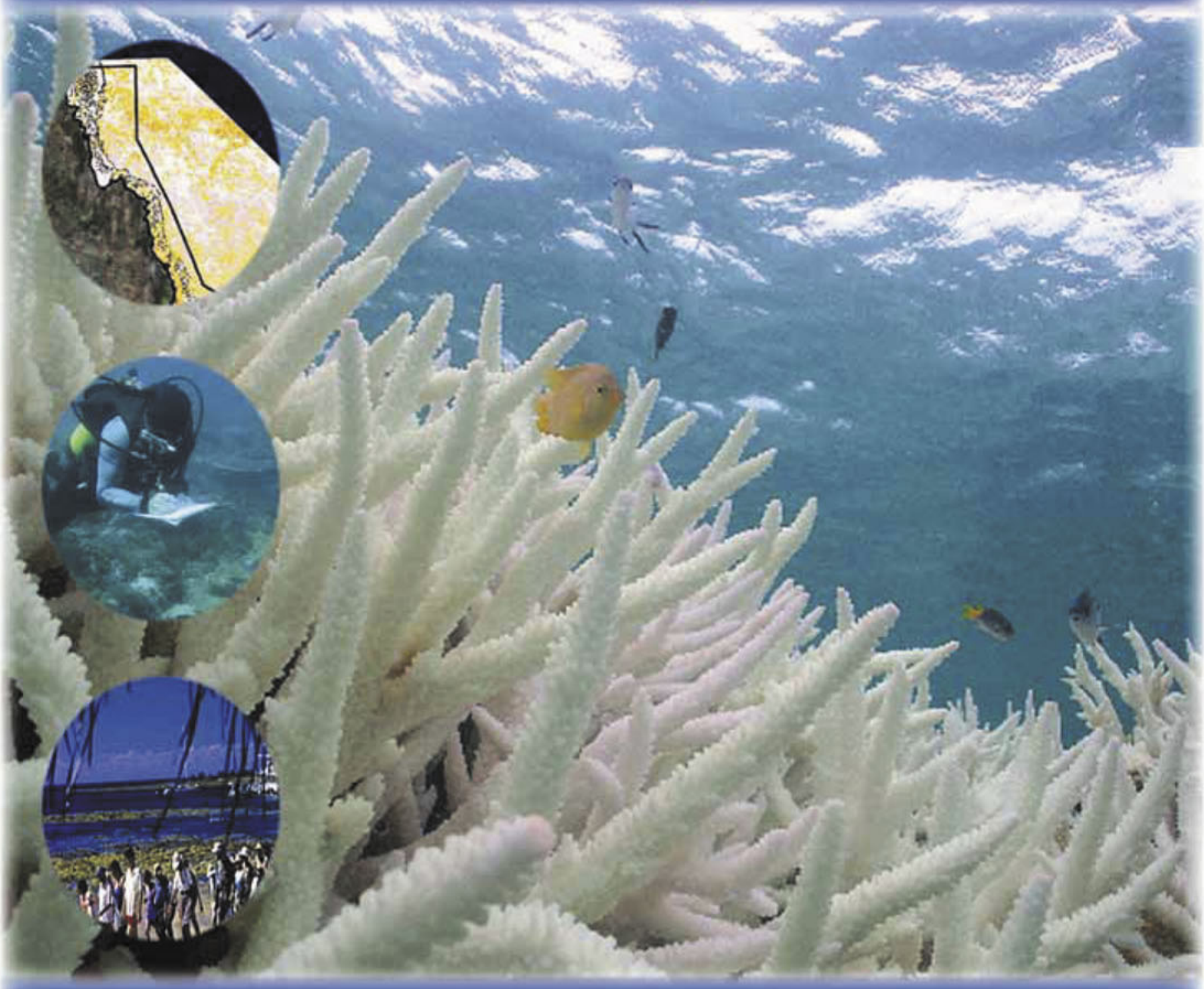
Australian Government
Great Barrier Reef
Marine Park Authority

Great Barrier Reef
Coral Bleaching Response Plan
summer 2007 - 2008



Climate Change Group

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Published by the Great Barrier Reef Marine Park Authority

ISBN: 978-1-876945-65-7

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1. Introduction

Large-scale coral bleaching events, driven by unusually warm sea temperatures, have now affected every major coral reef ecosystem on the planet (Wilkinson 2004). The effects of coral bleaching are pervasive, and potentially devastating to ecosystems and the people and industries that depend upon them. The frequency and severity of these large-scale disturbances is predicted to increase as temperatures continue to warm under a global regime of climate change. Climate change, in combination with the multitude of other stressors resulting from human activities, is leading to unprecedented pressure on coral reefs. Understanding the effects and implications of coral bleaching, and identifying strategies to reduce stress and mitigate impacts, are urgent challenges for the conservation and management of coral reefs worldwide.

The Great Barrier Reef (GBR) has experienced two major coral bleaching events in recent years: 1998 and 2002. The spatial extent of these events, combined with the high level of mortality seen at severely affected sites, has lead to widespread concern about the future of the Great Barrier Reef in the face of global climate change. The Great Barrier Reef Marine Park Authority (GBRMPA), in collaboration with the Australian Greenhouse Office, has initiated a climate change critical issue group to address the challenges of climate change for the Great Barrier Reef. The climate change group aims to improve understanding of the linkages between major components of the social-ecological system, to evaluate their vulnerability under future climate scenarios, and to identify strategies to minimise the impacts of climate change.

The GBRMPA's Coral Bleaching Response Plan (the response plan) has been developed to provide an early warning system of conditions that lead to coral bleaching. The response plan outlines methods to document the extent and severity of coral bleaching, using broad-scale synoptic surveys to quantify the area of bleached coral and intensive in-water surveys to document the ecological impacts of coral bleaching. The information collected under this plan can be used to compare and analyse the frequency and patterns of bleaching events and to develop forecasting tools.

This plan has been developed to complement other monitoring programmes and to facilitate data exchange and synthesis. The bleaching survey design uses the Australian Institute of Marine Science (AIMS) Long-term Monitoring Programme protocol and field sites. The broad-scale synoptic surveys are carried out in collaboration with the remote sensing group at the University of Queensland and CSIRO.

The response plan was first developed in 2003 (Figure 1). Improvements to the response plan have been developed each year and trialled and reviewed prior to their incorporation. Ongoing updates have also been informed by feedback from participants in the response plan (eg BleachWatch volunteers).

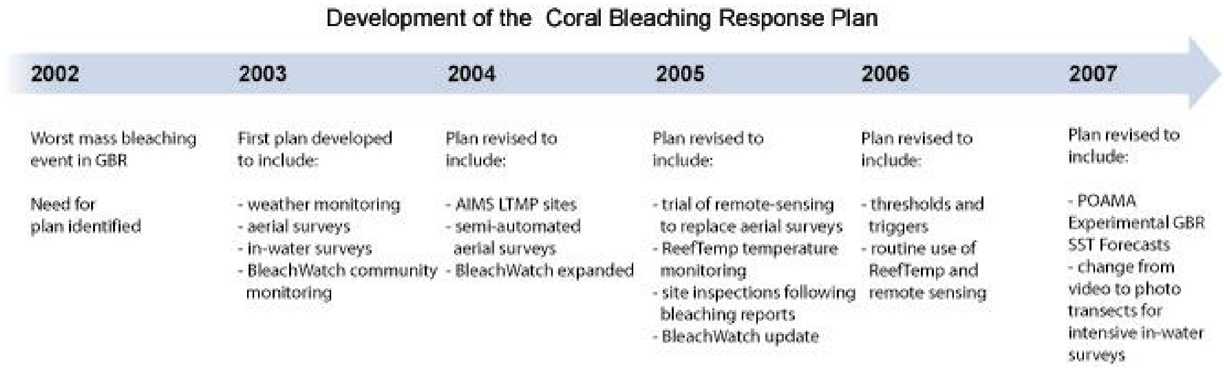


Figure 1: Timeline for the development of the Coral Bleaching Response Plan

2. Plan Overview

This document describes the response plan for the Great Barrier Reef. This will enable GBRMPA to:

- develop a system to forecast bleaching events
- provide early warnings of a major bleaching event
- measure the spatial extent and severity of bleaching events
- assess the ecological impacts of bleaching events
- involve the community in monitoring the health of the Great Barrier Reef
- communicate and raise awareness about coral bleaching and climate change impacts on the Great Barrier Reef
- provide information to evaluate the implications of coral bleaching events for management policy and strategies.

The response plan has been developed in conjunction with *A Global Protocol for Assessment and Monitoring of Coral Bleaching* (prepared by WWF, FishBase and GBRMPA) and *A Reef Manager's Guide to Coral Bleaching* (an international collaborative effort led by the US Coral Reef Task Force and GBRMPA) to maximise comparability and consistency with bleaching response plans in other regions. The response plan also links in with Great Barrier Reef tourism industry-based monitoring programmes such as Eye on the Reef[1] and the marine monitoring component of the Reef Water Quality Protection Plan[2].

The response plan has three main components that feed into and are dependant on each other (Figure 2). These are described in further detail in sections 3, 4 and 5:

- Early Warning System
- Bleaching Assessment and Monitoring
- Communication Strategy

[1] http://www.eyeonthereef.com.au/
[2] http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/management.html

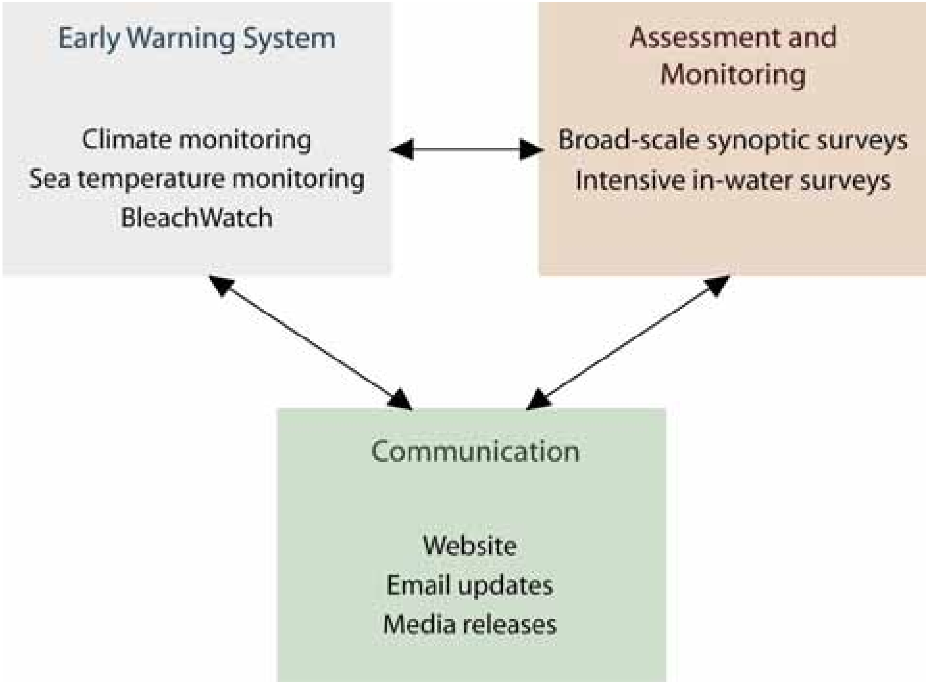


Figure 2: Components of the Great Barrier Reef Coral Bleaching Response Plan

2.1 Objectives of the response plan

The broad objectives of the response plan are to document and assess:

1. The extent and severity of coral bleaching (if an event occurs).
2. The duration of a coral bleaching event.
3. The ecological impacts of a coral bleaching event including changes to:
    a. species diversity and/or coral cover
    b. relative abundance of different species eg reef structure and habitat complexity
    c. impacts on other species
    d. the ability of reefs to recover after an impact.
4. Other anthropogenic stresses that may affect the severity of coral bleaching and recovery in collaboration with other reef managers.

