

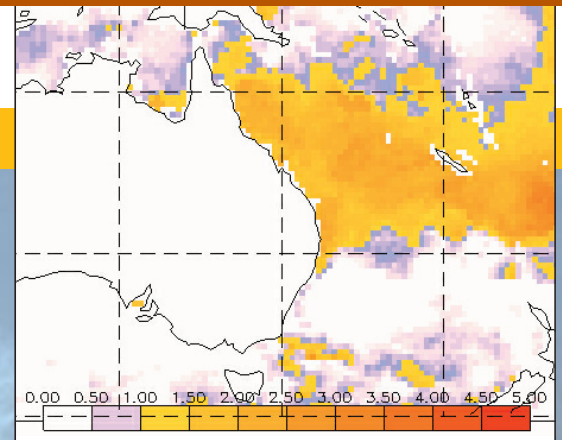


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Climate Change Program - Research & Monitoring Coordination Unit

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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. In combination with the multitude of other stressors resulting from human activities, climate change leads 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 Marine Park 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 led 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's Coral Bleaching Response Program has been developed to provide an early warning system for conditions that are conducive to coral bleaching, and to document the extent and severity of coral bleaching events using aerial surveys and ecological surveys. The information collected under this program can be used to compare and analyse the frequency and patterns of bleaching events and to develop forecasting tools.

1. Program Overview

This document describes a Coral Bleaching Response Program for the GBRMPA. The program will enable GBRMPA to:

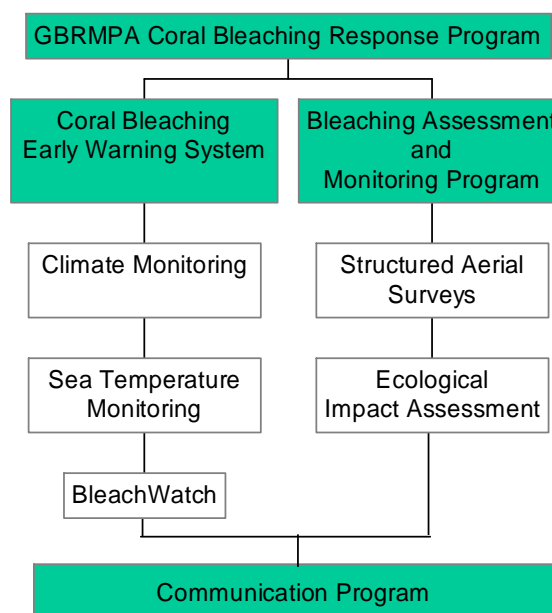
- Develop a system to forecast coral bleaching events;
- Provide early warnings of a major coral bleaching event;
- Measure the spatial extent and severity of mass coral bleaching events;
- Assess the ecological impacts of mass coral bleaching events;
- Involve the community in monitoring the health of the GBR;
- Communicate and raise awareness about coral bleaching and climate impacts on the GBR;
- Provide information to assist evaluate the implications of coral bleaching events for management policy and strategies.

The Great Barrier Reef Coral Bleaching Response Program (GBR CBRP) has been developed in conjunction with A Global Protocol for Assessment and Monitoring of Coral Bleaching (WWF, FishBase and GBRMPA), A Reef Manager's Guide to Coral Bleaching (an international collaborative effort lead by the US Coral Reef Task Force and GBRMPA) and to maximise comparability and consistency with bleaching response plans in other regions. The GBR CBRP also links in with GBR tourism industry-based monitoring programs such Eye on the Reef.

The GBR Coral Bleaching Response Program has the following three main sub-programs (Figure 1):

- Early Warning System
- Bleaching Assessment and Monitoring Program
- Communication Program.

Figure 1. Schematic overview of GBR Coral Bleaching Response Program elements



The following sections detail the rationale, strategies and methods for each of the sub-programs, and conclude with an implementation plan.

1.1. Selecting an Appropriate Monitoring Program for the GBR

A Global Protocol for Monitoring and Assessing Coral Bleaching outlines a range of monitoring activities that can be conducted to address the objectives of a coral bleaching monitoring program. The broad objectives of the GBR Coral Bleaching Response Program are to document and assess:

1. The extent and severity of bleaching (if an event occurs);
2. The duration of a bleaching event;
3. The ecological impacts of a bleaching event;
 - a. Does bleaching result in changes to species diversity and/or coral cover?
 - b. Does bleaching result in changes to relative abundance and dominance of different species?
 - c. Does bleaching result in changes to reef structure and habitat complexity e.g. are there impacts on other species?
 - d. Does bleaching result in changes to the ability of reefs to recover after an impact?
4. Other anthropogenic stresses that may affect the severity of bleaching and recovery;

The GBR Coral Bleaching Response Program also expects to provide a foundation to develop an understanding of the social and economic impacts of bleaching.

Table 1 from the Global Protocol provides a guide to the types and frequency of monitoring which should be considered for different resource scenarios and for different objectives. The GBRMPA Coral Bleaching Response Team reviewed the needs of the program and designed the monitoring program using the following selected methods based on the available resources.

