ECOSYSTEM RESILIENCE

CHAPTER SEVEN

"Nature's restorative operations are performed unceasingly, with never-failing design and often with the exhibition of wonderful power ...."

E.J. Banfield, 1925
Journalist, naturalist and beachcomber

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

7 ECOSYSTEM RESILIENCE

7.1 Background

A resilient ecosystem can withstand shocks and pressures and rebuild itself.

Ecosystem resilience refers to the capacity of an ecosystem to recover from disturbance or withstand ongoing pressures.[1 2] It is a measure of how well an ecosystem can tolerate disturbance without collapsing into a different state that is controlled by a different set of processes. Resilience is not about a single ideal ecological state, but an ever-changing system of disturbance and recovery.

Coral reef and other tropical marine ecosystems are subject to frequent disturbances, from threats such as cyclones, crown-of-thorns starfish outbreaks and influxes of freshwater as well as from a range of human activities. These events often damage, stress or kill components of the ecosystem. Given enough time, a resilient ecosystem will be able to fully recover from such disturbances and become as biodiverse and healthy as before the impact. Similarly, a resilient ecosystem may be able to absorb the stresses caused by these disturbances with little or no sign of degradation.

The Great Barrier Reef ecosystem is facing some very serious threats. An understanding of the ecosystem's resilience - its ability to absorb or recover from these threats - is an important part of predicting its likely outlook.

7.1.1 Factors that affect resilience

Ecosystem resilience is complex to understand and assess because a number of factors can affect it.[2 3 4] An ecosystem's ability to absorb or recover from impacts, and its rate of recovery, depend on the inherent biology and ecology of its component species or habitats; the condition of these individual components; the nature, severity and duration of the impacts and the degree to which potential impacts have been removed or reduced. If all of these features are in place, populations of species or habitats can often absorb or recover from impacts, thus allowing the ecosystem to continue to function. However, if any limitations exist, the capacity of the ecosystem to absorb impacts without changing will be lower than optimal and recovery will take much longer, or even fail.

The key features on which to base an assessment of ecosystem resilience can be grouped as:

Ecosystem biodiversity The variation contained within species and between species and the condition of populations of species and their habitats can be a key factor in resilience.

- It is generally considered that the greater the biodiversity of an ecosystem, the greater the likelihood that an organism can perform a different ecological role when the ecosystem is under pressure (known as 'functional redundancy') and thus adapt to changing ecological conditions.[2]
- Shifts in an ecosystem's biodiversity may indicate that the system is under pressure. For example, a coral reef habitat with a diverse array of corals and fish and a relatively low abundance of fleshy algae usually indicates a habitat that is in relatively good condition. Pressures, such as overfishing, excess nutrients and ocean warming will often cause a long-term shift towards abundant algae and few corals (known as a phase shift).
- The rate at which a species is able to recover within an ecosystem is limited by its biology and ecology. Species can only breed when they reach adulthood, which, in the Great Barrier Reef, can range from five weeks for the pigmy goby (the shortest known vertebrate life history)[4] to over 40 years for green turtles. Some species may require specific breeding areas or conditions (e.g. temperature, phase of the moon or day length) before they are successful in reproducing; for example, coral spawning occurs one to six nights after the full moon in October. Some species may breed annually, some at intervals of five or more years.

The current state and trends of biodiversity in the Great Barrier Reef ecosystem are presented in Chapter 2.

Ecosystem health Natural functioning of an ecosystem's physical, chemical and ecological processes is likely to result in a resilient ecosystem that can absorb stress and rebuild after disturbances. For example:

- Coral recruitment is likely to be strong at reefs with intact herbivore populations because the ecological equilibrium between corals and algae is largely determined by the ecological process of herbivory[5 6](Section 3.4.4).
- The replenishment of fish and coral larvae between and within habitats requires ocean circulation patterns (Section 3.2.1) to maintain connectivity (Section 3.4.9).[7 8]

In assessing resilience, it is important to remember that ecosystems are complex, with countless inter-relationships and the effects of change are not always predictable. The effects of different impacts on an ecosystem often compound and magnify each other. Many ecological processes contain feedbacks that may either regulate or magnify changes.

The current state and trends of health in the Great Barrier Reef ecosystem are presented in Chapter 3.

Impacts on the ecosystem A number of factors affect ecosystems and in many ways, either individually or in combination and at various time and geographic scales.

- A resilient ecosystem will be able to recover from most of these impacts. However, chronic widespread impacts (such as climate change) can seriously affect the resilience of an ecosystem and even short-term local impacts (such as cyclones[9]) can affect resilience, especially when acting in combination with other impacts.
- Impact frequency is also critical to resilience because an ecosystem will always require time to recover from an impact. If recovery takes too long, or disturbances are too frequent or continual, the system may not fully recover before the next disturbance, leading to gradual, long-term degradation.[9 10]

The current and projected factors that are influencing the Great Barrier Reef Region are presented in Chapter 5.

Protection and management For an ecosystem that is already under pressure, the effectiveness of protection and management measures at addressing the threats to that ecosystem is an important factor in retaining or restoring resilience.

- This includes management actions both within the ecosystem and those addressing threats external to the ecosystem.
- The recovery of an ecosystem usually will be stronger if all of the threats are mitigated including those that may be short-term or localised. For example, if one activity has led to a decrease in the population of a species and that activity is removed, assuming all other ecosystem requirements can be met, the species should recover at its maximum population growth rate. However, if many impacts are affecting the species and not all are addressed, the species will not recover at its maximum rate, if at all.

The overall effectiveness of existing protection and management is assessed in Chapter 6.

7.1.2 Comparison with other coral reef ecosystems

There are many examples around the world where coral reefs, or other marine habitats, that lacked resilience have collapsed into a completely different state after being subjected to a range of pressures such as coastal development, poor water quality and fishing pressure.[10] Visitors to the Caribbean may now be diving on reefs that are dominated by algae, with only a few small corals.[10] A number of historically significant fisheries have collapsed and are not yet recovered, causing enormous social, economic and ecological consequences.[11] In countries where reef ecosystems suffer chronically increased sediment loads and where fishing pressures are high, reefs have only partially recovered or have become algae-dominated ecosystems.[12]

The overall condition of the Great Barrier Reef has been considered by a range of scientific experts from a variety of perspectives and their overall consensus is that, while the Great Barrier Reef has suffered significant degradation compared to its pristine condition, it is in far better health than most other reefs around the world (figure 7.1). In the Australia and Papua New Guinea region, 83 per cent of reefs are estimated to be at no immediate threat of significant losses (except for climate change) where as in the United States Caribbean and South-East Asia this percentage drops to 29 per cent and 15 per cent respectively.[13]

7.2 Case studies of recovery after disturbance

Recovery of species or groups of species is a function of their biology, the presence of suitable habitats and the absence of pressures on the species. Without addressing all pressures, recovery will either be slower than its maximum potential, or will not occur.

