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Environmental Status:

Corals

our great barrier reef
let's keep it great

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Corals

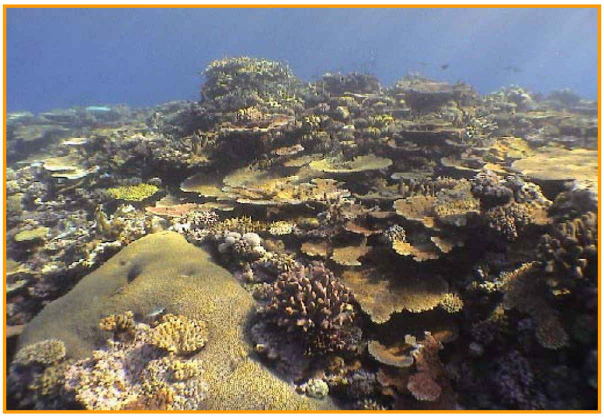
Condition

The Great Barrier Reef is part of a global centre of coral diversity located in the Indo-Pacific and includes more than 70 hard coral (Scleractinia) genera. Coral reefs are a significant component of the Great Barrier Reef World Heritage Area with over 2900 individual coral reefs stretching for more than 2300 kilometers. Some 350 coral species inhabit the Great Barrier Reef compared with the global maximum of about 450 species found in Indonesian and Philippine waters. Most of the hard coral species on the Great Barrier Reef are also found on coral reefs elsewhere in the Indo-Pacific, but 10 species are considered endemic, being found only on the Great Barrier Reef. Soft corals (Alcyonaria – octocorallia) are also an important component of many reefs, however their taxonomy is not well documented and less is known about their ecology and condition.

Condition: Hard Corals

Extensive surveys of hundreds of reefs over the last 20 years have shown that corals (like fishes, sponges and macroalgae) show a marked change in species composition moving from sheltered inshore fringing reefs to the exposed shelf-edge reefs of the outer barrier in clear, nutrient-poor water. Inshore reefs are often characterised by a relatively high abundance of corals such as *Galaxea*, *Montipora* and *Goniopora*, compared to mid-shelf reefs that have more plate-forming *Acropora* species, and outer-shelf reefs that are frequently dominated by digitate or sub-massive *Acropora* species.

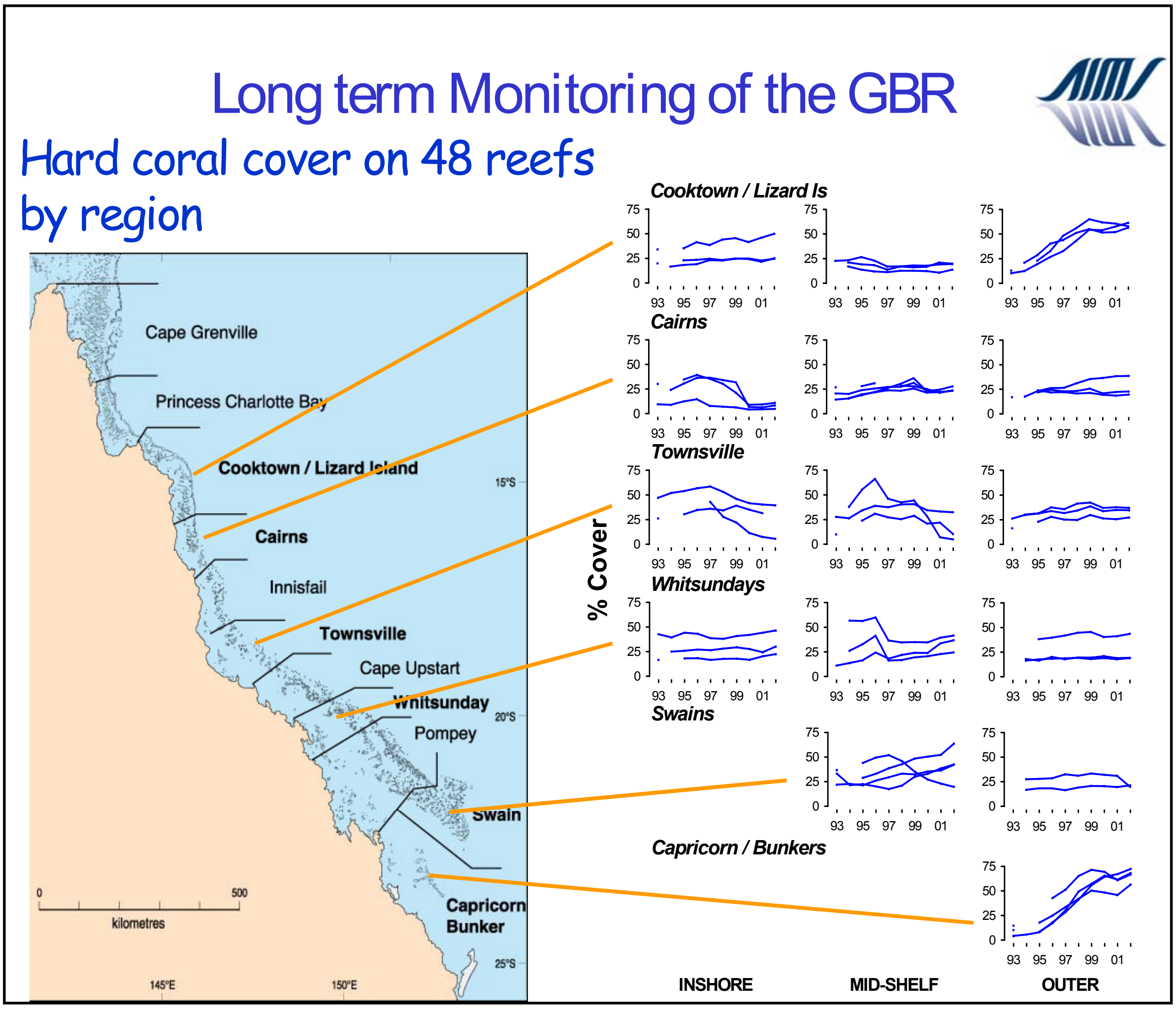
The cross-shelf pattern is correlated with an increase in wave exposure and light availability from inshore to offshore reefs. In terms of species diversity, the inner-most mainland fringing reefs or platform reefs within a few kilometres of the coast have the lowest diversity (100-150 species), but this rises rapidly away from the coast so that fringing reefs around high island groups such as the Palm Islands have over 300 species. Platform reefs further offshore in mid- and outer-shelf areas have high cover but somewhat lower species counts. Coral cover is extremely variable between reefs but surprisingly, highest cover is often found on pristine nearshore reefs.



Hundreds of hard coral species inhabit the Great Barrier Reef, but reef communities vary from one place to another

North-south variations in hard corals also exist but are less conspicuous than the cross-shelf differences. In particular, species diversity tends to decrease from north to south along the eastern Australian coast, with up to 343 species found in the northern and central Great Barrier Reef, but only 244 recorded in the reefs of the Capricorn-Bunker group in the south.