Table 1 Monitoring activities of the GBR Coral Bleaching Response Program

Question	Resource Scenarios (see definitions below)		
	1. Low	2. Medium	3. High
A. What is the general extent and severity of the current bleaching event?	A1 <ul style="list-style-type: none"> • Circulate questionnaires amongst local divers and other reef users • Submit information to ReefBase 	A2 <ul style="list-style-type: none"> • Identify major species affected (take photos or video footage) 	A3 <ul style="list-style-type: none"> • Conduct detailed surveys of representative sites using transects and a precise measure of percentage of coral affected (line transect, video-transect) • Use aerial surveys to obtain synoptic estimates over wider geographic area
B. Is the bleaching associated with specific environmental factors such as temperature, solar radiation, water circulation?	B1 <ul style="list-style-type: none"> • Ask other reef users to collect similar data 	B2 <ul style="list-style-type: none"> • Get local weather data from Meteorological office on air temperature, sun hours, wind • Consult with oceanographers regarding the circulation patterns, water exchange and any upwelling features in the area • Compare bleaching records with hotspots and degree heating weeks on NOAA's website 	B3 <ul style="list-style-type: none"> • Install recording temperature loggers at main bleaching sites • Install remote weather stations to record temperatures, wind and solar radiation • Measure currents and tidal flow at key sites • Acquire and analyse NOAA Local Area Coverage data to correlate bleaching records with thermal anomalies and degree heating weeks
C. How long will it last and is it a recurring event?	C1 <ul style="list-style-type: none"> • Ask local reef users for details on bleaching events and record these on BleachWatch questionnaires 	C2	C3 <ul style="list-style-type: none"> • Repeat detailed observations in A3 • Repeat same observations for any subsequent bleaching events

<p>D. What are the ecological impacts on the reef system?</p>	<p>D1</p> <ul style="list-style-type: none"> • Conduct before and after bleaching observations including mortality/recovery 	<p>D2</p> <ul style="list-style-type: none"> • Measured estimates of benthic cover through time (transects/quadrats) 	<p>D3</p> <ul style="list-style-type: none"> • Measured estimates of benthic cover through time at higher taxonomic resolution (transects/quadrats) • Transects include other macro-invertebrates • Fish abundance and diversity surveys
<p>E. Are adjacent human impacts causing or exacerbating the bleaching?</p>	<p>E1</p> <ul style="list-style-type: none"> • Note location, timing (onset, duration, cessation) and severity of local human impacts • Ask other reef users to give you similar information 	<p>E2</p> <ul style="list-style-type: none"> • Collect information on key environmental variables at impacts sites (turbidity, sedimentation, gross pollution indicators) 	<p>E3</p> <ul style="list-style-type: none"> • Detailed surveys at control and impact sites • Collate existing data on human impacts such as water quality, chronic disturbance from destructive fishing

2. Early Warning System

Mass coral bleaching is preceded by a series of stages, beginning with the build-up of climatic conditions that warm sea temperature, followed by above-average water temperatures, which in turn can lead to patchy bleaching or bleaching of more vulnerable species. 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.

The GBRMPA Early Warning System consists of three elements designed to detect the onset of each of the three stages that lead to a mass coral bleaching event:

1. *Climate Monitoring*: 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; and
3. *Bleach Watch*: Early signs of bleaching on reefs, and the extent of any bleaching.

2.1. Climate Monitoring

Above-average sea temperatures are associated with El Niño conditions in many reef regions around the world. While the El Niño Southern Oscillation is an important influence on weather patterns over eastern Australia, other factors are also known to result in high sea temperatures in the GBR region. In particular, delayed or weak development of the monsoonal trough over northern Australia during summer appears to be a strong precursor to anomalously warm conditions that cause stress to corals. Based on an emerging understanding of the relationship between weather and sea temperatures for the GBR, current and forecast weather conditions can provide a useful indicator of pending warming of waters in the GBR, and thus serve as early warnings of potential stress.

Seasonal climate predictions will be reviewed in the early stages of summer to monitor the development of regional weather patterns that may lead to anomalous sea temperatures. These will be complemented with long- to mid-range weather forecasts as the summer progresses.

Objectives: Monitor climate and weather conditions in the lead up to summer to assess risk of elevated sea temperatures

Strategies:

- Monitor long-range climate predictions and weather forecasts;
- Obtain 4-Day forecasts and weather summaries from the Bureau of Meteorology;
- Explore value of long-range forecasts for predicting potential warming conditions.

Triggers: Forecasts of above average summer temperatures or below average rainfall will trigger logistic preparations for the Coral Bleaching Assessment and Monitoring Program.

2.2. Sea Temperature Monitoring Program

Sea temperatures on the GBR are an indicator of actual stress on corals, and thus serve as an early warning of potential bleaching on the GBR. The NOAA “HotSpot” program provides regional-scale near-real time measurements of sea surface temperature anomalies via the World Wide Web. HotSpots and Accumulated Heat Index products from the NOAA web site provide reliable indicators of levels of heat stress in reef regions. Excessive and persistent HotSpots indicate sea temperatures that are known to be stressful to corals and therefore provide an early warning of coral bleaching.

The development of conditions likely to induce bleaching will be monitored using HotSpots and Accumulated Heat Indices as indicators of local sea temperatures during the summer. Higher resolution HotSpot products specifically for the GBR are under development by NOAA, and may be available to GBRMPA in the near future.

Direct measurements of local sea temperatures will provide a more detailed record of water temperatures from a network of weather stations on the GBR. These weather stations record water temperature at the surface and 6 m depth, providing important information about any depth-related variability in water temperatures, while also providing a mechanism to ground-truth HotSpot predictions.

A network of temperature loggers is also maintained in a collaborative program with AIMS and the CRC Reef. The lengthy retrieval times required for these loggers precludes them from contributing to an early warning system. However, the data that they provide has proven invaluable in retrospective analyses of the links between sea temperatures and coral bleaching, enabling AIMS scientists to develop bleaching thresholds for key locations throughout the Great Barrier Reef.

- Objectives:** Obtain early warnings of temperature stress and conditions that could lead to bleaching on the GBR over summer
- Strategies:**
- Actively monitor NOAA “HotSpot” maps and “Degree Heating Weeks” charts for the GBR region
 - Evaluate sea temperature from AIMS/GBRMPA weather station data
 - Explore availability of high-resolution temperature anomaly maps from AIMS/NOAA
- Triggers:** The onset of stressful conditions will trigger increased vigilance of coral condition through the BleachWatch Program and Broad-scale Aerial Surveys. Stressful conditions are defined as:
- Strong hotspots (anomaly > 1.5 deg C) over majority of region for 2 weeks; or
 - Very strong hotspots (anomaly > 2 deg C) for 1 week; or
 - Degree heating weeks (DHW) > 9.