The following case studies showcase the extent to which some key functional habitats (coral reefs, lagoon floor) and ecological processes such as particle feeding (black teatfish), herbivory (urban coast dugong) and predation (coral trout) have demonstrated recovery after human and natural disturbances. They also showcase some specific management actions that have occurred to address declines in two species (loggerhead turtles, humpback whales).

These case studies are presented to provide examples of the resilience of the Great Barrier Reef ecosystem.

7.2.1 Coral reef habitats

Corals have a special role in reef recovery because they construct habitat for a variety of reef-dependent fish, invertebrates and plants. A coral reef ecosystem that has become damaged to the point where it is nothing but rubble offers little physical protection for small fish and most invertebrates. It is only when a three-dimensional habitat is rebuilt that the habitat can recover its full range of ecological functions.[5 15] Even then, there is a significant difference between an apparently recovered coral reef habitat (usually composed only of fast-growing *Acropora* coral species) and a fully recovered habitat (one that has the full diversity of corals). The former may show substantial re-colonisation within a few years whereas recovery of the full range of coral species, including massive corals and the associated coral reef species, may take decades, even centuries.[16]

In the Great Barrier Reef ecosystem, coral reef habitats are under pressure from a variety of human-related threats, including climate change, water quality, outbreaks of crown-of-thorns starfish, anchoring, dredging and ship groundings. Coral larvae are highly sensitive to water quality, especially sediment levels.[17]

Management A range of measures are used to either eliminate or substantially reduce the magnitude and likelihood of impacts on coral reef habitats. These measures include: protection of coral in Great Barrier Reef and fisheries legislation;

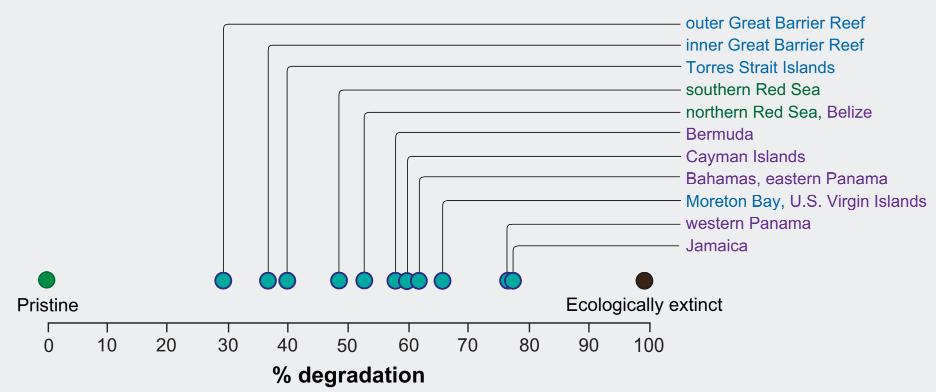


Figure 7.1 The degradation of coral reefs worldwide[14]

An independent analysis compared the relative extent of degradation of various coral reefs, based on the status of key groups of reef organisms. According to this analysis, the outer Great Barrier Reef, followed by the inner Great Barrier Reef and the Torres Strait (blue) are in better condition than reefs in the Red Sea (green) and the western Atlantic Ocean (maroon).

accreditation (with conditions) of the export component of the commercial coral harvest fishery under national sustainability guidelines; establishment of zones or special areas prohibiting certain activities; permit conditions for specific activities; guidelines and codes of conduct; Reef Protection Markers and moorings; implementation of activities to improve water quality (e.g. *Reef Rescue Plan, Reef Water Quality Protection Plan*), by reducing the runoff of terrestrial pollutants; and research and monitoring to assess impacts and monitor ecosystem condition.[18]

Evidence for recovery Corals on a resilient reef will gradually re-establish their dominance after disturbance, even though any dead coral may be initially, but temporarily, overgrown with macroalgae[19 20] (figure 7.2).

Under ideal conditions, coral reefs have an impressive ability to recover abundant coral cover within five to 10 years of single disturbances such as cyclones, crown-of-thorns starfish outbreaks (figure 7.3) or mass bleaching of corals (figure 7.4).

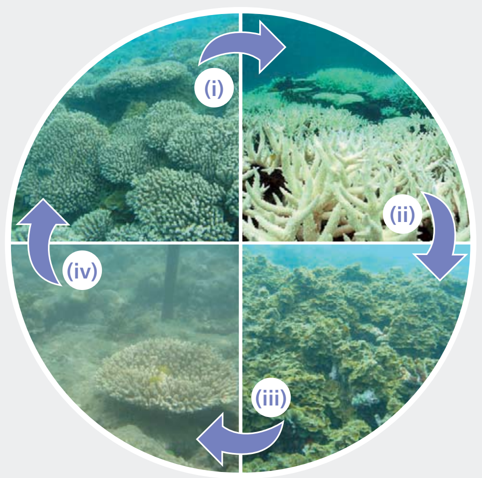


Figure 7.2 **Resilience of a coral reef habitat**

A healthy coral reef will recover from disturbances and return to its usual state. For example, in the Keppel Islands in 2006, abundant healthy corals (i) were bleached (ii), and subsequently overgrown by algae (iii). However, over the subsequent two years, surviving coral fragments regrew, and new corals settled and grew (iv), so that the reef is gradually returning to coral dominance (i). Human impacts may reduce the resilience of the system, and once disturbed, a less resilient ecosystem may fail to recover and may remain permanently in an algal dominated state (iii). (Photos i and iii by G. Diaz-Pulido, iv by L. McCook).

