

— 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 cent⁸⁷, 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

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).

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 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}

It is more cost-effective to prevent ecosystem impacts than restore ecosystems

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

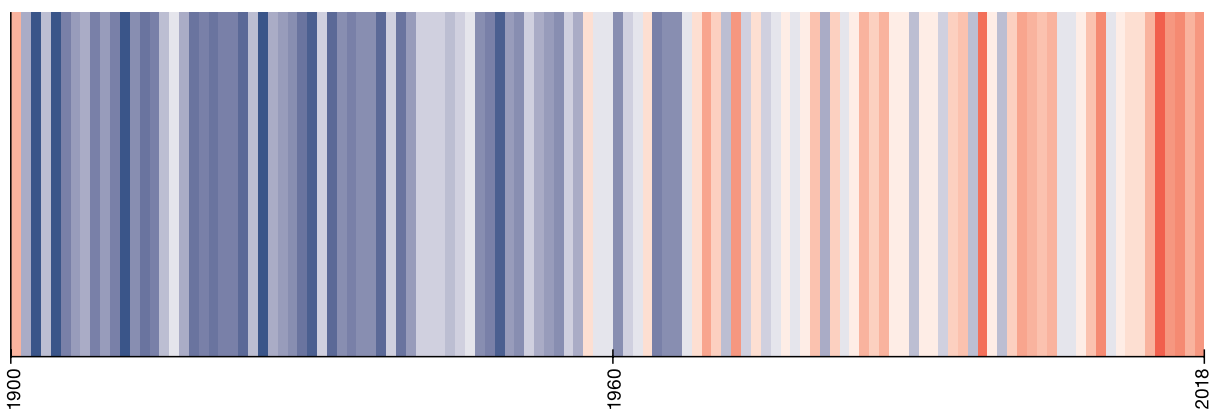


Figure 8.1 Annual sea surface temperatures on the Great Barrier Reef between 1900 and 2018

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 2018¹³⁹⁷ 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 years¹³⁹⁸, demonstrating remarkable resilience to past disturbances.¹³⁹⁹ Local disturbances (when not too frequent or severe) maintain diversity on coral 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

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 Resilience²⁴ 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

