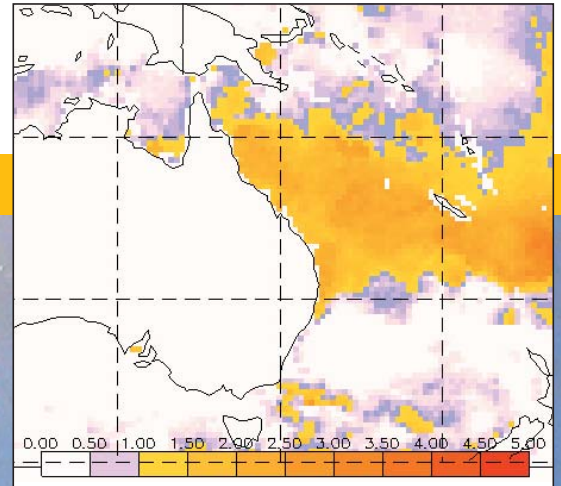




Australian Government  
Great Barrier Reef  
Marine Park Authority

# Great Barrier Reef Coral Bleaching Response Plan

SUMMER 2005 - 2006



Hotspot (thermal anomaly) Feb 2002



Climate Change Response Programme - Research & Monitoring Coordination Unit

# Contents

INTRODUCTION .....	1
<b>1. PLAN OVERVIEW.....</b>	<b>1</b>
1.1 SELECTING APPROPRIATE CORAL BLEACHING MONITORING FOR THE GBR .....	2
<b>2. EARLY WARNING SYSTEM .....</b>	<b>3</b>
2.1 CLIMATE MONITORING.....	3
2.2 SEA TEMPERATURE MONITORING .....	4
2.3 BLEACHWATCH.....	4
2.4 BLEACHWATCH (AERIAL).....	5
<b>3. BLEACHING ASSESSMENT AND MONITORING COMPONENT.....</b>	<b>6</b>
3.1 BROAD-SCALE SYNOPTIC SURVEYS .....	6
3.2 BLEACHING SURVEYS.....	7
SURVEY DESIGN AND METHODS .....	8
<b>3.2.1 Spatial and Temporal Scale.....</b>	<b>8</b>
<b>3.2.2 Survey Sites.....</b>	<b>9</b>
<b>3.2.3 Survey Design .....</b>	<b>9</b>
<b>3.2.4 Data Analysis &amp; Management .....</b>	<b>10</b>
<b>3.2.5 Complementary Studies .....</b>	<b>10</b>
<b>4. COMMUNICATION STRATEGY .....</b>	<b>11</b>
<b>5. IMPLEMENTATION.....</b>	<b>12</b>
5.1 RESPONSE SCHEDULE .....	12
<b>5.1.1 Routine Tasks .....</b>	<b>12</b>
<b>5.1.2 Responsive Tasks.....</b>	<b>13</b>
5.2 DEFINITION OF EVENT TRIGGERS FOR IMPLEMENTATION PLAN.....	13
<b>6. REFERENCES .....</b>	<b>13</b>
<b>APPENDIX A – BLEACHWATCH REPORTING FORM.....</b>	<b>17</b>
<b>APPENDIX B – RAPID ASSESSMENT SURVEY DATA SHEET.....</b>	<b>18</b>
<b>APPENDIX C – CODE TABLES FOR KEY VARIABLES.....</b>	<b>19</b>
<b>APPENDIX D – SCHEMATIC REPRESENTATIONS OF PERCENT COVER.....</b>	<b>20</b>

## 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 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 (GBRMPA) Coral Bleaching Response Plan 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 broad-scale synoptic surveys and ecological surveys. The information collected under this Response Plan can be used to compare and analyse the frequency and patterns of bleaching events and to develop forecasting tools.