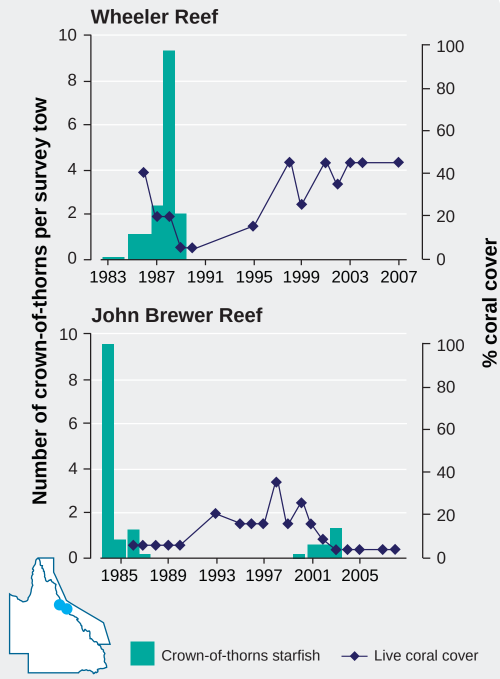


Figure 7.3 **Recovery of coral following disturbance by crown-of-thorns starfish[21]**

In the absence of other disturbances, coral reefs (such as Wheeler Reef) can show an increase in coral cover after an outbreak of crown-of-thorns starfish. On John Brewer Reef, the coral recovered after an outbreak of crown-of-thorns starfish in the 1980s but declined again after another outbreak.

Reefs can recover abundant coral cover within five to 10 years.

The recovery time of coral communities is strongly influenced by whether corals re-grow from existing colonies or rely on re-colonisation.[20] Crown-of-thorns starfish commonly leave parts of colonies untouched, which aids in recovery. In contrast, mass bleaching may kill whole colonies. In some cases, however, coral communities may recover rapidly from high coral mortality, as has recently occurred at the Keppel Islands (offshore Rockhampton) after a bleaching event (figure 7.4).

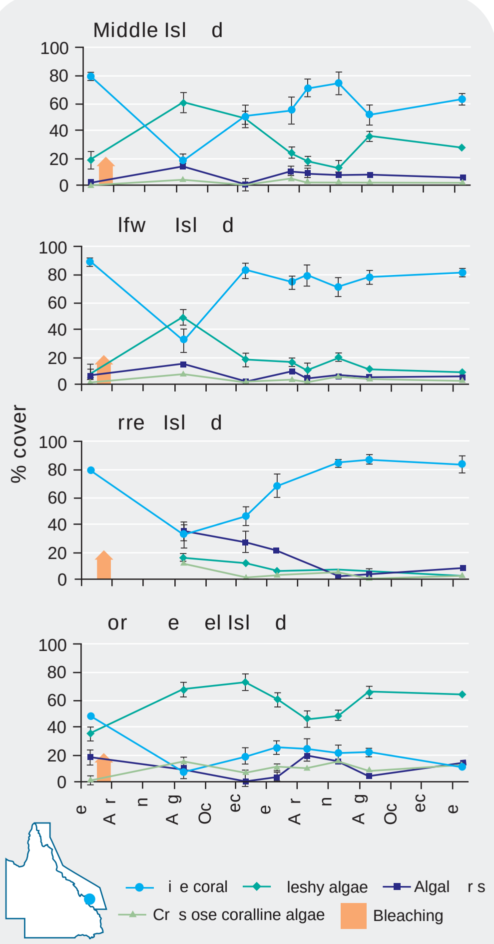


Figure 7.4 **Recovery of coral reefs at the Keppel Islands after a major bleaching event[20]**

A major coral bleaching event causing high coral mortality occurred in the Keppel Islands in 2006. For quick growing coral species, recovery from a disturbance, such as coral bleaching, can be very rapid. Recovery at North Keppel Island was weakest, possibly due to lower coral cover and higher cover of fleshy algae prior to the bleaching event and an increase in broken branching coral from bioerosion. The black bars indicate the standard error around the mean.

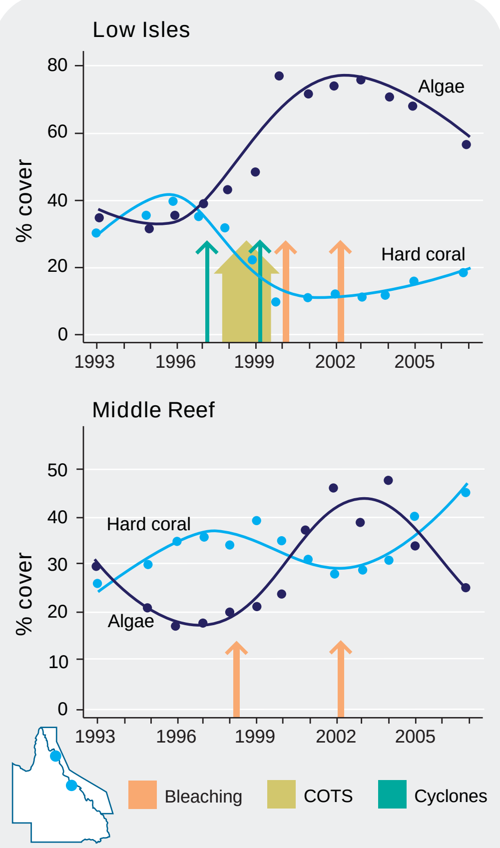


Figure 7.5 **Recovery of coral following various disturbances**

Multiple disturbances of bleaching, cyclones and crown-of-thorns starfish outbreaks (COTS), reduce the capacity of a reef to recover abundant corals, as seen in the slower recovery of hard coral at Low Isles. In comparison, Middle Reef experienced two bleaching events during the same time period and recovered well. (Adapted from Sweatman et al. 2008[21])

The frequency of repeated disturbances such as cyclones, crown-of-thorns starfish outbreaks and flood events have kept some coral reefs of the Great Barrier Reef partly degraded for decades (figures 7.5 and 7.6).

Coral reef habitats are recovering from multiple short-term disturbances.

Fish are essential to coral reef habitat recovery, not only in keeping macroalgae grazed but also in re-establishing other ecological processes, such as predation (for example by coral trout) and detritus recycling.

The projected vulnerability of coral reef habitats in the response to changing climate variables (Section 5.2.2), combined with degraded water quality continuing to enter the Great Barrier Reef (Section 5.4.2), means in the future coral reef habitats will face cumulative disturbance events more frequently and of increased severity. The recovery times of these habitats are likely to increase. Altered species composition of corals and the fish and invertebrates that depend on the habitat could have significant flow-on effects through the food web. Taken together, these factors suggest that the resilience of coral reef habitats on the Great Barrier Reef is declining.

