Australian Government

Great Barrier Reef Marine Park Authority

Extreme Weather and the Great Barrier Reef

The summer of 2010-11 brought unprecedented weather conditions to Queensland. Cyclone Yasi was one of the most powerful cyclones to have affected the Great Barrier Reef since records commenced, while South East Queensland experienced intense rainfall, up to 400 per cent higher than normal.

These extreme weather events damaged coral reefs and seagrass beds, leading to additional pressures on important species such as dugong and green turtle. They also had implications for the industries and communities that depend on the Reef, including direct damage to infrastructure and impacts to natural resources.

Coral reefs have a natural ability to recover from extreme weather impacts, enabling the Reef to bounce back from these events. While the Great Barrier Reef is expected to cope with the impacts of climate change better than most coral reefs around the world, the spate of severe floods and intensity of recent cyclones will test its resilience.

The Great Barrier Reef Marine Park Authority implemented the Extreme Weather Response Program to better understand the impacts of extreme weather on the Great Barrier Reef and help Reef industries and communities prepare for future extreme weather events.

Climate scientists predict increased frequency of extreme weather events such as flooding rains and intense cyclones as a result of climate change. The effects of recent extreme weather events highlight the need for effective management and active stewardship. Insights from the Extreme Weather Response Program are being used to guide the focus of management into the future and to help build the resilience of the Reef and its industries and regional communities to climate change.

What was so "extreme" about the summer of 2010-11?

Summer is always a period of heightened risk for the Great Barrier Reef. Warmer conditions bring the threat of high sea temperatures that can cause coral bleaching and wet seasons with strong monsoonal conditions can result in large flood plumes and damaging cyclones.

While regional climate processes such as El Niño Southern Oscillation (ENSO) cause seasonal weather patterns to swing between clear/dry (El Niño) and cloudy/wet (La Niña), global climate change is altering the underlying conditions. Already, we are seeing patterns consistent with predicted effects of climate change: an increased prevalence of coral bleaching in El Niño summers and more damage from floods and cyclones during La Niña years.

Flooding in the Great Barrier Reef catchment during summer 2010-11 created persistent flood plumes from the Fitzroy, Burnett and Mary Rivers.

The summer of 2010-11

- Cyclone Yasi was the first category five cyclone to cross the coast since 1918.
- South East Queensland experienced rainfall 300-400 per cent higher than average.

The summer of 2010-11 featured an unusually strong La Niña event. It brought exceptional weather across Australia, resulting in the second wettest summer on record. In South East Queensland, the summer saw intense rain and devastating floods. North Queensland experienced tropical cyclone Yasi's very destructive winds and a powerful storm surge. In combination, the summer of 2010-11 had brought conditions unprecedented in the history of the Great Barrier Reef Marine Park.

This was not the only wet and windy summer for the Great Barrier Reef. Three of the last four summers have all had above average rainfall in eastern Queensland associated with La Niña conditions.

About this report

The Great Barrier Reef Extreme Weather Program assisted us to understand what extreme cyclones and floods mean for the Reef and the people who depend on it. It also helped target efforts to support recovery of damaged areas and build the resilience of the Reef over the longer term. This report presents key findings from the Program and profiles management and stewardship efforts that have been put in place to help the Reef cope with the after-effects of extreme weather. It also provides an overview of extreme weather in the context of climate change and the long-term outlook for the Reef and its management.

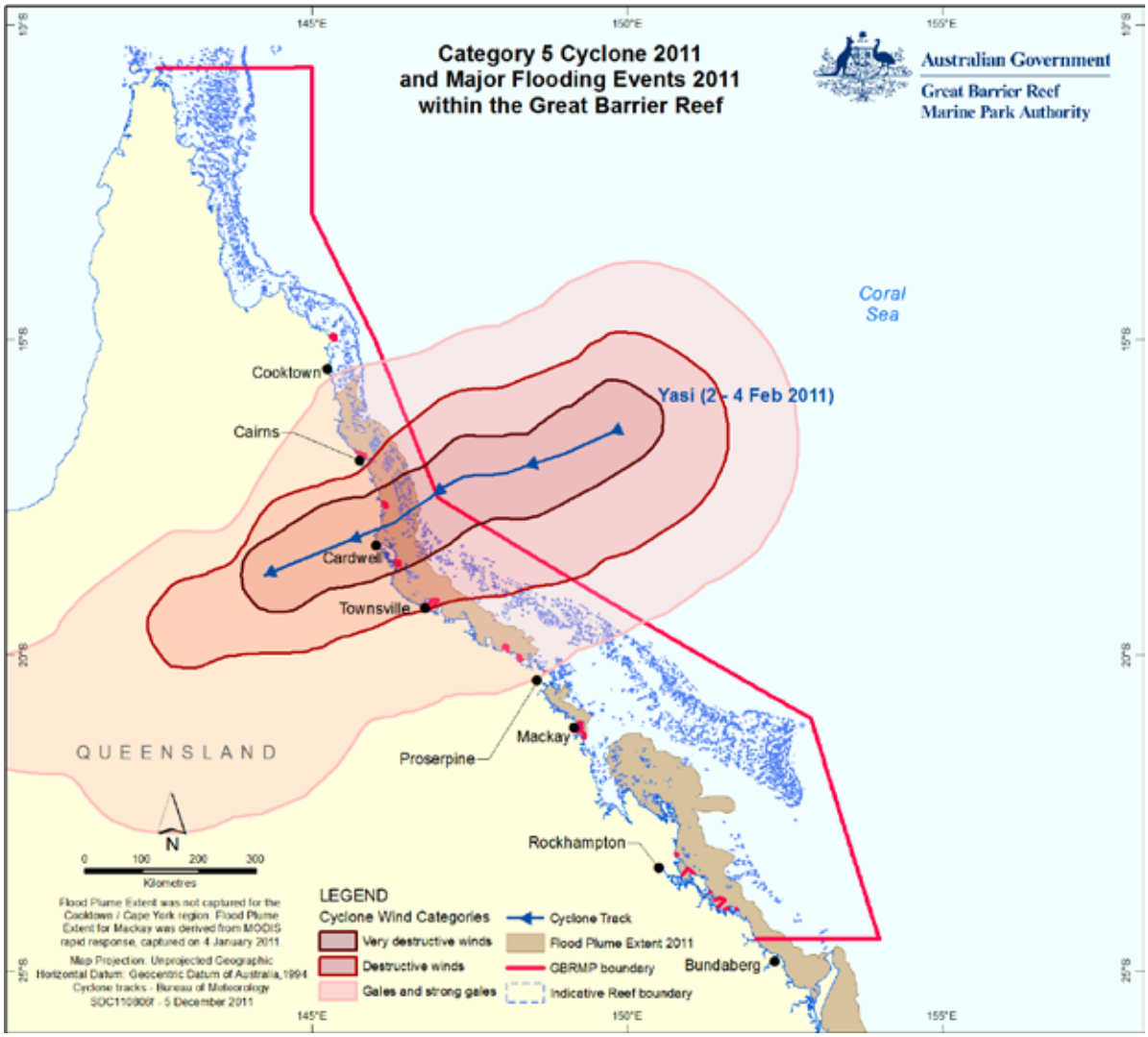
The cumulative effects of these wet seasons have meant that some sensitive species (such as corals, seagrasses, green turtle and dugong) were particularly vulnerable to the extreme weather conditions that occurred in the summer of 2010-11.