Surveys conducted by the Australian Institute of Marine Science (below) do not show any single, reef wide trend in hard coral cover through time, however this is not unexpected given the high natural variability of coral reefs (see "Variation on coral reefs"). Between 1993 and 2002, coral cover on offshore reefs of the Capricorn Bunker group in the southern Great Barrier Reef has continued to increase from very low levels caused by storm damage in 1988. Similarly, hard coral cover in both inshore and offshore reefs of the Cooktown/Lizard Island region in the northern Great Barrier Reef has also increased from low levels caused by severe storms a decade ago. Since 1995, coral cover on inshore reefs of the Cairns and Townsville sections, and mid-shelf reefs of the Townsville and Whitsunday regions have declined due to several major disturbance events including the reef wide coral bleaching event of 1998, Cyclone Justin in 1997, and outbreaks of crown-of-thorns starfish since the late 1990's.



Each blue line represents coral cover for one reef between 1993 and 2002

Condition: Soft Corals

Soft corals are commonly found throughout the Great Barrier Reef, however they have received relatively little scientific attention compared to hard corals. Due to the difficulties in identifying soft corals to species level, species distributions are currently not available and soft coral diversity is discussed here in terms of genera.

Although they are usually less abundant than hard corals, soft corals are important and visually spectacular members of the reef community

Surveys conducted between 1996 and 1999 by AIMS scientists have increased our understanding of soft coral abundance, diversity and distribution in the Great Barrier

Reef. During these surveys, the spatial distribution of 40 genera was estimated and mapped but a further 21 rare genera were not included in the analysis as the data were incomplete. Generally, soft coral diversity is highest in the mid-shelf regions of the Great Barrier Reef with fewer genera recorded in inshore and offshore regions. The greatest diversity of soft corals is found between 11^{0}S and 13^{0}S latitude and like hard corals, fewer genera are present in southern regions of the Great Barrier Reef.

Soft coral cover is usually less than 10% of the reefal benthos but can vary considerably between reefs. In shallow water less than five meters deep, soft coral cover tends to be higher on inshore reefs than on mid-shelf and outer reefs. However, this trend is less pronounced at deeper depths where similar levels of soft coral cover are found across inshore, mid-shelf and offshore reefs. In some circumstances, soft corals may form the dominant benthic group and some coastal reefs are inhabited by soft coral assemblages that cover up to 70% of the available space. It has been suggested that after episodic disturbance events such as cyclones, soft corals may out-compete hard corals, replacing them as the dominant benthic group. However, this has not been observed on the Great Barrier Reef where soft coral cover on reefs has remained remarkably consistent over time. Surveys have demonstrated that there was no shift from hard coral assemblages to soft coral assemblages up to ten years after removal of hard corals by crown-of-thorns starfish. Instead, the disturbed areas remained dominated by turf algae until fast growing hard corals re-colonised these sites.

Variation on coral reefs

Variation across space

Although some systematic cross-shelf and north-south trends can be found among the reefs of the Great Barrier Reef, a great deal of natural variation can exist among these reefs. It is not unusual for coral cover to vary greatly between two reefs that are relatively close to each other, as events such as storms or crown-of-thorns starfish outbreaks may devastate one reef while leaving a nearby reef relatively untouched. Furthermore, widely differing levels of coral cover and species assemblages (or community composition) are normally encountered at different depths, or on different sides of a reef.

Storm waves have significant effects on coral cover and composition. A cyclone can reduce coral cover to zero or leave only the most robust corals standing

Variation over time

Coral cover and community composition can vary greatly over time. During the summer, warmer water temperatures prompt the rapid growth of macroalgae on many inshore reefs, altering the reef's appearance and community composition. However, during the cooler winter months much of this marcoalgae dies and corals become dominant once more. Variability over time is further increased by disturbance events such as crown-of-thorns starfish outbreaks and cyclones. These events can reduce coral cover to zero but subsequent recovery and regrowth should return coral cover to pre-disturbance levels. As such, a 'normal' reef could exist in any of the following states:

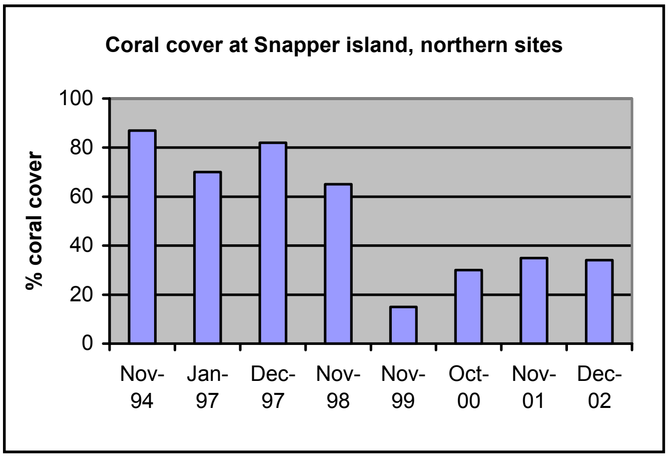
- low level of coral cover and reduced diversity (e.g. reef severely damaged by a recent cyclone with more fragile species being disproportionately affected);
- intermediate levels of coral cover and fluctuating community composition (e.g. reef recovering from the cyclone, some species recovering, pulse of new recruitment and

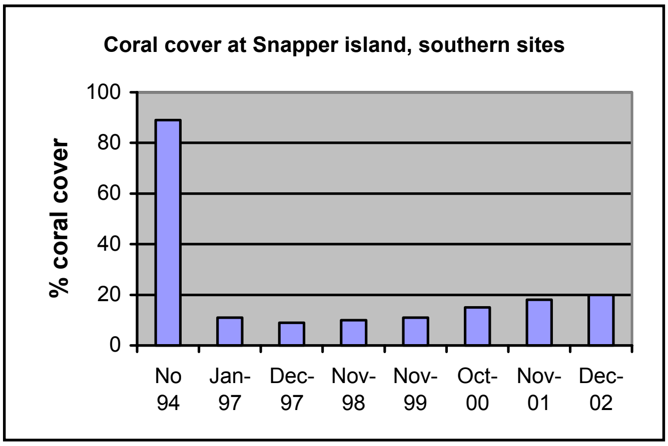
growth to colonise empty space, coral cover gradually increasing and bare substrate being colonised by new corals);
- high levels of coral cover (e.g. the reef exists in a relatively stable state or state of gradual change with mildly fluctuating coral cover and community composition).

The transition between these states may be as rapid as one or two years and any of these three states could be considered "normal" for a healthy reef. As such, the Great Barrier Reef has been described as a "patchwork mosaic" of reef communities at various stages of growth or recovery at any one time.

A number of studies have demonstrated the level of variability and extent of reef community mosaics. In one 30-year study on Heron Island in the southern Great Barrier Reef, coral cover was found to vary between 0 and 80% depending on the site. In another study, annual surveys of inshore reefs demonstrated large fluctuations in coral cover and community composition from year to year in response to cyclones, freshwater flood events and coral bleaching (see below). Furthermore, the extent of these impacts and recovery rate depended on the community composition present before and after the impact, and environmental conditions.

