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Climate Change Adaptation

Outcomes from the Great Barrier Reef Climate Change Action Plan 2007–2012

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Executive summary

CLIMATE CHANGE HAS been called the greatest challenge of our time. Coral reefs worldwide have already been affected and further decline is predicted as global warming and ocean acidification accelerate.

Tackling the source of the problem – greenhouse gas emissions – is a task of utmost importance. However, even if international efforts to reduce global emissions are spectacularly successful, further changes to the climate – and more damage to reefs – are inevitable.

The implications extend beyond damage to coral reef biodiversity. The decline of coral reefs is a warning about the vulnerability of

all natural systems to changes in the Earth's climate.

As resource managers, conservation practitioners, policymakers and stakeholders, we must recognise that there is no 'silver bullet' solution to this problem. Climate change is combining with the other pressures that we are putting on coral reefs placing them in serious jeopardy. However, there is much that can be done to build the resilience of reefs, reduce the vulnerability of the communities that depend on them, and help sustain the beauty and productivity of coral reefs.

The accumulating evidence from research and practical experience is clear: in the face of global climate change, local actions will make all the difference.

The *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) represents a concerted effort by governments, industries and communities to identify and test strategies that can help give the Great Barrier Reef the best chance of coping with climate change.

Under four major themes (Targeted science, a Resilient Great Barrier Reef, Adaptation of industries and communities, and Reducing climate footprints) the Great Barrier Reef Marine Park Authority (GBRMPA) has worked with a wide range of partners and stakeholders to better understand the nature and scale of climate change threats, to identify response strategies and to take local action to reduce vulnerability.

The GBRMPA's Action Plan was the first of its kind, and much has been learned during the five years of its implementation. We have realised the importance of partnerships in achieving adaptation goals. This includes ensuring that engagement activities are tailored to the needs, interests and capacity of partners. We have learned that facing a challenge that is bigger than us all can forge new relationships and strengthen old ones. In this way, climate change has fuelled an even more collaborative approach to the protection and care of the Reef.

The Action Plan has helped us understand the importance of sharing the responsibility of adaptation to climate change. Within the GBRMPA, this has led to a 'mainstreaming' of adaptation work across different groups and work areas. In the wider Great Barrier Reef community, there has been a stronger focus on stewardship and the exploration of a more regional approach to the management of some issues.

The GBRMPA's work under the Action Plan has also highlighted that building resilience to climate change cannot be achieved within the life of a five-year plan. The program of work under the Action Plan is best seen as research and development, which provides the crucial underpinnings to a larger, strategic and participatory process of adaptation that is integrated into the daily decisions and plans of all Reef managers and stakeholders.

All around the world, and across a broad range of sectors and jurisdictions, adaptation is being recognised as an urgent priority. However, adaptation efforts are generally still in their infancy. The lessons from the Action Plan have wide relevance, and the work is an important national and international case study in translating adaptation ideals into adaptation practice.

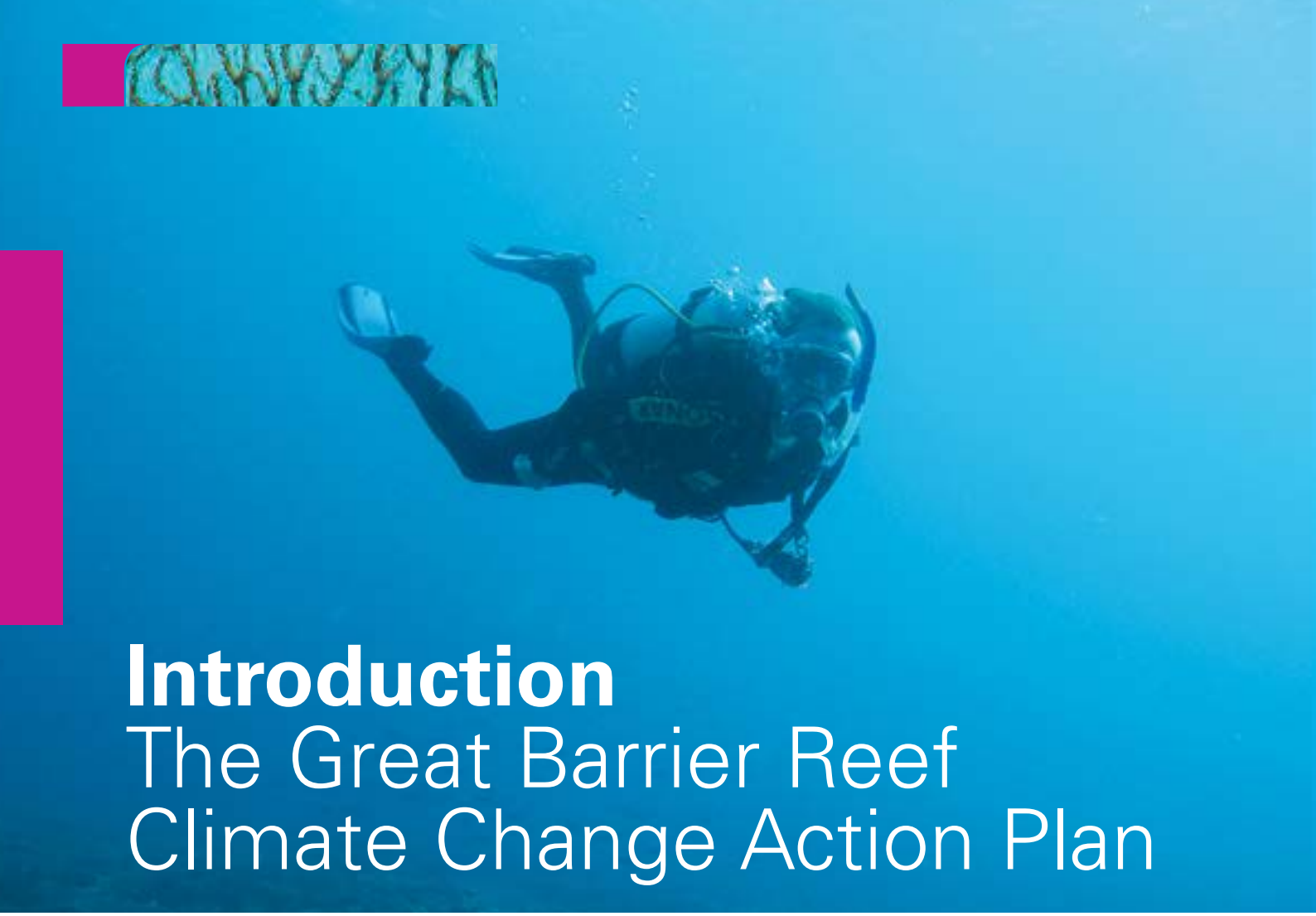
> There is no 'silver bullet' solution to this problem.

The GBRMPA has actively sought to capture its experiences and share them with its peers and the wider community through targeted communications materials, sharing results with other adaptation practitioners, participating in national and international expert working groups, collaborating on international initiatives and supporting capacity-building workshops. Highlights include collaboration with the US National Oceanic and Atmospheric Administration (NOAA) and The Nature Conservancy to train more than 300 coral reef managers from more than 60 countries in climate change and reef resilience; and development with AusAID of a multi-year program to support coral reef managers and policymakers in the Caribbean.

The stories in this report highlight key outcomes and lessons from activities under the Action Plan. They present just some of more than 250 projects and activities that make up the first five years of our adaptation work in the Great Barrier Reef region. They capture the breadth and spirit of the Great Barrier Reef community and the shared commitment to doing our utmost to ensure future generations have a chance to experience some of the wonder of this uniquely beautiful and productive ecosystem.

Building on the momentum of the 2007–2012 Action Plan, we have developed a vision for future efforts in the *Great Barrier Reef Climate Change Adaptation Strategy and Action Plan 2012–2017*. This adaptation strategy outlines the GBRMPA's broad approach, which draws on the principles of ecosystem-based adaptation and highlights the importance of communication and partnerships. The accompanying action plan for 2012–2017 lays out the objectives and activities that will enable us to tackle this greatest of challenges.

The last five years have placed the GBRMPA at the leading edge of efforts to understand, test and implement adaptation options to help the Great Barrier Reef cope with climate change. We have been fortunate to have had this opportunity, yet there is much more to be done if we are to protect the Reef, its heritage and its cultural values for future generations. The 2007–2012 Action Plan represents the crucial first steps of the very important adaptation journey for the Great Barrier Reef and its people. We are pleased to be able to share its stories in this outcomes report. □



Introduction
The Great Barrier Reef Climate Change Action Plan

IT IS HARD to imagine Australia without the Great Barrier Reef. Its worldwide appeal underpins a $5.1 billion per year tourism industry. The Reef also supports a commercial fishing industry that brings seafood to millions of dining tables and underpins many regional communities.

Rich biodiversity and pristine seascapes make the Great Barrier Reef a national icon that has World Heritage status. At 348,000 square kilometres, it is the world's largest continuous reef system. It is home to more than 1600 species of fish, 550 corals, innumerable other invertebrates and an array of 'charismatic megafauna' such as dugongs, sea turtles, dolphins and whales.

The Reef's importance was formalised in 1975 when, as the Great Barrier Reef Marine Park, it became the world's largest protected marine area. Since then, the Great Barrier Reef Marine Park Authority (GBRMPA) has managed the Reef in partnership with the Queensland Government. Our multi-use regime has become an international model for sustainable use and best-practice management.

Vulnerable

While the Great Barrier Reef is unique by many measures, it shares a major challenge with every other coral reef around the world – vulnerability to climate change. Corals are the central players in the formation and maintenance of coral reef ecosystems. The symbiotic relationship between corals and the microscopic plants that live within their tissues (zooxanthellae) is fundamental to their survival. This symbiosis is sensitive to changes in temperature. Temperature increases of only 1–2°C can result in coral bleaching. If high temperatures are sustained, corals can die.

Record high temperatures during 1998 destroyed an estimated 16 per cent of the world's reefs,[1] and regional warm water episodes have caused dozens of localised bleaching events since then.[2] The Great Barrier Reef experienced widespread bleaching events in 1998 and 2002, with another more localised, but still severe, event in 2006.

[1] *Status of the Coral Reefs of the World*

[2] *Reefs at Risk Revisited*

The risks from climate change extend beyond the effects of rising temperatures on corals. Many other parts of the Great Barrier Reef ecosystem are also vulnerable, including sea turtles, seabirds, fish, microbial communities and island habitats.

An assessment of these vulnerabilities served as a 'call to action' for governments, industries, communities and other groups with a stake in the future of the Reef. The *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) was developed as the primary response to the emerging challenges of climate change. This publication highlights key outcomes from this Action Plan.

Plan of action

There is global scientific consensus that the earth's climate is changing; the debate has moved on to how we respond. Climate change is a relatively new challenge, and strategies for addressing the risks remain a focus of strategic thinking at local, national and international levels of government.

Action on climate change can be broadly divided into two main areas: mitigation and adaptation. Mitigation refers to actions that reduce the rate and extent of increase in the concentration of greenhouse gases in the earth's atmosphere. Effective global action to mitigate the severity of climate change is imperative to the future of the world's coral reefs. Adaptation recognises that, even with effective mitigation, further changes to the earth's climate are inevitable, and seeks actions to minimise the impacts.

At global and national levels, coral reefs are a priority for climate change adaptation efforts.

In Australia, the Great Barrier Reef has been a focal area under the Council of Australian Governments (COAG) National Climate Change Adaptation Framework. Through this program, the Australian Government in 2007 allocated $1.8 million a year to implement the Action Plan; a strategic investment to build the capacity of the GBRMPA and its partners to make the Reef more resilient to climate change. Implementation of the Action Plan is also providing valuable lessons for other Australian and international climate change initiatives.

Coordinated strategies

The Action Plan provided coordinated strategies to help management agencies and stakeholders identify direct actions they could take to respond to climate change. By developing and testing strategies for building the resilience of the Reef, the Action Plan also aimed to help industries such as tourism and commercial fishing cope with climate change. It was underpinned by the world's first comprehensive assessment of climate risks for a coral reef system – *Climate Change and the Great Barrier Reef: A Vulnerability Assessment*. This highlighted key areas of vulnerability involving corals, seabirds, seagrasses and reef-dependent industries, and provided options to reduce climate-related risks.

The Action Plan outlined a five-year program of initiatives, which included working in conjunction with other relevant science and adaptation initiatives, including the National Climate Change Adaptation Research Facility and research programs funded by the Marine and Tropical Sciences Research Facility (MTSRF) and the Australian Research Council. It also complemented the Queensland Government and tourism industry's climate change response strategies.

Four core objectives provided the framework for the Action Plan: targeted science; a resilient Great Barrier Reef ecosystem; adaptation of industries and regional communities; and reducing climate footprints.

Targeted science

The Action Plan recognised that while knowledge of climate change vulnerabilities is growing, effective management is being limited by gaps in our understanding of the ecosystem and the implications of climate change.

The targeted science program has supported a range of initiatives to address these knowledge gaps and more clearly define the source of risks and potential adaptation strategies for vulnerable species, such as green turtles. Scientists are also exploring novel interventions

for priority habitats, such as using seaweed to reduce the impacts of stream discharges on water quality. They have also improved understanding of community attitudes and responses to climate change adaptation. An innovative program to monitor long-term trends in social and economic systems linked to the Reef has been initiated as a key strategy to understand and track the implications of climate change.

Resilient reef ecosystem

The ongoing health of the Great Barrier Reef ecosystem will be determined by how climate change unfolds and the Reef's resilience in the face of this. The Action Plan has sought to identify actions that can restore and maintain resilience – and thus minimise the impacts of climate change. This includes understanding how other stresses, such as degraded water quality, fishing and loss of biological diversity, affect the Reef's ability to cope.

Work in priority locations such as Raine Island and Keppel Bay have helped to engage communities and Traditional Owners in building ecosystem resilience. These projects also enabled Reef managers and policy-makers to test the feasibility and efficacy of management interventions, including reducing the mortality of nesting female turtles. Through collaborations with partners such as the Reef tourism industry, we have also developed a citizen-science program that encourages stewardship; a critical factor in building long-term resilience.

Adaptation of industries and communities

We have focused on helping the communities and industries that rely on the Reef to adapt to ecosystem changes, which has strengthened its relationships within the community.

Reef-based industries are now more aware of the implications of climate change and are working to increase their capacity to adapt to changing conditions. The Reef tourism industry and sectors of the commercial fishing industry have developed their own climate change action plans and are also more aware of their role as stewards of the Reef.

Reducing climate footprints

The fate of coral reefs will ultimately depend on the rate and extent of climate change. Awareness has been raised among decision makers, stakeholders and the broader community of both the Reef's vulnerability to climate change, and also the importance of reducing human influences on the climate.

The GBRMPA has supported climate-friendly makeovers of infrastructure on two high-profile islands, Low Isles and Lady Elliot Island. It has developed certification programs to encourage Reef tourism operators to reduce their climate footprints. New web-based tools are available for tourism operators and commercial fishers to identify and implement emissions-reduction strategies.

Partnerships

Adaptation is a participatory enterprise and partnerships have been instrumental to the success of the Action Plan.

The Great Barrier Reef tourism industry was an early leader in recognising the risks from climate change. Its active engagement, notably through the Association of Marine Park Tourism Operators (AMPTO) and

GBRMPA's Tourism and Recreation Reef Advisory Committee, has helped define a path for collaborative efforts in climate change adaptation.

Building on this, the various commercial fishing sectors operating in the Great Barrier Reef are rapidly becoming leaders in adaptation on national and international scales. Peak bodies, such as the Queensland Seafood Industry Association and Pro-vision Reef, are embracing the climate change challenge to futureproof their industries.

Traditional Owners and other Indigenous groups with interests in Great Barrier Reef sea country are working with us to understand and incorporate the implications of changing conditions, such as extreme weather events and a shifting climate, into strategies for the management and the traditional use of marine resources.

The communities living in the Great Barrier Reef catchments are key partners in the protection and wise use of the Marine Park. Through the Reef Guardians program, councils and schools are leading local communities in understanding and adapting to the implications of climate change.

Management of the Great Barrier Reef is a formal partnership between the Australian and Queensland Governments. Under this arrangement, the Queensland Parks and Wildlife Service (QPWS) has played a key role in implementing the Action Plan. As the day-to-day managers of the Reef, the QPWS is at the front-line in dealing with implications of climate-related events. The GBRMPA's partnership with the QPWS has enabled valuable advances in adaptation, especially in the development and testing of strategies for building Reef resilience.

An important goal has been to 'mainstream' climate change adaptation work. While a specialist climate change group within the GBRMPA has coordinated the Action Plan, a broad range of internal and external partners have helped to implement it through their administrative support, strategic guidance and technical advice.

The next stage

To maintain the momentum, the original Action Plan will be succeeded by the *Great Barrier Reef Climate Change Adaptation Strategy and Action Plan 2012–2017*. The new program builds on the successes and the structure of the first Action Plan. It has the original four objectives and two additional objectives that recognise an increasing focus on stewardship and communication activities.

The conclusion of the *Great Barrier Reef Climate Change Action Plan 2007–2012* represents an important milestone for managers and stakeholders associated with the Great Barrier Reef. It is a valuable opportunity to reflect on the successes, capture the lessons and share the experiences of implementing one of the first strategic, multi-year adaptation efforts in the world. More than 250 individual projects or activities were implemented as part of the strategic program of work coordinated under the Action Plan.

This report presents an overview of outcomes from implementation of the Action Plan. It highlights achievements, profiles projects and people, and shares lessons from our shared efforts in climate change adaptation. Importantly, the stories that follow are also a celebration of the passion and commitment that Great Barrier Reef stakeholders show towards helping the Great Barrier Reef cope with the effects of climate change. □

Targeted science: Understanding risks and responses

The GBRMPA is working with leading scientists to fill critical knowledge gaps and improve our understanding of how we can support the resilience of the Great Barrier Reef in a changing climate.

Without science, looking after the Great Barrier Reef would be incredibly difficult, especially in a changing climate. Science is essential to track the underlying changes in the climate as well as the Reef's responses to those changes. It is also crucial in developing management strategies and informing decisions that will support the Reef's resilience and help Reef-associated industries and communities adapt to climate change.

Cutting-edge science

Many of the issues associated with climate change, such as the extent and potential impacts of ocean acidification, are only just beginning to be understood. It is a new frontier in many ways and the Great Barrier Reef Marine Park Authority (GBRMPA) is working with researchers at the leading edge of these fields.

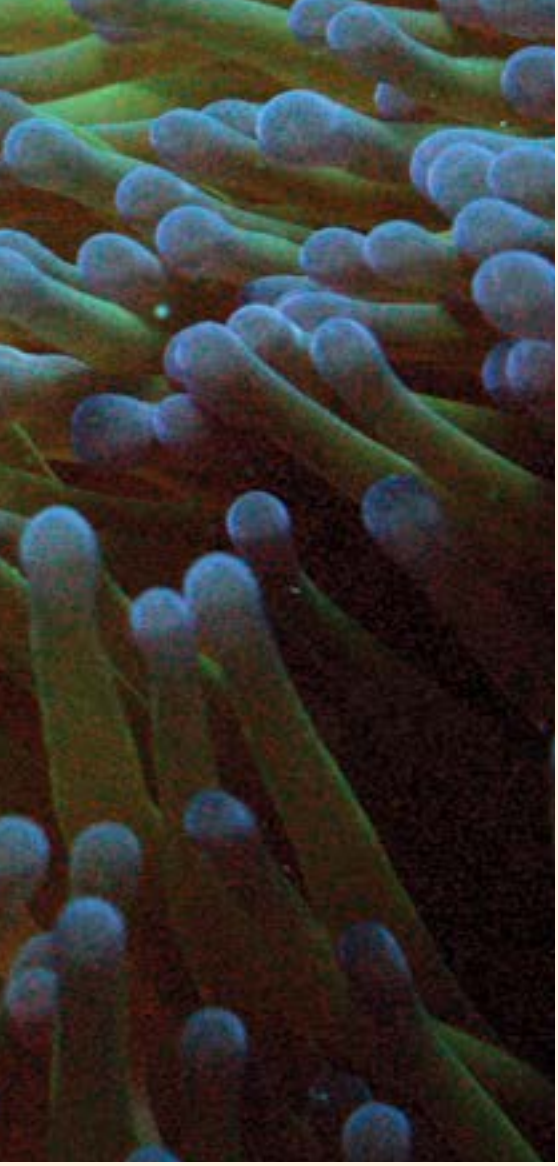
The 2007 publication *Climate Change and the Great Barrier Reef: A Vulnerability Assessment* identified 22 knowledge gaps that were critical in managing the Reef's response and resilience to climate change. Filling these knowledge gaps has required new ways of thinking, integrated approaches to modelling and mapping, collaborative monitoring programs and the use of emerging technologies.

Research priorities addressed

During the life of the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), we have supported new research and brought together information from diverse scientific disciplines to address key gaps in the knowledge needed to effectively manage the Great Barrier Reef in the face of climate change. Research areas have included:

- the risk that climate change poses to corals, seagrasses, predators, sea turtles, seabirds and islands
- the implications of ocean acidification for the Great Barrier Reef ecosystem
- identifying areas of refuge from environmental stressors
- climate influences on resilience, recovery and recruitment dynamics
- Australian attitudes and beliefs about the effects of climate change on the Reef and the industries that rely on it.

To help assess future risk, projects have analysed more than two decades of the Reef's exposure to key environmental and ecological stressors, including temperature, flood plumes, storms and predation. We have also commissioned expert reviews of climate stressor effects on key ecosystem processes such as reef calcification, disease processes, genetic connectivity, and the productivity of macroalgae and seagrass.



The research program has extended to the social sciences as well as natural and geophysical sciences. Community attitudes will be essential in driving action to address climate change. While the initial research is establishing baseline data, in future it will help identify both changing perceptions and the social and economic impacts of climate change on our communities and Reef-dependent industries.

Other research has helped identify and refine our knowledge of environmental thresholds. We have an increasingly robust understanding of the water temperatures that trigger coral bleaching, the conditions that can lead to coral disease outbreaks and the environmental drivers for tropical cyclone damage. Improved knowledge of these triggers, combined with new, integrated monitoring systems, is helping managers predict and respond quickly to threats to both assess damage and implement recovery strategies.

Building scientific capacity

Collaborations have been essential to the success of our targeted science program. We work with more than 35 national and international research and management agencies to develop and share climate-related Reef science. Major research partners include the Australian Institute of Marine Science (AIMS), the Australian Bureau of Meteorology (BoM), the University of Queensland, James Cook University, CSIRO and the National Climate Change Adaptation Research Facility.

Work with the AIMS and BoM, for instance, has been essential in developing and refining remote-sensing tools that forecast coral bleaching and coral disease outbreak risk in the Marine Park.

Our approach has helped increase researchers' understanding of what information is most urgently needed. This approach has also developed the capacity of both established and new researchers to contribute to Reef-relevant climate change work. It has brought together the particular strengths of different agencies to integrate ecosystem assessments, complex systems modelling, decision support and social and economic research to support the portfolio of activities under the Action Plan.

Strong relationships with the scientific community are helping to maximise research outcomes from Australian Government funding by building climate change considerations into existing projects. The GBRMPA has been an active participant in the process of identifying priorities for multi-year research funded through the Australian Research Council, the Marine and Tropical Sciences Research Facility, the National Climate Change Adaptation Research Facility and the National Environmental Research Program.

The Action Plan has also enabled us to commission specific new work. We support fellowships and postgraduate research that help address key climate change knowledge gaps. Our Science for Management Awards program has been particularly successful in encouraging early career scientists to pursue research questions that improve our understanding of the implications of climate change on management of the Great Barrier Reef.

International collaborations, including partnerships with the US National Oceanic and Atmospheric Administration, The Nature Conservancy, the International Union for Conservation of Nature and the United Nations Environment Programme, have enabled us to share knowledge and tap into world-leading research and management initiatives relating to climate change risks for coral reefs and adaptation strategies.

Community involvement

Sharing knowledge has been an important part of the research and awareness-raising process that is central to Action Plan outcomes. Research outputs are publically available through websites and other distribution points. Findings are regularly presented at scientific forums and to Reef communities as a part of our stakeholder engagement activities. Community members have actively supported research efforts, contributing to a variety of monitoring programs that provide critical information for analysis and risk assessment.