These outcomes will also feed into and provide the foundation for the identification of social and economic impacts of coral bleaching. These are considered in further detail in the Great Barrier Reef Climate Change Action Plan 2007 - 2012.

2.2 Selecting appropriate coral bleaching monitoring tasks for the Great Barrier Reef

The Global Protocol outlines a range of monitoring activities aimed at addressing the objectives of a coral bleaching monitoring plan. It provides a guide to the types and frequency of monitoring which should be considered depending on resource availability and the objectives of the monitoring plan. Table 1 is an abbreviated version of that found in The Global Protocol. Current resource availability enables the response plan to adopt high resource scenario recommendations (last column). All options under the low, moderate and high resource availability scenarios are also recommended under this scenario.

Table 1 Monitoring activities recommended by The Global Protocol

Question	Resource scenarios		
	1. Low	**2. Medium**	**3. High**
A What is the general extent and severity of the current bleaching event?	- Circulate questionnaires amongst reef users - Submit information to ReefBase	- Identify major species affected (take photos or video footage)	A1 and A2 plus - Conduct detailed surveys - Use remote sensing to obtain synoptic estimates of bleaching
B Is the bleaching associated with specific environmental factors such as temperature, solar radiation, water circulation?	- Ask reef users to collect parallel environmental data	- Get local weather data - Consult with oceanographers on circulation patterns - Compare bleaching records NOAA's hotspots and degree heating weeks	B1 and B2 plus, at key sites - Install temperature loggers and remote weather stations - Measure currents and tidal flow - Correlate remote sensing data with thermal anomalies and degree heating weeks
C How long will it last and is it a recurring event?	- Ask local reef users to continue recording data		C1, repeat A3 plus - Repeat observations for any subsequent bleaching events
D What are the ecological impacts on the reef system?	- Conduct before and after bleaching observations including mortality and recovery	- Measure benthic cover through time	- Measure benthic cover through time, including other macro-invertebrates, at high taxonomic resolution - Survey fish abundance and diversity
E Are adjacent human impacts causing or exacerbating the bleaching?	- Note location, timing and severity of local human impacts - Ask other reef users for similar information	- Collect basic environmental information at impact sites	- Collect detailed environmental information at control and impact sites - Collate all existing data on human impacts

3. Early Warning System

Mass coral bleaching is preceded by a series of stages. Beginning with the build-up of climatic conditions that warm sea temperatures, above-average water temperatures follow, which in turn can lead to patchy bleaching or bleaching of more vulnerable coral species (Figure 3). If stressful conditions persist, widespread bleaching of a range of coral species can ensue, resulting in a mass bleaching event. The onset of each of these stages can be used to provide an early warning of a mass bleaching event.

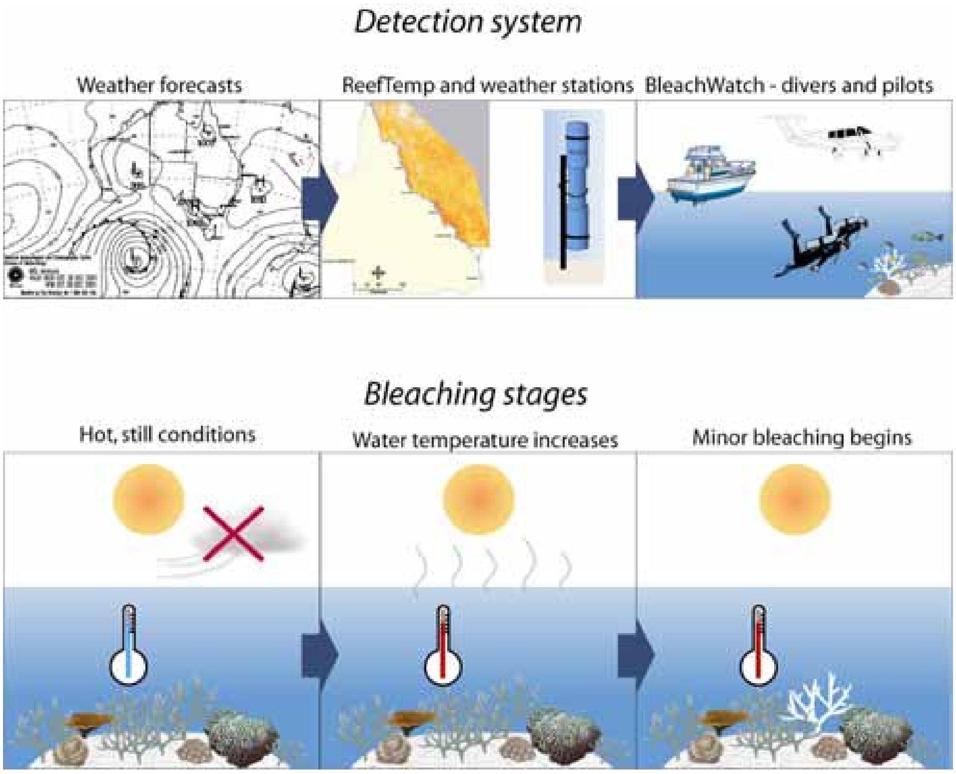


Figure 3: Detection of coral bleaching can occur at a number of stages including (a) forecasts of hot, still conditions, (b) mapping by ReefTemp or weather stations of anomalous high water temperatures, (c) reports by reef users of the initial stages of coral bleaching

The GBRMPA early warning system consists of four elements designed to detect the onset of each of the three stages that lead to a mass coral bleaching event and each of these are described in further detail below:

1. *Climate monitoring*. Forecasts of sea temperature anomalies from the POAMA climate model at the Bureau of Meteorological Research Centre and the development of weather conditions that are conducive to elevated sea temperatures
2. *Sea temperature monitoring*. Persistence of increased sea temperatures to levels known to cause stress to corals
3. *BleachWatch*. Early signs of bleaching on reefs and the spatial extent and severity of any bleaching.

3.1 Climate monitoring

Objectives	To assess the likelihood of elevated sea temperatures occurring
Strategies	• Monitor long-range sea temperature forecasts from the POAMA climate model at the Bureau of Meteorology Research Centre • Obtain and examine 4-day forecasts and weather summaries from the Bureau of Meteorology
Triggers	Forecasts of calm clear conditions, above average summer temperatures, or below average rainfall will trigger logistic preparations for the Bleaching Assessment and Monitoring component, months in advance.

A number of factors are known to cause high water temperatures in the Great Barrier Reef region. In particular, delayed or weak development of the monsoonal trough over northern Australia during summer appears to be a strong precursor to the anomalous warm conditions that cause stress to corals (Figure 4). Based on an emerging understanding of the relationship between weather and sea temperatures for the Great Barrier Reef, current and forecast weather conditions can provide a useful indicator of pending warming of waters in the Great Barrier Reef, and thus serve as early warnings of potential stress. Weather forecasts will be monitored for the onset of these high-risk conditions throughout the summer period.

Even before the summer, the probability that sea temperatures will be warmer than usual can be monitored using an experimental forecasting product developed by the POAMA group at the Bureau of Meteorology. The 'POAMA GBR SST Forecasts[3]' have lead times ranging from 1-8 months and can, therefore, provided an indication of the likelihood conditions will be conducive to bleaching mid-summer (January to February) as early as July. Seasonal climate predictions will also be reviewed in the early stages of summer to monitor the development of regional weather patterns that may lead to anomalous sea temperatures. Above-average sea temperatures are associated with El Niño conditions in many reef regions around the world. The prediction of El Niño conditions will heighten the alert level of the response team to a high risk of bleaching.

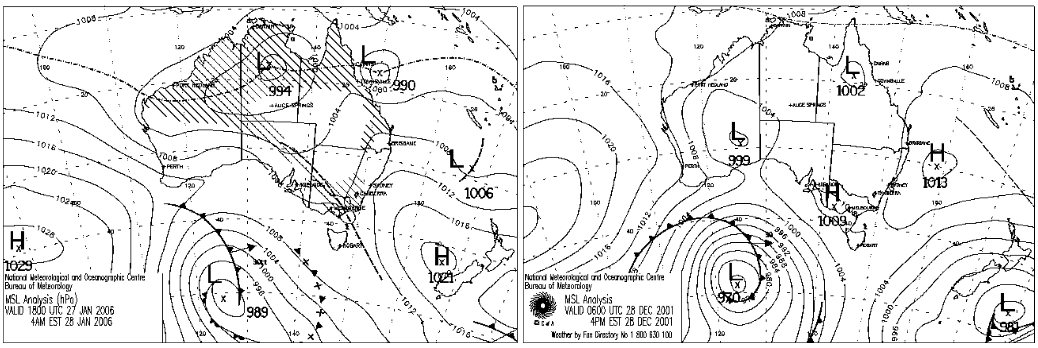


Figure 4: (a) Monsoonal trough development over northern Australia leads to a low risk of high water temperatures. (b) This weather chart from 28 December 2001 leading up to the 2002 mass bleaching event illustrates hot, still conditions that led to anomalously high water temperatures. Weather maps are monitored during summer for the development of high bleaching-risk conditions

[3] http://poama.bom.gov.au/experimental/poama15/sp_gbr.htm

3.2 Sea temperature monitoring

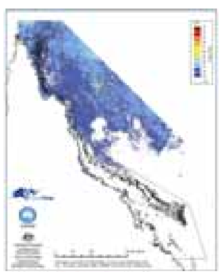
Objectives	Identify sea temperature conditions that could lead to bleaching over summer
Strategies	• Actively monitor ReefTemp • Evaluate sea temperature from weather station data to validate the remotely sensed sea temperatures used in ReefTemp • Actively monitor NOAA HotSpot and Degree Heating Week maps
Triggers	The onset of stressful conditions will trigger increased vigilance of coral condition through BleachWatch and site inspections

A number of conditions can lead to coral bleaching, however it is well established that anomalously high sea temperatures are the primary cause of bleaching. Excessive and persistent sea surface temperature (SST) anomalies indicate sea temperatures are approaching levels that are known to be stressful to corals. Sea temperatures can therefore serve as an early warning of potential bleaching on the Great Barrier Reef.