Why is extreme weather a problem for coral reefs?

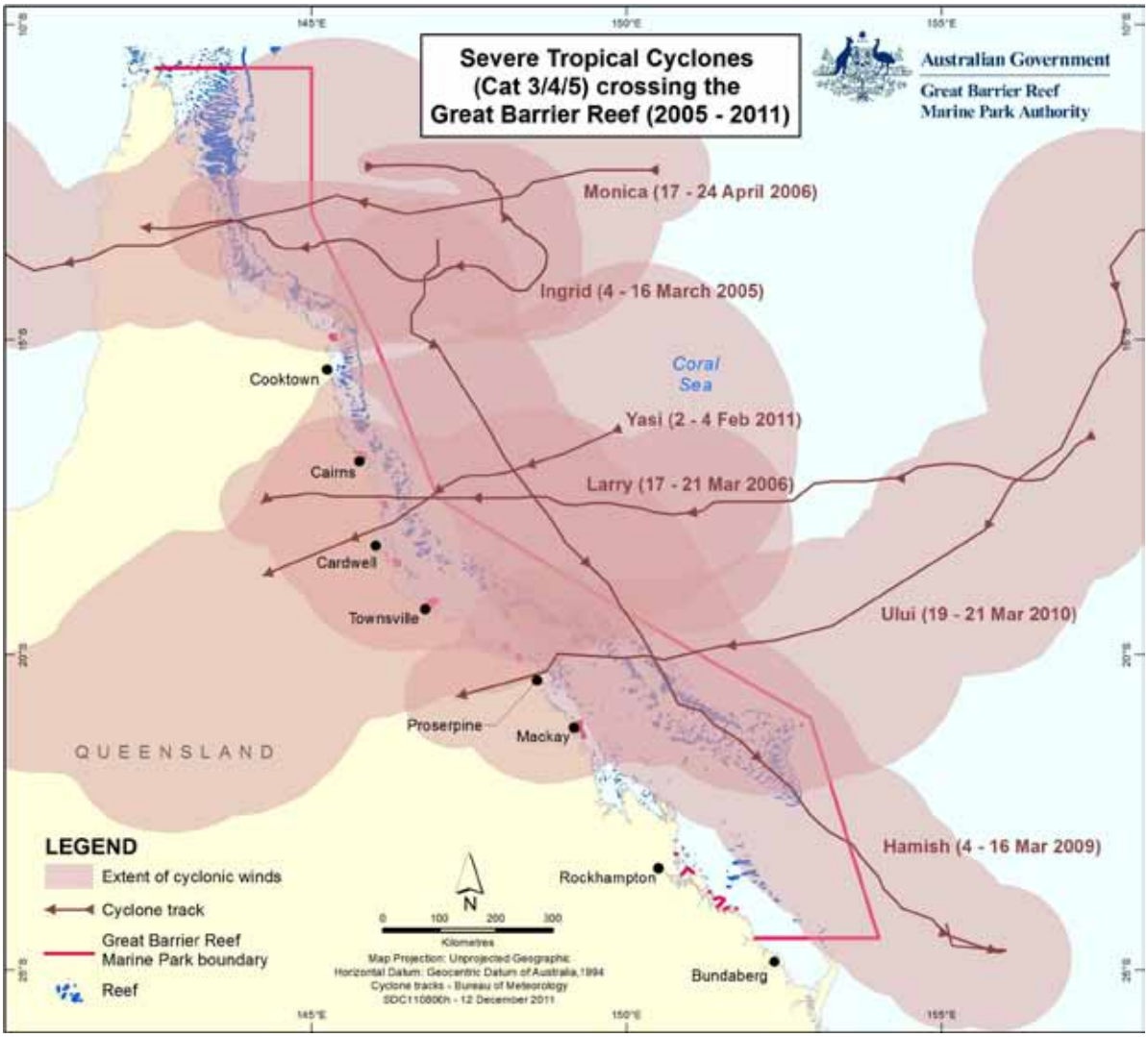
Cyclonic winds and floodwaters can have severe impacts on coral reef ecosystems. Floodwaters entering the Great Barrier Reef can cause stress to inshore ecosystems through reduced salinity, increased turbidity and elevated concentrations of nutrients and agricultural chemicals. Prolonged exposure can lead to death in some species, especially sessile (attached) organisms such as corals and seagrasses.

Large, intense cyclones, such as cyclone Yasi, can have impacts that affect large areas and last for decades, if not centuries.

Corals and seagrasses provide essential habitat and food for many other species such as fish, turtles and dugong; their loss can have flow-on effects through the system.



Cyclone Yasi crossed the Great Barrier Reef near Dunk Island, exposing the coast and adjacent areas of the Great Barrier Reef Marine Park to wind gusts up to 285 km/h. Extensive flooding resulted in persistent floodplumes in the central and southern Great Barrier Reef.



Six severe cyclones have impacted the Great Barrier Reef since 2005. The greater frequency of extreme weather events will reduce the time for reefs to recover between disturbances.

Some species, especially various types of algae and crown-of-thorns starfish, can actually benefit from the increased input of materials (e.g. nutrients), leading to imbalances in the system.

Cyclones cause strong winds that generate powerful waves, damaging turbulence and destructive currents. They can also cause intense rainfall and flooding.

Tropical cyclones affect coral reefs in different ways. Cyclones cause exceptionally strong winds which generate powerful waves that crash onto shallow reef areas and create damaging turbulence in deeper areas. Flood plumes, caused by the intense rainfall that often accompanies cyclones, can expose large areas to stressful changes in water quality. Particularly intense and large cyclones, such as cyclone Yasi, can also cause destructive currents as huge amounts of water are driven by sustained winds and waves.

Through the direct forces of waves and currents, and the impacts of sand and rubble tossed around by underwater turbulence, cyclones can cause extensive damage to corals and the underlying reef structure.

Cyclones can cause severe damage to coral and the underlying reef structure through the direct forces of waves and currents, and the impacts of sand and rubble tossed around by underwater turbulence.

At reefs exposed to the full force of a cyclone there can be near-complete destruction of the coral community and associated species, leaving a barren and pulverised reef substrate. For weaker cyclones or at reefs further from the centre of intense cyclones, damage is generally less severe. Patches of reef may still be denuded by the cyclone's force, but these are usually outnumbered by the many patches of surviving coral.