2.3. BleachWatch (Professional & Community)

The initial onset of mass coral bleaching can range from gradual and patchy to rapid and uniform, and can occur with varying synchrony over hundreds or thousands of square kilometres. Detecting the early signs of a mass bleaching event requires a wide network of observers providing regular reports of conditions throughout the region. BleachWatch is a program that has been designed to provide reliable reports of reef condition from a wide range of reef sites throughout the GBRMP. The program is built on a network of tourism professionals and other reef users who voluntarily monitor and report on conditions at reefs that they visit regularly.

This program was initially established at the start of 2002, during the major bleaching event that occurred that summer on the GBR. Tourism operators operating between Port Douglas in the north and Rockhampton in the south have been enlisted to provide regular reports on the appearance and health of their main tourism sites during summer. The number of participants and geographic coverage of the program has continued to grow, with currently 52 tourism operators participating.

BleachWatch participants are divided into “Professional” and “Community” groups. *BleachWatch (Professional)* program comprises mostly tourism operators who visit the same reef sites regularly throughout summer. These participants complete purpose-designed monitoring forms on a weekly basis. Observers are asked to provide general information about their site, type of habitat (section 1) and specific weather conditions (section 2) that are known to influence risk of bleaching (i.e. water temperature, cloud cover, air temperature, wind speed). Detailed information about reef condition and bleaching observations (section 3) is also collected (a copy of the form is at Appendix A). Once the observer has submitted the first site report to the GBRMPA, they need only fill out sections 1 and 2 and tick ‘no change’ unless coral bleaching is observed or there has been a change in conditions at the reef site. It is expected that completion of the forms will take approximately 10 minutes per week for each participant. The data submitted by participants of the *BleachWatch (Professional)* program will be compiled and summarised into monthly reports during the summer season, which will be sent to the participants for their information and for display to their clientele on board the vessel. This data collected is reviewed weekly to identify where coral bleaching has been sighted, whether it is spatially or locally significant and whether the Assessment and Monitoring Program should be implemented.

The *BleachWatch (Community)* program is designed for less regular reef visitors. This allows people who visit the reef irregularly, or even only on a single occasion over summer, to submit observations on reef status and coral bleaching to a central database. Participants include recreational boaters, divers, fishers, tourists and scientists. People wishing to submit reports to the *BleachWatch (Community)* program can enter their observations onto an online form on the GBRMPA web site. Reports will be compiled onto maps every 1-2 months during the summer season, and published on the web site. This program will mostly be activated during mass bleaching events only.

- 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 conditions at reefs that they regularly visit;
 - Provide operators with a monitoring kit as a module of the Tourism Operators Handbook¹ to report reef conditions and the coral bleaching kit includes:
 - Monitoring forms
 - In-water Identification aid
 - Interpretive material on coral bleaching
 - Regularly enter and evaluate data received to determine the composition of each reef and its bleaching susceptibility
 - Provide regular feedback in the form of monthly site reports to all participants
 - Develop and maintain a website providing information on the BleachWatch program, potentially including a downloadable version of the datasheet, on-line reporting form and copies of the site reports for each participant.
 - Provide regular feedback in the form of reports, web updates or informal communications, to all participants.
- Triggers:** Reports of spatially extensive or local bleaching will trigger the Bleaching Assessment and Monitoring Program.

¹ The Tourism Operators Handbook is currently under development by the GBRMPA with the aim to provide a consolidated guide that includes management arrangements, responsible reef practices and linkages with other programs and tools that will assist marine tourism operators operating within the GBRMP.

2.4. BleachWatch (Aerial)

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

- Objectives:** Assess the spatial extent and distribution of coral bleaching for the entire GBR Marine Park
- 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 GBRMP.
 - Utilise *BleachWatch (Aerial)* reports and photographs of suspected bleaching to select additional reefs for structured aerial surveys.
- Triggers:** Confirmation of conditions conducive to bleaching from the climate and sea temperature monitoring will trigger the Structured Aerial Surveys.

3. Bleaching Assessment and Monitoring Program

The objective of the Bleaching Assessment and Monitoring Program is to assess the spatial extent and severity of coral bleaching events and determine the ecological implications (e.g. coral mortality, shifts in community structure) resulting from coral bleaching.

Timing is critical for the implementation of bleaching surveys. A bleaching event can progress quite 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-April. If assessments are delayed beyond this time, they are likely to provide an under-estimate 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.

A tiered combination of two methods will be used to provide the best possible combination of spatial coverage, detail of information and cost effectiveness. The Bleaching Assessment and Monitoring Program will comprise of Structured Aerial Surveys and Fine-Scale Ecological Impact Assessments.

3.1. Structured Aerial Surveys

Broad-scale structured aerial surveys are the most effective method for obtaining a synoptic overview of where bleaching is occurring over spatial scales that are relevant to management on the GBR (i.e. hundreds to thousands of kilometres). As well as providing data on the extent of a coral bleaching event, broad-scale synoptic surveys help to identify the reefs or regions worst affected by thermal stress. The structured aerial survey sites will include the 45 ecological impact assessment sites plus a further ca. 500 sites selected based on region, shelf position, zoning, habitat etc. These sites will be permanent aerial sites that will provide important temporal data for assessing bleaching patterns and high risk areas over time.