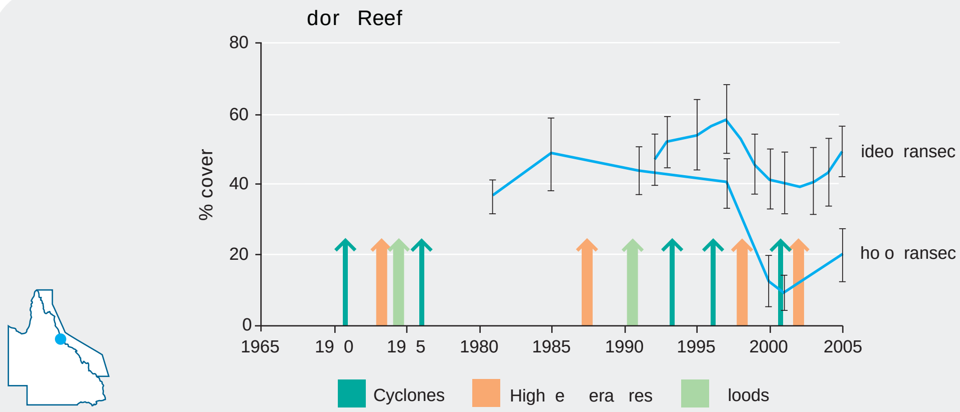


Figure 7.6 | **Recovery of coral reefs in inshore areas**[22]

The recovery of reefs depends on the frequency and nature of disturbances and the conditions for recovery. At Pandora Reef, an inshore reef north of Townsville, coral cover decreased in response to repeated disturbances and only increased once those disturbances ceased. The graph shows the percentage of coral cover (blue lines), measured by video and photo transects, in response to cyclones, high temperatures and floods. The black bars indicate the standard error around the mean.

Predicted increases in frequency and severity of disturbances will likely reduce the capacity for coral reefs to recover.

Success in recovering from a ship grounding

Michael Short from the **Queensland Department of Environment and Resource Management** has studied the recovery of coral reefs after ship groundings. He explains how site repairs and clean up has helped coral reefs recover:

"Since 1996 I have studied four ship grounding sites in the Great Barrier Reef, two where there has been extensive repair work and two with none. My research clearly shows that there are important advantages to stabilising the site where the ship has run aground … there is successful recruitment of coralline algae and juvenile coral and positive signs of successful coral reef recovery. However, at the sites that have not been repaired, the unstable nature of the area means the young corals are frequently damaged before they can contribute to reef recovery. As a result, it is likely to take many centuries for the coral to recover."

7.2.2 Lagoon floor habitats

The lagoon floor of the Great Barrier Reef is notably biodiverse, with more than 5000 species found in recent surveys of shallow benthic areas[23] (Section 2.2.3). Over the past 40 years, major impacts to the lagoon floor have included trawling (Section 4.4.3) and increased nutrients (Section 3.3.1) and pesticides (Section 3.3.2). The observable impacts from trawling have been quantified for a portion of the Region[24], whereas the effects of degraded water quality are more difficult to identify. For example, it can take years for the accumulation of pesticides to show effects in the ecosystem.

Management Today, the lagoon floor is managed in several ways. Marine Parks Zoning Plans protect representative examples of all habitats within the Great Barrier Reef ecosystem, with a minimum of 20 per cent of each of the 40 distinct non-reef bioregions (figure 2.3) protected.

Protection levels for all 840 recently identified seabed assemblages on the continental shelf of the Great Barrier Reef Region increased as a result of the 2004 rezoning of the Great Barrier Reef Marine Park.[25]

Managing risks from trawling in the Great Barrier Reef

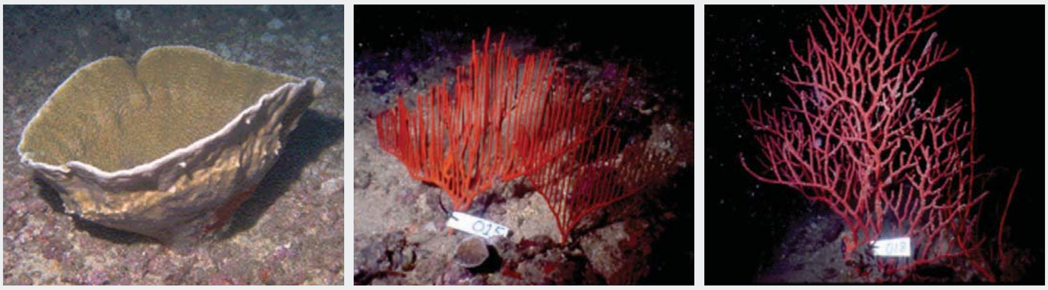
Management responses by the Queensland and Australian Governments and the fishing industry have substantially lowered the risk of trawling to the Great Barrier Reef ecosystem:

- The overall environmental footprint of the fishery is lower as a result of substantial reduction in fishing effort and fleet size.
- Trawling is allowed in 34 per cent of the Great Barrier Reef Marine Park and in 2005 occurred more than once a year in only six per cent (section 4.4.3).
- Investment in research has significantly improved the information base for the fishery and understanding of risks.
- Implementation of a satellite-based vessel monitoring system enables close monitoring of the fleet's activities, resulting in major benefits for compliance and fishery assessments.
- Mandatory use of turtle excluder devices and other bycatch reduction devices has reduced the impacts on bycatch, including species of conservation concern such as loggerhead turtles and large sharks.

Some lagoon floor habitats previously at risk are recovering from disturbances. Full recovery will take decades.

In addition to fishery management arrangements, the Queensland Government has declared 44 Fish Habitat Areas in or adjacent to the Great Barrier Reef, covering 741 813 hectares, to protect areas against physical disturbance from coastal development. A range of environmental impact assessment processes within Australian and Queensland Government legislation aim to minimise the impact of coastal development activities (e.g. dredging associated with port developments) on the lagoon floor. Measures to improve the quality of water entering the Great Barrier Reef, such as *Reef Rescue Plan* and the *Reef Water Quality Protection Plan*, are being implemented to reduce the runoff of terrestrial pollutants.

Evidence for recovery Experimental evidence indicates that some lagoon floor habitats have the potential to recover strongly after disturbances such as trawling.[24] Recovery rates vary: fast for some hard and soft corals and ascidians, moderate for a range of sponges, gorgonians and hard corals, slow for other sponge and gorgonian species (figure 7.7). The variability in recovery times (estimated to range from one to 64 years) depends on the intensity of trawling that has occurred[24] and the specific biology of the species (e.g. some reproduce or grow more rapidly). Although some individual species were shown to be recovering, the mix of species that make up the physical structure of the lagoon floor has changed over time, especially in those areas with higher trawl intensity or in deeper waters. Species assemblages in shallow water or in less intensively trawled areas are exhibiting signs of recovery.