The scientific knowledge that has been generated and supported through the Action Plan during the past five years has been important in advancing our ability to manage the Great Barrier Reef in the face of climate change. It underpins many of the new decision-making tools and processes that have enabled the GBRMPA to remain a global leader.

The stories that follow profile some of the major research efforts and introduce some of the people involved in collaborative efforts to target science in addressing the challenges of climate change to the Great Barrier Reef. □

Monitoring takes measure of climate change creep

Investment in ecological and social monitoring is tracking change and helping Great Barrier Reef stakeholders.

The human brain has a tough time seeing gradual change. That's why recognising the effects of climate change – and making good decisions to manage it – can be such a challenge.

Since the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) was launched, researchers, tourist operators, Traditional Owners, fishers and community groups have come together in new and unprecedented ways to document and compare changes throughout the Reef – from Hervey Bay to the Torres Strait and out to the Coral Sea. Together, these groups are developing a scientifically rigorous record of the ecological, economic and social changes in the region.

The Great Barrier Reef Marine Park Authority (GBRMPA) director of coastal ecosystems and water quality, Hugh Yorkston, works across a number of monitoring programs developed in response to the increased focus on climate change.

"The relationship between land management and water quality has been recognised for many years, well before climate change was a mainstream issue," Mr Yorkston says. "The Reef Rescue Marine Monitoring Program was originally established to monitor water quality and the health of coral reefs and seagrasses. In combination with data collected at paddock and catchment areas, it shows the direct impact that land practices have on the health of the Reef.

"Thanks to the funding and focus provided by the Action Plan, the Reef Rescue Marine Monitoring Program has improved and become a much more collaborative effort between government, community, scientists and managers. It is now managed by the GBRMPA in partnership with the Australian Institute of Marine Science (AIMS), the University of Queensland, James Cook University, the Queensland Government and the CSIRO. Through the program, we've developed a better understanding of how significant climate-related events such as the floods of 2011 will impact the Reef. It means we can look at the changes and improve the adaptation actions we take within the Marine Park."

The broader Reef community has become more involved in monitoring under the GBRMPA's Eye on the Reef program. The program helps facilitate the open sharing of information about Reef health between Reef-related businesses, tourism operators, community groups, fishers,

managers and Reef scientists.

Eye on the Reef helps identify changes people are seeing to the places they are familiar with and create an overall picture of the Reef's health. "We reach communities through training workshops and other engagement programs and, thanks to the Action Plan, have been able to invite more industries to get involved," explains Dr David Wachenfeld, the GBRMPA's director of ecosystem conservation and sustainable use.

"Tourism operators, as one example, are uniquely placed to provide data because they visit certain sites much more often than other Reef users. They are taught to look for impacts such as physical damage, predation by starfish, coral bleaching, and disease."

Coral bleaching is a key indicator of climate change and makes reefs more susceptible to disease outbreaks. It happens under stresses such as extreme water temperature, low salinity and pollution. The ReefTemp mapping product, updated under the Action Plan, uses sea surface temperature readings to identify areas at risk of coral bleaching.

"Although we have not seen a reef-wide bleaching event since 2002, small-scale bleaching still occurs," Dr Wachenfeld says. "The biggest achievement of ReefTemp has been to allow us to anticipate which Reef areas will be most stressed and prone to bleaching.

"Also, we've begun developing a three-dimensional picture of what is happening to water flow in the Great Barrier Reef. In time, this will include sea temperatures, not just on the surface but below the surface as well, where the impacts happen in reef systems."

The AIMS Long Term Monitoring Program (LTMP) and the Integrated Marine Observing System (IMOS) complement these programs. Dr Peter Doherty, research director at AIMS in Townsville, says the Action Plan reinforced the need to monitor the Reef's response to ocean warming.

"Since the plan was launched, we've put more monitoring instruments in place, as part of the IMOS, around the four research stations on Lizard Island north of Cooktown, Orpheus Island off Townsville, and Heron and One Tree Islands in the south."

"Although we have not seen a reef-wide bleaching event since 2002, small-scale bleaching still occurs."
Dr David Wachenfeld

Dr Doherty says these systems will also provide the capacity to develop ocean temperature forecasts, similar to weather forecasts.

Among the 2900 reefs that make up the Great Barrier Reef, the AIMS assesses the health of 100 'benchmark' reefs every year as part of its long-term monitoring. The program began in 1985 and currently involves a team of 30 people who dive on the selected sites to gather, analyse and report information on physical, chemical and biological conditions. The team counts fish, assesses the health of coral and tracks the impacts of cyclones, crown-of-thorns starfish populations, coral bleaching and disease. It also tracks inter-dependencies between healthy coral and fish populations.

"Our work shows the impact of any disturbance to the Reef and the very clear benefits of good management arrangements," Dr Doherty says. "We've demonstrated, for example, that closing areas of the Reef to fishing allows more and bigger fish spawning and a better replenishment of fish populations."

The changing picture of Reef health has been expanded to include the social and economic changes in the area. In 2011, the GBRMPA partnered with CSIRO to establish the Social and Economic Long Term Monitoring Program (SELTMP) to study social and economic conditions and trends, especially in relation to changing ecological conditions in the Marine Park. The SELTMP was created with funding from the National Environmental Research Program.

CSIRO's Dr Nadine Marshall is a senior social scientist and team leader of the SELTMP. She says gaining perspectives on the social and economic dimensions of the Reef area allows decision makers to develop and deliver more effective management policies and communications strategies.

"Our project is about understanding the social and economic dimensions of the area, and detecting the impacts of climate change. We do this by consolidating information collected by a range of other monitoring programs, as well as by an extensive program of primary data collection of our own. We are gathering data from a wide range of groups, including Traditional Owners, recreational users, agricultural and pastoral industries, commercial and recreational fishing, tourism and shipping," Dr Marshall says.

The program will also monitor how much climate change is costing industry and the community, and identify how the main drivers, such as the weather, economic conditions and the media, affect perceptions and behaviours in the community.

"For the first time, managers of the Reef can have their finger on the pulse of the social systems, as well as the ecological systems," she says. □

Great Barrier Reef managers monitor changes in Reef health.

The stressed coral domino effect

Coral reefs around the world are feeling the impacts of rising water temperature. Coral bleaching and disease outbreaks are now routinely monitored on the Great Barrier Reef to help conserve it for future generations.

As climate change intensifies the severity and frequency of extreme weather events, concern is growing for the wellbeing of corals inhabiting the world's reefs. The Great Barrier Reef is one of the best managed reefs in the world and while the 400 species of coral that live there have a better chance than many others of coping with climate change, the fact remains that they, too, are facing unprecedented stress.

Based on information gathered by the Australian Institute of Marine Science (AIMS) over 20 years, the threat to coral is now seen to come from four major stress factors. The greatest impacts over this time have come from predation (especially by crown-of-thorns starfish), storms, coral disease and coral bleaching.

While each has an impact, evidence is mounting that the 'Big Four' stressors can interact synergistically, creating a domino effect of cumulative damage. This is not only lethal for individual coral colonies, but also has severe implications for the entire reef ecosystem.

Given the scale and severity of stressors such as warming oceans and cyclones, the task of managing the Great Barrier Reef Marine Park is daunting.

Roger Beeden, from the Great Barrier Reef Marine Park Authority (GBRMPA), says that ways are being found to help protect the Reef's biodiversity and the health of corals by using early warning systems to target monitoring and response activities.

This reinforces the importance of efforts to reduce the stressors that can be managed by humans, such as water quality, fishing practices, shipping and anchor damage. Taking action in locally appropriate ways to support the natural resilience of coral reefs provides a stronger base for recovery from extreme temperatures and predation impacts.

Responding to bleaching

"Coral bleaching made us realise we needed response plans to guide our actions during periods of stress for the Reef. We started with bleaching because it is so visible," Mr Beeden says. "The Great Barrier Reef is vast but you can fly over a reef and, even though it is underwater, you can see areas of white when a mass bleaching event is occurring."

The need for a bleaching response plan became apparent following two major temperature-driven coral bleaching events in the summers of 1997–98 and 2001–02, which affected more than 50 per cent of the Great Barrier Reef.

While most corals survived these bleaching events, Mr Beeden says this experience triggered alarm bells within the GBRMPA because of the vast area of the Reef that was affected. "The outcome was the first coral bleaching response plan, which is designed to deliver critical information for managing the Reef in times of major stress, including via BleachWatch, a community based program," he says.

"Ten years on, under the guidance of the *Great Barrier Reef Climate Change Action Plan 2007–2012*, this approach has been expanded to cover three of the four big stressors – coral bleaching, coral disease and tropical cyclones. Planning is also underway to develop a crown-of-thorns starfish response plan."

Disease trigger

Monitoring since 2002 has found that warmer seawater temperatures and bleaching can trigger yet another, more delayed impact on corals. For several months after a bleaching event the incidence of one particular group of diseases, called white syndromes, increased up to 15-fold. White syndromes causes progressive tissue loss in a coral colony and it can prove lethal, sometimes killing corals in as little as a few weeks.

The finding highlighted the increased susceptibility to disease suffered by corals when stressed.

As a result, Professor Bette Willis from James Cook University has been running an annual survey of coral diseases on the Reef since 2004. The surveys are conducted at multiple inshore, midshore and offshore sites in northern, central and southern areas of the Great Barrier

Reef, during a six-week period.

Professor Willis explains that the synergy between bleaching and disease arises because of corals' unusual biology.

"Corals are actually a partnership between organisms from three biological kingdoms," she says. "Their major partner is the coral animal, which produces the calcium carbonate skeleton. The coral tissue hosts small plants – actually one-cell algae – that produce food through photosynthesis. In addition, corals also host friendly bacteria essential to their health."

It is the loss of the algal symbiont, known as zooxanthellae, that causes bleached corals to look white.

While bleaching is not necessarily lethal, the breakdown of symbiosis starves and weakens the corals, making them more susceptible to disease. The damage can then snowball because corals are fundamental to the entire reef ecosystem. Potential triggers to this whole domino effect are now known to include extreme water temperature.

"Experiments suggest that corals live within about 2°C of their upper thermal limits," Professor Willis says. "Currently, temperatures often reach 31°C in summer on some reefs. Some corals, however, bleach if exposed to temperatures of 32–33°C for five days. So the increase of 2°C predicted by climate change models over this century is viewed with immense concern."

As a result, the monitoring of water temperature plays a pivotal role in the GBRMPA's monitoring and response plans.

Mr Beeden explains that this takes the form of ReefTemp, a computer-based tool that uses data from satellites downloaded twice a day by CSIRO and the Bureau of Meteorology to assess risk to coral.

"By 2007 we saw the need for a tool that can model bleaching risk so we built ReefTemp, which acts as an early warning system," he says. "On the basis of these risk assessments, we send teams out to high-risk areas and assess what is actually happening to coral health. Only then can we get on top of developing both immediate response actions and longer term management strategies."

For coral disease, the information provided by ReefTemp is combined with known levels of coral cover – a factor that affects disease transmission – to model the risk of white syndromes across the entire reef. The validity of ReefTemp's disease predictions was validated with field surveys led by Professor Willis in 2009.

Some degree of disease, however, is normal on any reef. Professor Willis is using her accumulated survey data to establish normal or 'baseline' levels of disease for the Reef.

Establishing regional baselines has become an essential ingredient in worldwide responses to declining coral health, including work by the World Bank-funded Coral Disease Working Group, which Professor Willis co-chaired.

Under its auspices, she gives workshops on how to conduct coral health surveys to reef custodians in other reef regions, from Western Australia to developing countries like Indonesia and Tanzania.

Cyclones and starfish

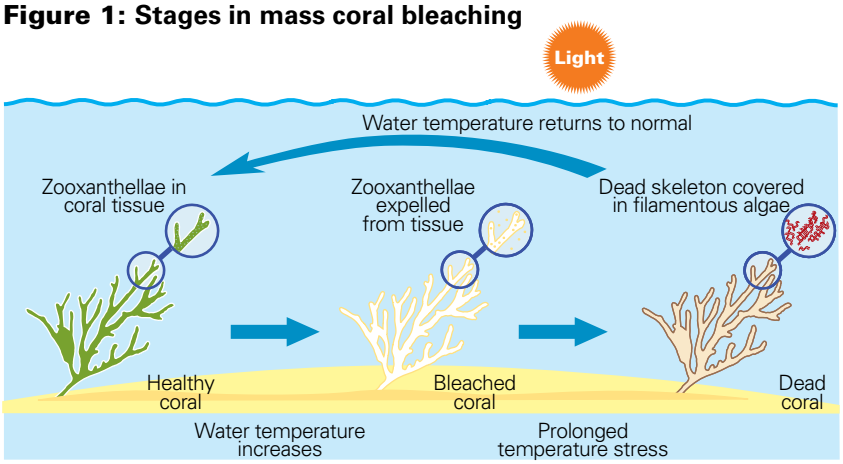
"Between 2009 and 2012, a database was developed as part of the Eye on the Reef program to manage all data coming in from Queensland's park rangers, tourism staff, and GBRMPA teams," Mr Beeden says. "The database produces Google Earth outputs, which summarise the current health status of the Reef each year, with more surveys being conducted when major events occur."

In 2011, when Tropical Cyclone Yasi hit, the GBRMPA was able to use the approach it had developed for bleaching and disease events to develop a Cyclone Response Plan. Underlying this plan was information from 882 surveys of 76 reefs undertaken over two weeks in the tracks of what was the biggest cyclone to cross the Queensland coast in nearly 100 years.

With concern mounting over the potential for a new crown-of-thorns starfish outbreak, the GBRMPA is working with the scientific community to develop a response plan for the starfish threat.

Stress by stress, the GBRMPA is coming to understand how the 'Big Four' interact and how it may be possible to manage the domino effect that threatens coral reefs. In the process, managers are integrating an immensely complex range of conservation efforts and identifying manageable actions that can be embraced by Reef users. □

Figure 1: Stages in mass coral bleaching



During mass coral bleaching, water temperature increases above a critical threshold. Under these stressful conditions, corals begin to lose their zooxanthellae, eventually appearing 'bleached'. If stressful conditions subside soon enough, they can regain their zooxanthellae. If temperature stress continues, corals are likely to die. Where mass coral bleaching causes high levels of coral mortality, these ecosystems typically take years to decades to recover.

The future on acid

The Great Barrier Reef is slowly – almost imperceptibly – being eroded by the interaction of seawater with a greenhouse gas: carbon dioxide.

Carbon dioxide is such a simple molecule – just two oxygen atoms joined by a carbon atom. Yet, for the past 20 years, the emission of this innocuous gas into the atmosphere has posed the most intricate of challenges for our world and its future.

While the build-up of greenhouse gasses is leading to physical changes in the world's climate, the oceans are becoming increasingly susceptible to the chemical consequence of carbon emissions.

Dr Ken Anthony of the Australian Institute of Marine Science (AIMS) studies a particularly thorny long-term impact: what happens when the carbon dioxide dissolves into seawater?

Chemically, the consequences are easy to understand. The seawater becomes more acidic, resulting in a lower pH. The acidification occurs at a rate directly linked to the amount of carbon dioxide in the atmosphere.

This results in ocean acidification, which intensifies in proportion with carbon dioxide emissions. Modelling indicates that the pH of seawater – currently about pH 8.1 – could fall to levels of pH 7.8 to 7.6 by the end of the century.

For the past 15 years, scientists have gathered evidence that ocean acidification poses serious problems for marine life. One of the first discoveries involved reef coral. Lower ocean pH was found to compromise the corals' ability to form their calcium carbonate skeleton.

"What we can conclude, based on experimental and observational studies, is that ocean acidification leads to a decline in the growth rates of a number of different coral species, especially the faster growing structural corals such as *Acropora*," Dr Anthony says.

"At a pH of 7.6, our experiments show that coral growth is severely reduced, they bleach more easily, and their skeletons are more easily broken by cyclones. When we start applying those results to reef models, the scenarios are causing concern.

"In turn, this has implications for reef resilience overall. For example, it makes it harder for reefs to grow back after disturbances such as cyclones or bleaching events."

Currently, there are no feasible geochemical or geoengineering solutions to mitigate ocean acidification. This raises serious concerns about the fate of the Great Barrier Reef.

In response, AIMS and the Great Barrier Reef Marine Park Authority (GBRMPA) have built long-term monitoring and response programs that include gauging coral health. The GBRMPA actively seeks to boost coral resilience through management strategies to reduce the impact from other, more manageable, stresses like water quality and fishing.

When it comes to ocean acidification, the urgent task is to better understand what happens to reef habitats as coral growth rates slow down, driven by continued acidification of seawater. Progress is being made but, at times, the findings have alarmed the researchers.

For instance, one study recently found that it is not just calcifying species like corals that are affected. Juvenile clown fish – the species featured in the animated film *Finding Nemo* – experience disruptions to their sensory system as ocean

chemistry changes. These are severe enough to affect their ability to find a reef after hatching.

Complicating matters are summertime spikes in seawater temperature that can exceed coral's thermal limits, and climate change-driven intensification of storms and cyclones. These stressors combine to cause cumulative damage that scientists need to understand if they are to help protect the Reef.

"Working with the GBRMPA, we are trying to learn whether there are differences in stress susceptibility within the Reef – areas that have different resilience and tolerances," Dr Anthony says.

"This includes identifying regions that may have historically experienced natural variation in pH, resulting in some degree of adaptation and acclimatisation to such chemical changes. These areas could potentially act as refuges in the short-term, where things don't get as bad as quickly. We also look for similar adaptation to warmer sea temperature."

Candidates for such refuges include shallow areas that are rich in seagrasses, where high rates of photosynthesis help reduce the amount of carbon dioxide present in local seawater. Such areas could benefit from intense management. Eventually, however, even localised sanctuaries will be overwhelmed if carbon dioxide emissions continue to rise.

"Almost all the studies based on 'business as usual' carbon emissions paint a picture of a Reef that will gradually degrade," Dr Anthony says. "It won't disappear but it will change from being the magnificent, high-diversity reef our parents knew to a place that is home to fewer and fewer species that provide fewer benefits to society."

Dr Anthony hopes that reefs are somehow capable of adapting fast enough, but there is nothing on the horizon to indicate that is the case. What eventuates in the long-term depends on how people behave as global citizens today. The question becomes: how much degradation of the Reef are people willing to accept?

"I guess that is the danger of accumulating stressors that degrade gradually but steadily – generations could become accustomed to what they see," Dr Anthony says.

"We may go into the Reef today and be stunned by its beauty, but if you take someone who knew the Great Barrier Reef 40 years ago they will probably be very upset because it is already degraded. It is highly urgent that we reduce carbon dioxide emissions. For every year we wait, we will pay the price in the future." □

PHOTO: JESSICA STELLA

Science awards build skills

Damselfish are a comparatively hardy tropical fish and are abundant on the Great Barrier Reef. In 2011, James Cook University postgraduate researcher Jennifer Donelson discovered that these fish may have competitive advantage over other Reef species in terms of climate change. Over the course of several generations, these fish can adapt to warmer than 'normal' water temperatures.

Her findings have prompted further research as part of the Great Barrier Reef Marine Park Authority's (GBRMPA) *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), and are just one example of the scientific information being generated through the Science for Management Awards program.

Since 2008, the GBRMPA has provided 39 competitive grants, averaging $4000, to Masters and Doctoral students for research targeting high-priority knowledge gaps.

GBRMPA chairman Russell Reichelt says the program is providing vital information to improve management of the Great Barrier Reef. It is also helping develop the skills of the next generation of scientists and building collaborations with research organisations around the world.

"The awards support projects addressing the risks faced under climate change and assist the development of tools to increase the Reef's resilience," Dr Reichelt says.

Other projects have focused on sea turtles, reef fish and shark ecology, the effects of climate change on islands and new tests to detect coral disease.

In 2012, grants were awarded to 14 projects. Among the recipients were students from James Cook University, Macquarie University, the Australian National University and Scripps Institution for Oceanography, California. The 2012 projects included: the effects of ocean acidification and increasing water temperature on reef fish; the growth and mortality in juvenile reef-building corals; the roles of territorial grazers in food webs; the response of a coral-eating fish to coral bleaching; and the viability of soft coral populations to climate change.

One of the 2010 recipients, Jessica Stella, praised the awards program for its support and unique approach. "The Science for Management Awards scheme has helped to steer the focus of my project, ensuring it also meets the needs of Reef managers. This not only results in more robust scientific knowledge, but also actual outcomes for the Reef," Ms Stella says. □

Technology reveals Reef's hidden depths

Exploration of deep reefs sheds light on potential climate change refuge for corals.

High-tech robots are venturing into unexplored deep waters in the Great Barrier Reef to discover new communities of coral species, and new hope for coral threatened by the impacts of climate change.

With funding from the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) are helping to explore, for the first time, the 'mesophotic' or deep-water reefs that have been beyond the reach of scuba divers.

The robots are deployed from ships stationed in deep waters within the Great Barrier Reef Marine Park. ROVs are attached by a cable to a ship and remotely controlled by an operator on board. They travel to 160 metres below the sea surface, collecting coral samples and recording video footage with a robotic arm. AUVs are not attached to ships; they rely instead on pre-programmed computer instructions to take pictures and collect environmental data, similar to those used by NASA to discover the surface of Mars.

The technology has allowed researcher Dr Tom Bridge, from James Cook University, to discover many species of coral previously unknown in the Great Barrier Reef – some of which may even be new species. However, it is not the discovery of previously unknown corals that excites Dr Bridge, but the presence of coral that is already known to live on shallower reefs.

"Everyone wants to talk about the new discoveries of corals," he says. "But finding the same species in a new place is much more interesting because it means this species of coral may be more adaptable than previously thought." The hope is that coral species that can inhabit both shallow- and deep-water reefs will have a better chance of surviving the damaging effects of climate change, which include bleaching and increased frequency of severe cyclones.

Most coral species reproduce by releasing sperm and eggs that float around before settling on a reef to attach and create a new colony. The larvae of many corals can travel great distances before settling, and coral larvae from deeper waters may travel to shallow waters and help repopulate reefs where coral has died.

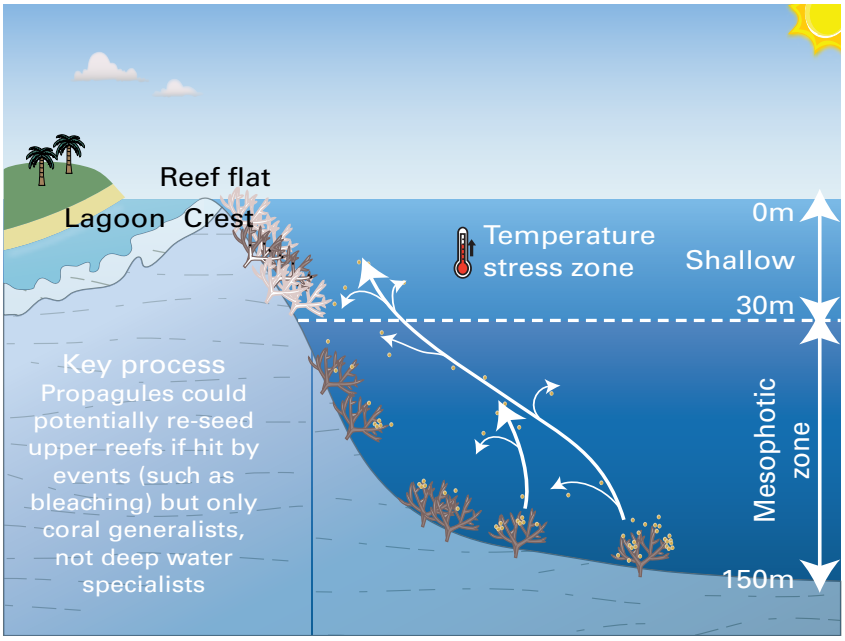
The potential of these coral species to repopulate damaged shallower waters in the Great Barrier Reef is still being investigated. It may depend on factors such as the specific spawning strategies of different coral species, how reefs are connected to each other, the environmental stability of the deep-water reefs and their susceptibility to climate change disturbances.

Dr Bridge along with his research partner Dr Pim Bongaerts from the University of Queensland, will employ the advanced ROV and AUV technology to gather long-term data on temperature, light and currents to improve understanding of the stability of the environment deep under the water.

Dr Bridge expects to find a generally stable environment, with smaller changes in light and temperature than in shallower reefs, leading to less vulnerability to impacts such as bleaching. "In many deep-water areas we do see very large coral colonies, suggesting that severe disturbances are rare," he says.