## 1. Plan Overview

This document describes a Coral Bleaching Response Plan for the Great Barrier Reef (GBR). This will enable GBRMPA to:

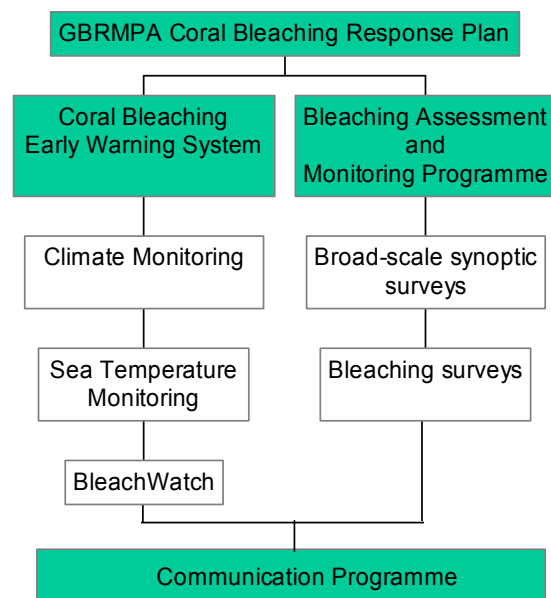
- Develop a system to forecast coral bleaching events;
- Provide early warnings of a major coral bleaching event;
- Measure the spatial extent and severity of mass coral bleaching events;
- Assess the ecological impacts of mass coral bleaching events;
- Involve the community in monitoring the health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

The Great Barrier Reef Coral Bleaching Response Plan (the Response Plan) 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 Response Plan also links in with GBR tourism industry-based monitoring programs such Eye on the Reef.

The GBR Coral Bleaching Response Plan has the following three main components (Figure 1):

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

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



The following sections detail the rationale, strategies and methods for each of the components. The final section of the Response Plan includes a detailed description of the implementation plan.

### 1.1 Selecting Appropriate Coral Bleaching Monitoring 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 plan. The broad objectives of the GBR Coral Bleaching 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
  - 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 coral bleaching and recovery

The GBR Coral Bleaching Response Plan also expects to provide a foundation to develop an understanding of the social and economic impacts of coral 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 Climate Change Response Team reviewed the needs of the Response Plan and designed the monitoring plan using the following selected methods based on the available resources.

**Table 1** Monitoring activities of the GBR Coral Bleaching Response Plan

Question	Resource Scenarios (see definitions below)		
	1. Low	2. Medium	3. High
<b>A.</b> What is the general extent and severity of the current bleaching event?	<b>A1</b> <ul style="list-style-type: none"> <li>• Circulate questionnaires (BleachWatch) amongst local divers and other reef users</li> <li>• Submit information to ReefBase</li> </ul>	<b>A2</b> <ul style="list-style-type: none"> <li>• Identify major species affected (take photos or video footage)</li> </ul>	<b>A3</b> <ul style="list-style-type: none"> <li>• Conduct detailed surveys of representative sites using transects and a precise measure of percentage of coral affected (line transect, video-transect)</li> <li>• Use remote sensing to obtain synoptic estimates over wider geographic area</li> </ul>
<b>B.</b> Is the bleaching associated with specific environmental factors such as temperature, solar radiation, water circulation?	<b>B1</b> <ul style="list-style-type: none"> <li>• Ask other reef users to collect similar data</li> </ul>	<b>B2</b> <ul style="list-style-type: none"> <li>• Get local weather data from Meteorological office on air temperature, sun hours, wind</li> <li>• Consult with oceanographers regarding the circulation patterns, water exchange and any upwelling features in the area</li> <li>• Compare bleaching records with hotspots and degree heating weeks on NOAA's website</li> </ul>	<b>B3</b> <ul style="list-style-type: none"> <li>• Install recording temperature loggers at main bleaching sites</li> <li>• Install remote weather stations to record temperatures, wind and solar radiation</li> <li>• Measure currents and tidal flow at key sites</li> <li>• Acquire and analyse remote sensing data to correlate bleaching records with thermal anomalies and degree heating weeks</li> </ul>
<b>C.</b> How long will it last and is it a recurring event?	<b>C1</b> <ul style="list-style-type: none"> <li>• Ask local reef users for details on bleaching events and record these on BleachWatch questionnaires</li> </ul>	<b>C2</b>	<b>C3</b> <ul style="list-style-type: none"> <li>• Repeat detailed observations in A3</li> <li>• Repeat same observations for any subsequent bleaching events</li> </ul>
<b>D.</b> What are the ecological impacts on	<b>D1</b> <ul style="list-style-type: none"> <li>• Conduct before and after bleaching observations</li> </ul>	<b>D2</b> <ul style="list-style-type: none"> <li>• Measured estimates of benthic cover through time</li> </ul>	<b>D3</b> <ul style="list-style-type: none"> <li>• Measured estimates of benthic cover through time at higher</li> </ul>