The correlation between sea surface temperatures and bleaching risk is an area of active research, and early results are indicating that sea surface temperatures are reliable indicators of regional-scale stress, but not an accurate predictor of bleaching at individual reefs. This is because many factors influence local water temperature (such as water depth, currents and upwelling) and the resolution of satellite data

may not be sufficient to detect these variations. Other factors, such as water quality, community composition, previous exposure and genetic composition, will exert a strong influence on whether a particular reef will show signs of bleaching in response to a given water temperature. Broad-scale aerial bleaching surveys are the most reliable method of determining the extent of reefs that are visibly affected by bleaching over the 2000 km length of the GBR and are important for temporal comparisons of the extent of future bleaching events with aerial survey data from the 1998 and 2002 bleaching events.

Objectives: Assess the spatial extent and distribution of coral bleaching for select locations along the GBR;

Strategies:

- Utilise aerial photography (at a spatially relevant scale) to document coral cover and extent of bleaching at target reefs
- Build hierarchical system using satellite imagery, aerial data and in-water data to get a complete picture and possibly predictive capacity for extent of bleaching

3.2. Fine-scale Ecological Impact Assessments

Although the phenomenon of bleaching has received much attention, the ecological significance of mass bleaching is still poorly understood. Severe bleaching events have the potential to kill large areas of living coral, and consequently cause major disturbance to coral reef ecosystems. However, the fate of bleached corals cannot readily be predicted from observations of the severity or extent of bleaching. Widespread bleaching does not necessarily equate to widespread coral mortality. Detailed information on the extent and patterns of coral mortality that result from bleaching need to be measured to better understand the long-term implications of these events.

Fine-scale Ecological Impact Assessments will provide more precise information about the percentage and types of corals that bleach, and then subsequently die or survive. Over longer time frames, the Program will also enable the direction and rate of community recovery to be evaluated. The quantitative data provided by Fine-scale Ecological Impact Assessment will also enable the testing of hypotheses about differences or trends between sites or through time. Differences in coral community structure that may occur because of bleaching and mortality will be detected, and information on whether certain community types are more susceptible to bleaching than others can be obtained.

Fine-scale Ecological Impact Assessments will use a combination of Rapid Visual Assessment and more detailed Video Transects to provide information about the bleaching event and its ecological impacts. The Rapid Assessment and Video Transects will be done simultaneously at the same sites. The two methods are designed to be complimentary: the Rapid Assessment provides basic information about the severity of the bleaching event in near real-time; the Video Transects provide more detailed information, but require intensive analysis that normally takes weeks to months to complete (see method details in the following sections).

Objectives: Assess the percentage of coral bleaching, affected species and mortality for select reefs along the GBR;

Strategies:

- Rapid visual assessments to document coral cover, community composition, and severity of bleaching at target reefs
- Video transects to quantify coral cover, community composition, and extent and pattern of bleaching at target reefs
- Ground truth aerial data using in-water fine scale surveys

Survey Design and Methods

3.2.1. Spatial and Temporal Scale

The program will build on existing programs, in particular the AIMS Long Term Monitoring Program (LTMP), which has a suite of core sites that are surveyed annually for benthic cover and diversity, fish diversity and abundance and other stressors (e.g. COTS). By surveying AIMS LTMP sites during a bleaching event, important baseline and recovery data can be incorporated in any assessments. Additionally, AIMS targeted bleaching surveys will complement the GBRMPA surveys. The dynamic nature of coral bleaching requires multiple temporal and spatial surveys in order to characterize the extent and severity of bleaching that occurs, and the ecological implications (i.e. the amount of mortality that occurs). This ideally requires three temporal surveys:

- *Baseline* - the first survey is used to document reef status (coral cover and composition) prior to any changes caused by bleaching. This is best conducted before the onset of bleaching. However, the GBRMPA CBRP will utilise AIMS LTMP data from the previous survey period.
- *Event Monitoring* - the second survey will be timed to coincide with the peak of the bleaching event, and is used to document the spatial and taxonomic patterns of bleaching. 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.
- *Recovery* - the third survey should be done shortly after the bleaching event, but not until all corals have either recovered or died. This survey determines the ecological impacts of the bleaching by assessing changes in coral cover or composition attributable to the bleaching event. The AIMS LTMP data set from the next survey period will be used to determine reef status after the bleaching event.

Structured survey sites will be monitored from Lizard Island in the north to One Tree Island in the south and have been selected to match the AIMS Long Term Monitoring Program (LTMP) sites (see section 3.2.2).

Table 1. Location of Sites for Fine Scale Ecological Impact Assessments

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

Transect Region	Reef Name*
Far Northern (Cooktown to Lizard Is)	Martin Reef (I)
	Linnet Reef (I)
	Decapolis Reef (I)
	MacGillivray Reef (M)
	Nth Direction Is (M)
	Lizard Island lagoon (M)
	Yonge Reef (O)
	Carter Reef (O)
Northern (Cairns)	No Name Reef (O)
	Green Island (I)
	Low Isles (I)
	Fitzroy Is (I)
	Mackay Reef (M)
	Michaelmas Cay (M)
	Hastings Reef (M)
	St Crispin Reef (O)
	Opal Reef (O)
Agincourt No.1 Reef (O)	
Central (Townsville)	Pandora Reef (I)
	Havannah Is (I)
	Middle Reef (I)
	Davies Reef (M)
	Rib Reef (M)
	John Brewer Reef (M)
	Chicken Reef (O)
	Dip Reef (O)
Myrmidon Reef (O)	
Southern (Whitsundays)	Hayman Is (I)
	Border Island (I)
	Langford & Bird Is (I)
	Reef 19131S (M)
	Reef 19138S (M)
	Reef 20104S (M)
	Slate Reef (O)
	Hyde Reef (O)
Rebe Reef (O)	
Far Southern (Capricorn Bunkers & Swains Sth)	Nth Keppel Is (I)
	Pelican Is (I)
	Humpy Is (I)
	Gannet Cay (M)
	Chinaman Reef (M)
	Reef 21529S (M)
	Turner Cay (O)
	Wreck Is (O)
	One Tree Island (O)

3.2.2. Survey Sites

Each survey will assess the condition and composition of the benthic community along five cross-shelf transects (Table 1 lists the reef sites for each of these transects). These will be located at latitudes centred on Lizard Island, Cairns, Townsville, Whitsunday Islands and the Capricorn Bunker Group. Previous surveys have included only three cross-shelf transects due to funding and time constraints. It is planned that Far Northern (Lizard Island) and Far Southern (Capricorn Bunker Group) transects will be added for future surveys to increase the spatial coverage.

