is

Dent Island lightstation is on the Commonwealth Heritage List; it includes a lighthouse (foreground), accommodation (background) and other structures. © GBRMPA 2018 not clear to what extent historical knowledge, such as of the history of conservation and science in the Region, has been documented. The Marine Park Authority has developed a heritage register that will capture all values for each of the Commonwealth Heritage–listed places within the Marine Park. The Australian National Shipwreck Database, established under the *Historic Shipwrecks Act 1976* (Cth), documents known historic shipwrecks, aircraft and maritime heritage sites in Australian waters. The Marine Park Authority's historic heritage guidelines consider three components of the Region: World War II features and sites; historic voyages and shipwrecks; and other places of historic significance.

Since 2015, legislative changes to the Marine Park regulations have increased the ability to protect underwater archaeological sites. Since that time, two Catalina aeroplane wrecks dating from World War II have been protected under a Maritime Cultural Heritage Protection Special Management Area. In 2018, the *Underwater Cultural Heritage Act 2018* (Cth) was passed to extend protections previously conferred to historic shipwrecks in Australian waters. The provisions will extend to historic aircraft wrecks and other forms of underwater cultural heritage in Commonwealth waters. The new Act will come into effect in mid-2019, replacing the *Historic Shipwrecks Act 1976* (Cth). This is intended to enable Australia to ratify the UNESCO Convention for the Protection of the Underwater Cultural Heritage.

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. Many of these attributes are values-based.

To understand community benefits, it is recognised that the Region is a multiple-use marine park and that people and their environment are interconnected, as reflected in the definition of the environment in the Act and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). Significant work has been undertaken over the past five years to understand the range of community benefits, and to incorporate community benefits into policy, assessment processes and decision-making guidelines. This reflects a high-level understanding by managers that the Reef provides substantial and diverse community benefits.

Community benefits are now included in many of the policy and decision-making guidelines because of the Reef 2050 Plan

Projects under the National Environmental Science Program are developing cost-effective indicators and metrics for human dimension outcomes, objectives and targets in the Reef 2050 Plan. Other projects are further investigating the aesthetic value of the Region.

Many of the issues associated with community benefits, such as population change, economic growth and climate change, are recognised as global issues and are difficult for a single planning system to encompass. The Social and Economic Long-Term Monitoring Program is helping managers understand the human dimensions of the Region and incorporate such considerations into their planning and management.[785]

Stakeholder engagement through the Reef Advisory Committees and Local Marine Advisory Committees informs management about community values and issues of concern. Volunteer programs, such as components of the Marine Monitoring Program and Eye on the Reef program, also provide avenues for community involvement in protecting the Region. The Reef Guardian program aims to engage the community in protection of the environment. The Reef Joint Field Management Program is also strongly committed to improving community understanding of values and threats to the Reef and islands, fostering responsible behaviour and providing visitor facilities. These actions help protect and maintain community benefits and connections.

7.4 Assessment of management approaches

The purpose of this section is to assess the three broad management approaches as described in Section 7.1.4; environmental regulation; engagement; and knowledge, integration and innovation. The findings are based on assessments of each of these approaches against all management topics (Section 7.3).

7.4.1 Environmental regulation

As previously reported, statutory management instruments within the Region remain contemporary and appropriate. While gaps exist in the regulation of climate change and agriculture, there is caution about the practicality of more regulation of these complex issues.[1382] The Reef 2050 Plan considers relevant existing regulation, policies and strategies across all government agencies. Some Commonwealth legislation has been reviewed to keep pace with emerging issues.

Statutory instruments within the Region remain contemporary and appropriate

The relevant Queensland legislation is not necessarily consistent between the Australian and Queensland governments, often due to differences in objectives of those governments. Some of these inconsistencies are managed through the *Environment*

Protection and Biodiversity Conservation Act 1999 (Cth) bilateral agreement between the Australian and Queensland governments. The Marine Park Authority and Queensland Government issue joint permits, and have done so for more than 20 years. Policies and processes relating to assessment and issue of permits have been reviewed, and new service level standards have been set (for example, for standard tourism permits).

The Reef 2050 Plan strengthens a number of policies, in particular, Indigenous engagement in ecosystem management, enhancing ecosystem resilience, biodiversity assessment and the protection of species and habitats considered to be of conservation concern. It also encourages increased consideration of cumulative impacts and community benefits.

Compliance systems are very sophisticated and focus on issues of risk to the Region

Zoning plans and dedicated fisheries management have been very effective for managing activities, such as fishing, resulting in higher biomass of targeted species in no-fishing zones compared with fished areas. The three plans of management complement the Zoning Plan and address issues in high-use and sensitive areas. The Whitsundays Plan of Management was updated in 2017. However, the Cairns Area Plan of Management has not been updated since 2008 and the Hinchinbrook Plan of Management has not been updated since 2004. The protection offered to the Marine Park through plans of management and zoning plans has not reduced impacts from global warming, as demonstrated by the two coral bleaching events in 2016 and 2017.

Compliance systems are very sophisticated and focus on issues of risk to the Region, such as illegal fishing. The *Queensland Sustainable Fisheries Strategy 2017–2027* requires all commercial fishing vessels (including dories) to be fitted with vessel tracking units by 2020, with a priority for net, line and crab vessels fitted by 1 January 2019. Illegal recreational fishing remains a concern and the number of incidents continues to increase. This is probably a combination of both increased illegal fishing and more effective detection of incidents. Additional Commonwealth funding announced in 2018 for the Reef Joint Field Management Program will further strengthen compliance activities within the Region.

A number of Commonwealth and Queensland policies, strategies, position statements and guidelines were prepared or updated in the lead-up to the 2019 Outlook Report. However, some have not been actively updated or fully implemented (for example, the Recreation Management Strategy[1007] and the Biodiversity Conservation Strategy[1379]). Of concern is the Marine Park Authority's Climate Change Adaptation Strategy and Action Plan 2012–2017[1370] which has not been re-funded or updated. Some of the policies and strategies would benefit from more outcome-oriented targets, with clear objectives, actions and milestones. To a limited extent, the Reef 2050 Plan has overtaken some of these strategies as an overarching plan for the Region and the 2018 review of the plan has increased focus on climate change.

7.4.2 Engagement

The 2015 Great Barrier Reef Intergovernmental Agreement between the Australian and Queensland governments[938] articulates joint management arrangements for the Region. It has been in place for over 40 years and was updated in 2015 to incorporate the Reef 2050 Plan. Positive engagement and collaboration between government agencies, partners and stakeholders has been encouraged and mandated through the Reef 2050 Plan.

Governance arrangements for the Region have become much more complex

The Reef Joint Field Management Program works well for cooperative engagement between the two levels of government (Commonwealth and Queensland) and requires each government to develop priorities for activities and allocation of funding. Adequate resourcing to enable staff to undertake required management remains a major concern despite record funding to address issues, such as water quality, crown-of-thorns starfish outbreaks and in the Reef Joint Field Management Program. The *Reef 2050 Investment Framework*[10], released in 2016, recognised a substantial funding gap of between $143 million and $408 million. Since then both governments have committed large amounts of new money to the Reef, exceeding the gap identified in the Investment Framework.

Engaging Traditional Owners as partners in the Region remains vital. This occurs through internal mechanisms in the Traditional Use of Marine Resources Agreement program, various Reef management initiatives and under the Reef 2050 Plan (for example, Traditional Owner advisory groups). The number of Traditional Owners gaining access to their sea country through the Reef Joint Field Management Program vessels has increased significantly since 2014. This has many benefits, including informal training of non-Indigenous staff in Indigenous culture, increasing management involvement of Traditional Owners and maintaining their connection to country.

Research collaboration between managing agencies and researchers is generally positive, although some researchers reported that engagement of Marine Park Authority staff in planning for research and monitoring had declined in recent times. The basis for this view was unclear, but may be due to the transition of senior staff from the Marine Park Authority or the perceived withdrawal of the Marine Park Authority from research and monitoring. It may also be a product of the Commonwealth Department of the Environment and Energy becoming more prominent through research funding programs (for example, the National Environmental Science Program) and policy matters in the Region.

Although the issues are outside its areas of responsibility, the Marine Park Authority was also perceived by stakeholders to have a diminished voice regarding land-based run-off and coastal development. Governance arrangements for the World Heritage Area have become more complex and 11 high-risk areas of governance were identified as requiring transformational change to address declining outcomes in the Region.[1383] Disengagement by the Marine Park Authority and other management agencies around factors that influence, but fall outside the formal mandates for management of, the Region is likely to heighten risks to the Reef.

One of the strongest aspects of management involves partnership and stewardship arrangements, such as Reef Guardians, Reef 2050 WQIP and the Eye on the Reef program. The Reef 2050 WQIP, for instance, depends on forming partnerships with NRM bodies, industry bodies and local governments and, through them, with land managers. The partnerships and stewardship programs are underpinned by long-standing consultation arrangements with key sectors and regions via the Marine Park Authority's Reef Advisory Committees and Local Marine Advisory Committees. In addition, face-to-face engagement through community access points (such as local businesses and fishing stores) and management presence at shows, events and meetings strengthens engagement, education and partnerships. Advisory bodies have also been established under the Reef 2050 Plan to provide independent expert advice and stakeholder views in relation to the plan's implementation.

7.4.3 Knowledge, innovation and integration

Research and monitoring Strong partnerships with managing agencies and research providers (CSIRO, Australian Institute of Marine Science and universities) have become more targeted as key knowledge gaps have been identified through the Outlook Report process, strategic assessments and Scientific Consensus Statements. Managing agencies and researchers have initiated programs and projects to fill these knowledge gaps, including Reef 2050 WQIP, Reef Blueprint for Resilience[24], aerial surveys of coral bleaching in 2016 and 2017, and the Marine Park Authority's Science Strategy and Information Needs[6]. However, the coral bleaching events in 2016 and 2017 have meant that knowledge of current condition and trends for many species and ecosystems has declined and it will take time to update this knowledge.

Despite extensive research and monitoring in the Region, up-to-date knowledge of ecosystem and socio-economic condition is struggling to keep pace with disturbances

The Australian Institute of Marine Science's long-term monitoring program represents the longest continuous record of change in Reef communities in the Region and has provided data critical to understanding the condition and trend of the Reef. The Social and Economic Long-Term Monitoring Program recognises the inter-dependencies of people within the Region and contributes to long-term planning and evaluation of management decisions. These programs demonstrate the value of maintaining consistent monitoring over a large area for an extended period of time.

The development of the Reef 2050 Integrated Monitoring and Reporting Program (RIMReP) may help to address some of the deficiencies in past monitoring efforts, especially in relation to cumulative impacts.

Reporting and evaluation The five-yearly Outlook Report provides the most comprehensive and regular basis for evaluation and reporting on the condition and management of the Region. The Reef 2050 Plan provides an overarching strategy for the management of the Region, including clear monitoring and reporting requirements. The development of the RIMReP is a positive initiative that will help to address some of the deficiencies in past monitoring efforts. This applies especially to monitoring cumulative impacts and overall ecosystem health to inform assessment of the Reef 2050 Plan. However, RIMReP has been very slow to develop with only very modest progress made over the past two years.

The Paddock to Reef program and its associated annual Reef report cards have been continually improved to provide a succinct snapshot of improvements and changes in land management practices, Catchment indicators (ground cover, riparian extent and wetland extend and condition), Catchment water quality (sediment, nutrients and pesticides) and the health of the inshore ecosystems. Apart from RIMReP, the reporting and evaluation frameworks for the management of the Region are generally on track.

7.5 Assessment summary — Existing protection and management

Paragraph 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.

Paragraph 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 five independent, expert assessors based on the six elements of the management cycle:

- 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

Grading statements — understanding of context				Trend since last report
🟩	🟨	🟧	🟥	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend
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.	

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Understanding of context**
🟩	🟩 ↑	🟨 ↓	Context is assessed as the strongest management effectiveness element in 2019. Across most management topics this element was mostly stable or improving. However, context has declined for biodiversity and traditional use of marine resources. Understanding of values, direct and indirect threats and stakeholders is generally strong. Some aspects of biodiversity, ecosystem health and environmental conditions are less understood as a consequence of the bleaching events and other cumulative pressures, such as cyclones and crown-of-thorns starfish predation. Tourism, defence activities, ports, recreation, research activities, shipping 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 in the Region.

7.5.2 Planning

Grading statements — planning				Trend since last report
🟩	🟨	🟧	🟥	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend
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 are 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.	

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Planning**
🟨	🟨 ↔	🟨 ↔	Significant efforts have been made in planning for a number of topics, such as ports, fishing, research activities, shipping and coastal development. However, planning effectiveness has continued to decline for climate change measures specific to the Region, principally as a result of defunding, changing policy and a lack of clarity about future directions. Planning has also declined for recreation largely because plans have not been reviewed since 2014. The lack of systems to ensure adequate monitoring is the weakest aspect of planning overall.

7.5.3 Financial, staffing and information inputs

Grading statements — financial, staffing and information inputs				Trend since last report
🟩	🟩	🟧	🟥	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend
Very good Financial and staffing resources are largely adequate to meet management needs. Biophysical, socio-economic and Traditional Owner knowledge is available to inform management decision-making.	**Good** Financial and staffing resources are mostly adequate to meet management needs. Biophysical, socio-economic and Traditional Owner knowledge is mostly available to inform management decision-making although there may be deficiencies in some areas.	**Poor** Financial and staffing resources are unable to meet management needs in some important thematic areas. Biophysical, socio-economic and Traditional Owner knowledge is variably available to inform management decision-making and there are significant deficiencies in some areas.	**Very poor** Financial and staffing resources are unable to meet management needs in many thematic areas. Biophysical, socio-economic and Traditional Owner knowledge to support decision-making is frequently deficient in some areas.	

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Financial, staffing and information inputs**
🟧	🟧 ↔	🟩 ↑	Adequacy of inputs is variable across management topics, being least effective for climate change. Most topics did not adequately understand and apply Indigenous heritage and historic heritage information inputs. Resourcing has significantly increased for many areas of Reef management, through the Reef 2050 Plan and associated investment strategy. The Reef Joint Field Management Program and the Marine Park Authority have received significant stabilisation funding. The Queensland Government has also provided significant funding through the Office of the Great Barrier Reef. Staff inputs have been variable since 2014 across both governments, with injections in some places (biodiversity and community benefits) and reductions in others (climate change and coastal ecosystems).

7.5.4 Management systems and processes

Grading statements — management systems and processes				Trend since last report
🟩	🟩	🟧	🟥	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend
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.	

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Management systems and processes**
🟩	🟩 ↓	🟩 ↔	Management processes are particularly strong for defence activities, shipping, research activities and management of land-based run-off. They are weakest for climate change. Stakeholder and community engagement and application of biophysical information are the strongest aspects of management across all topics. Governance is generally strong, except for climate change. The application of socio-economic and heritage knowledge, and setting of targets to benchmark performance are problematic for many topics, but processes are generally stable to improving.

7.5.5 Delivery of outputs

Grading statements — delivery of outputs

🟩 **Very good**	🟩 **Good**	🟧 **Poor**	🟥 **Very poor**
Management programs are mostly progressing in accordance with planned programs and are achieving their desired objectives. Managing agency and community knowledge base is improving.	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 agency and community knowledge base is generally improving.	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.	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.

Trend since last report

↑ Improved
↔ Stable
↓ Deteriorated
— No consistent trend

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Delivery of outputs**
🟩	🟩 ↔	🟩 ↔	Delivery of desired outputs was rated as effective or mostly effective for all topics except climate change and recreation. It is strongest for commercial marine tourism, defence activities, research activities and traditional use of marine resources. 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.

7.5.6 Achievement of outcomes

Grading statements — achievement of outcomes

🟩 **Very good**	🟩 **Good**	🟧 **Poor**	🟥 **Very poor**
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.	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.	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.	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.

Trend since last report

↑ Improved
↔ Stable
↓ Deteriorated
— No consistent trend

Grade and trend			Criterion summary
2009	**2014**	**2019**	**Achievement of outcomes**
🟧	🟧 ↓	🟩 ↑	Achievement of desired outcomes is highly variable across the management topics. Objectives are being achieved in relation to community understanding of issues and development of effective partnerships. Overall, performance is strong, particularly for research activities, shipping, ports, commercial marine tourism and defence activities. Performance is weakest for climate change and the management of climate change is ineffective. Biodiversity outcomes have declined markedly, principally as a result of cumulative impacts and bleaching events in 2016 and 2017.

7.6 Overall summary of existing protection and management

Effective management of the Region remains a complex task given local, regional and global threats. The effectiveness of existing measures to protect and manage the Region's ecosystem (natural heritage value) and its heritage value (Indigenous, historic and others) was independently assessed for 14 broad management topics. The activities of all relevant Australian and Queensland government agencies that perform Reef management and other contributing partners were evaluated for six elements of the management cycle: context, planning, inputs, processes, outputs and outcomes.

Improvements within management topics are most notable for ports, heritage values and fishing

The assessment concluded that the Region continues to be managed effectively in most areas of activity (Table 7.4). Since the independent assessment for the 2014 Outlook Report, considerable improvements have been made in parts of the management cycle for a number of management topics.

For example, the elements of context, planning and outputs have improved for coastal development through the introduction of the *Planning Act 2016* (Qld) and associated legislation, which established ecological sustainability as a core principle and reinstated coastal land surrender provisions.

The Reef 2050 Plan has improved jurisdictional consistency, coordination and resourcing across many management topics

Many of the improvements in management effectiveness are a result of the Reef 2050 Plan, which has improved jurisdictional consistency and coordinated a range of actions, targets and objectives to address the key threats to the Region. A number of assessment processes, policies and guidelines have incorporated understanding and consideration of cumulative impacts, such as on community benefits.

Planning systems for ports and fishing have received the most profound reforms under the Reef 2050 Plan. While only in the early stages of implementation, effective outcomes are already being seen for ports. For example, the management effectiveness elements of outputs and outcomes have improved for ports following improvements in planning, and in understanding the values, threats and opportunities available. Implementation and resourcing of the Sustainable Fisheries Strategy are expected to improve the management effectiveness of fishing over the next five years. This may have flow-on benefits to biodiversity and heritage values.

Stakeholder engagement remains a strong theme across most management topics. Significant work has also been undertaken to better recognise and embed less tangible values (such as community benefits and heritage) into management systems.

Management effectiveness remains strongest for topics of limited scale or complexity. For example, defence activities, research activities and shipping are managed effectively and improving across most indicators.

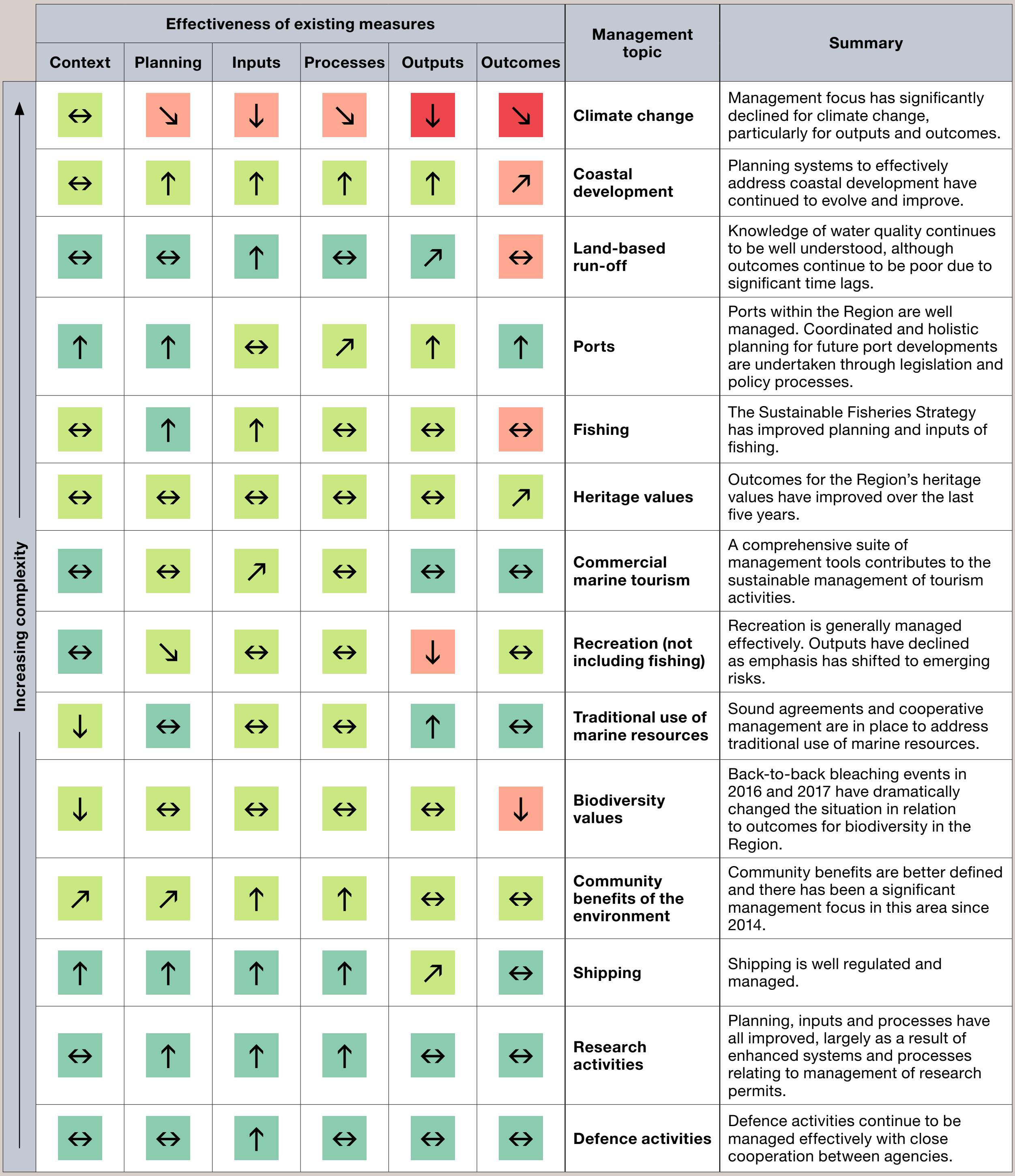
Achieving outcomes on the ground continues to be difficult for complex and spatially broad topics, such as climate change, land-based run-off and biodiversity

Management effectiveness challenges remain evident for broadscale, complex topics, such as biodiversity, climate change, fishing and coastal development, and achieving outcomes on the ground continues to be difficult. For example, while some targeted actions have locally reduced sediment and nutrient loads entering the Reef lagoon, Reef 2050 WQIP targets are unlikely to be achieved within the stated timeframes. With improved land management practices relying on voluntary uptake (and affecting a relatively small area of the Catchment), change is slow. Further, there are significant time lags between actions on the ground and observable improvements in water quality.

The extensive coral bleaching episodes in 2016 and 2017 highlight the vulnerability of the system, and the need to actively address climate change. These bleaching events have dramatically changed the situation in relation to management of biodiversity in the Region.

Table 7.4 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 only relates to management measures undertaken specifically to protect and manage the Reef. The degree of complexity shown in the first column is based on the analysis provided in Table 7.2.



Increasing complexity ↑

Effectiveness of existing measures						Management topic	Summary
Context	Planning	Inputs	Processes	Outputs	Outcomes		
🟨 ↔	🟧 ↘	🟧 ↓	🟧 ↘	🟥 ↓	🟥 ↘	**Climate change**	Management focus has significantly declined for climate change, particularly for outputs and outcomes.
🟨 ↔	🟨 ↑	🟨 ↑	🟨 ↑	🟨 ↑	🟧 ↗	**Coastal development**	Planning systems to effectively address coastal development have continued to evolve and improve.
🟩 ↔	🟩 ↔	🟩 ↑	🟩 ↔	🟩 ↗	🟧 ↔	**Land-based run-off**	Knowledge of water quality continues to be well understood, although outcomes continue to be poor due to significant time lags.
🟩 ↑	🟩 ↑	🟨 ↔	🟨 ↗	🟨 ↑	🟩 ↑	**Ports**	Ports within the Region are well managed. Coordinated and holistic planning for future port developments are undertaken through legislation and policy processes.
🟨 ↔	🟩 ↑	🟨 ↑	🟨 ↔	🟨 ↔	🟧 ↔	**Fishing**	The Sustainable Fisheries Strategy has improved planning and inputs of fishing.
🟨 ↔	🟨 ↔	🟨 ↔	🟨 ↔	🟨 ↔	🟨 ↗	**Heritage values**	Outcomes for the Region's heritage values have improved over the last five years.
🟩 ↔	🟨 ↔	🟨 ↗	🟨 ↔	🟩 ↔	🟩 ↔	**Commercial marine tourism**	A comprehensive suite of management tools contributes to the sustainable management of tourism activities.
🟩 ↔	🟨 ↘	🟨 ↔	🟨 ↔	🟧 ↓	🟨 ↔	**Recreation (not including fishing)**	Recreation is generally managed effectively. Outputs have declined as emphasis has shifted to emerging risks.
🟨 ↓	🟩 ↔	🟨 ↔	🟨 ↔	🟩 ↑	🟩 ↔	**Traditional use of marine resources**	Sound agreements and cooperative management are in place to address traditional use of marine resources.
🟨 ↓	🟨 ↔	🟨 ↔	🟨 ↔	🟨 ↔	🟧 ↓	**Biodiversity values**	Back-to-back bleaching events in 2016 and 2017 have dramatically changed the situation in relation to outcomes for biodiversity in the Region.
🟨 ↗	🟨 ↗	🟨 ↑	🟨 ↑	🟨 ↔	🟨 ↔	**Community benefits of the environment**	Community benefits are better defined and there has been a significant management focus in this area since 2014.
🟩 ↑	🟩 ↑	🟩 ↑	🟩 ↑	🟨 ↗	🟩 ↔	**Shipping**	Shipping is well regulated and managed.
🟩 ↔	🟩 ↑	🟩 ↑	🟩 ↑	🟩 ↔	🟩 ↔	**Research activities**	Planning, inputs and processes have all improved, largely as a result of enhanced systems and processes relating to management of research permits.
🟩 ↔	🟩 ↔	🟩 ↑	🟩 ↔	🟩 ↔	🟩 ↔	**Defence activities**	Defence activities continue to be managed effectively with close cooperation between agencies.

Grading statements

🟩 **Very good** The grading statements for each of the assessment criteria are provided in Section 7.5.1 to 7.5.6.

🟨 **Good** The grading statements for each of the assessment criteria are provided in Section 7.5.1 to 7.5.6.

🟧 **Poor** The grading statements for each of the assessment criteria are provided in Section 7.5.1 to 7.5.6.

🟥 **Very poor** The grading statements for each of the assessment criteria are provided in Section 7.5.1 to 7.5.6.

Trend since last report

↑ Improved, grade changed
↗ Improved within same grade
↔ Stable
↘ Deteriorated within same grade
↓ Deteriorated, grade changed

CHAPTER 8

RESILIENCE

« *Healthy coral reefs are resilient and support diverse communities of living things.* © Matt Curnock 2017

RESILIENCE

‘an assessment of the current resilience of the ecosystem …’ within the Great Barrier Reef Region, s 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, paragraph 116A(2)(c) of the *Great Barrier Reef Marine Park Regulations 1983*

8.1 Background

Resilience, in the broadest sense, is the capacity of a system to absorb disturbance and reorganise so as to retain essentially the same structure, function, identity and feedback systems.[1384] Resilience cannot be measured directly — assessing the resilience of a system depends on how well it responds to, withstands, adapts and recovers from disturbances.[1385] Climate change is by far the strongest driver of change in the Region.[1201] Recurrent temperature extremes are increasing in both severity and frequency, threatening to overwhelm the Region’s resilience by reducing its ability to withstand and recover from these adverse events.[99] While local management cannot prevent large-scale disturbances, such as coral bleaching, understanding how resilient a system is (and the elements that define that system) can help to identify its level of risk and potential resilience-based management actions to promote resistance and recovery.[1386]

The Region is a social-ecological system, with people, species and habitats interlinked. Therefore, the resilience of both human and ecological communities is critical for its long-term sustainability.[1387] A resilient system is characterised by processes that reinforce the current state and thereby reduce the likelihood that it will shift to a less desirable state.[1388] Critical processes that support resilience may include the ecological process of herbivory (Section 3.4.4) — reducing the abundance of macroalgae in a coral-dominated system, thereby reinforcing coral dominance. Or, from a social perspective, it might involve a tourism operator having a diverse business model in place that allows them to offer a range of alternative nature-based tourism options, while a particular tour site recovers from a disturbance (for example, cyclone damage).