At the worst affected sites (pictured right) the impact of waves and wave-borne debris removed almost all traces of sessile (attached) marine life down to at least 15 m depth. However, damage was patchy and areas of healthy reef (pictured left) were observed even within the region exposed to very destructive winds.

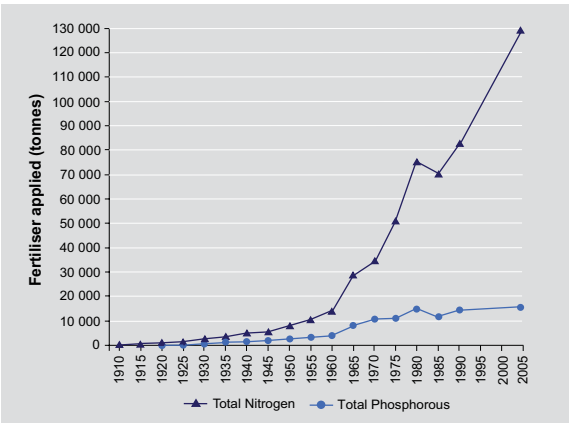
The Cardwell foreshore was significantly damaged by Yasi's very destructive winds and powerful storm surge. Image © Dieter Tracey.

Cyclones can also damage seagrasses and other coastal habitats such as mangroves and wetlands. Seagrasses in the intertidal zone can be ripped up by large waves, while deeper seagrass meadows can be scoured by strong currents. Mangroves and wetlands can suffer the effects of fierce winds and unusual or prolonged inundation.

Cyclones and floods in historical context

The Great Barrier Reef ecosystem has evolved under a natural regime of cyclones and floods, so in many ways severe weather is 'normal'. Between 1995 and 2009 approximately 34 per cent of all coral mortality recorded in long-term monitoring[1] of the Great Barrier Reef is attributable to storm damage.

Sediments carried into the Great Barrier Reef by floodwaters can settle out and smother corals and other animals and plants attached to the seabed. Image © Steve Spring | Marine Photobank.



There has been a large increase in the amount of fertilisers used in Great Barrier Reef catchments over the last century. Elevated levels of nutrients and sediments entering the Great Barrier Reef ecosystem are reducing its resilience.

1 Australian Institute of Marine Science Long Term Monitoring Program

Seagrasses provide important habitat and food for other species. Recent floods and cyclones have added to the cumulative impacts of multiple, harsh wet seasons, reducing the resilience of seagrass. Image © Dieter Tracey.

However, recent conditions are causing unprecedented challenges for the Great Barrier Reef. The floodwaters now entering the Great Barrier Reef carry chemicals (nutrients and pesticides) and quantities of sediments that would not have occurred prior to European settlement. Severe cyclones are predicted to occur more frequently as the climate warms, bringing a future where the recovery potential of coral reefs and seagrass meadows becomes increasingly important. Chronic stresses from reduced water quality can hinder recovery of damaged seabed communities. Therefore, the combined effect of increased flooding and more severe storms means efforts to restore the natural resilience of important habitats such as coral reefs and seagrass meadows are more important than ever before.

Beneath the surface: extreme weather impacts on the Reef

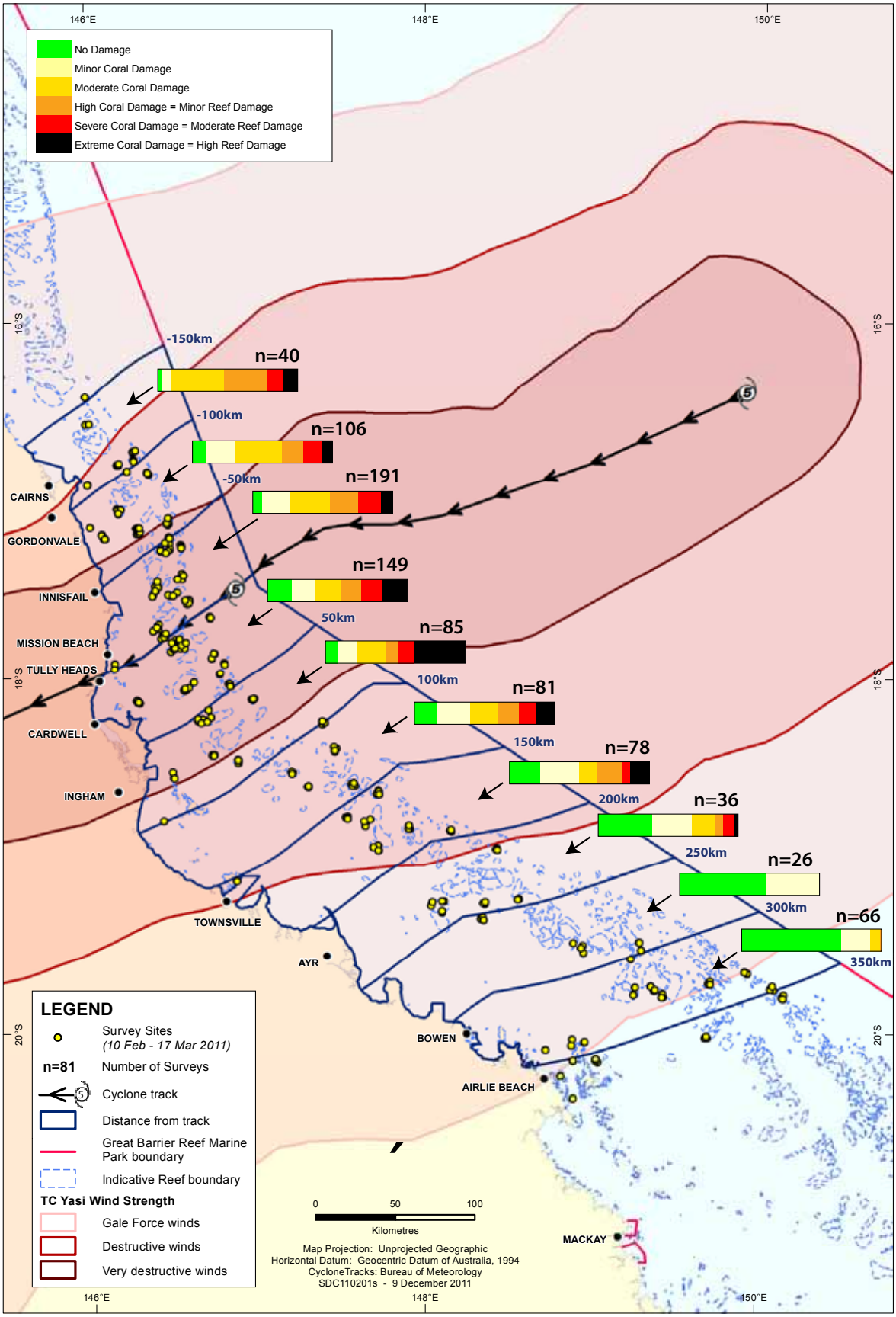
The extreme weather events of 2010-11 caused a range of impacts to the Great Barrier Reef ecosystem. Fortunately, the major tourism areas off Port Douglas, Cairns and Airlie Beach were spared serious damage. However, while the effects of these events were patchy, the combined damage from floods and cyclone Yasi spans a large area and the most severely damaged reefs could take decades to recover. Many of the impacts were immediate and direct, such as broken coral from cyclone-driven waves and seagrass meadows scoured by flood plumes. Other impacts are indirect and will take time to fully manifest. These include the effect of damaged seagrass meadows on dugong and green turtle populations and the potential effects on seabirds impacted by changes to islands and cays used for nesting.