A comparison of coral cover at two locations at Snapper Island demonstrates the variability of coral reefs. In March 1996, the Daintree region received heavy rainfall resulting in major freshwater runoff. Flood plumes inundated Snapper Island and coral cover on the south facing sites was reduced from 90% to just 10% with most of the surviving colonies being resistant *Porites* corals. Meanwhile, the northern facing sites (only 3 kilometres away from the southern sites) were only slightly affected, as they were protected from the flood plume. However, coral cover was dramatically reduced at these northern sites later by the 1998 reef wide bleaching event, and cyclone Rona in 1999. In contrast, the southern sites, while still having low coral cover, did not suffer such dramatic reductions as the remaining *Porities* corals are very robust and weathered the impacts of both the bleaching event and the cyclone. New growth of fast growing Acroporid corals is now occurring at the southern Snapper Island sites which should result in a rapid increase in coral cover - unless the reef is affected by some other disturbance event.





The variability of coral reefs is vividly demonstrated in another long-term study by AIMS scientists who regularly photograph patches of coral reef. In the example shown below, a patch of reef at Rib Reef in the Townsville area of the Great Barrier Reef Marine Park (GBRMP) had very high coral cover and diversity in 1980. However, an outbreak of crown-of-thorns starfish in 1985 and damage caused by Cyclone Aivu in 1989 reduced coral cover to almost nothing. However, over the next seven years, coral cover rapidly increased and by 1996 had reached pre-disturbance levels.

Photographs courtesy of Dr. Terry Done, Australian Institute of Marine Science

A different type of long-term study has involved the analysis of coral density bands, which provide estimates of growth similar to that obtained from tree rings. This study has shown that a full analysis of the last 231 years indicates a series of repeated declines and recoveries of similar or even greater magnitude.

The Great Barrier Reef is a "patchwork mosaic" of different reef communities, all at different states of growth, decline or recovery

Another method of investigating possible cases of reef degradation over long periods is through the comparison of historical photographs of the reef with contemporary scenes from the same location. A comprehensive survey of historical photographs dating back to 1893, undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA), has indicated that out of 14 reefs investigated:

- six showed no obvious changes;
- four showed decreases in hard coral cover; and
- four showed decreases in coral cover only in certain areas.

Interpreting the data: Spatial and temporal variability

The spatial and temporal variability of coral reefs makes it very difficult to identify a decline in coral reef condition that is clearly attributable to human activities. These long-term studies have shown that even in the absence of direct human impacts, coral cover, growth and degradation vary considerably over time. To date, these studies have not indicated a clear, overall reef wide decline in coral condition with increasing settlement and human influence in the region. Nevertheless, this is neither unexpected nor a cause for complacency as explained below:

- Given the natural variability of coral reef ecosystems and the lack of data predating European settlement, clear signals of reef decline would most likely appear only after many more years of survey data was collected.
- Readily observable symptoms of stress can lag far behind the onset of ecosystem dysfunction. As such, conclusive evidence of a decline may only be found after major and potentially irreversible impacts have occurred, by which time it may be too late to initiate a *response* to alleviate the pressures causing the decline.

The variability and complexity of coral reefs makes it very difficult for scientists to detect and identify clear declines in coral reef condition that is attributable to human influences. However, subtle signs of reef dysfunction are now apparent on some inshore reefs

- Declines in reef condition are likely to be patchy, occurring only in some areas and at certain times. The high cost of monitoring programs means that existing studies are capable of detecting only relatively large and uniform changes in coral reef condition and are not designed to detect these types of subtle, patchy declines.
- Pressures on reef condition are likely to affect the biological and ecological *functions* of the reef (for example, the ability to recover from disturbances), and would occur before clear trends in coral cover appeared. There are no long-term studies that explicitly monitor the condition of these ecological functions, and even if such data were available, our ability to interpret this information is limited by our incomplete understanding of these processes.

There is also considerable evidence suggesting that degradation of ecological processes on inshore reefs has occurred. Surveys on some inshore reefs have indicated that recovery from crown-of-thorns starfish outbreaks is taking longer than previously recorded, while other surveys have reported altered community composition and reduced recruitment success. Surveys have also shown that coral cover on inshore reefs adjacent to heavily modified catchments is lower than expected based on comparisons between inshore and offshore reefs in relatively pristine areas. While it cannot be proven that these observations are attributable to human activities, they indicate that the ecological capacity of these reefs to recover and reproduce is declining. Furthermore, these are the changes most likely to occur as a result of chronic, excessive pressure on coral reef ecosystems caused by human activities. Current studies into these issues are limited in both geographical and temporal scales, however given the potential pressures these reefs are experiencing (see *Pressure*) these observations of ecological dysfunction are of increasing concern to reef managers.

Interpreting the data: Ecological complexity

Another confounding factor concerns the nature of reef communities themselves. Coral reefs in different places and at different times are likely to support different coral communities, each with their own unique suite of ecological characteristics and mechanisms. As such, different reef communities (or even the same reef at two different times) may respond differently to similar environmental changes or disturbance events. For example, the susceptibility to cyclones and subsequent recovery rate of reefs dominated by fast growing Acroporid corals is much higher than that of reefs dominated by slow growing but more robust *Porites* corals. This ecological complexity makes it very difficult to accurately interpret long term monitoring data.

Current conditions assessment

- Clear pressures on the coral reefs of the Great Barrier Reef exist, many of which are known to have directly contributed to the degradation of coral reefs in other parts of the world (See *Pressure*).
- Considering the difficulties in detecting and identifying the subtle signs of human induced declines, the absence of a reef wide decline in the condition of coral reefs does not mean that coral reefs are not under pressure.
- Evidence suggests that some coral reefs in the Great Barrier Reef are experiencing increasingly unsustainable levels of stress that have caused subtle, localised declines in the condition of these reefs.
- The GBRMPA is taking action to reduce the pressures on the Great Barrier Reef in the short term to ensure that widespread declines in coral condition do not occur at a later stage (See *Response*).

The GBRMPA is taking action to reduce pressures on the Great Barrier Reef before widespread declines occur