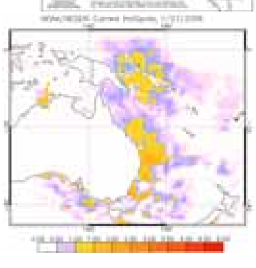
The occurrence of conditions likely to induce bleaching will be monitored using ReefTemp, and the accumulated stress indices therein, as indicators of local thermal stress during the summer. ReefTemp was developed and trialled in previous years by GBRMPA in collaboration with the Bureau of Meteorology (BoM) and the Commonwealth Scientific and Industrial Research Organization Marine and Atmospheric Research (CMAR). It is a locally developed equivalent of the National Oceanic and Atmospheric Administration's (NOAA) HotSpot programme at 2 km resolution. It provides an improved ability to monitor thermal stress, and allows for the now-casting of bleaching risk at the scale of an individual reef. Images of the (a) sea surface temperature anomaly, (b) number of degree heating days (DHD) and (c) rate of heat stress accumulation, or 'heating rate' are updated on the ReefTemp website daily (Figure 5). The sea surface temperature anomaly is the temperature above the long-term average for that month, while the degree heating days is an index that incorporates both the intensity and duration of heat stress. A degree heating day is equivalent to one day in which temperature increases by 1°C above the long-term average. The heating rate indicates the intensity of the temperature anomaly, it is calculated as degree heating days divided by the number of days temperatures have exceeded the long-term average.

Using both ReefTemp and NOAA HotSpots

The **GBRMPA ReefTemp** anomaly maps show the number of degrees C above the long-term average temperature for that month calculated using monthly data from 1993 to 2003 at a 2 km resolution. ReefTemp also provides maps of actual sea surface temperatures, degree heating days and rate of heating.



The **NOAA HotSpot** maps show regions where the sea surface temperature is 1 degree C or more greater than the maximum expected summer time temperature (i.e. warmest sea temperature for the summer period). Coral bleaching events have been noted in areas where the HotSpots are greater than 1 degree C.



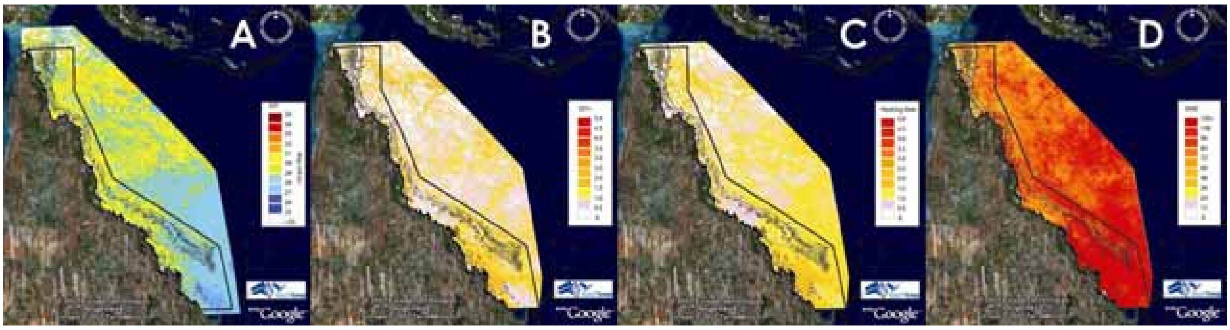


Figure 5: Examples of the ReefTemp maps available on the GBRMPA website throughout the summer period including (A) sea surface temperature, (B) sea surface temperature anomalies, (C) degree heating days, and (D) heating rate.

In addition, in situ measurements of local sea temperatures are available from a network of weather stations that are installed on the Great Barrier Reef and maintained through an AIMS and GBRMPA collaboration. These weather stations record water temperature at the surface and at 6 m depth, providing important information about any depth-related variability in water temperatures, while also providing a mechanism to ground-truth ReefTemp predictions.

3.3 BleachWatch

Objectives	To detect the early stages of coral bleaching events over a wide geographic area To involve the community in reef monitoring, reef education and reef conservation relating to coral bleaching and climate change
Strategies	• Develop and maintain a network of regular reef users who will provide reports of coral bleaching • Develop and maintain a dedicated BleachWatch website, including a downloadable version of the datasheet, and on-line reporting capabilities through the ReefBase website • Provide operators with a BleachWatch kit that assists them in reporting on reef conditions and detecting coral bleaching • Regularly enter and evaluate data received to determine bleaching susceptibility • Provide regular feedback to all participants in the form of reports, web updates and informal communications
Triggers	Reports of 'moderate' or 'severe' bleaching will trigger the Bleaching Assessment and Monitoring component

Detecting the early signs of a mass bleaching event requires a wide network of observers on the Great Barrier Reef as the initial onset of mass coral bleaching can range from gradual and patchy to rapid and uniform. BleachWatch is a community monitoring initiative that has been designed to provide reliable reports of reef condition over a broad area throughout the Great Barrier Reef. BleachWatch is built on a network of regular reef users, including tourism professionals, scientists, conservation groups, fishers and community members who voluntarily monitor and report on conditions at reefs that they visit. Participation spans the Great Barrier Reef from Port Douglas in the north to Bundaberg in the south. The number and geographic coverage of BleachWatch participants has continued to grow, with 95 participants currently enlisted.

BleachWatch was established at the start of 2002, during the major bleaching event that occurred that summer. BleachWatch participants are provided with a BleachWatch kit and asked to complete reef monitoring forms on a weekly basis. Participants are asked to provide general observer information, as well as details about their site, type of habitat and specific weather conditions that are known to influence the risk of bleaching (ie water temperature, cloud cover, air temperature and wind speed) (Appendix A). Detailed information about reef condition and bleaching observations is also collected only if a change has occurred since the previous submission.

The data submitted by BleachWatch observers will be compiled and synthesised into summary reports every one to two months during the summer season, these will be sent to participants for their information and for display to their clientele on board tourism vessels. The data is reviewed weekly to identify where coral bleaching has been sighted, whether it is spatially or locally significant and whether the assessment and monitoring component of the response plan should be implemented. Less regular or one off reef visitors can also submit observations on reef status and coral bleaching to a central database on the GBRMPA website. At the end of the high bleaching-risk season, a summary report describing BleachWatch participation, bleaching observations and recommendations for future years is prepared and posted on the website.

3.4 BleachWatch (Aerial)

Objectives	To detect the early stages of coral bleaching events over a wide geographic area
Strategies	Implement a partnership with Coastwatch to incorporate bleaching observations and photography into routine surveillance flights covering reefs spanning the full length and breadth of the Great Barrier Reef
Triggers	Reports of 'moderate' or 'severe' bleaching will trigger the Bleaching Assessment and Monitoring component.

BleachWatch (Aerial) is a partnership between the GBRMPA and Coastwatch and benefits from the active involvement of Coastwatch aeroplane pilots and crew who visit an extensive number of reef sites regularly throughout summer. Pilots and crew are trained to identify possible bleaching from the air and asked to take geo-referenced photographs for later analysis. The information collected by BleachWatch (Aerial) helps the GBRMPA detect the onset of bleaching and helps assess the full spatial extent and distribution of a bleaching event.

4. Bleaching Assessment and Monitoring Component

The overall objective of the Bleaching Assessment and Monitoring component is to assess the spatial extent and severity of coral bleaching events and determine the ecological implications (eg coral mortality, shifts in coral community structure and ecosystem flow-on effects) resulting from coral bleaching.

Timing is critical for the implementation of bleaching surveys. A bleaching event can progress quickly once visible signs of stress are prevalent, with only four to six weeks required for bleached corals to either recover or die. On the Great Barrier Reef, the peak of previous bleaching events has occurred around March to April. If assessments are delayed beyond this time, they are likely to provide an underestimate of the amount of bleaching that has occurred as many corals may have died or recovered, making it difficult to confidently attribute any coral mortality to bleaching-related stress. The early warning system is essential for providing early information on the onset of the bleaching events.

A two-tiered approach will provide the best possible combination of both spatial coverage and detailed information. The bleaching assessment and monitoring component is comprised of broad-scale synoptic surveys and intensive in-water surveys. This tiered approach is the most effective for obtaining a full overview of where bleaching is occurring from a Great Barrier Reef-wide perspective.

4.1 Site inspections

Objectives	Verify reports of coral bleaching for select locations along the Great Barrier Reef
Strategies	• Work with BleachWatch participants to revisit sites where bleaching has been reported, and discuss bleaching reports • Rapid visual assessments to document coral cover, community composition and severity of bleaching at select locations

When reports of moderate or severe bleaching are received from BleachWatch participants, the reports are verified by the GBRMPA through two means: (1) discussions with the participants and (2) site inspections using the standard bleaching rapid assessment technique, but not structured transects. This is an effective means of confirming early bleaching reports and liaising with BleachWatch participants, who know the sites well.

The site inspections provide basic information about the coral community at the site, the percentage and types of corals that are bleached and the severity of the bleaching in near real-time. Details on the rapid assessment survey method are outlined in section 4.3.

4.2 Broad-scale synoptic surveys

Objectives	Assess the spatial extent and distribution of coral bleaching along the Great Barrier Reef
Strategies	Use satellite imagery (at a spatially relevant scale) to document coral cover and extent of bleaching
	Build a hierarchical system using satellite imagery, and in-water data to improve the predictive capacity of remote sensing tools

Sea surface temperature is a reliable indicator of regional-scale stress but is not necessarily an accurate predictor of bleaching at individual reefs. Broad-scale synoptic surveys using remote sensing are the most effective method for obtaining an overview of where bleaching has occurred over spatial scales that are relevant to management of the Great Barrier Reef (ie hundreds to thousands of kilometres). As well as providing crucial baseline data, remote-sensing surveys help to identify the reefs or regions worst affected by bleaching.