Reefs feel the brunt of extreme weather

Coral reefs were affected by both flooding and cyclone Yasi with many inshore reef areas experiencing some stress from flood-waters during 2010-11. The exceptionally large volumes of water flowing from rivers in South East Queensland had the greatest potential to cause lasting damage.

The worst effects of the flooding were confined to inshore reefs close to the mouths of major rivers. Surveys of coral reefs in the Keppel Bay region, near the mouth of the Fitzroy River, showed floodwaters had caused severe damage to shallow reef areas. Reefs fringing the mainland sides of islands had the greatest exposure to floodwaters, and it was here that up to 85-100 per cent of corals were killed.

There can be near-complete destruction of coral communities at reefs exposed to the full force of a cyclone.



Cyclone Yasi caused patchy damage along 400 km of the northern Great Barrier Reef. Approximately 85 per cent of coral reef habitat in the Marine Park escaped largely undamaged by the cyclone, including the major tourism areas. However, approximately six per cent suffered severe damage.

Cyclones are major disturbances to coral reefs, causing damage to individual corals, entire coral communities, and also to the structure of the Reef itself.

While the reefs of the Keppel Bay region have historically shown an impressive resilience to impacts from floods and coral bleaching, recovery at the most severely damaged sites will take many years.

Cyclone Yasi is one of the most damaging single events to affect the Reef in the last 100 years. It caused patchy damage across offshore, mid-shelf and inshore reefs along 400 km of the northern Great Barrier Reef. Damage was largely confined to an area south of Cairns to around Townsville, sparing major tourism areas. Overall, approximately six per cent of reef habitat in the Great Barrier Reef Marine Park suffered severe damage (most corals broken or removed). Approximately 85 per cent of coral reef habitat in the Marine Park escaped largely undamaged by the cyclone.

Cyclone Yasi was not the only major cyclone to affect the Great Barrier Reef in recent years. In fact, four other category five cyclones have affected the Reef already this century (compared with only two last century – both in 1918). As a result of the large scale impact of these cyclones (especially cyclones Yasi and Hamish in the last few years), it is likely storm damage now accounts for the largest share of coral mortality on the Reef over the past two decades.

Coral trout catches dive in wake of cyclone

Many commercial fishers reported dramatic declines in catch rates of coral trout at shallow reef areas affected by cyclone Yasi. Follow-up research found this was not related to a change in the abundance of coral trout, but rather appeared to be explained by a decrease in the 'catchability' of these fish. These results are consistent with the effects reported following cyclone Hamish in 2009.

Underwater surveys of shallow reefs (less than 20 m) offshore Townsville found the numbers of adult coral trout in Marine National Park (Green) Zones – which are closed to fishing – had not been affected by cyclone Yasi. In contrast, the research documented a large decline in the abundance of adult coral trout at nearby reefs open to fishing (Habitat Protection (Blue) Zones) since previous surveys. The very low numbers of adult fish in Blue Zones compared with Green Zones suggests that Blue Zone reefs off Townsville have received substantial additional fishing pressure since the last surveys. This is likely to be the result of a northward movement of the southern commercial fishing fleet in response to depressed catch rates on reefs affected by cyclone Hamish.

Most commercial fishing activity targeting coral trout takes place in shallower waters. Although the post-Yasi surveys were restricted to these relatively shallow areas of the Reef, anecdotal reports from recreational and commercial fishers who fish deeper shoals suggest that populations of coral trout may have been less impacted in these deeper habitats. In combination with the Marine National Park Zones, these refugia will play an important role in the recovery of coral trout populations in shallow areas affected by intense fishing pressure. The research reinforces the importance of Green Zones for the protection of coral trout populations.

The Great Barrier Reef Marine Park Authority is continuing to work with fishers, peak industry bodies and management agencies to understand the effects of extreme weather events on fish populations.

Overall, the results indicate that coral trout remain prominent components of the fish community throughout the areas affected by extreme weather, even though specific sectors of the commercial fishing industry have been impacted by depressed catch rates.

Monitoring of recovery and further research are continuing, including a coral trout tagging program. This work will help fishers and management agencies better understand the implications of extreme weather on fish populations and inform management arrangements that can further improve the ecological sustainability of the coral reef finfish fishery.

Seagrass meadows in decline

Seagrass meadows are vitally important to the Great Barrier Reef ecosystem. They are also vulnerable to the effects of extreme weather.

Preliminary survey results indicate the extensive and prolonged floods have caused significant damage to important seagrass meadows in the southern Great Barrier Reef. Cyclone Yasi also damaged seagrass meadows. There are indications that many shallow water or intertidal meadows suffered severe scouring within the area affected by gale force winds. Deepwater surveys using remotely-operated vehicles indicate cyclone Yasi may even have damaged seagrass meadows down to at least 30m depth: deepwater sites known to have lush seagrass meadows five years ago were found to be almost completely barren following cyclone Yasi.

The difficult task of assessing the full extent of seagrass loss is continuing, but it is likely there will be more seagrass lost as the long-term impacts of flooding manifest. The rate of seagrass decline depends on the type of seagrass community, with some species of seagrass able to tolerate longer periods of light limitation than other species.

Recovery rates are also highly variable. Some meadows with intact seed banks or remnant plants can show strong recovery in a year or so, while other slower-growing species and areas with diminished seed banks may not recover for decades.

Increased monitoring of seagrass beds is aiming to better understand the status of this habitat which is a vital food source for species such as dugong and green turtle.

The effects of the extreme weather events follow a series of stressful wet seasons for seagrasses. Prior to the 2010-11 summer, many intertidal seagrass meadows had shown a trend of declining abundance[2]. In combination, these observations indicate that seagrasses, and the species that depend on them, are especially vulnerable to changing conditions and will require increased management focus in coming years. It is critical that monitoring and research continue to build knowledge of the status and trends of this very important habitat and the options for building their resilience in a changing climate.

