Australian Government
Great Barrier Reef
Marine Park Authority

RESEARCH PUBLICATION NO. 87

Great Barrier Reef coral bleaching surveys 2006

Undertaken as a part of the Climate Change Coral Bleaching Response Plan
March - April 2006

let's keep it great

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Coral Bleaching Response Plan 2006 Report

Summary

Coral bleaching surveys of 34 reefs in the Great Barrier Reef were undertaken by the Climate Change Group of the Great Barrier Reef Marine Park Authority between March and April 2006 to assess the extent and severity of coral bleaching. Surveys were conducted on most of the core survey sites of the Coral Bleaching Response Plan[1] and included five cross-shelf regions, representing a latitudinal range of 9 degrees. Within each region, reefs representing inshore, mid-shelf and outer reef habitats were surveyed using standard rapid assessment and video transect techniques.

Overall, minimal to no bleaching was observed (<5 per cent of colonies affected on average) on the majority of the reefs surveyed and any observations of bleaching were usually limited to sensitive coral genera such as *Acropora* and *Pocillopora*. Severe bleaching was limited to the inshore and mid-shelf reefs of the Far Southern Region (reefs around the Keppel Islands and in the Capricorn Bunker Group). Signs of bleaching at these sites included paling, white and some fluorescent corals. These are typical responses of corals to elevated sea surface temperatures and up to 100 per cent of corals in the Keppel Island sites were affected by bleaching to some degree. No extensive coral mortality was observed at the time of these surveys.

Coral communities that experienced mild bleaching are expected to regain their zooxanthellae and survive, with few cases of mortality. Sites where bleaching was both extensive and severe (Far Southern Region) were closely monitored for survival and mortality rates in the months that followed the surveys presented in this report. Surveys in June 2006 estimated coral mortality among the Keppel Islands sites to be 31 per cent, with over 33 per cent unbleached (having regained their zooxanthellae) and 10 per cent still showing signs of bleaching. A further survey by the Australian Institute of Marine Science in August 2006 recorded 40 per cent mortality of corals in the Keppel Islands. Importantly, reefs in the Keppel Island region have experienced bleaching before with up to 100 per cent of corals affected during the 1998 and 2002 bleaching events. Following these events though survival rates were far higher than in the 2006 event and very little mortality was observed.

Implementation of the Coral Bleaching Response Plan in 2006 further highlighted that the early warnings provided by BleachWatch community partnerships and the *ReefTemp* monitoring system are invaluable and allow for the strategic use of available resources.

[1] http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change/management_responses/coral_bleaching_response_plan

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 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 has experienced two major coral bleaching events in recent years: 1998 and 2002. The spatial extent of these events, combined with the high level of mortality seen at severely affected sites, has lead to widespread concern about the future of the Great Barrier Reef in the face of global climate change. The Great Barrier Reef Marine Park Authority's (Great Barrier ReefMPA) 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 intensive in-water ecological surveys if bleaching does occur. The information collected under this Response Plan is used to understand the frequency and patterns of bleaching events and to develop forecasting tools.

In December 2005, the Response Plan early warning systems (BleachWatch and *ReefTemp*) signalled an increase in local sea-surface temperatures in the Keppel Islands area of the Southern Great Barrier Reef. Satellite data showed sea-surface temperatures to have exceeded 10-year averages by at least 2°C during late December 2005 and early January 2006. Site assessments by the Climate Change team in January and February 2006 confirmed reports of widespread coral bleaching in the Keppel Islands area and, to a lesser extent, among reefs in the Capricorn Bunker group (Coral Bleaching Inspection Report, Great Barrier ReefMPA 2006). Sea temperatures across the rest of the Great Barrier Reef were not as extreme as in the south but were above average and minor bleaching was reported by BleachWatch observers. The results of these site assessments and the BleachWatch reports triggered widespread surveys of the Great Barrier Reef to assess the full extent and severity of coral bleaching.

Methods

Spatial coverage and survey sites

The Response Plan has identified 45 core survey sites (in most cases these are sites monitored by the Australian Institute of Marine Science's Long-Term Monitoring Program, AIMS LTMP) for intensive in-water ecological surveys if bleaching occurs. These sites represent cross-shelf as well as latitudinal gradients. The benefit of using these sites is that baseline and recovery data can be obtained from AIMS and contribute to the assessment made by the Great Barrier ReefMPA. The spatial distribution of the survey sites represents five major regions, Far Northern, Northern, Central, Southern and Far Southern with latitudes centred on Lizard Island, Cairns, Townsville, Whitsunday Islands and the Capricorn Bunker Group respectively (Map 1). The sample design includes three inshore, three mid-shelf and three outer-shelf reefs within each of the five sectors. Sampling was modified during the survey because of adverse weather conditions and the re-prioritisation of one sector to document the impact of Tropical Cyclone Larry on mid-shelf reefs. For these reasons, only 34 reefs were surveyed under the Response Plan in 2006 (Map 1).

Design and data analysis

Each survey site was divided into two depth zones: the upper reef slope (~2-3m) and the lower reef slope (~6-8m). The upper reef slope includes the reef crest and upper slope and the lower reef slope includes both the mid and lower slope.

Three 50 m transects were surveyed parallel to the reef slope in both depth zones, at each site. Random transects were used, rather than fixed, to reduce survey time, to avoid unsightly markers on the reef and to ensure independence among consecutive surveys. Each transect was surveyed simultaneously by two independent divers conducting a rapid assessment survey as well as a video survey.

a) Rapid Assessment Survey: the rapid assessment technique is the Coral Bleaching Response Plan's standard survey method that records benthic structure and condition within an area of approximately 50 m by 5 m and is done by swimming through the site in a matter of minutes. Three sets of information are recorded within the survey area: (1) site information (site name, depth, transect number and water temperature), (2) coral and algal cover and (3) bleaching severity for each of the major coral groups.

b) Video transects: video transects are collected using a five minute swim with the video held 30 cm above the target substrate at a speed of 10m/min (in accordance with the standard protocol used by the AIMS LTMP, English et al. 2004). Video images were analysed by taking 40 regular-interval sub-samples per 50 m transect. Each sub-sample had five regularly distributed points on the screen. The substrate under each point of the sub-sample was identified to life form or species group. The video transects are used as a long-term record of the substrate, provide greater taxonomic detail, and can be reanalysed in the future for further research.

Results

Bleaching responses at the majority of the 34 surveyed responses were mild and were limited to sensitive coral genera such as *Acropora* and *Pocillopora*. Extensive bleaching was limited to the inshore and mid-shelf reefs of the Far Southern Region (reefs around the Keppel Islands and in the Capricorn Bunker Group, Table 1). Signs of bleaching at these sites included paling, white and some fluorescent corals. These are typical responses of corals to elevated sea surface temperatures and up to 100 per cent of corals around the Keppel Islands were affected by bleaching to some degree. No extensive coral mortality was observed during initial Coral Bleaching Response Plan surveys in March, however, the results of a Coral Bleaching Response Plan follow-up study of Keppel Islands sites in June 2006 and a further study of the same sites in August by AIMS show a progressive increase in mortality from 31 per cent to a final total of 39 per cent for reefs in the Keppel Bay area.

Table 1. Percentage of hard corals affected by bleaching during the 2005/2006 summer by survey region.

Region	**Percent affected**
Far Southern	46 per cent
Southern	0.5 per cent
Central	0.75 per cent
Northern	0.5 per cent
Far Northern	1.5 per cent

The 2006 surveys confirmed reports from BleachWatch observers that bleaching impacts were limited to inshore and mid-shelf coral communities in the Far Southern Region of the Great Barrier Reef, including Wreck Island, One Tree Island, Gannet Cay and Chinaman Reef. Bleaching impacts were particularly extensive around the Keppel Islands. For all other areas surveyed, the incidence of bleaching was low, patchily distributed and confined to a few individual colonies.

The minor bleaching recorded among corals on reefs in the Far Northern, Northern, Central and Southern regions was consistent with bleaching sensitivities reported for diverse communities throughout the Great Barrier Reef during a mild warming event (Done et al. 2003). Corals in these areas that completely bleached were most often Pocilloporids and branching *Acropora* sp. while some massive Faviids and plating *Montipora* sp. were pale on the upper surfaces. For the Central Region (offshore Townsville) priority was given to surveys of mid-shelf reefs in the wake of Cyclone Larry that had just crossed the Great Barrier Reef. Only two of the planned Response Plan sites were surveyed: John Brewer Reef and Rib Reef. These reefs showed no signs of bleaching but did show evidence of infrastructure damage from Cyclone Larry. Chin et al. (2006) provides a more detailed discussion of the effects of Cyclone Larry on central and northern reefs.