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

## 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 temperatures, above-average water temperatures follow, which in turn can lead to patchy bleaching or bleaching of more vulnerable coral 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 spatial extent and severity 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 the 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 forecast for predicting potential warming conditions

**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

## 2.2 Sea Temperature Monitoring

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 HotSpots programme provides regional-scale near-real time measurements of sea surface temperature (SST) anomalies above the maximum expected summer time temperature. HotSpots and Accumulated Heat Index products from the NOAA web site provide reliable indicators of levels of heat stress in reef regions and coral bleaching events have been noted in areas where the HotSpots are greater than 1 degree C anomalous. Over the last year, the GBRMPA has been developing ReefTemp, an improved sea temperature monitoring product for the GBR region with the Bureau of Meteorology (BoM) and the Commonwealth Scientific and Industrial Research Organization (CSIRO). ReefTemp improves the GBRMPA's ability to monitor thermal stress, and allows for the now-casting of bleaching risk at the scale of an individual reef (~2 km resolution). Images of the a) SST anomaly (above the long-term average temperature for that month); b) number of Degree Heating Days; and c) Rate of Heat Stress Accumulation are updated on the ReefTemp website daily.

Excessive and persistent SST anomalies indicate sea temperatures are approaching levels 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 ReefTemp and the accumulated stress indices therein as indicators of local thermal stress during the summer.

In addition, *in situ* measurements of local sea temperatures are available 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 ReefTemp predictions.

A network of temperature loggers is also maintained in a collaboration with Australian Institute of Marine Science (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 ReefTemp
  - Evaluate sea temperature from weather station data to validate the remotely sensed sea temperatures used in ReefTemp
  - Actively monitor NOAA HotSpots
- Triggers:**
- The onset of stressful conditions will trigger increased vigilance of coral condition through BleachWatch and site inspections (Table 2). Stressful conditions (event triggers) are defined in Table 3

## 2.3 BleachWatch

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 community monitoring initiative that has been designed to provide reliable reports of reef condition from a wide range of reef sites throughout the GBR. 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 regularly.

BleachWatch was initially established at the start of 2002, during the major bleaching event that occurred that summer on the GBR. Participants visiting reefs between Port Douglas in the north and Bundaberg in the south have been enlisted to provide regular reports on the appearance and health of

the sites they visit during summer. The number of participants and geographic coverage of BleachWatch has continued to grow, with currently 87 participants.

BleachWatch participants are provided with a BleachWatch kit and asked to complete purpose-designed monitoring forms on a weekly basis. Participants are asked to provide general observer information (section 1), as well as details about their site, type of habitat 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 (section 3) and bleaching observations 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 estimated that completion of the form takes approximately 10 minutes per week for each participant. The data submitted by BleachWatch observers will be compiled and synthesised into summary reports 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 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 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. Reports will be compiled onto maps every 1-2 months during the summer season, and published on the website.