A total of 45 sites have been selected based on existing AIMS LTMP site locations, to provide for a long-term data set on coral cover and community composition at the sites. Three inshore, three midshelf and three outer shelf reefs were selected for each transect. Sites were selected from the AIMS LTMP database 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 Plan² (Reef Plan) survey sites (see section 3.2.5).

The benefit of this approach is that baseline and recovery data can be obtained from the AIMS LTMP routine surveys and thus reduce the need for multiple GBRMPA survey trips and duplication with existing programs.

Some remote locations along the GBRMP have been omitted from the sites selected, such as the northern Swains and Pompey Complex. These locations are rarely visited and do not have long-term datasets as they are not included in the AIMS LTMP surveys. If a significant bleaching event occurs, these sites will be surveyed using the Structured Aerial Surveys.

Additional sites may be surveyed using manta tow or rapid assessment techniques in a bleaching event. These sites would be selected to match those surveyed in the 1998 and 2002 bleaching events, reefs surveyed under the Reef Plan monitoring program (e.g. Daydream Is, Dent Is and Double Cone Is), and other sites of interest. They will be surveyed as time and resources permit.

3.2.3. Survey Design

Three shelf positions will be surveyed in each transect: inshore, mid-shelf and outer shelf. Three replicate reefs will be surveyed at each shelf position. Sites will be those established by the AIMS LTMP and will be divided into 2 depth zones: shallow and deep. The shallow station includes the reef crest and upper slope from about 1 m to 4 m in depth. The deep station includes the mid to lower reef slope from 5-10 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, once established, will be fixed for each station.

Three random transects will be surveyed at each depth at each station. Random transects will be used rather than fixed transects to reduce time required for establishment and survey, avoid unsightly markers on the reef and ensure independence among consecutive surveys. Each transect will be surveyed simultaneously by two independent methods: a Rapid Visual Assessment and Video Transects.

Two divers will swim along a 50 m belt transect, one recording information on the Rapid Assessment Survey data sheet and the other recording the same substratum area with an underwater video camera. The Rapid Assessment Survey will record observations on condition of corals and other benthos within a band five metres wide along the length of the transect. Three sets of information will be recorded:

² The Reef Water Quality Protection 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 program in the GBR lagoon.

station information; general coral and bleaching observations; and detailed information for selected coral groups. All data will be entered directly onto the specially designed Rapid Assessment Survey data sheets (see Appendix B). The categories for estimating percent cover and progress of bleaching have been standardised on the survey sheet to enable consistent surveying methods by different observers. Lists of codes for each variable are provided in Appendix C. A table showing schematic representations of percent cover will be utilised to maximise consistency in estimates made under water (Appendix D).

Video Transect Surveys will be recorded at a distance of 40 cm above the substrate at a speed of 10 metres per minute (in accordance with the standard protocol used by AIMS).

3.2.4. Data Analysis & Management

Video transect data will be analysed by an appropriately skilled and experienced analyst, and stored in a database maintained by GBRMPA and shared with AIMS. Data from Video transects will be used to quantify coral cover, community composition, and extent and pattern of bleaching at target reefs. Data collected from in-water (Rapid Visual Assessment) surveys will be stored in a database maintained by GBRMPA. Data will be used to document coral cover, community composition, and severity of bleaching at target reefs

3.2.5. Complementary Studies

AIMS Climate Change program – temperature loggers

AIMS coordinate the Sea Temperature Monitoring Program, which includes the deployment and collection of in-situ data loggers, and the maintenance of a network of weather stations. Data loggers have been placed on the reef flat, at or near Lowest Astronomical Tide, and on the reef slope at ~ 50 locations spanning the extent of the GBR. At some locations, loggers have been placed on the upper reef slope (~ 5-9m), or on the deep reef slope (~ 20m). Following the 1998 and 2002 bleaching events, data from these loggers allowed for a better understanding of the link between temperature and the severity of bleaching responses. Bleaching ‘thresholds’ developed from this research can currently be monitored at the weather station sites on the Reef Futures website, and are an important component of the Early Warning systems in the CBRP. Additionally, AIMS targeted bleaching surveys will complement the GBRMPA surveys.

AIMS LTMP

The AIMS Long-term Monitoring program has been tracking the condition of the Great Barrier Reef (GBR) for more than a decade, by surveying fish, corals, crown-of-thorns starfish, and coral disease. The Monitoring Team is the one of the premier research bodies focussing on the condition of coral reef ecosystems in the Great Barrier Reef World Heritage Area. The GBR Coral Bleaching Response program utilises the information collected under the LTMP program to obtain baseline and recovery data.

Reef Plan

In addition to the fine-scale ecological surveys, water quality data collected for the Reef Plan marine monitoring program will be utilised to assess the influence of water quality stressors on resilience to bleaching and recovery post-bleaching. The Reef Plan monitoring program 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. Many of these sites overlap with proposed fine scale ecological impact assessment sites of the GBR CBRP and there is the opportunity to correlate these sites further for aerial and fine-scale surveys during a bleaching event.

4. Communications Program

Coral bleaching and global climate change are issues that attract strong interest from the public, the media and senior decision-makers. It is important to proactively release information about coral bleaching events to all stakeholders as it becomes available in order to raise awareness and ensure discussions and debate are well-informed. The GBR Coral Bleaching Response Program will be the main source of timely and credible information on coral bleaching on the GBR, and on the ecological implications for the reef ecosystem.