During the 2005 to 2006 summer, a pilot project trialed MERIS remote sensing mapping to detect coral bleaching at 300 m resolution. The pilot project included field validation of MERIS (provided by CSIRO) and Quickbird (provided by the Centre for Remote Sensing and Spatial Information Science at the University of Queensland) satellite images to provide a high level of detail on the health of corals during a localised bleaching event. Due to the high resolution, the pilot project was spatially limited to inshore reefs around the Keppel Islands. The MERIS data was also captured for other reefs in the Great Barrier Reef where bleaching did not occur, to test the mapping algorithm developed at CSIRO, for both inshore and offshore reefs.

During a coral bleaching event, MERIS remote sensing mapping (300 m pixels) will be used to detect the extent of bleaching in the Great Barrier Reef. This satellite information will be validated in the field using intensive in-water surveys at a local scale. If there is only localised bleaching, Quickbird (2.4 m pixels) image data will also be captured as they cover an area of 10 km × 10 km sections and provide more detailed resolution to map bleached versus non-bleached coral areas at a smaller scale.

4.3 Intensive in-water surveys

Objectives	Assess the percentage of coral bleaching, mortality and ecological implications for select reefs along the Great Barrier Reef
Strategies	• Rapid visual assessments to document coral cover, community composition and severity of bleaching at target reefs • Photo transects to quantify coral cover, community composition and extent and pattern of bleaching at target reefs • Ground truth broad-scale synoptic data using intensive surveys

Fortunately, widespread bleaching does not necessarily equate to widespread coral mortality. After bleaching, corals can again recover their zooxanthellae and survive, or they can die. Severe bleaching events have the potential to kill large areas of living coral, and consequently cause major disturbance to coral reef ecosystems. To better understand the long-term implications of these events, the extent and patterns of coral mortality that result from bleaching need to be measured.

Intensive surveys will provide more precise information about the percentage and types of corals that bleach and then subsequently die. Changes to coral community structure that may occur because of bleaching and mortality will be detected. Information on whether certain community types are more susceptible to bleaching than others can be obtained from the surveys. Bleaching trends between sites with similar characteristics, or through time, can also be tested by analysis of the intensive survey data.

Intensive surveys constitute rapid visual assessment and more detailed video transects which will be carried out simultaneously along transects. The two techniques are designed to be complimentary: the rapid assessment provides basic information about the severity of the bleaching event in near real-time, while the video transects provide more detailed information, but require intensive analysis that normally takes weeks to months to complete. Details on site selection and survey methods are outlined in the following section ‘Survey Design and Methods’.

Recovery rates of reefs impacted severely by bleaching will continue to be surveyed for at least one year to quantify the long-term ecological impacts and recovery. These surveys will include rapid assessments as a minimum, and are likely to also include video transects. At locations where severe mortality is recorded, data on algal growth and coral recruitment over time may also be collected.

4.3.1 Temporal scale

An accurate description of coral bleaching and its impacts requires multiple surveys through time as bleaching is dynamic over spatial and temporal scales. To characterise the extent and severity of bleaching and the ecological implications (ie the amount of mortality that occurs) requires three temporal surveys:

1. Baseline surveys document reef status (coral cover and composition) prior to any changes caused by bleaching. This is best conducted before the onset of bleaching. The response plan will utilise AIMS Long-term Monitoring Programme data from the previous survey period.

2. Event monitoring will coincide with the peak of the bleaching event, and will be used to document the spatial and taxonomic patterns of bleaching. Each survey will assess the condition and composition of the benthic community along five cross-shelf transects. This information is necessary to report on the extent and severity of bleaching, and to interpret the causes and significance of changes in reef condition.

3. Recovery monitoring will be carried out shortly after the bleaching event, but not until all corals have either recovered or died. Multiple recovery surveys may be conducted depending on the level of mortality. This survey determines the ecological impacts of the bleaching by assessing changes in coral cover or composition attributable to the bleaching event. The AIMS Long-term Monitoring Programme data set from the next survey period will be used to determine reef status after the bleaching event.

4.3.2 Spatial scale and survey sites

The response plan will build on the AIMS Long-term Monitoring Programme, which has a suite of sites that represent cross-shelf as well as latitudinal gradients. By adopting the AIMS Long-term Monitoring Programme sites, baseline and recovery data can be easily incorporated into the intensive surveys. The transects will be located at latitudes centred on Lizard Island, Cairns, Townsville, Whitsunday Islands and the Capricorn Bunker Group (Figure 6). Three inshore, three mid-shelf and three outer shelf reefs have been selected for each transect. Sites from the AIMS Long-term Monitoring Programme database were selected for the response plan based on the existence of previous coral bleaching survey data (1998 and 2002), accessibility under predominant weather conditions and location of Reef Water Quality Protection Plan (see section 4.2.5) survey sites.

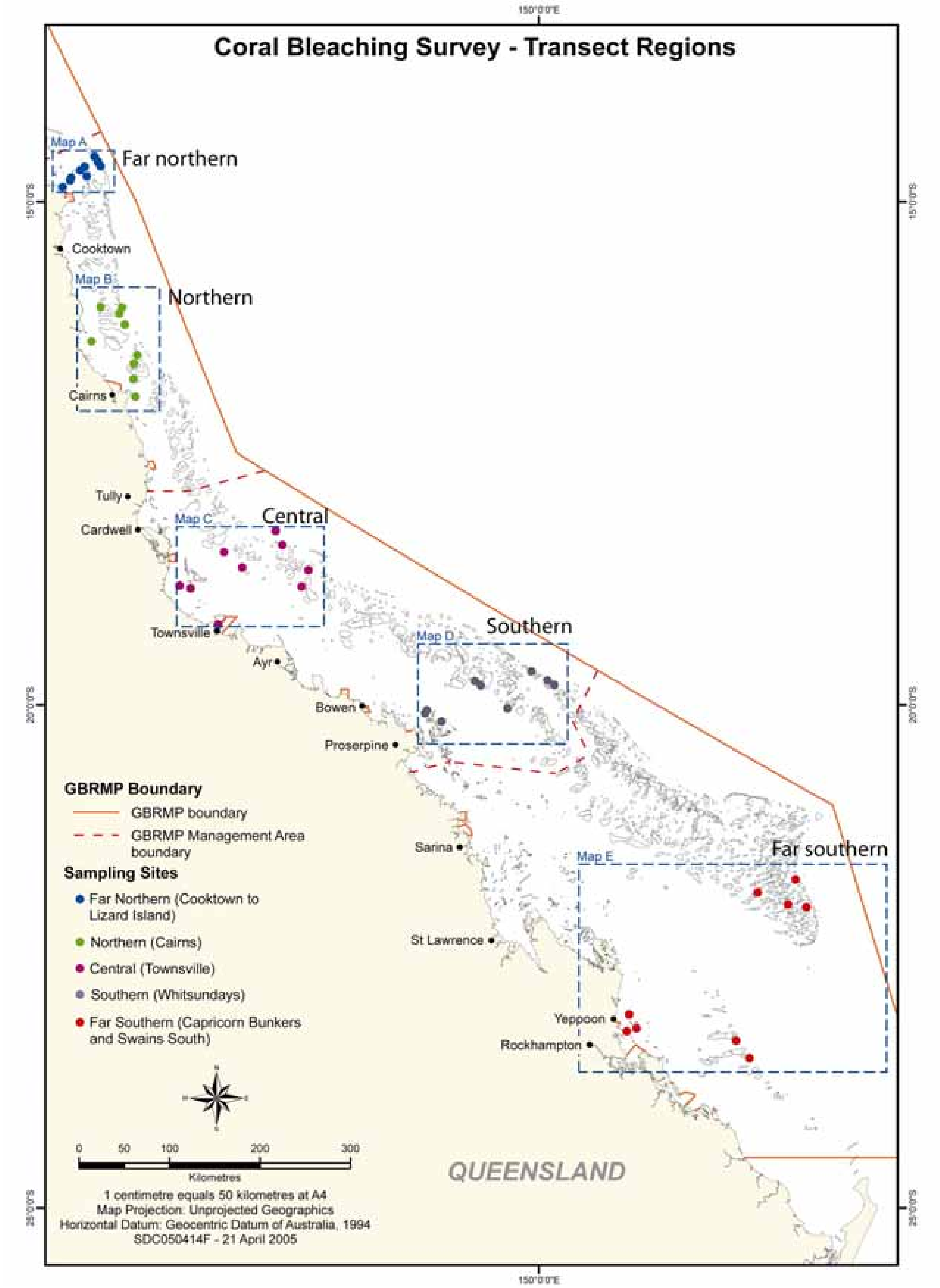


Figure 6: Bleaching survey monitoring sites adopted from the AIMS Long-term Monitoring Programme. There are three inshore, mid-shelf and outer reef monitoring sites for each of the five transects. See appendix B for detailed maps of each transect and for site coordinates

The benefit of this approach is that baseline and recovery data for the deep transects can be obtained from the AIMS Long-term Monitoring Programme routine surveys and thus reduce the need for multiple GBRMPA survey trips and duplication with existing programmes. However, the Long-term Monitoring Programme only surveys the coral community on the lower reef slope (6–9 m) while the GBRMPA response plan also surveys the community on the upper slope (1–4 m), as this is the area of reefs usually worse affected by coral bleaching. Quantitative baseline assessments of the upper slope community have been previously carried out to enable evaluation of the long-term ecological impacts of coral bleaching on the Great Barrier Reef.

Some remote locations along the Great Barrier Reef, such as the northern Swains and Pompey Complex, are not included in the response plan. These are difficult to access and there are no representative AIMS Long-term Monitoring Programme survey sites in these locations; long-term datasets are therefore not available. If a significant bleaching event occurs and logistics allow, these sites will be surveyed.

Additional sites may also be surveyed during a bleaching event. These sites will be selected to match those surveyed during the 1998 and 2002 bleaching events, reefs surveyed under the Reef Plan monitoring programme (eg Daydream Island, Dent Island and Double Cone Island), and other sites of interest. Rapid monitoring techniques will be employed at these sites, such as manta tow or rapid-assessment surveys (see below), as time and resources permit.