- 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 BleachWatch kit that assists them in reporting on reef conditions and detecting coral bleaching. The BleachWatch kit includes:
    - Interpretive material on coral bleaching and climate change
    - Examples of coral growth forms
    - Examples of bleaching severity
    - Monitoring forms
    - Instruction for the monitoring form
    - In-water identification wrist band
  - Regularly enter and evaluate data received to determine the composition of each reef to assist with evaluations of bleaching susceptibility
  - Provide regular feedback in the form of summary site reports and to all participants
  - Develop and maintain a website providing information on BleachWatch, 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 and informal communications, to all participants
- Triggers:** Reports of spatially extensive or severe local bleaching will trigger the Bleaching Assessment and Monitoring component.

## 2.4 BleachWatch (Aerial)

BleachWatch (Aerial) 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
- 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 GBR
- Triggers:** Confirmation of conditions conducive to bleaching from the climate and sea temperature monitoring will trigger the broad-scale synoptic surveys.

### **3. Bleaching Assessment and Monitoring Component**

The 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 (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 approach using two methods will be used to provide the best possible combination of spatial coverage and detailed information. The Bleaching Assessment and Monitoring component is comprised of broad-scale synoptic surveys and in-water bleaching surveys. The broad-scale synoptic surveys will use both MERIS and Quickbird satellite imagery to access different spatial resolution data. CSIRO will provide the MERIS mapping and the Centre for Remote Sensing and Spatial Information Science at the University of Queensland will provide the Quickbird high resolution and field mapping. The bleaching surveys will collect detailed ecological information from a set of established reef sites that represent cross-shelf as well as latitudinal reefs. This tiered approach is the most effective for obtaining a synoptic overview of where bleaching is occurring from a GBR-wide perspective.

#### **3.1 Broad-scale synoptic surveys**

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. Broad-scale synoptic surveys are the most effective method for obtaining an 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 being important for temporal comparisons of the extent of future bleaching events, broad-scale synoptic surveys help to identify the reefs or regions worst affected by thermal stress.

The MERIS based mapping will trial a small-scale pilot method during the 2005/2006 summer. The pilot will involve field validation of remotely sensed images, and will provide a high level of detail on the health of coral (e.g. healthy coral, bleached coral, recently dead coral). Due to the high level of resolution, this method will be limited in spatial coverage. The MERIS data will be captured over the entire GBR and will be used to test the mapping algorithm developed at CSIRO, over inshore and offshore reefs. The pilot will concentrate in areas around the field survey sites, which will allow the image data to be validated with field data.



If a bleaching event occurs, Quickbird (2.4m pixels) image data will be captured over the sites where bleaching surveys are conducted. These images will cover 10 km x 10 km sections and will be used to map bleached versus non-bleached coral areas.

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

**Strategies:**

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

### 3.2 Bleaching Surveys

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. To better understand the long-term implications of these events information on the extent and patterns of coral mortality that result from bleaching need to be measured.

In-water bleaching surveys 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 bleaching surveys will also enable the direction and rate of community recovery to be evaluated. The quantitative data provided by the bleaching surveys will 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.

Bleaching surveys 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 all sites. 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, integration with the AIMS LTMP and survey methods are outlined in the following section Survey Design and Methods.

**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 Coral Bleaching Response Plan will build on existing programmes, in particular the AIMS Long Term Monitoring Programme (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 characterise 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. The Response Plan 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 Programme (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)
	No Name Reef (O)
Northern (Cairns)	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 South)	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.

Forty five 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 mid-shelf and three outer shelf reefs have been 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 Plan<sup>1</sup> survey sites.

The benefit of this approach is that baseline and recovery data for the deep transects can be obtained from the AIMS LTMP routine surveys and thus reduce the need for multiple GBRMPA survey trips and duplication with existing programmes. However, the LTMP 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 (3-4 m), as this is the area most affected by coral bleaching. It is necessary to obtain a quantitative baseline assessment of the upper slope community at all of the survey sites to enable us to evaluate the long-term ecological impacts of coral bleaching on the Great Barrier Reef.