The exploration will also improve understanding of how different reefs are connected. The more connected reefs are, the easier it should be for coral to repopulate areas damaged by disturbances such as bleaching or cyclones.

Much of the Great Barrier Reef was mapped during World War II to allow passage for ships, with a focus on shallow waters, leaving significant areas of deep water unexplored. "I just love the fact that we are working on one of the best-studied coral reef systems in the world, yet there are still vast amounts of habitat no-one has ever seen," Dr Bridge says. □



Fin and feather studies raise red flags

From seabirds to sharks – tracking 'indicator' species is providing vital information about the potential impact of climate change on the Great Barrier Reef's wildlife.

A team of seabird ecologists, led by James Cook University's Dr Brad Congdon, spent from February to April 2012 on Heron Island, keeping an overnight watch on the underground burrows where the wedge-tailed shearwaters nest.

In rainy weather, they worked in a fug of ammonia fumes from an ongoing blizzard of bird droppings falling from thousands of black noddies nesting in the trees above. Their key piece of protective clothing was a big straw hat.

One major aim was to determine what feed the shearwaters needed to survive and thrive. To do this scientists waited through the night for signs that adults were about to leave their burrows. As the birds emerged they would remove the

perspex sheets that the team had placed over the burrow entrances, catching each bird as gently as possible for a daily weigh-in, before releasing it to forage. While the adult birds were absent any chicks in the nest were weighed to calculate how much fish they were being fed.

The researchers also tracked where and when the birds were foraging for the baitfish essential to their survival and to the rearing of their chicks. Using special tape, they attached small temperature loggers to the base of the adults' tails to establish the temperature of the water in which the birds foraged and GPS loggers also tracked the location of the water.

In a similar project, research team member Will Goulding spent 10 days in December 2011 on a Queensland Parks and Wildlife Service boat off the Far North Queensland coast at remote Raine Island, which is the most significant seabird rookery

on the Great Barrier Reef. He was collecting the same kind of food and sea temperature data from the island's population of ground-nesting brown and masked boobies, which proved even trickier to catch than the Heron Island shearwaters.

Around the same time, marine biologists Dr Dani Ceccarelli and Dr Tony Ayling were at their computers, reviewing more than 500 pieces of research on the functioning of sharks – the 'apex predators' at the top of the Great Barrier Reef's ecosystems.

All these scientists are on the front-line of an important Great Barrier Reef Marine Parks Authority (GBRMPA) climate change research initiative. Climate change is the biggest threat facing the long-term health of the Reef and its wildlife, but gaps in the knowledge of its effects are hampering effective management.

The GBRMPA has selected seabirds and sharks as 'climate change indicator species' for research to fill key knowledge gaps and develop strategies for helping Reef wildlife adapt to climate change.

Seabirds

Seabirds were identified as climate change indicators because of dramatic findings from earlier Heron Island research by Dr Congdon. This revealed that increases in sea-surface temperature caused a decline in the prey that adult seabirds brought back to feed their chicks. In 2002, when an El Niño effect kept temperatures high for an extended period, most chicks on the island starved.

The seabird research was supported by the Australian Government's Marine and Tropical Sciences Research Facility and the GBRMPA. The first phase involved measuring the temperature of the waters that the birds were foraging in and the amount of prey harvested in waters of differing temperatures.

The team has already learnt that the shearwaters routinely fly more than 1000 kilometres to waters in the central Coral Sea. The next phase will focus on establishing exactly where the birds go and defining the ocean dynamics that make good foraging conditions. The researchers will then examine satellite images of sea-surface temperatures and overlay predicted effects of climate change on the winds and currents. This will enable them to predict what prey will be available under different climate change scenarios.

Dr Congdon says this research will increase understanding of the Reef ecosystem beyond just the impact on seabirds. The availability of the birds' food is also dependent on the behaviour of the larger predatory fish. Mackerel, tuna and other pelagic fish drive balls of baitfish to the surface to feed on them from underneath, bringing the baitfish within reach of the dipping and diving seabirds.

The work will help the GBRMPA identify when and where the birds are at their most stressed and, potentially, allow managers to ease pressures associated with other human activities, whether on nesting islands or in the birds' fishing grounds.

Researchers tag a black tip reef shark.

PHOTO: © FEDE CARDONA 2010

Sharks

Marine ecologist Dr Tony Ayling carried out close-up research into the sharks of the Great Barrier Reef, counting reef shark populations along 500-metre stretches of reef, diving to 20 metres below the surface to record shark numbers using an ordinary pencil and slate and special underwater paper.

Dr Ayling and Dr Dani Ceccarelli recently did a desktop review for the GBRMPA looking at available information on the role, importance and vulnerability of the Reef's top

predators, most of which are sharks. They identified and ranked the 22 'apex predators' at the top of the Great Barrier Reef food chain in order of vulnerability, from the most vulnerable white shark down to the less-threatened tiger shark.

According to Dr Ceccarelli, a key concern about climate change is that changes in ocean temperature, major currents, and pH and salinity levels will potentially degrade the environments that sharks need for reproduction and feeding.

"The fear is that the important environments will become less suitable. For instance, sharks that use coastal areas for pupping may find that those areas are no longer suitable, while open-water sharks that chase patches of prey may be affected because climate change alters the position and predictability of the areas of prey availability."

Randall Owens, the GBRMPA's manager of sustainable fishing, explains that sharks, like seabirds, highlight the web of connections through complex ecosystems such as the Great Barrier Reef.

"While we are worried about shark populations in their own right – they are important elements of the Reef's biodiversity – we are also worried about what decreases in shark populations mean for the rest of the ecosystem."

He says there is a potential for 'trophic cascades' when an apex predator declines, as has been seen in other places around the world. In the waters off North Carolina in the US, for example, scalloped hammerhead sharks were wiped out through overfishing. The effects of this cascaded through the trophic system, or food web: it led to a dramatic increase in cownose rays, which ate all the scallops, precipitating the collapse of the local scallop industry.

Working with researchers, the GBRMPA will use information on the vulnerability of apex predators and other indicator species to improve the management of and outlook for key wildlife species, and in doing so build the resilience of the wider ecosystem to climate change. □

Atlas maps changing bird patterns

An analysis of long-standing coastal bird records is helping identify changes to local bird populations, which may be indicators of climate change. The Great Barrier Reef Marine Park Authority (GBRMPA) has commissioned the review as part of a two-phase project.

The coastal bird records are held in a database maintained by the Queensland Department of Science, Information Technology, Innovation and the Arts (SITIA), and contains more than 60,000 records of bird sightings, collected over 30 years.

Queensland Parks and Wildlife Service staff monitor birds using the guidelines of the *Coastal Bird Monitoring and Information Strategy*. Data is also contributed by members of independent research projects and volunteer and community groups, including Birds Australia and the Australasian Wader Studies group.

In 2008, a new analysis of coastal bird records was undertaken by researchers, with support from the *Great Barrier Reef Climate Change Action Plan 2007–2012*. The first phase of this research identified key breeding sites and regions and revealed significant population declines in some species between 1982 and 2001, including the redtailed tropicbird, lesser frigatebird, common noddy, roseate tern and black-naped tern. Results for the bridled tern, the crested tern, the masked booby and the sooty tern were mixed – sometimes inconclusive, and sometimes showing unchanged or even increased breeding activity.

The next phase of research will focus on identifying reasons for changes in breeding patterns.

Using the 20 years of breeding data available on sooty terns and common noddies at Michaelmas Cay, researchers have discovered that these birds are sensitive to the build-up phase of El Niño climate events, which starts with a change in sea levels. Numbers of breeding birds decreased with both a drop in phytoplankton productivity and an increase in the depth of the thermocline (the section of water which separates warmer surface water from cold deep water). Many seabirds rely on fish such as tuna to drive the prey they feed on to the surface. A change in thermocline depth may change the distribution of these fish, affecting the amount of food available.

From acceptance to action: identifying triggers for change

While extreme weather events make climate change more tangible, it may take more than a tropical cyclone or two to change people's behaviour.

There's been a lot of talk about climate change and, by and large, people are listening.

Social research commissioned under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) in 2010 found that 93 per cent of the people surveyed were concerned about the potential consequences of climate change for the Great Barrier Reef.

An encouraging 86 per cent agreed that if each and every one of us was to act – if we all were to reduce, re-use and recycle – these potential consequences could be reduced.

More people are doing something, such as recycling, and some respondents would like do more. The Great Barrier Reef Marine Park Authority (GBRMPA) has a number of stewardship initiatives, designed to recongise the efforts of those who are doing something and encourage others to take part. But despite the positive response to these programs, such as Reef Guardians, and more widespread acceptance of climate change as an issue, it doesn't mean that problems associated with inaction have been solved.

When it comes to climate change, there often seems to be a disconnect between what we think and what we do. While many people accept that climate change is happening, far fewer have changed their behaviour.

This disconnect has been a focal point of recent GBRMPA studies, which have drawn on the expertise of both social scientists and marketing agencies.

"We didn't just do the social research into current attitudes so we can improve the way in which we communicate with people," says Roger Beeden, the GBRMPA's manager of climate change ecosystem resilience. "We also wanted to identify constraints and motivations for adaptation. What are the barriers to adaptation for people who live beside the Reef and in what ways can we provide motivation for them to take action?"

Extreme events

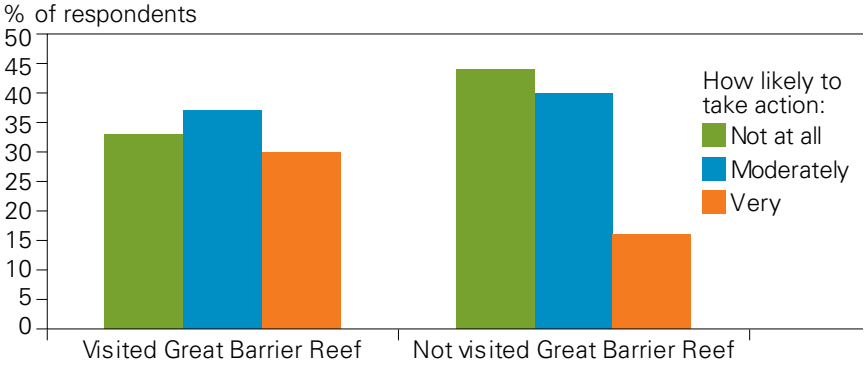
First, the good news: attitudes are changing and most people now believe climate change is real. Recent extreme weather events have been crucial to this new-found awareness, says Dr Paul Marshall, the GBRMPA's director of climate change. Whether you're a farmer in the Murray Darling, a fisher on the Great Barrier Reef or a city-dweller coping with water restrictions, chances are you've been touched by climate-related hardship.

He says people realise that climate change "isn't necessarily this slow, creeping phenomenon" but a process that's punctuated by extreme events such as cyclones and major floods.

"Climate change is often talked about with long-term statistics and in the sense of long-term change ... [but] social research has helped us to understand that it's through extreme events that people truly 'experience' climate change, and therefore that's how we need to communicate about it."

Dr Marshall cites the fishing industry as a great example of this.

Figure 1: Research has explored links between Reef visitation and how likely someone is to take action over the next 12 months to help reduce the impact of climate change on the Great Barrier Reef.



"There were tensions back in 2004, when the area of Reef protected from fishing was increased substantially, but the recent extreme weather events have helped people take a longer-term view and realise that the future impacts of climate change pose a threat that's common to all of us."

The GBRMPA's social research found that two groups seem especially concerned about this threat and its implications for the Reef. One such demographic was 30 to 40 year olds with young children. Mr Beeden speculates this may be because this group has "a longer event horizon". The other group was recent visitors to the Great Barrier Reef, presumably because they had built a greater emotional connection.

Paradoxically, people who live on the Queensland coast seem less inclined to worry. Mr Beeden says this may be because the vast majority of locals do not visit the Reef on a regular basis and have not yet witnessed major changes. The problem is that the science says the Reef is already changing and much more damage is likely in the coming decades.

Capacity to contribute

Mr Beeden says the GBRMPA's key findings indicate that people often simply don't know what they can do to help. "They often 'get' the problem. The tricky bit is that if it is unclear what they can do about it, they end up feeling powerless, that their contribution is so small it cannot have an effect, given the sheer scale of the problem," he says.

As with the movement to protect the ozone layer by eliminating chlorofluorocarbons (CFCs) toward the end of last century, he says individuals taking action to re-use, recycle and reduce their carbon footprint really can make a difference.

For Reef-dependent industries, such as farms and fisheries, the chief barrier to action is often financial, research has found. The daily pressures of running a business can make it hard to focus on, let alone invest in, the future. This finding has been critical in developing strategies under the Action Plan to help local industries adapt.

"The social science approach is all about understanding people's attitudes, needs and interests," Dr Marshall says. "We need to know where they're coming from and what kind of challenges they're facing. You can't protect the Great Barrier Reef through a top-down approach only. There really has to be a partnership between the people who set the policies and the rules and the people who use the Reef on a daily basis ... and they can't fully invest as partners if they're struggling to make a living."

Marine tourism spokesman Col McKenzie agrees that practical suggestions are needed to support behavior change. "If researchers just talk about climate change issues, then there's very little imperative for us to do anything about it. But, if you can link it together with a solid business case, it makes sense [for people] to do something," he says. □

Models reveal socio-economic connections

For most of us, doing our bit for the planet can be pretty straightforward. Take a train here, turn off a light there and don't pour dodgy things into gutters and drains. But for farmers in an ecologically sensitive area like the Great Barrier Reef, 'doing the right thing' can be infinitely more complicated and carry with it some economic risks.

Australian Institute of Marine Science (AIMS) scientist Dr Scott Wooldridge has been involved in a project with the GBRMPA to model the potential socio-economic impacts of different land-use scenarios on agricultural, tourism and fishing industries.

He says farm practices can contribute to the chemical and sediment loads that rivers and the Reef deal with. "This, in turn, determines whether the Reef can cope with additional stressors that are often difficult to manage at the local level, like rising sea surface temperatures, ocean acidification and outbreaks of invasive species or oil spills."

Reducing the amount of chemicals and sediments that flow off the land and into the Reef is a key strategy for improving the outlook for the Reef under a changing climate. This is the key goal of a multi-million dollar government program known as the Reef Rescue Plan.

However, these measures can come at a cost to land users. The GBRMPA project, supported under the Action Plan, aimed to understand these costs and relate them to the benefits for Reef users such as tourism operators.

The agricultural sector is already investing in strategies that will help halt and reverse the degradation in the quality of water entering the Reef and that also increase farm efficiency. Maximising the benefits to Reef tourism, however, would require more extensive changes to patterns and types of land use. Generally, these changes cannot be implemented by individual farmers; they require larger changes in land-use planning and regulations.

Dr Wooldridge's main conclusion was that communication was the most crucial aspect of dealing with the downstream impacts of land use. The best outcomes for both the agricultural sector and the Reef tourism industry would require strategic planning undertaken collectively, systematically and openly in a spirit of constructive discourse.

"Reconciling the needs and aspirations of the two very different – but intrinsically connected – industries is a deeply complex matter, and it will take time and courage to get there. It will take time because it is challenging to understand the connections within such a complex system and to understand the issue from the perspective of others. It will take courage because the open-mindedness and positivity required to develop and select new approaches can feel riskier than business-as-usual choices," Dr Wooldridge says.

Improving the outlook for the Great Barrier Reef: Building ecosystem resilience

In the face of predictions about the impacts of climate change, effective and innovative management has never been more important to the future of the Great Barrier Reef.

The Great Barrier Reef is already suffering under a combination of pressures that are expected to get worse with climate change. Over the past two decades these pressures have included more-frequent, temperature-driven coral bleaching events and a surge in the number of severe tropical cyclones. In combination with a string of crown-of-thorns starfish outbreaks, coral cover – a key indicator of ecosystem health – has been reduced to the lowest levels seen since scientific monitoring began.

At the Great Barrier Reef Marine Park Authority (GBRMPA) we have focused our efforts on giving the Reef the best chance of coping with climate change.

Managing the Great Barrier Reef in a changing climate requires a new paradigm that anticipates future conditions and plans for change rather than trying to maintain the status quo. Active, adaptive learning will be central to management strategies designed to prevent damage, as well as maintaining the processes and functions that help ecosystems bounce back from damaging events. The new paradigm also requires explicit recognition of Reef management as a collaborative enterprise, including the role of Reef users as stewards of the ecosystem.

Detect and respond

Through strategic research and development activities, we have employed tools and approaches to detect the early signs of trouble for the Reef and guide appropriate management responses.

Improved information systems, developed through the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), have allowed Reef managers to better coordinate responses to major Reef health incidents. A comprehensive incident response system employs state-of-the-art, satellite-based monitoring tools, and integrates monitoring from government, industry and community information sources under the new Eye on the Reef program. This will help ensure we have our 'finger on the pulse' of the Great Barrier Reef.

While the causes of most major Reef health incidents are beyond the ability of managers to control, the new response system ensures we are positioned to assess the impacts and evaluate the management implications of mass coral-bleaching events, coral disease, crown-of-thorns starfish outbreaks and extreme weather events such as floods and tropical cyclones.

This near real-time information about changes in Reef health provides the foundation for management measures to help the Reef recover. It has also been a key ingredient in adaptation planning and response by Reef-dependent businesses, such as tourism and fishing operators.

The extreme weather events of 2011 provided an opportunity to test the incident response system. Satellite monitoring combined with scientific modelling helped assess and predict the areas of the Reef at risk from flood and cyclone damage. It enabled assessment efforts to be accurately targeted.

The Eye on the Reef monitoring program was used to power a rapid assessment of the ecological impact

of Tropical Cyclone Yasi and the Fitzroy River flood plume, generating almost a thousand surveys assessing the severity of the damage in a few weeks. Through the Reef Health Incident Response System, we had an unprecedented understanding of the implications of these extreme weather events for the Reef.

Managing for resilience

We have also built our capacity to incorporate resilience thinking into policy and planning considerations, revamped our Reef monitoring systems to integrate community participation and developed approaches to climate change adaptation planning that are making waves around the world.

A priority of the Action Plan was to explore the concept of resilience and determine how to translate it into on-ground actions that help the Reef ecosystem cope with climate change.

The Keppel Bay region provided an ideal opportunity to field-test resilience theory and identify management strategies. The Keppel Bay project, profiled in one of the following stories, was implemented through a collaborative approach involving GBRMPA staff, Queensland Parks and Wildlife (QPWS) officers, scientists and community members.

It highlighted the importance of local action to support Reef resilience under global pressures such as climate change and the participatory approach helped to empower local community members to take on stewardship roles for their reefs. The use of resilience as both a stewardship-building approach and a way of prioritising local management initiatives has attracted strong international interest.

Building on this experience, we have embarked on a major initiative to map the vulnerability of the entire Great Barrier Reef. This work is integrating data on historical exposure to environmental stressors with information about the sensitivity of key habitat types. These maps will provide managers with decision-support tools that can help identify and prioritise strategies for building resilience to climate change at local, regional and ecosystem scales.

Supporting local efforts

The GBRMPA has a long history of consultative and participatory approaches to planning and management decisions, and our recent work under the Action Plan has broadened the opportunities for meaningful engagement between government and the community.

A key objective in the redevelopment of the Eye on the Reef program was to include Reef users as integral sources of information on Reef health. A tiered approach enables Reef visitors of all backgrounds and levels of knowledge to contribute information. The redesign of the monitoring framework, database and system interface enables broad-based participation while maintaining the reliability – and therefore usefulness – of the data provided.

Through its inclusive approach, the Eye on the Reef program provides a broad-scale view of Reef health that complements the intensive scientific surveys done as part of the Long Term Monitoring Program led by the Australian Institute of Marine Science. In combination, these programs are providing the most up-to-date and reliable picture of the health of the Great Barrier Reef that has ever been available.

Crafting adaptation

Interventionist strategies such as predator removal and exclusion fences have long been commonplace in land-based management, and climate change is challenging marine managers to consider similar approaches. It may no longer be enough to simply reduce human-induced pressures and leave nature to do the rest.

Green turtles epitomise the need for innovative approaches. Known to be highly vulnerable to climate change, and endangered internationally, a process was needed to identify, prioritise and test strategies for building their resilience. Under the Action Plan, we have worked with QPWS to develop and test a climate change adaptation planning framework. This simple, yet effective, framework identified and tested strategies to reduce the natural sources of mortality as a way of partially offsetting climate-related risks for green turtles. This project is an important case study for a new marine management paradigm.

The framework has since been used to guide other adaptation planning exercises. This includes a participatory adaptation process initiated with the commercial prawn trawling industry.

The challenge ahead

Building resilience has emerged as crucial to the management of coral reefs. Through the Action Plan, we have undertaken some of the first tests of applying resilience thinking to real-world management decisions.

The program of research and development has produced valuable lessons and insights that provide the foundations for further advances in management of the Great Barrier Reef, and for reefs around the world. The stories that follow highlight the efforts of the GBRMPA and its partners in this area. □

Anchors away to aid Keppel reef resilience

'No anchor' zones have provided the Keppel Bay community with a specific local initiative they can support to improve the resilience of their local reefs.

In Keppel Bay, off the coast of central Queensland, research on the ebb and flow of reef resilience has been met enthusiastically by community groups and regular users keen to support reef health in their region.

In 2008, voluntary 'no anchor' zones were introduced by the Great Barrier Reef Marine Park Authority (GBRMPA) and the Queensland Parks and Wildlife Service (QPWS) in some parts of Keppel Bay to help support recovery of areas of the reef that had been badly damaged following a coral bleaching event in 2006.

The zones were deployed after more than five years' study of the Keppel Bay reefs. The locations of the 'no anchor' zones were supported by extensive community consultation, which has resulted in widespread compliance.

A robust bit of reef

Understanding the influences on reef environments as a way to achieve the best possible outcomes for reef health has become a vital objective for marine environment custodians.

The GBRMPA and the QPWS have done considerable work in Keppel Bay, home to some of the most glorious and accessible reefs on the Great Barrier Reef, to determine what makes reefs more resilient and how we can improve such resilience.

The Keppel Bay area covers more than 1700 square kilometres and is fringed by 16 subtropical islands, including Great Keppel and North Keppel, which host pristine beaches, coves and a patchwork of coral reefs around the islands and, in some cases, stretching between islands.

The Keppel Bay reefs have provided an ideal location to research reef resilience and develop management response strategies. There have been frequent and diverse disturbances to coral health caused by flooding of significant watercourses flowing into the area, including the nearby Fitzroy River, which is the largest river catchment discharging into the Reef environment. The coral growth rates also appear to exceed the average for the Reef as a whole by as much as three or four times. This makes it possible for researchers to witness localised reef damage and observe recovery rates more quickly than in other areas.

Dave Orgill, QPWS operations manager for the southern half of the Great Barrier Reef, says major coral bleaching has affected the area in recent times. Flooding from the Fitzroy River in 1991 saw freshwater held in the bay area for an extended period due to extreme (or

unfavourable) weather conditions. The result was the death of 90 per cent of the coral on many south and west-facing reefs.

The natural vitality of the region's coral helped it bounce back between 1991 and 2006. "The coral cover through Keppel Bay increased to 60 per cent," Mr Orgill says. The average throughout the Reef was around 35 per cent live coral.

In 2006, however, disaster struck. An El Niño weather pattern caused higher sea temperatures, which triggered a coral-bleaching event. This was followed by unusually low tides and heavy rain, which combined to kill off up to 80 per cent of the Keppel Bay corals.

Dr Jeff Maynard, at that time project manager for the GBRMPA's climate change response program, was among those motivated to investigate management techniques that could help protect the Reef from climate-related damage.

Since 2004, Dr Maynard and other researchers had been working on ways to identify reef sites with greater relative resilience. By late 2007, the GBRMPA had developed a framework for assessing reef resilience. The framework combines field surveys with expert judgment and was applied to 31 reef sites in the Keppel Bay during a workshop exercise.

> "The high level of community engagement has been a primary factor of the success of the resilience work."
> *Dr Jeff Maynard*

The methodology involves measuring characteristics of reef condition, such as coral cover, coral type and herbivore abundance, and assessing levels of stress caused by people (such as anchoring, fishing pressure and water quality). A composite score is produced that enables comparisons between sites of both the capacity to resist coral bleaching and the likelihood a site could recover quickly after damage.

Spreading the word

After this technical work was completed, the GBRMPA and the QPWS took the results to the wider community, through a two-day workshop and a field day in 2008.

Participants from the two agencies, local marine advisory committees, Indigenous Traditional Owners and other stakeholders such as commercial and recreational fishers attended.