Again, the majority of bleaching observed in 2006 was restricted to far southern Great Barrier Reef locations, including the Keppels, Swains and Capricorn Bunker Reefs. Bleaching observations on the mid-shelf and outer-shelf reefs (Swains and Capricorn Bunker, respectively) were milder than at the Keppel Islands; an average of 21 per cent of corals were affected by bleaching compared to an average of 95 per cent of corals affected in the Keppel Island area (Tables 2A and B).

Table 2. Average percent cover of hard coral affected by one of five categories of bleaching for survey sites at a) the Keppel Islands area, and b) Swains/Capricorn Bunker reefs

A

Location	**Halfway Island**		**Middle Island**		**North Keppel Island**	
Depth	Deep	Shallow	Deep	Shallow	Deep	Shallow
No bleaching	3	1	16	1	3	4
Upper surfaces	6	12	13	12	5	11
Paling/fluorescence	22	31	17	31	11	12
Totally white	63	50	54	56	74	69
Recently dead	6	6	0	0	7	3
Total affected	**97**	**99**	**84**	**99**	**97**	**96**

B

Location	Reef 21-529		Wreck Island		Gannet Cay		One Tree Island		Chinaman Reef	
Depth	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow
No bleaching	84	96	80	68	64	91	88	61	80	76
Upper surfaces	7	4	13	19	22	8	12	5	7	7
Paling/fluorescence	7	0	5	2	3	0	0	9	10	7
Totally white	3	0	2	11	11	1	0	25	3	10
Recently dead	0	0	0	0	0	0	0	0	1	0
Total affected	**16**	**4**	**20**	**32**	**36**	**9**	**12**	**39**	**21**	**24**

Bleaching in the Keppel Island Area

Mortality from bleaching in the Keppel Island area was low (average four per cent) at the time of the first surveys in March 2006 (Figure 1). Sea temperatures were sustained above the seasonal average from December 2005 to April 2006 (Figure 2). A re-survey of the sites in June 2006 assessed that mortality had risen to 31 per cent as corals succumbed to protracted starvation during the bleaching event (Figure 3). Some corals were still in a stressed condition (pale or white). A survey in August 2006 estimated that the final coral mortality as a result of the 2006 bleaching event was approximately 39 per cent, with live corals having regained their colouration and, by inference, a serviceable population of zooxanthellae (Figure 4; Berkelmans et al. in prep). Later that same year, in November, heavy rainfall coincided with an extreme low tide resulting in hypo-saline mortality among 10 per cent of the shallow water corals on many reef flats (see Appendix A, Figure A2 for more detail). A return of normal colouration does not necessarily indicate a full recovery from the impacts of bleaching as extended stress levels have a physiological toll on corals that can manifest as both increased vulnerability to future disturbances (Bruno et al. 2007) as well as reduced reproductive output (Ward et al. 2000).

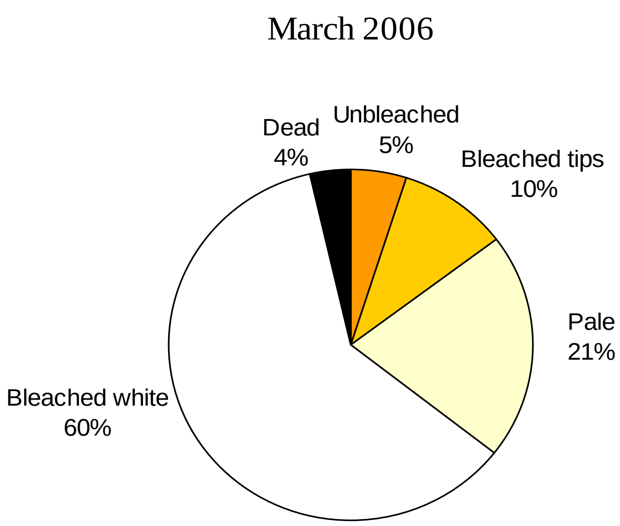


Figure 1. Bleaching severity at surveyed reefs within Keppel Islands, March 2006. Note the large proportion of completely bleached corals and low proportion of mortality.

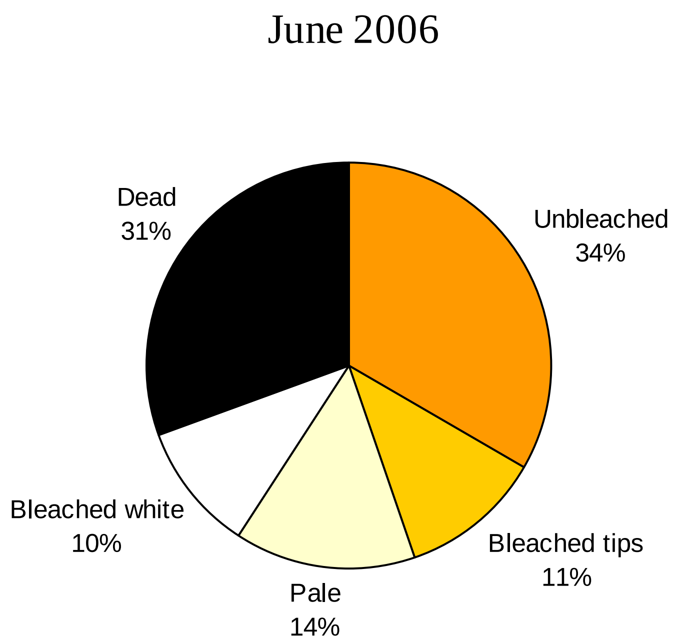


Figure 2. Bleaching severity at surveyed reefs within the Keppel Islands, June 2006. Note the high proportion of mortality.

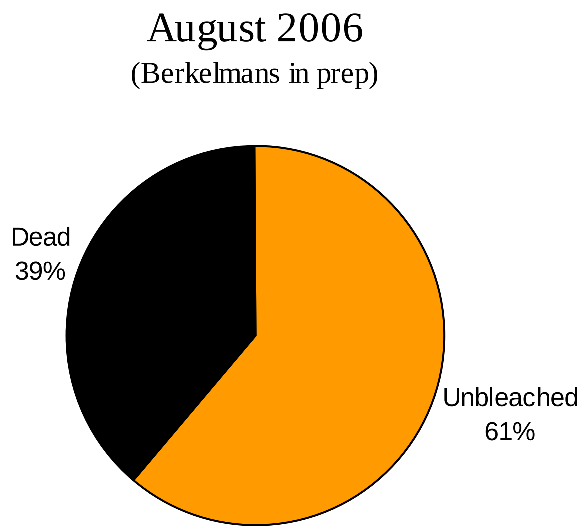


Figure 3. Bleaching severity at surveyed reefs within the Keppel Islands, August 2006. Note that the proportion of corals recorded as bleached in June 2006 nearly equals the difference in the proportion of corals dead during these surveys and the proportion dead during those undertaken in June.

In January and early February 2006, there was moderate bleaching within the Capricorn Bunker group (to the south-east of the Keppel Islands), at Heron Island, One Tree Island, Wistari Reef, Mast Head Reef and Erskine Reef (50-75 percent of corals affected; primarily paling, upper surfaces and fluorescent). These quickly recovered as temperature stress subsided. Minor bleaching was also observed at Lady Elliot Island and Fitzroy Reef (see Figure 4).

The 2006 bleaching event was driven by sustained sea temperatures above established bleaching thresholds of 27.5°C (+1°C – 1.5°C; Berkelmans et al. in press) that were observed as early as

December 2005 and continued into early 2006 (Figure 4, Maynard et al. in review). This thermal stress continued for 4 months in the Keppel Islands (Figure 5) and, for more than half that time, sea temperatures were at least 2°C above the threshold. This was unlike previous bleaching events (1998, 2002) where temperatures fluctuated throughout summer (Figure 5), possibly due to seasonal rains, cloud cover or winds.