Fast recovery	Moderate recovery	Slow recovery
Hard coral	Gorgonian	Fan gorgonian
Turbinaria frondens	*Ctenocella pectinata*	*Subergorgia suberosa*

Figure 7.7 | Examples of lagoon floor species and their recovery rates[24]

The location of this experiment, the far northern Great Barrier Reef, meant that other factors, such as degraded water quality, were considered unlikely to influence recovery. Obviously if impacts were occurring in addition to trawling, recovery times might be expected to be longer.

Ensuring that trawling is confined to the General Use Zone contributes to the recovery of lagoon floor habitats in other zones. However, records of trawling offences reported each year since the rezoning in 2004 indicates that a small number of trawlers continue to breach the management arrangements for the fishery (figure 4.15).

7.2.3 Black teatfish

Some species of sea cucumbers have been the focus of a commercial fishery in the Great Barrier Reef for more than 100 years[26] (Section 2.3.3). However, in 1999, the Queensland Government closed the fishery for one species, black teatfish, because of concerns for the long-term viability of the harvested stock. Populations of this species on fished reefs have been reduced by at least 75 per cent (to about five individuals per hectare).[27]

Black teatfish inhabit shallow waters. They spawn in winter and have limited migration between reefs. They are slow growing, have low recruitment and high survivorship as adults. These life history characteristics make the species susceptible to overfishing. It is estimated that an annual harvest as low as five per cent of the standing stock might be too great for the species on the Great Barrier Reef.[27]

Management Protection measures in addition to the fishery closure are limited to Marine Parks zoning, which protects a minimum of 20 per cent of all reef bioregions from extractive activities, including those inhabited by black teatfish.

Evidence for recovery For two years after the fishery was closed, reefs formerly fished and those unfished were surveyed to assess recovery of black teatfish. Results indicated no evidence of recovery in that period, with unchanged densities on both reefs that were previously open to fishing and those closed to fishing. Reefs that were already closed to fishing generally had four to five times the density of black teatfish than those that had been open to fishing.[27]

Recovery of this species is expected to be slow because of their life history characteristics and because they need to be close to each other to achieve fertilization after broadcast spawning. It is predicted that populations may take decades to recover.[28,29] These results are not only important for the species, but also for coral reef habitats, since sea cucumbers play an important role in mixing sediment particles and nutrient cycling. Ensuring the fishery and zoning closures are complied with will be a key determinant of recovery for this species.

Populations of black teatfish are low and are not recovering.

7.2.4 Coral trout

Coral trout are found on coral reef and shoal habitats within the Great Barrier Reef. Coral trout is the collective name used for several species of fish in the genus *Plectropomus*. They feed on other fish and invertebrates.[30] Adult coral trout are not thought to move great distances or between reefs, rather staying on resident reefs.[31] There is speculation that some coral trout species move greater distances when forming spawning aggregations, which happens around the new moons in Spring, as the water temperature increases. Little is known about movement of larvae between reefs; this topic is the subject of important current research.[32]

These life history traits mean that coral trout populations are influenced by the condition of coral reef habitats (Section 2.2.2) and the status of fishes (Section 2.3.5) and invertebrates (Section 2.3.3) that are their prey. In the future, coral trout may be influenced by increasing sea temperatures (Sections 3.2.6 and 5.2.1). Their spawning aggregation times and locations may alter, essential habitat may be affected by coral bleaching, and increasing ocean acidity may affect their habitats and the ability of larval fish to find and settle on reefs (Sections 3.3.3 and 5.2.1). Potential changes to ocean circulation could have major impacts on the supply of larvae to depleted populations.

Coral trout are a high-value food fish targeted by commercial and recreational fishers. Traditionally, they were marketed commercially either as fillets or as whole fish, but now most of the catch is sold in the Asian live fish trade.[33]

Management The Queensland Government manages the fishery focused on coral trout, primarily using the *Fisheries (Coral Reef Fin Fish Fishery) Management Plan 2003* and Regulations. In 2004, a total commercial allowable catch and spawning seasonal closures during the Spring new moons each year were introduced for coral trout.[34] There are also size limits and a limit on the number of fish that recreational fishers can have in their possession. The export of coral trout is accredited, with conditions, under national sustainability guidelines.

Marine Park zoning adds further management by protecting a representative portion of all reef habitats where coral trout live as well as the fish within these habitats and compliance patrols enforce the arrangements. Currently more than 65 per cent of the Great Barrier Reef is open to reef line fishing.

The number and size of coral trout is increasing rapidly in zones closed to fishing.

Evidence for recovery Surveys of coral trout on reefs recently closed to fishing have indicated an increase in numbers of up to 70 per cent within two years of closure (figure 7.8).[35] These closed reefs also have a significantly higher biomass of coral trout, because individual fish tend to be relatively large (figure 2.18). This is particularly important as large fish are disproportionately more fecund and therefore contribute most to future fish populations.[36]

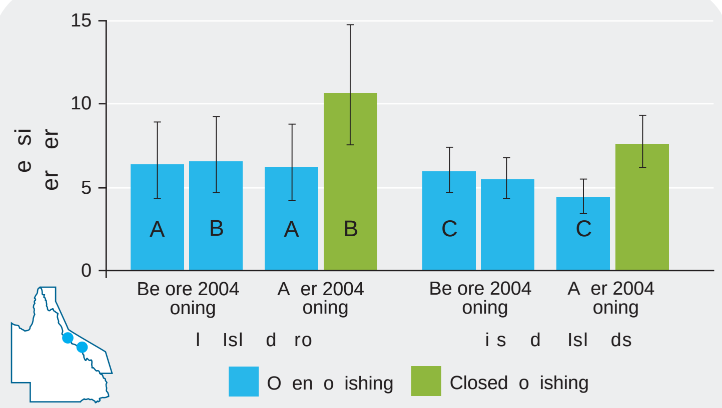


Figure 7.8 Density of coral trout on inshore reefs[35]

Abundance of coral trout can increase strongly once fishing pressure has been removed. In this study, the same sites were surveyed before and after the 2004 zoning. The removal of fishing pressure has also resulted in increases in the biomass of coral trout (figure 2.18). The black bars indicate the standard error around the mean.