Some remote locations along the GBR have been omitted from the standard 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 AIMS LTMP survey sites. If a significant bleaching event occurs, these sites will be surveyed if logistics allow.

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 programme (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 – 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 5 m wide along the length of the transect. Three sets of information will be recorded: station

---

<sup>1</sup> 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.

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. 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. A table showing schematic representations of percent cover will be utilised to maximise consistency in estimates made under water.

Video transects 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 using the 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 Programme: temperature loggers

AIMS coordinate the Sea Temperature Monitoring Programme, 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 (~ 5-9 m), or on the deep reef slope (~ 20 m). 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 System in the Response Plan. Additionally, AIMS targeted bleaching surveys will complement the GBRMPA surveys.

##### AIMS LTMP

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 World Heritage Area. The GBR Response Plan utilises the information collected under the LTMP to obtain baseline and recovery data.

##### Reef Water Quality Protection Plan

In addition to the fine-scale ecological surveys, water quality data collected for the Reef Water Quality Protection Plan (Reef Plan) marine monitoring 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. Many of these sites overlap with proposed fine scale ecological impact assessment sites of the GBR Response Plan and there is the opportunity to correlate these sites further for broad-scale synoptic surveys and bleaching surveys during a bleaching event.

## 4. Communication Strategy

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 accurate 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 Plan 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 initiatives such as Eye on the Reef, Tourism and Recreation Newsletter and LMACs) and email. Information will also be distributed more widely through the GBRMPA website and via media outlets. The Communication Strategy aims to increase awareness of the implications of climate change for the GBR, and the occurrence and consequences of coral bleaching events through a variety of 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 November, the website will be reviewed to present the most current information on 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 lists.
- During summer (December to April), the 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 Plan are shown in the Schedule below (Figure 2). Climate and weather conditions will be monitored from mid-November, approximately 3 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 are confirmed, or if there are any reports of significant coral bleaching, the Bleaching Assessment and Monitoring component will be implemented (Figure 2).