2 **Marine Monitoring Program report**: www.gbrmpa.gov.au/__data/assets/pdf_file/0009/7677/RRMMP_Seagrass_annual_report_2009_10.pdf
Reef Plan Report Card: www.reefplan.qld.gov.au/measuring-success/report-cards/first-report-card.aspx

Dugong and turtle lose food supplies

Dugong and green turtles are almost entirely reliant on seagrasses for their nutrition. This strong dependency has meant dugong and green turtles have also suffered from the 2010-11 summer's extreme weather.

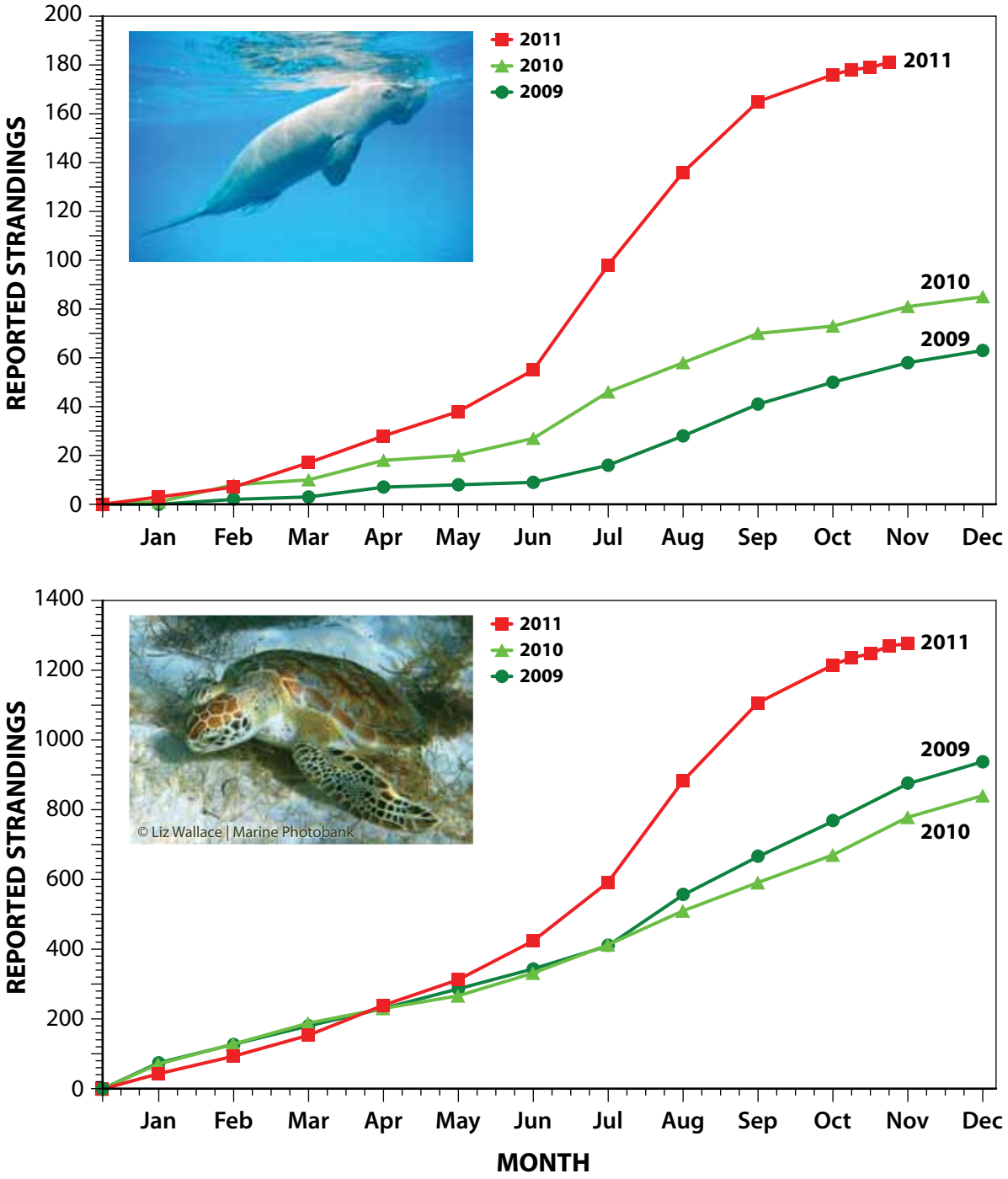
Information received through the Marine Strandings Program reveals a dramatic increase in the number of dead turtles and dugong reported from beaches in areas affected by extreme weather. Dugong deaths following cyclone Yasi and the floods were much higher than any previous year for which there are records. One hundred and eighty one strandings were reported up until November 2011 compared to 85 for the same period in the previous year. Due to chronic pressures and slow reproduction rates, dugong populations were only just beginning to stabilise after an extended period of decline. Experts are concerned the losses following extreme weather events could have a significant bearing on the long-term vulnerability of dugong, at least in waters south of Cooktown.

Stranding reports for green turtles in Queensland are also significantly higher than previous years. Reported deaths for 2011 up to November were 1275 compared with 754 for the same period in the previous year. Green turtles are able to partially compensate for decreased seagrass availability by eating algae and mangrove leaves and by having relatively low energy demands. While this enables them to cope with declines in seagrass better than dugong, the lower nutritional value of these foods renders them more susceptible to ill health and death.

It is likely the impacts of the extreme weather of 2010-11 on dugong and green turtles are being exacerbated by the longer-term decline in seagrass abundance. As a result, experts are predicting the increase in dugong and turtle deaths may be a trend that continues at least into 2012. Reversal of this trend will require substantial recovery of seagrass meadows as well as careful management of other risks to these species.

Dugong depend almost entirely on seagrass for food. The poor nutritional condition of stranded dugongs suggests that many deaths are associated with the decline in seagrass following extreme weather events.

Further research is under way to track the movements of green turtles as they search for suitable feeding areas. Initial results show green turtles are concentrating their movements at particular sites, indicating they are locating suitable seagrass meadows even in areas affected by cyclone Yasi. This work will improve our understanding of changes in distribution and behaviour so managers can better target efforts to minimise avoidable risks and support recovery of dugong and green turtle populations.



Reports of dugong strandings in 2011 were much higher than any previous year for which there are records. Dugongs are thought to be suffering the effects of declining seagrass meadows, despite improvements in their level of protection. Reported turtle strandings in 2011 are significantly higher than in previous years. Green turtles are also being affected by loss of seagrasses, but they can supplement their diet somewhat with algae and mangrove leaves.

Islands and beaches

Islands provide habitat for a diversity of terrestrial species and are a critical breeding habitat for marine species such as seabirds and marine turtles. Many island features are vulnerable to extreme weather, with forest habitats and nesting beaches susceptible to cyclone impacts and ecosystems at risk from pest introductions facilitated by floodwaters.