The management arrangements for the Keppel Bay area now include voluntary 'no anchor' sites throughout Keppel Bay, which are marked with reef protection buoys, and boasts almost complete compliance from visitors to the sites.

Dr Maynard says the high level of community engagement has been a primary factor of the success of the resilience work in Keppel Bay to date.

"Engaging the community has increased their knowledge of climate change and the value of using resilience principles to inform management action," he says.

"For the reef protection buoys, the level of engagement and the outreach we undertook seems to have resulted in near 100 per cent compliance. The sense of Reef stewardship by the Keppel Bay community has increased. These high levels of stewardship and awareness have even resulted in aquarium collectors declaring a voluntary moratorium on the collection of species during coral bleaching events."

Formal follow-up work was done in 2010 and considerable informal observational work continues. It is too early to statistically show that 'no anchor' zones have changed the trajectory of reef recovery after an event, however, Mr Orgill says there has been a reduction in anchor damage to coral.

He says fishing pressure in the 'no anchor' zones appears to have decreased, as fishers have moved to other areas to anchor. Snorkelers, too, like to anchor their boats and so have moved elsewhere, reducing the damage that occurs when the snorkelers' fins strike coral.

The Keppel Bay process has empowered the local community to act in the interests of the Reef and shows how local communities and stakeholders can be vital in achieving the best management for resilience of this delicate ecosystem. □

Aid for turtles in turmoil

Cliff falls, seagrass losses and 'cooked' eggs are just some of the pressures facing a vulnerable green turtle population.

There is often complaint of a 'man drought' among humans in Australia as the female population outstrips that of males. Green turtles could also face a gender imbalance, as temperatures climb at their largest and oldest-known breeding ground, Raine Island, in Queensland's northern Great Barrier Reef.

The Great Barrier Reef Marine Park Authority (GBRMPA) field operations manager Malcolm Turner says the sex of young sea turtle hatchlings is determined by how hot the sand is. "If the temperature is lower, you get predominantly males, if the sand is hotter ... then you get predominantly females."

Thousands of turtles return to their birthplace, Raine Island, to lay their eggs and start the next generation between November and March every year. As many as 14,000 turtles have been recorded ashore for nesting in a single count. They can travel thousands of kilometres after spending years feeding in waters off Indonesia, the Solomon Islands, Papua New Guinea and the Great Barrier Reef. It is estimated that a nesting green turtle can produce between 4000 and 8000 eggs over her lifetime. Each turtle will return to nest at Raine Island many times over its life, with up to eight years between nesting events.

A potential gender imbalance is only one of the multiple environmental pressures facing the species, and work is underway to help both adults and young turtles through the vulnerable processes related to breeding and incubation.

"If the temperature gets too hot, then the eggs basically cook and don't hatch at all," says Mr Turner, pointing out that high temperatures have prevented turtle eggs hatching in central Queensland, but not yet on Raine Island.

"We are involved at the coalface. We see the changes that are occurring and we are trying to work out how best to deal with them."

One problem is that, over the past few years, the combined impact of Tropical Cyclones Larry and Yasi has led to a deterioration of seagrass meadows, which green turtles depend upon for their food. This means it can take longer for young female turtles to reach breeding size and for adult turtles to accumulate enough energy (in the form of body fat) to power breeding migrations and produce multiple clutches of eggs, extending the time between laying seasons.

"Cyclones and big floods kill seagrass and the turtles either starve to death or it delays their breeding," he says. "Climate change is happening ... and we need to try and build resilience to those changes or offset the damage that is being caused by other threats."

One way to do that is to try to

PHOTO: © DUNCAN LIMPUS

save as many adult breeding female turtles as possible. A significant number of breeding females lay their eggs but subsequently fall over Raine Island's limestone ledges, ending up on their backs. Once flipped, they are unable to turn themselves over, and they die.

The GBRMPA has teamed up with the Queensland Parks and Wildlife Service (QPWS) to devise a strategy to minimise turtle deaths from this island hazard. Raine Island's Traditional Owners, the Wuthathi people, are party to an Indigenous Land Use Agreement and are also working with authorities to help build the resilience of turtle populations on the island.

As head of the joint GBRMPA-QPWS field management program, Richard Quincey says conservation efforts are more effectively focused on the large mature breeding females rather than on saving small, individual hatchlings.

"We mapped rock ledges and considered options for being able to fence them so turtles didn't fall off, and we also put up some barriers so turtles didn't crawl into crevices under the cliffs and get stuck," he says.

In November 2011, 100 metres of modified aluminium pool fencing was installed around the eastern end of the island, at a cost of about $4000. The day before the fence was erected there were 60 turtle carcasses found at the base of the cliffs. Surveys by the QPWS in December 2011 and again in February this year indicated only two turtles died in the area of the fence after it was installed.

After the success of the trial, a further 800 metres of fencing is planned for Raine Island.

Mr Quincey says that, although such interventions might be seen as intruding on natural events, "we have decided to act, given the general pressure on the sea turtles and the ecosystems they rely on, including the impacts from climate change".

He says similar fencing work could benefit the green turtles that nest on Moulter Cay, a short boat ride north of Raine Island.

Raine Island, Moulter and MacLennan Cays, and the surrounding waters are managed in order to conserve natural and cultural heritage resources. Mr Quincey says only two or three trips are made to Raine Island a year because of its remoteness. The island is more than 600 kilometres north east of Cairns and each trip lasts 10 days, making this important site a difficult place to work.

Other adaptive management measures under consideration include filling the rock crevices in which turtles are prone to becoming stuck and building up sand in areas where turtle nests are being inundated with water. There are an increasing number of eggs drowned each year and researchers are working to identify the cause. Some suggest changing weather conditions are eroding sand from the island or that rising sea levels may be causing a change in wave patterns. Other scientists have suggested sub-surface sand may be solidifying into rock layers and trapping water.

As part of the work under the *Great Barrier Reef Climate Change Action Plan 2007–2012*, remote monitoring devices have been installed to help accurately measure sea level and tidal movements. The monitoring devices record and send data to a base station on Raine Island and have the capacity to transmit information back to the mainland via satellite.

Not only turtles

Climate change may also be having a detrimental effect on Raine Island's seabird population. The island is recognised as the most important seabird nesting place in the Great Barrier Reef, but there are fewer bird nestings now than there were 30 years ago.

Mr Turner says warmer waters may be leading to changes in the abundance or location of fish that the seabirds need to collect for their chicks, leading to increased risk of malnourishment and starvation. Adults and chicks can also suffer on very hot days, which are predicted to occur more often as the climate warms. These vulnerabilities are compounded by other changes, such as those caused by extreme weather events. The seabird populations from nearby Maclennan Cay, for example, have largely disappeared since cyclones destroyed the vegetation. Most of the cay has been washed away.

The plight of seabirds and green turtles highlights the importance of island habitats in the Great Barrier Reef. While it is early days, the results of the adaptation trials on Raine Island are providing encouraging signs that local management actions can help reduce the vulnerability of species and habitats to climate change. ☐

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Plan primes Reef watchers for action

An early warning system is the first step in a proactive approach to help the Reef recover from critical climate-related events

Tourists may have welcomed the unusually warm waters on the Great Barrier Reef in 1998, but the marine heatwave nearly spelled disaster for much of the Reef's corals.

The water temperature was on average 2°C above normal, which was enough to trigger one of the Reef's worst-ever coral bleaching incidents, affecting nearly 50 per cent of the Marine Park's reefs.

The coral bleaches when stressful conditions, such as increased water temperatures, drive out the microscopic plants – called zooxanthellae – that live symbiotically within the coral's living tissue. The result is bone-white coral. If stressful conditions persist, bleached corals can die. When this happens on a large scale, it is not only an ecological disaster but also an economic one, threatening reef tourism and other industries relying on a healthy reef ecosystem.

Fortunately, the hot conditions of 1998 abated before it became a disaster. But there was a clear message: the Great Barrier Reef is not immune from the effects of climate change.

Warmer temperatures are among the main causes of coral bleaching. Climate change is expected to accelerate the incidence of warmer ocean temperatures. In preparation, the Great Barrier Reef Marine Park Authority (GBRMPA) has developed a comprehensive plan to monitor, measure and respond to these kinds of events. The aim is to increase the Reef's long-term resilience.

The *Coral Bleaching Risk and Impact Assessment Plan* now underpins how the GBRMPA and its partners respond to a coral bleaching event.

The plan has achieved far more than was originally intended since its development in 2006. It has proven so successful and comprehensive that the model has been adopted in other reef environments around the world. It also forms the basis of response plans for a range of other potentially damaging incidents, such as severe tropical cyclones, which are expected to increase in frequency with climate change.

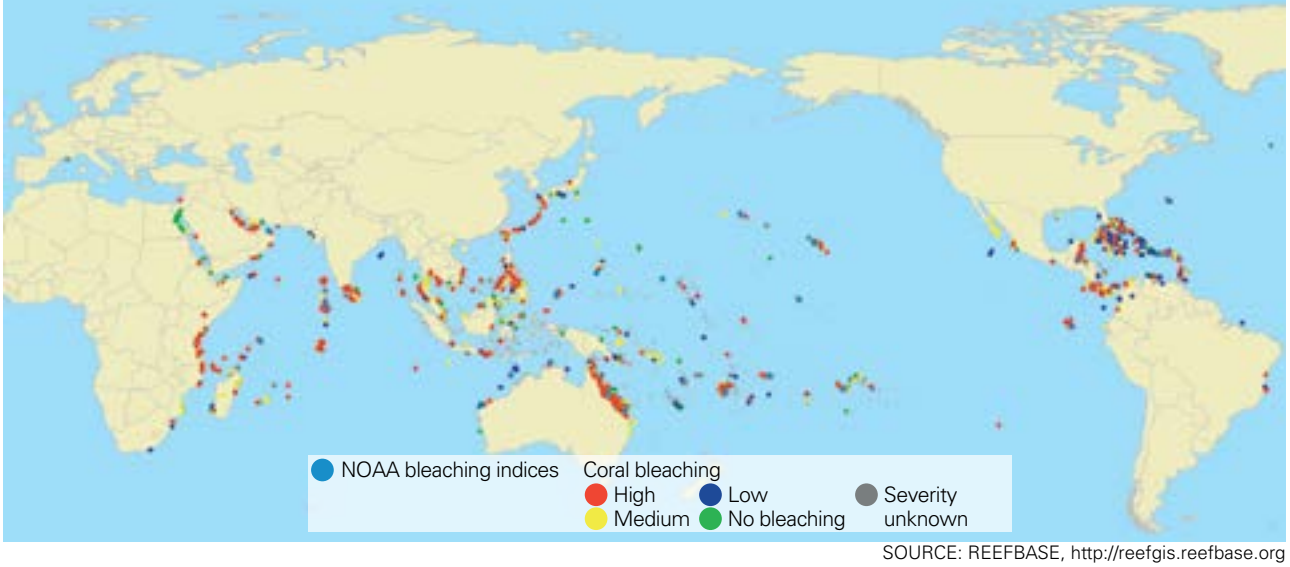
The GBRMPA's climate change director Paul Marshall says looking at the risks more closely has shown that many of the impacts to the Reef will occur during these incidents.

"We tend to think of climate change as being this slow, inexorable increase in average conditions. Statistically that's true, but from the experience of a coral or a fish, what happens is that extreme events happen more often and they're more severe. It's important that we monitor them and get a handle on what these incidents mean for the Reef from a climate change perspective."

The three key components of these incident response plans are simple: an early warning system, an incident response and a communications strategy.

"It's a strategic and structured response that includes our partners and ensures that we identify when conditions are getting stressful and when an incident is happening," Dr Marshall says. "For example, coral bleaching is triggered by unusually warm water, so when data from remote sensors and satellite monitoring suggest an increase in water temperature, the

Figure 1: Reported events of mass coral bleaching worldwide as at 2012



SOURCE: REEFBASE, http://reefgis.reefbase.org

Coral Bleaching Risk and Impact Assessment Plan swings into action.

"Once things look like they might be getting stressful for corals, we ramp up our efforts to get people who are out on the Reef on a daily basis, such as Marine Park rangers and tourism operators, to report if they're seeing any signs of bleaching."

If coral bleaching is reported, an on-call team of marine biologists is sent to do verification surveys as part of a full-scale assessment of the extent and severity of the bleaching event.

The same approach has been taken in the case of extreme weather events, such as Tropical Cyclone Yasi, which struck the Queensland coast in February 2011. In this case, there was a need to quickly assess the damage caused by the cyclone and consider if additional protective actions were required, as John Hicks, northern marine regional manager for the Queensland Parks and Wildlife Service, explains.

"Working with, and under the leadership of, the GBRMPA, we sent joint survey teams out onto the Reef to conduct underwater surveys of the damage," he says. "We had an assessment sheet that allowed us to collect that data and, in the end, there were 882 joint site surveys done over a 400-kilometre length of the Great Barrier Reef, between Cairns and Townsville and a little to the south down to the Whitsundays."

The result was a detailed map of the severity of damage and pattern of impact across the affected area, which also provided a baseline for monitoring the Reef's recovery. While the nature of coral bleaching and other climate-related events means that little can be done by managers to prevent them happening, the incident response plans enable the GBRMPA and its partners to understand where and how badly reefs are damaged. This information can be built into future management decisions aimed at helping the Reef recover.

"It is also important that we communicate what is going on, so we can share critical information with people who use and care about the Reef, so they can also do their bit to help their local reefs cope better. We can then work with them to come up with plans or strategies they can use," Dr Marshall says.

This may mean working with tourism operators to help visitors avoid a bleached section of reef, which will reduce the risk of stressing the coral even further, or if the bleaching is more severe, looking at reducing other potential stressors. "In the past, we've also used it where there might be construction activities and coastal development; we don't want dredging to be occurring at times when corals are already stressed," he says.

Another response option is to set up 'no anchoring areas' to protect the surviving remnant corals in high impact areas. For example, 'no anchoring areas' were put in place to assist fringing reefs to recover around the Keppel Bay Islands following a major river flood.

While the key elements of these incident response plans may seem obvious, this new approach is about being proactive, rather than reactive, Dr Marshall says. "We're getting ready for it, we have communications ready, we have our partners all lined up, and they're aware that summer's a stressful time for the Reef. It's building knowledge and capacity amongst Reef users, Reef stakeholders and our partners."

Mr Hicks says this preparedness also enables resources to be deployed more strategically. "It puts you in the best possible position to use your available resources – people, vessels, equipment – wisely. You have the opportunity to think through the issues, map out the response structure, decide who's going to be involved, and conduct exercises to train people up.

"The end result is you get an efficient, prompt response under a known pre-agreed structure. Having these plans in place is at the heart of good marine park management, and one of the ways we are working to improve the outlook for the Reef," he says. □

Many eyes help track Reef health

Community members keen to contribute their knowledge have significantly improved the reach and response capacity of the Great Barrier Reef observation network known as the Eye on the Reef.

Not long after Tropical Cyclone Yasi struck off the coast of North Queensland in 2011, phones at the Great Barrier Reef Marine Park Authority (GBRMPA) offices started ringing. Tourism operators and community members who were part of the integrated monitoring program, Eye on the Reef, were calling in to report the damage at their reef sites.

Eye on the Reef is a network of monitoring programs that includes state and federal government and a number of 'citizen science' monitoring programs, co-ordinated by the GBRMPA in collaboration with the Queensland Parks and Wildlife Service (QPWS).

The Australian Institute of Marine Science (AIMS) regular long-term scientific reef monitoring program has been in place on the Great Barrier Reef for many years. But detailed surveys are only conducted on specific sites every one or two years.

GBRMPA project manager Jen Dryden says relying only on this program meant that the information available, although comprehensive, was limited to a small proportion of the 2900 reefs within the Great Barrier Reef World Heritage Area.

"When a situation like Tropical Cyclone Yasi arises, we need to gather information on the status of reefs quickly. This helps users know how the Reef is faring and identifies whether there's a need to put in place a responsive management action to prevent further damage and to help the Reef recover."

Under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), the Eye on the Reef program has brought together GBRMPA managers, Marine Park rangers, AIMS staff, reef scientists, fishers, tourism operators, local business operators and community members to expand the observation network.

Reef stakeholders are involved in a range of different monitoring initiatives, which all come together through the Eye on the Reef program. These include the Reef Health and Impact Surveys, the Tourism Weekly Monitoring program, the Rapid Monitoring survey program and the Sightings Network. In combination, these programs help provide everything from an early warning system through to impact assessments, which are already being used to manage Reef health incidents such as coral bleaching and tropical cyclones. They may also be used in the future to respond to coral disease and crown-of-thorns starfish outbreaks.

"Prior to the integration of community monitoring programs we could only get information on around 100 reefs," Ms Dryden says. "By the time Tropical Cyclone Yasi hit, thanks to the Eye on the Reef program we had a network of vessels and people all along the coast who were keen to get out there and collectively report on the condition of hundreds of reefs."

Ms Dryden says the response following the cyclone was an example of how much more could be achieved by collaborating with the broader range of stakeholders living and working on the Reef. Within two weeks of Tropical Cyclone Yasi, 882 Reef Health Impact Surveys had been completed to provide a comprehensive assessment of reef damage on over 76 reefs affected by the cyclone.

"Thanks to everyone's efforts, we ended up with an excellent set of data relatively quickly that helped us see exactly how the cyclone had affected different reefs along its track," Ms Dryden says. "The survey outputs provided quality data and on a vastly larger scale that previously possible."

Richard Quincey, director of the field management program and regional manager for QPWS, was in charge of the operational resources that helped move people and vessels after Tropical Cyclone Yasi hit.

"We needed to look after our own staff, look after infrastructure issues in national parks on some of the islands and assess the damage throughout the area," he says. "What

impressed me the most about Eye on the Reef was that it was so easy to layer in the reef health impacts and observational monitoring and assessment with everything else that was happening. I think it shows the value of the GBRMPA focus on gathering information that's important for the health of the reef, and the social and economic use of the Reef as well."

Eye on the Reef also played its part after the south-eastern Queensland floods of 2011. Large freshwater flood plumes carried sediment, nutrients, pollutants and debris from the mainland to the fringing reefs around islands in Keppel Bay, causing bleaching on a similar scale to the 2006–07 thermal bleaching event.

"The Keppel Bay community is highly involved in helping protect the coral reefs in this area," Ms Dryden says. "After we surveyed the extent and severity of the flood impacts in the region, the local marine aquarium collection industry actually came to us to see what they could do.

"They voluntarily put a temporary moratorium on themselves, deciding not to collect in heavily affected areas until the impact from the flood plume had abated. We'll continue to monitor recovery of coral reefs in that area and share that information with them so that we can continue our collaborative efforts to help protect corals in Keppel Bay."

Eye on the Reef also receives reports on the Reef through community programs such as the Sightings Network, which records sightings of marine animals, and rapid monitoring program, which sets up regular reporting on local sites throughout the Reef.

Jim Buck, a Department of Environment and Heritage Protection volunteer who co-ordinates a turtle monitoring program in the southern Great Barrier Reef, also contributes to the program. He says Eye on the Reef is a rewarding way to contribute to reef conservation.

"Getting involved with Eye on the Reef through rapid monitoring was a natural addition to our activities. It presented another opportunity to contribute to GBRMPA's understanding and management of the Reef," he says.

"We have identified seven fixed monitoring sites on the reef at Lady Musgrave Island, which will be assessed annually. They will provide an ongoing record of coral bleaching, damage to coral, numbers of different fish species and any accumulation of rubbish at the sites."

Mr Buck and his team operate from an under-canvas camp on the coral cay for five to six weeks a year. "Collecting this information in our recreational time also provides our volunteers with a better perspective of the total reef environment. Over time, these observations may also contribute to our understanding of climate change," he says.

Ms Dryden says she hopes the program continues to extend interactions between all those involved with the Great Barrier Reef. "It's not just a matter of 'what gets measured gets managed'. It's also about building a better sense of stewardship – so people understand how their actions will affect the Reef and how they can do their part to help keep an eye on it and protect it." □

Development assessments

The GBRMPA is exploring global best practice around incorporating climate change into assessment processes.

THE GREAT BARRIER Reef supports many businesses, large and small. It is also a national icon significantly threatened by climate change.

Being aware of climate footprints and looking for ways to reduce them is globally responsible practice. The Australian Government is strongly committed to reducing Australia's carbon pollution. The Government's Clean Energy Future package supports this endeavour, including helping businesses and households reduce their footprints. The Great Barrier Reef Marine Park Authority (GBRMPA) contributes to helping Australia reach its carbon pollution reduction targets by encouraging and supporting Reef stakeholders to minimise the carbon footprint of their operations.

The GBRMPA must also deal with climate change considerations in managing the Great Barrier Reef Marine Park. The agency has a key role in decisions about what goes on in the Marine Park: what can and can not be built, what activities are allowed and how many individual operations can occur within an area. It is important to consider how new developments are likely to experience the effects of climate change and the extent to which a development will influence how its surrounding natural environment responds to climate change.

New port developments, the building of marinas and resorts, and shipping and tourism activities can have multi-billion dollar benefits, but there is also the potential for serious negative environmental and social impacts. All applications are carefully assessed. However, the existing 'rulebook' does not recognise that the climate is changing and that this has implications for the assessment of risks.

Director of the GBRMPA's environmental assessment and management group, Dr Adam Smith, says current policies and assessment tools do not clearly articulate how climate change impacts should be considered in the assessment process. To explore this, the GBRMPA commissioned a review of its environmental assessment and management instruments to look at incorporation of climate change. The review looked at policies, plans and other instruments.

Dr Smith says developments being proposed within the Marine Park are becoming bigger and more complex. Failure to adequately identify important climate change considerations associated with these could have significant long-term implications for the Reef and those who depend on it.

"We want to be able to look at potential climate-related impacts, not only those on the development but also those potentially resulting from the development," Dr Smith says.

As an example, the GBRMPA may want to ensure that developments have been designed to allow for rising sea levels and that structures will remain intact over the long-term. Structures that collapse into the surrounding area or leak pollution could damage the Reef environment.

"To assess these issues consistently, climate change needs to be built into the GBRMPA's environmental assessment and management policy and processes," Dr Smith says. "This will provide a clear message that climate change needs to be taken seriously in proposals and operations.

"We've seen some industries provide leadership voluntarily, such as the tourism, ports and Defence stakeholders, but this doesn't exist across the board, which is why there is still a need to embed climate change considerations into formal Environmental Impact Assessment (EIA) processes," Dr Smith says.

The suggestions for the EIA 'rulebook' that came out of the commissioned review of existing policies and plans could put the GBRMPA on the front foot in protecting the Reef, and bring its processes into line with guidance from international EIA leaders such as the International Association of Impact Assessment's *Climate Change in Impact Assessment: International Best Practice Principles* or Canada's *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners*.

Dr Smith says the GBRMPA is keen to work closely with its stakeholders in developing and communicating any new policy or process. "We want to help them understand why incorporating climate change considerations is so important and that doing so has benefits for not only the Reef, but also for the industries and communities that depend on it."

Outside the EIA process, the GBRMPA has already begun building climate change into interactions with stakeholders who use the Marine Park. "We've recently built it into our memorandum of understanding with the ports corporations and we're looking at doing the same with the Australian Department of Defence," Dr Smith says.

"Climate change is the biggest threat to the Reef's long-term survival. The GBRMPA is the Commonwealth agency charged with Reef protection. We recognise that climate change influences the type and extent of risks posed by infrastructure developments and other activities.

"To ensure we make good decisions, we need to evolve our policies and practices to build in climate change considerations. Promoting action that helps Australia meet its targets for reducing carbon emissions is part of this, and important in supporting the long-term health of the Great Barrier Reef and our communities." □

Ecosystem research reveals new pressures on Reef adaptability

Analysis of flooding and the role of coastal ecosystems is identifying 'hot spots' most at risk from climate change pressures.

What began in the 1990s with a concern about the quality of stormwater flows into the Great Barrier Reef has evolved into an examination of the complex relationship between the many ecosystems that connect the Reef to its catchment. An essential part of this examination is an understanding of current stresses and the potential impacts of climate change.

Hugh Yorkston is director of coastal ecosystems and water quality for the Great Barrier Reef Marine Park Authority (GBRMPA) and has been working on coastal management issues for almost 20 years. During that time there has been ongoing research into the effects of poor-quality run-off into the Reef system.