Information will be delivered directly to stakeholder groups via public meetings, existing formal and informal networks (including GBRMPA programs such as Eye on the Reef, Tourism and Recreation Newsletter and LMACs) and email. Information will also be distributed more widely through the GBRMPA web site and via media outlets. The communications program aims to increase awareness of the occurrence and implications of coral bleaching events through a variety of communication strategies. Information about coral bleaching will be communicated using the following methods:

- In the months prior to the period of high bleaching risk, beginning in December, the web site will be reviewed to present an up-to-date overview of predicted climate and local weather conditions and the estimated potential for coral bleaching.
- Information about bleaching issues and notification of web updates will be circulated via industry newsletters, meetings, and email discussion lists.
- During summer (December to April), GBRMPA will post regular web reports (every 2-4 weeks) on bleaching conditions on the GBR.
- Reports will also be sent directly to stakeholder groups (tourism operators, Marine Parks staff, scientists, etc) via email on a semi-regular basis (every 2-4 weeks).
- Media statements will be prepared and released if/when:
 - conditions develop which indicate a high risk of coral bleaching;
 - a bleaching event occurs (describing spatial extent and general severity); and
 - the bleaching event has concluded (describing coral mortality and ecological impacts).

5. Implementation

The sequence of events and decision points for implementation of the GBR Coral Bleaching Response Program are shown below (Figure 2). Climate and weather conditions will be monitored from November, approximately 3-4 months prior to the period of greatest bleaching risk. Sea Temperature Monitoring and the BleachWatch Program will be implemented from December. If the onset of stressful conditions is confirmed, or if there are any reports of significant coral bleaching, the Bleaching Assessment and Monitoring Program will be implemented, as depicted below.

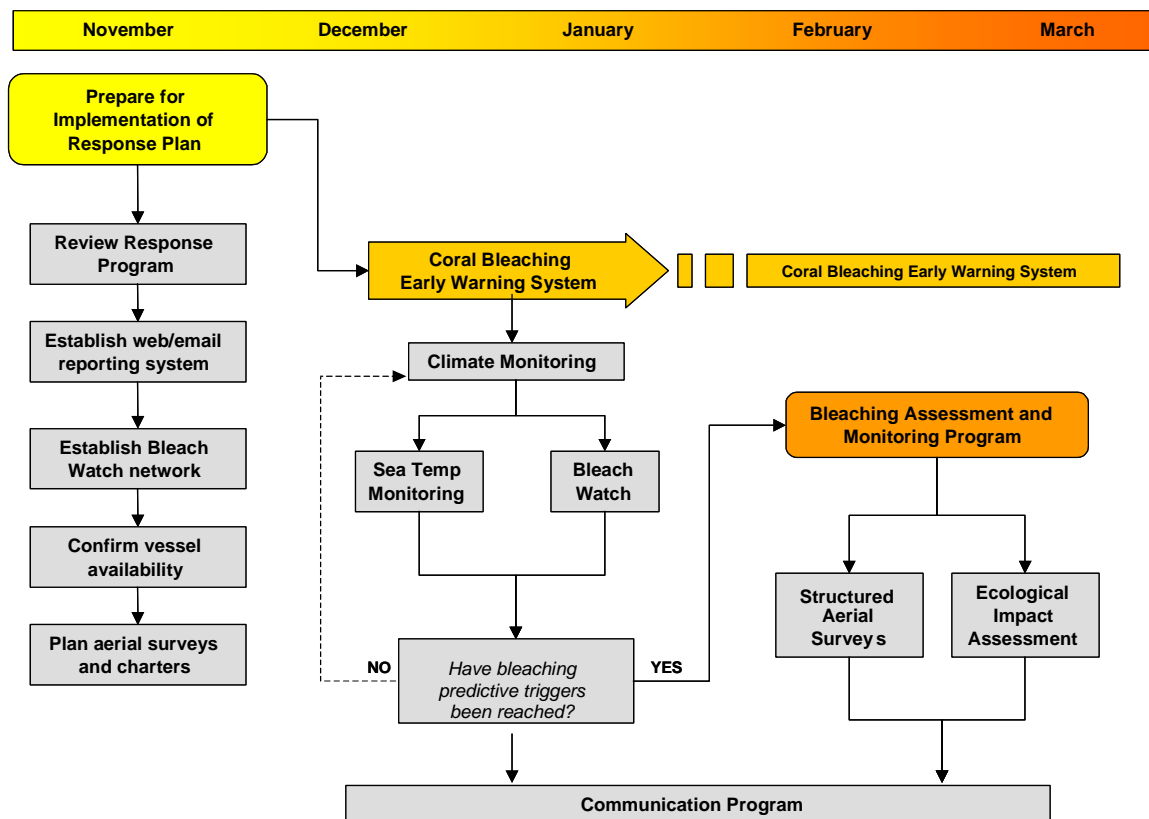


Figure 2. Implementation plan for the GBR Coral Bleaching Response Program.

5.1. Response schedule

The GBR Bleaching Response Program consists of a combination of routine tasks and responsive tasks that are triggered by thresholds.

Routine tasks are designed to provide basic information to help determine if and when a bleaching event is occurring, and to ensure the Coral Bleaching Response Team is prepared for the responsive tasks. Responsive tasks are implemented if it appears that a major bleaching event is imminent, and are designed to provide a more detailed picture of bleaching conditions and their ecological significance. An outline of these tasks is provided below, with a detailed breakdown of tasks provided in Table 2.