Island surveys confirmed cyclone Yasi caused extensive damage to vegetation. Large trees and entire sections of rainforest were destroyed on islands exposed to very destructive winds, resulting in the loss of food and habitat for many animals that rely on island forests. Numbers of breeding pied imperial pigeon on North Brook Island in 2011 are less than ten per cent of previous years, suggesting the island or mainland feeding habitats are too damaged to support normal breeding.

Many island habitats were denuded by the destructive winds of cyclone Yasi. Rainforest and bushland birds are expected to recover as the vegetation re-establishes.

Cyclone Yasi, possibly in combination with cyclone Anthony, caused the formation of new rubble cays on some reefs and the loss of some sandy cays. The erosion of shorelines by waves has changed beaches and sand spits on many islands. These changes impacted turtles and seabirds that use these sandy areas. Breeding was disrupted on affected islands, with loss of eggs and chicks recorded.

Over 900 islands in the Great Barrier Reef provide habitat for a diverse range of animals and plants and essential breeding areas for seabirds and marine turtles.

Michalmas Cay, a very important area for seabird breeding and tourism, lost half of its available nesting habitat. The effects on seabirds will continue until there is substantial recovery of these habitats.

Large amounts of marine debris, including vegetation, logs, damaged vessels and infrastructure, were reported to have washed up on islands impacted by floodwaters. The debris increases the risk that mainland pest species are transferred onto islands.

Island vegetation is already showing early signs of recovery, with abundant re-shooting from broken stems and seeds on many islands. However, there is concern that weeds will slow, or prevent, full recovery in some areas. Sections of fringing mangroves killed by cyclone Yasi will take many years to recover, although foliage is quickly sprouting on surviving trees.

Rainforest and bushland birds on islands are expected to recover as the vegetation re-establishes. Turtles and seabirds are likely to adjust to changes in beaches and islands over time, although there is the risk that breeding success in the coming season will still be affected. Further surveys are planned to assess longer-term impacts on these species at key locations.

Cyclones can have direct effects such as bird mortality, as well as indirect effects such as reduced nesting success.

Islands are also an important focus for people visiting the Great Barrier Reef, with many receiving high numbers of visitors annually. Key infrastructure, such as landing facilities and walking tracks, were damaged by cyclone Yasi. Queensland Parks and Wildlife Service repaired these as a priority and some key sites were operational within a few weeks after the cyclone. Others, like the Thorsborne Trail on Hinchinbrook Island and facilities on Dunk Island have taken months just to clear and re-open. Some of the restoration work will not be completed for another 12 months.

"Cyclone Yasi really battered some of our national parks, especially the islands and coastal areas close to the eye. Some of our no-anchoring and zoning markers which have concrete anchors weighing hundreds of kilograms, were found several kilometres from their normal spot. We were worried about the impact on walking tracks, day use facilities and camp grounds on the islands. These are important to local communities and tourism operators, so we have tried to get these cleared and available for use again as quickly as we can."

Richard Quincey
Regional Manager
Queensland Parks and Wildlife Service

The human dimension: implications for Reef industries

Extreme weather doesn't just affect the ecosystems of the Great Barrier Reef; it also impacts the industries and communities that depend on them. Insights into the social and economic impacts can help Reef industries and communities better prepare for future events, and identify ways they can support the recovery of the Reef in the wake of extreme weather impacts. Understanding the consequences for Reef industries and communities is also important for effective conservation of the Great Barrier Reef, as changes in patterns of use following extreme weather events can create new 'hotspots' of pressure on the ecosystem.

Following cyclone Yasi and the floods, a rapid assessment of social and economic impacts on the commercial tourism and fishing industries evaluated the effects of these events on Reef-dependent industries.

Tourism operators

The Great Barrier Reef marine tourism industry is a significant contributor to regional economies along the Great Barrier Reef coast. This makes the Great Barrier Reef tourism industry particularly vulnerable to declines in reef health.

The extreme weather events of the 2010-11 summer did not cause serious damage to the major tourism destinations off Port Douglas, Cairns and Airlie Beach. Minor damage was reported at some fragile reef sites as far as 500 km from the eye of cyclone Yasi, but the majority of tourism sites were providing high-quality reef experiences for visitors within days following cyclone Yasi.

Despite minimal damage to major tourism destinations and popular reef sites, tourism operators did suffer impacts following the extreme weather. Many businesses – especially those affected directly by cyclone Yasi – lost operating days due to damaged infrastructure such as vessels, berthing facilities and shore-based facilities. There were 1.58 million visitor days to the Marine Park in the 2010-11 financial year, a 10 per cent decline from the previous year. Much of the tourism industry is reliant on access to healthy reefs to present to their visitors.

For many tourism operators a decline in overall visitation to the region was the source of most economic hardship.

The extreme weather events of 2010-11 did not cause serious damage to major tourism destinations off Port Douglas, Cairns and Airlie Beach. Despite minimal damage to reef tourism sites, many tourism operators still suffered economic impacts.

The social and economic surveys revealed many tourism operators believe the high profile of cyclone Yasi and the floods in local and international media gave the impression the entire Great Barrier Reef was severely damaged, causing tourists to postpone or cancel their plans for travel to the region. Although the vast majority of Reef tourism operations and destinations were fully operational within days following cyclone Yasi, industry sources reported visitors from outside the region (especially internationally) perceived the Great Barrier Reef as being unlikely to provide a good tourism experience as a result of cyclone Yasi and the South East Queensland floods.

The tourism industry was also affected by the disruption to normal transport routes across Queensland. Impacts on air, rail and road networks from the extreme weather events forced visitors to change their travel plans and bypass or curtail their stay in the Great Barrier Reef region. Reduced opportunities for seasonal work in agricultural sectors damaged by cyclone Yasi also contributed to reduced visitation to the region.

The extreme weather during summer 2010-11 caused major disruptions to road, rail and air transport links across Queensland forcing many visitors to delay their travel to the region. Image © Dieter Tracey.

"We were open for business soon after cyclone Yasi, but the slump in visitation, on the back of the impacts of the global financial crisis and the strong Australian dollar, nearly crushed us. We've made it through this season, at least – due to diversification in our family business and Hinchinbrook Island being opened in June, which is a big part of our winter tours. Tourists are coming back to the area, but some of our key destinations like The Family Islands, especially Dunk Island, need work before we can take visitors there. For now, we are still in the game, but I'm worried about the future of our sea kayaking business. Mission Beach has so much potential - I hope we can make it through."

Atalanta Willy
Coral Sea Kayaking

Many Reef tourism businesses lost operating days due to damage to infrastructure including vessels, berthing facitlities, jetties, and shore-based facilities.

A number of northern Great Barrier Reef island tourism resorts were very badly damaged by the cyclones that occurred in the summer of 2010-2011 and were closed while damage was repaired. Resorts at Dunk and Bedarra islands have been most severely damaged, and both remain closed and are unlikely to re-open in the immediate future.