The Reef receives run-off from 38 major catchments that drain 424,000 square kilometres of coastal Queensland. River discharges are the single biggest source of nutrients to the inshore areas of the Reef and, during the past 150 years, the sediment in these flows has increased four to fivefold in most catchments and up to 10-fold in some areas.

Mr Yorkston says the quality of run-off has been identified as the second most significant pressure on the Reef, after climate change, and it is expected to significantly compound the effects of climate change. In addition to sediments, run-off often contains high loads of nutrients and other pollutants.

Wetlands have always provided a natural filter to the Reef and the loss of many wetlands during the past century has reduced the filtering capacity of coastal areas. Other issues have exacerbated water quality problems. These include increased sediment and contaminant loads in the run-off, increased volume of run-off from more severe storm events, and modification of the landscape.

One recent project supported under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) has been mapping the frequency and duration of flood plumes into the ocean in addition to the quality of the plume water. James Cook University water quality scientist Dr Michelle Devlin has collated flood data covering more than 20 years to identify water quality 'hot spots'. These are areas where the poor quality of run-off is most likely to affect the Reef's ability to withstand additional climate-related stresses such as the extreme weather events of 2011.

Mr Yorkston says Dr Devlin's work quantifies the areas of greatest risk in a way that has not been done before. It clearly identifies the areas and the ecosystems at greatest risk from poor water quality.

Dr Devlin found there was a high risk of water quality targets exceeding the amount of total suspended solids – a sediment indicator – in seven per cent of Reef waters, potentially affecting the health of 53 seagrass meadows and 35 inshore coral reef systems. About 26 per cent of the Reef area was at high risk of exceeding chlorophyll targets (chlorophyll levels reflect nutrient loads), potentially affecting 144 seagrass meadows and 242 inshore coral reefs.

The information is already helping prioritise management responses, including efforts to improve the quality of run-off and the Reef's

capacity to cope with poor water quality by reducing other stressors.

"Last year showed us that we may already have reached a tipping point for some ecological systems in the Reef," Mr Yorkston says.

"There were new flood level records set in half a dozen major rivers along the coast and we also had Tropical Cyclone Yasi. Before this we had seen a gradual decline in seagrass health as a result of water quality issues. Afterwards there was a significant loss of seagrasses – even seagrasses we thought were relatively healthy. They couldn't cope with the additional impact of the extreme weather. Some seagrass meadows will take years to recover.

"Seagrass is a critical food supply for green turtles and dugongs, and their death rates almost doubled in the central and southern parts of the Great Barrier Reef where the seagrasses had been lost."

Mr Yorkston says the *Reef Water Quality Protection Plan* (Reef Plan) has been addressing the quality of water flowing into the Reef since it was first implemented in 2003. "Much of what needs to be done requires the co-operation of individuals and organisations outside the GBRMPA's actual area of legislative authority, so we have to rely on relationships and co-operation from other agencies. The Reef Plan is essentially a toolkit to help do this," he says.

He is confident that new monitoring reports, initiated in 2011, will show improvements in the quality of outflows to the ocean. However, the effects of climate change will exacerbate existing stressors, even where those stressors can be reduced.

"Once climate change factors were added to water quality issues, we realised further research was needed. With our coastal ecosystems project and supported by the Action Plan, we're effectively tracing our steps back from the Reef, following the journey of the water and wildlife through those systems and

Wetland stress links to bigger picture

For thousands of years wetlands have naturally 'polished' water. In the catchment areas of the Great Barrier Reef, they play a crucial role in slowing water flows and filtering nutrients and sediment from runoff before it enters the ocean. Too many nutrients or too much sediment can undermine the health of exiting marine ecosytems.

However, many Queensland wetlands have disappeared during the past century, says Donna-marie Audas, the manager of coastal ecosystems for the Great Barrier Reef Marine Park Authority (GBRMPA).

"In the coastal catchments along the Great Barrier Reef up to 80 per cent of coastal wetlands linked to the Reef have been modified or lost," she says. "The remaining wetlands are under increased stress with changes to hydrological flows and the increases in sediment and nutrient inputs from human activities, making it difficult to filter run-off as effectively as before. As a result, the water quality in the Reef suffers."

In 2003, the GBRMPA partnered with the Queensland and Australian Governments to initiate the Queensland Wetlands Program. Its purpose is to develop tools and resources to help sustainably manage wetlands in Queensland. The program has mapped and classified wetlands, aiming to help protect those that remain.

A state planning policy was introduced in 2010. This ensures that future development in or near wetlands of high ecological significance in Reef catchments will be planned, designed, constructed and operated in a way that protects or enhances the wetlands and their environmental values.

Ms Audas says conceptual modelling has also been developed to help people understand how wetlands work, their value and how the threats can be better managed. These mapping and modelling programs can be accessed at the Queensland Wetlands Program's WetlandInfo website.

For most freshwater (inland) wetlands, climate change is expected to exacerbate existing threats rather than generating new ones. However, for coastal wetlands – the ones adjacent to estuarine and marine areas – changing tidal influences and sea level rise due to climate change pose new and serious threats.

Under the *Great Barrier Reef*

the interconnectivity with coastal ecosystems and the Reef."

The GBRMPA has supported wetland mapping and modelling programs across Queensland, including specific estuarine and marine wetlands models. The coastal ecosystems research has expanded to take in the ecological functions or services provided by the 70 different bioregions that make up the Great Barrier Reef ecosystem.

"We have also looked at how people have modified those coastal ecosystems, how that impacts on the connectivity and health of those systems, and their ability to adapt to climate change," Mr Yorkston says.

The loss of wetland connections, for example, affects the quality of run-off into the Reef. Barriers on waterways can also affect the breeding cycle of some fish species such as mangrove jack, which is popular for both recreational and commercial fishing. As an adult, it lives and breeds in open waters on the Reef, but the fry travel into the freshwater river systems to grow, before returning to the estuaries and then back to the Reef.

While the ecosystems are essentially dynamic and can shift in response to changing conditions, Mr Yorkston says the speed of climate change is a major problem, particularly for long-lived species such as trees. Changes that might previously have taken 1000 years are expected to occur within 100 years.

'Hard boundaries' such as urban and farm infrastructure have emerged as another issue that will hinder ecosystem adaptation to climate change. Mangroves, for instance, will be affected by changing sea levels, which are predicted to rise 800 millimetres by 2100. While it may be possible for mangroves to effectively retreat to higher ground, given enough time, many are already being squeezed out by human development along the coast and have nowhere to go. □

Climate Change Action Plan 2007–2012, the GBRMPA has funded a project to assess the impact of climate change and add this information into the current wetlands conceptual modelling. The Queensland Wetlands Program has also been contributing to the GBRMPA's coastal ecosystem project, which looks at the connectivity between different components in the landscape, and how these will be affected by climate change.

"Looking at wetlands on a site-by-site basis can be limiting when it comes to addressing larger-scale issues like connectivity and climate change, and integrating responses to these issues into day-to-day management," Ms Audas says.

The ecosystem project helps provide a 'bigger picture' by working to identify the processes provided by different elements in the landscape such as wetlands, including the hydrological and biological functions and connections. It will then overlay how human activities affect those different processes and the impact or exacerbated impacts of climate change on those modified systems. Maintaining the connectivity of coastal ecosystems is essential in contributing to their health and resilience to climate change. □

■ **More information**:
www.wetlandinfo.derm.qld.gov.au

Seaweed nutrient sinks investigated

Seaweed cultivation and harvesting could offer a new management strategy to reduce the impact of nutrients from land-based run-off onto the Great Barrier Reef.

Seaweeds have the potential to act as significant sinks for nutrients, carbon, trace elements and organic compounds, which makes them well-suited to removing pollutants in coastal waters. A review of existing research has found that dense stands of seaweed have the potential to remove more than 350 kilograms of nitrogen and 35 kilograms of phosphorus per hectare of seaweed per year. The annual nitrogen load into the Reef from land-based sources is estimated at 25,000 tonnes.

The Great Barrier Marine Park Authority (GBRMPA) project manager Paul Groves says that at this stage the project is theoretical, but there is evidence the concept could work, although it would take 70,000 hectares of seaweed to remove the entire nitrogen load.

"That would equate to more than 25 million tonnes of seaweed – or double the current annual global production. So it's unlikely that seaweed will be the solution to the nutrient loads in run-off, but it could be part of a multi-pronged strategy to reduce risks from nutrients in the Great Barrier Reef," he says.

An added benefit of using seaweeds as nutrient sinks is that they can be harvested and put to good use. Potential end uses include agricultural and industrial applications, such as agricultural fertiliser, biochar and biofuels, and also food, health and wellbeing products.

The evaluation project was undertaken by Professor Rocky De Nys at James Cook University. He reported that water quality remediation using seaweeds was an established practice in integrated aquaculture, where nutrients are recycled from animal wastes into valuable seaweed products. Excess nutrients typically concentrated in seaweed and remained in the harvested seaweed, providing an effective way to reduce dissolved nutrients in coastal waters.

At least 50 large, fleshy seaweeds suited to open water culture have been identified in Queensland waters and they could be candidates for further investigation into the most appropriate species and propagation techniques.

Mr Groves says the culture of seaweed falls within the definition of aquaculture, which is not currently permitted within the Great Barrier Reef Marine Park. Further work would also be required to identify the most appropriate species and propagation techniques.

Revelations in the wake of extreme weather

The wild weather of the 2010–11 summer has helped the GBRMPA prepare its response systems for climate change.

The summer of 2010–11 brought extraordinary weather conditions to Queensland. Severe Tropical Cyclone (TC) Yasi was one of the most powerful cyclones to affect the Great Barrier Reef since records began. At the opposite end of the state, south-east Queensland experienced intense rainfall, up to four times the average.

While the cyclone caused severe structural damage to more than 1500 square kilometres of the coral reef area within the Great Barrier Reef Marine Park, the wild summer weather caused a wide range of other damage.

The cyclonic winds and extensive freshwater flood plumes affected wildlife habitats, such as seagrass beds, mangroves and islands, leading to additional pressures on species including dugongs, seabirds, green turtles and fish stocks.

The interconnected nature of the Reef's habitats led to inevitable flow-on effects through almost all parts of the system. There was direct damage to infrastructure and natural resources within the Marine Park, and stress on the industries and communities that depend on them.

The detailed information available about the direct and indirect impacts of weather events last year can be attributed to the Extreme Weather Response Program initiated immediately after TC Yasi by the Great Barrier Reef Marine Park Authority (GBRMPA) and the Queensland Parks and Wildlife Service (QPWS).

The program, funded through the Australian Government's Caring for our Country initiative and the *Great Barrier Reef Climate Change Action Plan 2007–2012*, drew together many streams of existing research and monitoring to identify the extent of damage and the potential implications.

It included a review of both the environmental and human impacts of the extreme weather, such as the loss of infrastructure for Reef-dependent communities and businesses, and the effect of fish movements on the viability and management of the commercial fishing industry.

The program was characterised by strong collaborations with research agencies including CSIRO, James Cook University and the Australian Institute of Marine Science; Traditional Owners; coastal communities; and Reef industries, including tourism and commercial fishers.

The program involved a suite of government and other management responses to support the recovery of damaged reefs, seagrass beds and animals that rely on the Reef. Among these were voluntary initiatives from Reef community partners who are taking a more proactive role as Reef stewards – Traditional Owners and the aquarium collection industry both agreed to temporarily suspend some activities in order to help the Reef ecosystem recover.

The intense scrutiny that followed TC Yasi has also led to important insights about the potential cumulative impacts of climate change and their implications for Reef ecosystems, industries and regional communities. This is helping refine management responses.

The GBRMPA's manager of climate change ecosystem resilience, Roger Beeden, led the reef impact assessment part of the response. "Last summer provided a robust test of our capacity to manage in the wake of extreme weather events. It clearly showed that our work to integrate our monitoring programs and develop our capacity to respond to climate incidents over the past five years has been moving in the right direction," he says.

Within five months of TC Yasi, the GBRMPA released two reports on the impacts of extreme weather on the Great Barrier Reef: *Impact of Tropical Cyclone Yasi on the Great Barrier Reef*, followed by *Extreme Weather and the Great Barrier Reef*.

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION AND BUREAU OF METEOROLOGY

Satellite image of a tropical cyclone crossing the Great Barrier Reef.

The reports present key findings from the Extreme Weather Response Program and profile management and stewardship efforts that have been put in place to help the Reef cope with the after-effects of extreme weather.

As a result of this work, extreme weather events are recognised as a significant risk to the Reef, with climate scientists predicting increasingly frequent extreme weather events, such as flooding rains and intense cyclones, as a part of a changing climate. The GBRMPA has developed an integrated response strategy for such events.

"Thanks to the Action Plan, we now have a much better understanding of climate change impacts. This is helping to focus management into the future and to help build the resilience of the Reef, and its industries and regional communities, to climate change," Mr Beeden says. ☐

Adaptation of industries and communities: Preparing for change

The GBRMPA is working with Great Barrier Reef industries and communities to help them – and the Reef – cope with climate change.

The people who depend on the Reef have long known that it's a two-way street: look after the Reef and it will look after you. Climate change poses especially big challenges for the Reef and the industries and communities that depend on it.

Through the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), the Great Barrier Reef Marine Park Authority (GBRMPA) has been working with Reef-based industries, regional communities and Traditional Owners to better understand the implications of climate change. By helping those who depend on the Reef to explore climate vulnerabilities and adaptation options, we have also helped them realise the importance of their role as stewards of an ecosystem of inestimable cultural and heritage values. It is also a system that supports more than $5.1 billion a year in economic activity.

Partnerships have been crucial to the success of the Action Plan and have strengthened the GBRMPA's relationships with Reef stakeholders, especially major industries. We have helped industries and communities understand adaptation concepts and the links to Reef resilience, supported industry efforts to put adaptation into action, and increased opportunities for Reef stewardship by industries and communities.

Partnering with industry

Under the Action Plan, we have facilitated information sessions, discussion forums and workshops for Reef tourism and commercial fishing industries. This has helped them access the latest scientific information on the risks and opportunities presented by climate change, explore the implications for their businesses, identify strategies to reduce their vulnerability and improve their ability to adapt to changes.

The Reef tourism industry and key sectors of the commercial fishing industry – including the coral and aquarium collectors and the otter trawl (prawn) sector – are now leaders in adaptation among reef-based industries globally.

Our engagement has been focused around the realities of people's lives on a range of issues in conjunction with climate change. A mix of strategies has maximised the ability of individuals and industries to participate. Work with industry groups has fostered supportive networks and built skills in risk analysis and forward planning: all core ingredients for successful adaptation.

In recognition of the experience and expertise within the tourism and commercial fishing sectors, we have promoted opportunities for industry members to serve as adaptation coaches, communicators and mentors to their peers. We have also provided support funding to create a dedicated climate change position within the Queensland seafood

industry and to fund dedicated climate change work in the coral and aquarium fishery. The success of this approach has motivated exploration of similar arrangements in other sectors.

Putting adaptation into action

In working with Reef businesses under the Action Plan, we have moved beyond an academic approach to adaptation. Tourism operators and commercial fishers bring a focus on practical actions to the discussion and have created nationally-significant opportunities to apply and test ideas for tackling the risks presented by climate change.

We have worked with the tourism industry to establish a Tourism Climate Change Action Group. The group, comprised of the Queensland Tourism Industry Council, the Association of Marine Park Tourism Operators, the Whitsunday Charter Boat Industry Association, Tourism Queensland, the Queensland Parks and Wildlife Service and the GBRMPA, developed the *Great Barrier Reef Tourism Climate Change Action Strategy (2009–2012)*, the first of its kind in the world. The strategy has guided a range of real-world adaptation actions among tourism operators, including emissions-reduction programs, tests of renewable energy options, implementation of site-based management strategies that support reef resilience, and new awareness and education campaigns. These have been recognised through the new Climate Action Certification program, developed with Ecotourism Australia and supported by the Action Plan.

The coral and aquarium fish collecting industry, which involves hand-collecting marine life for education and display purposes, has been another adaptation leader. The industry group Pro-vision Reef has developed the first *Reef Stewardship Action Plan* in the fisheries sector and led a range of innovative approaches to address climate change and other external risks to the industry.

Under the Action Plan, marine collection operators have become key partners in detecting and assessing climate change impacts on the Reef. They have initiated strategic analyses of adaptation options for the industry, including a sector-specific vulnerability assessment and a supply-chain analysis to drive future planning and development of the industry in the context of climate change.

Fishers in this sector have a strong personal commitment to Reef stewardship, enacting a voluntary moratorium in key sites within Keppel Bay following climate-related stress on reefs in the area.

Other commercial fishing sectors have picked up the adaptation baton, including the reef line and trawl fisheries and, with the support of the GBRMPA, are undertaking a range of vulnerability assessments and adaptation planning activities.

Caring for the Reef: a job for everyone

The increasing pressures from climate change have highlighted the importance of community and industry stewardship for the Great Barrier Reef. We have dedicated significant effort to increasing opportunity and recognition for stewardship among local councils, schools and Traditional Owners.

Local councils within the region have a particularly important role in helping the Reef cope with climate change. Every day, they make decisions that can affect the Reef's resilience through development approvals, environmental regulations, land-use planning and education of the community. With support from the Action Plan, our Reef Guardian program was expanded to help councils incorporate climate change into their policies and activities. This has enabled better management of local stressors and created increased stewardship of local reefs.

Through the Reef Guardian program, we have provided school children with information about climate change and Reef resilience that will help them grow into informed Reef stewards. Children can also help pass key messages through the community via family and friends. Highlights include incorporating climate change into science curriculum teaching resources and establishing an awards scheme to recognise adaptation leadership.

The GBRMPA has a proud history of working closely with Indigenous groups that have traditional ownership of land and sea country within the Great Barrier Reef region. Through the Action Plan, Traditional Owners have gained an appreciation of the implications of climate change for their sea country. We have demonstrated the feasibility of incorporating climate change into Traditional Use of Marine Resources Agreements and supported collaborative responses to extreme climate-related weather events such as the sea turtle tracking initiated following Tropical Cyclone Yasi in 2011.

The stories that follow highlight how Reef industries and communities are tackling the climate change challenge with adaptation in mind, to reduce their own vulnerability and to support the natural resilience of the Reef. □

Tourism industry safeguards Reef for visitors

Tourism is the business of inspiring memorable experiences, so adapting to climate change makes good business sense for the future.

The visitor book from a Quicksilver cruise says it all: "Best thing we've ever done in our lives"; and "Better than sex". Tourists of all ages bear witness to the singular magnificence of the Great Barrier Reef. Their reactions underpin the success of tourism on the Reef and highlight what is threatened by climate change.

The importance of the Reef extends beyond local marine tourism. It is Queensland's main tourism asset, says Daniel Gschwind, CEO of the Queensland Tourism Industry Council. To safeguard this asset into the future, industry has been a key partner in the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) by developing specifically tailored guidance: the *Great Barrier Reef Tourism Climate Change Action Strategy 2009–2012* (Tourism Action Strategy).

Out on the Reef, operators are feeling the effects of climate change and extreme weather events. Environmental impacts have been felt in the form of changes to coral cays, coral bleaching, outbreaks of coral predators, cyclones and floods.

Potential risks to operators range from infrastructure damage to disruption of schedules, impacts which decrease their ability to provide a quality service befitting a world-class destination.

From a visual perspective, coral bleaching and loss of biodiversity mean a less attractive Reef. This could damage the industry's ability to market the Reef to tourists, and threatens the viability of future tourism, in both environmental and economic terms. Supporting more than 54,000 jobs and more than

$5.1 billion of economic activity annually, the implications extend beyond the region.

To maintain the ongoing attraction of the Reef to more than 1.9 million visitors a year, industry clearly needs to adapt to the changing environment. According to Mr Gschwind, a large challenge is how to actively manage the situation while mitigating potentially negative tourist perceptions of damage to the Reef.

Former Great Barrier Reef Marine Park Authority (GBRMPA) manager of policy and sustainable development (tourism and recreation) Lorelle Schluter suggests that, since the release of the Tourism Action Strategy, there has been less debate within the industry about whether climate change is real, and more about what operators can do. "People are aware they have to make changes," she says.

Working to create a more-resilient reef is one approach, and a key objective of the strategy. Reducing human impact means a healthier Reef that is better able to withstand the stresses of climate change. Doing so will also protect the tourism dollar, and keep the Great Barrier Reef magic alive.

Initiatives include both practical action and awareness-raising activities. The GBRMPA has worked closely with operators and tourism representatives, developing products and programs such as a tourism carbon emissions calculator, the Climate Action Certification program in partnership with Ecotourism Australia, a climate incident response plan and an improved, integrated Eye on the Reef monitoring program. It has also spearheaded industry workshops and research into Reef resilience and protection.

The GBRMPA and tourism representatives agree that the initiatives have resulted in a strong sense of partnership and shared responsibility among operators on the Reef. "The onus is on us to take on a stewardship mentality and attitude to our Reef sites to try to preserve and protect as much of the Reef as possible," says Doug Baird, environment compliance manager for Quicksilver Group, which operates Reef cruises and is one of the largest private employers in Northern Queensland.

To protect Reef health and ensure future business, operators have put practical measures in place, such as reducing reliance on fossil fuels and moving towards sustainable sources of energy, monitoring the Reef for changes, calculating carbon emissions, training their staff to be environmentally responsible and becoming certified under the Climate Action Certification program. "A number of operators have been incredibly proactive in gaining certification that includes Climate Action," Ms Schluter says.

This awareness is, in turn, passed on to visitors and communities through tourism staff, who can encourage individuals to make simple changes to lessen their own carbon footprint.

Regardless of ethical or environmental motivation, money remains a major driver of business decision making. The Tourism Action Strategy has shown that climate action can lead to significant financial benefit for operators. A number of businesses are achieving cost savings and efficiency by making climate-aware choices, such as changing motor types and installing solar panels.

Broader business benefits are being gained through the GBRMPA's High Standard Tourism program, which recognises operators that have achieved the highest levels of Eco Certification. Accredited operators are rewarded with a 15-year permit and earn a valuable endorsement to aid their promotions.

"The High Standard Tourism operators get world-leading best-practice status and are promoted at tourism industry shows," Ms Schluter explains. "People are selecting tourism products with sustainability as one of their criteria."

In 2011, almost 60 per cent of Reef visitors used an Eco or Climate

Testing practical solutions to climate change risks

The Great Barrier Reef Marine Park Authority (GBRMPA) is keen to trial methods to protect coral at specific sites and has facilitated research by the University of Queensland and major industry operators.

Tourism operators running cruises and diving trips on the Reef are restricted in site choice. There are a limited number of sites suitable for permanent platforms, so protecting these sites is critical. Full sun is the best way to view the beauty of the Reef but, ironically, it can also exacerbate bleaching risk when sea temperatures soar.

Using shadecloth to reduce UV exposure has been shown in the laboratory to diminish the risks of coral bleaching. In a partnership between researchers and the tourism industry, the feasibility of transferring this idea to protect a valuable tourism site was tested.

Results of this test case suggest that although such mechanisms can make a difference, it is not financially or physically viable at a scale large enough to make a difference to a tourism operation. The problem is that shadecloth floating on the surface over the reef is a genuine impediment to operations. It impedes snorkel access and makes the monitoring of divers challenging for lifeguards.

The GBRMPA has shown a commitment to helping tourism operators mitigate risks from climate change. Other mitigation strategies trialled included using sprinkler systems to break up the water surface as a way to reduce UV exposure without impeding the enjoyment of tourists. While this may not prevent bleaching, it may still benefit the recovery of corals that are bleached. There is still hope that a way may be found that provides practical solutions to protecting coral while allowing tourists to experience the diversity of the Reef.

Action certified tourism operator – evidence of the willingness of tourists to make environmentally friendly choices.

Industry members admit to ongoing concerns, such as engaging late adopters. Despite the wealth of information available, "there is a lot of work needing to be done with some individual operators to bring them up to speed," says Col McKenzie, executive officer of the Association of Marine Park Tourism Operators (AMPTO). He says there are still plenty of opportunities for the Reef tourism industry to demonstrate their leadership in climate change adaptation.

Mr McKenzie suggests one-to-one assistance will be the most effective way to help operators through the process of becoming Eco or Climate Action certified. "I think the GBRMPA could get more bang for their buck this way," he says. Operators are also keen to see carbon offset programs that will directly benefit the Reef.

This kind of constructive discussion between the GBRMPA and tourism partners underlines a collaborative spirit and deep enthusiasm for the Reef that has been crucial to the Tourism Action Strategy's success so far. It's a model that Mr Gschwind agrees could be applied to tourism industries in other areas.