5.1.1. Routine tasks

- ❑ Prepare for implementation of Responsive Tasks
- ❑ First assessment of probability of stressful conditions to corals based on long term climate predictions for summer (i.e. ENSO conditions; development of monsoonal trough);
- ❑ Establish bleaching reporting system, including email updates and web site;
- ❑ Establish BleachWatch networks;
- ❑ 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 Programs;
- ❑ Advise Senior Management of any increase in bleaching risk or bleaching reports.

5.1.2. Responsive tasks

- ❑ Advise Senior Management, stakeholder groups and the community of onset of coral bleaching;
- ❑ Implement structured aerial survey of bleaching extent;
- ❑ Deploy ecological survey teams to measure extent and severity of bleaching;
- ❑ Monitor ecological impacts of bleaching.

5.2. Thresholds or triggers for responsive tasks

The thresholds for responsive tasks, as referred to in the Response Task Schedule (Table 2) are defined below. Table 2 is an indicative response table outlining the appropriate responsive tasks once triggers have been reached during a summer season. The colour coding indicates whether a mild, moderate or severe bleaching event is likely for that suite of triggers. If multiple triggers are reached simultaneously, the higher level action should be taken (e.g. if degree heating weeks >9 and the bleaching thresholds have been exceeded at multiple sites, briefings should be prepared for senior management and the Minister, and the structured aerial surveys implemented).

‘*Substantial increase in environmental stress*’ is defined as:

- Persistence of strong hotspots (anomaly > 1.5 deg C) over majority of GBR region for 2 weeks; or
- Very strong hotspots (anomaly > 2 deg C) for 1 week;
- Bleaching thresholds exceeded at inshore *and* offshore in-situ sea temperature monitoring sites; or
- Degree heating weeks greater than 9.

A ‘*moderate bleaching event*’ shall be declared if:

- There are reliable reports of low to moderate coral bleaching (5-30% of colonies completely white) from multiple sites from multiple locations spanning at least two GBRMP sectors; or
- Severe bleaching is reported from a few sites only, scattered throughout the GBRMP or concentrated in only one sector.

A ‘*major bleaching event*’ shall be declared if:

- There are reliable reports of high to extreme coral bleaching (>30% of colonies completely white) from multiple sites from multiple locations spanning at least two GBRMP sectors; or
- from multiple sites from multiple locations spanning the shelf within one sector.

Table 2. Bleaching prediction triggers, as referred to in the Implementation Plan (Figure 2), and their respective responses

	Brief Senior Management	Brief Executive/ Minister	Structured aerial surveys	Site inspections	In-water ecological surveys
SST within summer range	X				
Severe bleaching reported from a few sites only	X	X			
Degree heating weeks >9	X	X			
Bleaching thresholds exceeded at multiple sites	X	X	X		
Persistence of strong hotspots (>1.5 °C) for 2 weeks	X	X	X		
Very strong hotspots (>2 °C) for 1 week	X	X	X		
BleachWatch reports <ul style="list-style-type: none"> • low to moderate bleaching at multiple sites and locations; • severe bleaching at multiple sites; • high to extreme bleaching 	X	X	X	X	X






 = no to mild bleaching event
 = moderate bleaching event
 = severe bleaching event

Table 3. Bleaching Response Program: Task Schedule

Trigger type	Timing	Information
Routine - weekly	Monday	Check NOAA HotSpot and Degree Heating Weeks (DHW) charts on web
		Receive updated GBR Sea Temperature graphs from AIMS (operational)
		Receive high resolution sea temperature maps for GBR (2 km resolution) from BOM (developmental)
		Get weather summary for week, e.g. air temperatures, cloud cover and wind (Bureau of Meteorology)
		Review bleaching reports received via BleachWatch Professional & Community and update maps
		Review bleaching reports and images received via BleachWatch Aerial surveys and update maps
Routine – weekly/fortnightly	Tuesday	Summarise weather, sea and coral conditions and draft updated Bleaching Risk Report for web site. Include any recent images that may be available
Routine – weekly/fortnightly	Wednesday	Have updated Bleaching Risk Report reviewed, approved and published on external web
		Send brief update to all-staff and other lists (ACRS; DDM Program, AIMS, CRC Reef, Coral-List and BleachWatch participants)
Routine - weekly/fortnightly	Constant	Monitor extent of bleaching using existing information channels and evaluate for trends (i.e. is the bleaching situation worsening/improving)
		Advise Senior Management if dramatic worsening of conditions is evident
Event-based	Substantial increase in environmental stress ¹	Actively seek and solicit confirmatory bleaching reports from reliable sources, including BleachWatch participants, DDM Field officers, AIMS, other researchers, etc.
		Alert relevant project coordinators and managers
		Brief Senior Management
Event-based	Moderate bleaching event detected ¹	Brief Executive
		Prepare media position, draft statement and consult with Media Coordinator and Executive
		Brief all staff and stakeholders
		Brief collaborators (especially AIMS, NOAA, DDM)
		Release media statement
		Actively promote and solicit submissions to Online Bleaching Reporting Program to provide wide spatial coverage
Implement Bleaching Assessment and Monitoring Plan		

¹see Section 6.2 for description of thresholds for event-based tasks.