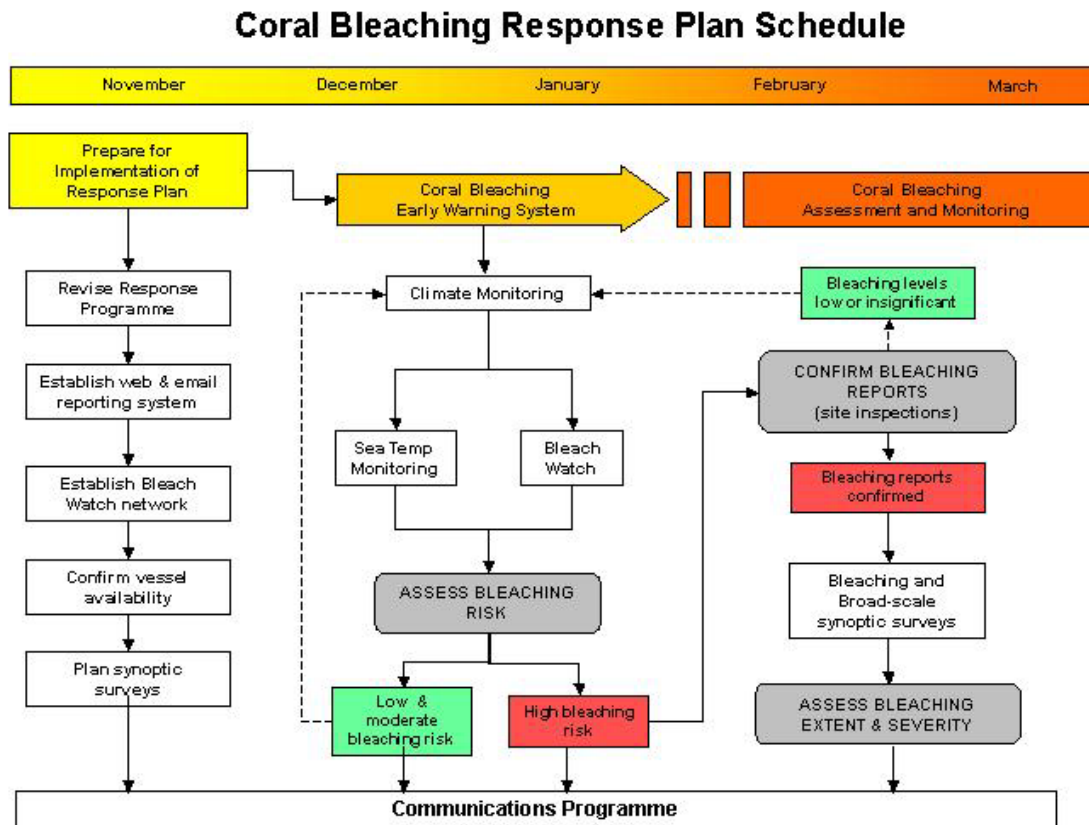


Figure 2. Schedule for the GBR Coral Bleaching Response Plan.

### 5.1 Response schedule

The GBR Coral Bleaching Response Plan 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 Climate Change 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
- ❑ Initial 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 website;
- ❑ 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;
- ❑ Advise Senior Management and Minister of any increase in bleaching risk or bleaching reports.

### 5.1.2 Responsive Tasks

- ❑ Confirm bleaching reports (site inspections)
- ❑ Advise Senior Management, Minister, stakeholder groups and the community of onset of coral bleaching;
- ❑ Implement broad-scale synoptic surveys to assess bleaching extent;
- ❑ Deploy bleaching survey team to measure extent and severity of bleaching;
- ❑ Monitor ecological impacts of bleaching.

## 5.2 Definition of Event Triggers for Implementation Plan

The triggers for monitoring tasks and briefings outlined in the Implementation Plan (Tables 2 and 3) are defined below.

‘*High bleaching risk*’ is defined as:

- Persistence of strong hotspots (anomaly > 1.5 deg C) for 2 weeks or very strong hotspots (anomaly > 2 deg C) for 1 week over majority of GBR 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 GBR Marine Park sectors; or
- Reliable reports of mild bleaching (10-50%) from a few sites only, scattered throughout the GBR 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 GBR Marine Park sectors; or
- Reliable reports of severe bleaching (>50%) from a few sites only, scattered throughout the GBR 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 GBR sectors.

## 6. References

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

**Table 2. Implementation Plan for Summer Period 2005-06**

TRIGGER <sup>1</sup>	ACTIONS						
	Monitoring			Briefings			
	Site inspections	Broad scale synoptic	Bleaching surveys	Brief Senior Management	Brief Minister	Press release	Message
1 December				✓	✓	✓	Summer approaching; bleaching risk period; GBRMPA is prepared
20 December				✓			Temperature trends for December; plans for xmas period
High bleaching risk	✓			✓	✓		Temperatures unusually high; coral bleaching event probable
Moderate bleaching	✓	✓	✓	✓	✓	✓	High temperatures recorded; moderate bleaching observed; areas worst affected
Severe bleaching <sup>2</sup>	✓	✓	✓	✓	✓	✓	Very high temperatures recorded; severe bleaching observed; areas worst affected; mortality likely
15 February <sup>3</sup>				✓			Temperature trends for first half of summer; summary of reports of coral bleaching
31 March (if no significant bleaching observed)				✓	✓	✓	Summer concluding; bleaching risk period over; no significant bleaching observed
31 March (if moderate or severe bleaching reported)				✓	✓	✓	High water temperatures recorded during summer; bleaching observed; preliminary assessment of extent and severity; detailed surveys underway
31 April (if moderate or severe bleaching reported)				✓	✓	✓	Summary of full extent and severity of bleaching; implications for GBRMP
Monthly <sup>4</sup>				✓			Updates on temperature trends and coral condition; also publish to web and email to all staff etc.