Maintaining or promoting system integrity can be one way of strengthening resilience. Coral reefs have been estimated to reduce wave energy by up to 97 per cent[87], highlighting their importance in coastal protection. Coastal and island communities may also increase their resilience to cyclone and storm events by conserving wetlands and island vegetation, which stabilises islands and coastlines.[430] Maintaining a resilient system is a primary management goal, which requires a detailed understanding of the dynamics of complex and highly variable interconnected systems.[1389] While the aim of resilience-based management is to maintain essential functions (functional resilience) and avoid shifts to less desirable states, the exact nature of critical thresholds and whether a system is approaching a threshold are largely unknown, due to complexities within the social and ecological systems.

The assessment is based on:

- ecosystem resilience (natural heritage value)
- heritage resilience (Indigenous and historic heritage value).

8.2 Ecosystem resilience

Now, more than ever before, it is critical that everything possible is done to minimise the rate of climate change, otherwise resilience-based management will be limited in what it can achieve

A resilient ecosystem is able to return to its pre-disturbance state, as long as the right combination of functions and processes are maintained, and given sufficient recovery time.[1384,1390] Determining how resilient a system is before a disturbance occurs is a key challenge, particularly where chronic drivers, like climate change, have gradually caused an ecosystem to shift. In some cases, biodiversity of a system was used as a crude proxy for ecosystem resilience, in part because the greater the number of species performing similar functions, the greater the potential for functional redundancy — if one species declines another species can take its place, maintaining ecosystem function (Section 3.4.4 Figure 3.8).[1391,1392,1393] While many functions contribute to the overall resilience of the system, some are more important than others. Ecosystem functions and processes that confer greater resilience include high connectivity among sites and adequate recruitment.[601,618,1394,1395] In 2009, the Reef's overall resilience was assessed as good, but it was being reduced by threats from climate change, coastal development, catchment runoff and some aspects of fishing.[1] In 2014, overall resilience was assessed as poor and since that time many critical ecological processes have continued to deteriorate (Chapter 3).

It is more cost-effective to prevent ecosystem impacts than restore ecosystems

A resilience-based management approach highlights the importance of maintaining key species and habitats, supporting key processes, and reducing drivers that cause pressures on the system.[24] As climate change impacts become more frequent and severe, a resilience-based management approach will become more important. It is also critical that everything possible is done to minimise future increases in climate change impacts, otherwise resilience-based management will become limited in what it can achieve.[24,1396]

The long-term rise in average and extreme temperatures is one of the most persistent stressors, and is affecting survivorship of species and having destabilising effects on many processes, such as symbiosis, recruitment, and connectivity. Years marked by hotter than average sea surface temperatures have become more frequent in the Region, particularly in the past 40 years (Figure 8.1). Increasing sea surface temperatures can delay recovery of vulnerable species and habitats from disturbances, such as cyclones and flood events. Limiting future warming would substantially reduce risks to marine biodiversity, ecosystems and the services provided to humans.[1141]

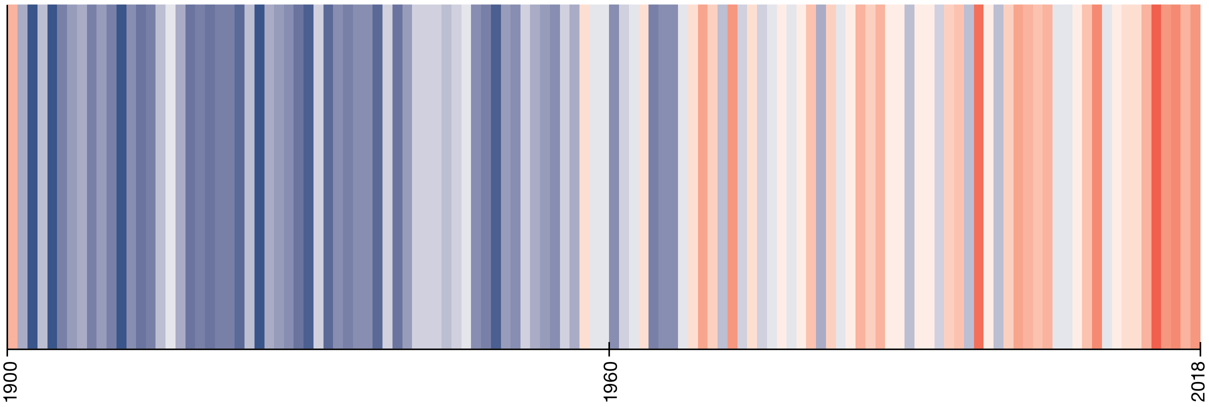


Figure 8.1 Annual sea surface temperatures on the Great Barrier Reef between 1900 and 2018
The colour of each stripe represents the annual mean sea surface temperature anomaly of a single year ordered from the earliest available data. The colour scale ranges from colder than average temperatures (shades of blue) to warmer than average temperatures (shades of red). If there was no trend of global warming, the colour pattern of bars would appear random.
Source: Adapted from Hawkins 2018[1397] reflecting data from the Australian Bureau of Meteorology

8.3 Case studies of recovery and decline in the ecosystem

The capacity of a system to recover after disturbance is a critical attribute of a resilient system. In the 2009 and 2014 Outlook Reports, signs of ecosystem resilience were examined through a series of case studies assessing recovery of natural heritage values after disturbance. These case studies were selected because they represented a range of species, habitats and processes and many had long-term datasets. These same case studies were also assessed for the 2019 Outlook Report.

The series of case studies below illustrate the extent to which some natural heritage values of the ecosystem have recovered or declined following disturbance. The aspects of resilience focused on in each case study include:

- the extent to which some key habitats and species have responded after human and natural disturbances — coral reefs, lagoon floor and the black teat fish (sea cucumber)
- the extent to which some key ecological processes have responded after human and natural disturbances — herbivory (urban coast dugongs) and predation (coral trout)
- the effectiveness of specific management actions to address declines in specific species — loggerhead turtles.

8.3.1 Coral reef habitats

Corals have persisted for over 200 million years[1398], demonstrating remarkable resilience to past disturbances.[1399] Local disturbances (when not too frequent or severe) maintain diversity on corals reefs[428,1400] because they can prevent dominant species from becoming too abundant.[1401] However, disturbances only promote diversity when there are adequate windows to allow the system to reassemble and recover. Chronic drivers, such as continual water pollution, have persistent effects on the environment, whereas acute disturbances, such as a single storm or bleaching event, are short-term events. Disturbances that affect coral reefs are becoming more prevalent and widespread, diminishing the recovery potential of coral communities.[99,219,501,1303] In the 1980s, the average return time between pairs of recurrent bleaching events throughout the tropics was 25 years, compared to about six years since 2010.[99] Since 1996, coral cover has declined on 90 per cent of the reefs in the Great Barrier Reef.[1303] In 2016 and 2017, the Reef experienced its first back-to-back bleaching events which caused mass mortality of corals in shallow reef habitats. In 2018, recruitment by corals across the entire Region declined on average by 89 per cent, and by 93 per cent for *Acropora* corals (Section 3.4.7 Figure 3.11).[96]

Reef resilience is being degraded by frequent and severe disturbances

The nature of disturbances influence coral recovery trajectories, with fast recovery observed after disturbances that leave coral skeletons intact.[195,219,1303] Coral cover can re-establish in two ways after disturbance: growth of surviving coral colonies and the recruitment and growth of new corals. Recovery of coral cover depends on multiple processes that influence larval supply (including adequate broodstock, fecundity, fertilisation and connectivity), successful settlement of coral larvae (availability of stable surfaces for coral recruits to attach to), and coral growth.[96,423,601,1402] If one or more of these processes is lacking, recovery can be delayed or, in worst case scenarios, may not occur at all.[195,1403,1404] For example, Havannah Reef near Townsville shifted from a coral-dominated to an algal-dominated system in 2001 after bleaching and cyclone damage, and failed to recover to its original coral-dominated state.[594] Although Havannah Reef had an adequate supply of incoming coral larvae as at 2014, two factors prevented coral recovery: dense patches of macroalgae that exclude coral recruits, and an unstable rubble base that reduces the ability of coral larvae to settle and hold fast.[195] This highlights the importance of multiple processes for sustaining Reef resilience.

Management Reducing compounding stressors will help reefs recover from disturbances, such as cyclones and coral bleaching, but only to a limited degree.[1405] If the strongest possible action to reduce global emissions does not begin immediately, there is a high risk of exceeding a two degree Celsius global average warming and not being able to avoid a projected collapse of the Reef.[487,1141] Immediate and drastic reductions to carbon emissions to limit warming to less than 1.5 degrees Celsius will increase the likelihood that the Reef will persist into the future, although it will be different from the Reef today.[1405] Effective global action on climate change will also greatly increase the effectiveness and positive impact of management actions in the Catchment and Region.

Management approaches in place for some time remain effective (Chapter 7) and necessary to address particular local and regional threats. Zones in the Marine Park that are closed to fishing have demonstrated recovery up to 20 per cent faster after a disturbance than areas open to fishing.[756] At a more local scale, installing over 140 public moorings and over 100 reef protection markers since 2016 has increased protection of coral habitats from anchoring (Section 5.5.1). This direct measure has been critical in high-use areas, such as the Whitsunday Islands, where reefs are still recovering from cyclone damage that occurred in 2017. Additional management actions are being undertaken to reduce land-based run-off and crown-of-thorns starfish predation on corals, in an attempt to reduce stressors, maintain resilience and provide greater recovery opportunities for the Reef.[759,1406,1407]

In addition to established management actions, initiatives are being explored to enhance the resistance and recoverability of reefs to disturbances. The Great Barrier Reef Blueprint for Resilience[24] describes the 10 management approaches the Marine Park Authority and its partners should take to strengthen coral reef resilience to existing and future challenges (Chapter 7 Box 12). In 2019, the prototype of the Reef 2050 Integrated Monitoring and Reporting Program will be delivered to enable early detection of changes in the Reef's environment.[1021] As the program evolves, it will help to inform timely management responses and support resilience-based management.

Given the current condition of coral reefs (Section 2.3.5), different research and management approaches are being explored that were not contemplated in the past. Focus is increasing on attempted intervention through restoration and assisting corals to adapt faster to a warming climate.[1134,1408] Since 2018, the Australian Government has invested in the scoping and design phase for the Reef Restoration and Adaptation Program and understanding and managing potential risks. This program aims to create innovative and targeted coral reef restoration and adaptation measures to help preserve the Reef's values. Although every avenue should be explored to reduce local stressors and provide corals with the best chance to adapt, there are no substitutes for the strongest possible action on climate change.

Evidence for recovery or decline Since 2014, reefs in all regions of the Reef (northern, central and southern) were affected by a range of disturbances at different times, including freshwater flood plumes, destructive waves associated with cyclones and extreme thermal stress (Figure 8.2). As a result of these cumulative impacts, average hard coral cover has undergone a steep decline (Figure 8.3).[95] The 2016 and 2017 mass bleaching events resulted in the loss of at least 30 per cent of shallow-water corals within the Region (Section 2.3.5). The loss of coral in the

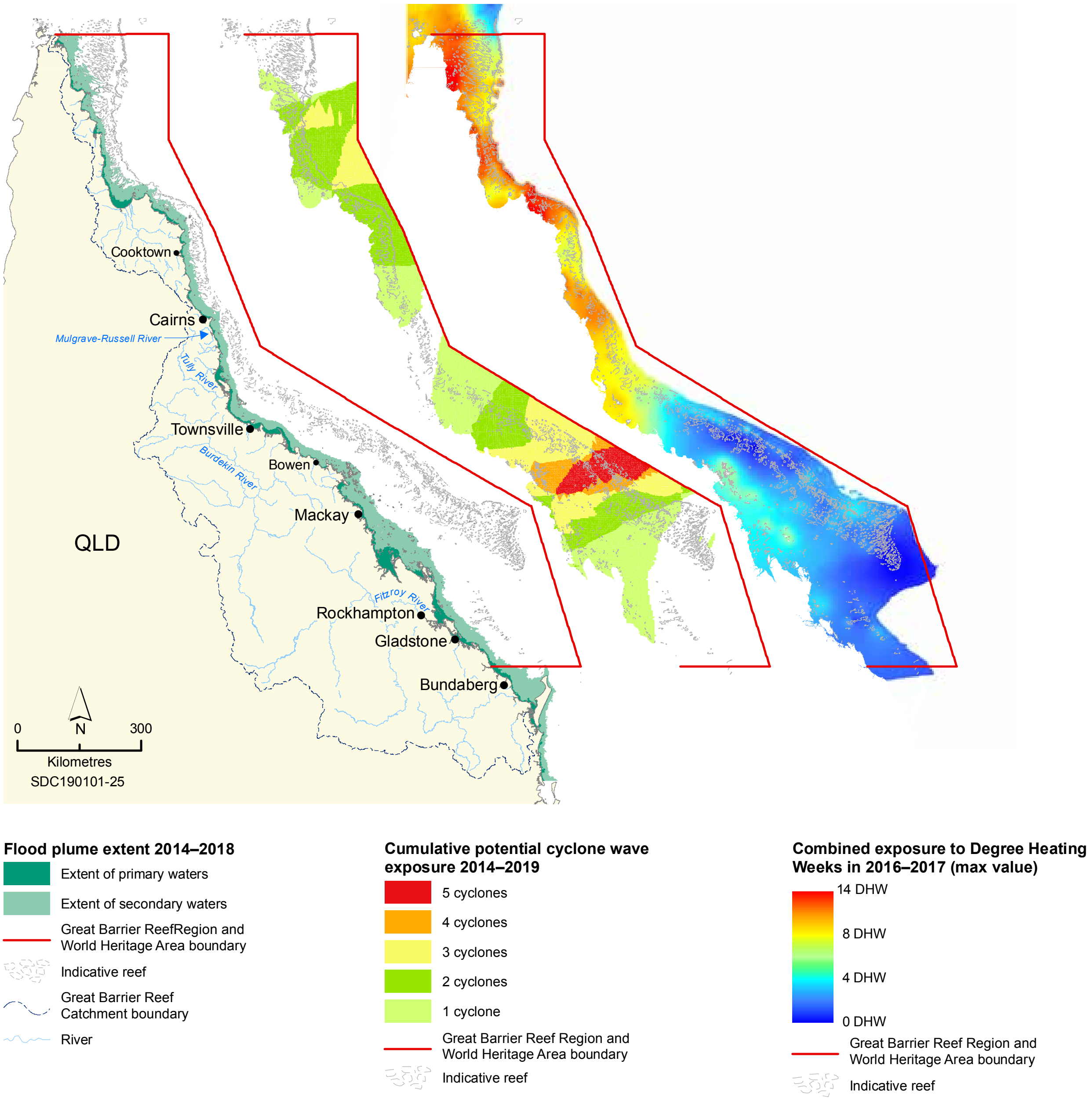


Figure 8.2 Multiple disturbances have impacted the Great Barrier Reef since 2014

The Reef has been exposed to multiple, severe disturbances that have reduced resilience.

Left map: Primary and secondary flood plumes have exposed most inshore reefs and some mid-shelf reefs to land-based run-off and freshwater between 2014 and 2018. Source: Adapted from Gruber *et al.* 2019[155]

Middle map: An estimated 68 per cent of the reef area within the Region was exposed to destructive waves (significant wave height of four metres) from one or more tropical cyclones between 2014 and 2019. Source: Adapted and updated from Poutinen *et al.* 2016[434]

Right map: Accumulated heat stress, represented as Degree Heating Weeks (DHW) due to global warming induced mass coral bleaching in the northern two-thirds of the Region in the summers of 2016 and 2017. Cumulative heat exposure is represented on the map by plotting the maximum DHW value that occurred in either 2016 or 2017 quantified at 5 kilometre resolution, using the NOAA Coral Reef Watch version 3 DHW metric. Source: Adapted from Hughes *et al.* 2019[88] and Lui *et al.* 2017[1409]

Whitsundays area as a result of cyclone Debbie is still being quantified. However, recent monitoring of inshore reefs found a substantial reduction in coral cover and juvenile corals.[193,615]

Region-wide patterns of coral decline are described below, collated from survey data collected by the Centre of Excellence for Coral Reef Studies, the Australian Institute of Marine Science and the Marine Park Authority. Overall, the survey data indicates that, as at 2018, average coral cover in the Region is among the lowest ever recorded.[95] Coral decline has been significant over the past four years, although timing of declines varied for different parts of the Region, due to the impacts of cyclones, mass bleaching and crown-of-thorns starfish outbreaks. Declines in coral cover have not been equal across the entire Region, but have exhibited a north to south gradient.[88,90,1410]

- **Northern region** (estimated 65 per cent decline in coral cover since 2013): Most coral death during the 2016 mass bleaching event occurred in the northern third of the Reef, with an average 80 per cent loss of shallow-water coral cover on inshore and mid-shelf reefs off Cape Grenville and Princess Charlotte Bay.[90,95] In addition to the 2016 mass bleaching event, reefs in this area were exposed to two severe cyclones since 2014, ongoing crown-of-thorns starfish outbreaks and a second mass bleaching event in 2017. Mean coral cover on reefs under long-term monitoring has decreased from 30 per cent in 2013 to 10 per cent in 2017, the lowest observed coral cover for these reefs in 30 years of monitoring.[95]
- **Central region** (estimated 35 per cent decline in coral cover since 2016): Although there was modest coral recovery in the central Reef in the five years following severe cyclone Yasi in 2011[432,1411], this recovery has been largely reversed by unprecedented bleaching in 2016 and 2017.[88] Offshore from Townsville, average coral cover declined from 22 per cent in 2016 to 14 per cent in 2018, due to coral bleaching and outbreaks of crown-of-thorns starfish.[95]
- **Southern region** (estimated 24 per cent decline in coral cover since 2017): Reefs in the Pompey Complex (offshore Mackay) were subjected to destructive waves from cyclone Marcia in 2015 which set back recovery from cyclone Hamish (2009). Reefs in the southern region were not exposed to extreme sea surface temperatures in 2016 or 2017, but an outbreak of crown-of-thorns starfish in 2017 on the Swain Reefs reduced mean coral cover from 33 per cent to 25 per cent. Damage due to cyclone Debbie, which affected reefs in the northern part of this region, has been assessed on six inshore reefs surveyed in 2017. An average loss of coral cover of 70 per cent at two metres depths and 64 per cent at five metres depth, has been estimated.[440] Coral cover on four reefs surveyed in the Capricorn Bunker group in 2018 is considered to be high (>40 per cent).

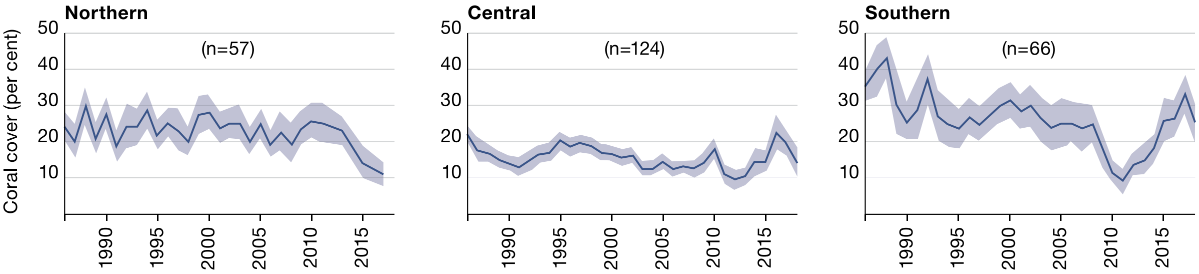


Figure 8.3 Trends in mean hard coral cover since 1986 for the northern, central and southern Reef
Coral cover trends for the northern, central and southern Great Barrier Reef are based on broadscale (manta tow) surveys up to May 2017, May 2018 and March 2018, respectively. The symbol 'n' indicates the number of reefs contributing to the analyses; shading represents 95 per cent certainty. Between eight and 69 reefs are surveyed per year, meaning that trends in hard coral cover for each part of the Region can be calculated from the pool of available reefs in a given year. Reefs used in the analyses may change from year to year. Source: Australian Institute of Marine Science 2018[95]

Importantly, the health and resilience of the Reef cannot be measured by live coral cover alone. Changes in coral community structure and larval recruitment can also indicate declining reef resilience. For example, following mass bleaching, branching and staghorn corals declined by more than 75 per cent on severely bleached reefs compared with other growth forms.[91] The substantial loss of adult coral broodstock resulted in an 89 per cent decline in coral recruitment, compared with a long-term average.[96] Because branching and tabular corals are the most common host coral for many coral-reliant Reef species, the significant loss of these growth forms has potentially severe implications for dependent fish and invertebrates.[83,211] The flow-on effects of habitat loss on reef fishes is already occurring[273] (Section 8.3.4).

Replenishment of coral habitat, and associated fish communities, will largely depend on successful recruitment and colony growth during disturbance-free periods. Historically, most coral communities recovered within 10–15 years of an acute disturbance, provided no other disturbances occurred.[1412,1413] Modelled estimates of coral recovery time in the Region since 2009 are approximately double the historical experience: 14 years for the fastest growing corals and at least 30 years for slower growing corals, with the slower recovery rate attributed to ocean warming.[219] Globally, the time between severe bleaching events across tropical reefs had decreased from once every 27 years between 1980 and 2016, to once every six years since 2010[99], and is predicted to become annual by 2050 or earlier if emissions are not drastically reduced.[1149,1414] In the Region, shorter recovery windows between disturbances limit the capacity for coral populations to recover, and increase the probability of the depletion of vulnerable coral species.[1415] This highlights the importance of local and regional management actions to reduce chronic and acute disturbances while strong global action limits the extent of future climate change.[99,487,1141,1405,1416]

Although the Reef has bounced back from many disturbances in the past, the overall trend for coral reef habitats within the Region is one of long-term decline.[141,219,755,1402] Global warming has deprived the Reef of sufficient time for many coral communities to recover between acute events. The direct impacts of further climate change (Section 6.3.2), combined with chronic stressors, will further reduce reef resilience and deplete coral-associated species.[99,141,501] Because of the increase in the frequency and intensity of disturbances, ecosystem resilience may already be on an irreversible path of decline.[96,99] These impacts have serious implications for Reef-dependent industries and community benefits.

8.3.2 Lagoon floor habitats

The lagoon floor is one of the most expansive habitats within the Region, and its condition is likely to vary spatially (Section 2.3.6). Limited monitoring of the lagoon's seabeds has been conducted since the first assessment in 2009.

Since the 2014 Outlook assessment, the lagoon floor has been exposed to various impacts and human activities. Impacts associated with climate change, bottom trawling and dredging are known to pose the greatest risks to this habitat.[109,110,111] The current and projected effects of climate change (Section 6.2), such as rising temperatures, thermal extremes and an increase in storm severity, directly threaten a broad suite of lagoonal species, such as sponges, corals and molluscs.[109]

Impacts associated with bottom trawling have not changed since 2014 and may include the removal of key habitat-forming species (such as corals, algae and sponges) and damage to the seafloor. Although reduced trawling effort and better management since 1999 have reduced the area of lagoon floor being affected by trawling by approximately 40 per cent[110,114], some lagoon floor areas within the southern Reef are still exposed to high levels of trawling.[894] However, there is essentially no information on the distribution and abundance of sensitive habitat-forming benthos within these areas. Long-lived vulnerable deep-water elasmobranch species are known to occur in those areas[1417,1418], and the area trawled by the deepwater eastern king prawn fishery has previously been identified as a high priority for ecological risk assessments.[110]

Dredging the lagoon floor in order to increase access to an area is an activity associated with ports, shipping and direct use (Chapter 5). Suspended sediments from dredging activities are harmful to many lagoon floor animals, particularly corals, fish and suspension feeders. Impacts include a reduction in water clarity and light attenuation[1419,1420], increase in coral disease[1421], effects on respiration and feeding ability of suspension feeders[1422], delayed development of fish larvae[1312], impairment of fish chemosensory abilities[1314], and changes in fish gill structure.[1316] Additional impacts to the lagoon floor originate from land-based run-off, anchoring and strong storm activity.

Management Potential threats to the lagoon floor are managed through a range of environmental regulations, policy and research. A number of spatially based protection measures are in place:

- In 2015, the Australian Government established legislation to restrict the disposal of dredge material in the Marine Park from capital dredging projects.
- Marine Park zoning continues to protect representative examples of all habitats within the 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 restrict trawling to about one third of the Marine Park.
- Seventy Fish Habitat Areas covering 8,800 square kilometres[1423] in or adjacent to the Region protect areas against physical disturbance from coastal development.

Evidence for recovery or decline The Outlook Reports in 2009 and 2014 concluded that some lagoon floor habitats previously at risk are recovering from disturbances with the expectation that full recovery will take decades.

8.3.3 Black teatfish (sea cucumber)

Globally, approximately 70 species of sea cucumbers are commercially fished, although commercial value is highly variable between species.[106] One species, the black teatfish (*Holothuria whitmaei*), had a particularly high commercial value in the Queensland East Coast Bêche-de-mer Fishery. When this fishery was open, harvests were entirely exported, predominantly to China and other Asian nations for consumption and use in traditional Chinese medicines. Over-harvesting caused the fishery to close in 1999, because fishing had reduced the density and biomass of this species by at least 75 per cent on fished reefs north of Townsville.[1424]

The resilience of black teatfish populations is limited and their sensitivity to over-fishing and climate change will affect recovery

Sea cucumbers spawn in winter when water is cooler[1425], and have low recruitment rates.[241] In 2015, the black teatfish was assessed as one of the most vulnerable key Torres Strait fisheries species to a variety of climate change pressures. This is due to its limited mobility, high exposure to warmer waters on the shallow reef areas and generally low adaptive capacity.[1426] Any rise in water temperature is likely to restrict or prevent spawning[1427], undermining the resilience of this species and the important nutrient cycling process it performs.

Management Zoning protects a minimum of 20 per cent of each reef bioregion from extractive activities, including those containing suitable habitat for this vulnerable sea cucumber. The sea cucumber fishery is managed by the Queensland Department of Agriculture and Fisheries and has been closed since 1999. Recent calls to reopen the fishery[1428] are based on industry-led surveys conducted in 2015, which concluded the black teatfish population may have recovered. The Sustainable Fisheries Expert Panel has assessed the commercial fishery for reopening. In order to reopen the fishery, several requirements must be met and measures designed to monitor the effectiveness of management arrangements must be followed to make sure the fishery is ecologically sustainable.

Evidence for recovery or decline Evidence for recovery of this species is limited. The 2015 industry-led surveys found the population biomass had increased to at least 70 per cent of its unfished biomass. However, these data were collected before several acute and severe disturbances to the surveyed areas between Townsville and Cape Grenville to the north. Considering their high vulnerability to climate change and the recent record-breaking temperatures in the Region[165], particularly during their winter spawning season, it is possible that black teatfish recovery may have been affected by thermal stress.

8.3.4 Coral trout

Coral trout is the collective name for several species of coral reef-associated, predatory fishes on the Reef. This case study pertains to the collective group, including the three most common species on the Reef: the common coral trout (*Plectropomus leopardus*), bluespotted coral trout (*P. laevis*) and barcheek coral trout (*P. maculatus*). These three species are highly targeted by recreational and commercial line and spear fishers on the Reef. While these species occur throughout the entire Region, common coral trout and blue spot coral trout are more common on mid and offshore reefs, and barcheek coral trout is more common on inshore reefs.[611]

Coral trout spend most of their life on or near reefs with some limited adult movement between reefs.[1429,1430] As a key reef predator, they play an important role in the transfer of energy in the food chain and influence the composition of fish assemblages through competition and prey behaviour.[1431] Coral trout use a range of coral reef habitats and depths and can be found residing under large plate corals and reef crevices that provide shade, protection and potential ambush sites.[622] Coral colonies have also been shown to provide critical habitat for the post-larval settling and growth of young coral trout[1432], making live coral structure a key factor for coral trout population resilience.

Following loss of coral habitat to varying degrees across the Region from cyclones, coral bleaching, fresh water inflow and crown-of-thorns starfish outbreaks, coral trout abundance declined in some locations (for example, around Magnetic Island and Palm Island) since 2007.[1433] This was most pronounced on reefs in the Keppel islands where coral trout density declined by half following a 50 per cent decline in live hard coral and the coral trout's preferred prey between 2009 and 2013 (Figure 8.4).[1433] Reductions in coral trout abundance around the Keppel islands were similar across reefs open and closed to fishing (Figure 8.4). However, recovery of coral trout has been faster in both 'old' and more recently established no-take areas (established in 2004), than in areas open to fishing. Further monitoring in late 2017 indicated trout numbers have increased around the Palm and Whitsunday islands, with recovery in no-take marine national park zones at least double that of fished areas.[615]

A delayed response to coral loss is common for longer-lived reef fish species, such as coral trout.[271] Following habitat loss, shorter-lived coral-dependent prey items preferred by coral trout (for example, planktivorous damselfish) can decline rapidly.[269] In the Keppel islands, coral trout have been shown to switch diet to less preferred species (benthic-feeding damselfish).[269] Given widespread coral loss and reduced capacity for recovery, coral cover is likely to be supressed for several years[96] and this is likely to impact on replenishment and prey availability for coral trout.