4.3.3 Design and data analysis

Each intensive survey site will be divided into two depth zones: shallow and deep. The shallow station includes the reef crest and upper slope from about 1–4 m in depth while the deep station includes the mid to lower reef slope from 6–9 m. Actual depths at each station vary according to the reef morphology and coral community type and distribution. At more turbid stations, or areas with poorer reef development, these depths may be shallower, while at stations that are generally characterised by clear conditions they are deeper. In the few stations with very restricted reef development, only the shallow depth zone is present. These depth zones have been fixed for each station.

Three random 50 m transects will be surveyed at each depth, at each site. Random transects will be used rather than fixed transects to reduce time required for establishment and survey, to avoid unsightly markers on the reef and to ensure independence among consecutive surveys. Each transect will be surveyed simultaneously by two independent divers conducting: (1) a rapid assessment survey and (2) a video survey.

The rapid assessment survey will include the area within a 5 m wide band along the length of the transect. Three sets of information will be recorded within this band: (1) site information (site name, depth, transect number and water temperature), (2) coral and algal cover and (3) bleaching severity for each of the major coral groups. All data will be entered directly onto the specially designed data sheets (appendix C). The categories for estimating per cent cover and bleaching stage have been standardised on the survey sheet to enable consistent surveying methods by different observers (appendix D). A table showing schematic representations of per cent cover will be utilised to maximise consistency in estimates made under water (appendix E).

Photo transects will be systematically carried out by holding the camera 40 cm above the substrate and the diver taking 1 photo every mete for a total of 50 meteres.

Data from photo transects will be used to quantify coral cover, community composition, and extent and pattern of bleaching at target reefs. Data will be categorised according to the per cent cover and per cent bleaching pro forma's similar to those used during the rapid assessment surveys (appendix D). All data collected using the rapid visual assessment surveys and photo transects will be stored in a database maintained by the GBRMPA and shared with AIMS.

4.3.5 Complementary studies

AIMS Climate Change Programme: temperature loggers

AIMS coordinate a sea temperature monitoring programme, which includes the deployment and maintenance of weather stations (section 3.2) and deployment and collection of in situ temperature loggers. Temperature loggers have been placed on the reef flat, at or the near Lowest Astronomical Tide, and on the reef slope at ~50 locations spanning the extent of the Great Barrier Reef. At some locations, loggers have been placed on the upper reef slope (~5–9 m), or on the deep reef slope (~20 m). The lengthy retrieval time of these loggers and the delay between changes of sea temperature and obtaining the data precludes them from contributing to an early warning system. Instead, data from these loggers has been used to strengthen our understanding of the link between temperature and bleaching, particularly for the 1998 and 2002 mass bleaching events. Bleaching 'thresholds' developed from this research and real time temperature data can currently be monitored at the weather station sites on the Reef Futures website[4], and are an important component of the early warning system in the response plan.

AIMS Long-term Monitoring Programme

The AIMS Long-term Monitoring Programme has been tracking the condition of the Great Barrier Reef for more than a decade, by surveying fish, corals, crown-of-thorns starfish, and coral disease. The AIMS monitoring team is the one of the premier bodies focussing on the condition of coral reef ecosystems in the Great Barrier Reef. The response plan utilises the information collected under the Long-term Monitoring Programme to obtain baseline and recovery data.

Reef Water Quality Protection Plan

The Reef Water Quality Protection Plan (the reef plan) is a joint Australian and Queensland Government initiative to 'halt and reverse the decline in water quality entering the reef within 10 years'. The reef plan has a number of actions for addressing declining water quality, including the implementation of a water quality and ecosystem health long-term monitoring programme in the Great Barrier Reef lagoon. Water quality data collected for the reef plan will be utilised to assess the influence of water quality stressors on susceptibility to bleaching and recovery post-bleaching. The reef plan monitoring programme will collect information on temperature, salinity, turbidity, chlorophyll *a*, sediment and nutrients loads, flood events (pollutant loads, salinity and flow), pesticide concentrations and reef health at a number of inshore locations. Some of the reef plan sites are also intensive survey sites adopted by the response plan. Additional information on these sites could be obtained using broad-scale synoptic surveys and targeted intensive surveys during a severe bleaching event.

[4] http://www.aims.gov.au/reeffutures

5. Communication Strategy

Objectives	To increase awareness of the implications of climate change for the Great Barrier Reef, and the occurrence and consequences of coral bleaching events
Strategies	• Website and web-based current conditions reports • Email distribution of current conditions reports to stakeholder groups • Media statements • Senior management and ministerial briefings • Books, reports and fact sheets
Triggers	Commencement of summer

Coral bleaching has implications for and attracts strong interest from the public, the media and senior decision-makers. It is important to provide clear, yet comprehensive, background information in readily accessible formats. This will raise awareness of coral bleaching issues and ensure discussions and debates are well informed. Throughout the high bleaching-risk period, the response team will also proactively release the latest accurate information about coral bleaching risks and events. The response plan will be the main source of timely and credible information on coral bleaching on the Great Barrier Reef, and on the ecological implications for the reef ecosystem.

1. *The Website* will be the first port-of-call for anyone interested in information on climate change and coral bleaching. In addition to providing background information on climate change and implications for the Great Barrier Reef, 'current conditions' reports will be regularly posted on the web throughout summer. Beginning in November, reports will be posted every two to four weeks presenting the most current information on climate and local weather conditions and the potential for coral bleaching.

2. *Email* alerts of web updates and reports will also be sent directly to:
   - all GBRMPA staff
   - GBRMPA networks (including GBRMPA initiatives such as Eye on The Reef, BleachWatch, Local Marine Advisory Committees)
   - email lists (Australian Coral Reef Society, MTSRF, ARC Reef)
   - Response Plan collaborators (AIMS, National Oceanic and Atmospheric Administration (NOAA), GBRMPA's Day to Day Management (DDM) administered through Queensland Parks and Wildlife Service (QPWS).

3. *Public meetings and industry newsletters* will provide a means for distribution of updates.

4. *Media* statements may be prepared and released if/when:
   - conditions develop which indicate a high risk of coral bleaching
   - a 'moderate' to 'severe' bleaching event occurs (describing spatial extent and severity)
   - the bleaching event has concluded (describing coral mortality and ecological impacts).

5. *Briefings* to GBRMPA senior management team and the Minister for the Environment and Heritage will be regularly prepared throughout the bleaching season (see section 6.2)

6. *Fact sheets* describing coral bleaching and climate change and a *book* describing bleaching management (*A Reef Manager's Guide*) will be available on an ongoing basis.

7. *Summary reports* describing the spatial extent, severity and ecological consequences of coral bleaching will be posted on the web at the end of summer. In addition to this, a report summarising data collected by BleachWatch volunteers will be posted on the web and sent to participants (see section 3.3).

6. Implementation

Objectives	Implement the response plan in a timely and efficient manor
Strategies	• Develop and adopt schedules for the early identification of bleaching and responding to moderate to severe bleaching • Develop strategies to coordinate with collaborators
Triggers	The plan will be implemented each summer, with implementation of responsive stages dependant on high risk or moderate to severe occurrence of coral bleaching

The tasks performed throughout the high bleaching-risk period and decision points for implementation of the response plan are shown in the schedule below (Figure 7). Climate and weather conditions will be monitored from mid-November, approximately three months prior to the period of greatest bleaching risk. Sea temperature monitoring and BleachWatch will be implemented from December each summer. If the onset of high bleaching risk conditions is confirmed, or if there are any reports of significant coral bleaching, the bleaching assessment and monitoring component of the response plan will be implemented.

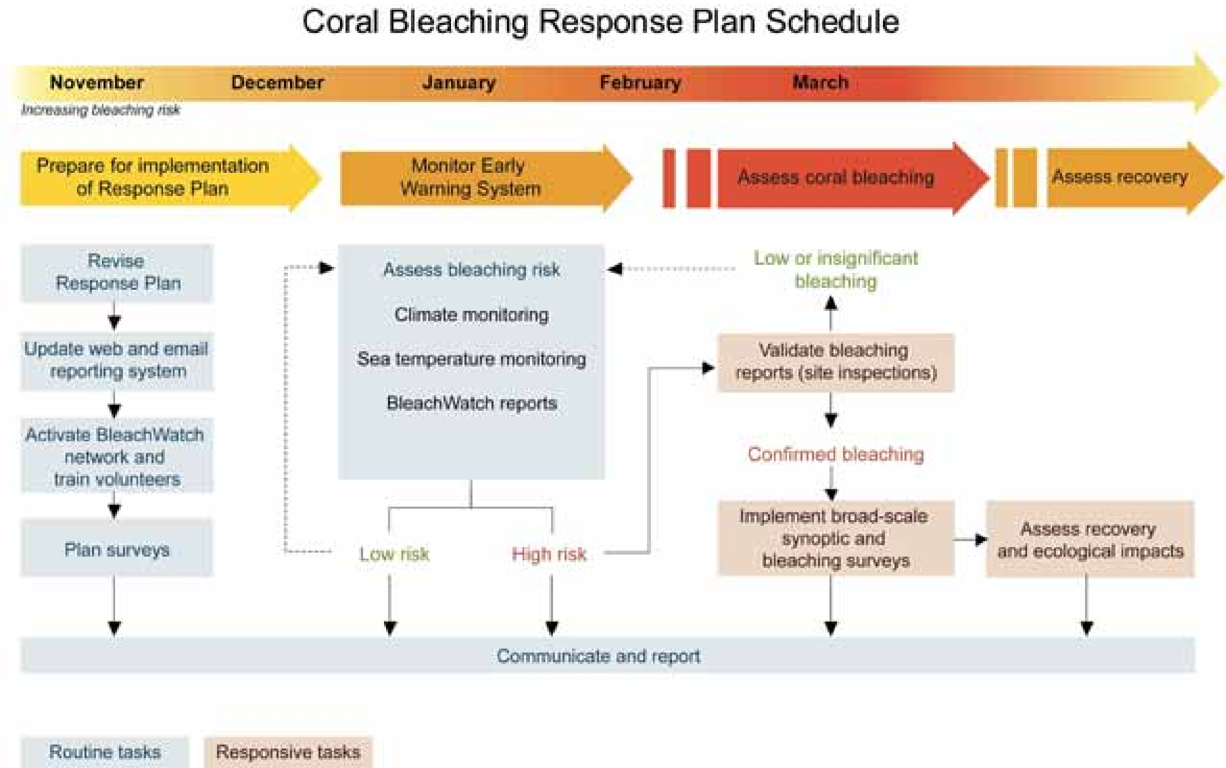


Figure 7. Schedule for implementation of the response plan

6.1 Response schedule

The response plan consists of a combination of routine tasks (in blue boxes, Figure 7) and responsive tasks that are triggered by thresholds (in red boxes, Figure 7). Routine tasks provide the basic information to determine when a bleaching event occurs, and to ensure the response team is prepared for the responsive tasks. Responsive tasks are implemented if moderate or severe bleaching is reported, and are designed to provide a more detailed picture of bleaching conditions and their ecological significance. The first stage in the responsive tasks are to confirm bleaching reports, if these are not validated, the responsive phase will not continue any further. An outline of these tasks is provided below.