Pressure

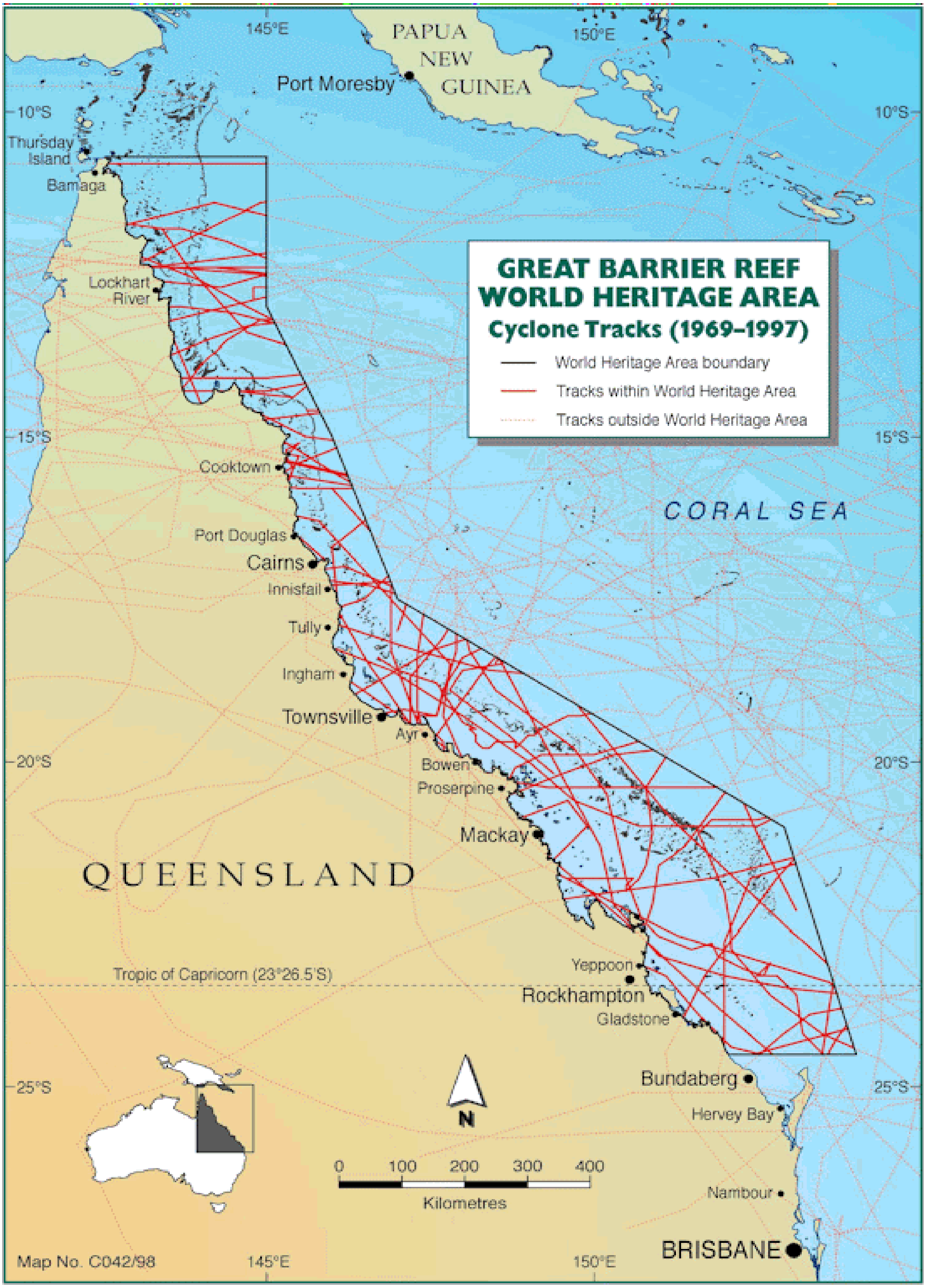
The coral reefs of the Great Barrier Reef experience a wide range of pressures from both natural events and human activities. For some pressures such as crown-of-thorns starfish outbreaks, there is no scientific consensus as to whether they are caused by human activity (see *Environmental Status – Crown-of-thorns starfish*). As such, the section on Pressures is divided into Pressures from natural causes, Pressures from human activities, Pressures of unknown origin and Pressures from global phenomena.

Episodic pressures that result in major disturbances such as cyclones, coral bleaching and crown-of-thorns starfish outbreaks cause the most noticeable changes on coral reefs. Furthermore, coral reefs may be affected by several different pressures at the same time which makes it difficult to accurately detect or predict the impact of any one pressure. As such, while pressures are described as separate entities, the overall pressure on coral reefs in the Great Barrier Reef is a cumulative combination of a number of pressures. For this reason, otherwise insignificant declines in coral condition or increases in the intensity or frequency of major disturbance events, may have disproportionate long-term effects on the condition of corals on the Great Barrier Reef.

Pressure from natural events

Cyclones

Cyclones are one of the most common sources of natural impact on coral communities. For instance they account for virtually all of the declines in coral cover documented during a 30-year study of Heron Island corals.


GREAT BARRIER REEF
WORLD HERITAGE AREA
Cyclone Tracks (1969–1997)
World Heritage Area boundary
Tracks within World Heritage Area
Tracks outside World Heritage Area
PAPUA
NEW
GUINEA
Port Moresby
CORAL SEA
QUEENSLAND
Thursday Island
Bamaga
Lockhart River
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Ingham
Townsville
Ayr
Bowen
Proserpine
Mackay
Yeppoon
Rockhampton
Gladstone
Bundaberg
Hervey Bay
Nambour
BRISBANE
Tropic of Capricorn (23°26.5'S)
145°E
150°E
10°S
15°S
20°S
25°S
N
0 100 200 300 400
Kilometres
Map No. C042/98

A recent compilation of cyclone data indicates that over the last 28 years there have been 135 cyclones in Queensland waters and that all areas of the Great Barrier Reef have been affected by at least one cyclone in this period. The reefs off Townsville have been particularly hard hit, having been within about 100 kilometres of a cyclone 11 or more between 1969 and 1997. Furthermore, evidence from alluvial sediment deposits indicates that every two to three hundred years, the Great Barrier Reef is likely to experience a "super-cyclone" that may have significant and wide ranging effects on the long-term development and dynamics of the Great Barrier Reef.

While cyclones can have large impacts on reef communities, the overall effect of a cyclone may depend on the types of corals living in the community at that time

The effects of cyclones on reef communities are extremely variable, depending on the severity of the cyclone, its duration, its proximity to the reefs, the orientation of the reef with respect to the wind and waves, and the depth of the corals. In extreme cases the reef can be stripped of all living corals and other benthic organisms, while in mild cases only the most fragile shallow corals are damaged. On the same reef, one side can be stripped while the other is virtually undamaged.

In the absence of further disturbances, even severely affected reef areas (reduced to nearly zero per cent) are able to regain their original cover after a cyclone. Recovery of fast growing corals may occur within 5 years however, in cases where the original community possessed very old or slow growing corals, the time required to return to the same species and size composition could be substantially longer. Since many parts of the reef experience more than one cyclone in 10-20 years, the reef can be considered as a mosaic of patches at different stages of recovery. Physical disturbance and recovery are therefore natural phenomena on the Great Barrier Reef and play an important part in determining the abundance and species composition of coral communities.

Floods

The Great Barrier Reef is located in the monsoonal tropics and experiences distinct wet and dry seasons. During the summer wet season, major rainfall events associated with monsoon troughs or cyclones can lead to extensive flooding of rivers and the discharge of millions of litres of sediment-laden freshwater into the coastal area. Depending on wave current and wind patterns, as well as the volume of discharge, flood plumes can extend for many kilometres offshore and impact mid-shelf and offshore reefs.

Flood plumes usually migrate north along the coast due to the influence of the south-easterly trade winds, however calm conditions can result in plume migration in an easterly direction away from the coast. Lowered salinity from flood plumes have been recorded up to 40 kilometres off the coast in the central Great Barrier Reef. Following the 1991 Fitzroy River flood, visible flood plumes were observed out to the Capricorn-Bunker reefs up to 100 kilometres from the river mouth. Recent research has investigated the behaviour of flood plumes and identified the reefs most likely to experience them. Under certain conditions, flood plumes can travel for great distances along the coast, reaching reefs hundreds of kilometres away from the river mouth. The reefs closest to the river mouths are not necessarily affected more frequently than those further away. Flood plumes are subject to a large number of influences such as volume of discharge, coastal topography, continental islands and wind conditions that can direct flood plumes towards reefs far from the river mouth. While many inshore reefs may experience flood plumes every one to three years, many mid-shelf reefs also experience flood plumes quite regularly. An assessment of the reefs most likely to regularly experience flood plumes has been completed.