Decreases in coral trout catch are likely to occur as sea temperatures increase, particularly in the warmer northern sector of the Reef. © Matt Curnock

Management Total allowable commercial catches of coral trout are managed by the Queensland Government under a commercial licence regime that is reviewed annually. The total allowable commercial catch was reduced to 917 tonnes in 2015 by the Queensland Government. The annual coral trout quota has subsequently been increased by about 23 per cent to 1163 tonnes for 2018–19 based on quota decision rules relying on commercial catch per unit effort data.[885] Recreational harvest of coral trout is regulated through individual possession limits. Estimates of recreational harvest are based on surveys and are less robust than estimates for the commercial sector.

In addition to limits on the total commercial take, management tools are in place to regulate the take of coral trout and make sure the stock is sustainable. These management tools include minimum size limits (to ensure fish reproduce at least once before being caught), a maximum size limit of 800 millimetres for blue spot coral trout, recreational take bag limits, two 5-day fishing closures around their spawning period, and year-round compliance and enforcement of fisheries and marine park legislation. Generally, despite some poaching, coral reefs that are within no-take marine national park zones have more than twice the biomass of coral trout than similar, nearby fished reefs.[998,1433,1434,1435] The effectiveness of reserves in supporting healthy populations of coral trout also yields benefits to adjacent areas open to fishing through the export of larvae.[618,619]

Illegal fishing of coral trout reduces the population and can impact on the important predation function they perform. For recreational fishing, the number of reported offences has averaged around 500 each year since 2012–13, gradually increasing to 653 reported offences in 2017–18. This reflects both improved surveillance capability and heightened compliance focus on recreational fishing activity (Section 7.3.3). Commercial line fishery offences over the same five-year period were fewer and more variable between years, with the number of offences ranging between five and 64 per year. However, some fishers employ counter-surveillance tactics, and the actual extent of illegal fishing activity by both sectors is much greater than the number of offences detected.[992,1433] Illegal take of coral trout causes local depletion, disrupting the natural food chain and leading to wider ecosystem effects. When others break the rules and fish illegally, fishers who keep to the rules suffer because there are fewer fish in the longer term. Large female trout in no-take areas supply larvae to reefs open to fishing up to 205 kilometres away.[618,619] This level of larval exchange is an important process in maintaining the resilience of coral trout populations and the fishers that depend on them.

Evidence for recovery or decline While a suite of management approaches is in place to manage the direct take of coral trout, management approaches to address other key pressures, such as increasing sea temperature and severe cyclones, are far more challenging. These pressures pose the greatest threat to the long-term resilience of coral trout (and their predatory role), and may undermine fisheries management, threatening the viability of commercial and recreational fisheries.

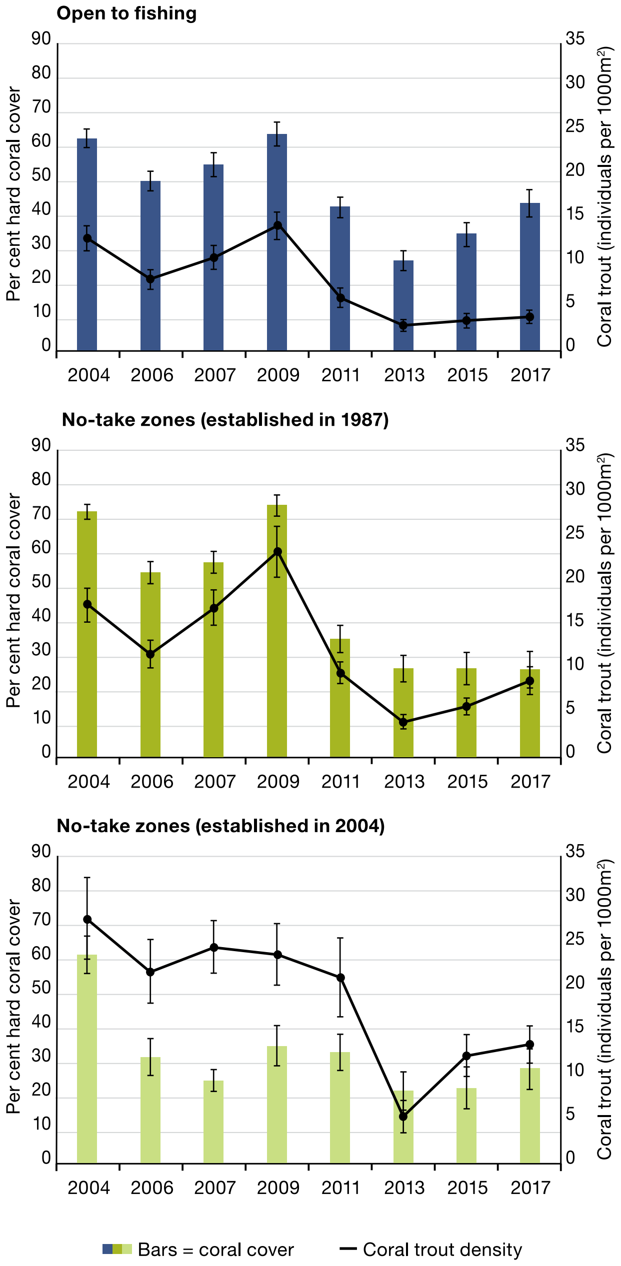


Figure 8.4 Comparison of average coral trout abundance and live coral cover at the Keppel islands from 2004–2017 across different zones
The black line represents average coral trout density (+/- standard error). Average live hard coral cover percentages (+/- standard error) are shown as columns. Blue columns represent reefs open to fishing, dark green columns represent older no-take marine national park zones (established in 1987), and lighter green columns represent more recent no-take marine national park zones (established in 2004). Source: Williamson 2014[1433] and Williamson *et al.* 2019[615]

Coral trout have some ability to acclimate to increased sea temperatures, if given time and adequate food resources.[504] Laboratory studies have shown coral trout embryos perish at water temperatures above 33 degrees Celsius.[1199] Adult coral trout also increase their food intake at higher temperatures, to compensate for an increased metabolism. Therefore, as the ocean continues to warm, coral trout and other predatory fish may have to feed more[90], but at the same time conserve their energy, which means they will move less within and between reefs[1436,1437], which may affect their catchability and have ecosystem effects from changed predation patterns.[269,504]

In the mid 1990's, coral trout populations displayed some recovery capacity following post-disturbance habitat loss.[95] Following the 2016–2017 mass coral bleaching events, reef fish communities at Lizard Island changed, with a decrease in many potential prey species.[1438] This will probably have flow-on effects through the food chain to predatory species, such as trout, as the habitat shifts and recovers (Section 3.4.5). The capacity of coral trout to resist disturbances in the future is decreasing due to two distinct effects of climate change: the direct effects of environmental change (increasing sea temperature), and indirect effects of habitat degradation. Direct effects from both commercial and recreational fishing also influence the resilience of coral trout, particularly in the northern Region, where coral trout are more susceptible to increasing temperatures. As coral trout respond to increasing temperatures, by conserving energy and moving less[1436], they may become harder to catch and spawning aggregations may be impacted[1023], resulting in lower reproductive output.

8.3.5 Loggerhead turtles

Mon Repos on the Woongarra coast, near Bundaberg, is currently the most significant nesting beach for the South Pacific Ocean loggerhead turtle *(Caretta caretta)* population, and is located just outside the southern boundary of the Region. Other key nesting locations are Wreck, Erskine and Tryon islands and Wreck Rock beaches in the southern Reef.

Bycatch mortality in the otter trawl fishery was linked to a decline in South Pacific Ocean loggerhead turtles from approximately 3500 nesting females in the mid-1970s to only 500 by the year 2000.[1439] Other pressures have also contributed to population decline, including fox predation on nests and, most recently, ingestion of marine debris, and poor hatching success due to natural erosion and flooding of nesting beaches.[648] Coastal development has continued to increase light pollution along the Woongarra coast, affecting nesting success and the number of hatchlings successfully reaching the ocean.[331,332] Nest invasion by roots and vines of native and non-native plants is an emerging risk, resulting in incubation failure and entrapment of hatchlings on the mainland.[321,327] It can take decades for loggerhead turtle population decline or recovery to become evident, due to their slow growth rates, changes in habitat use as they mature and other life history traits.[1440]

Overseas fishing bycatch and marine debris are likely to be limiting recruitment of loggerhead turtles

Management Eighty per cent of the loggerhead turtle population's nesting habitat in eastern Australia is protected — higher than anywhere else in the world.[328] Loggerhead turtles are listed under the Convention for Conservation of Migratory Species (CMS) and the Convention for International Trade of Endangered Species (CITES) both of which Australia is signatory to. Within Australia, they are listed as an endangered species under Commonwealth and Queensland legislation, including the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) and the *Nature Conservation Act 1992* (Qld). Protection within marine parks along the Queensland coast is provided by the *Great Barrier Reef Marine Park Act (1975)* (Cth) and *Marine Parks Act 2004* (Qld). The Reef 2050 Plan, the *Recovery Plan for Marine Turtles in Australia 2017–2027* and the *Queensland Marine Turtle Conservation Strategy* also commit to turtle conservation.[9,308,328]

The Queensland Government has amassed 50 years of continuous research and monitoring of nesting loggerhead turtles along eastern Queensland.[328] Management actions that are focused on the Woongarra coast include a public education campaign to change community behaviour (Box 14), revegetation of frontal dunes, and relocation of egg clutches at high-risk sites.[1441] Knowledge of how many hatchlings die because of light pollution and how many nesting turtles move away from light-affected beaches is still lacking.[1441]

Evidence for recovery or decline Mandatory use of turtle excluder devices for trawl nets was introduced in 2001 and successfully reduced the number of deaths of loggerhead turtles.[320] Management intervention since the late 1980s has also included fox baiting programs and active intervention through rescuing otherwise doomed eggs.[648] These actions have allowed 50,000 or more hatchlings to leave the beaches every year.[648] At the nesting population's lowest point (the 1997 nesting season), only 118 females came ashore along the Woongarra coast. Since then, numbers have generally been increasing (Figure 8.5). The drop to 302 nesting females in 2011 may have been caused by the extreme weather in 2010–11 affecting food supply, although this is not known for certain. By 2016, nesting numbers had rebuilt to 454, comparable to levels in the mid-1970s (Figure 8.5).

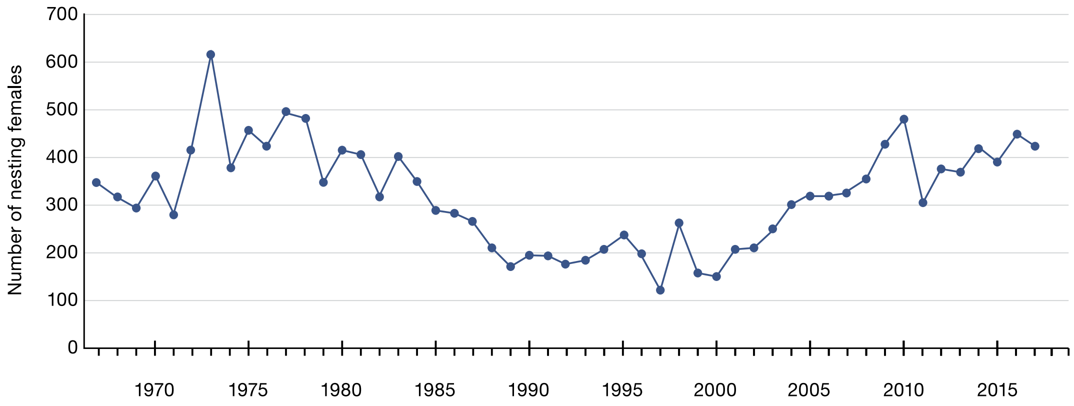


Figure 8.5 Number of tagged loggerhead turtles nesting, Woongarra coast, 1967–2017
Data for the 1967 and 1968 nesting seasons are population estimates. Data for nesting seasons from 1969 to 2017 are derived from population censuses. Nesting seasons occur over summer and are referred to by the year in which they start.
Source: Department of Environment and Science Qld 2018[312] and Limpus 2008[320]

Impacts that affect nesting success, hatchling survival, juvenile recruitment and adult survival have implications for the resilience of the species. Although management interventions have reversed the declining trend in turtles nesting on the Woongarra coast, considerable concerns remain, and recruitment of young turtles into foraging areas is an emerging issue. The recovery of nesting loggerhead turtles has mostly occurred on the mainland beaches rather than the islands. This is despite islands being the primary nesting areas in the 1970s. For example, nearly 600 nesting turtles were found on Wreck Island in 1977, yet there were fewer than 100 in 2011.[1441] Turtles nesting on islands are more likely to be migrating in from more distant foraging areas[680], and may be particularly affected by mortality occurring in international waters.

Over the last 20 years, there has been a decline in recruitment of juvenile loggerheads returning and settling into foraging areas in southern Queensland. Despite significant management actions by the Australian and Queensland governments, overall recruitment rates of loggerhead turtles to Australian coastal waters are approaching zero, which will eventually reduce nesting population numbers.[648] The decline in recruitment to Queensland foraging areas is believed to be a result of mortality of immature loggerhead turtles caught incidentally in long-line and gill net fisheries in Peru and Chile[648,1442,1443] and from entanglement and ingestion of marine debris inside and outside the Region.[1441]

BOX 14

The Low Glow collaboration project to protect loggerhead turtle

The Low Glow collaboration project is based in the Bundaberg region and aims to improve nesting success and hatchling survivorship of loggerhead turtles at Mon Repos beach on the Woongarra coast — a very significant site for the Region's loggerhead turtle population. Ambient night-time light negatively affects female turtles' nesting and can confuse hatchlings emerging from nests. Reef Guardian Schools around Bargara, Burnett Heads and Elliot Heads conduct light audits on their homes, schools and in their community during nesting season (October–December) and hatching season (January–March). The data captured will help local residents and organisations to 'cut the glow' of ambient light. The project brings together Reef Guardian Schools, a Reef Guardian Council, Queensland Parks and Wildlife Junior Turtle Rangers and the Burnett Local Marine Advisory Committee, working in partnership for a more sustainable future for local nesting turtles.

Sky glow viewed from Mon Repos Beach in 2010. © Queensland Parks and Wildlife Service

Hatchlings running to the ocean.
© Queensland Parks and Wildlife Service

8.3.6 Urban coast dugongs

Dugongs are relatively slow growing, have low reproductive rates and restrictive dietary requirements (almost exclusively seagrasses) and are highly vulnerable to a wide range of direct impacts. Their abundance and distribution within the Region is generally discussed in terms of two geographic areas: the remote coast and the urban coast (Section 2.4.16). This section relates to the portion of the dugong population that resides along the urban coast between Cooktown and the southern extent of the Region.

Urban coast dugongs remain at risk from human activities and factors affecting seagrass health

Cumulative impacts have exacerbated the vulnerability of urban coast dugongs.[1444] Even though urban coast dugongs may be showing some signs of recovery since 2011, the remaining population continues to be challenged by high levels of mortality in 2010–2011[1445], slow recovery of their food source in some areas after multiple disturbances (Section 2.3.4), extreme weather events[1446] and ongoing pressures from human use of the Region.

Aside from seagrass habitat degradation and a delayed recovery (Section 2.3.4), the greatest threats to dugongs are from human activities that kill adult animals. These threats include incidental capture in commercial and illegal fishing nets (Section 5.4.3), poaching (Section 5.9.3) and vessel strikes. Many Traditional Owner groups with an accredited Traditional Use of Marine Resource Agreement have set a voluntary moratorium on the harvest of turtles and dugongs (Section 5.9). Scientific modelling of dugong populations in Torres Strait concluded that traditional use of dugongs is sustainable.[1111,1116] An equivalent understanding of the legal harvest and illegal poaching of dugongs across the entire Region remains a knowledge gap. The impacts on dugongs of projected increases in shipping, regional recreational use and associated maritime infrastructure remain largely unknown.

Management The 2009 and 2014 Outlook Reports outlined a number of planning, policy and statutory management measures to reduce direct and indirect impacts on dugongs. These tools included dedicated trawling closures, Dugong protection areas, the Zoning Plan, voluntary go-slow areas, sustainable traditional hunting agreements, and commercial netting restrictions. New management measures since the 2014 Outlook Report include:

- improving water quality targets to help build the resilience of inshore seagrass areas that support marine biodiversity, including dugongs[9,527,941]
- developing the *Queensland Sustainable Fisheries Strategy 2017–2027*[892], a strategic approach to mitigating commercial fishing impacts on non-target and protected species
- the Queensland shark control program permanently replacing the final few shark nets inside the Marine Park with drumlines in early 2017
- establishing new and re-accrediting existing Traditional Use of Marine Resource Agreements along the urban coast to support sustainable traditional use, research and monitoring (Section 5.9.1).

Regular aerial surveys have been conducted since the 1980s to estimate dugong populations within the Region and Torres Strait.[413,414] Also, Indigenous ranger groups collect localised information on sightings and impacts.[414] The Marine Wildlife Strandings program (StrandNet) reports on dugong strandings and causes of mortality[1445,1447], and is the main source of information on related trends along the urban coast.[1448] The Queensland Government provides annual data on inadvertent dugong capture in shark nets as part of the Queensland shark control program. Data on commercial fishery bycatch, legal traditional hunting and illegal poaching are lacking for much of the Region.[1447]

While there is a growing body of biological and ecological information on dugongs, data gaps currently remain an issue for conservation.[1449] A priority listing of specific dugong information needs is provided in *The Action Plan for Australian Mammals 2014*.[1450]

Evidence for recovery or decline Even under the best conditions (low natural and no anthropogenic mortality) the urban coast dugong population has a maximum biological recovery rate of under five per cent per year.[1451] Current population numbers are a fraction of pre-European settlement levels and may never recover to pre-harvest levels.[1,1452,1453]

Aerial surveys of the urban coast estimate that dugong abundance declined in overall terms between 2005 and 2016 (Section 2.4.16).[414] Mortalities recorded in 2011 by the Marine Wildlife Strandings program were the highest since reporting began in 1998 and followed several severe weather events. Since then, the number of stranded or dead dugongs across the Queensland east coast has declined again[1447], and body condition of individual dugongs appeared to be better in 2016 than in 2011[413,414] (Section 2.4.16). The observed increase in abundance south of Cooktown[414] is attributed to dugongs migrating back into the urban coast area from further north as seagrass meadows recovered from the effects of a series of wetter than normal years (culminating in the floods and cyclones of 2010–11)[59] (Section 2.3.4).

Despite evidence of some improvement since 2011, the potential increase in urban coast dugong populations would be strongly dependent on the condition of seagrass meadows and efforts to reduce direct mortality threats. Over the long-term, the resilience of urban coast dugongs and the herbivory role they perform will continue to be influenced by interactions between direct anthropogenic impacts and those related to climate change (including increased intensity of cyclones and altered rainfall patterns).

8.3.7 Humpback whales

The eastern Australian humpback whale (*Megaptera novaeangliae*) population exhibited strong recovery as of 2015.[385] At the last survey in 2015, approximately 24,000 whales were estimated from visual surveys (58–98 per cent of the original pre-whaling population).[385] The population is expected to have continued on this recovery trajectory and reached more than 30,000 in 2018. Due to their increasing population, it has been proposed that their conservation status in Australian waters be revised.[11] As the population approaches its carrying capacity, a modelled estimate of up to 40,000 whales, food availability, disease and climate change will become important limiting factors for the population.[387,1454]

Threats to individual whales transiting through the Region include entanglements in nets, underwater noise and vessel strike, but the greatest threat to population persistence is climate change and the related effects on food sources outside the Region.[385,389,390,391,1056] While vessel strike is presently not considered a major threat to the Reef humpback whale population, the increasing abundance of humpbacks in the Region coupled with increasing numbers of vessels increases the likelihood of vessel strikes.[392]

Management Banning whaling in 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 through a combination of legislative requirements, operational policy, and research and monitoring have further enabled their recovery.

Evidence for recovery or decline Annual recovery rates of the east Australian humpback whale stock have been estimated at 10–11 per cent per year.[385] Recovery is estimated to be 58–98 per cent of the original pre-whaling population.[385]

8.4 Heritage resilience

Community awareness and appreciation are key contributors to the Region's heritage resilience

Heritage resilience is the ability of a heritage place, structure or value, to experience impacts or disturbance while retaining the inherent heritage value for which it has been recognised. Poor community awareness and lack of appreciation of heritage values are recognised as key threats to the Region's heritage values and its resilience.[2,1446] Communication and interpretation of heritage values are important drivers of resilience, making heritage accessible to the community and engendering community support and protection of heritage.[1455] One threat to physical maintenance and restoration of historic heritage is loss of knowledge, specifically through a continuing decline in access to specialised professional and trade skills, and an ageing workforce.[1455]

Internationally, heritage resilience in disaster risk management and disaster recovery for culturally significant places is becoming more prominent, including from a community well-being perspective.[1456] Since 2014, there has been improved focus (both nationally and at the state level) on social and economic elements of heritage resilience, including the importance of collaboration and partnerships, sustainable tourism and adaptive re-use, and engaged and appreciative communities.[1455]

The Reef 2050 Plan[9] has identified specific actions, targets and objectives to observe, protect and manage Indigenous and historic heritage values, particularly as a means of maintaining their significance for current and future generations. Currently, these actions are based on four main heritage resilience themes:

- building the capacity, support and involvement of Traditional Owners and other community members
- ensuring protection through appropriate legislation, policy, planning and impact assessment
- completing, updating and implementing specific planning instruments (for example, for identified historic shipwrecks and lightstations)
- enhancing identification, monitoring and reporting on key Reef heritage values and sites.

As part of the mid-term review, and in anticipation of the 2020 review of the Reef 2050 Plan, a consultancy firm with Traditional Owners was engaged. Their report provided 10 broad recommendations about governance, funding, co-design and partnerships.

More broadly, loss of knowledge and tradition, and incremental damage continues to impair the resilience of intangible cultural knowledge across many of the world's Indigenous cultures including in the Region (Section 4.3). However, on a Region-wide scale Indigenous heritage values have experienced heightened awareness and reconnection. The Reef's Traditional Owners continue to access sea country and strengthen their natural and cultural resource management capacity (Sections 4.3 and 5.9.1). A new strategy to guide management, adopted since 2014, is the 2019 *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park.*[803] The strategy aspires to keep Indigenous heritage value in the Marine Park strong and resilient. It includes specific objectives and actions under three outcomes: keep heritage strong; keep heritage safe; and keep heritage healthy.

8.5 Case studies of heritage resilience

The three case studies below illustrate the likely resilience of some Indigenous and historic heritage values in the Region, and whether they have recovered or declined following disturbance. The case studies presented are:

- Indigenous heritage — cultural practices, observances, customs and lore
- historic heritage — lightstations
- historic heritage — underwater wrecks.

8.5.1 Cultural practices, observances, customs and lore

Indigenous heritage values are interconnected with the natural heritage values of the Region, and Traditional Owners are the custodians of Indigenous heritage values (Section 4.3). Resilience of these values depends on Traditional Owner's connection to culture and sea country as well as the condition of the natural heritage values. There is a long history of traditional use of the Reef and management of the Region's marine resources and values. Contemporary conservation management activities (undertaken both independently and in partnership with Traditional Owners) significantly help to maintain the Region's Indigenous heritage value (Section 5.9).

Traditional Owners spending time on country continues to strengthen connections, transfer knowledge and maintain Indigenous heritage values

As a case study, the Lama Lama people from the Princess Charlotte Bay area in the far northern part of the Region, are a Traditional Owner group that have developed a successful community-based governance structure over a 10 year period. The Lama Lama Ranger program delivers contemporary island and sea country management that complements traditional knowledge and local skills base. These efforts have helped maintain resilience of Indigenous values by reasserting cultural connections through knowledge transfer. For example, established Junior Ranger programs focus on the transfer of knowledge between generations.

The Lama Lama people's history and connection to their land and sea country, along with their ambition for managing their heritage through tenure (ownership) reform, is well documented.[809,1457,1458] The Lama Lama Rangers protect an area of about 3000 square kilometres of Cape York Peninsula land and sea country, extending from Massey River in the north, to the Normanby River at the top end of the Rinyirru (Lakefield) National Park in the south.[1459] This Traditional Owner-led management also covers the offshore islands and reefs within Princess Charlotte Bay, an area covered by a Traditional Use of Marine Resource Agreement (Section 5.9.1 Figure 5.28), including Marpa National Park (and some of the Claremont Isles). In 2016, coral reefs in this area were severely impacted by coral bleaching, causing significant concern and questions within the Traditional Owners.

Lama Lama Junior Rangers participating in a drone demonstration over their country with a representative from the Great Barrier Reef Marine Park Authority. © GBRMPA 2017, photographer: Gus Burrows

Management The Lama Lama people are engaged in formal management arrangements under Australian and Queensland government statutes for their land and sea country.[1460,1461] The area is owned under Queensland law by the Lama Lama people and jointly managed in partnership with the Queensland Government. In 2013, the Lama Lama people developed a Traditional Use of Marine Resource Agreement that covers 2323 square kilometres of sea country extending through Princess Charlotte Bay to the Normanby River in the south. This five-year accredited statutory agreement outlines actions to protect sea country and increase the resilience of Indigenous heritage values.

Evidence for recovery or decline Indigenous customs and lore are tangible and intangible and, on a Region-wide scale, are not well known by Reef managers. However, the resilience of this value is measured by its ability to retain its inherent heritage value after experiencing impacts or disturbance. In this way, strong Traditional Owner connection to country (for example, continuance of cultural practices and established governance arrangements) and the capacity to access country is essential to the resilience of this value. The condition of this value is improving in some areas and progress can be demonstrated through actions outlined and achieved through the Lama Lama land and sea country activities, for example:

- an increase in on-water compliance achieved through a strategic program of collaborative and independent sea country patrols
- an increase in the number of collaborative research and monitoring programs (for example, bird surveys on Pelican Island) and protection of island cultural sites, particularly Marpa rock art sites
- continuation and growth of the Junior Ranger program with a marine focus
- strong Elder-led governance.

In addition, in July 2018, the Lama Lama people celebrated the success of a long-term national park joint management partnership with the Queensland Government.[1460] The partnership included recognition of the collaboration over Marpa Island, where Lama Lama rangers lead on-ground monitoring and protection of the island's heritage values, including the highly significant Wind Story. Lama Lama rangers have established a large female cohort, an important element in ensuring appropriate protection of women's heritage. A strong emphasis on ranger skills and training has been established, including fire management, cultural site management, tour guiding and compliance training. A number of rangers have also gained a Certificate III in Conservation and Land Management.[1462] Cultural practices, observances, customs and lore are being maintained within the Lama Lama country (both land and sea) and its resilience is inferred to be improving.

8.5.2 Lightstations

Historic lightstations within the Region comprise four lightstations on the Commonwealth Heritage List and Pine Islet lightstation (Section 4.4.1 Figure 4.7). At the time of the 2014 Outlook Report, heritage management plans that described and assessed in detail the lightstation's historic heritage values, were in place for the Dent Island[831] and Lady Elliot Island[833] lightstations. Since that time, several new management tools have been implemented for the Commonwealth listed lightstations.

Lightstations rely on management actions to support their resilience and maintain their inherent heritage value

Lightstations are threatened by damage and erosion, and their resilience is dependent on management effort to maintain heritage value where possible. While it is generally accepted that the Region's lightstations are well maintained, disaster risk management remains a gap for these highly exposed heritage values of the Region. Even though safeguards provided by maintenance programs are having a positive influence on the capacity of historic heritage to withstand adverse events,[1348] more intervention is likely to be required in the face of a changing climate. Climate change adaptation strategies for built assets in the Region require more disaster risk management innovations than have currently been documented by managers, such as considering options to stop saltwater inundation and installing cyclone rods into buildings. However, under the *Burra Charter*[1463], if a lightstation or lighthouse sustains significant damage so most of the original fabric is destroyed, the structure is likely to be demolished rather than repaired. For example, Pine Islet lightstation remains derelict and the lighthouse has been relocated to Mackay marina. In those cases, the physical heritage value would be lost permanently even though the intangible heritage value remains (the place remains significant). Furthermore, to safeguard the historic heritage value of the place and property, the extent of any repair or modification to the structures, would have to be inconsequential.