Australian Government
Great Barrier Reef
Marine Park Authority

The Great Barrier Reef Marine Park Authority
values your time and assistance
Contact: Gillian Goby
Phone: 07 4750 0762 Fax: 07 4772 6093



observe to conserve

1. OBSERVER DETAILS

Name: _____
 Email: _____
 Phone: _____
 Vessel/Organisation: _____

GPS Coordinates: _____

Please circle the category that best describes you.
 Reef Visitor Marine Tourism Industry Scientist QPWS Officer
 Other: (Please specify): _____

2. INFORMATION ABOUT THE SITE

Name/ID reef: _____ Nearest Port/Marine Park Section: _____

Date of visit: _____ Site name or description (eg NE point): _____

Type of habitat: (please circle): Lagoon Crest Slope Flat Bommie Field Front Reef Back Reef Other:

Wind Speed: _____ Cloud cover (please circle): Clear Partly cloudy Mainly cloudy Overcast

Air Temperature: _____ Water Temperature (0-3 metres): _____
 Water Temperature (5-10 metres): _____

Has your site changed since your last submission? (please tick): No change Change

3. REEF CONDITION AND BLEACHING OBSERVATIONS

How much live coral was at this site? (both hard and soft coral - enter %): (see Table 1)

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

What are the three most common types of coral in order of abundance? (1 = most common): (see Table 2)

Branching Bushy Plates Digitate Brain Encrusting Soft Coral

Was there any signs of bleaching? YES NO If yes, what portion of the corals were bleached? (enter %):

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

What types are bleached? (tick all relevant categories): (see Table 2)

In general, how severe was the bleaching? Indicate depth range of bleaching Min (m) Max (m)

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

4. DETAILED SECTION

Detailed identity of bleached corals (if known): (B = bleached U = unbleached N = not present):

Acropora Favillidae Fungillidae Montipora Pocillopora Porites Seriatopora Stylophora Turbinaria Lobophytum Sarcophyton Simularia

REMEMBER: Even if there is no bleaching, we still want to know regularly about your site.

Appendix B – Rapid Assessment Survey Data Sheet

Great Barrier Reef Marine Park Authority Coral Bleaching: Rapid Assessment Survey Datasheet

Region		Observer	Date	Time	Vessel	Dive Buddy	
Site Details		Reef Name		Notes			
Site Feature (table 3, 4, 5)							
Depth		Water Temp	Surface -		Transects -		
			Transect 1		Transect 2		Transect 3
Hard coral cover (1)							
Soft coral cover (1)							
Macroalgae cover (1)							
Other live cover (1)							
Bleaching level (6)							
Bleaching Notes							
Disease (2)							
COTS (2)							
Anchor Damage (2)							
Other orgs. Bleached? (Notes)							
			Transect 1		Transect 2		Transect 3
Bleaching Characterisation	CVR	0	1	2	3	4	5
Acropora							
Montipora							
Pocilloporids							
Porites							
Favids							
Soft corals							
Others? eg. Turbinaria, Goniopora							
Algae	Cover		Cover		Cover		
Fucales							
Other fleshy/upright/macroalgae							
CCA							
Filamentous							
Ephemeral/scuzzy							
Spongy/thick/tough matt							
Canopy height min/max/mode (cm)							
Fish Groups	Count		Count		Count		
Chaet. trifasciatus							
Labrichthys unilineatus							
Dascyllus							
Pom. amboinensis							
Other Observations							

Appendix C – Code tables for key variables

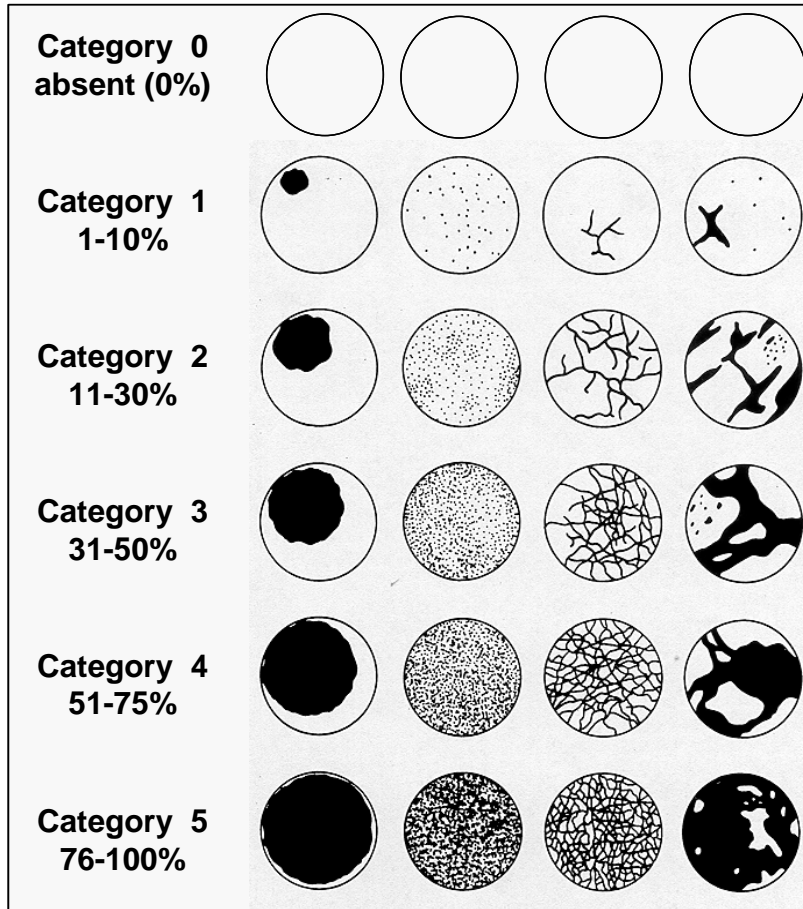
Table 6. Site bleaching category table

Index	%	Description	Visual Assessment
0	< 1	No Bleaching	No bleaching observed, or only very occasional, scattered bleached colonies (one or two per dive)
1	1-10	Low or Mild Bleaching	Bleached colonies seen occasionally and are conspicuous, but vast majority of colonies not bleached
2	10-50	Moderate bleaching	Bleached colonies frequent but less than half of all colonies
3	50-90	High Bleaching	Bleaching very frequent and conspicuous, most corals bleached
4	>90	Extreme Bleaching	Bleaching dominates the landscape, unbleached colonies not common. The whole reef looks white

Table 7. Colony bleaching table (for use in Line Intercept or Video Transect surveys)

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

Appendix D – Schematic representations of percent cover



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