6.1.1 Routine Tasks

- Prepare for implementation of responsive tasks
- Assess probability of stressful conditions to corals based on long-term climate predictions for summer (ie ENSO conditions; development of monsoonal trough)
- Establish bleaching reporting system, including email updates and website
- Activate BleachWatch networks, BleachWatch training
- Monitor weather conditions and sea temperatures and compare against thresholds
- Update assessment of conditions and predicted levels of stress to corals
- Solicit and coordinate information about early signs of bleaching through BleachWatch
- Advise GBRMPA senior management team and the Minister for the Environment and Heritage of any increase in bleaching risk or bleaching reports

6.1.2 Responsive Tasks

- Confirm bleaching reports (site inspections)
- Advise GBRMPA senior management team, the Minister for the Environment and Heritage, stakeholder groups and the community of onset of coral bleaching
- Implement broad-scale synoptic surveys to assess bleaching extent
- Deploy survey team to measure extent and severity of bleaching using intensive surveys
- Monitor ecological impacts of bleaching

6.2 Reporting and briefing schedules

The response plan outlines a number of tasks to be executed throughout the summer high bleaching-risk period. Table 2 details the schedule with which these tasks will be undertaken by the response team and the schedule for reporting information to all sectors.

Table 2: Response plan tasks and reporting schedule

Frequency	Timing	Information
Weekly	Monday	Check GBRMPA ReefTemp and NOAA HotSpot maps on web
		Receive updated Great Barrier Reef sea temperature graphs from AIMS
		Review weekly weather summary, eg air temp, cloud cover and wind from Bureau of Meteorology
		Review BleachWatch (including BleachWatch Aerial) reports and update maps
		Print out ReefTemp and NOAA HotSpot maps for GBRMPA Science Technology and Information Group Director to brief senior management team
Weekly/ fortnightly	Tuesday	Summarise weather, sea and coral conditions and draft bleaching risk current conditions report for website. Include recent images.
Weekly/ fortnightly	Wednesday	Have updated current conditions report reviewed, approved and published on external web
		Announce web update and send brief report
Weekly/ fortnightly	Constant	Monitor extent of bleaching using existing information channels and evaluate for trends (ie change in bleaching extent)
		Advise GBRMPA senior management team and the Minister for the Environment and Heritage if dramatic worsening of conditions is evident
Event-based	High bleaching risk[1]	Actively solicit confirmatory bleaching reports from reliable sources, including BleachWatch participants, Day-to-Day Management field officers, AIMS, other researchers, etc.
		Alert relevant project coordinators and managers
		Brief GBRMPA senior management team
Event-based	Moderate bleaching event detected[1]	Brief GBRMPA executive and the Minister for the Environment and Heritage
		Prepare media position, draft statement and consult with GBRMPA media coordinator and executive
		Brief all GBRMPA staff, stakeholders and collaborators
		Release media statement
		Actively promote and solicit submissions to online bleaching reports to provide wide spatial coverage
		Implement Bleaching Assessment and Monitoring component

[1]see Section 6.3 for description of thresholds/triggers for event-based tasks.

In addition to the task and reporting schedule outlined in Table 2, a briefing schedule for GBRMPA senior management team, the Minister for the Environment and Heritage and stakeholders is outlined in Table 3. This schedule ensures that these groups are aware of when delivery of reports is expected and adherence to this schedule by the response team ensures the timely delivery of regular updates.

Table 3: Briefing schedule to senior management, the minister, the press and the message to be conveyed according to the risk or severity of bleaching

Approx. date	Trigger[1]	Briefings			
		Senior Management	Minister	Stakeholders	Message
1 Dec		^	^	^	Summer approaching; bleaching risk period; GBRMPA prepared
20 Dec		^			Temperature trends for December; plans for Christmas break
	High bleaching risk	^	^		Temperatures unusually high; coral bleaching event probable
	Moderate bleaching	^	^	^	High temperatures recorded; moderate bleaching observed; areas worst affected
	Severe bleaching[2]	^	^	^	Very high temperatures recorded; severe bleaching observed; areas worst affected; mortality likely
15 Feb[3]		^			Temperature trends for first half of summer; summary of reports of coral bleaching
31 March	No bleaching	^	^	^	Summer concluding; bleaching risk period over; no significant bleaching observed
	Moderate or severe bleaching	^	^	^	High water temperatures recorded during summer; bleaching observed; preliminary assessment of extent and severity; detailed surveys underway
31 April	Moderate or severe bleaching	^	^	^	Summary of full extent and severity of bleaching; implications for Great Barrier Reef
Monthly[4]		^			Updates on temperature trends and coral condition; also publish to web and email to all staff

[1]Event-based triggers are defined in Table 4 of the response plan
[2]Site inspections and surveys are likely to have been triggered by moderate bleaching
[3]This briefing will not be necessary if moderate or severe bleaching event has already been declared
[4]These reports may be twice-monthly if conditions are changing rapidly

6.3 Definition of triggers for implementation plan

The following definitions will be used to set triggers in the task and briefing schedules during the implementation of the response plan:

'High bleaching risk' is defined as:

- Persistence of strong hotspots (anomaly > 1.5 °C) for two weeks or very strong hotspots (anomaly > 2 °C) for one week over majority of Great Barrier Reef region;
- Degree heating days index is greater than 21 at multiple sites;
- Bleaching thresholds exceeded at inshore *and* offshore sites; **or**
- There are anecdotal reports of bleaching from multiple sites.

'Low bleaching level' is defined as:

- Reliable reports of low coral bleaching (1–10% of colonies completely white) from multiple sites from multiple locations spanning at least two Great Barrier Reef Marine Park sectors; **or**
- Reliable reports of mild bleaching (10–50%) from a few sites only, scattered throughout the Great Barrier Reef or concentrated in only one sector.

'Moderate bleaching level' is defined as:

- Reliable reports of moderate coral bleaching (10–50% of colonies completely white) from multiple sites from multiple locations spanning at least two Great Barrier Reef Marine Park sectors; **or**
- Reliable reports of severe bleaching (>50%) from a few sites only, scattered throughout the Great Barrier Reef or concentrated in only one sector.

'Severe bleaching level' is defined as:

- Reliable reports of severe to extreme coral bleaching (>50% of colonies completely white) from multiple sites spanning multiple Great Barrier Reef sectors.

7. References

English S, Wilkinson C and Baker V (1997). *Survey Manual for Tropical Marine Resources.* 2nd edition, ASEAN, Australia Marine Science Project, Living Coastal Resources, Australian Institute of Marine Science, Townsville, Australia.

Oliver J, Marshall P, Setiasih N and Hansen L (2004) *A global protocol for assessment and monitoring of coral bleaching*. WorldFish Center and WWF Indonesia, Jakarta, Indonessia.

Wilkinson C (2004). Status of Coral Reefs of the World: 2004 Summary, AIMS.

Appendix A — BleachWatch kit and reporting form

The BleachWatch kit contains reporting forms (enlargement shown next page), fact sheets and identification keys for use both underwater (neoprene armband) and above water, all packaged within a BleachWatch folder.

BleachWatch reporting form page one

Australian Government
Great Barrier Reef
Marine Park Authority

BleachWatch
observe to conserve

1. Observer Details

Observer ID: .... Observation Date: ....

Last Name: .... First Name: .... Email: ....

Phone: .... Vessel/Organisation: ....

Observer Category: Reef Visitor ☐ Marine Tourism Industry ☐ Scientist ☐

Other*(Please specify)*: ....

2. Information about the site

Reef ID /Name: .... Site name: ....

Habitat: Lagoon ☐ Crest ☐ Slope ☐ Flat ☐ Bommie field ☐ Front Reef ☐ Back Reef ☐

Other: ....

Cloud Cover *(please circle)*: Clear Partly Cloudy Mainly cloudy Overcast

Air Temp: ☐ Water Temperature: 0-3m ☐ 5-10m ☐

Wind Speed *(please circle)*: 0 0-5kn 5-10kn 10-15kn >15kn

Is this your first submission? No Yes Has this site changed since your last submission? Yes ☐ No change ☐

3. Reef Condition

- Live Coral at this site *(Table 1)*:

Category 0 (0%) ☐ Category 3 (31-50%) ☐
Category 1 (1-10%) ☐ Category 4 (51-75%) ☐
Category 2 (11-30%) ☐ Category 5 (76-100%) ☐

- Three Most Common Coral Types Present: *(in order of abundance)*

Branching ☐ Bushy ☐
Plate ☐ Digitate ☐
Massive ☐ Encrusting ☐
Soft Coral ☐

4. Bleaching Observations

- Bleached Coral at this site *(Table 1)*:

Category 0 (0%) ☐ Category 3 (31-50%) ☐
Category 1 (1-10%) ☐ Category 4 (51-75%) ☐
Category 2 (11-30%) ☐ Category 5 (76-100%) ☐

- Types Bleached *(Table 2)*:

Branching ☐ Bushy ☐
Plate ☐ Digitate ☐
Massive ☐ Encrusting ☐
Soft Coral ☐

- Most Common Level of Bleaching Severity *(only select one)*:

Bleached only on upper surface ☐
Pale/Fluoro (very light or yellowish) ☐
Totally bleached white ☐
Dead coral with algae ☐

Indicate the depth range of the **bleaching**
Min: ☐ Max: ☐

5. Detailed Types Present / Bleached

	Present	Bleached		Present	Bleached		Present	Bleached
Acropora	☐	☐	Turbinaria	☐	☐	Porites	☐	☐
Fungiidae	☐	☐	Stylophora	☐	☐	Sarcophyton	☐	☐
Pocillopora	☐	☐	Faviidae	☐	☐	Lobophytum	☐	☐
Seriatopora	☐	☐	Montipora	☐	☐	Sinularia	☐	☐

Comments: ....

BleachWatch reporting form page two

Table 1: Amount of Coral or Bleaching

The figure below is designed to assist in estimating percentage cover. It can be used to:

1) estimate the percentage of living coral covering the seafloor; and
2) to estimate the percentage of living coral that is affected by bleaching.