With a sustainable tourism industry and collaborative efforts to build the resilience of the Reef, there's reason to hope the Great Barrier Reef will continue to elicit colourful responses in tourist visitor books for years to come. As Ms Schluter muses, the Reef may be vast enough to be visible from space, but what's important is "the intimate, personal experience that people have when they get here." □

Quicksilver takes action

The Quicksilver Group is one of the largest and longest-running tourism operators on the Great Barrier Reef. While environmental impacts are already on the radar for the Port Douglas-based company, environmental compliance manager Doug Baird sees the total effect of the *Tourism Climate Change Action Strategy 2009–2012* (Tourism Action Strategy) as raising awareness of climate change across the industry.

As a Climate Action Innovator and Ecotourism-accredited operator, the company has responded to the strategy's initiatives and is enjoying the benefits. The 15-year permit for High Standard Operators offers tangible advantages, and climate-savvy decisions make good business sense, he says. "If you're reducing your carbon footprint it means you're using less electricity and less fuel, so at the end of the day you're saving money."

Staff have a high level of environmental awareness, passed on through company induction sessions. "The onus tends to be on us as business managers to try and show people how climate change could directly affect them. If you can point out the cause and effect scenario for individuals, then they'll buy into it." The flow-on effect is that tourists are more aware of their own impact, while continuing to participate in and enjoy what the Reef has to offer.

The Tourism Action Strategy, developed with support from the GBRMPA, has also prompted changes in the company, such as investigating ways to improve fuel efficiency and moving towards wind and solar-powered components. The Quicksilver Group actively participates in collaborative Reef research projects, such as those related to coral bleaching, and is keen to continue partnering with government and universities.

The partnership with marine park managers has been of particular advantage in discussing issues around the effects of climate change and practical responses, Mr Baird says. "They're keen to work with us and we all have the same goal."

As to his optimism around the future of the famous ecosystem, he assures us the Reef still holds some surprises yet.

Fishers at front-line of climate impacts on Reef

Consultation with the commercial fishing industry is tracking changes to fish populations and helping the industry develop adaptation strategies.

When long-time commercial fisher Geoff Tilton noticed how frequently coral trout were being caught on the southern Queensland coast he became convinced that the sea temperature rise predicted under climate change might really be happening.

"You rarely saw a coral trout south of Noosa a few years ago, but they seem to have been coming down a lot more often lately. It made me realise that the changes they have been predicting are real," Mr Tilton says.

The impact of rising sea temperatures on the distribution of fish species is just one of the effects fishers are concerned that climate change may have on the environment from which they make their livelihood. There's also the impact of ocean acidification, which compromises the growth of corals, and the effect of changes in sea currents on the distribution of nutrients to ocean food webs. Then there is the link with extreme weather events, such as the succession of floods and cyclones that have lashed the coast and destroyed fishing grounds in recent years. These events are predicted to become more intense as the climate changes.

Mr Tilton is the former president of the Queensland Seafood Industry Association (QSIA), the peak body representing Queensland's fishing industry. He says it has been the cyclones and floods that have particularly shaken the industry into realising that fishers desperately need to find ways to adapt to the possible changes climate change might bring.

It was no accident, he says, that one of the biggest turnouts to a recent series of seminars regarding climate change and the fishing industry was in Cairns, not long after Tropical Cyclone Yasi.

"A certain amount of science was saying this is what's happening," he says. "But we're also seeing it around us, in changes in sea temperatures, changes in the pH of the ocean, the

PHOTO: QUEENSLAND DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

effects on the Reef of the run-off from floods and those extreme weather events. It's something we just can't ignore any more."

The fishing industry has always had to adapt to change – to weather, to sea currents, to fluctuations in the supply of fish stock. Climate change is simply the latest change to which fishers on the Great Barrier Reef must adapt. The outlook is not all negative. In some cases the rise in water temperatures means wider distribution of species. But it also means that fishers cannot expect to continue operating the way they do now.

That realisation has brought together the QSIA and the Great Barrier Reef Marine Park Authority (GBRMPA), in a partnership under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan). The partnership aims to both minimise the impact of the fishing industry on the Reef and help the industry understand and negotiate the effects climate change may have on its operations in the future.

The relationship between the GBRMPA and the industry has not always been happy. Back in 2003, the industry felt it was being pushed out of the Great Barrier Reef Marine Park under the Representative Areas Program, which significantly reduced allowable fishing grounds.

Mr Tilton says the picture has changed dramatically since then. Recent efforts by the GBRMPA have shown that the agency not only recognises the value of the Great Barrier Reef fishing industry but is working actively to support its survival and resilience in the face of challenges like climate change.

The fishing industry, which is made up of the line, net, crab, trawl and dive-based fisheries, contributes more than $300 million to the Queensland economy each year, with wild-caught product representing almost 70 per cent of this. Thousands of people are employed directly and in ancillary businesses and trades.

A significant aspect of the Action Plan partnership was the engagement of Eric Perez as climate change and fisheries liaison at QSIA. His role has been to get industry talking to the Marine Park regulators and to experts in the industry who can provide information on the science of what is likely to happen under climate change. "It's been about building relationships and sharing information," he says.

With the support of the Action Plan, Mr Perez has run two Australian Seafood Industry and Climate Change symposiums, which gathered together a range of experts from research agencies, government, fisheries management and the industry. "That was groundbreaking," he says. "It was a great achievement to get these people to take time out from their businesses and into the same room talking about these issues."

> "...it has made such a concrete connection between good environmental practice and good business practice."
> *Geoff Tilton*

Contrary to some perceptions, the industry has never been opposed to the aims of the Reef conservation movement. "We want the same thing. Fishers are not about pillaging the Reef. They want longevity. Fishers have mostly been good stewards, and I don't think that was really getting through to the public and to the government," Mr Perez says.

However, the message seems to be getting through now. Randall Owens, the GBRMPA manager of sustainable fishing, says there is no doubt that many in the industry care as much about the Reef as does the GBRMPA. "We know that our interests aren't that different from the interests of the fishing industry. We're both about looking after the ecosystem."

The survival of the Reef and the fishing industries have always been inextricably intertwined, he says. "We are interested in this industry because we want them to be good stewards for the Reef. Having an industry that's healthy and sustainable means they will be able to go the extra distance in making those adaptations they will need to survive."

One of the most promising outcomes of the partnership is the recognition that information goes both ways. It is not about the GBRMPA simply dictating

PHOTO: QUEENSLAND DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

environmental obligations to fishers. Instead, the authority acknowledges and appreciates the huge contribution the fishing industry is making to a broader understanding of how climate change and other environmental factors are affecting the health of the Reef.

"People working in the fishing industry are operating in this environment on a day-to-day basis," Mr Owens says. "They can see what is happening and they know firsthand the impact of these kinds of changes. When we've had a big flood they can see exactly where the fish are moving to."

Changes in the industry will be ongoing. "It's not about saying we need to do this by this time and this is how we get there," Mr Owens says. "It's about trying a whole lot of different things and seeing what works."

Mr Tilton says helping those in the industry anticipate and adapt to changes involves communicating up-to-date information and research. "The more information we have the better. "The science is useful for providing the predictions as to what is likely to happen over the next few years so we can work out ways of adapting."

That might involve fishers needing to move to other fishing grounds until Reef areas recover from coral bleaching, for instance, or learning how to broaden their markets for alternative species that have increased in number while their own specialty species have gone off the bite. Industry and management agencies are working towards an adaptation plan for the Queensland East Coast Otter Trawl Fishery. Among the suggested options is better information to help trawl fishers adapt to the changes in the distribution of prawn species expected as a result of warmer seas.

Many practices that aim to minimise the stresses on the Reef coincide with practices that result in a more efficient and profitable business operation. The Fishing Industry Emissions Calculator is one example of a project that has been extremely popular in this area. "The logic was to get individuals to use the tool as part of a mitigation and adaptation program in which they could save fuel and reduce carbon emissions at the same time," says Mr Perez, who oversaw the development of the calculator in 2011. "It's been a great success because it has made such a concrete connection between good environmental practice and good business practice."

Communicating knowledge and information about the adaptation program to the wider industry is an ongoing challenge. The QSIA represents around 25 per cent of the Queensland fishing industry, and the receptiveness of members to the climate change initiatives varies enormously. Mr Tilton says it is an evolving process. Once the message is taken up by a few proactive people it will eventually flow through the rest of the industry.

Younger, newer members of the industry, who have recently made substantial outlays on boats and other infrastructure, are especially likely to be looking at the predictions for the next 20 years.

"These people can't afford to be thinking short term. They've got to be thinking about what we can expect under climate change and how they're going to adapt their business plans to cater for that," Mr Tilton says. □

Aquarium industry has clear vision for the future

A code of conduct evolves to incorporate climate contingency planning, and becomes an example of international best practice in the fishing industry.

PHOTO: PRO-VISION REEF

Lyle Squire Junior of Cairns Marine examines reef fish species collected on the Great Barrier Reef for display in aquariums across Australia and around the world.

Just over 10 years ago the Great Barrier Reef aquarium collection industry was on the brink of oblivion. There was widespread concern that collecting coral was not compatible with a World Heritage Area. Today, it is considered to be the most progressive fishing industry sector working on the Great Barrier Reef.

Pro-vision Reef is the industry association representing licensed collectors of fish and coral for display in aquariums. In 2009, the association produced a novel stewardship initiative to establish uniform standards across the industry, as well as a plan for how members should operate in the aftermath of natural catastrophes, such as coral bleaching, tropical cyclones and coastal flooding. This 'climate change contingency planning' was considered a world-first for a commercial fishery and led to a comprehensive vulnerability assessment for the industry being produced.

"This industry is engaging in world's best practice," says Randall Owens, the Great Barrier Reef Marine Park Authority (GBRMPA) manager of sustainable fishing. Ironically, it was Mr Owens who was initially charged with the task of closing down the industry. He changed direction after a technical report published by the CRC Reef Research Centre (and known as the Harriott Report) found that the fishery did not represent a risk to the integrity of the Reef system. It found that many in the collection industry were already practising in a way that supported the sustainability of the Reef.

"What the Harriott Report found was that they have incredibly professionally run operations and that they are very interested in the health of the Reef, because they know that if they don't have a resource, they won't have an industry in the future," Mr Owens says.

Ryan Donnelly is the strategic projects manager at Australia's largest aquarium specimen supplier, Cairns Marine, and the spokesman for Pro-vision Reef. He says that before the Harriott Report, the industry was poorly understood by the community.

"Coral was not exported from Australia back then but the market was changing and live coral was growing in popularity among home hobbyists," he says. "Like all commercial fisheries in Australia, we had new federal environment legislation that required our management arrangements to be assessed as a condition of granting export eligibility. Both the industry and the management of the fisheries needed to step up to the mark."

Australia's aquarium collection industry is a very small part of a huge global aquarium industry that is estimated to be worth US$15 billion. The marine aquarium sector, which requires more complex equipment and expertise than freshwater aquariums, represents about 10 per cent of the total trade by value but only about one per cent by volume of fish traded. With the development of more affordable, self-contained

home marine aquariums systems it is expected to be a growing industry.

The industry in Queensland has two parts. The marine aquarium fish fishery is limited to 42 licences and the coral fishery to 59 licences. Collectively, these licences are owned by about 30 businesses, ranging from micro-businesses operating a single vessel and keeping marine life in tanks under a house to multi-vessel businesses like Cairns Marine, which maintains a multi-million dollar, shore-based facility and employs about 30 staff, many of whom have relevant tertiary qualifications.

Competing with poorly regulated industries in Indonesia and the Philippines, which make up around three-quarters of the world market, the Australian industry has had to position itself in the market to reflect its higher cost base. Mr Donnelly says: "We cannot compete on price so we have to tell the story of a specimen's provenance and appeal to buyers who want to support sustainable fisheries. But the story has to be robust and defendable. It has to be a true story."

To tell the story, Pro-vision Reef developed the *Stewardship Action Plan: A Statement of Operational Standards and Climate Change Contingency Planning* (Stewardship Action Plan). The plan described the regulatory environment and the continuous improvement model to which all Australian commercial fisheries are subject. It also created a set of uniform standards that govern collection practices for the industry. "The Stewardship Action Plan started out as a code of conduct but grew into something much more with the inclusion of contingency planning for reef recovery after natural disturbance," says Mr Donnelly, who led production of the Plan.

"The climate change contingency planning enabled us to link the plan with recovery plans developed by the Great Barrier Reef Marine Park Authority (GBRMPA) and Fisheries Queensland – formalising collaboration between the managers and the managed. It's a platform that can be built upon substantially in the future."

The key component of the first edition of the plan is its stipulation of alternative collection practices while reefs recover after natural disturbance, including coral bleaching. It provides clear guidelines on how operators should interpret the extent of reef damage and how they should act. "It doesn't make sense to have anyone collecting off a site that's experiencing a high degree of stress," Mr Donnelly says. "We have to allow recovery to proceed without exacerbating the stress."

In some cases, Pro-vision Reef has opted for a complete moratorium on collection in heavily stressed areas. This was the case in Keppel Bay following severe flooding of the Fitzroy River catchment early in 2011. Flood waters carried tonnes of fresh water, sediment and nutrients into the bay, damaging coral reefs in nearshore areas. Given the extent of the damage, the organisation recommended a moratorium on collecting from the bay until surveys by Queensland Parks and Wildlife Service rangers and the GBRMPA decide that the affected areas are sufficiently recovered. It is now a year and a half since the floods, and operators are still continuing their moratorium on collection under the Plan.

"That was an example of the high levels of leadership in this particular industry," Mr Owens says. "No other industry has declared a voluntary moratorium on their fishing grounds as this industry did at Keppel Bay."

According to Mr Donnelly, that kind of stewardship not only makes sense for those in the industry but is also an important part of industry planning for the future, especially given the predicted effects of climate change.

"This is a very capital-intensive industry. It's not just about catching fish and handing them over at the shore then going home," he says. We've got a huge amount of onshore infrastructure to keep our fish alive and in good condition ready for distribution all over the world. We have an interest in ensuring that all that investment doesn't go to waste by keeping our resource, the Reef, in very good health."

There are many family businesses involved in the aquarium collection industry, some of whom have been in operation since the 1950s and 1960s. Their knowledge of the biology and geography of the Great Barrier Reef is astounding, Mr Donnelly says. "People enter the industry because they love diving on the Reef and because they love the rich tropical marine life." Some have complemented this passion with academic qualifications.

Aquarium collection divers spend about 150 days a year and six to eight hours a day diving on the Reef.

"They spend many times more hours in the water than do most marine scientists. That means they have an opportunity to collect an amazing amount of information about Reef condition and the distribution and abundance of many species of marine life."

That puts the aquarium collection industry at the front-line of monitoring the impact of climate change on the Reef, Mr Owens says. "The great thing about this industry is that it is small enough and cohesive enough to make the changes necessary to work out strategies to respond to any vulnerability to climate change. They want to be recognised as professional fishers with an eye to the future of both the Reef and their own industry." □

Trawl industry prepares itself for change

Adaptability has been a key trait of the fishing industry, and one that may be called on more than ever as the effects of a changing climate take hold.

"A bad day of fishing is still better than a good day at the office!" So goes the old joke. But it may not be so funny in future, as climate change affects fish populations and threatens the viability of the Great Barrier Reef's fishing industries.

Trawl operators, the hardy men and women who provide us with fish, prawns, bugs and scallops, have had some very bad days lately, caused by Tropical Cyclone Yasi and the Queensland floods. And there may well be more to come.

The Queensland East Coast Otter Trawl Fishery is the largest in Queensland, both in terms of the volume of product caught and the economic value of the product. Almost 70 per cent of the fishery's area lies within the Great Barrier Reef Marine Park, where 400 of the 450 operators are also based. They land about 6000 tonnes of product a year, with an estimated value of $80 million.

However, a recent report commissioned under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) found several aspects of the Queensland East Coast Otter Trawl Fishery's operation that may be vulnerable to climate change. Increased ocean temperatures and altered ocean circulation may send some species southwards, while the prospect of changing rainfall patterns, (and thus nutrient inputs), combined with floods, ocean acidification and more intense cyclones, will also present some challenges.

Collaborative approach

What can fishers do about it? Great Barrier Reef Marine Park Authority (GBRMPA) project manager Dr Rachel Pears says finding solutions should not depend on the fishery industry alone. "The GBRMPA is committed to helping local industries adapt, and we have launched a number of initiatives in the past few years to help the trawl fishery face its future challenges," she says.

Chief among those initiatives has been a series of adaptation planning workshops, supported under

the Action Plan. These were held during 2011–12, in collaboration with the Queensland Seafood Industry Association (QSIA), the Department of Agriculture, Fisheries and Forestry Queensland (DAFF) , Queensland's Climate Change Centre of Excellence and other organisations. The workshops used a structured process called the Climate Change Risk Management Matrix to help identify the impacts, adaptive responses, risks and vulnerabilities associated with climate change.

The idea was to put managers, scientists and industry representatives in the same room as trawl operators, processors and marketers, to talk about what is known about climate change and what its consequences for the industry could be. Crucially, the discussions focused not just on long-term scientific theory, but also on day-to-day business practice. How many dollars will be made in a night's fishing two decades from now? What will the average total catch be in a year?

The workshops "were my awakening", said the QSIA's former trawl-fishing president, Geoff Tilton. "I went there probably with an empty head about climate change, (but) came away thinking you better put your thinking cap on here, this is not just a debate between people in the media … Let's have a look at some of the science, let's talk about some of the impacts, let's think about some of the things that are going to, or could possibly be going to, happen."

Dr Pears says it would have been difficult in past years to imagine trawl industry members sitting down together with managers and scientists for discussions about climate change. The trawl fishery has faced a number of challenges of late and the possible implications of long-term weather patterns haven't topped the list.

Dr Paul Marshall, the GBRMPA's director of climate change, suggests that recent extreme weather events may have helped generate this change of heart. Things like floods and cyclones, he says, "give a 'face' to climate-related risks, and help people to visualise what some of the impacts might mean for them. If they're not able to visualise the risk, they're not going to be able to visualise their response and adaptation."

Whatever the cause, Dr Pears reports that many trawl industry members have been embracing the opportunity for dialogue – and enjoying the fact that it goes both ways. The workshops are designed as a collaborative process, where different viewpoints can be freely aired. That includes learning about the approaches many fishers and businesses are already taking to deal with current challenges and ways they have coped or adapted in the past.

DAFF trawl fishery manager Eddie Jebreen agrees that the workshops have been a great opportunity for managers and fishers to talk about the ecological processes that underpin the fishery, and explore the relationship between the environment and their businesses. Other participants have added there is a definite need to stand back from day-to-day activities and consider how climate change may influence their lives.

Search for solutions

The workshops have focused on finding solutions as well as understanding the problem. Modernising the fishing fleet was identified as a priority, to better meet changing consumer preferences and marketing opportunities and – importantly – to reduce running costs. Increasing fuel efficiency and moving to a leaner fleet structure would make economic and environmental sense, as would tactics like fishing more co-operatively, and improving onboard product handling and storage.

These sorts of solutions reflected the tone of the workshops, which were very much about how trawl operators could take care of their bank balances, as well as take care of the planet. "We definitely recognise that when fishing businesses are viable and doing well, they have more capacity to protect the marine environment and try to minimise their environmental footprint," Dr Pears says.

Some of the potential strategies discussed included more collaboration among fleet members, diversifying income streams, and developing more forward-looking business strategies to take climate change and extreme weather events into account. A greater sharing of resources, it was suggested, could also help to maximise collective buying power.

Participants were also keen on a more flexible fisheries management policy framework – one that would be better able to track changes in circumstances, both ecological and economic. More flexible season opening and closing dates, for example, could help trawl operators sustain stocks and maximise their profits as well.

Real-time fisheries data collection could help support these more flexible arrangements, as it would mean up-to-date information was always at hand. Fishers are out on the ocean much more often than managers and scientists can be and some trawl operators have offered to record their observations of marine life and note down changes in the sea's temperature, salinity and acidity. Such records could be used as an early warning system and to help understand the rate of change. "Fishers can greatly assist scientists and managers and, in turn, their industry," Dr Pears says.

"Even before climate change raised its head as an issue, the trawl industry itself has demonstrated its capacity to develop innovative solutions and embrace change over the years," she says. "Many fishers have already taken steps, such as improvements to their boats and fishing gear, that will help them to be better prepared for current and future challenges, such as increasing energy costs."

"The science tells us changes are coming," Mr Tilton says. "While we may not be able to completely understand them now, it makes sense to prepare our businesses. And we can be good stewards of the marine environment at the same time." □

Traditional knowledge informing climate adaptation

Traditional Owners are concerned about the effects of climate change on their 'sea country' and are working with researchers and managers to exchange information and identify adaptation options that will help protect their cultural resources and heritage sites.

The close connection with their land – and sea country – means the Great Barrier Reef region's Traditional Owners are among the first to recognise the effects of climate change.

The Great Barrier Reef Marine Park Authority (GBRMPA) has been working closely with Traditional Owner groups to provide information about climate change, and to help them incorporate it into their thinking, planning and management of sea country.

This integration of Indigenous and scientific knowledge has been formally incorporated within the Traditional Use of Marine Resources Agreement (TUMRA) of the Wuthathi Traditional Owners group. The agreement incorporates climate change as a key priority.

TUMRAs are formal agreements that describe how Traditional Owner groups work with each other and with government to manage Traditional Use activities in the sea country. The GBRMPA has helped the Wuthathi people develop their TUMRA, which has provided an opportunity to share current scientific information on issues such as the status of seagrass beds and turtle and dugong populations.

Wuthathi sea country is in the northern part of Cape York between the Olive River in the north and Captain Billy Landing in the south, which includes Home Island and Raine Island, an important nesting site for green turtles and seabirds. With guidance under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), the Wuthathi TUMRA became the first to identify climate change as an issue. The TUMRA's climate change strategy will focus on minimising human impacts within Wuthathi sea country.

Further south, the Nywaigi and Girramay Traditional Owner groups are already taking part in a several climate-related initiatives. Following Tropical Cyclone (TC) Yasi and the extreme weather events over the 2010–11 summer, both groups voluntarily suspended hunting of sea turtles and dugongs in their sea

PHOTO: LARISSA HALE

Yuku-Baja-Muliku rangers undertake turtle monitoring.

country, off Ingham and Cardwell.

The Nywaigi and Girramay Traditional Owners are two of six saltwater groups represented by the Girringun Aboriginal Corporation, which was the first organisation to implement a TUMRA. Nywaigi Traditional Owner and CEO of Girringun Aboriginal Corporation Phil Rist said the suspension aimed to ensure the long-term sustainability of the two species.

"We share the community's concern about these species," he said, in announcing the suspension. "Our decision to temporarily suspend hunting in our sea country is our own way of directly supporting the Great Barrier Reef that has been important to our people for over 60,000 years."

The GBRMPA Indigenous partnerships group director Liz Wren said the decision was carried out under the TUMRA framework, recognising the stress turtle and dugong populations were suffering following TC Yasi.

"The hunting suspension was one of several actions the groups implemented to protect these iconic animals, which were affected by extreme weather and seagrass die-off. The suspension also represents a specific adaptive response to climate change," she says.

Girringun Rangers are taking part in a project with James Cook University (JCU) researchers, satellite-tracking five green turtles in the Cardwell region of the Great Barrier Reef. The aim is to identify changes in behaviour patterns after TC Yasi and flooding in the region compromised food sources for this species.

The GBRMPA species conservation expert Dr Mark Read says this work is helping scientists understand how green turtles use their habitat and the results from this research will help managers identify actions to protect turtle populations from additional stress.

"By working with the Girringun Rangers and researchers from JCU we will be able to combine traditional knowledge with scientific information to analyse the effectiveness of current management strategies and possibly improve them further," he says.

Project leader Dr Mark Hamann, from JCU's School of Earth and Environmental Sciences, says it is important to understand more about how turtles responded to cumulative impacts such as loss of food, habitat degradation and increased air temperatures.

"This current situation is unprecedented. We need to see how turtles react to this so we can prepare for similar conditions in coming wet seasons," he says. "We know the loss of seagrass is impacting coastal green turtle populations, with unusually high numbers of deaths. We now need to know how the remaining turtles are responding to these conditions."