Some of the impacts of the tourism downturn were offset by the influx of workers involved in the post-Yasi recovery efforts. However, this tended to assist accommodation and restaurant businesses rather than reef-based tourism operations. The surveys also found the impacts of the extreme weather events were significantly exacerbated by the underlying downward trend in tourism visitation to the Great Barrier Reef region associated with global economic conditions and other externalities.

Commercial fishers

Commercial fishers suffered a range of impacts following the extreme weather of summer 2010-11. The effects of cyclone Yasi on coral trout catches were a major impact on many Reef-dependant fishing businesses. In addition to decreased catch rates, cyclone Yasi reduced the ability of fishers to access fishing locations, compromised water quality and created debris that caused damage to fishing gear. Fishing businesses also suffered damage to vessels and land-based infrastructure.

"Cyclone Yasi was a big hit for us and only a couple of years after Larry smashed us. It's hard to catch fish after cyclones. Between low catch rates out on the reef, rivers choked with logs and freshwater and having to spend time fixing up the house – it was hell for a while. But luckily we had been diversifying our businesses. My wife's gym business kept some cash coming in, and my new aquarium collecting business will help us get over the slump in the other fisheries. It's not easy, but I love fishing, and want to make it work as a business and a lifestyle so I am always thinking about ways to minimise risks."

***Glenn Murray** (left; with Steve Howe), Commercial Fisher*

Cyclone Yasi led to decreased catch rates of some fish species, including coral trout. The cyclone also reduced the ability of fishers to access fishing locations, compromised water quality and created debris that caused damage to fishing gear.

In the southern Great Barrier Reef, the major flooding in South East Queensland affected inshore fishers, especially those targeting mudcrabs and barramundi. Catches of both of these species increased in many locations due to favourable conditions caused by strong freshwater flows into estuarine systems.

Research revealed some commercial fishers have strategies in place to build resilience to unpredictable events such as extreme weather. Diversification proved a particularly important strategy following cyclone Yasi and the floods, as this enabled some fishers to switch to other target species (such as mudcrabs or barramundi) or focus on other (non-fishing) business interests to maintain income while coral trout catches were low. Fishers who have managed to adopt these resilience-building strategies are likely to have an improved business outlook in the wake of extreme weather impacts. However, most fishers expect to suffer some level of financial hardship for an extended period as a result of cyclone Yasi.

Bouncing back: building the Reef's resilience

The Great Barrier Reef is a dynamic ecosystem that is naturally resilient to severe weather events such as cyclones and floods. However, mounting local and global pressures mean many aspects of the Great Barrier Reef system are under growing stress, potentially undermining its resilience. The implications of the extreme weather events of 2010-11 have caused lasting impacts, but they also create an opportunity to learn about ways managers, Reef industries, researchers, Traditional Owners and the community can help the Reef be resilient to the effects of extreme weather events and a changing climate.

Reef recovery

While storms are a normal part of the Great Barrier Reef environment, cyclones of Yasi's intensity and size have historically been rare events, recurring on timescales of centuries, rather than decades. Climate scientists are concerned that climate change could cause an increase in the frequency of extreme intensity storms, potentially making these very rare events more common in the future.

Yet, cyclones are not the only risk predicted to increase as the climate changes. Coral bleaching events, already attributed with causing severe and lasting damage to 18 per cent of the world's coral reefs, are projected to increase in frequency and severity as global average temperatures rise over the course of this century.

While the Great Barrier Reef is healthier and more resilient than most coral reefs around the world, the cumulative effects of climate change and coastal development mean coral reefs around the globe will be damaged more often and spending more time in recovery.

Coral reefs can regenerate from surviving patches of healthy coral but chronic stresses from reduced water quality can hinder recovery of damaged reefs. Image © Jeffrey Maynard.

Although pressures from climate change are largely beyond the control of marine managers, modelling studies clearly show effective management of local stresses such as pollution and overfishing will play an increasingly crucial role in the fate of coral reefs.

In recognition of the growing pressures associated with extreme weather events and climate change, the GBRMPA and its partners are focused on restoring the resilience of the Great Barrier Reef. Major initiatives include the Australian Government's Reef Water Quality Protection Plan, which aims to halt and reverse the decline in water quality entering the Great Barrier Reef, the rezoning of the Reef in 2004 (which increased the coverage of no fishing areas from five per cent to 33 per cent) and widespread efforts to ensure sustainable fishing practices.

For reefs in healthy conditions, signs of new coral growth and recovery can be often seen within a few years. However, full recovery of a coral reef community can take more than a decade, even for offshore reefs, which are less affected by degraded water quality. Efforts to build the resilience of the Great Barrier Reef will be crucially important to the ability of reefs to recover from future impacts.

Partnerships in resilience

Reef industries, researchers, communities and Traditional Owners are all key partners in the protection and care of the Great Barrier Reef and many are proactively taking steps to support the resilience of the Reef in the wake of the extreme weather events of 2010-11.

Tourism operators protect reef resilience

The Reef tourism industry is a key partner in Marine Park management and is working in partnership with the GBRMPA to build the resilience of the Great Barrier Reef and improve responses to extreme weather events. For example, through the integrated Eye on the Reef program, tourism operators and other reef visitors have been helping managers assess the spatial extent of damage from extreme weather, and to provide early warning of new issues that might be a concern for the Reef's health.

Commercial fishers are working with the Great Barrier Reef Marine Park Authority to reduce pressures on dugong and turtles by changing their netting practices.

Individual operators and tourism associations are also working in partnership with managing agencies to ensure arrangements and mechanisms are in place to promptly respond to industry needs as a result of an environmental incident such as a cyclone or coral bleaching.

The control of crown-of-thorns starfish is a direct way in which individual tourism operators are supporting Reef resilience. Crown-of-thorn starfish are a natural predator of corals on the Great Barrier Reef and scientific research has shown the devastating outbreaks over recent decades are linked to an increase in nutrients entering the Reef. While there are strategic programs to improve water quality on a Reef-wide scale, the Reef tourism industry has invested large efforts in limiting the local-scale impacts of the starfish through control programs focused on important tourism sites. These efforts have been beneficial to tourism businesses operating in the Great Barrier Reef Marine Park.

Crown-of-thorns starfish (COTS) outbreaks can impede the recovery of the Reef. The COTS control program run by the Great Barrier Reef tourism industry is ensuring localised protection at valuable tourism sites.

It is possible that local-scale starfish control could provide important, wider ecological benefits to reefs struggling to recover from storm damage. As part of the response to the extreme weather impacts, GBRMPA has partnered with the Association of Marine Park Tourism Operators to reinvigorate the crown-of-thorns starfish control program, including new equipment to increase the industry's capacity to remove starfish from multiple high use tourism locations and to extend control work into other areas.