Whether corals are arranged in clumps, dots, networks or patches, the diagrams can be used to determine which category best describes the area you are assessing.

Category 0 absent (0%)

Category 1 (1-10%)

Category 2 (11-30%)

Category 3 (31-50%)

Category 4 (51-75%)

Category 5 (76-100%)

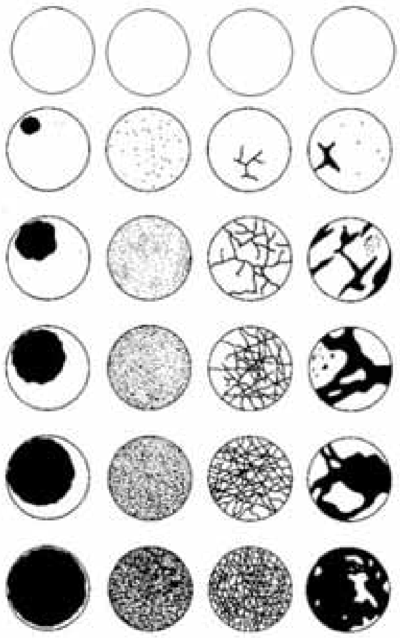


Table 2: Coral ID Key

The diagrams below are a guide to the main lifeforms, or shapes, of corals. Lifeform is a good general indicator of the type of coral, although more experienced observers are encouraged to identify corals to higher levels of resolution (ie. family or genus) where possible.

Branching:
Includes all branching corals
- staghorn
- open branching

Bushy:
Includes all bushy corals
- compact branching

Plates:
Includes all horizontally flattened corals
- table

Digitate:
Includes all digitate corals
- pillar
- knobbly
- finger-like

Massive:
Includes all massive/boulder corals:
- brain
- honeycomb
- kidney (Porites)

Encrusting:
Includes all corals that form thick layers as they grow over the reef surface. (often taking on the shape of whatever they overgrow)

Soft Corals:
Flexible and they move with water motion

Please send back information to the GBRMPA using our reply paid address or website ***www.gbrmpa.gov.au***

REMEMBER: *We still appreciate your weekly reports, whether you have recorded bleaching or not.*

Thank you.

FOLD HERE

Australian Government
Great Barrier Reef Marine Park Authority

Delivery Address:
PO Box 1379
TOWNSVILLE QLD 4810

No stamp required if posted in Australia

ATTACH TAPE HERE

ATTACH TAPE HERE

Great Barrier Reef Marine Park Authority
Reply Paid 1379
TOWNSVILLE QLD 4810

ATTACH TAPE HERE

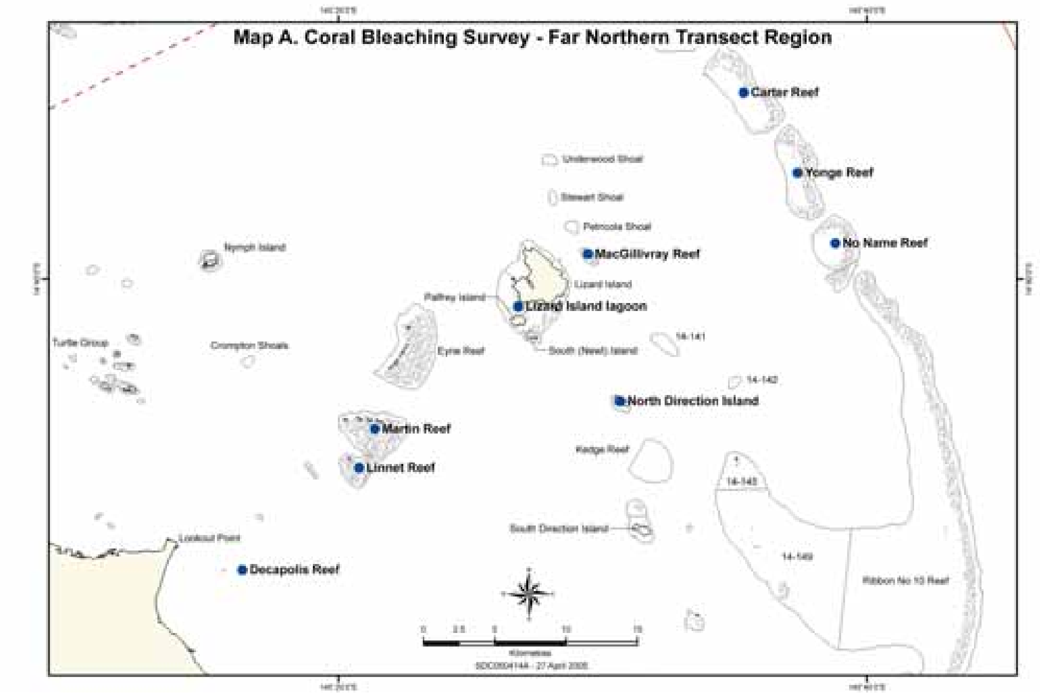
Appendix B — Intensive survey sites

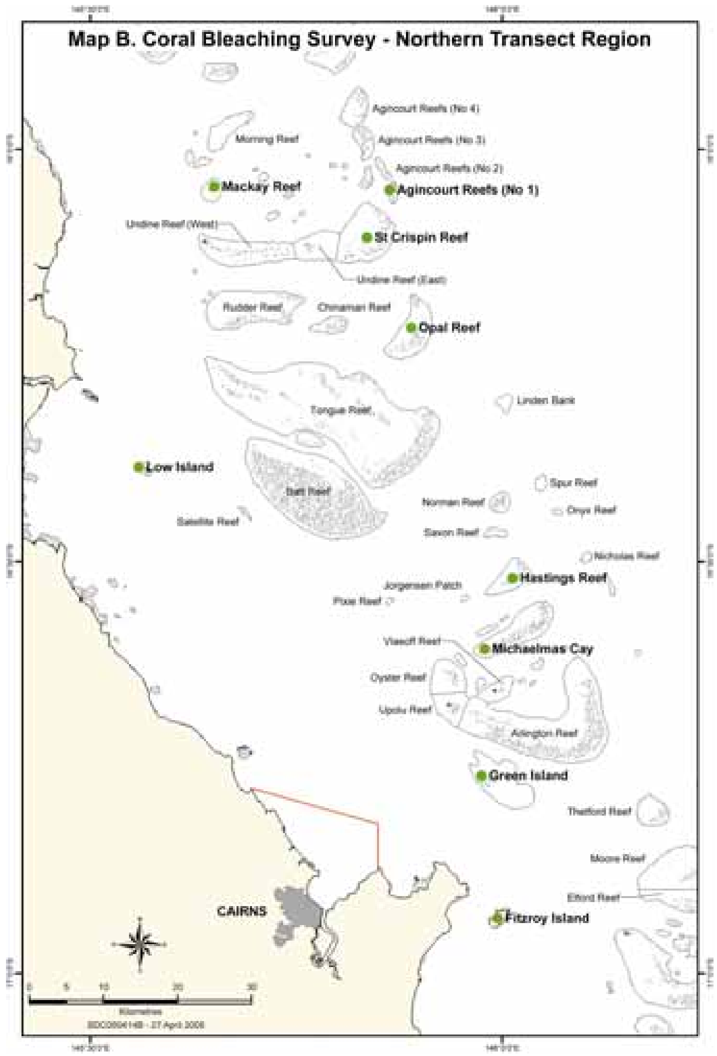
Coordinates

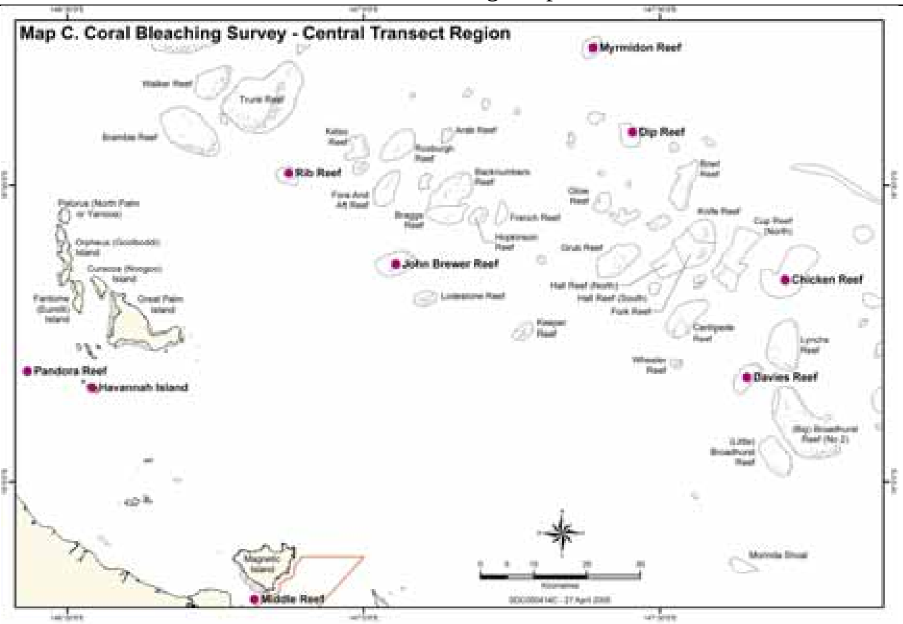
((I) inner-shelf reef; (M) mid-shelf reef; (O) outer shelf reef)