Grave of Jane Ann Owen (nee Coulsen) on Low Isles. Jane Owen was the wife of the first superintendent (head lightkeeper), Daniel Owen, who died in 1880. The grave is situated about two metres above sea-level on the north-western side of the island and is susceptible to sea-level rise. © GBRMPA 2017[1464]

Management Heritage strategies, registers and management plans outline the roles and priorities of managers to maintain these historic heritage assets and are used widely across the Region.[831,834,1465,1466] The focus of these plans is to protect, conserve and preserve the historic heritage of lightstations for current and future generations. These management tools, however, do not address the direct impacts of climate change, disaster risk management or resilience strategies. Through maintenance and renewal actions these plans indirectly adapt lightstations and lighthouses against a changing climate and, by passing on knowledge, they further transmit the significance of these places.

Evidence for recovery or decline Evidence of improved resilience of lightstations or lighthouses since 2014 is limited, although managers are confident the inherent heritage value of these assets is retained. How these properties adapt and respond to changes that affect their exposure to damage (from seawater inundation, catastrophic winds and severe weather) can determine their level of resilience and is an ongoing challenge for managers. The Region's lightstations are located on exposed islands within the Region, so their historic heritage value is highly vulnerable to the threats posed by climate change (Section 6.7). This vulnerability extends to the place (the land in which they sit), which may contain artefacts yet to be discovered and identified. Buried artefacts are most at risk from seawater inundation.[1347]

8.5.3 Historic shipwrecks

The vessel *Foam* took its final voyage on 5 February 1893 and the historic wreck now rests in the lagoon of Myrmidon Reef about 125 kilometres north-east of Townsville.[835] No monitoring, survey, recovery or analysis of the *Foam* artefacts occurred between 2009 and 2015. However, managers inspected the site in 2015 and 2018 to accurately record its location and condition. As a case study of resilience, the recent inspections of the *Foam* provide updated evidence that the wreck remains in good condition. Ongoing monitoring of its condition is important for understanding its resilience.

Management Vessels that have been in Commonwealth waters for at least 75 years are automatically protected by the *Underwater Cultural Heritage Act 2018* (Cth) (Section 4.4.3). The *Foam* is located in a protected zone with a 200-metre radius, which includes the seabed and water column. By the very nature of their location, historic shipwrecks naturally erode and degrade. This is not considered loss of resilience because, in most cases, their inherent heritage value is retained. Resilience of an underwater relic is dependent on management effort, taking into consideration the relic's remoteness and ability to ward off the corrosive processes of the marine environment. The main risks to the resilience of historic shipwrecks include altered weather patterns (such as cyclones) and illegal activities and behaviours (such as looting and anchoring on the wreck) that can accelerate natural degradation rates. Future management initiatives, such as developing a conservation management plan for the *Foam* site will help guide management and the behaviour of Reef users. Inspection of heritage sites after cyclonic activity will help preserve and conserve artefacts exposed by storm action.

Evidence for recovery or decline Components with underwater historic heritage value are susceptible to damage from severe weather events through physical movement and abrasion from waves containing suspended sediments. The abrasive wave action often removes the protective marine growth, exposing the fabric of the site to corrosion and frequently uncovering fragile artefacts.

The 2015 inspection of the *Foam* site observed some damage from cyclone Yasi (2011), evidenced by the anchor winch being more deeply buried in 2015 than in 1984 (Figure 8.6). A bronze ship fastening and iron bracing knee had been dislodged and repositioned among live coral. Minor contemporary damage to the protective calcareous layer was also observed, speculated to be caused by grazing herbivores. In spite of these observations, the *Foam* remains in good condition.

> *By the very nature of their location, shipwrecks naturally erode and degrade*

Coral growth over an artefact can protect it from physical damage and help stabilise corrosion through the reduction of contact with oxygenated water. The loss of this cover will lead to increased deterioration of the artefact. A re-survey of the *Foam* in 2018 discovered that coral and sediment had moved (presumably because of cyclone Debbie in 2017), and was covering parts of the shipwreck. This provided a protective layer that could potentially slow corrosion and limit erosion.[835]

Figure 8.6 Historic shipwreck, *Foam* 1984 and 2015
In situ anchor winch.
Left: © Queensland Museum 1984
Right: © GBRMPA 2015[835]

8.6 Assessment summary — Resilience

Paragraph 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.

Paragraph 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 Great Barrier Region.

These assessments of ecosystem and heritage resilience are based on the information provided in earlier chapters, namely the current state and trends of the Reef's natural heritage value (biodiversity and ecosystem health) and heritage value (Indigenous and historic). They are also based on trends in direct use, the factors influencing future value and the effectiveness of protection and management arrangements. A series of case studies provide more information on the two areas of assessment:

- ecosystem resilience (natural heritage value)
- heritage resilience (Indigenous and historic heritage value).

Over time, the case studies may be expanded or more case studies developed.

8.6.1 Ecosystem resilience

Grading statements — ecosystem resilience

🟩	🟩	🟧	🟥	⬜⬜
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.	**Borderline** Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟩	🟧 ↓	🟧 ↓			**Ecosystem resilience:** Black teatfish, loggerhead turtles and dugongs have shown an ability to recover from disturbance after significant management intervention. As a result of severe disturbance (thermal stress) coral reef habitats have significantly decreased. As a result, coral trout, which depend on these habitats, are also in decline. Increasing frequency and severity of some threats are likely to reduce the resilience of species and habitats in the Region.
🟩	🟧 ↓	🟥 ↓	●	◐	**Coral reef habitats:** Significant losses in coral broodstock has occurred in the northern two thirds of the Region. Coral recruitment has declined by up to 89 per cent. As a result, some species and habitats are failing to recover to their previous state and function within the five year Outlook Report cycle.
🟩	🟩 ↔	🟩 ↔	◐	◐	**Lagoon floor habitat:** Some previously affected lagoon floor areas are probably still recovering. Shallow lagoon floor areas have been exposed to prolonged thermal stress and damaging waves from several cyclones. The impacts of these disturbances are unknown, as no recent monitoring has been conducted.
🟥	🟥 ↑	🟥 ↑	◐	◐	**Black teatfish:** Industry-led surveys conducted in 2015 indicated black teatfish populations in some of their range in the northern half of the Reef had recovered to above 70 per cent of the unfished population density. The effect of the 2016 and 2017 thermal stress events is not known.
🟩	🟩 –	🟩 ↓	◐	◐	**Coral trout:** Coral trout resilience has deteriorated following disturbances causing broadscale loss of habitat structural complexity and their preferred prey in some locations. Some recovery since 2013 is evident and more pronounced in no-take areas. As temperatures increase, physiological tolerances of coral trout may be exceeded in the northern third of the Region. The full effects of recent habitat loss may take several years to manifest, but are likely to result in decreased condition of coral trout and altered food chain dynamics.

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
🟧	🟧 ↑	🟧 –	●	●	**Loggerhead turtles:** Management interventions have reversed the declining trend in nesting loggerhead turtles on some nesting beaches. Nesting loggerhead turtle populations on those beaches continue to recover and are comparable to nesting levels in the mid-1970s. However, overseas fishing bycatch and marine debris may be limiting recruitment of loggerhead turtles and may affect population resilience into the future.
🟥	🟥 ↓	🟧 ↑	●	◐	**Urban coast dugongs:** The urban coast dugong population has shown some signs of recovery in the south since 2011 despite the overall decline between 2005 and 2016. Slower than expected recovery of seagrass habitats has affected dugong recovery rates. Continued effective implementation of all management arrangements is required to reduce direct threats.
🟩	🟩 ↑	🟩 ↑	●	●	**Humpback whales:** Humpback whales have demonstrated resilience to past over-harvesting, recovering to at least 60 per cent of the pre-whaling population. Currently, the recovery trend continues to increase exponentially. Resilience of this species will now depend on impacts of climate change, particularly on their food source outside the Region.

8.6.2 Heritage resilience

Grading statements — heritage resilience

🟩 **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.

☐☐ **Borderline**
Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑ 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

Grade and trend			Confidence		Criterion and component summaries
2009	2014	2019	Grade	Trend	
	🟨	🟨 –			**Heritage resilience:** The resilience of Indigenous heritage values continues to depend on the active involvement of custodians, and access to land and sea country. Resilience of the Region's historic heritage value has not been widely analysed by managers. Shipwrecks exist in a dynamic marine environment, which may degrade their structure naturally over time. Limited evidence is available to comprehensively quantify the resilience of the Region's heritage values.
	🟨	🟨 ↑	○	○	**Cultural practices, observances, customs and lore:** The resilience of this component depends on Traditional Owners maintaining connection with their land and sea country. Strong governance and an increase in Indigenous ranger and junior ranger programs contribute to maintaining the resilience of this value.
	🟨	🟨 –	◐	◐	**Lightstations:** The Commonwealth heritage-listed lightstations in the Region are well recorded and maintained, contributing to their resilience. Evidence of these components becoming more resilient to impacts or disturbances, as opposed to being well maintained, is lacking.
	🟧	🟧 –	◐	◐	**Historic shipwrecks:** The main risks to historic shipwrecks include natural and human impacts that can accelerate natural degradation rates. More frequent site inspections assist understanding and enable timely intervention. However, limited evidence is available to indicate that resilience increased since 2014.

8.7 Overall summary of resilience

The Region is one of the world's most diverse and remarkable ecosystems. However, along with every other tropical marine ecosystem, it is under increasing threat. Elements within the ecosystem are exhibiting a reduced capacity for resistance and recovery, although the extent of the decrease varies considerably between ecosystem components. The natural resilience of the Region's values is being undermined by increases in the severity and frequency of disturbances.

The natural resilience of the Region's values is being undermined by increases in the severity and frequency of disturbances

There is a recognised lag between implementing meaningful actions to improve resilience and observable ecosystem improvements. As climate change impacts accelerate, recovery windows will shrink and the effects of other pressures will be amplified. Managing for resilience is most important in situations where there is uncertainty about risks and the effectiveness of management responses. The combined consequences of climate change and local and regional impacts on the Reef present such a situation.

The Region's resilience is assessed through 10 case studies (seven ecosystem case studies and three heritage case studies). Humpback whales are the only ecosystem component described in the case studies that has made a strong recovery. Their recovery is due to international legislation put in place several decades ago to protect these species from hunting in the Southern Ocean. Urban coast dugongs have shown signs of recovery from impacts in 2011. In contrast, the resilience of coral reefs has deteriorated from poor to very poor. Black teatfish populations in the northern Reef are thought to have been recovering since the last assessment although remain graded as having very poor resilience. Some previously affected lagoon floor areas are probably still recovering from cyclone disturbances. The latter two assessments are based on limited evidence, and the effect of the 2016 and 2017 thermal stress events is not known. For coral trout, recovery is slow (although evidence is only based on several locations) and is likely to remain limited until reef structure and prey species abundance bounces back following disturbances.

In future, increasing sea temperatures (especially in the northern two-thirds of the Reef) are likely to reduce the resilience of coral trout through lower condition and reproductive output. Management interventions over the last few decades have successfully reversed declines in loggerhead turtle nesting numbers on some beaches. However, the effects of overseas fishing bycatch and marine debris on the number of juvenile turtles reaching and settling into Reef feeding grounds may be undermining the population's overall resilience.

Community awareness and appreciation are important to the resilience of the Region's historic and Indigenous heritage values

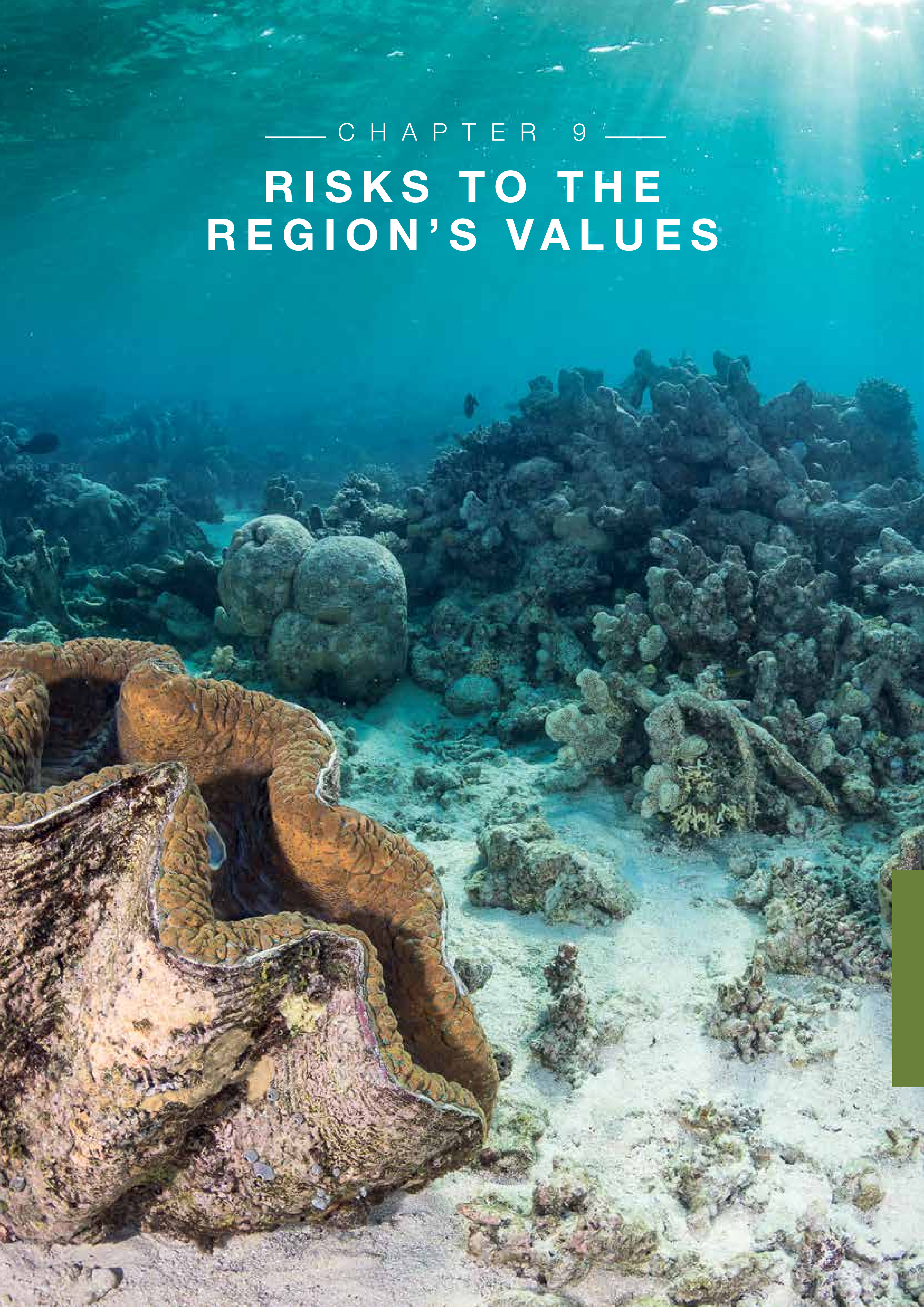
Of the three heritage case studies, two elements (lightstations and historic shipwrecks) are being maintained with limited evidence of improvement or decline in resilience. Resilience of cultural practices, observances, customs and lore has probably improved within the Lama Lama case study area, given well-established governance and management systems. 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 to make sure connections and knowledge are kept alive. 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.

Pine Islet lighthouse at its current location at Mackay marina. © Chloe Schauble

Lagoon floor habitats support an array of species. © Matt Curnock

CHAPTER 9

RISKS TO THE REGION'S VALUES



« *Giant clam in a degraded reefscape.* © Matt Curnock 2017

RISKS TO THE REGION'S VALUES

'an assessment of the risks to the ecosystem …' within the Great Barrier Reef Region, s 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, paragraph 116A(2)(b) of the *Great Barrier Reef Marine Park Regulations 1983*

9.1 Background

Management of the Region must consider the full range of threats to the Region's ecosystem and heritage values (natural, Indigenous, historic and other heritage values). Action should be focused on addressing those threats that pose the greatest risk and, increasingly, recognise the cumulative contribution of those threats and the interactions among them.[1467,1468]

The comprehensive risk assessments contained in the 2009 and 2014 Outlook Reports[1,2] identified climate change, land-based run-off, coastal development and some aspects of extractive direct use as the areas of most serious risk. The assessments have guided subsequent decision-making and helped set management priorities.[1,9,1468,1469]

The risk assessment described below is based on the information presented in preceding chapters. The assessment systematically reviews the current and future risks presented by known threats, and summarises the residual risk to the Reef after consideration of existing protection and management measures.

The assessment is based on overall risk to the ecosystem (natural heritage value) and overall risk to heritage values (Indigenous, historic and other 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 informed by the evidence presented in Chapters 5 and 6. The 45 threats considered in this risk assessment are listed in Appendix 6, including a comparison with those assessed in the 2014 Outlook Report.

Forty-five threats are identified for assessment

The list of threats includes direct and indirect threats and some that are consequential (arising as a result of other threats). For example, stress on corals from environmental pressures, such as sea-temperature rise and nutrient and sediment run-off, may increase the likelihood of coral disease outbreaks.

Four threats have been added to the assessment since 2014 (defined in Appendix 6). In combination with previously included threats, such as marine debris and chemical and oil spills, the addition of 'genetic modification' recognises emerging and potential future activity in relation to coral reef restoration and resilience-building interventions.[24,1020,1470] The three other newly-added threats acknowledge the potential for undesirable behaviours and other considerations to affect the condition of Indigenous and historic heritage values in ways not captured in the previous list of threats.

It is important to note that this assessment can only consider the threats that are known and identified. There are likely to be more unknown and unexpected threats that have not been considered. These other threats will be assessed in future reports as they are identified.

9.2.2 Assessing threats

A standard risk assessment method is used, taking into account likelihood and consequence

Two separate risk assessments are presented — one for the Region's ecosystem (natural heritage value) and one for its heritage values (Indigenous, historic and other). The Australian Standard for risk management (AS ISO 31000)[1471] was followed. The likelihood and consequence of each threat is ranked on the five-point scale set out in Appendix 7. The criteria for selecting a consequence level for the ecosystem are different to those for heritage values. An overall risk level for each threat is determined by applying a risk matrix that combines its likelihood and consequence. Risk is considered to be residual — the risk that remains once any reductions provided by existing management measures have been taken into consideration.

The assessment is based on information in Chapters 2 to 8 of this report, including the current state and resilience of the Region's ecosystem and heritage values, major factors influencing the Region's values (including human use), and effectiveness of management. Additionally, input on risk levels from experts external[7] and internal to the Marine Park Authority made an important contribution to the process.

Because of the size and complexity of the Region, and because many threats affect its values over different time and spatial scales and at different intensities and interact in many different ways, the assessment presented here is necessarily 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, where relevant, 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 (that is, the mitigating effect of a management measure was only considered if the measure was already in place).

In understanding the consequence of a threat to the ecosystem (natural heritage value), variations in the extent of the threat's likely effect are taken into account by having different criteria for broad-scale and local-scale effects (Appendix 7). In order to understand the true level of risk, for each threat the higher consequence grade is adopted in determining the overall risk. For heritage values (Indigenous, historic and other), consequence level is considered using a single criterion that encapsulates both the geographic scale of effects and the range of heritage values affected (Appendix 7).

9.2.3 Information on community views

Community views informed the risk assessment

The risk assessment process considered input from Reef scientists on risks to the Reef. As part of an elicitation workshop, members of the Reef scientific and heritage expert communities provided advice on likelihood and consequence for a supplied list of threats.[7] In addition, the views of other community sectors were considered in a qualitative way, using information from various sources:

- Respondents to a national opinion survey were asked to rank a provided list of threats.[844]
- Residents of the Catchment as well as members of the fishing and tourism sectors (including both tourists and tourism operators) were surveyed regarding the three most serious threats.[785]
- The public and targeted consultation processes used to develop the *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park* were drawn on.[803,1472]

9.3 Outcomes of risk assessment

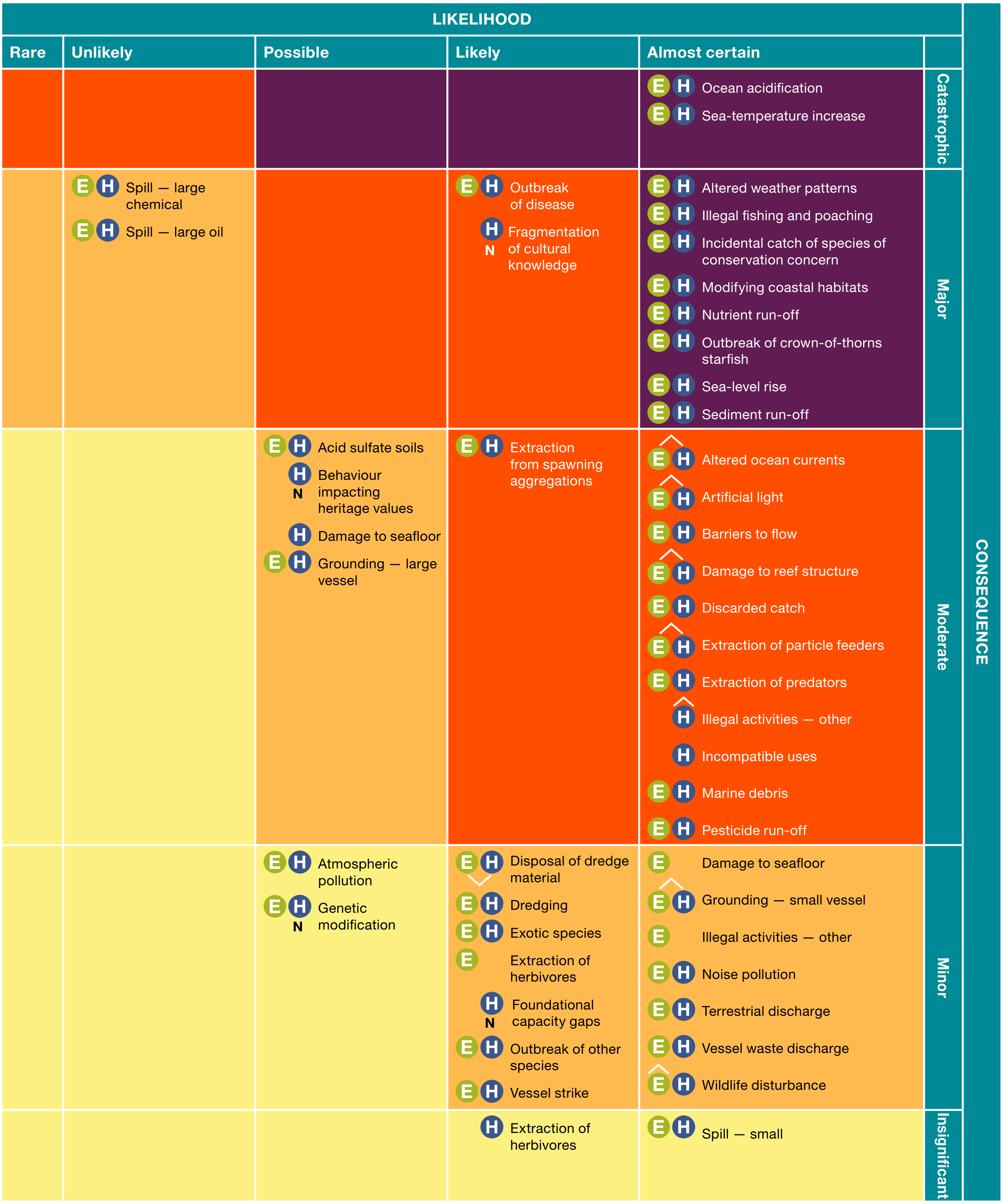
9.3.1 Community views

While community views on the key threats to the Reef vary, climate change and pollution are common concerns

The views of various community sectors on threats to the Great Barrier Reef are summarised in Table 9.1. Many sectors named climate change, pollution (including marine debris), land-based run-off and fishing as key threats. Concern about marine debris and other pollution has continued to increase since previous Outlook Reports and concern about natural disasters, such as cyclones and floods, has also become more prominent.

Table 9.1 Community views on threats facing the Great Barrier Reef
A range of sectors were canvassed about their views on threats to the Great Barrier Reef ecosystem using various survey methods (Section 9.2.3).[844,785,803,1472] *The data gathered is not directly comparable among groups.*

<table>
<tr><th rowspan="2">Community sector</th><th colspan="5">Ranking of perceived threats</th></tr>
<tr><th>First</th><th>Second</th><th>Third</th><th>Fourth</th><th>Fifth</th></tr>
<tr><td>Australians generally</td><td>Marine debris and beach litter</td><td>Climate change</td><td>Agricultural run-off</td><td>Crown-of-thorns starfish</td><td>Shipping</td></tr>
<tr><td>Reef Catchment residents</td><td>Pollution (includes marine debris)</td><td>Climate change/global warming</td><td>Fishing (includes overfishing, illegal fishing)</td><td>Poor water quality (for example, from land-based run-off)</td><td>Coral bleaching</td></tr>
<tr><td>International tourists</td><td>Climate change/global warming</td><td>Pollution (includes marine debris)</td><td>Tourism</td><td>Humanity (for example, overpopulation)</td><td>Fishing (includes overfishing, illegal fishing)</td></tr>
<tr><td>Domestic tourists</td><td>Pollution (includes marine debris)</td><td>Climate change/global warming</td><td>Humanity (for example, overpopulation)</td><td>Tourism</td><td>Mining</td></tr>
<tr><td>Marine tourism operators</td><td>Climate change/global warming</td><td>Poor water quality (for example, from land-based run-off)</td><td>Fishing (includes overfishing, illegal fishing)</td><td>Governance (for example, government policies and management)</td><td>Natural disasters (for example, cyclones and floods)</td></tr>
<tr><td>Commercial fishers</td><td>Fishing (includes overfishing, illegal fishing)</td><td>Poor water quality (for example, from land-based run-off)</td><td>Climate change/ global warming</td><td>Governance (for example, government policies and management)</td><td>Natural disasters (for example, cyclones and floods)</td></tr>
<tr><td>Traditional Owners and others consulted on the Aboriginal and Torres Strait Islander Heritage Strategy</td><td colspan="5">(threats of concern mentioned in feedback, in alphabetical order)
Climate change, damage to sites and other components of heritage, illegal hunting/ harvesting of marine resources, sea-level rise, species shifts</td></tr>
<tr><td>Scientific and heritage experts</td><td colspan="5">(highest perceived threats for either ecosystem or heritage values at either a Region-wide or local scale, in alphabetical order)
Altered weather patterns, barriers to flow, dredging, illegal fishing and poaching, incidental catch of species of conservation concern, marine debris, modifying coastal habitats, nutrient run-off, ocean acidification, outbreak of crown-of-thorns starfish, sea-level rise, sea-temperature increase, sediment run-off, vessel strike</td></tr>
</table>



CONSEQUENCE	LIKELIHOOD: Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic	🟥	🟥	🟪	🟪	🟪 E H Ocean acidification E H Sea-temperature increase
Major	🟧	🟧 E H Spill — large chemical E H Spill — large oil	🟥	🟥 E H Outbreak of disease H N Fragmentation of cultural knowledge	🟪 E H Altered weather patterns E H Illegal fishing and poaching E H Incidental catch of species of conservation concern E H Modifying coastal habitats E H Nutrient run-off E H Outbreak of crown-of-thorns starfish E H Sea-level rise E H Sediment run-off
Moderate	🟨	🟨	🟧 E H Acid sulfate soils H N Behaviour impacting heritage values H Damage to seafloor E H Grounding — large vessel	🟥 E H Extraction from spawning aggregations	🟥 ∧ E H Altered ocean currents ∧ E H Artificial light E H Barriers to flow ∧ E H Damage to reef structure E H Discarded catch ∧ E H Extraction of particle feeders E H Extraction of predators ∧ H Illegal activities — other H Incompatible uses E H Marine debris E H Pesticide run-off
Minor	🟨	🟨	🟨 E H Atmospheric pollution E H N Genetic modification	🟧 E H ∨ Disposal of dredge material E H Dredging E H Exotic species E Extraction of herbivores H N Foundational capacity gaps E H Outbreak of other species E H Vessel strike	🟧 E Damage to seafloor ∧ E H Grounding — small vessel E Illegal activities — other E H Noise pollution E H Terrestrial discharge E H Vessel waste discharge ∧ E H Wildlife disturbance
Insignificant	🟨	🟨	🟨	🟨 H Extraction of herbivores	🟨 E H Spill — small

🟨 Low risk 🟧 Medium risk 🟥 High risk 🟪 Very high risk E Ecosystem H Heritage

∧ Risk increased since 2014 ∨ Risk decreased since 2014

N New addition

Figure 9.1 Risks to the Region's ecosystem and heritage values from identified threats
This risk matrix is consistent with the principles, framework and processes outlined by the Australian Standard (AS ISO 31000) using terms and definitions detailed in Appendix 7. The assessment is based on current and documented future trends in the identified threats and existing management measures. The compounding effects of threats are not considered. The full description for each of the identified threats is provided in Appendix 6 and the risk assessment for each threat is summarised in Appendix 8. The four threats added in 2019 are marked as new additions. Symbols indicate where a threat has been assessed as having the same combination of likelihood and consequence ratings for both ecosystem and heritage values (that is, its natural, Indigenous, historic and other heritage values). If a threat has different ratings for ecosystem and heritage, it is presented twice and each entry is shown with a single symbol. Some threats are only relevant to heritage values and only appear once. If the assessed risk has increased or decreased since the 2014 Outlook Report this is indicated.