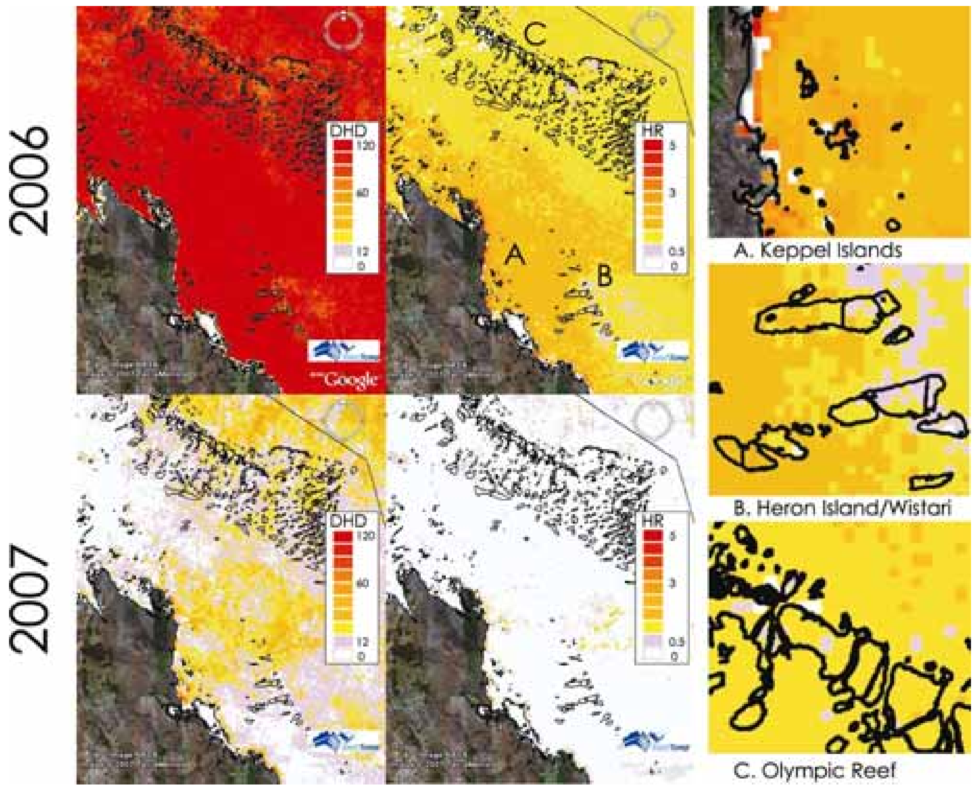


Figure 4. *ReefTemp* images from the end of the 2006 and 2007 summers. Heating rate, shown in the middle accurately predicted that bleaching responses would be severe in the Keppel Islands in 2006 (A) and mild at both Heron Island and Olympic Reef in 2006 (B and C, respectively), as well as that there would be no bleaching in the 2007 summer.

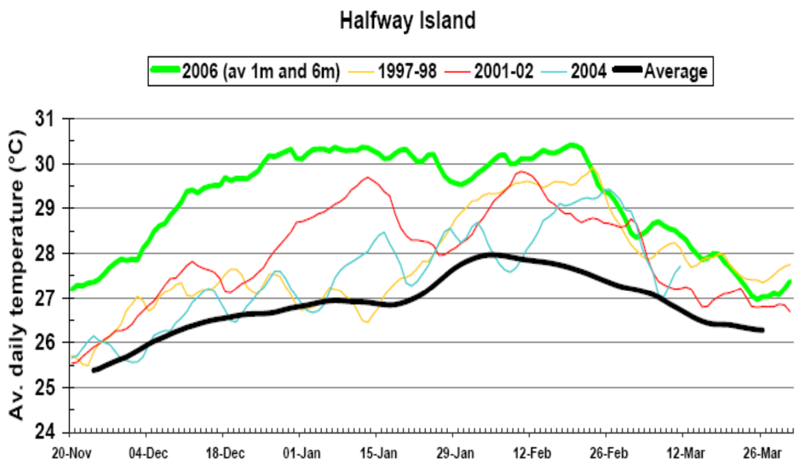


Figure 5. Sea temperature logger data from Halfway Island in the Keppel Islands showing a rapid increase and sustained high temperatures during the summer of 2005/2006; greater than other recent years of significant temperature increases (Berkelmans et al. in press).

In 2006, the water mass surrounding the Keppel Islands, while subject to a tidal range of up to 5 m, did not mix or exchange with appreciably cooler waters and, at over 100 km from the 100 m bathymetry contour did not appear (from satellite sea surface temperature data) to be significantly cooled by upwelling. This coincided with an extended period of clear skies over the southern region, with associated sustained exposure to UV radiation. The southern Great Barrier Reef has been noted to receive higher solar radiation than the northern Great Barrier Reef (Masiri et al. in press). Conditions were cloudy during the same period over the central and northern regions of the Great Barrier Reef. Higher levels of sunlight, combined with sustained levels of high sea temperatures caused the severe bleaching observed there (Hoegh-Guldberg et al. 2002, Masiri et al. in press).

Detailed summaries of survey results for each survey region can be found below. The percent cover of the major benthic components and hard coral categories are displayed graphically for each site and a brief description of site habitat and impact history for each reef is given. Sites with extensive bleaching (Far Southern Great Barrier Reef) are further described by graphs of bleaching impact levels and distribution of bleaching among main coral taxa for the March 2006 survey.

Appendix A contains the results of the surveys taken in the Keppel Bay area in June 2006 with graphs comparing the benthic cover estimates and distribution of bleaching among main coral taxa between those and the surveys undertaken in March.

Coral Bleaching Response Plan Regional Survey Results – March to April 2006

Far Southern Region

Table 3. Summary of Far Southern Region bleaching surveys

Reefs surveyed		Hard coral cover	Bleaching severity
Inshore	Halfway Island	very high	severe
	Middle Island	high	severe
	North Keppel Island	high	severe
Mid-shelf	Wreck Island	moderate	moderate
	Gannet Cay	moderate	intermediate
	Reef 21-529	very high	moderate
Outer	One Tree Island	very high	moderate
	Chinaman Reef	moderate	moderate

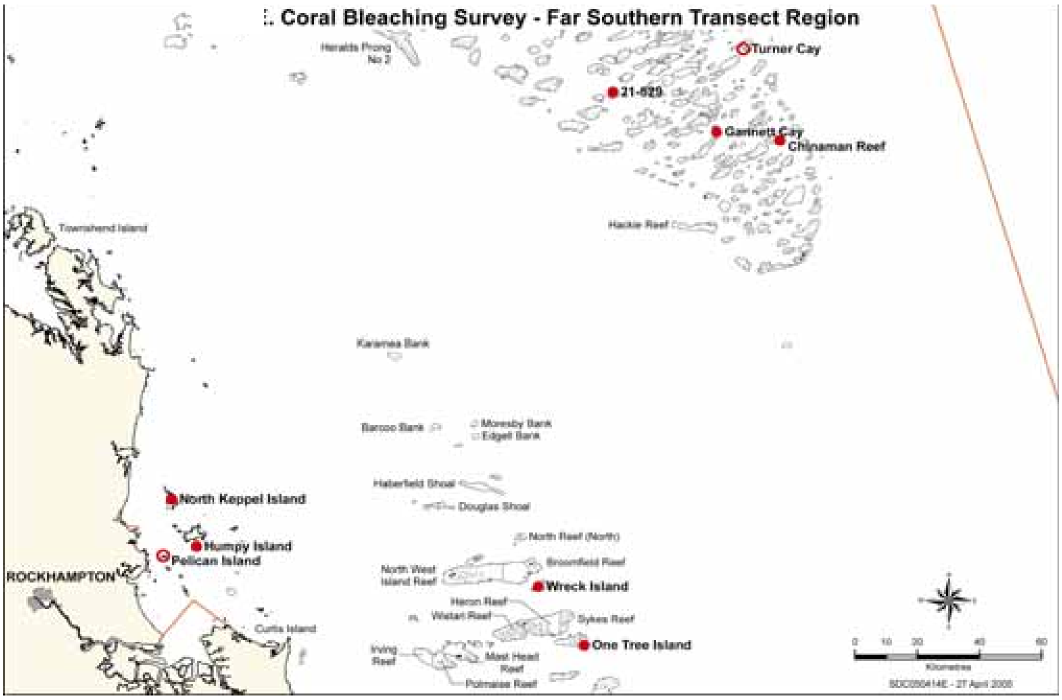
Key: Nil – 0 per cent, Low – 1-10 per cent, Moderate – 11-30 per cent, Intermediate – 31-50 per cent, High – 51-75 per cent, Very high or severe – 76-100 per cent

Assessments of individual sites with graphs of benthic cover, coral community composition and distribution of bleaching for reefs surveyed in the Far Southern Region can be found below.

Survey sites in the Far Southern Region were spread across three main geographical areas: inshore (off Yeppoon, Map 1); the Capricorn Bunker group and; the Swains complex. Within the Capricorn Bunker group and the Swains complex both mid-shelf and outer reef habitats were included.

The coral communities across the Far Southern Region have, on average, high coral cover with a predominance of branching *Acropora* sp. Only at Gannet Cay was coral cover substantially below 50 per cent (average 23 per cent). Diversity within coral communities was moderate with the main groups (*Acropora*, *Montipora*, *Porites*, Pocilloporids, Faviids) well represented at most locations.

Coral bleaching was recorded at every site surveyed in the Far Southern Region (see map below). The proportion of corals bleached at each site ranged from 1.5 per cent (lower slope of Wreck Island reef) to 100 per cent (upper slope of Halfway Island reef), with an overall average of 46 per cent for the region. Mortality from bleaching was generally very low at the time of the survey (two – six per cent), and confined to the inshore sites around the Keppel Islands. By August of 2006 bleaching-related mortality had risen to 39 per cent among the Keppel Islands.