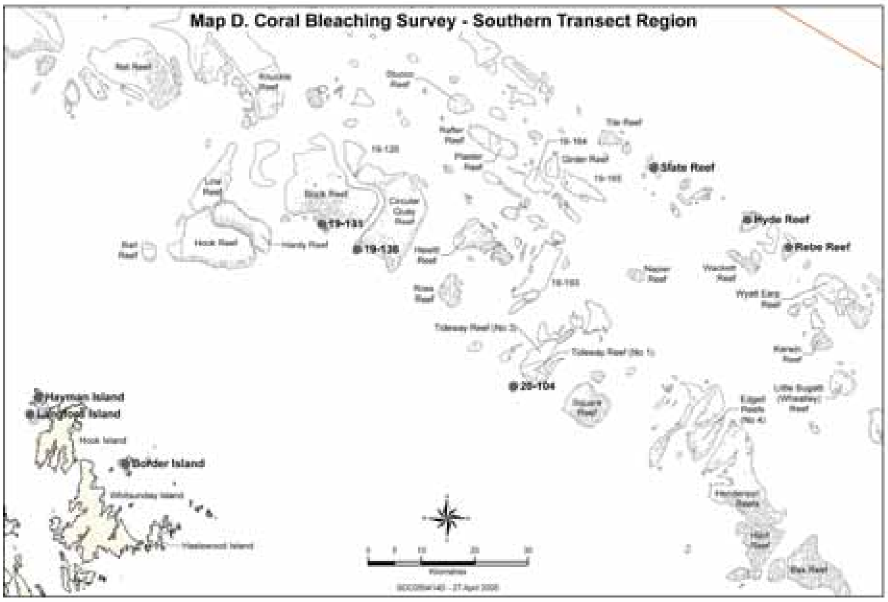
		Site coordinates (deg min)	
Transect and Region	**Reef Name**	**Latitude**	**Longitude**
Far Northern (Cooktown to Lizard Is)	Martin Reef (I)	14 45.566	145 22.586
	Linnet Reef (I)	14 47.33	145 21.21
	Decapolis Reef (I)	14 51.021	145 16.401
	MacGillivray Reef (M)	14 39.02	145 29.65
	Nth Direction Is (M)	14 44.784	145 31.02
	Lizard Island lagoon (M)	14 41.661	145 27.935
	Yonge Reef (O)	14 34.431	145 37.251
	Carter Reef (O)	14 31.584	145 35.1
	No Name Reef (O)	14 37.776	145 38.967
Northern (Cairns)	Green Island (I)	16 46.372	145 58.601
	Low Isles (I)	16 23.189	145 34.356
	Fitzroy Is (I)	16 55.384	145 59.765
	Mackay Reef (M)	16 2.697	145 39.147
	Michaelmas Cay (M)	16 33.09	146 3.241
	Hastings Reef (M)	16 30.182	146 1.594
	St Crispin Reef (O)	16 4.399	145 50.975
	Opal Reef (O)	16 12.451	145 54.452
	Agincourt No.1 Reef (O)	16 2.509	145 52.209
Central (Townsville)	Pandora Reef (I)	18 48.694	146 25.803
	Havannah Is (I)	18 50.04	146 32.482
	Middle Reef (I)	19 11.759	146 48.799
	Davies Reef (M)	18 48.679	147 40.231
	Rib Reef (M)	18 28.495	146 52.863
	John Brewer Reef (M)	18 37.358	147 5.045
	Chicken Reef (O)	18 39.348	147 43.43
	Dip Reef (O)	18 24.227	147 27.32
	Myrmidon Reef (O)	18 15.278	147 23.163
Southern (Whitsundays)	Hayman Is (I)	20 3.58	148 54.099
	Border Island (I)	20 10.517	149 2.098
	Langford & Bird Is (I)	20 4.78	148 52.614
	Reef 19131S (M)	19 46.162	149 22.719
	Reef 19138S (M)	19 48.5	149 25.58
	Reef 20104S (M)	20 2.007	149 41.686
	Slate Reef 19159 (O)	19 39.837	149 55.061
	Hyde Reef (O)	19 44.488	150 5.187
	Rebe Reef (O)	19 47.829	150 9.775
Far Southern (Capricorn Bunkers & Swains South)	Nth Keppel Is (I)	23 5.187	150 54.311
	Middle Is (I)	23 9.896	150 55.42
	Halfway Is (I)	23 12.193	150 58.187
	Gannet Cay (M)	21 58.743	152 28.955
	Chinaman Reef (M)	22 0.116	152 40.119
	Reef 21529S (M)	21 52.02	152 11.183
	Turner Cay (O)	21 42.204	152 33.807
	Wreck Is (O)	23 19.149	151 58.785
	One Tree Island (O)	23 29.261	152 5.554

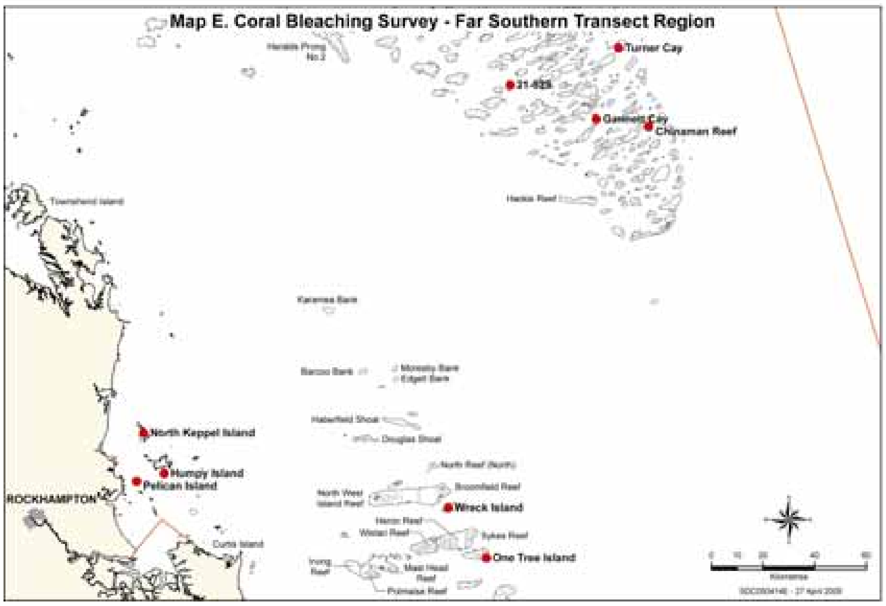
Detailed maps






Map C. Coral Bleaching Survey - Central Transect Region
Myrmidon Reef
Dip Reef
Rib Reef
John Brewer Reef
Chicken Reef
Davies Reef
Pandora Reef
Havannah Island
Middle Reef


Map D. Coral Bleaching Survey - Southern Transect Region
Slate Reef
Hyde Reef
Rebe Reef
19-131
19-138
20-104
Hayman Island
Langford Island
Border Island


Map E. Coral Bleaching Survey - Far Southern Transect Region
Turner Cay
21-529
Gannett Cay
Chinaman Reef
North Keppel Island
Humpy Island
Pelican Island
ROCKHAMPTON
Wreck Island
One Tree Island

Appendix C — Rapid assessment survey data sheet

GBRMPA Rapid Assessment Monitoring Sheet

Region:	**Reef Name:**	**Date:**	**Time:**
Observer:	Dive	Vess	

Site Details: Upper slope	Depth	Water Temp	
		Surface:	**Depth:**

Notes:

Benthos	% cvr (1)	**Transcect 1**					% cvr (1)	**Transect 2**					% cvr (1)	**Transect 3**				
Abiotic		**Notes**						**Notes**						**Notes**				
Sand																		
Rubble																		
Other																		
Other Live																		
Coral		Bleaching severity (2)						Bleaching severity (2)						Bleaching severity (2)				
		0	1	2	3	4		0	1	2	3	4		0	1	2	3	4
Soft																		
Hard																		
Acropora																		
Montipora																		
Pocilloporids																		
Porites																		
Faviids																		
Algae		**Notes**						**Notes**						**Notes**				
Fleshy/upright/macro																		
CCA																		
Filamentous (Turf)																		
Ephemeral/scuzzy																		
Total	100%						100%						100%					
Canopy height min/max/mode (cm)																		
Other Impacts																		

Reef flat observations

Other notes and observations

Appendix D — Codes for intensive surveys

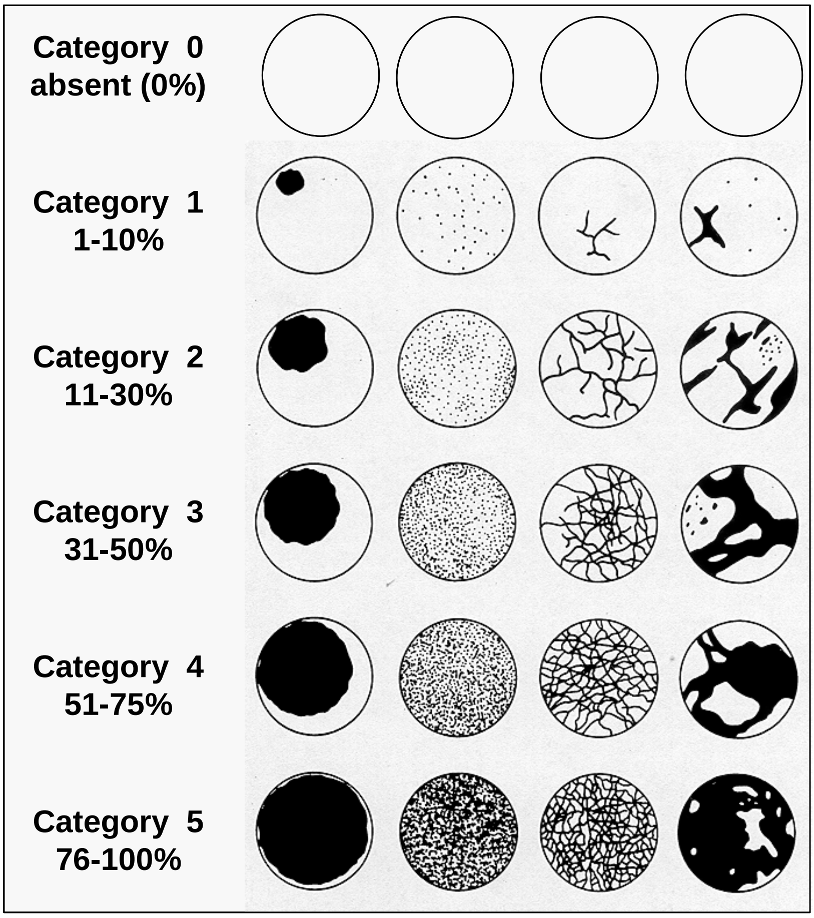
Bleaching categories used in the rapid assessment surveys based on percentage of total reef area bleached (within a 5 m band)

Index	% cover	Bleaching level	Visual assessment
0	<1	None	No bleaching observed, or only very occasional, scattered bleached colonies (one or two per dive)
1	1–10	Low	Bleached colonies seen occasionally and are conspicuous, but vast majority of colonies not bleached
2	10–50	Moderate	Bleached colonies frequent but less than half of all colonies
3	50–90	Severe	Bleaching very frequent and conspicuous, most corals bleached
4	>90	Extreme	Bleaching dominates the landscape, unbleached colonies not common. The whole reef looks white

Colony bleaching table describing the proportion of a coral colony bleached in video surveys

Index	Description
0	No bleaching evident
1	Partially bleached (surface/tips) or pale but not white
2	White
3	Bleached and partly dead
4	Recently dead

Appendix E — Schematic representations of per cent cover



(Adapted from English et al. 1997; after Dahl 1981 – Category 0 added)