9.3.2 Level of likely risk

The outcomes of the risk assessments for the 45 threats to the Region's ecosystem (natural heritage value) and heritage values (Indigenous, historic and other) are presented in Appendix 8 and summarised in Figure 9.1.

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 and consequence of the effect differ between ecosystem and heritage values.

Two threats present a different level of risk to the Region's heritage values when compared to their impact on the ecosystem. Illegal activities that damage Indigenous and historic sites and intangible cultural values poses a higher risk to heritage. Extraction of herbivores poses a lower risk to heritage values as, when performed by Traditional Owners, this activity supports traditional use and maintenance of cultural practices. Assessments for the threats 'illegal activities' and 'extraction of herbivores' did not include consideration of illegal fishing and poaching activities, due to the separate assessment conducted for 'illegal fishing and poaching'.

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. Figure 9.2 links these individual threats to their probable causes (the factors identified in Chapter 6 as key influences on the condition of the Region's values) and indicates the spatial scale and likely timing of each threat's effect.

The threats that pose the highest risk are Region-wide in scale; most are already having an impact

The threats identified as highest risk are affecting the ecosystem and heritage values at a broad, often Region-wide, scale and are happening now. Most of the very high risk threats are associated with climate change or land-based run-off, and the remainder are linked to coastal development (modifying coastal habitats) and direct use of the Region (illegal fishing and poaching, and incidental catch of species of conservation concern). The threats rated as high risk are almost all related to direct use, at both Region-wide and local or regional scales (for example, extraction of predators, discarded catch, marine debris, damage to reef structure, and several threats related to the ability of Traditional Owners (and others) to access and maintain cultural heritage). Overall, 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.

9.3.4 Highest risk threats

Based on assessments of the 45 identified threats (Figure 9.1 and Figure 9.2), the 10 threats identified in 2014 as presenting a very high risk to the Region's ecosystem and heritage values are again rated as very high risk. Another 11 and 14 threats are rated as high risk to the Region's ecosystem and heritage values, respectively. Very high is the highest level of risk in the assessment matrix (Appendix 7); no further increase in risk level occurs even if a threat's likelihood continues to increase or its consequences continue to worsen.

The threats that pose highest risk arise from climate change, coastal development, land-based run-off and some aspects of direct use

Climate change remains the single most pervasive and persistent influencing factor, with four climate change-related threats posing very high risk (and one posing high risk) to the Reef on a Region-wide scale (Figure 9.2). These risks are predicted to increase in the future (Sections 3.2 and 6.3). The implications of global tipping points in the physical climate system are of urgent concern[487] (Section 6.3.1). Not only is the direct influence of these threats on the Region's values significant, they also have the potential to exacerbate and amplify the impact of other threats. For example, corals already under stress due to poor water quality and interactions with direct use activities (such as fishing) may be further stressed by the effects of sea-temperature rise (such as increased frequency, distribution and intensity of coral bleaching). The effects of these threats may also exacerbate the susceptibility of corals to disease (Section 3.6.1).[2,990,1421,1473]

Risks to Indigenous, historic and other heritage values from activities that physically disturb or place material on the seafloor may be underestimated because systematic identification and understanding of the extent and location of many heritage values (for example, burial sites, wrecks and archaeological sites) is limited. The potential for significant or permanent damage to sites of particular cultural or historical importance is a concern.

Figure 9.2 Summary of threats arising from factors influencing the Region's values, and associated scale, timing and risk level
This figure links identified threats with the key factors (Chapter 6) that have most influence on them, either directly or indirectly. Instances where a factor is likely to only have an insignificant influence on a threat are not displayed (no dot shown). The risk level for each threat is shown, along with the scale of the risk and expected timing of the effects of the threat.

Threat	Risk		Timing	Influencing factor			
	Ecosystem	Heritage values		Climate change	Coastal development	Land-based run-off	Direct use
▨ Altered weather patterns	🟪	🟪	▲	●			
▨ Sea-temperature increase	🟪	🟪	▲	●			
▨ Ocean acidification	🟪	🟪	▲	●			
▨ 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	🟪	🟪	▲				●
▨ Altered ocean currents	🟥	🟥	▲	●			
▨ Barriers to flow	🟥	🟥	▲		●		
▨ Marine debris	🟥	🟥	▲			●	●
▨ Discarded catch	🟥	🟥	▲				●
▨ Extraction of particle feeders	🟥	🟥	▲				●
▨ Extraction of predators	🟥	🟥	▲				●
▨ Fragmentation of cultural knowledge		🟥	▲				●
▨ Foundational capacity gaps		🟥	▲				●
▨ Incompatible uses		🟥	▲				●
░ Artificial light	🟥	🟥	▲		●		●
░ Damage to reef structure	🟥	🟥	▲				●
░ Extraction from spawning aggregations	🟥	🟥	▲				●
░ Illegal activities — other	🟧	🟥	▲				●
░ Pesticide run-off	🟥	🟥	▲			●	
░ Outbreak of disease	🟥	🟥	▲	Cumulative effect of many factors			
░ Outbreak of other species	🟧	🟧	▲	Cumulative effect of many factors			
░ Terrestrial discharge	🟧	🟧	▲			●	
░ Acid sulfate soils	🟧	🟧	▲		●	●	
░ Disposal of dredge material	🟧	🟧	▲		●		●
░ Dredging	🟧	🟧	▲		●		●
░ Noise pollution	🟧	🟧	▲		●		●
░ Exotic species	🟧	🟧	▲		●	●	●
░ Behaviour impacting heritage values	🟧	🟧	▲				●
░ Damage to seafloor	🟧	🟧	▲				●
░ Extraction of herbivores	🟧	🟨	▲				●
░ Grounding — large vessel	🟧	🟧	▲				●
░ Grounding — small vessel	🟧	🟧	▲				●
░ Spill — large chemical	🟧	🟧	▲		●		●
░ Spill — large oil	🟧	🟧	▲		●		●
░ Vessel strike	🟧	🟧	▲				●
░ Vessel waste discharge	🟧	🟧	▲				●
░ Wildlife disturbance	🟧	🟧	▲				●
░ Atmospheric pollution	🟨	🟨	▲		●		●
▨ Genetic modification	🟨	🟨	5+				●
░ Spill — small	🟨	🟨	▲				●

Threat	Risk		Timing	
▨ Region-wide	🟨 Low risk	🟥 High risk	▲ Now	10+ More than 10 years
░ Local or regional	🟧 Medium risk	🟪 Very high risk	5+ More than 5 years	

9.3.5 Trends in risks to the Region's values

The risk level for a number of the threats to the Region's ecosystem has changed since the assessment presented in the Outlook Report 2014 (Figure 9.3).

Increases in assessed risk: Risk level has increased for seven threats: altered ocean currents, artificial light, damage to reef structure, extraction of particle feeders, illegal activities (not including illegal fishing and poaching), grounding of small vessels, and wildlife disturbance (Figure 9.3). Increases in a risk grade since 2014 have generally been attributed to an increased understanding of the threat, its distribution and frequency, or the likely severity of its consequences.

Some changes to ocean currents (for example, the East Australian Current) are starting to be observed, noting that the understanding of likely future consequences for the Region's ecosystems is limited.

Risks posed by several threats associated with direct use have increased; in other cases, management changes have mitigated risk increases

The current context of widespread elevated environmental stress on sensitive habitats (Chapters 2, 6 and 8) amplifies the overall consequences of minor disturbances or damage. Small vessel groundings and damage to reef structure (from anchors, snorkelling and diving fins, fishing equipment and other direct use interactions) are now considered to be more significant risks than they were in 2014. Anecdotally, these interactions are commonplace and reporting of damage to reef structure from them is likely to be low. Individual incidents may be relatively minor and people may not always be aware damage has occurred.

Extraction of particle feeders from the ecosystem by fishing activities was considered a medium risk in 2014. Since then a significant decline in the saucer scallop population has been detected and there are concerns around declining catch rates and potential localised depletion for some crab species (Section 5.4). Successful implementation of management reforms under the Queensland Sustainable Fisheries Strategy[892] may reduce the risk to crustaceans and other particle feeders in the future.

Since 2014, understanding has improved about the increase in artificial light glow emitted from ports and developed areas, and its effects on sensitive species, including those of conservation concern (Sections 2.4.10, 6.4.2 and 8.3.5). Also, people's ability to access the Region through vessel ownership and availability of boat ramps and road access continues to become more widespread (Sections 5.5 and 6.2.2). These factors, along with the ready availability of personal drones, have increased potential levels of wildlife disturbances.

The assessment of the threat posed by illegal activities (other than illegal fishing and poaching, which are assessed separately) now explicitly includes illegal damage to Indigenous or historic heritage sites and objects (Appendix 6). The risk posed to the Region's heritage values by this threat is considered high, an increase from a medium level of risk in 2014. This increase in assessed risk reflects the more specific inclusion of illegal damage to heritage sites within the scope of illegal activities, and also the concerns expressed by Traditional Owners and Reef managers regarding the potential for serious impacts as a result of some activities. The consequence of vandalism, looting and accidental illegal damage of places and artefacts of Indigenous or historic heritage value can be significant at multiple scales, and can be irreversible.

Risk posed by threats added to assessment: The four new threats not described or assessed in 2014 are considered to present a range of risks (from low to high) to the Region (Figure 9.3). Information on the likelihood and consequential impact of genetic manipulation (including assisted evolution[1134]) is expected to grow rapidly over the next decade as scientific knowledge and manipulation techniques advance and the results from various trials of restoration and adaptation interventions (including coral gardening) become available. Likewise, there is a need for an improved understanding around

↑	**Increased risk**
🟥	**Altered ocean currents**
🟥	**Artificial light**
🟥	**Damage to reef structure**
🟥	**Extraction of particle feeders**
🟥	**Illegal activities — other *(for heritage)***
🟧	**Grounding — small vessel**
🟧	**Wildlife disturbance *(for ecosystem)***
↓	**Decreased risk**
🟧	**Disposal of dredge material**
	Threats added to assessment
🟥	**Fragmentation of cultural knowledge *(for heritage)***
🟧	**Behaviour impacting heritage values *(for heritage)***
🟧	**Foundational capacity gaps *(for heritage)***
🟨	**Genetic modification**

🟨 **Low risk** 🟧 **Medium risk** 🟥 **High risk** 🟪 **Very high risk**

Figure 9.3 Threats with a changed risk level since 2014
Threats that have a different risk level in 2019 compared to 2014 are shown, as are threats added to the assessment in 2019. Seven threats are assessed as having a higher risk than in 2014. Where the change is only related to either the ecosystem or heritage values, this is indicated. One threat (disposal of dredge material) has a lower risk than in 2014, due to new management requirements that restrict some marine disposal of material from capital works.

the nature, intensity, distribution and impact of the three new heritage-related threats — behaviour that affects intangible heritage values; fragmentation of cultural knowledge; and foundational capacity gaps — so associated risk levels and management responses may be better informed.

Reductions in assessed risk: The risk posed to the Region's ecosystem and heritage values by disposal of dredge material has been lowered to medium (Figure 9.3). A reduced risk level is warranted given sea disposal of large amounts of capital dredge material is no longer allowed in the Marine Park (Section 5.7).

Unchanged risk levels: Ongoing and evolving management of direct use activities has, in general, resulted in stable risk levels for many associated threats. This effectiveness limits the risk of impacts on the Region's values from oil and other chemical spills, exotic species, large vessel groundings and other threats. Nevertheless, further effort to limit and reduce very high and high-risk threats from direct use is still needed. For example, reducing illegal fishing and poaching and incidental catch of species of conservation concern remains a high priority.

Climate change is an extremely significant influence on the Region, as reflected in the continued assessment of very high risk levels for the related threats (including sea-temperature increase and altered weather patterns). Similarly, risk levels for several coastal development-related threats have not changed since 2014. Barriers to flow and modification of coastal habitats continue to be of concern given the implications for functional connectivity among terrestrial, freshwater and marine ecosystems and the delivery of ecological services to the Region.

9.3.6 Effectiveness of threat management

It is widely acknowledged that many of the threats with the highest risk levels originate outside the Region. The overall risk associated with climate change (very high), coastal development (high) and land-based run-off (high) have remained the same as in the 2009 and 2014 Outlook Reports. However, the effectiveness of management in relation to climate change has continued to weaken (Figure 9.4, Sections 7.3.9 and 7.6).

Some Region-wide threats have the highest risk levels and are being managed least effectively, particularly those related to climate change

By contrast, positive management effectiveness gains have occurred for coastal development in almost all parts of the management cycle, and also for the inputs and outputs aspects of management of land-based run-off (Figure 9.4, Sections 7.3.10, 7.3.11 and 7.6). Progress in reducing threats related to land-based run-off relies heavily on industry members voluntarily adopting best practice land management, and uptakes rates can be difficult to measure, accelerate and maintain. There are also time lags between on-ground action and better water quality outcomes in the Region (Sections 6.5 and 7.3.11). As a result, major improvements in effectiveness in terms of outcomes have not yet been realised for the Region's values. Development of northern Australia (including parts of the Catchment) may be a future influence on the risk posed by threats from coastal development and land-based run-off (Section 6.4.2).

The overall risk to the Region from direct use remains medium (Figures 9.2 and 9.4). Among the many uses of the Region, ports and fishing have begun major reform processes during the last five years. Some positive achievements have occurred for ports in the early stages of implementation (Sections 5.7 and 7.3.4). Nevertheless, maintenance dredging and disposal can still be permitted and, with larger ships visiting the Region (Section 5.8), port related infrastructure and activities may need to evolve to accommodate larger ships. This may increase the risk of damage to the seafloor (for example, from increased ship anchoring and resuspension of sediments from ship propellers).

Signs like this one at Cape Bowling Green help Reef users avoid fishing illegally. © GBRMPA

A vessel pushed up on the shore by cyclone Debbie in 2017. © GBRMPA

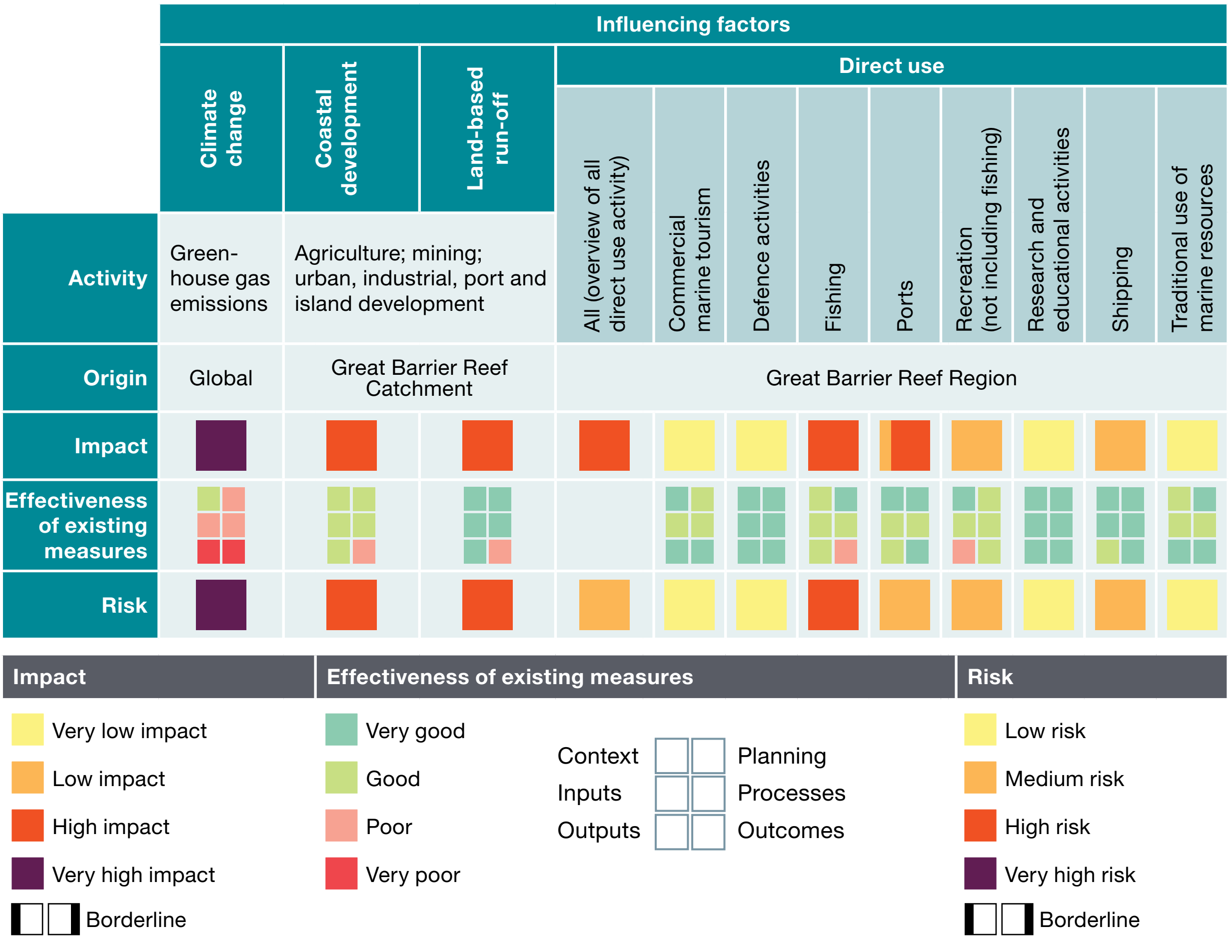


Figure 9.4 Management effectiveness, impacts and risk associated with factors influencing the Region's values
Impact grades for the factors influencing the Region's values (Chapters 5 and 6), the independent assessment of the effectiveness of current protection and management (Chapter 7), and overarching risk levels (Figure 9.2) are shown, including for component activities of direct use. The effectiveness grades are for the six elements of the management cycle (Chapter 7). The assessment for the topic of climate change is only in relation to management measures undertaken specifically to protect and manage the Reef. 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.

Management effectiveness gains in relation to fishing are expected to strengthen over the next five years through implementation of the Queensland Sustainable Fisheries Strategy (Sections 5.4 and 7.3.3).[892] Increasing coastal populations, changing demographics and expanding access in the north of the Catchment have the potential to increase risks associated with recreational fishing. This increased level of risk is based on recent information on rates of non-compliance with Marine Park zoning (Section 5.4.3).

The effectiveness of management for shipping, defence and research activities is, overall, very good (Section 7.6).

9.3.7 Cumulative impacts

The threats assessed individually in Figure 9.1 do not operate in isolation. Threats are connected through the geographic areas in which they occur, the timeframes in which they act, and the affect they have on the Region's natural heritage value (habitats, species, ecosystem processes) and Indigenous, historic and other heritage values. Cumulative impacts result from the interaction of effects from one or more threats as well as past, present and reasonably foreseeable future influences.[1467,1468]

Threats from climate change are having a critical and immediate impact on the Great Barrier Reef; they also intensify the effect of other threats

Impacts from a single threat can accumulate in a range of ways through time and space.[1468,1474] For example, seagrass meadows can receive sequential influxes of sediment-laden floodwater, a coral reef may not fully recover from a cyclone or marine heatwave before being affected by another one, a single reef may receive nutrients in land-based run-off from multiple catchments simultaneously, and ecosystem and heritage values can be exposed to both acute and chronic (long-term) effects of climate change. Some threats build up slowly over decades, while exposure to others can occur as acute events over short periods of time.

The cumulative effect of multiple threats is even more complex. Assessing cumulative impacts requires consideration of the direct, indirect and consequential impacts of threats that originate in the Region, the Catchment and globally (Figure 9.2 and Figure 9.5).[1475] On the Reef, coral reefs can be successively or simultaneously affected by crown-of-thorns starfish, cyclones and bleaching from thermal stress. Similarly, modification of coastal ecosystems and physical barriers within waterways and overland flow paths can have cumulative consequences in terms of altered connectivity between land and sea.[683,1476]

It is important to understand the area and time scale at which impacts are occurring and the scope of response needed to manage the relevant threats and impacts.[1474] Reef managers are increasingly likely to examine alternative strategies for management planning and intervention by using forecasting scenarios that explicitly consider climate, the global economy and other factors. Developing and implementing effective responses to cumulative impacts are areas of ongoing work for Reef managers, requiring continued evolution of policy and practical actions.[1467,1468,1477,1478]

The extent, nature and implications of the cumulative impacts on the Region's ecosystems from disturbances over the past 10 to 15 years are not yet fully understood. However, the extensive coral bleaching events in 2016 and 2017[88,91,141] highlighted the fragility of the system and the need to actively address climate change, continue efforts to support resilience, and reduce and manage all other threats (Chapters 6, 7 and 8).

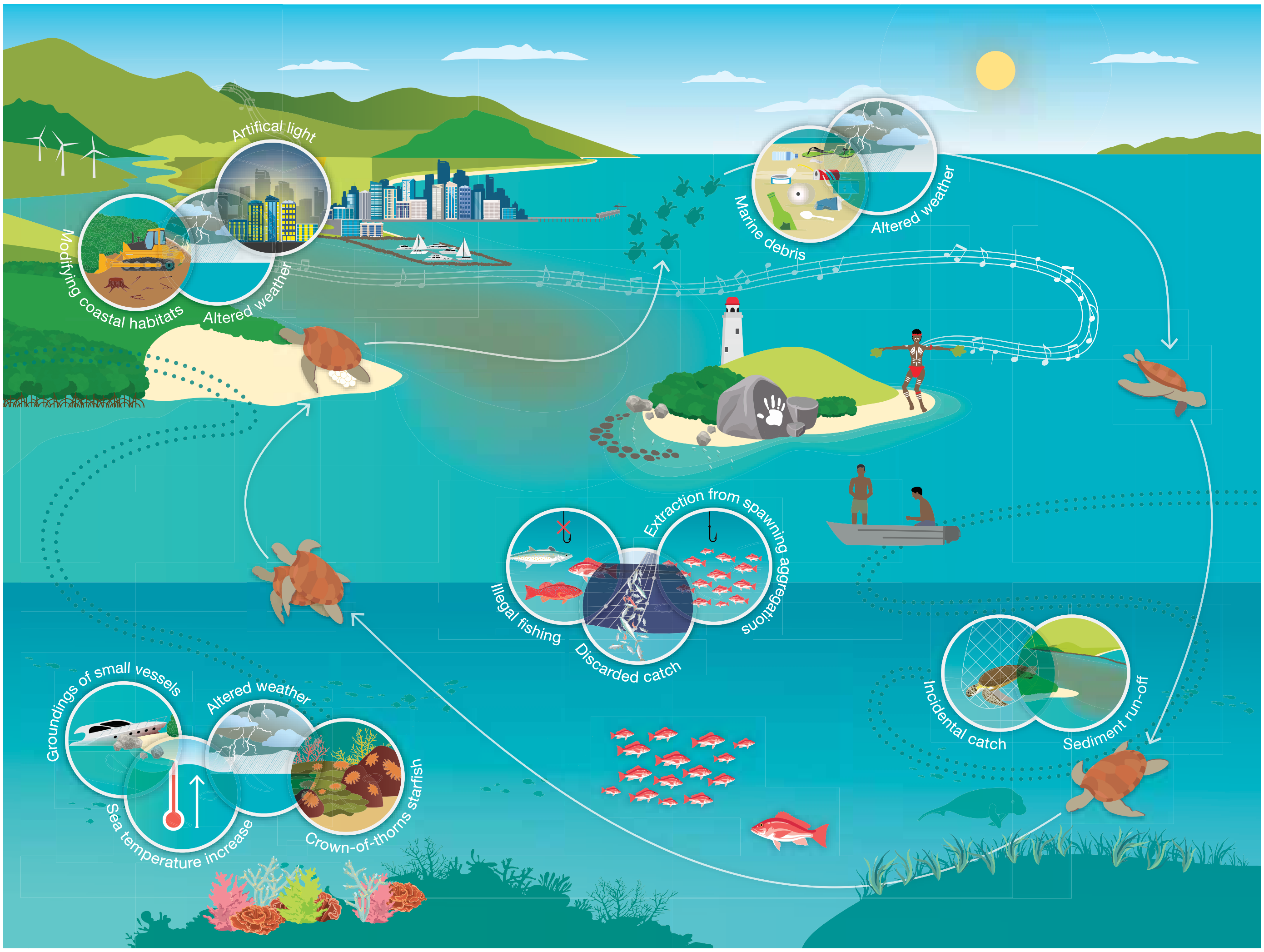


Figure 9.5 Threats to ecosystem and heritage values are cumulative
Multiple threats, including those presenting high risk to the Region's values, can affect an individual, species or habitat in multiple places and at multiple times. This exposure can combine to present a serious cumulative risk. The figure shows examples of location and lifecycle exposure.

9.4 Assessment summary — Risks to the Region's values

Paragraph 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.

Paragraph 116A(2)(b) of the *Great Barrier Reef Marine Park Regulations 1983* requires *'… an assessment of the risks to the heritage values …'* of the Great Barrier Reef Region.

Separate risk assessments are provided for the Region's ecosystem (natural heritage value) and its heritage values (Indigenous, historic and other) based on their current state and trends, factors influencing them, effectiveness of protection and management measures and an understanding of their overall resilience.

9.4.1 Risks to the Region's ecosystem and heritage values

Grading statements — risks

🟨	**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 ecosystem or heritage values. There may be minor or moderate consequences for the Region's ecosystem or 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 ecosystem or heritage values and none will have catastrophic consequences. Some unlikely threats may have major consequences for the Region's ecosystem or 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 ecosystem or heritage values.
🟪	**Very high risk**	Given current management arrangements, there are likely or almost certain threats that are predicted to have catastrophic consequences for the Region's ecosystem or heritage values.
⬜⬜	**Borderline**	Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	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

Grade and trend			Confidence		Criterion and component summaries	
2009	2014	2019	Grade	Trend		
🟥	🟥 ↑ ⍐	🟪 ↑ ⍐			**Overall risk to the ecosystem**	**Natural heritage values:** The threats likely to affect the Region's ecosystem in the future are increasing and compounding, placing the ecosystem at very high risk. The most serious risks arise from certain threats associated with 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.
	🟥 ⍐	🟪 ↑ ⍐			**Overall risk to heritage values**	**Indigenous, historic and other heritage values:** Many heritage values are closely connected to the ecosystem. The projected risk to the Region's heritage values from most threats are, therefore, the same as for the ecosystem. Heritage values are at very high and increasing risk. The most serious risks are climate change, land-based run-off, coastal development and some aspects of direct use.
🟪	🟪 ↑ ⍐	🟪 ↑ ⍐	●	●	**Climate change**	**Ecosystem:** The risk from climate change has continued to increase and the associated threats and their impacts are increasingly observed in the Region. Risk is likely to increase in future due to emission trajectories and unavoidable future climate change, locked in by past and current emissions.
	🟪 ⍐	🟪 ↑ ⍐	◐	◐		**Heritage:** The threats to the ecosystem associated with climate change flow on to present a serious risk to heritage values, particularly intangible Indigenous values and the Great Barrier Reef World Heritage Area's outstanding universal value.