Flood plumes do not necessarily affect the reefs closest to the river mouth as they may be directed by wind, currents and topography towards reefs much further away, even reaching mid-shelf reefs

The response of corals to flood plumes varies with the salinity and turbidity levels of the plume, and the duration of exposure. Substantial mortality can occur during extreme flood events. There was 85% mortality of shallow-water corals in the Keppel Islands following the 1991 Fitzroy flood and a 90% reduction in coral cover following floods at Snapper Island.

Pressure from human activities

Terrestrial influences from catchment use

Over the last 12 years a wide ranging research and monitoring program has investigated sources of pollution on the Great Barrier Reef Catchment, transport of pollutants from the catchment to the waters of the Great Barrier Reef and the effects of pollutants on various ecosystems. This research has identified land runoff as the most important issue affecting water quality in the Great Barrier Reef. It is now widely accepted that the amount of sediment, nutrients and other pollutant inputs to the Great Barrier Reef have significantly increased since European settlement. The capacity for flood plumes to disperse some of these pollutants out to distant reefs is a further cause for concern.

Low salinity, high nutrient levels and high turbidity can stress many corals and in severe cases, cause mortality. Coupled with changes in land use patterns and the loss of critical coastal habitats that might filter out some of these elements, terrestrial run-off is considered to be one of the greatest potential threats to the Great Barrier Reef. Today, many inshore coral reefs showing high levels of coral cover, are generally found in areas where there has been relatively limited changes to land management practices since European settlement. There is a growing body of evidence suggesting that the Great Barrier Reef lagoon is showing signs of eutrophication and that this has caused decreases in coral cover and diversity on some reefs. This evidence has been subject to extensive review and debate including review by an independent panel of scientists commissioned by the Queensland Government in 2002. There is also scientific consensus on the issue urging the reduction of terrestrial pollutants to the Great Barrier Reef as a matter of priority. A more detailed account of the nature of terrestrial runoff can be found in *Environmental Status - Water Quality*.

Anchoring

Anchoring by boats in coral reef areas is a cause of some major coral damage in heavily used areas. Anchors dropped in areas with more fragile coral species inevitably break at least some corals. Depending on the length and weight of the anchor line used, and the strength and wind conditions, the anchor chain can cause severe physical damage over a considerable area. While broken fragments of some species are capable of regenerating, recovery from a single anchoring event could take from one to ten years and repeated anchoring in the same area can result in persistent decrease in coral cover and species diversity that is ecologically unsustainable.

Reports from scientists, Marine Parks staff, tourist operators and locals in the Cairns and Whitsunday regions have suggested that severe localised effects have occurred at some popular anchorages. High-use anchorages are clearly the most likely areas suffering from this type of damage, but the absence of data on coral cover before and after the commencement of frequent anchoring makes it impossible to determine the extent and severity of this impact on the Great Barrier Reef. While the damage caused by anchoring is small compared to other pressures such as cyclones and crown-of-thorns starfish outbreaks, the impacts observed were sufficient to warrant a management response to address the issue including no-anchoring zones, a mooring policy and education in best environmental practices (see *Response*).

Diving and snorkelling

Divers, snorkellers and reef walkers can break or abrade corals through physical contact. These impacts are likely to be highest at major tourist destinations or around tourist pontoons. The impact of divers on coral reefs has been extensively studied. Generally, only a small percentage of divers damage corals, mostly through contact with their fins. Interestingly, male divers appear to be more likely to damage corals than female divers and dedicated photographers with specialist equipment were more likely to break corals than non-photographers or divers with small disposable cameras.

Properly managed diving and snorkelling activities can have relatively little impact compared to natural disturbances or other pressures

Research has shown that snorkellers using snorkelling trails can cause considerably more damage than divers with six times more broken corals recorded on trails compared to that of adjacent sites after two months of use. Snorkelling trails concentrate use in clearly defined areas where snorkellers stand on corals or kick them with their fins. Coral breakage is highest around interpretative signs and rapidly accumulates until reaching a relatively stable state under continued use. The use of general snorkelling areas does not appear to result in as much coral breakage, however opportunities for education and interpretation in general snorkelling areas may be diminished.

While diver and snorkeller damage can be observed in high-use sites, the level of impact is relatively low and the area of reef affected is small in proportion to the surrounding reef. When compared to the impact natural disturbances such as cyclones have on coral reefs, diver and snorkeller damage is not considered a major cause of concern. Furthermore, studies of pontoon based dive sites demonstrated that the repeated use of dive sites has not necessarily lead to their degradation with no cumulative effects detected. Nevertheless, intense snorkelling and diving activities can cause declines in the aesthetic quality of high use sites and should be taken into account (see *Response*).

Construction and operation of tourist facilities
Corals can be damaged during activities associated with the construction of tourist facilities such as marinas and breakwaters, and the installation of piles for jetties. Although localised impacts from these activities have occurred in the past, careful site selection, planning and environmental control of construction can minimise impacts. Most facilities are now preferentially located away from areas of high coral cover. For those structures that have been monitored for ongoing impacts after construction (breakwaters, jetties) no major adverse impacts on adjacent coral areas have been detected once construction is completed. In the case of tourist pontoons, the area directly under the pontoon is usually shaded to some extent and this has resulted in some coral death. Nevertheless, careful site selection and use of appropriate technology and design can significantly reduce the risk of damage to corals from the movement or failure of pontoon anchoring systems and reduce the impact on corals from shading. Generally, tourist structures have a localised effect during construction that is superseded by colonisation by corals after construction or installation is complete.

Pontoons are installed over sand to reduce the impact to corals of shading and reduce the risk of damage from the mooring chains and anchors

Stormwater run-off containing rubbish and pollutants, and sewage effluent are also potential impacts on coral reefs adjacent to tourist facilities. However, management regulations usually minimise these effects, and no major problems have been documented during monitoring of such facilities.

Pollution and shipping
Shipping can impact on corals through direct grounding of ships on reefs and through spills of toxic cargo and fuel. Although there have been no major oil spills in the Great Barrier Reef World Heritage Area (and only one major spill in Torres Strait), two hundred and sixty shipping and boating incidents were recorded in the waters of the Great Barrier Reef World Heritage Area between 1987 and 1997. Since 1995 there have been six major ship groundings. Site assessments show that in general, groundings result in severe but localised physical damage. Corals directly under the grounding scar are pulverised and compacted and adjacent corals toppled over and pushed into ridges. Residues of toxic Tributyl tin (TBT) and copper used in ships anti-foulant paint are scrapped off the hull and can later be resuspended and distributed, affecting corals some distance from the grounding site. Recovery from physical damage is likely to take decades but the long term effects of TBT contamination are poorly understood. More details on the management of shipping-related issues in the Great Barrier Reef World Heritage Area can be found in *Management Status - Shipping and Oil Spills.*

Ship groundings pose a significant risk to coral reefs due to the potential for oil spills, physical damage and from toxic residues from anti-foulant paint

Dredging

Dredging of harbours and boat channels creates highly turbid sediment plumes that can kill corals up to hundreds of metres away. Most ports along the Queensland coast require periodic dredging after initial construction. Maintenance dredging at ports with nearby coral reefs is a potentially significant impact for these corals. In addition, construction of new marinas and boat channels is also occurring along the Great Barrier Reef coast.