Reef resilience is being degraded by frequent and severe disturbances

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

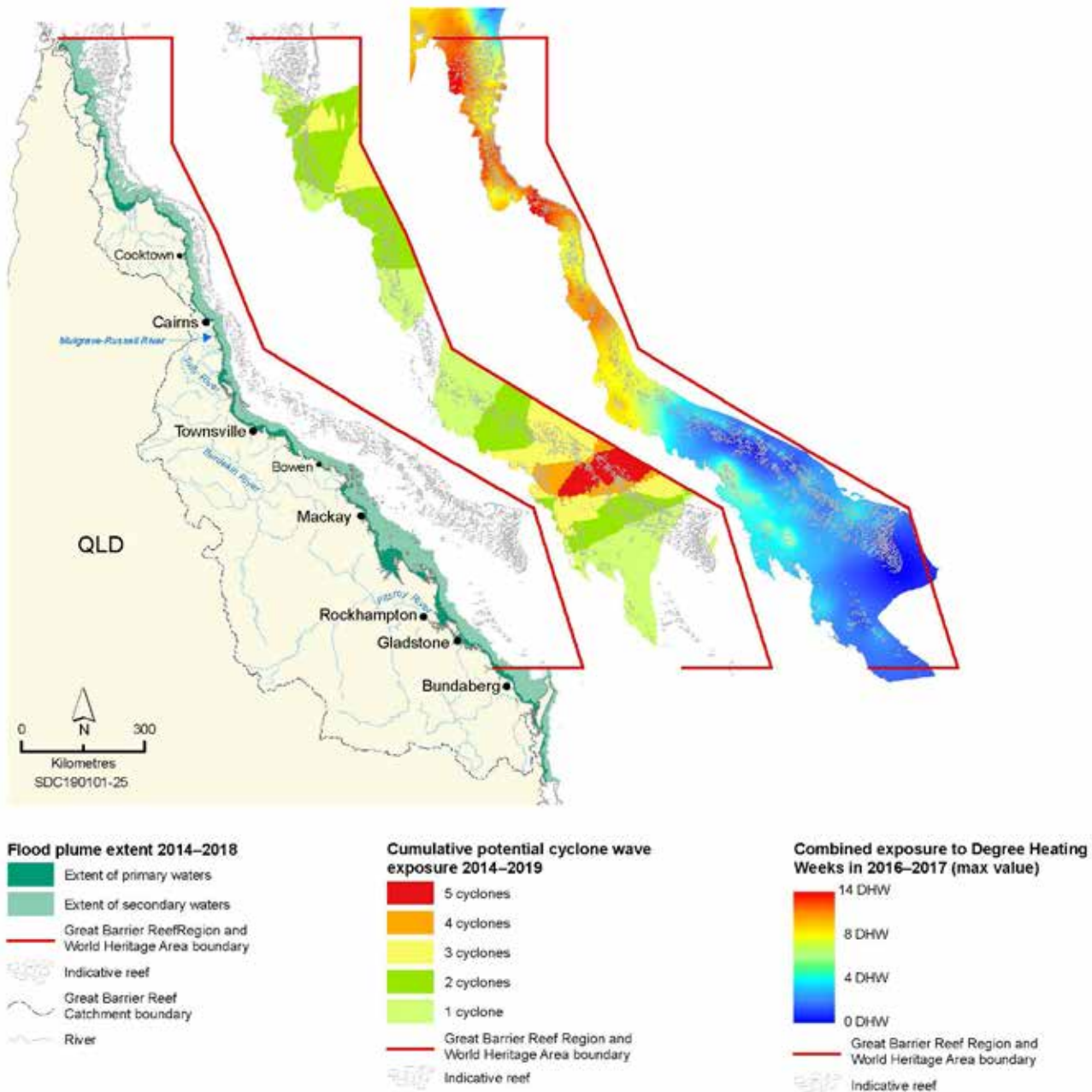


Figure 8.2 Multiple disturbances have impacted the Great Barrier Reef since 2014

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 runoff and freshwater between 2014 and 2018. Source: Adapted from Gruber et al. 2019¹⁵⁵

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. 2016⁴³⁴

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. 2019⁸⁸ and Lui et al. 2017¹⁴⁰⁹

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).

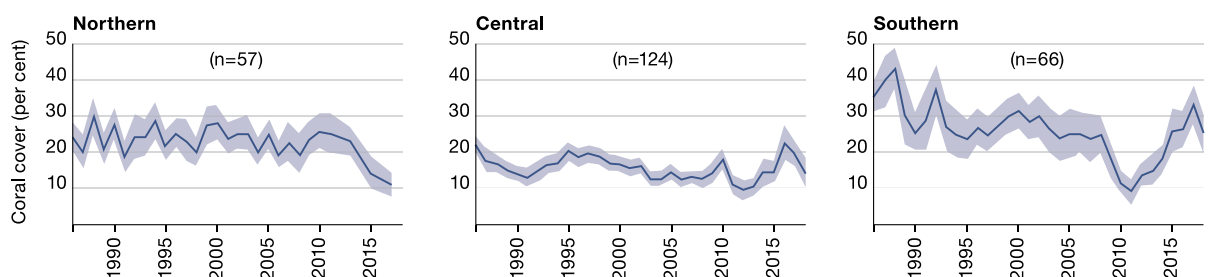


Figure 8.3 Trends in mean hard coral cover since 1986 for the northern, central and southern Reef

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 2018⁹⁵

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 occurring²⁷³ (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 2010⁹⁹, 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 disease¹⁴²¹, effects on respiration and feeding ability of suspension feeders¹⁴²², delayed development of fish larvae¹³¹², impairment of fish chemosensory abilities¹³¹⁴, 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 kilometres¹⁴²³ 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 cooler¹⁴²⁵, 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 spawning¹⁴²⁷, 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 fishery¹⁴²⁸ 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 Region¹⁶⁵, 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 trout¹⁴³², 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 suppressed for several years⁹⁶ 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.