Map 1. Survey sites in the Far Southern Region, Great Barrier Reef *(filled circles represent sites surveyed, empty circles were proposed survey sites that could not be surveyed due to inclement weather)*

One Tree Island

One Tree Island is an outer-shelf lagoonal reef. Coral cover has recovered over the past decade from impacts, principally storm damage, to a high level (65 per cent) in 2005, while the incidence of white syndrome disease has dropped (LTMP 2005). The Coral Bleaching Response Plan survey site is on the exposed eastern slope of the reef.

The reef flat and crest area has a solid surface with deep channels. Coral cover is very high (88 per cent) with the coral community dominated by broad tabulate *Acropora* sp., almost to the exclusion of other coral genera (Figures 6 and 7). Branching and bushy *Acropora* sp. are common. The slope has a shallow gradient to depth. Coral cover is high (94 per cent) with dominant tabulate *Acropora* sp. and branching and digitate *Acropora* sp. common. Other coral taxonomic groups observed include; *Montipora* sp., *Porites* sp., Faviids and *Merulina* sp..

Bleaching was present in isolated colonies at both depths. On the upper reef slope a number of branching, bushy and digitate *Acropora* sp. showed signs of paling. On the lower reef slope, in addition to the pale branching and tabulate *Acropora* sp., a few *Montipora* colonies were pale or fluorescing. A small number of branching *Acropora* colonies were bleached white.

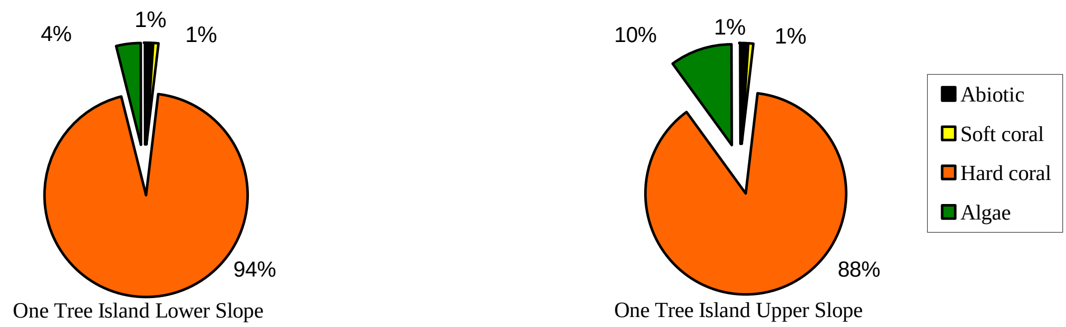


Figure 6. Substrate cover estimates at One Tree Island

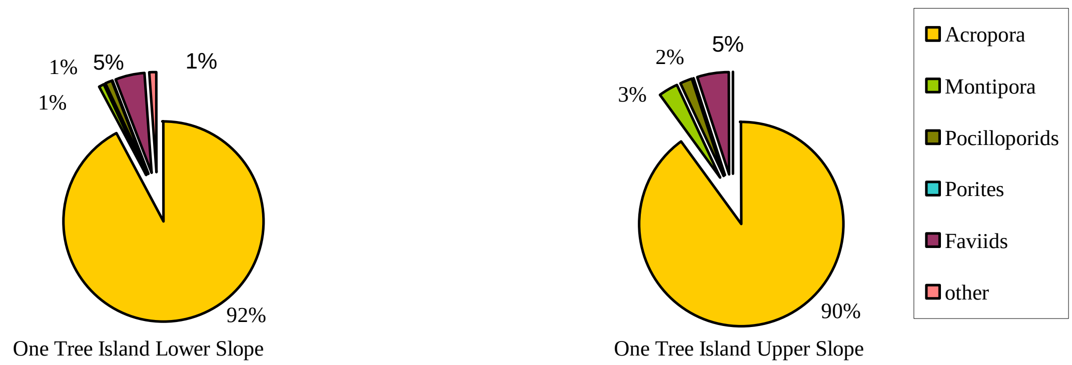
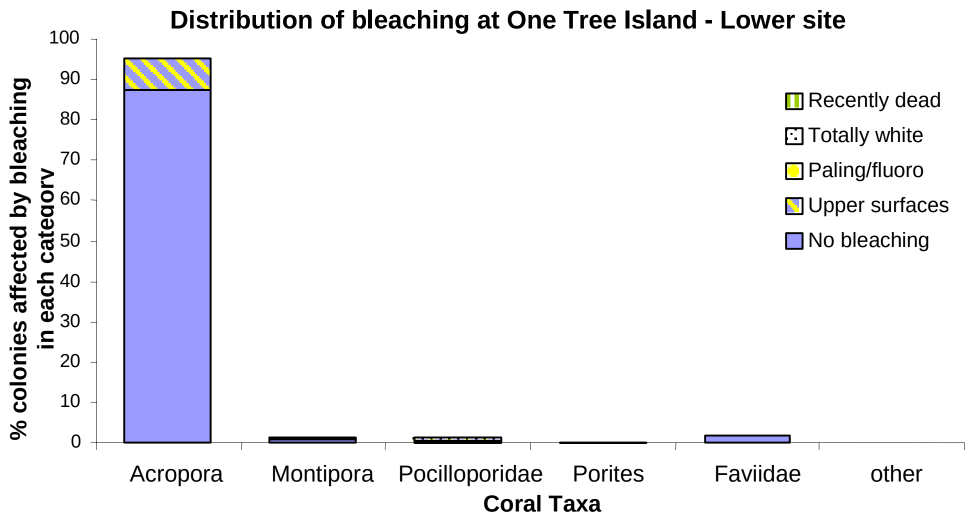


Figure 7. Coral community composition at One Tree Island at the time of surveys

A. Lower Reef Slope



B. Upper Reef Slope

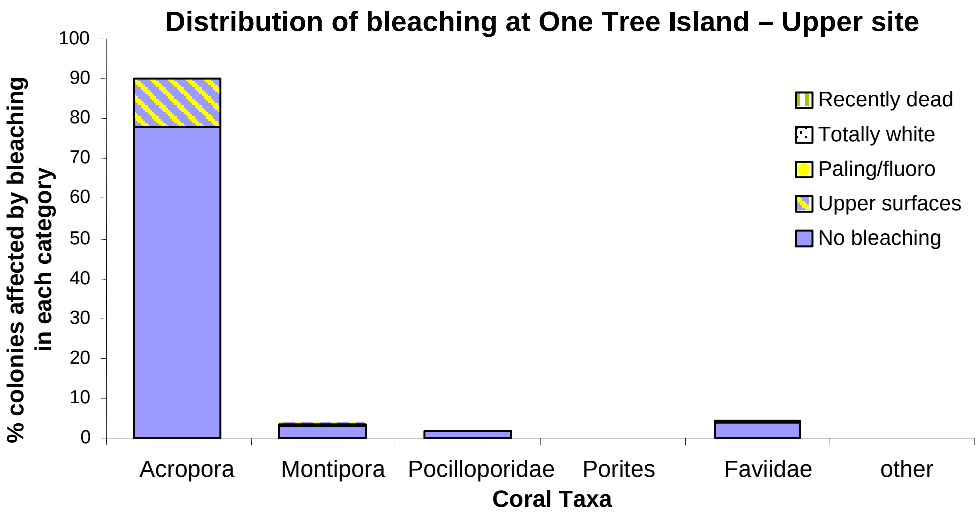


Figure 8. Distribution of bleaching among major coral groups at One Tree Island

Wreck Island

Wreck Island is an outer-shelf reef. Cycles of fluctuation in hard coral cover over the last decade has seen a decline in the dominant tabulate *Acropora* to 56 per cent in 2005, possibly due to an increase in the prevalence of white syndrome disease (LTMP 2005). The Coral Bleaching Response Plan survey site is on the eastern side of the reef.

The reef flat and upper reef slope is exposed to high levels of wave energy and is broken by deep gutters leading to the lower slope. Coral cover is very high (80 per cent) with the coral community composed of hardy *Acropora palifera* and digitate, branching and tabulate *Acropora* sp. Pocilloporid and Faviid corals are common. The broad lower reef slope has a slight gradient to depth. Coral cover is high (62 per cent, Figure 9) and primarily dominated by large tabulate *Acropora* sp. (often > 1m diameter). Branching *Acropora* sp. were common. *Montipora* sp. and Faviids were also present at the time of surveys (Figure 10).