Dredging near coral reefs poses a high risk that requires careful management and intense monitoring

There have been several major monitoring studies associated with dredging activities within the GBRWHA. The Magnetic Quays monitoring program, the Townsville Port Authority Capital Dredging monitoring program and Nelly Bay Harbour Development Impact Monitoring Program have shown that, if the appropriate management systems are put in place, it is possible for major dredging works to take place without causing widespread coral mortality on adjacent coral reefs. While these results are encouraging, it is important to note that these reefs are still likely to be subjected to some degree of sub-lethal stress, which would decrease their ability to cope with additional pressures. Furthermore, each dredging operation is likely to be unique in the nature and pattern of potential impact and environmental risk and as such, assessment of proposed dredging activities needs to be undertaken on a case by case basis. If dredging is approved, it should be implemented in accordance with a reactive management and monitoring regime specifically tailored to the operation which may require significant financial and institutional investment and commitment to environmental management and monitoring.

Pressures of uncertain origin

Crown-of-thorns starfish

Crown-of-thorns starfish outbreaks have caused significant and extensive mortality of corals in the Great Barrier Reef on two previous occasions, and a third outbreak is currently affecting reefs in the Townsville and Cape Upstart regions. The Swains reefs have experienced recurring outbreaks of crown-of-thorns starfish at intermittent periods. For more information on the crown-of-thorns starfish and its effects on corals, *see* *Environmental Status - Crown-of-thorns Starfish.*

There has been much debate about the cause of crown-of-thorns starfish outbreaks, and several theories have invoked human activities as an indirect cause. While there is no consensus on what causes outbreaks, it is possible that the frequency of outbreaks has increased due to human influences, particularly those associated with increased run-off from coastal areas. This possible increased frequency would cause affected reefs to be in a low coral, high algal state for longer periods and potentially impact biodiversity across the entire Great Barrier Reef.

Coral disease

Although diseases are frequently reported as an important threat to corals in the Caribbean, only isolated reports of disease exist for the Great Barrier Reef. While a variety of diseases and abnormalities are recorded as occurring on the Great Barrier Reef (e.g. black band disease, white syndrome, coral tumours), these do not seem to be affecting large areas of coral. Surveys by the AIMS LTMP show that while disease is distributed widely, the number of infected colonies on each reef tends to be low. Furthermore, surveys have shown that unlike the Caribbean, it is the offshore reefs that tend to have higher incidence of disease suggesting that pollution from coastal sources is not the primary cause of these coral diseases. Many of these offshore reefs have recently had high levels of coral cover which may aid the transmission of disease, and the incidence of coral disease has been closely linked with coral bleaching events and warm sea water temperatures, both of which have recently occurred (see below). Many disease agents are known to increase under unusually warm conditions, suggesting that greater incidence of coral disease may occur under predicted climate warming scenarios. Nevertheless, little is known about the incidence, causes and consequences of coral disease on the Great Barrier Reef and targeted research into these areas is only just beginning.

Pressures from global phenomena

Climate change and coral bleaching
In 2001 the Intergovernmental Panel on Climate Change (IPCC) released the report "Climate Change 2001, the *Third Assessment Report of the IPCC*" and it is clear that the overwhelming consensus of scientific opinion is that the Earth's climate is changing. Some of the major findings of the 2001 report include:

- an increase in global average surface temperature of about 0.6^{0}C over the 20^{th} century;
- a decrease in snow cover and ice extent;
- increases in global average sea level and ocean heat content;
- concentrations and effects of greenhouse gases have continued to increase as a result of human activities;
- new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities; and
- global average temperature and sea level are projected to rise even under the most conservative of the IPCC scenarios.

Bleached corals are not necessarily dead. In time they may regain their symbiotic algae and recover and returning to their normal colour

In terms of the Great Barrier Reef, climate change is predicted to increase the frequency and intensity of cyclones and severe storms, cause sea level change and has probably already increased the frequency of major coral bleaching events.

Coral bleaching occurs when corals become stressed and eject the brownish coloured algae that live within their tissues. When this happens the white coral skeleton is visible through the clear coral tissue and the corals appear bleached white. Bleached corals are not dead and, if they are not severely stressed, they can regain their original algal densities and make a full recovery. However, bleached corals will die if stresses are extreme or persistent

and bleaching has led to mass mortality in many places around the world. Even corals that survive bleaching however are likely to suffer reduced growth rates, decreased reproductive outputs and increased susceptibility to other factors such as disease.
The principal cause of mass coral bleaching (involving a high proportion of corals on reefs spread over hundreds of kilometres) is elevated summer water temperatures. In addition, high levels of sunlight and lowered salinity are known to contribute to and exacerbate bleaching. Bleaching has been formally documented on many occasions on the Great Barrier Reef with the earliest report in 1980, however, bleaching appears to have increased in both frequency and geographic scale in recent years. In 1998 and 2002, the Great Barrier Reef experienced major, reef wide bleaching events associated with high sea temperatures.

In 1998, sea temperatures in some parts of the Great Barrier Reef were between 1^0C and 2^0C above normal temperatures for that period. Globally, the temperatures reached and the extents of bleaching at this time were the highest ever recorded. Aerial surveys of the Great Barrier Reef showed that 87% of inshore reefs surveyed were bleached to some extent while bleaching affected 28% of surveyed mid-shelf and offshore reefs. Of the bleached reefs, the inshore reefs were the most severely affected, 67% with high levels of bleaching and 25% with extreme bleaching levels. In comparison, mid-shelf and offshore reefs were less affected with only 14% highly bleached and none bleached to extreme levels. Subsequent research found that different coral species were affected to different extents. Corals such as the Acroporids, branching *Porites* and Pocilloporids suffered extreme bleaching and mortality while *Turbinaria* corals tended to be unaffected or only slightly bleached. Researchers also found that the effect on any one reef depended on the coral community composition, but also varied according to water depth with the shallowest regions of reefs being the most affected. Post bleaching surveys revealed that inshore reefs suffered the highest mortality rates while mid-shelf and offshore reef corals had generally escaped with minimal mortality.

The 2002 mass coral bleaching event was the largest on record for the Great Barrier Reef. Two periods of several weeks of hot weather resulted in seawater temperatures several degrees centigrade higher than long-term seasonal averages. Aerial surveys conducted in March and April revealed that 60% of reefs surveyed were bleached. While inshore reefs were again the most affected, a greater proportion of mid-shelf and offshore reefs bleached in 2002 than in 1998. In terms of bleaching severity, 69% of inshore reefs had moderate to high levels of bleaching but mid-shelf and offshore reefs were much more affected than in 1998 with 51% showing moderate to high levels of bleaching. Surveys conducted by divers later showed that although few reefs escaped bleaching, the impacts varied between reefs. Some inshore reefs such as those off Bowen suffered between 50% and 90% mortality while inshore reefs of the Frankland Islands were almost completely unaffected. As in 1998, different species were affected to varying extents with the more susceptible Acroporid and Pocilloporid species most affected. Furthermore, corals in shallow regions of the reefs were again the most extensively bleached, however some bleached corals were also found at depths between ten to fifteen metres. While data on mortality of bleached corals is still being

The Great Barrier Reef experienced mass coral bleaching events in 1998 and 2002. The frequency of coral bleaching episodes appears to be increasing and most evidence points to a positive link between global warming and increased coral bleaching analysed, the 2002 event was more severe than that of 1998 with bleaching spread across a much larger area of the Great Barrier Reef.