<sup>1</sup> Event-based triggers are defined in Table 3 of the GBR Coral Bleaching Response Plan

<sup>2</sup> Aerial surveys, site inspections and bleaching surveys are likely to already have been triggered by moderate bleaching levels

<sup>3</sup> This briefing will not be necessary if a moderate or severe bleaching event has already been declared

<sup>4</sup> These update reports may be made twice-monthly if conditions are changing rapidly



**Table 3. Definition of event triggers for Implementation Plan**

Trigger	Definition
<i>High bleaching risk</i>	<ul style="list-style-type: none"> <li>• Persistence of strong hotspots (anomaly &gt; 1.5 deg C) for 2 weeks or very strong hotspots (anomaly &gt; 2 deg C) for 1 week over majority of GBR region;</li> <li>• Degree heating days index is greater than 21 at multiple sites;</li> <li>• Bleaching thresholds exceeded at inshore <i>and</i> offshore sites; or</li> <li>• There are anecdotal reports of bleaching from multiple sites.</li> </ul>
<i>Low bleaching level</i>	<ul style="list-style-type: none"> <li>• Reliable reports of low coral bleaching (1-10% of colonies completely white) from multiple sites from multiple locations spanning at least two GBRMP sectors; or</li> <li>• Reliable reports of mild bleaching (10-50%) from a few sites only, scattered throughout the GBRMP or concentrated in only one sector.</li> </ul>
<i>Moderate bleaching level</i>	<ul style="list-style-type: none"> <li>• Reliable reports of moderate coral bleaching (10-50% of colonies completely white) from multiple sites from multiple locations spanning at least two GBRMP sectors; or</li> <li>• Reliable reports of severe bleaching (&gt;50%) from a few sites only, scattered throughout the GBRMP or concentrated in only one sector.</li> </ul>
<i>Severe bleaching level</i>	<ul style="list-style-type: none"> <li>• Reliable reports of severe to extreme coral bleaching (&gt;50% of colonies completely white) from multiple sites spanning multiple GBR sectors.</li> </ul>

**Table 4. Coral Bleaching Response Plan: Task Schedule**

<b>Trigger type</b>	<b>Timing</b>	<b>Information</b>
Routine - weekly	Monday	Check GBRMPA ReefTemp and NOAA HotSpot maps on web
		Receive updated GBR sea temperature graphs from AIMS (operational)
		Receive high resolution sea temperature maps for GBR (2 km resolution) from BoM
		Get weather summary for week, e.g. air temperatures, cloud cover and wind (BoM)
		Review bleaching reports received via BleachWatch and update maps
		Review bleaching reports and images received via BleachWatch (Aerial) surveys and update maps
		Print out ReefTemp and NOAA HotSpot maps for STIG Director to brief SMT
Routine – weekly/fortnightly	Tuesday	Summarise weather, sea and coral conditions and draft updated Bleaching Risk Current Conditions Report for website. Include any recent images that may be available
Routine – weekly/fortnightly	Wednesday	Have updated Current Conditions Report reviewed, approved and published on external web
		Send brief update to all-staff and other lists (ACRS; DDM, 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 and Minister if dramatic worsening of conditions is evident
Event-based	Substantial increase in environmental stress <sup>1</sup>	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 <sup>1</sup>	Brief Executive and Minister
		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 reports to provide wide spatial coverage
		Implement Bleaching Assessment and Monitoring component

<sup>1</sup>see Section 6.2 for description of thresholds for event-based tasks.