Bleaching was most common on the upper reef slope, affecting 30 per cent of the corals (Figure A7). Most of the bleaching observed was mild and consisted of the paling of *Acropora palifera* and *Platygyra* sp. More severe bleaching was confined to a few colonies of *Montipora* sp. and Pocilloporids that were completely bleached. On the lower reef slope, the only bleaching observed was of three *Montipora* sp. colonies and a small patch of *Acropora micropthalma* with pale upper branches.

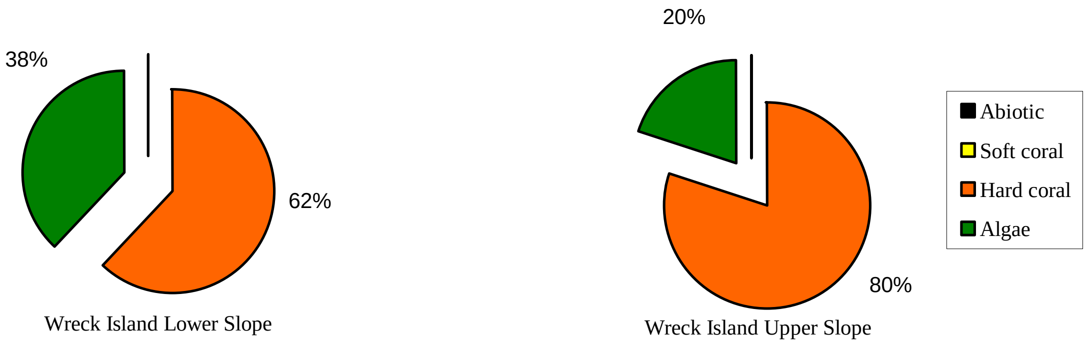


Figure 9. Substrate cover estimates at Wreck Island

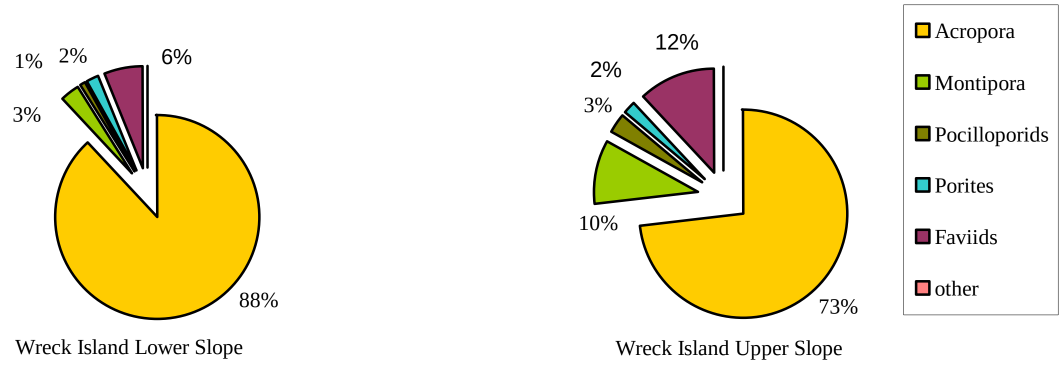
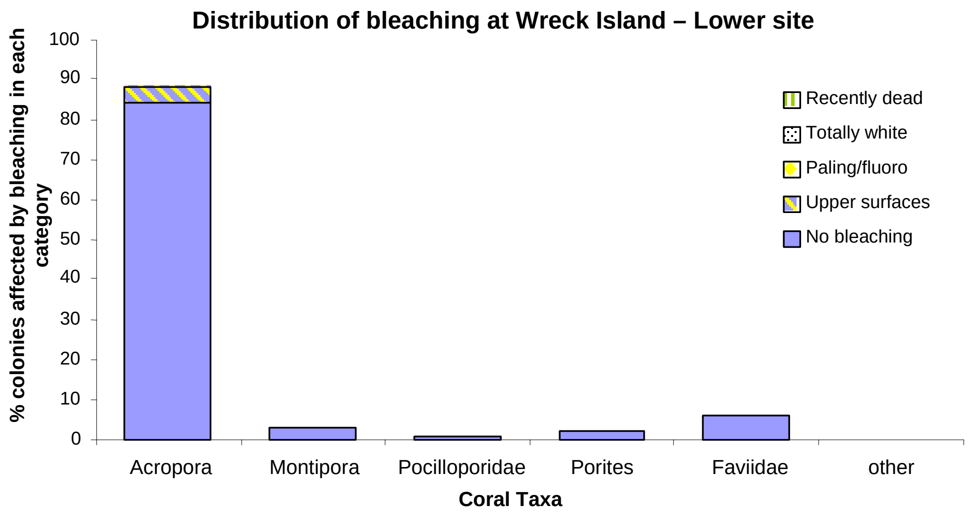


Figure 10. Coral community composition at Wreck Island at the time of surveys

A. Lower Site



B. Upper Site

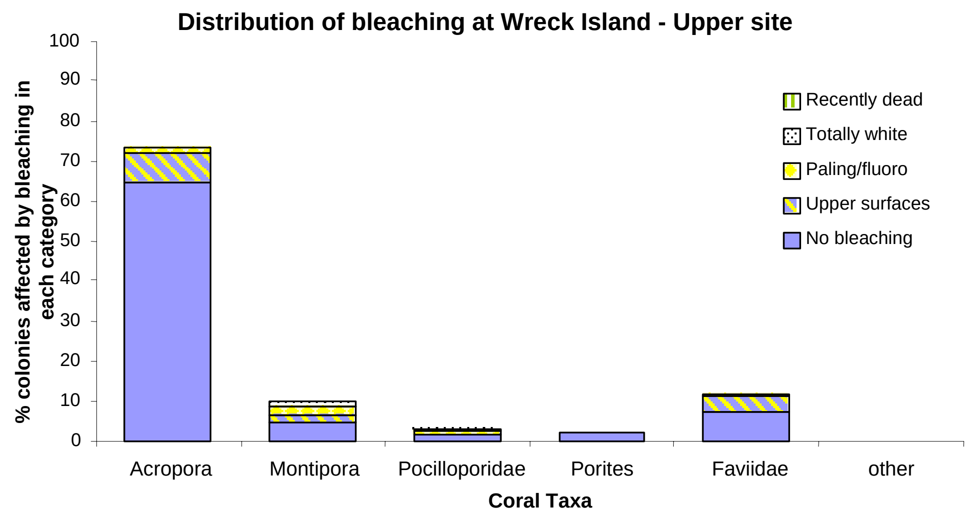
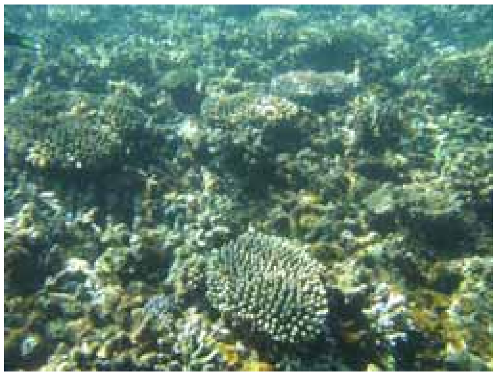


Figure 11. Distribution of bleaching among major coral groups at Wreck Island

Halfway Island



Halfway Island is a small rocky island to the south of Great Keppel Island, adjacent to Humpy Island. A fringing reef extends to the west of Halfway Island and is the location for the Coral Bleaching Response Plan survey site.

The reef flat and shallow reef slope have high coral cover (75 per cent, Figure 12) with the coral community dominated by branching *Acropora* sp., with bushy and tabulate *Acropora* sp. being less abundant (Figure 12). A few foliose *Montipora* sp. and bushy Pocilloporid colonies contribute to a coral community with limited diversity. The reef slope continues to a sand base at 9m. As on the upper reef slope, coral cover is very high (82 per cent, Figure 13) on the lower slope with the branching *Acropora* sp. dominating the coral community. The occasional non-*Acropora* corals include *Turbinaria* colonies at the slope / sand boundary, foliose *Montipora* sp., small massive Faviids and bushy Pocilloporids. The macroalgae *Lobophora* is common among the base of branching *Acropora* sp.

Bleaching impacts observed at the site were severe with 100 per cent of upper reef slope corals affected and 89 per cent of lower slope corals affected by bleaching (Figure A10). On the upper slope the majority of corals were fully white or fluorescing. Scattered patches of recently dead corals were observed. On the lower slope corals were mostly white or fluorescing with only a few isolated colonies unaffected by bleaching.