The Great Barrier Reef, as a whole, was less affected by both bleaching events than many other reefs around the world. Relatively few reefs within the Great Barrier Reef World Heritage Area suffered extensive mortality and in the absence of further pressures, most are expected to recover. Many other reefs around the world have been completely decimated by coral bleaching. The 1998 bleaching event saw catastrophic bleaching with massive mortality occurring on reefs in Bahrain, Maldives, Sri Lanka, Singapore, and parts of Tanzania. While some reefs are showing encouraging signs of recovery, there are also many reefs where recovery is barely evident. Increases in the frequency and severity of coral bleaching will have significant and cumulative effects on the corals of the Great Barrier Reef. Considering its potential to directly affect the entire Great Barrier Reef at one time, and the potential to exacerbate the effects of other pressures, climate change and coral bleaching are likely to pose the greatest long-term risks to the Great Barrier Reef. While the long-term effects of climate change and increased coral bleaching on the Great Barrier Reef are unknown, most scientists agree that the link between climate change and coral bleaching is well established. It is widely accepted that climate change will cause coral reefs to change, the challenge now is to determine what changes are likely to occur, how these changes will occur and what effects these changes will have on reef ecosystems and on people interacting with them.

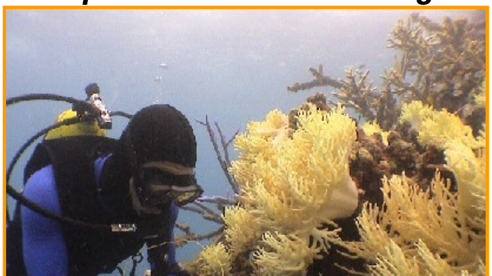
Response

The GBRMPA uses a variety of measures to either eliminate or substantially reduce the magnitude and likelihood of impacts on corals in instances where human activities could potentially impact on corals. These measures include the establishment of zones or special areas prohibiting certain activities, the application of permit conditions associated with specific activities, the establishment of guidelines and codes of conduct, and the development of research and monitoring programs to assess impacts and monitor ecosystem condition.

Response: Great Barrier Reef Marine Park Zoning Plan 2003

The GBRMPA recently re-zoned the entire Great Barrier Reef Marine Park (GBRMP) through the Representative Areas Program (RAP). The *Great Barrier Reef Marine Park Zoning Plan 2003* (the Zoning Plan) used the best available scientific knowledge to rezone the GBRMP to better protect all the types of habitats and ecosystems that make up the Great Barrier Reef, and to preserve the ecological connections between them. While some 200 coral reefs under the previous zoning systemwere in protected 'green zones', relatively few of the adjacent habitats that help to support coral reefs were protected. Furthermore, the few protected 'non-reef' habitats were clustered in the north of the GBRMP. The new Zoning Plan however, includes examples of every kind of non-reef habitat in a network of protected areas to ensure that the habitats that support life on coral reefs and help connect different reefs together are protected across the length of the Great Barrier Reef. This will help to ensure the ecological viability of coral reefs themselves. No-take areas or 'green zones' within the GBRMP have increased from 4.6% to 33.3%. The Zoning Plan came into effect on 1 July 2004.

Response: Climate change



The GBRMPA is involved with research aimed at identifying the effects of climate change on the Great Barrier Reef

Climate change is a global phenomenon that is beyond the scope of the GBRMPA to manage directly. Nevertheless, the GBRMPA is committed to ensuring that the uncertainties concerning the effects of climate change on the Great Barrier Reef are resolved. To this end, the GBRMPA is involved in collaborative research projects with NOAA in the United States and the AIMS to monitor sea temperatures and coral bleaching. GBRMPA has developed a coral bleaching response program so that if coral bleaching occurs, the extent and severity of the bleaching can be catalogued using standardised methods. This is a critical step in raising awareness about the impacts of climate change on coral reefs and in promoting international efforts to address the issue. The GBRMPA also supports a number of research projects on coral bleaching.

While the GBRMPA is unable to directly address global climate change, it is committed to ensuring that coral reef resilience is not degraded by human activities. Pressure from terrestrial run-off, over-fishing and losses in biodiversity will affect the ability of coral reefs to cope with stress from coral bleaching. By minimising these pressures through the Zoning Plan, the *Reef Water Quality Protection Plan* and various fisheries plans, the GBRMPA aims to ensure that coral reefs are relieved from other pressures when coping with coral bleaching, giving them a better chance of surviving and recovering from these events.

Response: Permits for commercial activities and research

Most commercial and research activities in the Great Barrier Reef Marine Park require a permit from the GBRMPA. During the assessment of each permit, potential impacts on corals are considered and, if necessary, permit conditions are imposed to eliminate or minimise these impacts.

Response: Terrestrial influences and water quality

In August 2002, the Commonwealth and Queensland Governments signed a Memorandum of Understanding (MOU) on developing a *Reef Water Quality Protection Plan* to address water quality degradation in the Great Barrier Reef Catchment. This included a comprehensive review of the scientific information on water quality in the Great Barrier Reef, which concluded that there is presently a serious risk to the long term future of inshore reef areas, and that immediate action is required to avoid further ecosystem damage and allow long-term recovery of affected ecosystems. The draft Reef Water Quality Protection Plan was released on 22nd May 2003 with the final scheduled for release in August 2003 following community consultation. Once the plan is implemented, progress will be reported to the Prime Minister and Queensland Premier in 2005, with a follow up report in 2010. For more information about the GBRMPA's response to water quality issues, see *Management Status – Water Quality and Coastal Development.*

Response: Moorings

Moorings and 'no anchoring areas' are used to reduce coral damage from boat anchors. Many commercial reef operators are required to install and maintain their own mooring, while public moorings are being progressively installed in sensitive, high-use anchorages throughout the Marine Park. In the Whitsunday Islands, 13 'no anchoring areas' have been created and moorings have been allocated under various management plans and policies. There are now 87 public moorings in the Whitsunday Islands and 53 distributed between the Cairns Planning Area and Magnetic Island off Townsville. Installation of private moorings in the Cairns Planning Area has been capped and in the Whitsundays, private moorings are restricted to certain areas. The

Volunteers and Marine Park rangers have installed markers to identify "no-anchoring" areas in the Whitsunday Islands

GBRMPA is progressively implementing the *Moorings Policy* starting with the standardisation of mooring buoys and a moorings register. This will allow the GBRMPA to monitor moorings infrastructure, ensure the number, types and locations of moorings are appropriate and maximise the sharing of moorings where possible. This also allows illegal moorings (which pose environmental, safety and amenity risks) to be identified and removed. *Best Environmental Practices* for moorings have been developed to educate boat operators about the risks of anchor damage and the use of moorings.