# Appendix A – BleachWatch Reporting Form



**Australian Government**  
**Great Barrier Reef**  
**Marine Park Authority**



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

## 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%)

• 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

• Types Bleached (Table 2):  
 Branching  Bushy   
 Plate  Digitate   
 Massive  Encrusting   
 Soft Coral

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

## 5. Detailed Types Present / Bleached

	Present Bleached		Present Bleached		Present Bleached			
Acropora	<input type="checkbox"/>	<input type="checkbox"/>	Turbinaria	<input type="checkbox"/>	<input type="checkbox"/>	Porites	<input type="checkbox"/>	<input type="checkbox"/>
Fungiidae	<input type="checkbox"/>	<input type="checkbox"/>	Stylophora	<input type="checkbox"/>	<input type="checkbox"/>	Sarcophyton	<input type="checkbox"/>	<input type="checkbox"/>
Pocillopora	<input type="checkbox"/>	<input type="checkbox"/>	Faviidae	<input type="checkbox"/>	<input type="checkbox"/>	Lobophytum	<input type="checkbox"/>	<input type="checkbox"/>
Seriopora	<input type="checkbox"/>	<input type="checkbox"/>	Montipora	<input type="checkbox"/>	<input type="checkbox"/>	Sinularia	<input type="checkbox"/>	<input type="checkbox"/>

Comments: .....



## Appendix C – Code tables for key variables

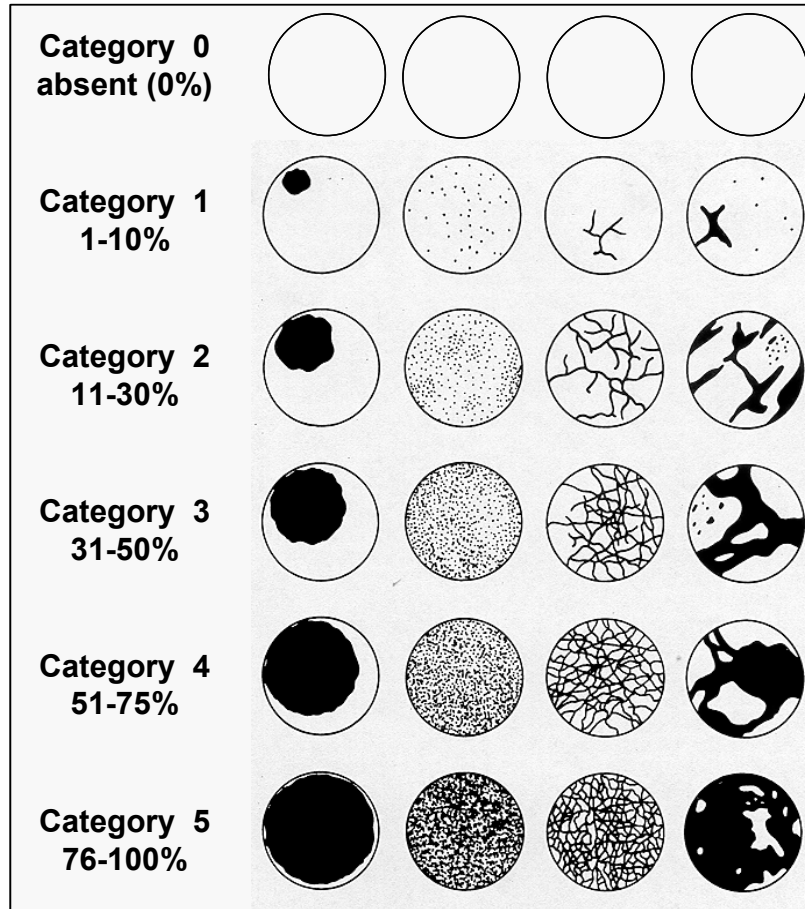
**Table 6. Site bleaching category table**

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 level Bleaching	Bleached colonies seen occasionally and are conspicuous, but vast majority of colonies not bleached
2	10-50	Moderate level bleaching	Bleached colonies frequent but less than half of all colonies
3	50-90	Severe 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)