The ecosystem effects of lower density and biomass of coral trout in zones open to fishing are largely unknown, particularly because the movement of adult coral trout between reefs is poorly understood; there is little understanding about how many spawning aggregations are protected by zoning; there is limited information on the extent to which closed reefs supply open reefs with coral trout larvae; and the flow on effects of losing predators, like coral trout (Section 3.4.5) from the Great Barrier Reef ecosystem are largely unknown but have the potential to alter food webs.[37]

Compliance with zoning arrangements, spawning closures, and quotas is a key contributor to the status of coral trout populations and their continued recovery in zones closed to fishing. Reports of non-compliance in the commercial line fishery have increased since 2004/05 (figure 4.15).

7.2.5 Loggerhead turtles

The eastern Australian loggerhead turtle nesting beaches, located along the Woongarra coast in south-east Queensland and the islands of the Capricorn Bunker Group and Swains region, support the only significant stock of this species in the South Pacific Ocean. The breeding population has declined by 70 to 90 per cent since the 1970s from an annual population of about 1000 females to less than 300. This, combined with their long maturation (age at first breeding is more than 20 years) and low reproductive rate (breeding every two to five years), means that the remaining loggerhead turtle population is at serious risk of local extinction from any increase in mortality or loss of nesting habitats.[38] Female turtles return to nest in the area where they hatched, so if the population did die out, it is highly unlikely that it would be readily recolonised by loggerhead turtles from another population elsewhere in the world.

Threats to loggerhead turtles include incidental capture in fishing gear, fox predation of mainland nests, incidental catch in shark control program gear (mostly drumlines), ingestion of marine debris, vessel strike, coastal development and increased incidence of disease.[38] Approximately 11 per cent of the foraging population in Moreton Bay, Queensland (south of the Great Barrier Reef Region) exhibited signs of anthropogenic impacts and/or health problems, with propeller cuts being the most frequently recorded.[39]

Management Loggerhead turtles are protected as a threatened species under Commonwealth, Great Barrier Reef and Queensland legislation. Management of loggerhead turtles within the Great Barrier Reef Region is through a combination of legislative requirements, operational policy and research addressing all known human-related pressures on loggerhead turtles. Management actions that have been specifically put in place to protect loggerhead turtles include:

- Identification of two key threatening processes under Commonwealth legislation (incidental catch of sea turtles during coastal otter-trawling and the ingestion of or entanglement in marine debris)
- The *Fisheries (East Coast Trawl) Management Plan 1999* required the mandatory use of turtle excluder devices
- A *Recovery Plan for Marine Turtles in Australia*
- Rezoning the Great Barrier Reef Marine Park increased the amount of loggerhead turtle habitat within highly protected zones[40]
- A summer trawl closure in the Woongarra Marine Park (south of the Great Barrier Reef Region) since 1991
- Baiting for foxes adjacent to nesting beaches in south-east Queensland
- 'Go slow' zones in Moreton Bay Marine Park, an important foraging area to the south of the Great Barrier Reef Region.

In addition, actions to address degraded water quality, such as *Reef Rescue Plan* and the *Reef Water Quality Protection Plan* and education campaigns to reduce litter entering the marine environment, should have flow-on benefits to loggerhead turtles.

Evidence for recovery The mandatory use of turtle excluder devices in the Queensland East Coast Otter Trawl Fishery was implemented in 2001. This has reduced the incidental capture and mortality of sub-adult and adult loggerhead turtles. With this major reduction in loggerhead turtle mortality, the nesting population increased over the next few years (figure 7.9) because more sub-adult turtles were able to become breeding adults and more adult turtles were able to complete their migrations to the nesting beaches.

Fox baiting programs implemented at mainland nesting beaches along the Bundaberg coast have positively influenced the success of loggerhead turtle nesting, by reducing the incidence of clutch destruction from 50 to 90 per cent in the 1970s and 1980s to nearly zero in 2003/04.[38]

However, the increase in the number of sub-adult and adult turtles may now be slowing due to declining recruitment of new immature loggerhead turtles into eastern Australian coastal waters over the last 15 years or more (Section 2.3.6). This decline may be due to incidental capture in international longline fisheries gear and the ingestion of marine debris. Also, expanding coastal development along the Woongarra coast has now resulted in more coastal lighting being visible to newly hatched turtles; this may significantly affect their ability to find the sea after hatching.[41]

In addition to direct threats to loggerhead turtles, climate change has the potential to affect nesting populations. Loss of nesting beaches from rising sea levels (Sections 3.2.5 and 5.2.1), altered sex ratios from increasing air temperatures (table 5.1) and projected changes in ocean circulation, storm intensity and the distribution of prey[42] (Section 5.2.1) will make recovery of the nesting population more difficult in the future.

Trawl turtle excluder devices have arrested the decline in loggerhead turtles but other pressures will influence their recovery.

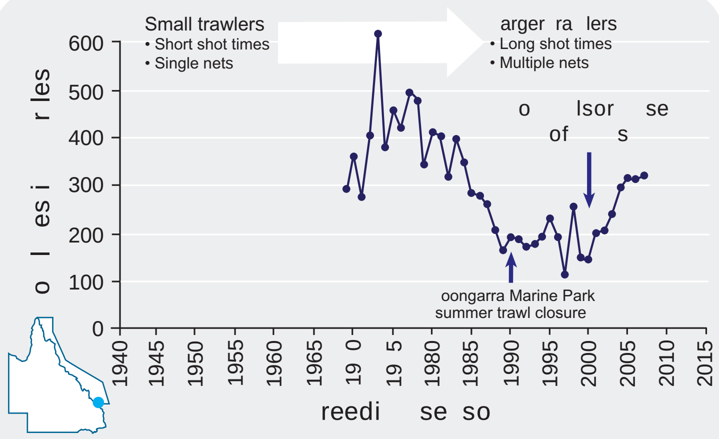
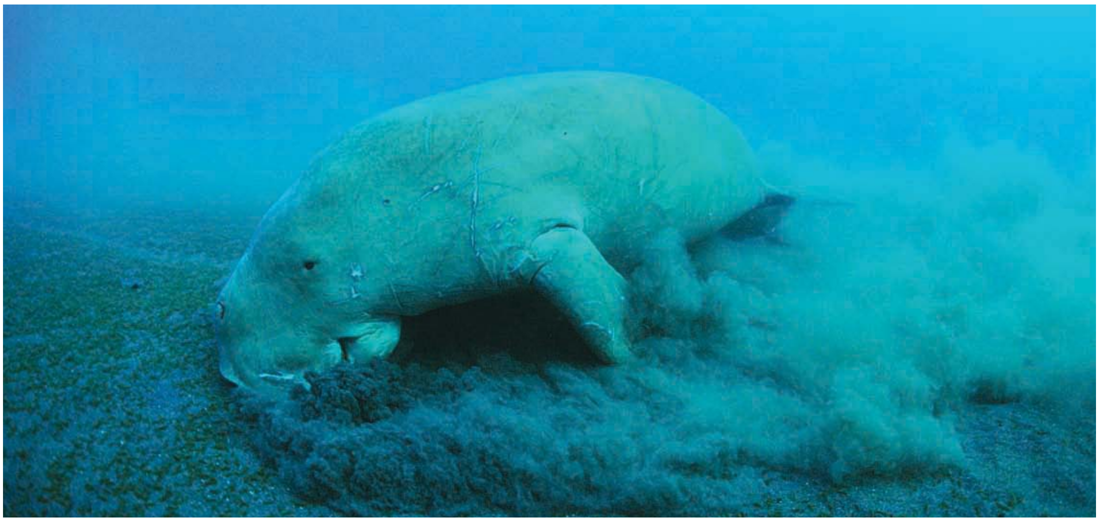