Response: Research and monitoring programs

An important management response to potential pressures is the establishment of monitoring programs to detect and assess human-induced or natural impacts. Monitoring Programs assess the effectiveness of management responses in eliminating or reducing impacts or environmental risks. Where an activity is predicted to pose a risk to coral reef environments (eg: dredging), monitoring programs are specifically designed and implemented for that activity to assess the risk it poses, document any impacts and manage the activity. As such, monitoring is often required as a condition of a permit to conduct commercial activities on the Great Barrier Reef, and can include a 'reactive monitoring' component. This ensures that adverse impacts during the construction or installation of a structure on the reef are detected at an early stage and action is taken to minimise impacts before significant damage occurs.

As well as management focused monitoring programs, the GBRMPA is involved in long-term monitoring programs through the CRC Reef Research Centre. These programs are designed to improve our understanding of the ecological processes and trends occurring on coral reefs. The GBRMPA needs this information to assess the potential risks posed by human activities, predict impacts, and interpret the results of management focused monitoring programs. For more information on the scope and extent of various monitoring programs on the Great Barrier Reef, see *Management Status - Monitoring.*

Response: Tourist guidelines for tourism structures, diving, snorkelling and reef walking

The CRC Reef Research Centre, the tourism industry and the GBRMPA have developed a set of *Reef Infrastructure Guidelines for Tourist Pontoons*. These guidelines describe how pontoons should be designed, installed and maintained. In general, new technology and care during installation has greatly reduced the potential risk pontoons pose to coral reefs.

Divers and snorkellers are urged to follow Best Environmental Practices

Tourists on most trips to the reef are given an introductory lecture, which stresses the importance of avoiding direct contact with coral. Floats are provided at many reef sites to allow snorkellers to rest without standing on the reef. Reef walkers are also briefed to avoid walking directly on corals and are often accompanied by a guide who encourages appropriate behaviour. The GBRMPA has developed a list of *Best Environmental Practices* which are used in briefings to help tourists understand how to minimise their impacts when visiting coral reefs.

Response: Shipping regulations and guidelines

In order to reduce the risk of ships grounding within the Great Barrier Reef it is compulsory for all vessels over 70 metres or any ships with a cargo of oil, chemicals or liquefied gas to carry a pilot whilst transiting the inner shipping route. As a response to political and community sensitivity, oil companies tend to direct crude oil tankers to travel outside the Reef when travelling along the Queensland coast. Further details on the management of shipping can be found in *Management Status - Shipping and Oil Spills*.

Summary

- The Great Barrier Reef World Heritage Area has a highly diverse coral fauna which varies most in composition from inshore to offshore.
- Natural disturbances such as cyclones, and the nature of coral reefs themselves, create a high level of natural variation in coral communities through time and within and between reefs.
- Impacts from crown-of-thorns starfish cause major changes to portions of the Great Barrier Reef at irregular intervals, but the link between these disturbances and human activities is uncertain.
- Climate change and increased frequency and intensity of coral bleaching pose significant risks to the Great Barrier Reef. The GBRMPA is involved in research to find out what the likely effects of climate change on the Great Barrier Reef will be, and to ensure that the Reef's ability to cope with climate change is not degraded by additional human pressures.
- No clear widespread declines in coral condition have been detected in relation to human impacts. Our ability to detect and identify a clear declining trend in coral condition from human activities is restricted by the variability, size and complexity of the Great Barrier Reef. The absence of a clear unequivocal trend of decline does not mean that coral reefs are not under pressure. Some signs of deterioration of ecological functions that could lead to severe and persistent problems in the Great Barrier Reef are already apparent in some areas.
- The *Great Barrier Reef Marine Park Zoning Plan 2003* will help to ensure the ecological viability and resilience of coral reefs by protecting reefs and adjacent habitats that are critical to the ecological functioning of coral reefs in a network of no-take protected areas. The network of protected areas will help protect biodiversity, maintain ecosystem function and preserve interconnectivity both within and between coral reefs and these habitats.
- New fisheries plans and the *Reef Water Quality Protection Plan* will be instrumental in reducing the impacts of factors such as fishing and sediment run-off on the Great Barrier Reef. These plans will help to relieve coral reefs from additional pressures when coping with climate change, and are vital management responses to complement the new Zoning Plan.
- Coral reefs are subjected to various pressures from tourism and development activities. The impacts of these activities are managed on a case-by-case basis through permits and environmental management and monitoring.
- Increased amounts of nutrients, sediments and pesticides are being transported to the Great Barrier Reef through terrestrial run-off. This is one of the most important management issues for the GBRMPA and is being addressed through the joint State and Commonwealth *Reef Water Quality Protection Plan*.

Further reading:

Information about the biology of coral reefs and the Great Barrier Reef:

- http://www.reefed.edu.au/
- http://www.reef.crc.org.au/aboutreef/coral/index.html
- http://www.bbc.co.uk/nature/blueplanet/webs/index.shtml
- http://www.aims.gov.au/pages/search/search-corals.html
- http://www.epa.qld.gov.au/cgi-bin/w3-msql/environment/plant/animals/resultframe.html?id=10

About soft corals

- http://www.aims.gov.au/pages/search/search-soft-corals.html

Research publications about the Great Barrier Reef are also available at:

- http://www.gbrmpa.gov.au/corp_site/info_services/publications/index.html
- http://www.reef.crc.org.au/publications/techreport/index.html

Information on the long term monitoring of the Great Barrier Reef:

- http://www.aims.gov.au/pages/research/reef-monitoring/reef-monitoring-index.html

About crown-of-thorns starfish:

Crown-of-thorns starfish on the Great Barrier Reef

- http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/1998/cots_frame.html
- http://www.aims.gov.au/monmap/COTSPage/COTSPage.html
- http://www.reef.crc.org.au/publications/brochures/index.html

Managing crown of thorns starfish outbreaks

- http://www.reef.crc.org.au/publications/explore/feat45.html

About climate change, coral bleaching and coral reefs:

About GBRMPA's coral bleaching program

- http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/index.html

Coral bleaching on the Great Barrier Reef

- http://www.reef.crc.org.au/publications/brochures/index.html
- http://www.aims.gov.au/pages/search/search-coral-bleaching.html
- http://www.reef.crc.org.au/publications/explore/feat37.html

August 2003 report on climate change and coral bleaching on the Great Barrier Reef

- http://www.nrm.qld.gov.au./science/climate.html

About climate change and coral reefs

- http://www.ipcc.ch/ (see section 5.3 of "Climate Change 2001, Impacts, adaptation and vulnerability" for specific reference to the Great Barrier Reef)
- http://www.aims.gov.au/pages/research/project-net/reefs-at-risk/apnet-rar00.html

About coral disease:
On the Great Barrier Reef
- http://www.aims.gov.au/pages/research/reef-monitoring/coral-diseases/diseasecp.html

General coral disease information
- http://www.coral.noaa.gov/coral_disease/cdhc.shtml
- http://ourworld.compuserve.com/homepages/mccarty_and_peters/coraldis.htm

About water quality and coral reefs
Please visit the chapter *Environmental Status – Water quality*

Information on coral reefs around the world
- http://www.aims.gov.au/pages/research/coral-bleaching/scr2002/scr-00.html
- http://www.jcu.edu.au/school/mbiolaq/ccrbio/
- http://www.coral.noaa.gov/
- http://www.reefbase.org/
- http://www.coralreef.org/
- http://www.gcrmn.org/
- http://www.coralreefalliance.org/

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