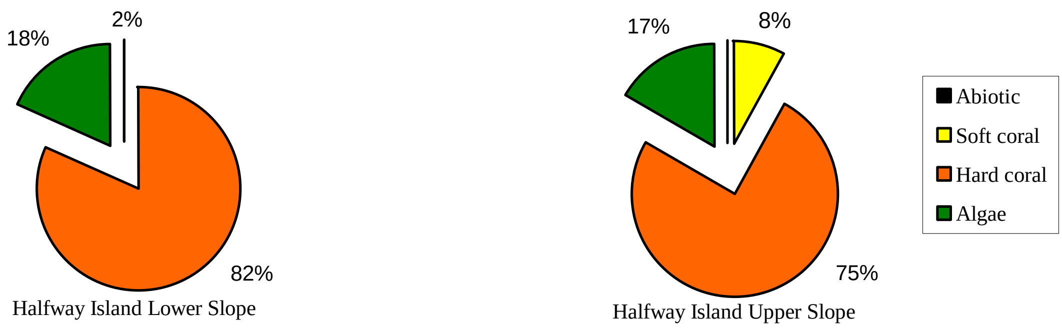


Figure 12. Substrate cover estimates at Halfway Island

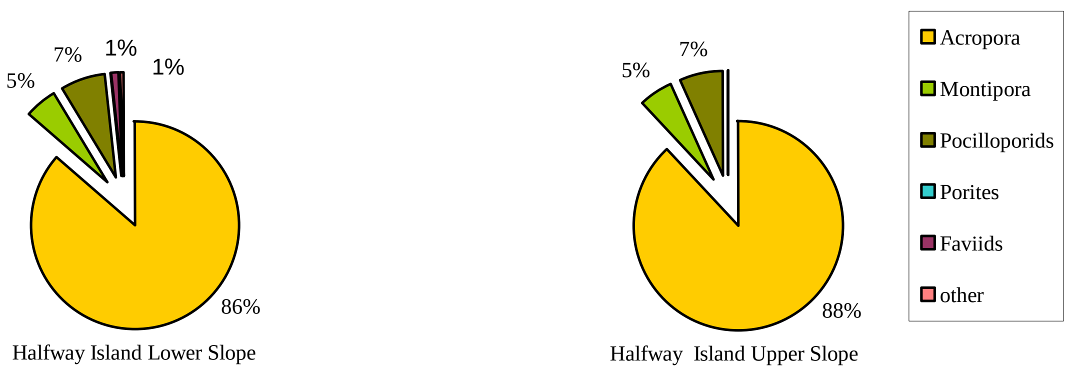
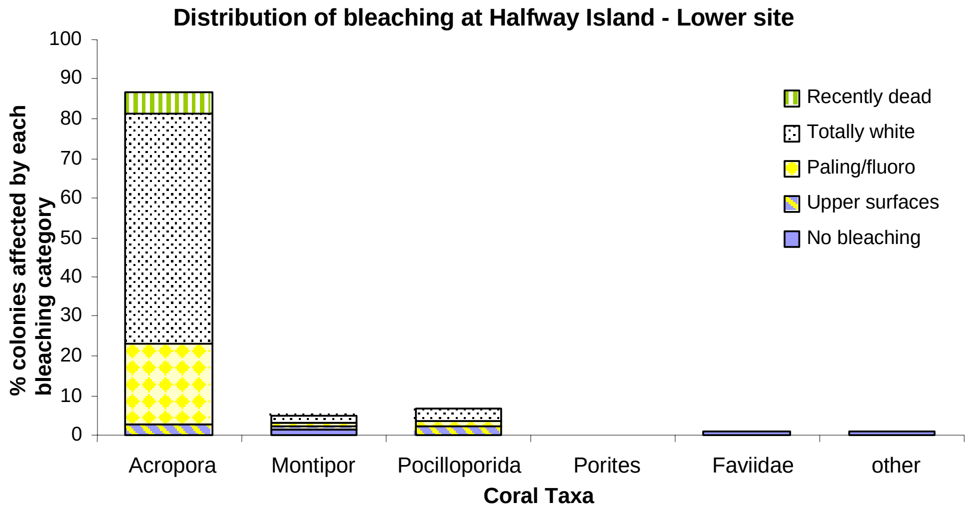


Figure 13. Coral community composition at Halfway Island at the time of surveys

A. Lower Site



B. Upper Site

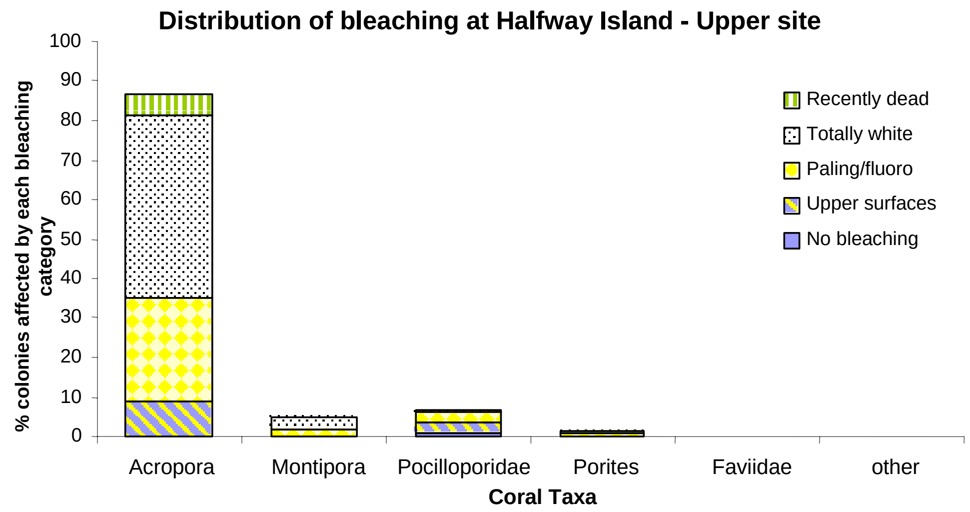


Figure 14. Distribution of bleaching among major coral groups at Halfway Island

Middle Island

Middle Island is a small rocky island lying just to the north of Great Keppel Island. A fringing reef is patchily distributed around the island. The Coral Bleaching Response Plan survey site is on the north–eastern side of the island.

The reef flat leads on to a shallow, undulating slope of loose and consolidated rubble. Coral cover is very high (88 per cent, Figure 15) and the coral community is dominated by *Acropora* sp., with branching being the dominant morphology (Figure 16). A few other corals present include tabulate *Acropora* sp., Pocillopoids, Faviids, *Porites* sp. and *Montipora* sp. The reef slope continues with a shallow gradient to a sand base at a relatively shallow depth of 6m. The lower reef slope is composed mostly of rocky outcrops with corals separated by patches of rubble. Coral cover is moderately high (52 per cent, Figure 15), and the coral community at the time of surveys was composed primarily of branching *Acropora* sp. Other corals in the community include foliose *Turbinaria* sp., foliose and encrusting *Montipora* sp., massive Faviids (including *Platygyra* sp. and *Favia* sp.), and Pocilloporids (Figure 16).

Almost all corals (94 per cent) on the upper reef slope were affected by bleaching. The majority of these corals are pale or fluorescing (Figure 17). Only a few Faviid colonies were unaffected by bleaching. *Sarcophyton* soft corals, though few in numbers, were noted to have pale surfaces. Most corals on the lower slope were also affected by bleaching (68 per cent, Figure 17). On the lower reef slope mostly *Acropora* sp. were affected by bleaching. Interestingly, some of the foliose *Turbinaria* sp., one of the coral types most resistant to bleaching, were also pale.