Figure 7.9 **Decline and recovery in the nesting population of the east Australian loggerhead turtle[38]**

Oral history indicates that the loggerhead nesting population was stable prior to the 1960s. Prior to the 1970s, trawl vessels were smaller than those used today, trawlers used single nets and kept them underwater for shorter periods of time. After the 1970s, increases in both the size of trawl vessels and the length of time the nets were deployed (shot time), and the use of multiple nets, contributed to decreases in the loggerhead turtle nesting population. Changes in management of coastal prawn trawl fisheries, including the introduction of turtle excluder devices (TEDs) appear to have resulted in an increase in the number of nesting turtles.



Dugong

7.2.6 Urban coast dugongs

Historical records suggest that dugongs occurred in very large numbers in Great Barrier Reef coastal waters prior to the mid-nineteenth century.[43] Today, the dugong population adjacent to the urban coast (defined as the area in the Great Barrier Reef from Cooktown south) is estimated to be less than 10 per cent of what it used to be.[44] Despite reductions in most sources of human pressure, dead dugongs continue to wash up on Queensland coasts and, of those where the cause of death has been determined, human activity is often implicated.[45]

The urban coast dugong population may take more than a century to recover and is subject to many continuing pressures.

The life history characteristics of dugongs are particularly relevant to conservation of the species. Dugongs are long-lived (over 70 years), slow to reach sexual maturity (females have their first calf at six to 17 years of age), and only calve once every two and a half to seven years.[46]

Management Dugongs are considered a threatened species within Queensland and are protected under Commonwealth, Great Barrier Reef and Queensland legislation. Management actions in response to declines in the dugong population along the urban coast of Queensland have partially addressed impacts associated with: incidental entanglement in large mesh (gill) nets in the Queensland East Coast Inshore Finfish Fishery and the Queensland Shark Control Program; Indigenous hunting; habitat degradation and declining water quality; vessel strikes; and the use of high explosives during defence activities. Relevant management actions have included:

- Establishment of 15 Dugong Protection Areas along the coast of the Great Barrier Reef (south of Mission Beach)
- A substantial increase in protection for key dugong habitats in the Great Barrier Reef Marine Park as a result of rezoning[47]
- A national partnership approach to assist Indigenous communities achieve sustainable harvests of dugongs
- Monitoring of dugong mortality along the Queensland coast as part of the Marine Wildlife Stranding Program
- Implementing voluntary vessel transit lanes in important dugong habitat in the Hinchinbrook area near Cardwell
- Protection of all seagrass under Queensland fisheries legislation and declaration of Fish Habitat Areas in some inshore seagrass habitats.

Evidence for recovery Based on population estimates in 2005 (figure 2.23), it appears that the dugong population is stable at the scale of the urban coast and has been for the past two decades.[48] However, it is not known whether this population will recover such that they can completely fulfil their ecological role as the largest herbivore on the Great Barrier Reef. Their very slow recovery is due in part to their very slow breeding rate and their extremely small population (less than 5000 individuals), and is exacerbated by the cumulative effects of continuing human impacts (e.g. incidental capture in fishing gear, poaching, ingestion of marine debris, boat strike, loss of seagrass foraging areas, traditional use of marine

Lionel Bevis is based in Yeppoon and has lived and worked throughout Queensland most of his life. He recollects his time in the 1950s working out of the **Tangalooma Whaling Station**.

"Then they [the Australian Whaling Commission] would determine a starting date which was usually about the first week in May because that's when the whales would start their migration. We'd go hell for leather then. Once you started whaling, you didn't stop until you had your quota… You don't have to be a mathematician to work it out, if you're knocking off a thousand a year – and that's exactly how it went, from 1952 to 1962… It was like going out and shooting the last elephant. Why would you if you knew, but we didn't. It was the times we lived in."

resources). Even under optimum conditions, dugong populations can only increase at about five per cent per year.[46]

The recovery of dugongs along the urban coast will be influenced by the state of seagrass habitats (Sections 2.2.1 and 2.3.1), its principal food source. Inshore seagrass beds are particularly vulnerable to disturbance and loss due to coastal activities such as reclamation, dredging and other foreshore development, increased sedimentation and degraded water quality.[49] After serious disturbance, intertidal seagrasses normally recolonise areas within months to years.[50] This recovery depends on the availability of seed banks, water quality and the amount of sedimentation.

7.2.7 Humpback whales

When the hunting of humpback whales was banned in Australia in 1963, the eastern Australian population was less than five per cent of that estimated earlier in the century and they were seldom seen on the Great Barrier Reef. The prohibition on whaling addressed the single biggest factor in the decline of the humpback whale population.

Management Humpback whales are considered a species of conservation concern (Section 2.1.2) and are protected under Commonwealth, Great Barrier Reef and Queensland legislation. Today, human impacts on humpback whales include incidental catch in gear associated with fishing and the Queensland Shark Control Program, collisions with vessels and the potential effects of whale watching by recreational visitors and tourists. Their management within the Great Barrier Reef ecosystem is governed by a system of legislative requirements (e.g. regulations on how close vessels and aircraft can approach whales, a national recovery plan); operational policy (e.g. addressing tourism-related whale watching activities); national guidelines and best practices.

Evidence for recovery Humpback whales appear to be recovering steadily, with the population that migrates up the east coast of Australia each winter increasing at about 10 per cent per year[51] (figure 7.10). Numbers of humpback whales on the east Australian coast today are estimated to be about half their pre-whaling numbers and at current rates of increase could return to their earlier numbers within the next 20 years.