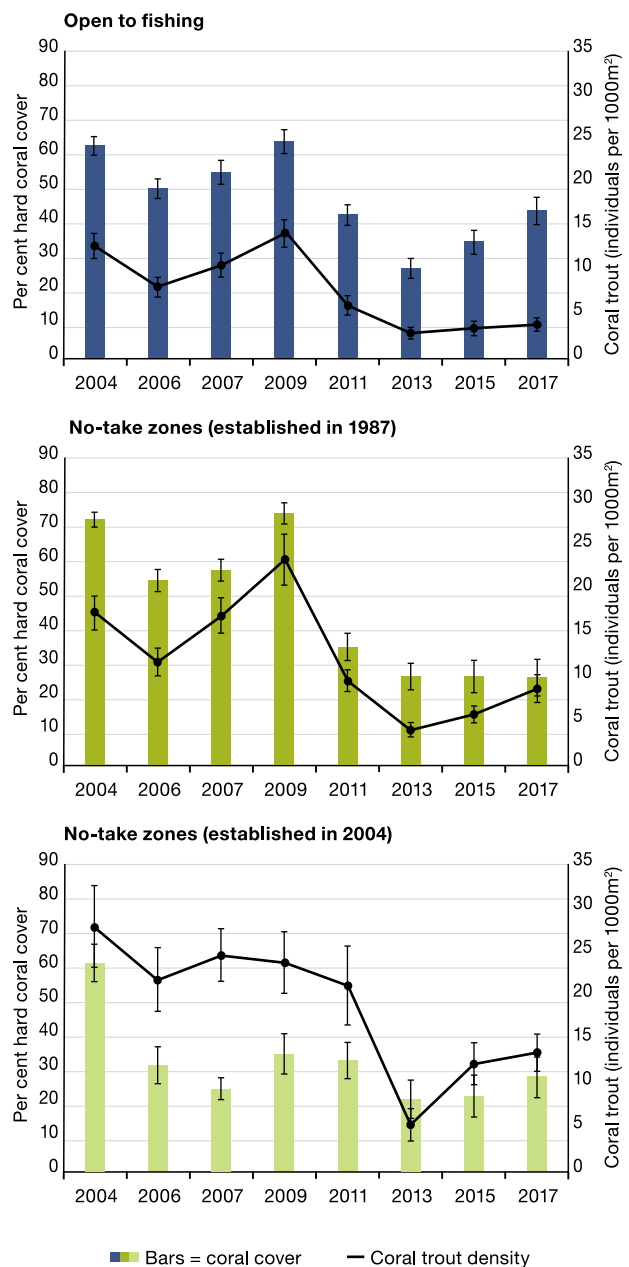


Figure 8.4 Comparison of average coral trout abundance and live coral cover at the Keppel islands from 2004–2017 across different zones

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 2014¹⁴³³ and Williamson et al. 2019⁶¹⁵

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 more⁹⁰, 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 less¹⁴³⁶, they may become harder to catch and spawning aggregations may be impacted¹⁰²³, 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).

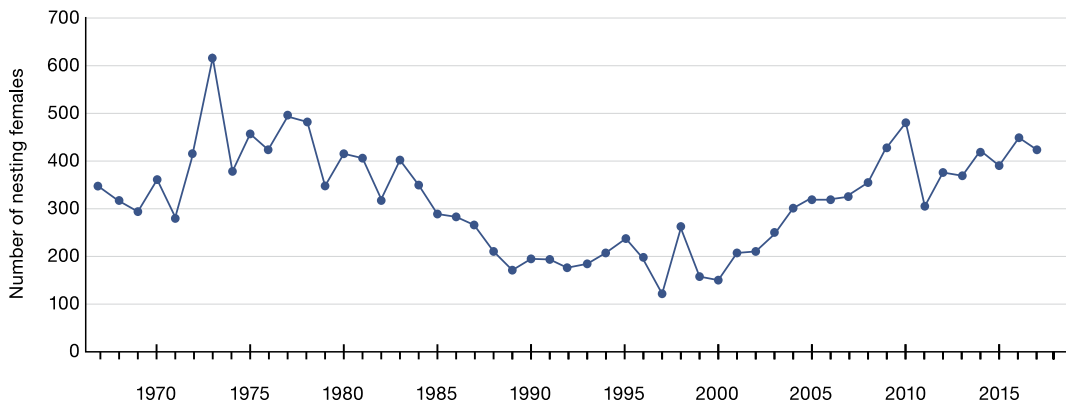


Figure 8.5 Number of tagged loggerhead turtles nesting, Woongarra coast, 1967–2017
 Data for the 1967 and 1968 nesting seasons are population estimates. Data for nesting seasons from 1969 to 2017 are derived from population censuses. Nesting seasons occur over summer and are referred to by the year in which they start.
 Source: Department of Environment and Science Qld 2018³¹² and Limpus 2008³²⁰

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 areas⁶⁸⁰, 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 2010–2011¹⁴⁴⁵, slow recovery of their food source in some areas after multiple disturbances (Section 2.3.4), extreme weather events¹⁴⁴⁶ 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 again¹⁴⁴⁷, 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 Cooktown⁴¹⁴ 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

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

Community awareness and appreciation are key contributors to the Region's heritage resilience

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 Plan⁹ 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).

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.

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.

Traditional Owners spending time on country continues to strengthen connections, transfer knowledge and maintain Indigenous heritage values



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

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 Island⁸³¹ and Lady Elliot Island⁸³³ lightstations. Since that time, several new management tools have been implemented for the Commonwealth listed lightstations.

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.

Lightstations rely on management actions to support their resilience and maintain their inherent heritage value



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 2017¹⁴⁶⁴

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 2015⁸³⁵

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					Trend since last report	
						Improved
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.		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					Trend since last report	
						Improved
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.		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.

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.

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.

The natural resilience of the Region's values is being undermined by increases in the severity and frequency of disturbances

Community awareness and appreciation are important to the resilience of the Region's historic and Indigenous heritage values



Pine Islet lighthouse at its current location at Mackay marina. © Chloe Schauble



Lagoon floor habitats support an array of species. © Matt Curnock