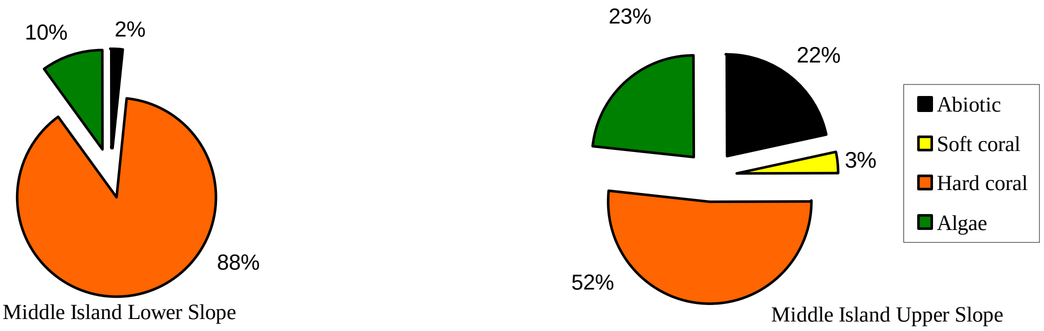


Figure 15. Substrate cover estimates at Middle Island

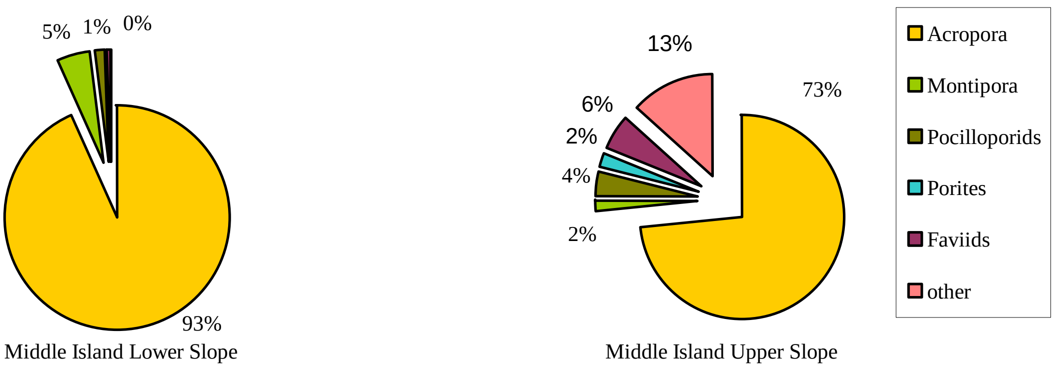
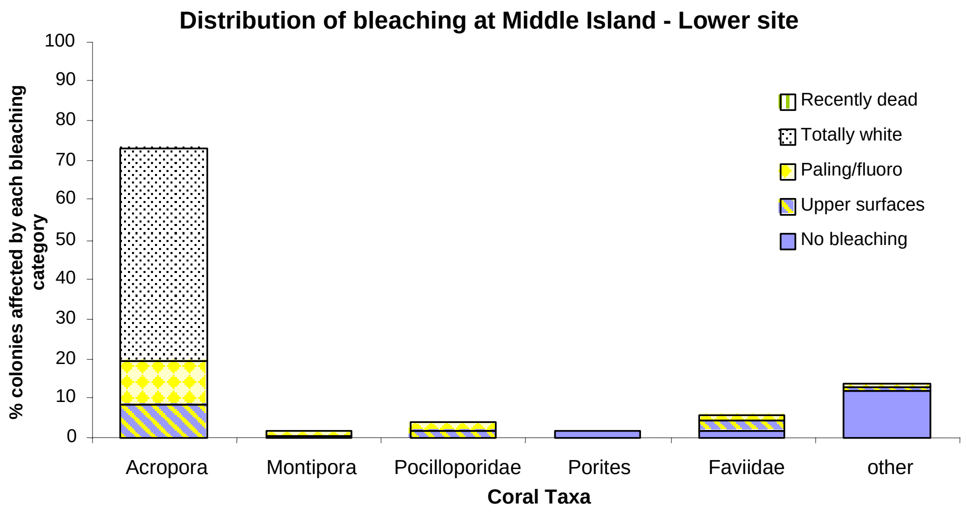


Figure 16. Coral community composition at Middle Island at the time of surveys

A. Lower Site



B. Upper Site

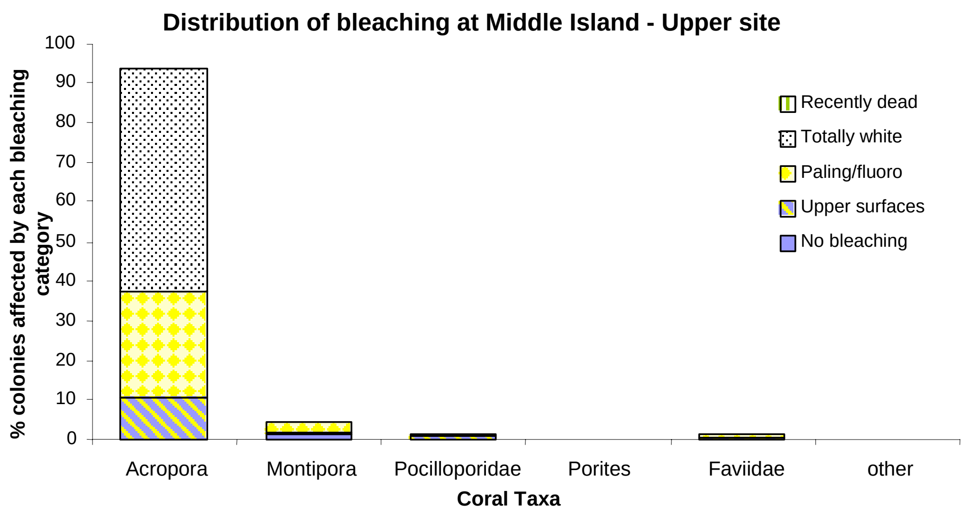


Figure 17. Distribution of bleaching among major coral groups at Middle Island

North Keppel Island

North Keppel Island is a continental island to the north of Great Keppel Island. The sheltered southern bay has an extensive fringing reef and is the location of the Coral Bleaching Response Plan survey site.

The reef flat and upper reef slope have an undulating slope composed of consolidated rubble. Over this substrate lies a coral community with high cover (69 per cent, Figure 18) and low diversity, dominated by branching *Acropora* sp. (mainly *A. muricata* and *A. intermedia*). Other corals observed at the time of surveys include tabulate and bushy *Acropora* sp., some foliose *Montipora* sp. and a few Pocilloporids (Figure 19). This coral community continues down the reef slope to a sand / rubble base at 10m. Coral cover on the lower reef slope remains high (60 per cent, Figure 18) and branching *Acropora* sp. remains dominant. Unlike the upper slope, the macrolagae *Lobophora* sp. was observed among the bases of branching *Acropora* sp on the lower reef slope.

The coral community at both depths was severely affected by bleaching with 72 per cent of upper reef slope corals and 82 per cent of the lower reef slope corals affected (Figure 19). Those not affected included bushy *Acropora* sp., foliose *Montipora* sp., massive Faviid and a foliose *Turbinaria* colony. On the upper reef slope, recently dead coral, presumably from bleaching, was patchily distributed.

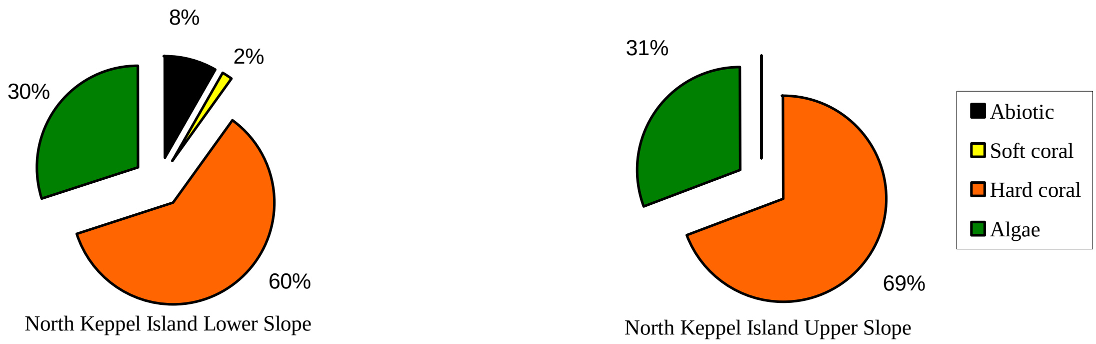


Figure 18. Substrate cover estimates at North Keppel Island

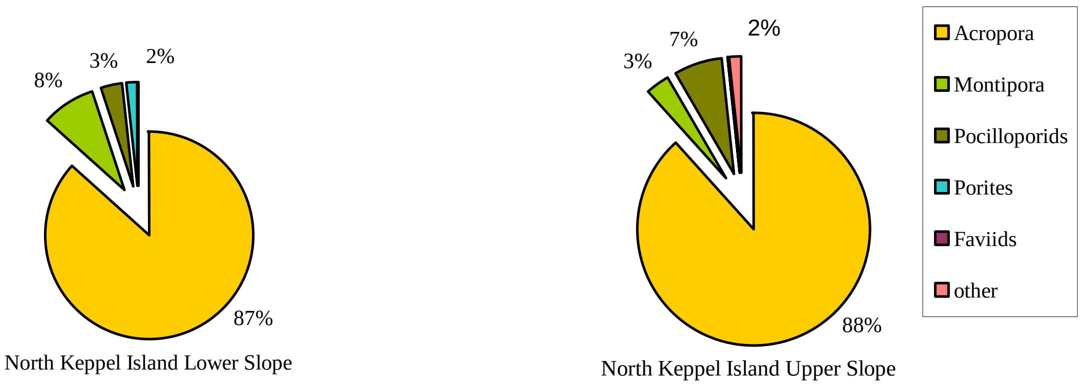
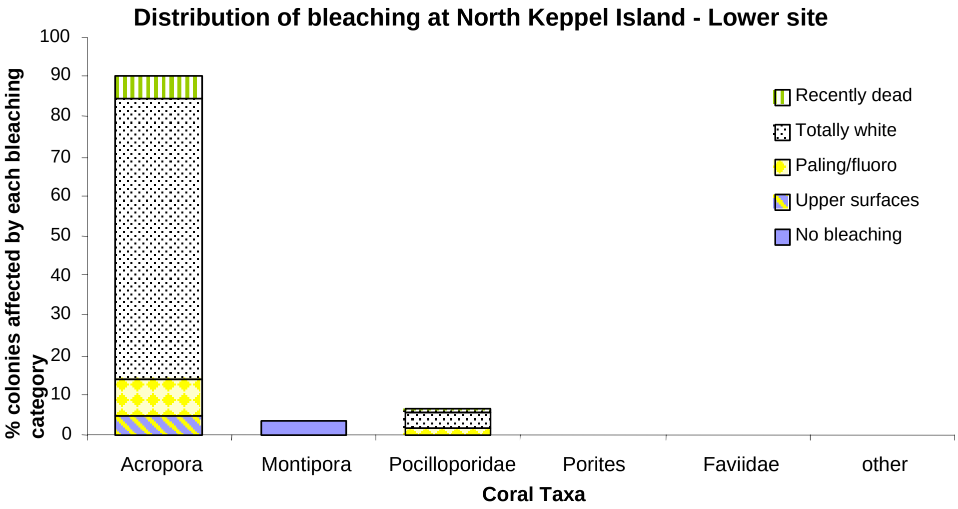