Grade and trend			Confidence		Criterion and component summaries	
2009	2014	2019	Grade	Trend		
🟧	🟧 ↑ ↑	🟧 ↔ ↑	●	●	**Coastal development**	**Ecosystem:** Coastal development remains a serious risk to the Reef. The combined effect of modifications to coastal ecosystems across the Catchment is not irreversible but widespread and serious. The function of linked terrestrial–freshwater–estuarine–marine ecosystems is affected by barriers to flow and modification of coastal habitats. Artificial light from urban and industrial facilities and developments will continue to grow. Direct use creates demand for some aspects of coastal development. Further development of the northern portion of the Catchment is likely.
	🟧 ↑	🟧 ↔ ↑	◐	◐		**Heritage:** Legacy and some contemporary changes in terrestrial coastal habitats as a result of coastal development will continue to affect the outstanding universal value and integrity of the world heritage property. Natural aesthetic values may also be further diminished, along with Indigenous heritage values.
🟧	🟧 ↔ ↓	🟧 ↔ ↓	●	●	**Land-based run-off**	**Ecosystem:** The continuing inputs of nutrients, sediments and pesticides and the time lag between reduced inputs and improved ecosystem condition, mean land-based run-off will continue to be a serious risk to the ecosystem. Marine debris from all sources is likely to remain a high risk. If outcomes from current management efforts in the Catchment can be accelerated, future risk is expected to decrease.
	🟧 ↓	🟧 ↔ ↓	◐	◐		**Heritage:** Indigenous heritage values and the overall aesthetic value of wide areas of the Region will continue to be affected by declines in the condition of ecosystem values from pollutants carried by land-based run-off. Attributes of outstanding universal value will continue to diminish, especially in inshore areas. If outcomes from current management efforts in the Catchment can be accelerated, future risk is expected to decrease.
🟨 (non-extractive) 🟧 (extractive)	🟨 ↑	🟨 ↑ ↑	●	●	**Direct use**	**Ecosystem:** While some threats from direct use are of low risk to the Region's values, others continue to pose a significant risk. Illegal fishing and poaching, extraction of predators and particle feeders, extraction from unidentified or unprotected spawning aggregations, incidental catch of species of conservation concern and discarded catch are all rated as high or very high risk. The escalating activity around active physical interventions in the Region (for example, coral gardening and assisted evolution) to support the resilience of the Reef has introduced more threats to consider.
	🟨 ↑	🟨 ↔ ↑	◐	◐		**Heritage:** The risks that direct use presents to the ecosystem (and its associated natural beauty) are reflected in its risk to heritage values. Risks may arise from some threats that cause serious or irreversible damage to heritage sites and artefacts (for example, vandalism). The effects of fragmentation of cultural knowledge and undesirable behaviours at heritage sites are likely to continue, and may affect the ability of Traditional Owners to undertake cultural practices.

9.5 Overall summary of risks to the Region's values

Based on current management, the Region's ecosystem and heritage (natural, Indigenous, historic and other heritage) values face a range of increasing risks in the future. The identified threats to the Region's values arise from a range of sources and are highly variable in both scale and timeframe. The close connections between ecosystem components and heritage values mean the projected risk for many threats is equivalent for both sets of values. The 2019 risk assessment considers several threats not examined in 2014. These threats have been added either because of their emerging relevance to the Region or to better capture influences on heritage values.

Of the very high risk threats, most relate to climate change or land-based run-off (water quality)

The overall risk to both ecosystem and heritage values is very high, and has increased since 2014. The most serious threats are those associated with climate change, land-based run-off, coastal development and some aspects of direct use (including the remaining impacts of fishing).

The implications of global tipping points in the physical climate system are of urgent concern. Threats associated with climate change, such as increased sea temperatures, altered weather patterns, ocean acidification, and rising sea level, are expected to become increasingly severe in the future. Each impact will be compounded by the others, as well as by other existing regional and local threats. This amplifies the risk they pose to the Region's ecosystem and heritage values. Significant impacts from sea temperature increases and extremes have already occurred in the Region.

Land-based run-off and coastal development are assessed as posing high risk overall. Nevertheless, some positive gains have been made since 2014 in management effectiveness for coastal development and land-based run-off, and the risk from associated threats may decrease somewhat over time as a result. Proposed development of the northern part of the Catchment could have significant implications for threats to the Region's values.

Threats identified as posing the highest risk are already affecting ecosystem and heritage values at a Region-wide scale

Management arrangements are keeping many risk levels stable; examples include the continued strong management of direct uses, such as defence, research activities and shipping. Direct use of the Region is assessed overall as a medium risk. However, at a more detailed level, some significant risks remain. Fishing activities contribute to multiple threats assessed as posing very high risk (illegal fishing and poaching and the incidental take of species of conservation concern) and high risk (discarded catch, extraction from unprotected or unidentified spawning aggregations, and extraction of particle feeders, predators and herbivores).

Across the whole assessment, only one risk has decreased since 2014 — the risk posed by disposal of dredge material. It has decreased from high to medium because of new management measures that restrict disposal of material from capital dredging. Maintenance dredging remains an ongoing activity.

Community members viewed climate change, pollution (including marine debris), land-based run-off and fishing as among the greatest threats to the Region. Community concern about some threats, including marine debris and extreme weather events, appears to have increased since 2014.

There is a very real and present danger that the combination of threats present in the Region will continue to weaken the resilience of the Reef ecosystem. As a consequence, the Reef's ability to recover from serious and increasingly frequent environmental disturbances (such as mass coral bleaching events) remains at high risk. The need for a combination of Reef-wide, regional and local solutions is well recognised, as is the importance of continuing to improve methods for understanding and responding to cumulative impacts.

Painted sweetlips at Lizard Island. © Victor Huertas 2017

CHAPTER 10

LONG-TERM OUTLOOK

« *People's experiences when they visit, recreate and work in the Region may be different in the future.* © Matt Curnock

LONG-TERM OUTLOOK

'an assessment of the long-term outlook for the ecosystem…' within the Great Barrier Reef Region, s 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, paragraph 116A(2)(f) of the
Great Barrier Reef Marine Park Regulations 1983

10.1 Background

Chapters 2 to 9 of this Report provide the evidence to inform an assessment of the long-term outlook for the Region's ecosystem and heritage values. Specifically, the long-term outlook discussed below is built from an understanding of: current condition and trend of the ecological (natural heritage value), economic, social and heritage (Indigenous and historic) values of the Region (Chapters 2, 3, 4 and 5); the factors influencing 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 the risks the ecosystem and heritage values are facing (Chapter 9). Figure 10.1 summarises key findings from these chapters.

The main influences on the long-term outlook for the Region include human-induced climate change, population growth, land-based run-off and direct use of the Region (Chapters 5 and 6). These drivers and pressures interact, resulting in cumulative effects on the condition and trend of values.

Everyone's actions are important. © GBRMPA, photographer: Pine Creek Pictures

Values

CHAPTER 2

Biodiversity

- The condition of seagrass meadows and coral reefs, the habitats most is known about, are assessed as being poor and very poor. Most other habitats are considered in good condition, although less is known about them and confidence in grades is lower.
- Several species or groups of species have deteriorated since the last Outlook Report. Over half of those assessed are in poor condition and corals are in very poor condition.
- Unprecedented declines in coral habitat since 2016 across the northern two-thirds of the Region have outweighed recovery.
- Inshore seagrass meadows have not recovered as quickly as expected since disturbances in 2011–12.
- Heightened concerns exist for the future of loggerhead, hawksbill and northern green turtles, due to climate change and fishing pressures outside the Region.
- Humpback whale and southern green turtle populations continue to recover strongly.

CHAPTER 3

Ecosystem health

- Sixty per cent of 31 assessed ecosystem health components remain in good to very good condition; the remainder are in poor to very poor condition.
- Region-wide deterioration has occurred in ecological processes, including symbiosis, recruitment and reef building.
- Connectivity, which is crucial for recovery from disturbance, remains in good condition.
- Vegetation clearing in the Catchment continues to contribute to soil erosion and release of fine sediment into the Region.
- A crown-of-thorns starfish outbreak has persisted and expanded for almost a decade, causing significant coral damage across much of the Region.

CHAPTER 4

Heritage values

- Declines in natural heritage values are affecting Indigenous and world heritage values.
- Commonwealth historic heritage and other heritage values (social, aesthetic and scientific) are being maintained.
- Outstanding universal value remains intact but is being increasingly challenged.
- The size of the World Heritage Area is becoming less effective as a buffer to disturbance, particularly against the broadscale impacts of climate change.

Values | Threats, responses and risks

CHAPTER 5

Commercial and non-commercial use

- Marine tourism visitation has generally increased since 2014.
- Fishing practices and management continue to improve. Sustainability concerns exist for some species and illegal fishing and poaching remain issues.
- Legislative changes have improved management of ports and shipping, reducing capital dredge material disposal and the risk of shipping incidents. Increasing size and numbers of ships continues to be a concern.
- Research and monitoring remain critical to effective management of the Region.

Outlook

CHAPTER 10

Long-term outlook for the Region's ecosystem and heritage values

Figure 10.1 Summary of the findings underpinning the long-term outlook for the Region's ecosystem and heritage values

Threats, responses and risks

Factors influencing the Region's values

CHAPTER 6

- Societal attitudes about the Reef are complex and influence behaviours and decision-making.
- Overwhelmingly, climate change is the primary issue affecting the Reef, and its influence is increasing faster than previously predicted.
- Increasing and record-breaking sea temperatures have affected the Region and pose the most immediate threat to values.
- Efforts to improve water quality entering the Region have resulted in a gradual reduction in some pollutants from the Catchment. However, water quality targets are not being met, which is compounding the effects of climate change and slowing recovery of inshore ecosystems.
- Poor agricultural land management practices in the Catchment remain the greatest contributor to poor water quality.
- Past and current development (such as land clearing and modification of waterways) in the Catchment continues to affect the Region.
- Human population in the Catchment is expected to grow at 1.1 per cent per year, further increasing direct use of the Region (for example, tourism, recreation and recreational fishing).

Existing protection and management

CHAPTER 7

- Management of the Region is good across all six effectiveness criteria when considering the 14 management topics as a group.
- The Reef 2050 Plan has improved jurisdictional consistency, coordination and resourcing across many management topics.
- Improvements within management topics are most notable for ports, heritage values and fishing.
- Declines in effectiveness occurred for some aspects of managing biodiversity values, climate change and recreational use (excluding fishing).
- Management challenges remain for complex, spatially extensive values such as biodiversity and threats from climate change, land-based run-off and fishing.
- Some threats (such as sea-temperature increase) are both global and national issues, not directly in the control of day-to-day Reef and Catchment managers. For other threats, recent plans have not had time to translate into outcomes (such as the Queensland Sustainable Fishing Strategy).
- Knowledge of ecosystem and heritage condition is not keeping pace with disturbance frequency, delaying management actions.

Resilience

CHAPTER 8

- Case studies of some species show continuing recovery from past impacts, but concerns remain for other species. Humpback whales have demonstrated resilience by continuing to recover strongly since harvesting ended outside the Region.
- Reef resilience is being severely compromised by global warming, which has resulted in mass mortality of adult coral and subsequent 89 per cent decline in coral recruitment.
- Loggerhead turtle recovery may be affected by low levels of juvenile recruitment.
- Community awareness and appreciation are important to the resilience of the Region's historic and Indigenous heritage values. Lack of data makes the current state of heritage resilience difficult to quantify.
- The Region's resilience has deteriorated due to an increased frequency of disturbances; ecological recovery from recent disturbances will take far longer as a result.
- Sea-temperature extremes and other threats will continue to undermine resilience.
- Management actions at all scales are needed to reduce drivers, support recovery and build resilience. For example, localised coral reef restoration efforts are increasing and the largest ever crown-of-thorns starfish control program is underway.

Risks

CHAPTER 9

- Threats identified as posing the highest risk are already affecting ecosystem and heritage values at a Region-wide scale.
- The 10 threats identified in 2014 as presenting a very high risk to the Region's ecosystem and heritage values are again the highest ranked.
- Of the very high risk threats, most relate to climate change or land-based run-off (water quality).
- Direct use impacts are amplified by climate change and pose ongoing risk given the declining state of the Region's ecosystem.
- Interest in habitat restoration and other interventions is increasing, and the risks posed by these activities are not yet well understood.
- Developing and implementing effective responses to cumulative impacts requires continued evolution of policy and practical actions.

10.2 Likely future trends

Given the current state of the Region's values, actions to reduce the highest risks have never been more time-critical. Strong mitigation actions within the next decade are necessary to achieve the best possible outlook for the Reef and future generations.[1141] Specifically, early and effective global and national action on climate change, coupled with local actions to maintain condition and facilitate recovery from disturbances, are imperative over the next 10 years if the Region is to have a positive long-term outlook.

10.2.1 Possible long-term futures for the Region

The condition of the Region is deteriorating due to anthropogenic global warming and other escalating drivers (such as population growth). Even a scenario of reduced greenhouse gas emissions that could restrict a global temperature increase to less than 1.5 degrees Celsius (which is what the Reef needs) would still see substantial changes occurring to marine ecosystems and associated community benefits.[1159] Future coral reefs are unlikely to be as diverse and colourful as they were a decade ago[273], and the fish life seen while snorkelling and caught while fishing may also change. People and Reef-dependent industries need to prepare for this change.

Actions taken now can influence the Reef's future pathway

Figure 10.2 shows two possible futures for the Region, for the medium term (2030 to 2050) and long term (beyond 2050). These possible long-term outlooks are indicative, and are based on information presented in preceding chapters of this report.

Whether the Region's condition continues to deteriorate depends on a combination of immediate global action on climate change[1129], effective management of remaining risks that originate within the Region and its Catchment, and the Region's resilience. At a regional level, the rate and scale at which water quality can be improved is also a critical factor for coastal habitats. Locally, given a steadily increasing Catchment population, use of the Reef will grow, requiring effective and agile Marine Park management and compliance.

The Reef has limited capacity to adapt to the current rate of climate change. The scale of the threats posed by climate change means further change to the Reef ecosystem is inevitable. Notwithstanding the seriousness of the challenges the Region faces, there is still hope for its recovery if effective and timely mitigation of risks occur within the next decade. By protecting the environmental and heritage values of the Region, the lifestyles and livelihoods of the communities who live on its coastline and the intrinsic value to the global community will also be maintained. All actions that promote recovery processes and limit further decline will improve the Region's long-term outlook.

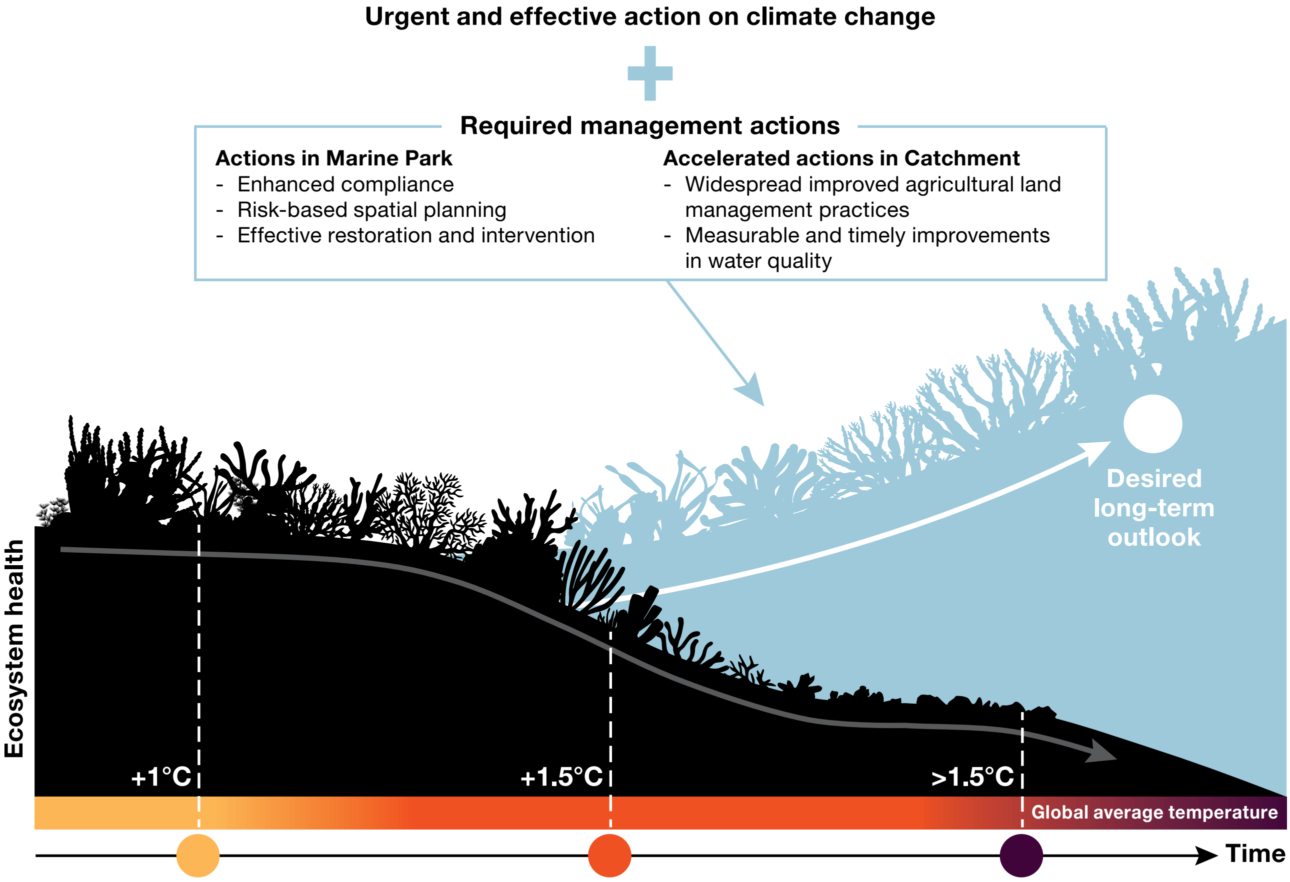
10.2.2 Prospects for the outstanding universal value of the Great Barrier Reef World Heritage Area

The spatial extent of the World Heritage Area has not changed. However, the Reef is being increasingly exposed to broadscale impacts that are affecting it at a regional level. Given the global scale of human-induced climate change, the size of the Region is becoming a less effective buffer to broadscale and cumulative impacts. While the property is still whole and intact, recent temperature extremes have forever changed the World Heritage Area and its integrity is deteriorating. World heritage attributes that remain in good condition at a Region-wide scale include the geographic scale and extent of the property, over half of the ecosystem processes, most habitats (noting large data gaps exist for many habitats) and some species components.

The property's outstanding universal value will be further impacted as the ocean continues on its rapid warming trajectory

Outstanding universal value remains across all four criteria for which the Reef was inscribed on the World Heritage List. However, the condition of the property has deteriorated to varying extents with respect to criteria vii, viii, ix and x:

- The beauty of underwater seascapes (criterion vii) is deteriorating (in terms of water clarity and coral reefs) and tourists surveyed believe the beauty of the Reef has declined since 2013.[785]
- Overall, there has been alteration of some elements important to major stages of the Earth's evolutionary history (criterion viii) (Section 4.2.3).
- One third of the ecosystem processes assessed (criterion ix) are in poor to very poor condition (Chapter 3), including several critical processes essential for whole-of-system functioning (recruitment, symbiosis and reef building).
- Two of the Region's most important habitats, seagrass meadows and coral reefs, support a high diversity of species including species of conservation concern (criterion x) and are in poor and very poor condition, respectively (Chapter 2).



2019 — Current Reef condition

- World heritage values deteriorated
- Less diverse coral reefs and some reef fish declining
- Coral bleaching events and other impacts accumulating, and recovery time increasing
- Intensifying pressures are slowing seagrass meadow recovery
- Warmer temperatures cause more female and fewer male marine turtles
- Indigenous heritage and community wellbeing impacted
- A stable nature-based tourism industry, but in restricted locations as areas recover post-disturbance
- Viable fishing industries, but lower catches post-disturbances

2030 to 2050 — Possible Reef

- World heritage elements significantly deteriorated
- More drab looking reef with fewer branching and plate corals
- Fewer colourful reef fish
- Loss and degradation of some seagrass meadows
- Annual marine heatwaves twice as likely
- Unreliable weather affects reef use
- More island-based and water sport tourism; less snorkelling and diving
- Fisheries may target different species, more disease prevalence in fish and crustaceans

2050 onwards — Possible Reef

- World heritage elements lost and not intact
- Coral reefs replaced with flatter, more drab, algal-dominated systems
- Major reductions in seagrass abundance
- Mangroves shift shoreward in response to rising sea level
- Coastal protection reduced and coast less habitable
- Turtles, seabirds and dugong in rapid decline
- Annual marine heatwaves three times as likely
- Extreme weather events far more frequent
- Irreversible impacts to Indigenous heritage and community wellbeing
- Fisheries may transition to new products and markets (algae and herbivorous fish)

Figure 10.2 Future pathways for the Great Barrier Reef Region
The two outlook pathways shown provide examples of what the future might look like depending on whether key risks are adequately mitigated within required timeframes.[96,1139,1141,1159,1172,1479] *The pathways are indicative and based on a large body of evidence from the previous chapters. Reef condition and social values have already changed and will continue to change. The desired outlook pathway is still possible if global, regional and local mitigation and management actions are accelerated and implemented in time.*

Previously, when the climate regime was considered more stable, protection and management approaches were generally considered to be effective in protecting the World Heritage Area. However, the Great Barrier Reef World Heritage Area, like other world heritage properties globally, is increasingly affected by anthropogenic climate change.[1480] Australia and many other countries will find it increasingly challenging to deliver effective protection and management for their world heritage listed properties. To combat the deterioration of values, managers, Traditional Owners and stakeholders are increasingly intervening where the condition of critical habitats or species can be improved (Chapter 8). The most significant interventions for World Heritage Area values have been on the Reef's islands, where active conservation actions have protected critical nesting habitats for vulnerable species and restored ecosystems.[1481]

While understanding of the Region's heritage values remains far from comprehensive, an increased effort is progressing under the *Reef 2050 Long-Term Sustainability Plan*[1482] to improve this knowledge base. Building on previous efforts, heritage values continue to be better defined, including aesthetic[1010,1483] and geomorphological[655,795,1484] attributes and Indigenous heritage[814] values (Chapter 4).

10.3 Current and future initiatives to improve the long-term outlook

Threats are multiple, cumulative and increasing, requiring constantly evolving and agile management approaches

Predicting the long-term outlook for the Reef remains a complex task. Threats to the Reef are multiple, cumulative and intensifying, requiring constantly evolving and agile management approaches. Finding increasingly effective ways to plan for, and respond to, the Reef's rapidly changing environmental and social condition is essential.

The assessment of the long-term outlook for the Region's ecosystem and its heritage value includes consideration of current management arrangements and relevant management initiatives identified but not yet fully implemented (Figure 10.3). The future initiatives under the Reef 2050 Plan[9,941], the *Great Barrier Reef Blueprint for Resilience*[24], and the *Reef 2050 Water Quality Improvement Plan*[527] set the framework for improving resilience-based management and protection of values. Also considered here are the future commitments of both the Australian and Queensland governments and partners under the Reef 2050 Plan.[9]

Several significant management initiatives have been in place for some time and continue to protect values and support resilience of the Region. In spite of this, the resilience of the Region is deteriorating. The scientific evidence is clear — the most urgent initiatives are those that will halt and reverse climate change at a global level and effectively improve water quality at the regional scale.[1396] In addition, there is some scientific consensus that controlling crown-of-thorns starfish populations is one of the most scalable and feasible on-ground actions for reducing coral mortality at local scales and enhancing Reef resilience in the face of increasing climate impacts.[752,757]

Engagement Ongoing and collaborative working relationships are the strongest they have ever been due to a greater collective understanding of pressures affecting the Region and shifting sentiments.[857] Stewardship within the Region and continued on-ground initiatives to reduce risks and improve Reef and catchment health are important and make a collective difference. This continued approach will provide a strong foundation for maintaining a balance between protecting the Region's values and supporting sustainable use.

Australian and Queensland government agencies, Traditional Owners and many other partners continue to make significant contributions to protecting and managing the Region. The scientific research community and multi-generational ecological knowledge are both critical to inform effective management of the Region. A mature, independent and enduring research community and strong partnerships with Traditional Owners and Reef users are necessary to strengthen and enable effective management.

Many stakeholders and community members continue to participate in voluntary research and monitoring programs. These groups are becoming more active in delivering local management actions, such as removing marine debris and responding to marine animal strandings. Twelve Local Marine Advisory Committees, from Cooktown to Bundaberg, comprising more than 170 community members, continue to advise management agencies on local issues. A range of specialist advisory committees have been established since 2015 to advise government on matters relating to the Reef and help improve the quality, effectiveness and transparency of management actions. With increasing levels of partnership, local communities are undertaking specific actions to implement the Reef Blueprint.[24]

Environmental regulation Effective education and enforcement of current management tools, such as regulations, zoning plans, plans of management and permits, will continue to be important in reducing direct risks to the Region and supporting resilience of the Reef. To enable this, significant investment in the Reef Joint Field Management Program has increased the capability of marine and island national park management (Box 15). Initiatives are underway to transform Marine Park policy and planning and the regulatory framework, specifically to modernise the risk approach and make sure policies and plans are contemporary, pre-emptive and strategic so they can adapt to how people want to use and access the Reef in a sustainable manner.[24,1485]

Overarching

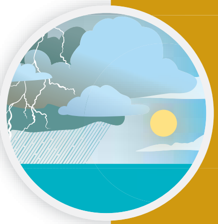
- *Reef 2050 Long-Term Sustainability Plan* (2018) and Reef Trust investment
- *Great Barrier Reef Blueprint for Resilience* (2017)
- Reef 2050 Integrated Monitoring and Reporting Program
- Scientifically valid, ongoing monitoring involving the community

Natural heritage values (biodiversity and ecosystem health)

- Reef Joint Field Management Program — expanded biodiversity protection and enhanced compliance activities
- *Queensland Sustainable Fisheries Strategy 2017-2027* — commitment to implementation and outcomes
- Crown-of-thorns starfish control — expanded efforts to protect coral cover
- Islands and fringing reefs — Queensland Government values-based framework for Queensland islands
- Reef Restoration and Adaption Program — implementation

Heritage values (Indigenous and historic)

- *Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park* (2019) — increasing understanding and protection of Indigenous heritage



Climate change

- *Queensland Climate Transition Strategy* and *Queensland Climate Adaptation Strategy* (2017)
- Marine Park Authority climate change position statement — due for release 2019
- Options paper on post-2020 action to transition Queensland to a zero net emissions economy by 2050
- National Environmental Science Program— long-term commitment to environment and climate research
- Clean Energy Finance Corporation and the Australian Renewable Energy Agency — Reef funding program
- State-wide Land Restoration Fund— support for carbon-reduction projects

Coastal development and land-based run-off

- *Reef 2050 Water Quality Improvement Plan* (2018)
- Queensland vegetation management laws and State Planning Policy
- *Sustainable Ports Development Act 2015* (Qld) — management of port related development
- *Wetlands in the Great Barrier Reef Catchments Management Strategy 2016–21*

Direct Use

- Public moorings and reef protection markers — expanded network
- *North-East Shipping Management Plan* — revision due for release 2019
- Port master plans and *Maintenance Dredging Strategy for Great Barrier Reef World Heritage Area Ports*
- Vessel monitoring — for commercial fishing vessels
- Traditional Use of Marine Resources Agreements — expanded coverage
- Marine debris reduction initiatives — national threat abatement plan, Marine Park Authority position statement, and funded citizen science programs

Improved resilience of the Great Barrier Reef Region

Figure 10.3 Current and future initiatives to improve the Region's values and support resilience

BOX 15

Expansion of island and marine park management capacity

Rangers inspecting newly installed moorings at Yanks Jetty, Orpheus Island. © Queensland Parks and Wildlife Service 2019

Since the last Outlook Report, the Reef Joint Field Management Program has received a number of funding and capacity increases. In 2017–18, the Australian and Queensland governments provided an additional $73.7 million over six years, with an ongoing commitment of a further $20.6 million per year. This is the largest expansion of the program since its inception in 1979. An additional $6 million has been put towards construction of a second 24 metre vessel and increased operating funds, which will enter service in 2019. The program also administers $5 million to $9 million annually from a number of sources to deliver additional field activities that would otherwise not be achievable, such as the Raine Island Recovery Project, expansion of Whitsunday Island visitor facilities and expansion of reef protection infrastructure.

The program is responsible for practical, on-ground delivery of marine and island national park management. The additional funding will enable delivery of field activities identified in the Reef 2050 Plan and Reef Blueprint. The program's on-water capacity has been drastically increased, growing from an annual base funding commitment of $17 million to over $38 million in 2020–21. This funding will see more than a sixty per cent increase in staffing and an enhanced vessel fleet of more than 21 vessels (including two 24 metre vessels). This will enable an increased focus on compliance, island and reef restoration activities, incident response, collaboration with Aboriginal people and Torres Strait Islander people to deliver field activities, and engagment with Reef and island users.