Commercial fishers tag trout for the future

Commercial fishers are participating in a tag and release program to help the industry and management agencies learn more about coral trout before and after extreme weather events. Tags and tagging kits have been distributed to Reef Guardian Fishers, enabling baseline information on coral trout growth, survival and movement to be obtained from a number of reefs throughout the Marine Park. Information from the tagging program will contribute to the ecologically sustainable management of coral trout.

Commercial fishers have also been helping to reduce pressures on turtles and dugong. In stranding 'hot-spots' fishers have altered their netting practices to minimise the risk of animals being caught in nets.

Aquarium collectors: stewardship in action

Aquarium fishers demonstrated their stewardship of local resources through a self-imposed moratorium on collecting at reefs affected by the South East Queensland floods. Many of the reefs in the Keppel Bay region are important to the commercial fishers that collect corals and fish for the aquarium trade. Pro-vision Reef, the peak body for these aquarium fishers, collaborated with management agencies to activate their Stewardship Action Plan following reports of damage to Keppel Bay reefs. Aquarium fishers also assisted in the collection of information on the Reef's condition by providing the first underwater images of reefs after the floods.

Aquarium collectors enacted a self-imposed moratorium on collecting at damaged reefs in the Keppel Bay region. Image © Richard Fitzpatrick.

Traditional Owners caring for sea country

Traditional use activities in the Great Barrier Reef Marine Park are managed under the *Great Barrier Reef Marine Park Act 1975*, and the *Great Barrier Reef Marine Park Regulations 1983*. The *Great Barrier Reef Marine Park Zoning Plan 2003* recognises that under section 211 of the *Native Title Act 1993*, Native Title holders may undertake traditional use of marine resources in the Great Barrier Reef Marine Park.

While Traditional Owners have Native Title rights to conduct traditional use activities, many Traditional Owners share conservation concerns due to the combined effects of extreme weather events, boat strikes, coastal development, habitat degradation, netting and pollution that impact on marine environments and resources.

"We share the community's concern about these species [green turtles and dugong]. Our decision to temporarily suspend hunting in our sea country is our way of directly supporting the Great Barrier Reef that has been important to our people for over 60,000 years."

Phil Rist

Nywaigi Traditional Owner and CEO Girringun Aboriginal Corporation

Some Traditional Owner groups are actively engaged with the Great Barrier Reef Marine Park Authority through formal management arrangements. These partnerships involve management elements such as compliance activities and monitoring human impacts and the condition of plants and animals. Traditional Owner groups play an important role in research occurring on the ground with some groups actively involved in turtle tagging and tracking programs on their sea country areas.

Recreational users and the community

A key challenge for marine managers lies in understanding the impacts of events such as extreme weather on rare or highly mobile species such as dugong and turtles. However, with the help of people who are visiting the Reef or adjacent coastline, managers can get a better idea of changes in the behaviour, movement or death rates of these important species. The Eye on the Reef and Marine Strandings programs enable Reef visitors and members of local communities to help keep an eye on the health of the Reef by reporting sightings of iconic species, unusual behaviours and injured or dead wildlife. Following the extreme weather of summer 2010-11, these programs have been especially important. Reports from members of the public about the number and location of stranded dugong and turtles is providing managers with an important measure of mortality and helping to assess the ongoing impact of extreme weather on these species.

Girringun Rangers, James Cook University and the Great Barrier Reef Marine Park Authority are using satellite tracking to understand how green turtles respond to the impacts of extreme weather.

Recreational users can provide important information on the health of the Reef by reporting sightings of iconic species, unusual behaviours, and injured or dead wildlife.

Looking to the future

It is impossible to attribute any single weather event to climate change. However, there is mounting evidence weather patterns are changing as the concentration of greenhouse gases in the atmosphere continues to rise. Although the total amount of rainfall and the average number of cyclones is not predicted to increase, intense rainfall events (with increased flooding risk) and severe cyclones are predicted to occur more frequently under a changing climate. Small changes in the strength or pattern of extreme weather can significantly affect an ecosystem. For example, scientific modelling suggests an increase in cyclone intensity of half a category would result in 50 – 60 per cent greater loss in coral cover as a result of cyclones. This highlights the value of learning about the implications of extreme weather events such as those that affected the Reef in the 2010-11 summer if we are to help build the resilience of the Reef to future challenges.

We can't control the weather, but we can help reefs be more resilient

A future of increased frequency of extreme weather events brings greater risk to reefs from floods, cyclones and high water temperatures. It also shortens the time available for reefs to recover between damaging events. Reef recovery is particularly sensitive to environmental conditions (such as water quality), so changing weather patterns mean efforts to restore the natural resilience of the Reef are increasingly important. Reducing the amount of fertiliser and pesticides entering the Great Barrier Reef, minimising loss of soils into our rivers and ensuring our fishing is sustainable will all help the Reef cope with climate change. Through measures such as Marine Park zoning, improved fisheries management arrangements and the Reef Water Quality Protection Plan, the Australian and Queensland governments are seeking to reduce non-climate change related pressures and disturbances, so the Reef is more able to withstand, and recover from, the impacts of climate change.

Managing the Great Barrier Reef in the wake of extreme weather

The Great Barrier Reef Extreme Weather Program has provided important insights into the potential impacts from extreme weather events and their implications for Reef industries and regional communities. As a result of this work, extreme weather events are now recognised as an important risk to the Great Barrier Reef and the GBRMPA has developed an integrated response strategy for extreme weather events.

The Great Barrier Reef is one of the most healthy coral reef ecosystems in the world but effective management and local stewardship is needed to help it cope with climate change.

The recent impacts from extreme weather have reinforced the importance of effective management of the Great Barrier Reef and highlighted the critical role of stewardship in ensuring its conservation and sustainable use. Focal areas for the GBRMPA include inshore biodiversity, the Reef Guardians stewardship program and the Reef Water Quality Protection Plan 2020 targets. The Great Barrier Reef Outlook Report, Climate Change Action Plan and the Biodiversity Conservation Strategy (currently under development) are key documents outlining the future focus for management of the Great Barrier Reef Marine Park.

The Extreme Weather Response Program—a government partnership

The Extreme Weather Response Program was implemented by the GBRMPA and Queensland Parks and Wildlife Service to improve our understanding of the impacts and implications for the Great Barrier Reef following Queensland's floods and cyclone Yasi in the 2010-11 summer.

The program was supported by funding from the Australian Government's Caring for our Country initiative. It built on existing Reef conservation programs of the GBRMPA and the Queensland Parks and Wildlife Service, and benefited from strong collaborations with research agencies (including the CSIRO, James Cook University and the Australian Institute of Marine Science), Traditional Owners and Reef industries including tourism and commercial fishing.

For more information on extreme weather in the Great Barrier Reef, please visit the GBRMPA website: www.gbrmpa.gov.au.

Restoring the resilience of the Reef will give it the best chance of coping with the effects of climate change and extreme weather.

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