In a separate initiative, the Girringun Aboriginal Corporation has undertaken coastal surveys to identify the impact of the TC Yasi event on cultural heritage sites. Some previously mapped sites have been lost, while new sites, previously covered by sand deposits, have emerged. □

Ripples of change gather momentum for Reef Guardians

From school children to the farming and fishing industries, the Reef Guardian program is helping introduce practical actions to protect the Great Barrier Reef for future generations.

The Reef Guardian Farmers and Graziers program promotes environmental best practice and recognises the efforts of leading farmers and graziers in adopting more sustainable practices.

Over 110,000 students across Queensland are involved in the Reef Guardian Schools program.

Turning the tide, one ripple at a time – that's the thinking that guides more than 110,000 students across Queensland in building anything from worm farms to veggie patches and permaculture gardens.

The school activities are part of the Great Barrier Reef Marine Park Authority's (GBRMPA) highly successful and wide-reaching Reef Guardians stewardship program, aiming to help turn – or at least stem – the tide on the degradation of the Great Barrier Reef.

The Reef Guardian program was launched in 2003 with Reef Guardian Schools to guide everyday actions and decisions in a way that will have long-term environmental benefits for the Reef. These include initiatives to reduce greenhouse gas emissions as part of general efforts to address climate change, as well as initiatives with Reef-specific benefits such as wetland restoration.

The Reef Guardian Schools annual awards – Ripples of Change – provides more than 30 schools with the capacity to receive either a $1000 award, or access to $500 for specific projects to improve school sustainability and reduce human pressures on the Reef. Funding for the awards has been provided through the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan).

The GBRMPA's Reef Guardians director Karen Vohland says the impact of the awards, and the Reef Guardian Schools program, goes far beyond the school gate. "Through this program, we're raising awareness by encouraging practical projects and actions – everything from compost bins to mangrove clean-ups and sustainable fishing events," Ms Vohland says. "The messages that students hear through the development of these projects invariably end up being repeated at home and elsewhere. That's why we're confident there's a ripple effect at work."

While the projects may be local, they underpin a wider discussion with students about the global issue of

climate change. To support teachers in their communications with students, the GBRMPA dedicated its annual educational resource called 'Reef Beat' to the theme of climate change and its impacts on the Great Barrier Reef.

The topic was selected in response to a lack of educational material on the subject. By the end of 2009, more than 1700 Reef Beat kits had been distributed. The kits include multimedia resources such as climate change animations, short movies and a teacher presentation. The Reef Beat activities book has changed from printed material to a DVD, in keeping with efforts to reduce paper-based products.

While touching on subjects such as coral bleaching, ocean acidification, water quality, and impacts on coral reefs, the Reef Beat climate change edition sought to drive home a message of stewardship by answering the key question of 'what can you do?'.

Ms Vohland said a survey at the completion of the project canvassed students and teachers. "The feedback showed the kit was regarded as an excellent resource and well-targeted to a young audience," she said. "The material also fitted in well with the school curriculum where climate change is gaining increasing prominence as a theme."

Now in its tenth year, the Reef Guardian Schools program involves more than 285 schools and 111,000 students. While the program was initially aimed at instilling a sense of stewardship in younger generations, it has also sought to achieve a broader understanding among local councils of how climate change impacts can be minimised.

Reef Guardian School students work on permaculture gardens to benefit the Great Barrier Reef and reduce global greenhouse gas emissions.

Effective protection and management of the Reef requires coordinated efforts from all levels of government, industry and communities, and all local councils with links to the Great Barrier Reef Marine Park have become members of the Reef Guardian Council program.

Substantial changes to the Reef's condition as a result of climate change will have serious implications for local government as the viability of certain industries will be affected. Under the Action Plan, the GBRMPA developed a Reef Guardian Council Climate Change Module in 2008 to strengthen the capacity of local councils to build resilience in coastal and marine areas.

By detailing priority actions such as vulnerability assessments, planning schemes, building designs, public places, stormwater management and biodiversity conservation polices, the module provides a comprehensive suite of best practice measures to help local government mitigate the effects of, and adapt to, climate change.

The result has been a more coordinated approach, as well as a heightened awareness of the potentially serious economic and social disruptions that climate change could have on local communities.

Mayor of Cassowary Coast Regional Council Bill Shannon sees the Reef Guardian program as a win for council and for the environment. "With pressures on the Reef such as climate change, to have something as valuable as the Great Barrier Reef on our doorstep it's imperative that everything is done to ensure that this asset is not lost," he says.

The program has recently expanded to incorporate Reef Guardian Farmers and Graziers, and Reef Guardian Fishers. It both promotes environmental best practice in these industries and recognises the efforts of leading farmers and fishers in adopting more sustainable practices.

Innisfail banana grower Brett Gaia says he was prompted to become part of the Reef Guardian program for the opportunity to show the wider community some of the initiatives he, and others in his industry, were already implementing in an effort to improve practices and promote water quality in the Great Barrier Reef.

"It's important that we all work together to protect the Great Barrier Reef, to sustain the wonderful environment that we have here and the ability to live the lifestyle we have. Using the Reef and the water is a big part of our life here," he says. □

PHOTO: FITZROY BASIN ASSOCIATION

Stewardship in action: members of the Nine Mile Beach Club held a clean-up day to remove marine debris that washes up along the the Byfield National Park and Great Barrier Reef. Marine debris on Nine Mile Beach is mostly made up of plastic with both local and global origins.

Stewardship a collage of community effort

Small actions taken by many individuals can make a great difference to the future of the Reef.

Local community action is key to building the Great Barrier Reef's resilience to the effects of climate change. In the face of mounting pressures, stewardship may be the saviour of the Reef.

Dr Bill Carter, from the University of the Sunshine Coast, has been investigating the stewardship potential of coastal communities. He says only so much can be achieved through laws and regulations.

"The long-term protection of the Reef requires the community to take responsibility for its protection. But protection of the Reef can't be left solely to an organisation such as the Great Barrier Reef Marine Park Authority (GBRMPA). Its resources are limited. It can contribute to it, help lead it and support it. But the real hands-on effort must come from the users of the Reef," he says.

The GBRMPA's manager for adaptation partnerships, Dr Chloe Schäuble, says the research by Dr Carter and colleagues is one of a range of stewardship projects supported by the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan). Another project is a snapshot of stewardship in action in the Fitzroy Basin.

"Stewardship is important in having people who use the Reef help look after it and keep it as resilient as possible," Dr Schäuble says. "That need was always there, but it's even more important now because climate change is creating an extra layer of pressure on everything.

"There are many people in the community doing things, and sometimes they aren't aware of how their individual efforts contribute to the larger picture of Reef stewardship. The snapshot project, in particular, is about raising awareness about what is being done and how it helps to improve the Reef's resilience."

Dr Schäuble says there are three elements to stewardship for the Reef. First is improving the Reef's resilience. This might include restoring wetlands, which act as nursery grounds for some reef species and filter excess nutrients and sediments from water flowing into the Reef.

The second is reducing carbon emissions, which can help slow climate change, giving the Reef more time to adapt.

The third element is adaptation by both communities and ecosystems. Examples include moving Reef tours to alternative sites when extreme weather or coral bleaching put primary locations out of action, and commercial fishers switching species or locations.

A community snapshot

The Fitzroy Basin Association (FBA) is the peak natural resource management group on the Capricorn Coast, which takes in about 150 kilometres of coastline around

Rockhampton. FBA communications manager Jody McDonald says the association has worked in conjunction with the GBRMPA to identify what was being done in the basin and to recognise the efforts of those involved.

"In 2011, we called for people to participate in the snapshot project and 51 community groups and schools were interviewed about their activities," she says. "We documented 71 activities that were either directly related to climate change or to improving the health and resilience of the Reef."

Recycling was a common activity, particularly for schools, with many participants making the link between reduced landfill, reduced emissions and preventing pollution of local waterways, beaches and the Reef. Other initiatives included litter collection campaigns, habitat restoration, education and skill development, and monitoring programs.

Participants ranged from schools to conservation and landcare groups, recreational clubs, local and state governments, and non-government organisations.

A DVD created as part of the project tells the story of five projects as examples of what community members are doing. It shows how even simple actions can help protect the Reef.

Ms McDonald says some of the important messages to come from the project are:

- good things are being done in the community
- actions that support the Reef are not necessarily new, complicated or difficult
- all kinds of people and organisations take part
- there is more to be done and it's easy to lend a hand
- many small actions can add up and make a big difference.

"The snapshot is really a story about the power of volunteers. For FBA, it affirmed the value of supporting grassroots community groups and offering training and development opportunities," she says. "We're also hoping to generate enthusiasm for volunteerism in young people by showcasing the video in our FLOW Visitor Centre, which has regular visits by school groups."

> "Individual efforts contribute to the larger picture of Reef stewardship."
> *Dr Chloe Schäuble*

Dr Schäuble says each individual or group effort might seem relatively small. "But, when you look across the landscape and see that there are many and varied efforts going on, you realise together these add up to something really significant. The Fitzroy Basin community on the Capricorn Coast is a great example, as demonstrated in the DVD.

"We, and others, are helping people develop the knowledge and skills to be proactive in future marine stewardship activities," she says.

Stewardship skills

The research from the University of the Sunshine Coast found a need for good information and specific solutions.

In 2010, 53 community representatives were surveyed about climate change messages and actions.

Participants were asked about the stewardship skills and potential of their own communities, as well as potential barriers to stewardship, and opportunities to improve stewardship activities.

Dr Carter says stakeholders considered themselves reasonably well-informed on climate change issues and there was a strong sense of stewardship among them. However, many were quite concerned about climate change generally at a community level. Almost a third were uncertain about how vulnerable their businesses were to the impact of climate change on marine resources and on their livelihood. Some participants were also confused by mixed messages on climate change.

A lack of trust between community and government organisations (in general) was commonly seen as a barrier to stewardship. Some respondents considered this the result of a poor flow of information that could motivate communities to take stewardship action or a need for greater leadership.

Dr Carter says the research has highlighted the need to move away from "consultation just for the sake of it" to a more meaningful inclusion of different views, a process that can help build trust.

"Science is one source of information, but there are also people who have been living and working on the Reef for many decades, including Indigenous people. It is important to recognise the validity of other sources of information. There is a lot of hope and faith and trust wrapped up in effective stewardship," he says.

Providing stakeholder-specific information on the impacts of climate change could help build stewardship programs. Generic information, lacking in details and specifics, was unlikely to encourage attitudinal and behavioural change.

The research identified the following elements as important for successful stewardship:

- **practical and strong leadership from key organisations and individuals**
- **good information flows through community networks and communication channels to foster action**
- **acknowledging that individual, group, and/or community action is essential for the realisation of stewardship potential**
- **a coordinated and unified approach to engaging the community, industry and government to build trust and connectivity.**

Overall, the community and the GBRMPA have learned a lot about what makes stewardship work, and its importance to the Reef's future. In the context of climate change, collaborations that span community groups and connect top-down and bottom-up efforts are key to success. □

Reducing climate footprints: Inspiring action

The desire to protect the Great Barrier Reef is motivating communities, businesses and policy makers to take action on climate change.

Living on the edge can be exciting, but climate change has made it a dangerous place for coral reefs. Corals live close to their temperature thresholds; even small increases in sea temperature can cause major problems. They turn stark white when heat-stressed, and can die if bleached for too long.

Vast areas of the world's coral reefs have shown what we can expect with global warming. In the past two decades, coral bleaching events have affected reefs across the globe and led to mass die-off of corals. The vulnerability of corals has earned them the role of 'canary in the coalmine' for climate change. Coral bleaching provides a dire warning of the scale and severity of impacts ahead.

Our own Great Barrier Reef could be one of the early victims of climate change if we fail to take effective action. The threat of climate change dominates the outlook for almost every aspect of Reef health.

Promoting action on greenhouse gas emissions has been an important focus for the Great Barrier Reef Marine Park Authority (GBRMPA) under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan). Work is required at all scales – from local to global – to prevent greenhouse gases reaching levels that lead to the devastation of coral reefs.

Supporting local action

Through the Action Plan we have supported a range of community-based activities to help individuals, households and businesses reduce greenhouse gas emissions. Participants in the Reef Guardian Schools program have benefited from new information modules, teaching activities and funding support for innovative education initiatives. Leading Reef Guardian schools have been developing environmental management systems that identify ways of reducing emissions.

Schools participating in the Holloway's Beach Environmental Education Centre's Energy Wise Schools program, have shown great commitment to environmental stewardship, reducing their electricity usage by up to 33 per cent.

We have also produced a range of information products that explain key concepts and issues relating to climate change and the Reef. We

have worked with Ergon Energy's powersavvy program to develop Reef-relevant information on energy efficiency and climate change, produced fact sheets and posters on climate change, and developed a suite of online animations that help non-scientists understand coral bleaching, ocean acidification and the implications of climate change for the Reef.

Reef destinations show the way

For decades, the Great Barrier Reef has been a leading destination for environmentally sustainable tourism. It is now also being recognised as a showcase for its climate-friendly tourism offerings and destinations. Through partnerships under the Action Plan, many tourism operators have reduced their energy use, adopted renewable or low-emission fuels and implemented climate change education programs to gain Climate Action Certification.

Business owners and managers have embraced these opportunities to lead the way in reducing climate footprints, demonstrating their commitment to good Reef stewardship and gaining a market advantage.

Coral cays are an iconic part of the Great Barrier Reef, and two of these islands have become shining lights in climate change action.

Low Isles, off Port Douglas in the north of the Reef, is the site of historic buildings that are now the hub of public interpretation and caretaker facilities to service crowds of visitors each day. Through support under the Action Plan, these facilities are now climate neutral and the focus of an education trail that highlights the issues – and solutions – relating to climate change.

At the southern end of the Reef is Lady Elliot Island, home to an internationally acclaimed eco-resort. The resort has invested in a range of measures that have seen a dramatic decrease in its climate footprint. Driven by an ethos of stewardship, the resort's emission reductions have also made good business sense, showing that tourism and the Reef can co-exist even in the face of climate change.

Putting the Reef into climate policy

Under the Action Plan, we have had a strong focus on ensuring a sound scientific basis to climate change education and awareness programs. We have combined this with its knowledge of the policy and decision-making processes to provide information that can be readily and credibly used in media articles, public debate and policy negotiations.

A key indication of the value of these efforts is the frequency with which the Great Barrier Reef's fate is used in national and international debates about greenhouse gas emissions reduction policies. The threat to the Reef from climate change was a recurrent thread in the parliamentary debate that led to the adoption of an Emissions Trading Scheme in Australia, and the risks to the Reef have become a frequent reference in national policy documents relating to climate change.

Linking carbon offsets with Reef resilience

A reality of modern living is that emissions can only be reduced so far. Beyond that point, households and businesses look for carbon offsets to compensate for the greenhouse gases that they emit.

Responding to a call from Reef tourism operators and other businesses, we have developed a system to certify carbon offset projects that provide specific benefits to the Reef, such as reforestation of streamside habitats in Reef catchments.

With the advent of the national Carbon Farming Initiative and associated programs supporting the Australian Government's carbon policy, the Reef-friendly Carbon Offset accreditation scheme is a step closer to implementation.

Leading by example

When it comes to reducing emissions, it is important that the GBRMPA 'walks the talk'. In the past five years, we have reduced its energy use, waste and overall emissions through an audit of our operations, and the introduction of an environmental management system and a greenhouse gas reduction strategy.

Our major educational facility, Reef HQ Aquarium, is now a best-practice example of how a big energy user can have a small climate footprint, with innovative pump and water management systems, energy efficient displays, and one of the largest photovoltaic systems of its kind in Australia.

The stories that follow profile these and other steps we have taken with our Action Plan partners to reduce climate footprints and help protect the Reef's vulnerable ecosystem from climate change. □

Clear message supports call to action

Having a message to share is one thing – getting that message heard is quite another.

The clamour around climate change in the public sphere has been rising and falling with the political tides for more than a decade: Is it real? Who's to blame? What do we do now?

The 'climate change market place' has become crowded, according to Karen Vohland, who leads the stakeholder engagement and stewardship activities for the Great Barrier Reef Marine Park Authority (GBRMPA) through its regional engagement and Reef Guardians program.

Ms Vohland has been involved in the communication efforts since the early stages of the GBRMPA's climate change initiative. She says that, despite the clear scientific consensus on climate change, messages in the media are often mixed and confusing for the public. That's why it has been a priority for the GBRMPA to develop clear and consistent messages in its climate change communication strategies.

"Our message has always been that climate change is real, that it is having an impact on the Great Barrier Reef, and that you can do something about it," Ms Vohland says.

It's a simple message that has been delivered many times during the past five years, through fact sheets, brochures, fridge magnets, posters, art competitions, advertising, community events and advisory group meetings, as well as animations and short documentary-style features on YouTube and signage on walking trails.

The GBRMPA's message is being heard. It is also being taken up and amplified by other groups and individuals who have recognised that they too have a stake in the future of the Reef.

Doon McColl is a member of the GBRMPA's regional stakeholder engagement team, based in Cairns. As part of the activities supported through the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), she often attends festivals and other community events to talk about climate change and the positive things people can do to help.

"Face-to-face contact is really important and reaches people who might otherwise be tempted to turn off when they hear the words 'climate change'," she says.

"A lot of these community events are a group of stakeholders getting together, and often they're selling the same message. That's powerful. People realise that all these different groups – the GBRMPA, the local school, the local council – are all saying the same thing, they're all aligned.

"I think it helps to shift people's compass of beliefs when they see that."

This alignment of messages has taken time to develop, as has the broad range of climate change information resources now available. Ms McColl says when she first began working with the GBRMPA in 2006, climate related information amounted to two fact sheets: one on climate change and one on coral bleaching.

The resources available today are far more comprehensive and have been packaged and delivered in a variety of ways to suit specific audiences, often complementing existing engagement programs such

The GBRMPA has developed clear and consistent messages in its climate change communication strategies.

as the Reef Guardians.

Many schools and local councils in the Great Barrier Reef coastal catchment have joined with the GBRMPA to become Reef Guardians, actively promoting stewardship of the Reef within their communities. More than 285 schools in the Reef region, with more than 110,000 students, are registered with the Reef Guardian Schools program. Other schools may be using the relevant materials without having registered, particularly as a wide range of information is available online through the GBRMPA website and YouTube channel.

The Reef Beat poster series developed for schools has been well received in Queensland and further afield – even making its way overseas. The posters highlight a range of environmental impacts, including climate change, and actions that can be taken to address them. Ms McColl said the posters regularly appear in public spaces within the broader community. There's even a restaurant in Port Douglas that uses them as placemats.

The GBRMPA's Action Plan work has helped update older initiatives, such as the interpretative nature trail walk at Port Douglas. The trail and signage was developed in the 1990s. Ms McColl says new signage has added climate change information, including actions that people can take when they go home.

The GBRMPA regularly surveys consumers to monitor community recognition of its message. Ms Vohland says a survey after an advertising campaign about the Reef Guardian program in 2011 showed that climate change was well recognised as one of the top three threats to the Great Barrier Reef.

However, she says mixed messages in the media have created confusion and anxiety in the community. As a result, she says there's been a "slight shift" in the language used to talk about climate change, to provide a more forward-looking, action-based focus. "Now we speak with our stakeholders about the 'impacts of a changing climate', and leave people to determine the genesis of change for themselves," she says.

"I'm sure some people think that climate change will be here when they wake up and the sky is purple. But it's not like that. Climate change is a slow, insidious creep, in many ways."

Extreme weather events may be the exception to this. Ms Vohland says the major cyclones that have hit the Queensland coast in recent years have provided a strong link for the GBRMPA's climate change message.

"Even for those who relate more to climate variability, as opposed to climate change, it's an indication that 'normal' is changing, and that people will have to do things differently. The impacts – whether it is extreme weather events, or sea level rise, or something else – are what we have to deal with," she says.

Specific engagement programs have been developed for Reef-dependent industries such as tourism operators and the fishing industry, working through peak industry bodies, which are now helping to spread the GBRMPA's climate change message. Chief among these partner bodies are the Association of Marine Park Tourism Operators and Queensland Seafood Industry Association.

Ms Vohland says that when industry helps deliver a message in a way that resonates with its members, the message gains more traction.

"We might say that the Reef needs some help because that's our job. But when an industry body is saying it, and then joins the discussion about what to do, that's really important. The approach to the communication is as important as having the right messages and the right materials available." □

Energy-smart islands reduce climate footprint

Energy makeovers at Lady Elliot Island and the Low Isles have led to dramatic reduction in greenhouse gas emissions for these two Commonwealth islands.

Lady Elliot Island and the two tiny Low Isles, located at opposite ends of the Great Barrier Reef Marine Park, have been the focus of efforts to reduce greenhouse gas emissions.

Lower fuel consumption, increased use of solar power, improved waste management and better energy efficiency are just some of the measures being taken toward making these islands carbon neutral.

Lady Elliot Island (in the south) and Low Isles (off the coast of Port Douglas) are important for environmental, historical, tourism and cultural reasons. More than 80,000 people visit the islands each year.

They are among Australia's 70 Commonwealth islands – islands with lighthouses that were once operated by the early colonies, but were turned over to Commonwealth governance in 1915 to ensure consistent management of sea passages and navigation in Australian waters. Since 1988, 21 of the Commonwealth islands have been managed by the Great Barrier Reef Marine Park Authority (GBRMPA), with some sections leased to private operators for research and tourism.

All Great Barrier Reef islands, both Commonwealth and privately-owned, are vulnerable to the effects of climate change – rising sea levels, more frequent severe weather events, ocean acidification and rising sea and air temperatures.

The adaptation measures at Lady Elliot Island and Low Isles have come about as part of activities under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan). The sustainable energy initiatives are being showcased to tourism operators, Reef communities and policymakers as examples of best-practice management for carbon emission reduction.

Lady Elliot Island Eco Resort is leading the way when it comes to climate-friendly resorts in the Great Barrier Reef. The 40-hectare island, shows how reducing climate footprints makes good business sense.

"We are very proud of what we have been able to achieve on our beautiful little island," says Peter Gash from the Lady Elliot Island Eco Resort. "In consultation with the managers of the Great Barrier Reef Marine Park, we have taken huge steps forward in reducing our emissions, decreasing energy use, saving money and increasing our appeal as a destination."

The Low Isles lie 15 kilometres off Port Douglas, the departure point for about 60,000 day-trippers each year. The two small islands are part of a two-hectare coral cay, surrounded by about 22 hectares of reef. The larger of the islands has a lighthouse and small scientific research station.

Both Lady Elliot Island and Low Isles adaptation measures were instigated by an energy audit in 2007,

which found scope for reducing energy by up to 35 per cent at Lady Elliot Island and 40 per cent at Low Isles. The island caretakers implemented the suggested measures over two years.

With the GBRMPA's support and encouragement, Lady Elliot Island's resort management conducted a follow-up audit to determine how their management strategies had improved energy efficiency and to suggest further improvements. The resort has continued to reduce energy use and has introduced steps to reduce reliance on diesel-generated electricity. It has also minimised the risk associated with large volumes of bulk diesel fuel being stored on a pristine coral cay.

Trail signage highlights island vulnerability

An important part of the 'green' makeover of the two islands includes raising awareness of the vulnerability of the islands and their communities to the effects of climate change. The combination of climate change risk and related actions to address risk effectively make the islands ideal 'climate change classrooms'.

A climate change walking trail, supported through the Action Plan, informs visitors to Lady Elliot Island. "It's the first such trail on a Commonwealth island in the Great Barrier Reef," the GBRMPA project manager Anna Lyons says. "The interpretive signage highlights mitigation activities that help protect these fragile ecosystems."

On Low Isles, an existing walking trail has been refreshed with new signs that contain climate change material relevant to each island. Visitors now learn about the environmental and cultural value of island features (including the historic Low Isles lighthouse) and associated climate change considerations.

"The signage projects at Lady Elliot Island and Low Isles have helped us to showcase examples of best-practice island management, communicate the vulnerability of islands and motivate visitors and locals alike to take action on climate change." Ms Lyons says. □

PHOTO: LADY ELLIOT ISLAND ECO RESORT

Peter Gash from the Lady Elliot Island Eco Resort, with the solar panel array that helps power resort facilities on the island.