Knowledge, integration and innovation The independent management effectiveness review (Chapter 7) rated managers' understanding of the Region and its stakeholders as the strongest element of management overall. This reflects the large body of collaborative research and monitoring effort undertaken to date. Despite this, researchers and managers are finding it increasingly difficult to maintain up-to-date knowledge of ecosystem and heritage condition, given the rate and cumulative nature of disturbances in the Region. Following the 2014 Outlook Report, a review of the available scientific and other knowledge about the Region was undertaken and gaps were identified. The resulting report, *Science Strategy and Information Needs 2014–2019*[6], summarises high-priority science needed to improve management of the Reef. This report will be updated following release of the 2019 Outlook Report and will be critical to informing future research needs and resourcing.

Developing ways to understand and respond to the effects of cumulative impacts on the Region's values remains paramount, and is guided by a Reef-wide policy released in 2018.[1468] While implementation of this policy is underway[1486], cumulative impact management of multiple uses in and adjacent to the Region remains a challenge, especially as some uses are highly regulated (ports and tourism) while others are not (recreational fishing). Escalating climate change pressures have heightened the importance of implementing this policy and progressing pre-emptive spatial planning in the Region and Catchment.

Effective Reef management will increasingly require access to integrated information on Reef condition, Catchment inputs and human use of the Region

Agile approaches are needed to protect key values and prevent undesirable human use patterns becoming entrenched, unsustainable and hard to manage. To do this, managers require up-to-date spatial and temporal information on how and where people use the Region and the condition of associated local environmental, Indigenous and social values. Additionally, access to the best available science from a network of providers will continue to underpin management and allow evaluation of the effectiveness of actions. Access to relevant information on biological and human dimensions will be key to supporting evolving policies and spatial planning.

Implementing a Reef-wide integrated monitoring and reporting program that directly links to an outcomes-based management framework will underpin a transformative adaptive management approach. The Reef 2050 Integrated Monitoring and Reporting Program (RIMReP), which is under development by the Marine Park Authority and many partner agencies, aims to address integrated information needs for future management of the Reef (Box 16). The RIMReP monitoring program and online platform will provide access to up-to-date, reliable information to support pre-emptive planning and responsive management. For example, it will provide information to inform management and provide guidance on where to best target crown-of-thorns starfish culling and increased compliance efforts.

Given the increasing frequency of acute and chronic stressors, timely information on the health of key indicators and their trajectories (species, processes and human dimension values) over time and space is critical. Thresholds for ecosystem health and community wellbeing are being developed through RIMReP to measure condition and trend of values. Good alignment between what is measured, how it relates to relevant thresholds, and how that is meeting the desired outcomes for the Region's values will provide the most powerful insight.

There is also an immediate need to explore scalable and effective strategies and technologies for restoring degraded habitats.[1026,1487] Research into reef restoration is being expanded under the Reef Restoration and Adaptation Program.[1026] The program is currently investigating and developing feasible restoration techniques that can be applied at sufficient scale to have a positive effect on Reef condition. This will require a combination of discovery research and applied field testing. Given the connection to, and value of, the Region for Traditional Owners and the community, those undertaking restoration activities must understand and consider social attitudes. Information on how restoration activities can be effective at scale, while minimising harm, is important for researchers, managers and the community.

Investment in innovative field-based and desk-top technologies is needed to support improvements in monitoring and management. Increasing use of drones, night vision and vessel tracking will increase surveillance and enforcement of Reef rules. Currently, drones are providing increased and cheaper monitoring capability and aerial mapping. Use of underwater acoustic technology in compliance is an emerging innovation[1488], which could be used to detect fishing vessels in areas where access or fishing is prohibited.

BOX 16

Bringing knowledge together for Reef management

The vision for the Reef 2050 Integrated Monitoring and Reporting Program is to develop a knowledge system for resilience-based management of the Reef and its Catchment. It will also provide managers with an understanding of how the Reef 2050 Plan is progressing.

Program development commenced in 2016 and more than 70 experts have been involved in the design of the program. A prototype, designed to be the first edition of the knowledge system, is scheduled for testing from mid–2019.

Program development focuses on three knowledge system components:

- **Collecting and integrating data:** For the first time, access to information from monitoring and modelling of the Reef's biophysical, social, economic, Indigenous and heritage values, as well as the drivers and pressures on those values, will occur through a centralised location.
- **Improving data access:** Enabling access to data through the knowledge system requires meeting sufficient standards for data management collection and sharing. This is a complex task involving input from those involved in collecting Reef data and establishing technical infrastructure.
- **Visualising data:** The knowledge system will allow users to access consolidated and integrated information, becoming a 'first-stop-shop' for Reef managers.

Monitoring programs provide vital information on reef health, such as the extent and severity of coral bleaching.
© Tane Sinclair-Taylor

The program's knowledge system is intended to enable the early detection of trends and changes in the Reef's environment. The goal is to drive effective, efficient and transparent management decisions. The knowledge system will evolve in response to changes in the Reef's condition, new science and technologies, and high-priority needs of management and stakeholders. It will be used to guide day-to-day decisions, shape strategic policy and inform future Great Barrier Reef Outlook Reports.

10.4 Assessment summary — Long-term outlook

Paragraph 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.

Paragraph 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.

Grading statements — long-term outlook

🟩 **Very good**
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.

🟩 **Good**
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.

🟧 **Poor**
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.

🟥 **Very poor**
Without urgent and effective additional management intervention, the values are likely to deteriorate rapidly with the loss of most values in the longer term.

☐☐ **Borderline**
Indicates where a component or criterion is considered close to satisfying the adjacent grading statement.

Trend since last report

↑	Improved
↔	Stable
↓	Deteriorated
▬	No consistent trend

Future trend

↑	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

10.4.1 Outlook for the Region's ecosystem

Grade and trend			Confidence		Criterion summary
2009	2014	2019	Grade	Trend	
🟧	🟧 ↓ ↓	🟥 ↓ ↓	●	●	**Outlook for the ecosystem:** The Reef has fundamentally changed since 2009. The threats affecting the Region's ecosystem (natural heritage values) are increasing, compounding and expanding in scale; they are driven strongly by climate change. Multi-jurisdictional solutions and on-ground management involving stakeholders and the community are highly valuable. However, outcomes are being undermined by climate change. The window of opportunity to influence the Reef's long-term future is now. Strong, effective management actions are urgent at global, regional and local scales.

10.4.2 Outlook for the Region's heritage values

Grade and trend			Confidence		Criterion summary
2009	2014	2019	Grade	Trend	
	🟩 ↓	🟧 ↓ ↓	◐	◐	**Outlook for heritage values:** Many of the Region's heritage values are closely tied to the condition of the ecosystem. The projected risk to these values from most threats is, therefore, the same as for the ecosystem. The most serious risks to the Region's heritage value are from climate change, land-based run-off, coastal development and some aspects of direct use. Identification and monitoring of the broad range of Indigenous, historic and other heritage values is not yet well established. Greater shared knowledge of heritage values among the Region's managers, Traditional Owners and stakeholders is critical to ensuring recognition and continued protection of those values.

10.5 Overall summary of long-term outlook

The Great Barrier Reef is already a changed system — the effects of climate change are happening now. The Region's current long-term outlook is for continued deterioration: this could be altered with urgent and coordinated actions to curb greenhouse gas emissions. The Region's short to medium-term future will be determined by the actions of many within the next five to 10 years. By 2030, or within the next decade, without timely and effective management actions a declining outlook for the Region will continue to manifest. Every action taken to improve Reef health and reduce drivers, threats and impacts is critical.

The Region was at a crossroads in 2009, with an opportunity for the right decisions to protect the Reef into the future. In 2014, assessments indicated all threats needed to be reduced to prevent the Region's overall condition worsening from poor. Since then, the outlook for the Region's ecosystem has become very poor. The outlook is no longer about forecasting the effects of climate change; the Region and those people dependent on it are already experiencing climate change and, as a result, a changed and less resilient Reef.

The current rate of global warming will not allow the maintenance of a healthy Reef for future generations. Increasingly frequent temperature extremes are the highest and most immediate risk, significantly affecting a range of species and habitats on a Region-wide scale. In turn, Traditional Owners' enduring connection to sea country and the quality and quantity of economic and social benefits the Reef provides to all people who value, enjoy or depend on it are being affected.

The Reef can recover from major impacts if its broader resilience is high and it experiences adequate disturbance-free periods. However, disturbances are becoming more frequent and are undermining recovery in many places. Mitigation of threats and resilience-based management on global and local scales remains essential to reinvigorating recovery of the system.

Everything possible should be done to create recovery windows for the Reef. Current efforts that are effective in ensuring that use is sustainable and compliant with environmental protection rules should be continued. Catchment management actions aimed at reducing pollution in land-based run-off are not working fast enough and a significant step change is needed to accelerate improvement in the quality of water flowing into the Reef.

Every action taken to improve Reef health and reduce drivers, threats and impacts is critical

In 2015, one of the greatest multi-jurisdictional efforts to protect the Reef, the Reef 2050 Plan, was implemented. Progress has occurred in many areas, including sustainable port development and sustainable fisheries management, however, the full benefits of this improved planning are still to be seen. Although beyond the scope of the Reef 2050 Plan, demonstrable effective global, national and local efforts to mitigate climate change are needed urgently within the next decade if the Reef is to recover and persist.

Given the global scale of human-induced climate change, the size of the Region is becoming a less effective buffer to broadscale and cumulative impacts

At local and regional levels, direct management actions do reduce some pressures. Localised ecosystem recovery is being observed in some areas, but it is slow. Additional actions to address all threats — large and small, widespread and local — are imperative, and many people and organisations play a critical role. At a broader scale, efforts to improve water quality entering the Reef have gradually reduced land-based pollutants in some areas. Multi-agency efforts to explore tangible and scalable reef restoration and adaptation measures have begun to create a suite of innovative and targeted measures that may provide large-scale options for management in future. However, the success of restoration efforts depends on favourable Reef conditions for growth and recovery, which will not occur unless the rate of anthropogenic climate change is halted and reversed.

The Reef can recover from major impacts if its broader health is strong and disturbance-free periods are long enough

Catchment population growth is likely to increase people's use of the Reef. Compliance incidents, such as fishing in no-take areas, are affecting biodiversity and reducing the Region's resilience. Therefore, marine policies and planning that aim to protect representative areas while allowing for multiple use will need to be agile and responsive to changing use patterns and disturbances.

The success of restoration efforts depends on favourable Reef conditions for growth and recovery, which will not occur unless the rate of anthropogenic climate change is halted and reversed

Given the accumulation of these and many other risks (Chapter 9), broad, multi-jurisdictional management actions that involve the community and behaviour change are essential. The Reef 2050 Plan has made progress in this direction. A comprehensive review of the plan in 2020 will need to address the findings of this Outlook Report to continue the transformational progress required within the critical time window (the next 10 years).

The challenge is big, but not insurmountable – actions taken now will matter

As a social-ecological system, the health of the Reef ecosystem will continue to have both impacts on, and benefits for, the community (socially, culturally and economically). Society will need to play a pivotal and urgent role in mitigation and adaptation to support the Region's resilience. It is important not to lose optimism by thinking the job is too big, or to think that a changed Reef is far in the future — actions taken now will matter.

« *Seagrass meadow at Green Island.* © Dieter Tracey 2013

APPENDICES

Appendix 1 Statutory requirements for the Outlook Report

Extract from the *Great Barrier Reef Marine Park Act 1975*

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.

Extract from the *Great Barrier Reef Marine Park Regulations 2019*

Part 18—Application, saving and transitional provisions

256 References to old regulations

(1) In this Division, the old regulations are the *Great Barrier Reef Marine Park Regulations 1983*.

266 Application of section 176

(1) Section 176 applies to the Great Barrier Reef Outlook Report for 2024 and later such reports.

(2) Despite the repeal of regulation 116A of the old regulations, that regulation continues to apply, after the commencement of this instrument, in relation to the Great Barrier Reef Outlook Report for 2019.

Extract from (repealed) *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 2014

Chapter 1 — About this report

- New term added – Great Barrier Reef 'Catchment' is used throughout the report. The capitalisation distinguishes the term from river catchments.
- Section 266 of the *Great Barrier Reef Marine Park Regulations 2019* provides a transitional provision. Despite the repeal of regulation 116A of the *Great Barrier Reef Marine Park Regulations 1983*, that regulation continues to apply to the 2019 Outlook Report.
- Headers, including 'state and trend' have been amended to 'condition and trend' throughout the report for consistency.

Chapter 2 — Biodiversity

- *Open water* component has been renamed *Water column*, to clarify the habitat is the entire water body rather than a specifically offshore habitat. The scope of what is assessed remains consistent.
- *Macroalgae* and *Benthic microalgae* components have been combined and amended to *Benthic Algae* to enable consolidated discussion of all three types of benthic algae.

Chapter 3 — Ecosystem health

- *Sedimentation* component has been renamed adding 'exposure' to the title. The updated component name *Sediment exposure* reflects the process and emerging use of this term more widely.
- Term amended – *Terrestrial habitats that support the Great Barrier Reef*, the term *terrestrial habitats* has been replaced with *Coastal ecosystem* to be consistent with the Marine Park Authority's position statement released in 2018.
- Extent of woody vegetation clearing has been added to the assessment of 'Coastal ecosystems that support the Great Barrier Reef'.

Chapter 4 — Heritage values

- New terms defined – domains, components and attributes.
- Heritage assessment framework has been restructured.
- Historic heritage values – the assessment has been refined. Places on the Commonwealth Heritage List continue to be a standalone assessment. Also, the combined grades of the Commonwealth heritage lightstations are assessed with Other historic lightstations.
- Section on Benchmarking outstanding universal value has been deleted. This section was not a component that was assessed and graded. The Australian Government's State Party periodic report addresses this framework. Appendix 3 has been added.
- A broad assessment of the world heritage integrity test has been added in Appendix 4.

Chapter 5 — Commercial and non–commercial use

- *Shipping* has been moved from Section 5.5 to Section 5.8 for readability of common elements with ports in Section 5.7.

Chapter 6 — Factors influencing the Region's values

- Vulnerability of heritage values has been merged into a single section covering all four factors influencing the Region's values to enhance the readability of common elements.
- *Coastal development* component has been amended adding *'in the Catchment'* to the title. The original title implied the assessment was restricted to development on the coastline, whereas agricultural land uses (cropping and grazing) occur throughout the Catchment.

Chapter 9 — Risks to the Region's values

- New threats have been added to the risk assessment to identify key emerging threats and some specific threats to Indigenous heritage values.

Appendices

- The order of the appendices has been revised.
- Appendix 1 – updated regulatory provisions have been added.
- Appendix 3 – the content has been replaced with a table mapping Outlook Report components to the elements of the Reef's outstanding universal value.
- Appendix 4 – an assessment of the world heritage integrity test has been added.
- Appendix 6 – definitions of the new threats in the risk assessment have been added.

Appendix 3 Complementary assessments — linking the Outlook Report to the Great Barrier Reef's outstanding universal value

The Outlook Report assesses around 87 components within a broad analysis of the Great Barrier Reef's natural, Indigenous and historic heritage value. This table maps these components against the Reef's outstanding universal value[28], and outlines where the assessment within the Outlook Report is broader than an assessment of outstanding universal value.

The *Statement of the Outstanding Universal Value of the Great Barrier Reef World Heritage Area*[28] is the official statement adopted by the World Heritage Committee outlining how the property meets the criteria for outstanding universal value (OUV). The following excerpts from the statement indicate the attributes considered to contribute to the property's outstanding universal value. The Great Barrier Reef Region Strategic Assessment[1446] Section 7.6.1, introduced an assessment of the Reef's outstanding universal value based on 38 attributes (in parentheses). The table below includes the current criteria (italic text in parentheses) as well as the original criteria (italic text in square brackets) applied at the time of inscription. Many Outlook Report components address several attributes and may be listed more than once in the left column.

Outlook Report 2019 Components	**World Heritage Area** Great Barrier Reef World Heritage Area
	Statement of outstanding universal value: 38 attributes *(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*
2.3.5 Coral reefs 2.4.4 Corals 2.4.7 Bony fishes 4.5.1 Social heritage values 4.5.2 Aesthetic heritage values 8.3.1 Coral reef case study	(1) Superlative natural **beauty** above and below the water (2) Some of the most spectacular **scenery** on Earth (3) One of a few living structures **visible** from space (4) A complex string of reefal structures along Australia's north-east coast (5) Unparalleled aerial panorama of **seascapes** comprising diverse shapes and sizes (10) Beneath the ocean surface, there is an abundance and diversity of shapes, sizes and **colours** ... Spectacular coral assemblages of hard and soft corals (11) Thousands of species of reef fish provide a myriad of **brilliant colours**, shapes and sizes (12) The internationally renowned **Cod Hole** is one of many significant **tourist** attractions
2.3.1 Islands 2.3.2 Beaches and coastlines 2.4.10 Marine turtles 2.4.12 Seabirds 4.2.2 Natural beauty and phenomena 8.3.5 Loggerhead turtles case study	(6) Whitsunday islands provide a magnificent vista of green vegetated **islands** and white sandy beaches spread over azure waters (8) On many of the cays there are spectacular and globally important breeding colonies of **seabirds** and marine **turtles** (9) Raine Island is the world's largest green **turtle** breeding area
2.3.3 Mangrove forests 2.3.2 Beaches and coastlines 2.4.1 Mangroves 3.5.1 Saltmarshes 3.5.2 Freshwater wetlands 3.5.3 Forested floodplain 3.5.4 Heath and shrublands 3.5.5 Grass and sedgelands 3.5.6 Woodlands and forests 3.5.7 Rainforests	(7) Vast **mangrove** forests in Hinchinbrook Channel, or the rugged vegetated mountains and lush **rainforest** gullies
2.3.5 Coral reefs 2.4.3 Corals 2.4.10 Marine turtles 2.4.14 Whales 8.3.1 Coral reef case study 8.3.5 Loggerhead turtles case study 8.3.7 Humpback whales case study	(13) Superlative natural phenomena include the annual **coral** spawning, migrating **whales**, nesting **turtles**, and significant **spawning aggregations** of many fish species

Outlook Report 2019 Components	**World Heritage Area** Great Barrier Reef World Heritage Area
	Major stages of the Earth's evolutionary history (viii) *(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*
3.4.8 Reef building 4.2.3 Major stages of the Earth's evolutionary history	(14) Globally outstanding example of an ecosystem that has evolved over millennia (15) 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 (16) Today, the Great Barrier Reef forms the world's largest coral reef ecosystem ... Including examples of all stages of reef development (17) Processes of **geological** and **geomorphological evolution** are well represented, linking continental islands, coral cays and reefs
3.2.1 Currents 3.2.2 Cyclones and wind 3.2.3 Freshwater inflow 3.2.4 Sediment exposure 3.2.5 Sea level 3.2.6 Sea temperature 3.2.7 Light 3.3.2 Ocean pH (acidity) 3.3.3 Salinity 3.4.8 Reef building	(18) 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
2.3.9 Continental slope 2.3.10 Water column	(19) 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 (ix) *(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*
2.3.1 Islands 2.3.5 Coral reefs 2.3.8 *Halimeda* banks 2.4.4 Corals 3.4.8 Reef building 3.3.2 Ocean pH (acidity) 8.3.1 Coral reef case study	(20) Significant diversity of reef and island **morphologies** reflects ongoing geomorphic, oceanographic and environmental processes (25) 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
3.2.1 Currents 3.2.2 Cyclones and wind 3.4.10 Connectivity	(21) Complex cross-shelf, longshore and vertical connectivity is influenced by dynamic **oceanic currents**
3.3.1 Nutrient cycling 3.4.1 Microbial processes 3.4.2 Particle feeding 3.4.3 Primary production 3.4.5 Predation 3.4.6 Symbiosis 3.4.7 Recruitment	(22) Ongoing ecological processes, such as **upwellings, larval dispersal and migration**
3.2.2 Cyclones and wind 3.2.4 Sediment exposure 3.4.4 Herbivory 3.4.8 Reef building 3.4.9 Competition	(23) Ongoing **erosion and accretion** of coral reefs, sand banks and coral cays combine with similar processes along the coast and around continental islands
2.3.8 *Halimeda* banks	(24) Extensive beds of ***Halimeda* algae** represent active calcification and accretion over thousands of years
2.4.12 Seabirds 2.4.13 Shorebirds 2.3.1 Islands 3.4.7 Recruitment	(26) Vegetation on the cays and continental islands exemplifies the important role of **birds** ... in seed dispersal and plant colonisation

Outlook Report 2019 Components	**World Heritage Area** Great Barrier Reef World Heritage Area
	Habitats for conservation of biodiversity (x) *(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*
2 Biodiversity **3 Ecosystem Health** 2.4.3 Benthic algae (includes macroalgae and microalgae) 2.4.5 Other invertebrates 2.4.6 Plankton and microbes 2.4.7 Bony fish 2.4.8 Sharks and rays 2.4.9 Sea snakes 2.4.11 Estuarine crocodiles 2.4.12 Seabirds 2.4.13 Shorebirds 8.3.3 Black teatfish case study 8.3.4 Coral trout case study	(28) One of the richest and most complex natural ecosystems on Earth, and one of the most significant for **biodiversity** conservation (29) Tens of thousands of **marine** and **terrestrial species**, many of which are of global conservation significance
2.3.5 Coral reefs 2.4.3 Corals 8.3.1 Coral reef case study	(30) The world's most complex expanse of **coral reefs** ... Contain some 400 species of corals in 60 genera
2.3.3 Mangrove forests 2.4.1 Mangroves	(31) Large ecologically important inter-reefal areas. The shallower marine areas support half the world's diversity of **mangroves**
2.3.4 Seagrass meadows 2.4.2 Seagrasses	(32) Large ecologically important inter-reefal areas. The shallower marine areas support … many **seagrass** species
2.4.16 Dugongs 8.3.6 Urban coast dugongs case study	(33) Waters also provide major feeding grounds for one of the world's largest populations of the threatened **dugong**
2.4.14 Whales 2.4.15 Dolphins 8.3.7 Humpback whales case study	(34) At least 30 species of **whales** and **dolphins** occur here (35) A significant area for humpback **whale** calving
2.3.1 Islands 2.4.10 Marine turtles 2.4.12 Seabirds 2.4.13 Shorebirds 8.3.5 Loggerhead turtles case study	(36) 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 (37) 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 (38) The continental **islands** support thousands of plant species, while the coral cays also have their own distinct flora and fauna
4.3.6 Integrity **7 Existing protection and management**	Related to assessment of integrity of the property's outstanding universal value
Broader than outstanding universal value	
4.3 Indigenous heritage values 5.9 Traditional use of marine resources	(27) Human interaction with the natural environment is illustrated by strong ongoing links between Indigenous people and their sea country, and includes numerous shell deposits (middens) and fish traps, plus the application of story places and marine totems
2.2 Legacies and shifted baselines 3.6 Outbreaks of disease, introduced species and pest species 4.4 Historic heritage values **5 Commercial and non-commercial use** **6 Factors influencing the Region's values** **7 Existing protection and management** 8.5 Heritage resilience (Indigenous and historic heritage value) **9 Risks to the Region's values** **10 Long-term outlook**	

Appendix 4 Integrity test — Great Barrier Reef World Heritage Area

Integrity of the Great Barrier Reef is a measure of the wholeness and intactness of the property's natural heritage value.[781] The integrity test involves the interaction with people, therefore, management and domestic policies are an element of the integrity test (unlike the assessment undertaken for the four world heritage criteria, which is about condition and trend of elements or components that make up a criterion). The test is broad and cuts across all the world heritage criteria and natural heritage attributes of the Reef. The test can also prioritise and consider the key aspects of a functioning system to gauge the integrity of the property. An overall integrity grade is included in Section 4.6.1.

Integrity score

🟩	**Very good**	🟩	**Good**	🟧	**Poor**	🟥	**Very poor**	☐☐	**Borderline**

World heritage criteria and integrity test criteria	Assessment	Integrity score
(vii) Natural beauty and natural phenomena		
The Great Barrier Reef depends on scenic beauty as a value and areas that are integrally linked to the maintenance of the aesthetic qualities of the property	The aesthetic value and naturalness of the world heritage property are heavily reliant on the condition of the Region's biodiversity (Chapter 2) and ecosystem health (Chapter 3). The wholeness and intactness of the Reef's aesthetic attributes, above and below the water, are in good condition overall. But many elements which contribute to this criterion (such as clear water and bright colourful reef fish) are deteriorating. Some critical elements of natural phenomena, such as coral spawning, have deteriorated on a broad scale due to significant loss of coral broodstock following back-to-back bleaching events in 2016 and 2017. The criterion overall is considered good borderline poor. Quantifying the condition of this attribute on a Region-wide scale is difficult as it relies upon the state of the system, its appearance and perceptions of beauty.	🟩🟧
(viii) Major stages of the Earth's evolutionary history		
The Great Barrier Reef contains all or most of the key interrelated and interdependent elements in their natural relationships	At a Region-wide scale the Reef continues to provide outstanding examples of the Earth's evolutionary history and geomorphological diversity. However, unprecedented recent disturbances will have long-lasting effects. Processes that influence reef formation and maintain sediment accumulation on reef islands (for example, ocean acidification, sea temperature and sea-level rise) have deteriorated since 2014. The processes are intensifying in a negative way due to climate change, and pose the greatest threat to the Reef's contemporary geomorphology. Further deterioration of this element may occur if supporting physical and chemical processes continue to alter the geomorphology of the Region.	🟩
(ix) Ecological and biological processes		
The Great Barrier Reef is a sufficient size and contains the necessary elements to demonstrate the key aspects of processes that are essential for the long-term conservation of the ecosystems and the biological diversity they contain	The condition of key processes that interlink and operate to keep the ecosystem functioning are assessed in Chapter 3. Ecological processes have not ceased to operate, although processes that are fundamental to a functioning ecosystem (such as symbiosis, recruitment and reef building) are considered to be in poor condition and are causing the good grade to be borderline with poor. Multiple disturbances have transformed the ecosystem on a broad scale and cumulatively hindered recovery. Historically, the Region's size has provided a buffer to periodic and dispersed damage due to its broad latitudinal extent. However, given the global scale of human-induced climate change, the size of the Region is becoming a less effective buffer to some broadscale impacts. Deterioration has been more rapid and widespread than was evident in the period 2009 to 2014.	🟩🟧
(x) Habitats for conservation of biodiversity		
The Great Barrier Reef is one of the most important properties for the conservation of biological diversity and those that contain habitats for maintaining the most diverse fauna and flora characteristic of the bio-geographic province and ecosystems under consideration	As a value distributed throughout the whole of the property, habitats to support species continue to deteriorate and are assessed as poor overall. Habitats for conservation of biodiversity face growing direct threats and external pressures. Safeguard measures to mitigate climate change are essential for the long-term conservation of the ecosystem. Declines in key habitats have been more rapid and widespread than was evident in the period 2009 to 2014. An emerging field of science around intervention and restoration measures has established since 2014, but many measures are yet to be fully tested or implemented.	🟧

World heritage criteria and integrity test criteria	Assessment	Integrity score
Safeguarding (protection and management)		
The Great Barrier Reef World Heritage Area has adequately delineated boundaries	The size of the world heritage property has remained consistent since inscription, at about 348,000 square kilometres. The Region's size is becoming a less effective buffer to some broadscale impacts. A buffer zone to the boundary of the World Heritage Area has never been a feature of the property. However, the Wet Tropics World Heritage Area provides an upstream buffer to a small part of the property. The health of the adjacent coastal ecosystems which link to the property, influences the Reef's outstanding universal value.	🟩
The Great Barrier Reef is adequately protected at the national, regional, municipal, and/or traditional level by legislative, regulatory and contractual measures. Appropriate management plans are in place, specifying how the outstanding universal value of the property will be preserved	Adequate regulatory controls continue to be in place to protect and manage direct use of the property (Chapter 7). Aspects of management effectiveness for some management topics have improved since 2014 (ports, defence, shipping and research). However, management effectiveness has declined in some areas, particularly for complex and spatially broad topics (climate change and biodiversity). Complementary management arrangements between the Australian and Queensland governments strengthen the regulatory protection of outstanding universal value. The zoning regime of the Reef encompasses about 33 per cent of the World Heritage Area in 'no-take' or 'no-entry' zones. The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) also provides protection and management of potential impacts from proposed actions outside the World Heritage Area that may significantly impact on its values. External pressures from global drivers, such as climate change, remain the greatest threat to the World Heritage Area and other properties globally.	🟩

Appendix 5 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 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) associated with the 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 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 or specifically disallowed, 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 industries 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 objectives 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 monitoring information is applied appropriately to make relevant management decisions regarding the topic.
- The best available socioeconomic research and 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 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 Reef are protected.
- The outputs for management of the topic are reducing the major risks and the threats to the Reef.
- Use of the Reef relating to the topic is demonstrably environmentally sustainable.
- Use of the Reef relating to the topic is demonstrably economically sustainable.
- Use of the Reef relating to the topic is demonstrably socially sustainable, in terms of understanding and enjoyment.
- The relevant managing agencies have developed effective partnerships with local communities and stakeholders to address the topic.