Humpback whales appear to be recovering at their maximum rate 45 years after whaling stopped.

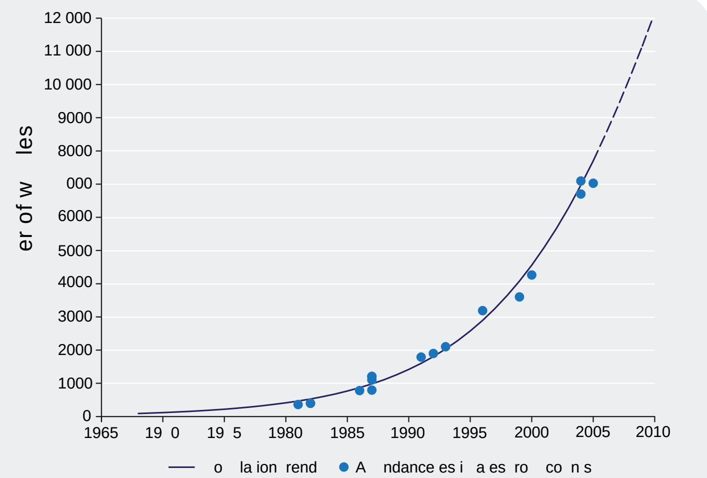


Figure 7.10 Recovery of the eastern Australian humpback whale population since whaling ceased in the 1960s

Humpback whales appear to be recovering steadily, with the population that migrates up the east coast of Australia each winter increasing at about 10 per cent per year. (The data to construct this graph was collated by Dave Paton (Centre for Cetacean Research and Conservation) and Dr Mike Noad (University of Queensland) using individual population estimates extracted from several sources[52 53 54 55 56 57 58 59])

7.3 Assessment summary – Ecosystem resilience

Section 54(3)(e) of the *Great Barrier Reef Marine Park Act 1975* requires *"…an assessment of the current resilience of the ecosystem …"* within the Great Barrier Reef Region. This overall assessment of ecosystem resilience is based on the information provided in earlier chapters of this Report, namely the current state and trends of the Great Barrier Reef ecosystem's biodiversity and health as well as the trends in direct use, the factors influencing future environmental values and the effectiveness of protection and management arrangements. It is supplemented by a series of case studies addressing:

- recovery after disturbance.

7.3.1 Recovery after disturbance

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Coral reef habitats	Coral reef habitats are recovering from multiple short-term disturbances. Predicted increases in frequency and severity of disturbances will likely reduce the capacity for coral reefs to recover.		●		
Lagoon floor habitats	Some lagoon floor habitats previously at risk are recovering from disturbances. Full recovery will take decades.		●		
Black teatfish	Populations of black teatfish are low and are not recovering.				●
Coral trout	The number and size of coral trout is increasing rapidly in zones closed to fishing.		●		
Loggerhead turtles	Trawl turtle excluder devices have arrested the decline in loggerhead turtles but other pressures will influence their recovery.			●	
Urban coast dugongs	The urban coast dugong population may take more than a century to recover and is subject to many continuing pressures.				●
Humpback whales	Humpback whales appear to be recovering at their maximum population growth rate 45 years after whaling stopped.	●			
Recovery after disturbance	Some disturbed populations and habitats have demonstrated recovery after disturbance (for example coral reefs, lagoon floor, coral trout, humpback whales). For some species recovery has been very slow (for example loggerhead turtles) or not evident (black teatfish, dugongs) and is dependent on the removal of all major threats. Increasing frequency and extent of threats are likely to reduce the resilience of species and habitats.		◉		

GRADING STATEMENTS

Very good - Under current management, throughout the ecosystem, populations of affected species are recovering well, at rates close to their maximum reproductive capacity. Affected habitats are recovering within expected natural timeframes, following natural cycles of regeneration.

Good - Populations of affected species are recovering at rates below their maximum reproductive capacity. Recovery of affected habitats is slower than naturally expected but structure and function are ultimately restored within a reasonable timeframe.

Poor - Populations of affected species are recovering poorly, at rates well below their maximum reproductive capacity. Recovery of affected habitats is much slower than expected natural timeframes and the resultant habitat is substantially different.

Very poor - Affected species are failing to recover and affected habitats are failing to recover to their natural structure and function.

7.3.2 Overall summary of ecosystem resilience

At the scale of the Great Barrier Reef ecosystem, most habitats or species groups are in good condition; however there have been declines in species that play key ecological roles. These declines have been mainly due to direct use of the ecosystem, land management practices in the catchment, or declining environmental variables because of climate change.

There are concerns about aspects of the ecosystem's health. Sea temperature, sea level and sedimentation are all expected to increase because of climate change and catchment runoff, causing deterioration to the ecosystem. Changes in the chemical processes of ocean acidity, nutrient cycling and pesticides now affect large areas of the ecosystem. At the same time, reductions in some predator and herbivore populations may have already affected ecological processes, although the specific effects remain unknown. Outbreaks of diseases appear to be becoming more frequent and more serious.

The vulnerabilities of the ecosystem to climate change, coastal development, catchment runoff and some aspects of fishing mean that recovery of already depleted species and habitats requires the management of many factors. In some instances, the ecosystem's ability to recover from disturbances is already being compromised with either reduced population growth or no evidence of recovery.

The independent assessment of existing protection and management found that management is most challenging for those topics which are broad in scale (often well beyond the boundaries of the Great Barrier Reef) and complex. For example addressing climate change impacts requires global responses; coastal development and water quality require coordinated actions throughout the catchment. The management of fishing is socially and biophysically complex. The assessment indicated that addressing cumulative impacts is one of the least effective areas of management.

Notwithstanding these challenges, many of the management measures employed in the Great Barrier Reef Region and beyond are making positive contributions to resilience (as evidenced by recovery of some species and habitats). The Zoning Plans for both the Great Barrier Reef Marine Park and the adjacent Great Barrier Reef Coast Marine Park that were introduced in 2004 are the most significant action taken to enhance biodiversity protection. They provide a robust framework for management and are already demonstrating positive results. Compliance with and public support for these and other measures is a critical factor in building the resilience of the ecosystem.

Taken together, available information indicates that the overall resilience of the Great Barrier Reef ecosystem is being reduced. Given the effectiveness of existing protection and management in addressing the most significant pressures on the ecosystem (principally arising from outside the Region), this trend is expected to continue.

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