Less fuel and reduced energy consumption define GBRMPA's smart islands: the facts

Lady Elliot Island

- 32 per cent overall energy reduction due to energy-saving initiatives since the 2007 energy audit, with further improvements continually being made.
- Almost 70 per cent reduction in fuel consumption following installation of the solar-diesel generator hybrid power system .
- More efficient production of fresh water from the island's desalination plant, now fitted with improved membranes.
- Utilities and equipment on the island have been changed and practices have been modified and adapted to increase energy efficiency.
- Timers installed on fridges and cool rooms enable them to shut off at night. Aged equipment including air-conditioners, light globes and ovens have been replaced by newer, more efficient models. The hot water system now runs on gas.
- Staff and guests are encouraged to adopt energy efficient practices, such as turning off fridges in rooms if not required and minimising the use of clothes dryers.

Low Isles

- Nearly 40 per cent reduction in energy consumption since energy audit in 2007.
- Only 374 kilogram CO_2 equivalent was produced from energy use in 2008–09 (equivalent to 17 days of energy use by the average Queensland household).
- 100 per cent solar-powered operation of Low Isles facilities under most operating conditions, with local biofuels used for generators to 'top up' energy supplies if needed.
- Upgraded sewerage treatment system with more energy efficient equipment and parts, and day-time only operation.

Calculators help cut costs and carbon emissions

Partnerships with industry are producing practical ways for businesses to address climate change.

Simple-to-use, online greenhouse gas emission calculators are proving a popular tool for tourism operators and fishers on the Great Barrier Reef, helping to improve their businesses and combat climate change.

The calculators provide a practical approach to cutting costs and working out 'climate footprints'. Under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan), the Great Barrier Reef Marine Park Authority (GBRMPA) has worked closely with both sectors to develop calculators that address the specific needs of the marine tourism and fishing businesses operating on the Reef.

The Tourism Operator's Emissions Calculator was developed in 2008, and the Queensland Seafood Industry Association (QSIA) Emissions Calculator for fishers followed in 2009. Both calculators have been supported under the Action Plan.

The GBRMPA's director of tourism and recreation Chris Briggs says the web-based calculators take operators through the process step-by-step, itemising the greenhouse gases produced each year by different components of their businesses. They look at both consumption and waste production.

The calculators provide suggestions for immediate action and advice on longer-term planning, such as operational and financial strategies to gradually improve business efficiency and boost profits.

Both versions address business risks, such as rising energy costs and a growth in the number of days that severe weather will prevent access to Great Barrier Reef each year. Industry-specific risks include the tightening of international tourists' budgets and, for fishers, competition from imported seafoods.

Working with the GBRMPA as a project manager, Margie Atkinson helped develop the emissions calculators in conjunction with industry groups. She says the project has helped develop relationships with business operators as well as raising awareness about climate change and its impacts. "Partnering in this way has helped increase understanding of our common interests," she says.

Fuel use is one of the major contributors to greenhouse gas emissions for marine operators. Karen Collard, co-owner of a Townsville prawn trawling business, says it is the single biggest consumable in her business. "If we can cut down on that, we're going to be more profitable and kinder to the environment in which we operate," she says.

The QSIA calculator identifies opportunities to do this, including well-planned travel and regular vessel maintenance. Vessel design also influences fuel consumption. Some operators have moved to alternative fuel blends or hybrid systems for vessels and vehicles, and also updated basic equipment, such as propellers.

Both the tourism and the fishing calculators recommend continuous self-auditing and the ongoing reduction of pollutants where possible to mitigate long-term risk to biodiversity and to improve sustainable business practices.

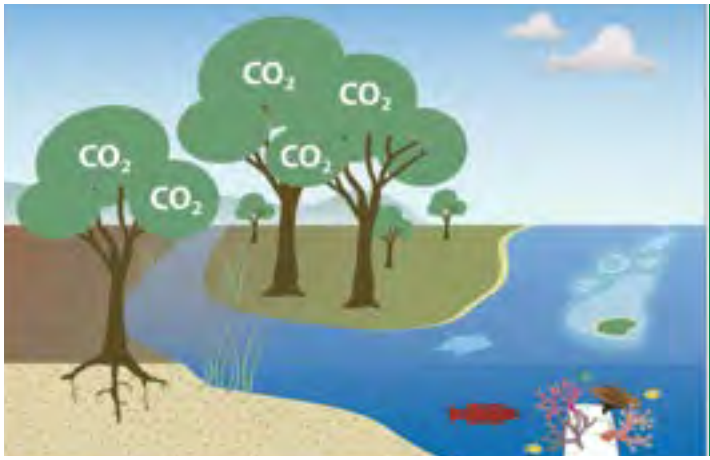
They also encourage businesses to invest a portion of their profits in carbon offset initiatives, particularly initiatives that provide specific benefits to the environment in the Great Barrier Reef region. The highest achievement is to become emission 'neutral' by balancing recognised or accredited offsets against emissions.

Steve Edmondson operates Low Isles Sailaway, offering catamaran cruises out of Port Douglas. He says that although the business has only a small carbon footprint, he wanted to invest in offsets as part of a commitment to environmental best practice in the Great Barrier Reef Marine Park. To do this, the business invested in the Eco Shamba Tree Farm. The tree farm is being reforested as permanent rainforest on former cane farming land adjacent the World Heritage National Park in the Port Douglas region.

Low Isles Sailaway has achieved Climate Action Leader status as part of the Climate Action Certification program developed by Ecotourism Australia in collaboration with the GBRMPA and the South Australian Tourism Commission. Mr Edmondson says the certification generates interest among customers and provides an opportunity to increase their awareness of the challenges to our fragile ecosystems while they enjoy their holiday. □

More information:
Tourism Operator's Emissions Calculator: **www.emissionscalculator.gbrmpa.gov.au**
QSIA Emissions Calculator: **www.emissionscalculator.qsia.com.au**

Reef water quality the target of carbon offset program



A new initiative by the GBRMPA will provide consumers with a new way to identify carbon offsets that will benefit the local environment and generate a net benefit for the Great Barrier Reef.

Acting locally on climate change could soon include investing in certified 'Reef-friendly' carbon storage projects that support the resilience of the Great Barrier Reef.

The development of a Reef-friendly carbon offset program will help businesses reduce their carbon footprint, while providing specific benefits for the Great Barrier Reef.

The Reef-friendly Carbon Offset (ReeFCO) program is an initiative under the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) that originated through discussions with the Reef tourism industry. It has been developed in conjunction with regional natural resource management groups.

Dr Chloe Schäuble, who manages the GBRMPA's climate change adaptation program, says the ReeFCO concept represents an exciting new way for consumers to identify the carbon offsets that are most attractive to them.

"We've had local businesses tell us that they'd prefer to buy carbon offsets that will benefit the local community and generate a net environmental benefit for the Great Barrier Reef," Dr Schäuble says.

"By offering local carbon offsets with multiple environmental benefits we should see more people buying offsets locally, lower carbon footprints and benefits for the Reef."

Badging offset products as 'Reef-friendly' should increase their attractiveness and offers a marketing advantage to businesses that sell them as well as businesses that buy them.

"Local businesses can promote the local benefits of their purchase to their customers," Dr Schäuble explains.

Developing the ReeFCO program required identifying what type of carbon storage projects would provide the greatest benefit for the Reef. The highest priority has been given to reforestation of water catchment areas where plantings will help improve the quality of water flowing into the Reef.

As the recent CEO of Terrain Natural Resource Management, Dr Allan Dale, was involved in developing the ReeFCO program. He says the process has drawn on the expertise of local natural resource management groups. These groups, which work in the catchments that collect and feed water into the Reef system, often lack the financial backing to turn many of their catchment revegetation plans into reality. However, the health and resilience of the Reef relies on land-based efforts to address water quality issues.

By joining forces, the GBRMPA and natural resource management groups aim to achieve better outcomes for the Reef, as well as helping to mitigate climate change generally. The introduction of a carbon price provides a greater financial incentive to contribute to improving catchment health via revegetation schemes, and the impetus to finalise and implement the ReeFCO program.

"Now that carbon has a price and the Australian Government has introduced the Carbon Farming Initiative, farmers can sell the carbon credits they earn from storing carbon in their trees and soil to businesses seeking to offset their emissions and reduce their carbon tax payments," Dr Dale explains.

The GBRMPA worked with local natural resource management groups to create criteria for priority and non-priority planting areas. Regional maps identify those areas with the greatest links between coastal catchments and the Reef.

The proposed offset program encourages plantings that will capture carbon and improve water quality by slowing water movement, and trapping sediment and nutrients. Revegetation on steep slopes and in riparian areas, for example, will provide maximum environmental benefit. The criteria incorporate localised priorities such as hotspot areas for reducing high nutrient and sediment runoff.

The types of trees to be planted are also considered. Using the same species of trees and shrubs that occur naturally in the area can help ensure successful growth and avoid potential negative effects, such as the introduction of weed and pest species. □

Smaller climate footprint for the GBRMPA

Sustainability initiatives at the GBRMPA and Reef HQ Aquarium are reducing carbon footprints and showcasing best environmental business practices.

Solar panels atop the roof of Reef HQ Aquarium.

Staff at the Great Barrier Reef Marine Park Authority (GBRMPA) come to work each day to help care for one of the world's most magnificent natural wonders – the Great Barrier Reef. It's little wonder then that the GBRMPA is keen to build its own environmental sustainability.

Improvements to facilities and better waste management are some of the major areas the agency has been concentrating on recently.

"Our staff have a passion for the environment and our job is to look after one of the most magnificent ecosystems on earth. We have to be true to this in the way we run our business operations," says Bruce Elliot, general manager of the GBRMPA's corporate services.

"We started looking at our environmental footprint some time ago. This was based on a genuine desire to be as environmentally aware as possible, and minimise our footprint. It wasn't just about meeting government requirements."

In the past three years, the GBRMPA has made a significant investment in new equipment and processes to reduce its greenhouse gas emissions, and to further build environmentally sustainable practices.

Energy and waste reduction are key target areas for the GBRMPA. Energy costs are significant, given that offices at its four main locations cater for more than 250 staff.

The Townsville base also hosts Reef HQ Aquarium, the national education centre for the Great Barrier Reef.

Major upgrades of the pumping and air-conditioning systems within Reef HQ Aquarium and a new C-Bus energy control system in the main office area have been part of strategies to reduce energy use.

"We now have an automatically controlled central system that operates on timers to minimise the use of lights overnight, which has reduced our carbon emissions and helped to cut energy costs," says office services coordinator Barney Bebendorf.

Office printers have also been rationalised and upgraded and staff are involved in awareness programs targeting daily printing practices.

Easy-to-implement, practical approaches to reducing waste have been highly effective. A new desktop waste management system was introduced in 2010 to manage the office waste.

"We replaced all under-desk waste bins with colour-coded eco bins, asking staff to separate waste into recycling, biowaste and other. It's a simple step that has been adopted across the organisation, and it has made a big difference to the amount of waste going to landfill," Mr Bebendorf says.

The GBRMPA has been making positive changes over many years to reduce its environmental footprint, but in the past things were generally being done 'on the smell of an oily rag'. "When something broke or needed replacing that's when we'd make changes," Mr Bebendorf says. "We had few opportunities to really actively accelerate the change process."

The advent of the *Great Barrier Reef Climate Change Action Plan 2007–2012* (Action Plan) changed that. "It provided the opportunity to really get our teeth into developing good strategies to reduce our environmental footprint (including emissions)," Mr Elliot says. "When we went to develop our Environmental Management System it was the first time we had access to any dedicated support. It provided just the leg-up we needed."

In 2007, the GBRMPA's Green Office Committee commissioned an audit of how well the agency was meeting the federal Energy Efficiency in Government Operations Policy guidelines and sought advice on how to improve its footprint. This was followed by work looking at how to implement the recommendations. Formal strategies

Reef HQ Aquarium halves energy use

Each year, more than 130,000 visitors pass through Reef HQ Aquarium, the world's largest living coral reef aquarium and the GBRMPA's educational facility. Now they can marvel at more than just the floor-to-ceiling aquariums filled with vibrant tropical fish and coral. Reef HQ has slashed its power consumption and greenhouse gas emissions over the past five years, thanks to active sustainability planning and effective 'reduce and recycle' policies.

With a $4 million funding injection by the Australian Government, Reef HQ is on track to halve its electricity use.

General manager for communication and policy coordination, Margaret Johnson says much of the saving has come through upgrades to pumping and air-conditioning equipment.

"The aquarium will also soon be part-powered by the sun," Ms Johnson said. "A savvy new solar system is on the way."

At the time of its installation, the 153-kilowatt, roof-mounted photovoltaic system will be one of the largest of its kind in the country. It will provide around 25 per cent of Reef HQ's entire energy needs.

An energy control centre display will show visitors how Reef HQ makes smart use of its power – how much is being used, where, and how the system ensures power is used in the most efficient way. Positioning the display next to information on climate change effects on the Great Barrier Reef will help visitors make connections between energy use, greenhouse gas emissions and the health of the Reef.

Reef HQ has used eco-friendly products such as carbon neutral paint, carpet made from recycled plastic bottles and wood from appropriately managed forests for recent major renovations.

Lighting products are selected for their efficiency and longevity, with globes using fewer toxic elements preferred. There is also regular recycling of scrap aluminium and other metals.

"Our staff and volunteers are extremely proud of what we have been able to achieve in terms of sustainability. Not only do our initiatives help us look after the environment, they also save us money,"
Reef HQ's director Fred Nucifora says.
"At Reef HQ Aquarium we strengthen our best-practice 'community, earth, business' approach through active education. This empowers us and the people we engage with to be active and informed citizens with a commitment to sustainability now and into the future."

Reef HQ regularly takes climate change and sustainability messages to the world during educational videoconferences with schools and communities around the globe.

for environmental management and greenhouse gas reduction were developed, and staff are now turning those words into actions.

The GBRMPA recognises that reducing its climate and environmental footprint is an ongoing process of continuous improvement. "We've started a journey and we've come a long way, but we realise there is still work to be done and progress to be made," Mr Elliot says. "Leadership in sustainability is something we'll continue to value and grow." □

In efforts to increase environmental sustainability, solar tubes were recently installed above the new Discovery Lagoon exhibit at Reef HQ Aquarium.

Reef an international icon in climate policy debate

Raising the profile of the effect of climate change on the Reef is helping to influence national and international policy.

PHOTO: PRO-VISION REEF

The image of a lone polar bear stranded on dwindling polar ice may be more emotive, but when it comes to getting the climate change message heard, the Great Barrier Reef is making an international impression.

The Great Barrier Reef is vulnerable to climate change; even slight increases in water temperature can trigger widespread coral bleaching, or create ideal conditions for coral disease outbreaks. The increasing frequency of extreme weather events such as cyclones exposes the coral, and the delicate ecosystem it supports, to the potential danger of serious, long-lasting damage.

In managing the impacts of climate change on the Reef, the Great Barrier Reef Marine Park Authority (GBRMPA) is working hard to influence relevant policy at the highest levels. This includes policy decisions relating specifically to the Reef and its catchment and to climate change generally.

Peter McGinnity, the GBRMPA's general manager of environment and sustainability, says climate change is the number one issue for the Great Barrier Reef, and the organisation needs to be heard at both national and international levels if coral reefs are to have a chance of surviving this century.

The GBRMPA representatives have spread key messages about climate change worldwide, in Europe, Asia, the Pacific and the Americas. "We attend conferences, hold workshops, and participate nationally and internationally in knowledge brokering to communicate the consequences of greenhouse gas emissions for the Reef, the importance of taking action on climate change and building the resilience of reefs under a changing climate," Mr McGinnity says.

The GBRMPA regularly provides expert advice to state and federal government ministers on the health of the Reef, and the risks posed by climate change, to help them make better-informed policy decisions. A recent review of state and federal Hansard parliamentary transcripts shows the GBRMPA's efforts to raise awareness of the Reef's plight within government circles are proving effective.

"We conducted a review of the Hansard reports for the past five years to find links to the Reef in arguments and debates about climate change and responses, to see how successful we are in using the Reef as a driver for climate change response," Mr McGinnity says.

The Hansard review showed that awareness and discussion of the expected impact of climate change on the Great Barrier Reef has been increasing. On several occasions, politicians cited statistics and descriptions about the effects of ocean acidification, sea temperature and sea level rise on coral and the overall health of the Great Barrier Reef ecosystem.

The review also found that the implications of climate change for the Great Barrier Reef have become a key consideration in legislation, policy and political discourse about climate change and emissions policies. Mr McGinnity says this reinforces the important role the GBRMPA plays in managing the impacts of climate change on the Great Barrier Reef.

The GBRMPA's work is being used as a national example of action to address climate change risks. Dr John Higgins, from the Department of Climate Change and Energy Efficiency, says other sectors and regions around Australia can learn from what is being done on the Reef. "The approaches, ideas and partnerships being formed under the *Great Barrier Reef Climate Change Action Plan 2007–2012* are models for how others can tackle climate change. It is great that the GBRMPA is so willing to be part of the climate change debate and share its experiences," he says.

Mr McGinnity is confident that progress is being made.

"How it is all going to end up – I don't know, but at least we are doing our best to give the Reef a fighting chance." □

When it comes to getting the climate change message heard, the Great Barrier Reef is making an international impression.

Climate Change Action Plan Resources

The following is a small selection of resources that have underpinned or been produced in association with the *Great Barrier Reef Climate Change Action Plan 2007–2012*.

Knowledge systems and tools

E-atlas.org – Latest environmental research, maps and data for the Great Barrier Reef and Queensland Australia, Australian Institute of Marine Science 2011, http://e-atlas.org.au

Reef health incident response system (including coral bleaching, coral disease and cyclones), Great Barrier Reef Marine Park Authority 2012, www.gbrmpa.gov.au/outlook-for-the-reef/climate-change/marine-park-management/building-resilience/climate-incident-response-actions

Eye on the Reef, Great Barrier Reef Marine Park Authority and Queensland Parks and Wildlife Service 2012, www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/science-and-research/our-monitoring-and-assessment-programs/eye-on-the-reef

ReefTemp, Great Barrier Reef Marine Park Authority, Bureau of Meteorology, and CSIRO 2011, www.cmar.csiro.au/remotesensing/reeftemp/web/ReefTemp.htm

Fishing Industry Emissions Calculator, Queensland Seafood Industry Association & Great Barrier Reef Marine Park Authority 2009, http://emissionscalculator.qsia.com.au/fisheries

Plans, strategies and vulnerability assessments

Pro-vision Reef: stewardship action plan. A statement of operational standards and climate change contingency planning, Donnelly, R. 2009, Pro-vision Reef, Cairns.

Climate change vulnerability assessment: Queensland marine aquarium supply industry, 2010, Donnelly, R. 2011, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef climate change action plan 2007–2012, Great Barrier Reef Marine Park Authority 2007, Great Barrier Reef Marine Park Authority, Townsville.

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Coral bleaching response plan 2009–2010, Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef tourism climate change action strategy 2009–2012 [abridged], Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Marine Park Authority, Townsville.

Bleaching risk and impact assessment plan, Great Barrier Reef Marine Park Authority 2011, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef biodiversity conservation strategy 2012, Great Barrier Reef Marine Park Authority 2011, Great Barrier Reef Marine Park Authority, Townsville,

Climate change adaptation principles: bringing adaptation to life in the marine biodiversity and resources setting, Great Barrier Reef Marine Park Authority and National Climate Change Adaptation Research Facility 2011, Great Barrier Reef Marine Park Authority, Townsville.

Climate change and the Great Barrier Reef: a vulnerability assessment, Johnson, J.E. and Marshall, P.A. (eds) 2007, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville.

Videos, displays, posters and other guidance

How a fishing family is tackling climate change, Australian Seafood Industry and Climate Change Symposium, 3rd – 4th March 2011 [presentation], Collard, T. and Collard, K. 2011, Queensland Seafood Industry Association, Brisbane.

Responding and adapting to a changing climate: What is the aquarium supply sector doing? Australian Seafood Industry and Climate Change Symposium, 3rd – 4th March 2011 [presentation], Donnelly, R. 2011, Queensland Seafood Industry Association, Brisbane.

Climate change will affect us all [display], Great Barrier Reef Marine Park Authority 2008, Great Barrier Reef Marine Park Authority, Townsville.

Climate change impacts on the Great Barrier Reef. GBRMPA Reef Beat poster 3, Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Marine Park Authority, Townsville.

Land, water, waste, community and climate change: current best practice for local governments motivated towards Reef protection, Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Marine Park Authority, Townsville.

Ocean acidification – Hermie the hermit crab [video], Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Marine Park Authority, Townsville.

Tourism operators responding to climate change: reducing outboard emissions, Great Barrier Reef Marine Park Authority 2010, Great Barrier Reef Marine Park Authority, Townsville.

QSIA/GBRMPA climate change and fisheries partnership, Great Barrier Reef Marine Park Authority and Queensland Seafood Industry Association 2009, Great Barrier Reef Park Authority, Townsville.

Trawl climate change adaptation planning, Australian Seafood Industry and Climate Change Symposium, 1st – 2nd March 2012, [presentation], Pears, R.J. and Jebreen, E. 2012, Part 2, Queensland Seafood Industry Association, Brisbane.

Keep it cool 2010 calendar, Wet Tropics Management Authority 2009, Wet Tropics Management Authority, Cairns.

Project bulletins

Lady Elliot Island climate change trail signage: thematic interpretation of a unique Commonwealth Island under threat, Great Barrier Reef Marine Park Authority 2010, Great Barrier Reef Marine Park Authority, Townsville.

Professor Ove Hoegh-Guldberg's Smart State Premier's Fellowship 2009—2014, Great Barrier Reef Marine Park Authority 2010, Great Barrier Reef Marine Park Authority, Townsville.

BleachWatch: Providing early warning of mass coral bleaching on the Great Barrier Reef, Great Barrier Reef Marine Park Authority 2010, Great Barrier Reef Marine Park Authority, Townsville.

A changing climate for the seabirds and shorebirds of the Great Barrier Reef, Great Barrier Reef Marine Park Authority 2010, Great Barrier Reef Marine Park Authority, Townsville.

Keppel Bay case study: managing for resilience on the Great Barrier Reef, Great Barrier Reef Marine Park Authority 2011, Great Barrier Reef Marine Park Authority, Townsville.

Acclimatise your business: climate change workshops for marine tourism operators, Great Barrier Reef Marine Park Authority 2011, Great Barrier Reef Marine Park Authority, Townsville.

Energy Wise Schools Program: working with local schools to raise awareness and improve energy efficiency, Great Barrier Reef Marine Park Authority 2011, Great Barrier Reef Marine Park Authority, Townsville.

Scientific publications

Coral reefs modify their seawater carbon chemistry–implications for impacts of ocean acidification, Anthony, K., Kleypas, J.A. and Gattuso, J.P. 2011, Global Change Biology 17(3655): 3666.

Ocean acidification and warming will lower coral reef resilience, Anthony, K.R.N., Maynard, J.A., Diaz-Pulido, G., Mumby, P.J., Marshall, P.A., Cao, L. and Hoegh-Guldberg, O. 2011, Global Change Biology 17: 1798–1808.

A framework for responding to coral disease outbreaks that facilitates adaptive management, Beeden, R., Maynard, J.A., Marshall, P.A., Heron S.F. and Willis B.L. 2012, Environmental Management, 49:1–13.

Drivers of change to seagrass distributions and communities on the Great Barrier Reef. Literature review and gaps analysis, Collier, C. and Waycott, M. 2009, Report to the Marine and Tropical Sciences Research Facility, Reef and Rainforest Research Centre Limited, Cairns.

High CO_2 enhances the competitive strength of seaweeds over corals, Diaz-Pulido, G., Gouezo, M., Tilbrook, B., Dove, S. and Anthony, K.R.N. 2011, Ecology Letters 14: 156–162.

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Predicting outbreaks of a climate-driven coral disease in the Great Barrier Reef, Maynard, J.A., Anthony, K.R.N., Harvell, C.D., Burgman, M.A., Beeden, R., Sweatman, H., Heron, S.F., Lamb, J.B. and Willis, B.L. 2011, Coral Reefs 30: 485–495.

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Climate Change in the Capricorn Coast: an analysis of stewardship potential, Myers, S., Carter, R.W. and Smith, T. 2011, Great Barrier Reef Marine Park Authority, Townsville.

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Marine climate change in Australia – impacts and adaptation responses – 2009 report card, Poloczanska, E.S., Hobday, A.J. and Richardson, A.J. 2009, National Climate Change Adaptation Research Facility, Gold Coast.

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"Individually, we are one drop. Together, we are an ocean."
Ryunosuke Satoro

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Further information

Climate Change Adaptation: Outcomes from the Great Barrier Reef Climate Change Action Plan 2007–2012 is available from the web: www.gbrmpa.gov.au

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