Appendix 6 Threats to the Region's values

The set of current and likely threats to the Region's ecosystem and heritage values (its natural, Indigenous, historic and other heritage values) considered in the risk assessment (Chapter 9) was developed from the evidence presented in the preceding chapters of this report (particularly 5 and 6), taking into account input from Reef scientists and managers and the outcomes of various community surveys. The 45 threats considered are listed in the table below. The table also provides a comparison with those assessed in the 2014 Outlook Report. As far as possible, the threats and their descriptions are consistent with those used in 2014; differences are shown in **bold** in the 2019 column.

Outlook Report 2019 (45 threats)	Outlook Report 2014 (41 threats)
Acid sulfate soils: Exposure of acid sulfate soils	*Acid sulphate soils:* Exposure of acid sulphate soils
Altered ocean currents: Climate change induced altered ocean currents	*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), **includes both chronic and acute aspects**	*Altered weather patterns:* Climate change effects on weather patterns (e.g. cyclones, wind, rainfall, air temperature)
Artificial light: Artificial lighting, including from resorts, industrial infrastructure, mainland beaches and coastlines, vessels and ships	*Artificial light:* Artificial lighting, including from resorts, industrial infrastructure, mainland beaches and coastlines, vessels and ships
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	*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
Barriers to flow: Artificial barriers to riverine and estuarine flow (e.g. dams, weirs, breakwalls, gates, **roads and linear infrastructure**)	*Barriers to flow:* Artificial barriers to riverine and estuarine flow (e.g. dams, weirs, breakwalls and gates)
***Behaviour impacting heritage values:* Disturbance of, or damage to, the values of intangible Indigenous and historic heritage site through inappropriate presence of people. Examples include: visitation to locations considered dangerous or sensitive in Indigenous culture; access by people of culturally inappropriate gender or seniority; overly high visitor traffic levels at Indigenous sites open to visitation (e.g. creating too much noise); and disrespectful behaviour or activities at Indigenous and historic heritage sites (e.g. burial areas)**	
Damage to reef structure: Physical damage to reef benthos (reef structure) through actions, such as snorkelling, diving, anchoring and fishing, but not vessel grounding (assessed separately)	*Damage to reef structure:* Physical damage to reef benthos (reef structure) through actions, such as snorkelling, diving, anchoring and fishing, but not vessel grounding
Damage to seafloor: Physical damage to non-reef benthos (seafloor) through actions, such as trawling and anchoring	*Damage to seafloor:* Physical damage to non-reef benthos (seafloor) through actions, such as trawling and anchoring
Discarded catch: Immediate or post-release effects (such as death, injury, reduced reproductive success) on discarded species (**non-retained catch**) as a result of interactions with fishing gear. Does not include species of conservation concern (assessed separately)	*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
Disposal of dredge material: Disposal and resuspension of dredge material	*Disposal of dredge material:* Disposal and resuspension of dredge material
Dredging: Dredging of the seafloor	*Dredging:* Dredging of the seafloor
Exotic species: Introduced exotic species from aquaculture operations, hull fouling, ballast release, **biocontrol, translocation of other marine species**, and release of aquarium specimens to the Region, plus the introduction of weeds, pests and feral animals to islands. **Includes both new introductions and outbreaks of previously introduced exotic species. Does not include considerations covered under the 'genetic modification' threat**	*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
Extraction from spawning aggregations: Retained take (extraction) of fish from unidentified or unprotected spawning aggregations	*Extraction from spawning aggregations:* Retained take (extraction) of fish from unidentified or unprotected spawning aggregations
Extraction of herbivores: Retained take (extraction) of herbivores (e.g. some fishes, molluscs, dugongs, green turtles) through commercial and non-commercial uses	*Extraction of herbivores:* Retained take (extraction) of herbivores (e.g. some fishes, molluscs, dugongs, green turtles) through commercial and non-commercial uses
Extraction of particle feeders: Retained take (extraction) of particle feeders (filter feeders, detritivores) through commercial and non-commercial uses	*Extraction of particle feeders:* Retained take (extraction) of particle feeders (filter feeders, detritivores) through commercial and non-commercial uses
Extraction of predators: Retained take (extraction) of predators (e.g. sharks, fish) through commercial and non-commercial uses	*Extraction of predators:* Retained take (extraction) of predators (e.g. sharks, fish) through commercial and non-commercial uses

Outlook Report 2019 (45 threats)	Outlook Report 2014 (41 threats)
***Foundational capacity gaps:* Lack of capacity of Traditional Owners to exercise their Indigenous heritage (cultural) rights by accessing and managing their land and sea country. Relates to capacity of Traditional Owners and their groups, and is not about loss of knowledge or about access restrictions or conflicting use. Potential impacts include those on the enduring connection Traditional Owners have with their land and sea country and on the maintenance of culture and the transfer of knowledge to younger generations (e.g. reduced opportunities to conduct knowledge transfer)**	
***Fragmentation of cultural knowledge:* Loss and fragmentation of knowledge of tangible and intangible heritage values (e.g. as Indigenous Elders age and young people leave their traditional land and sea country, or availability of specialist skills in historic heritage preservation declines)**	
***Genetic modification:* Genetic modification of native species, manipulation of natural genotype frequencies (e.g. through translocations or intentional/unintentional releases of specimens), and products of synthetic biology**	
Grounding — large vessel: Grounding of large vessels (>50m), including physical damage and the dislodging of antifoulants	*Grounding large vessel:* Grounding of large vessels (>50m), including physical damage and the dislodging of antifoulants
Grounding — small vessel: Grounding of small vessels (<50m), including physical damage and the dislodging of antifoulants	*Grounding small vessel:* Grounding of small vessels (<50m), including physical damage and the dislodging of antifoulants
Illegal activities — other: Illegal activities, such as entering a protected or restricted area, illegal release of industrial discharge, shipping outside of designated shipping areas, **and removal or damage of artefacts (e.g. ship anchors, stone implements), scar trees, middens, fish traps, burial grounds, stone arrangements, art work**	*Illegal activities — other:* Illegal activities, such as entering a protected or restricted area, illegal release of industrial discharge, shipping outside of designated shipping areas
Illegal fishing and poaching: Illegal fishing, collecting and poaching	*Illegal fishing and poaching:* Illegal fishing, collecting and poaching
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 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
Incompatible uses: Activities undertaken within the Region that disturb or exclude other users, such as recreational use in areas important for cultural activities	*Incompatible uses:* Activities undertaken within the Region that disturb or exclude other users, such as recreational use in areas important for cultural activities
Marine debris: Manufactured material discarded, disposed of or abandoned in the marine and coastal environment (including discarded fishing gear, plastics, **and abandoned or damaged equipment and infrastructure**)	*Marine debris:* Manufactured material discarded, disposed of or abandoned in the marine and coastal environment (including discarded fishing gear and plastics)
Modifying coastal habitats: Clearing or modifying wetlands, mangroves and other coastal **ecosystems in the Catchment or inshore areas or on islands**	*Modifying coastal habitats:* Clearing or modifying wetlands, mangroves and other coastal habitats
Noise pollution: Noise from human activities, both below and above water	*Noise pollution:* Noise from human activities, both below and above water
Nutrient run-off: Nutrients from diffuse land-based run-off	*Nutrient run-off:* Nutrients from diffuse land-based run-off
Ocean acidification: Decreasing pH of the Region's waters	*Ocean acidification:* Decreasing pH of the Region's waters
Outbreak of crown-of-thorns starfish: 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 disease:* Outbreak of disease, both naturally occurring and introduced
Outbreak of other species: Outbreak or bloom of naturally occurring species other than crown-of-thorns starfish	*Outbreak of other species:* Outbreak or bloom of naturally occurring species other than crown-of-thorns starfish
Pesticide run-off: Pesticides (including herbicides, insecticides, fungicides) from diffuse land-based run-off	*Pesticide run-off:* Pesticides (including herbicides, insecticides, fungicides) from diffuse land-based run-off
Sea-level rise: Rising sea level	*Sea level rise:* Rising sea level
Sea-temperature increase: Increasing **extreme and average** sea temperatures	*Sea temperature increase:* Increasing sea temperature
Sediment run-off: Sediments from diffuse land-based run-off	*Sediment run-off:* Sediments from diffuse land-based run-off
Spill — large chemical: Chemical spill that triggers a national or regional response or is more than 10 tonnes **(includes substances, such as sugar)**	*Spill — large chemical:* Chemical spill that triggers a national or regional response or is more than 10 tonnes

Outlook Report 2019 (45 threats)	Outlook Report 2014 (41 threats)
Spill — large oil: Oil spill that triggers a national or regional response or is more than 10 tonnes **(includes all petroleum products)**	*Spill — large oil:* Oil spill that triggers a national or regional response or is more than 10 tonnes
Spill — small: Chemical or oil spill that does not trigger a national or regional response and is less than 10 tonnes. **Includes materials (liquids and solids) used in attempts to restore or protect marine habitats but not materials considered under 'Marine debris'**	*Spill — small:* Chemical or oil spill that does not trigger a national or regional response and is less than 10 tonnes
Terrestrial discharge: Terrestrial point-source discharge **(including within ports), such as** polluted water, sewage, wastewater and stormwater	*Terrestrial discharge:* Terrestrial point-source discharge, including polluted water, sewage, wastewater and stormwater
Vessel strike: Death or injury to wildlife as a result of being struck by a vessel of any type or size	*Vessel strike:* Death or injury to wildlife as a result of being struck by a vessel of any type or size
Vessel waste discharge: Waste discharge from a vessel (including sewage)	*Vessel waste discharge:* Waste discharge from a vessel (including sewage)
Wildlife disturbance: Disturbance to wildlife (including from snorkelling, diving, fish feeding, walking on islands and beaches, and the presence of boats **and drones**); not including noise pollution	*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

Appendix 7 Criteria for ranking likelihood and consequence of threats to the Region's values

A standard set of criteria allows comparison of different types of threats within a single risk assessment, based on the likelihood and consequence of each threat. The likelihood and consequence of each predicted threat is ranked on the five-point scale described below.

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** (natural heritage)		**Heritage** (Indigenous, historic and other)
	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 destroying 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 adversely affecting, 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 affecting, 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 affecting, 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 is combined to determine risk level, consistent with the principles and guidelines of the Australian Standard for risk management (AS/NZS ISO 31000:2018). Risk is considered to be residual — the risk that remains once existing management measures have been taken into consideration.

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	*Low*	*Medium*	*High*	*Very high*	*Very high*
Likely	*Low*	*Medium*	*High*	*High*	*Very high*
Possible	*Low*	*Low*	*Medium*	*High*	*Very high*
Unlikely	*Low*	*Low*	*Low*	*Medium*	*High*
Rare	*Low*	*Low*	*Low*	*Medium*	*High*

Appendix 8 Assessment of risks to the Region's values

The assessment of the 45 threats is provided first for the Region's ecosystem (natural heritage values) and then for its heritage values (Indigenous, historic and other heritage). The description of each threat is included in Appendix 6.

Risks to the ecosystem

Potential threats — ecosystem	Likelihood	Consequence	Risk
Acid sulfate soils: Future coastal development in the Catchment in certain locations and intertidal areas creates possible risk of exposure to acid sulfate soils. Post-storm removal of vessels marooned in coastal mangroves and dredging can also expose these soils. 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 Reef over the next few decades 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.	Almost certain	Moderate	🟥
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, floods and heatwaves (acute events) and changes in wind patterns and average rainfall and temperatures (chronic effects). 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.	Almost certain	Major	🟪
Artificial light: Growth in shipping and urban and industrial development is likely to continue to increase the amount of artificial light. The main known issue is the effect on turtle hatchlings' orientation, including where artificial light leads to misdirection, aggregation and increased predation. Current hotspots for elevated light near turtle nesting beaches include the Woongarra coast, Gladstone and Mackay. Other impacts include effects on fish behaviour, including on juvenile fish and the orientation of pelagic species around vessel lights, and potential effects on seabird behaviour.	Almost certain	Moderate	🟥
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 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. There are concerns that fisheries productivity is reduced by reduced connectivity and freshwater flow.	Almost certain	Moderate	🟥
Behaviour impacting heritage values: Only assessed for heritage values.			
Damage to reef structure: There is likely to be damage from anchors, diving and snorkelling throughout the year. Marine debris, including from poorly secured equipment, may also cause damage. Damage from these sources is now occurring within a context of declined coral reef condition in many areas. If recreational vessel ownership and ease of access to the Region increase without a continued corresponding increase in education and supporting infrastructure (including reef protection markers and public moorings) it is likely damage will increase.	Almost certain	Moderate	🟥
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 is predicted to occur continuously, with combined broadscale consequences for populations of species commonly caught. Although equipment, such as bycatch reduction devices, assists 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 score			
🟨 **Low**	🟧 **Medium**	🟥 **High**	🟪 **Very high**

Potential threats — ecosystem	Likelihood	Consequence	Risk
Disposal of dredge material: Disposal of major amounts of dredge material from capital works is no longer allowed in the Marine Park. The frequency and volume of disposal of maintenance dredge material in the Region is likely to increase as already approved expansions and development continue to occur at priority ports. 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.	Likely	Minor	🟧
Dredging: While maintenance dredging is expected to occur at least one or more times per year in the Region, capital dredging is not expected to occur annually and only at priority ports with existing permissions. The consequence for biodiversity within the footprint of the dredging site would be serious and possibly irreversible.	Likely	Minor	🟧
Exotic species: Despite technological improvements for better detection and prevention, the projected increases in shipping, recreational visitation to islands, resort redevelopment and conservation intervention activities, make the transport and (re)introduction of exotic species likely. Some activities facilitate outbreaks of existing infestations. Consequences depend on the particular exotic species but are likely to be serious in a small area, such as adjacent to a marina or port, or on an island. Competition with, or predation of, native species is common.	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 of spawning aggregations can have implications for recruitment and future population sizes of the species.	Likely	Moderate	🟥
Extraction of herbivores: Herbivorous fishes 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, there is some spearfishing take, and discards occur in the trawl fishery (see Discarded catch). Current take of herbivorous fishes is low and is unlikely to become very common. Traditional hunting of green turtles and dugongs is currently managed in a number of areas under Traditional Use of Marine Resources Agreements, and more agreements may be implemented 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 allow them to be sustainably extracted if appropriately managed. Saucer scallops have experienced significant decline and are now considered recruitment overfished.	Almost certain	Moderate	🟥
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. Some shark species extracted through the East Coast Inshore Fin Fish Fishery have life history traits that lend themselves to sustainable exploitation. A range of 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.	Almost certain	Moderate	🟥
Foundational capacity gaps: Only assessed for heritage values.			
Fragmentation of cultural knowledge: Only assessed for heritage values.			
Genetic modification: Manipulation and modification of coral genetics is an accelerating area of research in the search for ways to increase the resilience of reefs to high sea temperatures, decreased ocean pH and other stressors. Potential negative impacts and, therefore, overall risk are not well understood. Major impacts could occur when modified organisms are released into the wild or attempts to influence genotype frequencies are implemented.	Possible	Minor	🟨
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. Cruise ships and superyachts are an increasing presence in the Region. Groundings can have extremely serious 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: Small vessel groundings are expected to continue to occur throughout the year and increase as recreational vessel use increases. These events are likely to be concentrated in areas of high use, such as the Whitsundays, where self-drive bareboats are common. Although most vessels are small in size, the decreasing condition of coral reefs generally in the Region has increased the potential for ecosystem-level consequence of cumulative damage caused by groundings of small vessels.	Almost certain	Minor	🟧

Risk score

🟨	**Low**	🟧	**Medium**	🟥	**High**	🟪	**Very high**

Potential threats — ecosystem	Likelihood	Consequence	Risk
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	🟧
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. Numbers of detected offences are significant (including among recreational fishers). Greater uptake of vessel monitoring systems may reduce likelihood of commercial fishing offences. The consequence is likely to be major at a broad scale. Increasing illegal activity could have major consequences, particularly for sensitive areas and species.	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 Queensland trawl fishery. Death of discarded and incidentally caught species of conservation concern across all fishing activities 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 Region 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 be present at a broad scale within the Region. While knowledge on distribution and movement of marine debris of all sizes continues to grow, less is known about the frequency, geographic extent and broadscale effects of its interactions with the Region's species.	Almost certain	Moderate	🟥
Modifying coastal habitats: The potential expansion and intensification of agricultural activities and continued growth in urban and industrial development makes the likelihood of vegetation clearing and modifying supporting terrestrial habitats almost certain. The consequence to the Region's values is likely to be major over a broad scale. Modification and loss of coastal ecosystems reduces their ability to provide important ecosystem services (including for marine species and habitats).	Almost certain	Major	🟪
Noise pollution: Current vessel use, projected increases in shipping, port development and recreational boat ownership means underwater anthropogenic 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 noise 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: Projections suggest the pH of waters of the Reef are almost certainly going to decrease. Regardless of the rate of change, even relatively small changes in ocean pH reduces the capacity of corals and other calcifying organisms to build skeletons and shells, which in turn reduce their capacity to create habitat.	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 very 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.	Almost certain	Major	🟪
Outbreak of disease: The causes of disease are difficult to ascertain but are likely to be varied. Increased susceptibility is caused by stress from both acute and chronic influences. For example, outbreaks of coral disease have been linked to increased sea temperature, making further outbreaks likely. Similarly, high disease rates in some commercially caught coral trout in 2016 may have been influenced by heavy bleaching on source reefs. Consequences will vary depending on the disease and duration of outbreak but could have major effects at a broad scale.	Likely	Major	🟥
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.	Likely	Minor	🟧

Risk score							
🟨	**Low**	🟧	**Medium**	🟥	**High**	🟪	**Very high**

Potential threats — ecosystem	Likelihood	Consequence	Risk
Pesticide run-off: Pesticides pose potentially serious consequences to some estuarine, seagrass and freshwater ecosystems. Ongoing use of pesticides in the Catchment means the Region will almost certainly continue to receive pesticides via land-based run-off. Concentration levels of pesticides in the Region vary, and for many areas are below those expected to cause significant risk to marine organisms. However, some locations are at higher risk. Additionally, the effect of ongoing low-level pesticide exposure on the inshore Reef area is a knowledge gap.	Almost certain	Moderate	🟥
Sea-level rise: Sea level increases are expected to continue into the future. This will have a noticeable effect on coastal and shallow-water habitats and species at a broad scale.	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 (for example, through its effect on the process of symbiosis within corals).	Almost certain	Catastrophic	🟪
Sediment run-off: Although improved agricultural land management practices and some restoration of riparian vegetation in some Catchment areas has continued to reduce sediment input, high anthropogenic sediment loads will continue to be transported to, and remain in, the Region. Improvements in agricultural land management practices may take some time to become evident in water quality within the Region due to the lag time of sediments passing through the ecosystem 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.	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 of small spills 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. Given the increasing interest in reef restoration and adaptation interventions, it is also possible that over the next decade unintentional pollution will be created by trials of new approaches (such as ultrathin films) — neither likelihood nor consequence for this aspect are well understood at present.	Almost certain	Insignificant	🟨
Terrestrial discharge: Projected increases in urban, industrial and mining developments in the coastal zone (within five kilometres of the coastline) and on islands will make discharges, such as sewage and stormwater, almost certain in the future. As regulations require sewage to be 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. The occurrence and impact of a range of firefighting and pharmaceutical compounds entering the Region is not well known.	Almost certain	Minor	🟧
Vessel strike: Continuing growth in shipping and recreational boating will increase the potential for vessel strikes on wildlife. Surface-breathing animals are most at risk (for example, humpback whales). Capital build projects, such as ports and other infrastructure, increase localised vessel use in coastal and island areas that contain important habitat for marine turtles, dugongs and inshore dolphins. The consequences of vessel strike may be more significant in some locations and for some species, than others.	Likely	Minor	🟧
Vessel waste discharge: Increases in vessel traffic and the continued unavailability of onshore pump-out facilities means there is likely to be more vessel-based waste discharge in the future. Effects on biodiversity are expected to be minor under current management arrangements.	Almost certain	Minor	🟧
Wildlife disturbance: Projected increases in population, tourism and expected associated increases in recreational vessel ownership are likely to lead to an increase in disturbance of wildlife from the presence of boats, drones, snorkelling and diving activities, and access to islands. These increases may cause some localised effects (for example, on seabirds and shorebirds).	Almost certain	Minor	🟧

Risk score							
🟨	**Low**	🟧	**Medium**	🟥	**High**	🟪	**Very high**

Risks to heritage values

Potential threats — heritage values (Indigenous, historic and other)	Likelihood	Consequence	Risk
Acid sulfate soils: Disturbance of acid sulfate soils by coastal development in the Catchment in certain locations and intertidal areas, may affect heritage places or values in a small area. Impacts may erode subsistence lifestyles of local Traditional Owners or corrode artefacts.	Possible	Moderate	🟧
Altered ocean currents: Dynamic ocean currents are recognised as an ecological process that contributes to the Reef's outstanding universal value. Changes could have flow-on effects to Indigenous heritage values, especially if species that have cultural significance for customary practice, lore, storylines and songlines are affected. Any changes in ocean currents are likely to have only minor effects on historic heritage values, such as shipwrecks.	Almost certain	Moderate	🟥
Altered weather patterns: A number of weather aspects are predicted to change as a result of climate change. An increase in extreme weather events will affect the Reef's outstanding universal value. Significant broadscale impacts from such events on some habitats and geomorphological features, especially coral reefs and seagrass meadows, will affect attributes that underpin the World Heritage Area's heritage values and integrity. In addition, cyclones can affect culturally important sites (including sacred sites) and places of Indigenous significance. It is 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 continue to increase the amount of artificial light. The main known issue with 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 and hatchling survival could have 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.	Almost certain	Moderate	🟥
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 other 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	🟥
Behaviour impacting heritage values: There is ongoing possibility of people exhibiting behaviours at Indigenous and historic heritage sites that affect the site's intangible cultural heritage values. The likelihood of impact may be higher at sites where visitors are more likely to not be aware of the site's local cultural significance or behavioural guidelines desired by Traditional Owners. Severity and longevity of impact varies depending on the nature, frequency and intensity of the undesirable presence or behaviour.	Possible	Moderate	🟧
Damage to reef structure: There is likely to be damage to the reef structure from anchors, diving and snorkelling throughout the year. Poorly secured equipment may also cause damage. This could affect the natural underwater beauty in heavily visited locations. Damage to culturally significant features is also possible.	Almost certain	Moderate	🟥
Damage to seafloor: Local effects on the seafloor are likely in intensely trawled areas and in ship anchorages. It is unlikely that any damage will significantly affect the condition of the area's ecologically important inter-reefal 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 that undiscovered heritage sites (including wrecks) and features could be damaged. If an interaction occurs, the consequences are likely to be serious, or even irreversible.	Possible	Moderate	🟧
Discarded catch: The discard of non-retained catch from fishing activities is 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	🟥

Risk score			
🟨 **Low**	🟧 **Medium**	🟥 **High**	🟪 **Very high**

Potential threats — heritage values (Indigenous, historic and other)	Likelihood	Consequence	Risk
Disposal of dredge material: Large amounts of dredge material from capital works can no longer be disposed in the Marine Park, although disposal from maintenance dredging continues. 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 would not be likely to affect heritage values over a wider area.	Likely	Minor	🟧
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 from 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 in progress, dredging can also affect the scenic values of an area and increase noise levels.	Likely	Minor	🟧
Exotic species: Despite improvements in detection and prevention of exotic species, projected increase in shipping, island-based activities and conservation interventions makes their introduction likely. The consequence would depend on the species and the heritage value affected, but there could be serious effects on 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. Local depletions may also affect social and economic values.	Likely	Moderate	🟥
Extraction of herbivores: Herbivorous fishes and molluscs are not the primary target of most commercial and recreational fishing. Traditional hunting of green 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. There are concerns for some species (including saucer scallops). 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 the cultural practices of Traditional Owners.	Almost certain	Moderate	🟥
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 the 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	🟥
Foundational capacity gaps: There is variable capacity (skills and equipment) among Traditional Owner groups to visit and manage country. Some areas are quite remote and safe transport is critical to frequency and efficiency of access to country. Management agencies have increased opportunities for Traditional Owners to join their trips. Potential impacts of capacity gaps include those on the enduring connection Traditional Owners have with their land and sea country, the maintenance of culture and the transfer of knowledge to younger generations.	Likely	Minor	🟧
Fragmentation of cultural knowledge: Efforts to reconnect with cultural knowledge are increasing within Reef and Catchment Traditional Owner groups and participation in Indigenous junior and adult ranger programs is growing. Availability of specialist skills in historic heritage preservation is thought to be stable.	Likely	Major	🟥
Genetic modification: Potential negative impacts and, therefore, overall risk for heritage values are not well understood. However, impacts on the ecosystem may have flow-on effects on Indigenous cultural values.	Possible	Minor	🟨
Grounding — large vessel: Current management of shipping significantly reduces the likelihood of groundings. However, if a grounding occurs, severe impacts on coral reef habitats can result 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	🟧

Risk score			
🟨 **Low**	🟧 **Medium**	🟥 **High**	🟪 **Very high**

Potential threats — heritage values (Indigenous, historic and other)	Likelihood	Consequence	Risk
Grounding — small vessel: Small vessel groundings are likely to occur throughout the year and be concentrated in areas of high use. Given the decreasing condition of coral reefs generally in the Region, the potential consequences of groundings for linked cultural heritage values has increased. Should there be an accumulation of such groundings at a site of heritage significance, the local condition of associated values may be further affected. If this occurs for multiple sites, it would affect heritage values at a wider scale.	Almost certain	Minor	🟧
Illegal activities — other: There is also ongoing possibility of intentional and unintentional illegal removal of, or damage to, the Region's Indigenous and historic heritage sites and associated artefacts. Occurrence of 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 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. Damage can be hard or impossible to repair. Monitoring of looting, souveniring, vandalism and other activities remains difficult due to limited availability of information on location and condition for many heritage sites. The maintenance of traditional cultural ties can be affected by use of the Region that does not keep to management arrangements designed to support traditional use.	Almost certain	Moderate	🟥
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. 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 or 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. Structures associated with tourism, ports and other activities can affect the scenic beauty of an area, as can commercial and recreational vessels.	Almost certain	Moderate	🟥
Marine debris: Marine debris affects many of the species that contribute to the outstanding universal value of the 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 of supporting terrestrial habitats in the 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 through changes to terrestrial habitats. In addition, without adequate consultation with Traditional Owners, reclamation on culturally significant sites may occur 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	🟪
Noise pollution: Little is known about the effects of noise on the Region's species, including for species that 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: The widespread effects of increased nutrients in coastal waters diminish many components of the Reef's outstanding universal value. This threat is closely aligned to modifying coastal ecosystems. Such declines in the environment will, in turn, affect the Indigenous heritage values of the Region. Nutrients are unlikely to affect historic heritage values, other than contributing to declines in the health of reefs of historic significance.	Almost certain	Major	🟪

Risk score							
🟨	**Low**	🟧	**Medium**	🟥	**High**	🟪	**Very high**

Potential threats — heritage values (Indigenous, historic and other)	Likelihood	Consequence	Risk
Ocean acidification: The pH of waters of the Reef is almost certainly going to decrease, which will affect coral reef habitats and many reef species. Given coral reefs are one of the fundamental attributes contributing to the Reef's outstanding universal value, this threat could have major consequences for the Region's 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 projected 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 heritage 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	Major	🟥
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 on 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. This threat is closely aligned with modifying coastal ecosystems. 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: Continued increases in sea level will have noticeable effects on coastal and shallow-water habitats and species over a broad scale. In particular, rising sea levels will affect the 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 for 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 simultaneously 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	🟪
Sediment run-off: Although improved agricultural land management practices and some vegetation restoration has continued to reduce sediment input, elevated anthropogenic 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 Area. Declines in the environment caused by increased sediments will affect the Indigenous heritage values of the Region. Increased sediments are unlikely to significantly affect historic heritage values.	Almost certain	Major	🟪

Risk score							
🟨	**Low**	🟧	**Medium**	🟥	**High**	🟪	**Very high**

Potential threats — heritage values (Indigenous, historic and other)	Likelihood	Consequence	Risk
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 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 a 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. Scenic beauty above and below the water may be slightly affected in small local areas. However, 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 in 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, dolphins 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, tourism and associated recreational vessel ownership, access to islands, drone use, snorkelling and diving activities 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 score			
🟨 **Low**	🟧 **Medium**	🟥 **High**	🟪 **Very high**

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INDEX

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Marine Park Authority

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