Figure 19. Coral community composition at North Keppel Island at the time of surveys

A. Lower Site



B. Upper Site

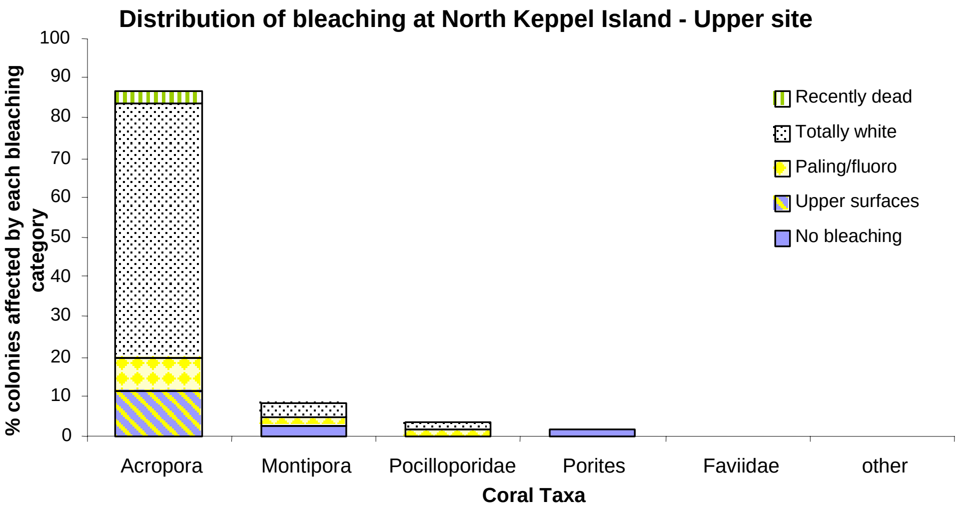


Figure 20. Distribution of bleaching among major coral groups at North Keppel Island

Chinaman Reef

Chinaman Reef is a small mid-shelf lagoonal reef. The coral community has been affected by storm damage and Crown of Thorns Starfish outbreaks over the last decade, with a recovery to 40 per cent coral cover in 2005 (LTMP 2005). The Coral Bleaching Response Plan survey site is on the eastern flank of the reef.

The reef flat and shallow slope is exposed to wave energy and crustose coralline algae were common at the time of surveys. Coral cover is moderate (45 per cent, Figure 21) with a coral community comprised primarily of tabulate, corymbose and encrusting *Acropora* sp., bushy Pocilloporids and encrusting *Montipora* sp. Soft corals are common (27 per cent) and made up of principally *Xenia* sp. (Figure 22). A similar coral community (40 per cent cover, Figure 21) extends onto the deeper reef slope, with the addition of encrusting *Porites* sp. and massive Faviids. As on the upper reef slope soft corals were common at the time of surveys (Figure 22).

Bleaching was observed in both the upper and lower reef slope communities (24 per cent and 40 per cent respectively). Most of the bleaching impacts observed were of foliose *Montipora*, which were commonly completely bleached (Figure 22, A). On the lower reef slope bleaching impacts were observed across a variety of corals with many colonies completely bleached (Figure 23).

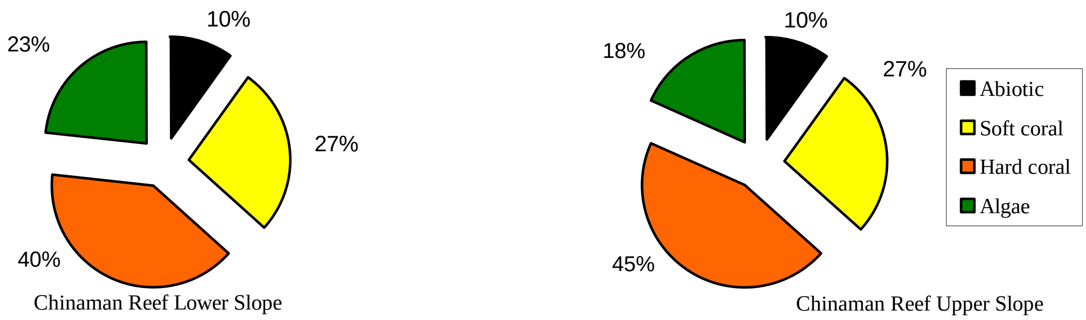


Figure 21. Substrate cover estimates at Chinaman Reef

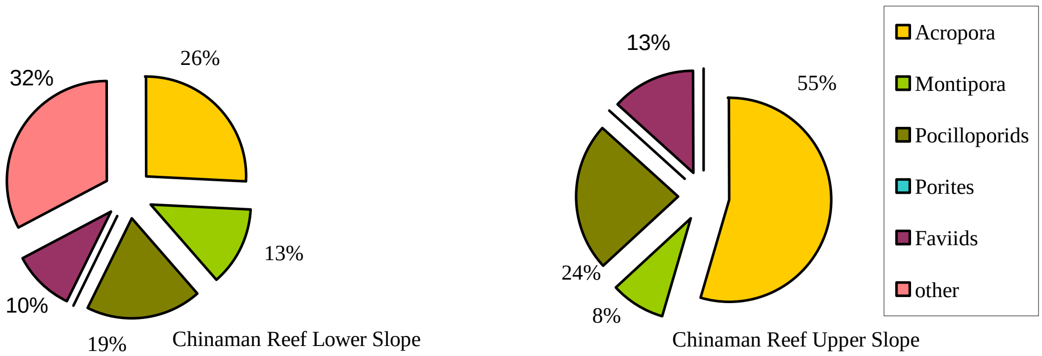
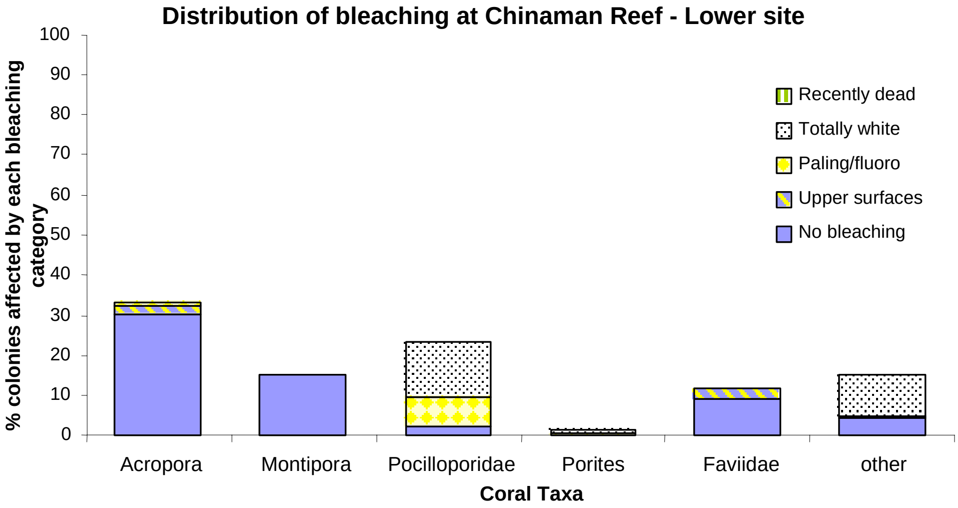


Figure 22. Coral community composition at Chinaman Reef at the time of surveys

A. Lower Site



B. Upper Site

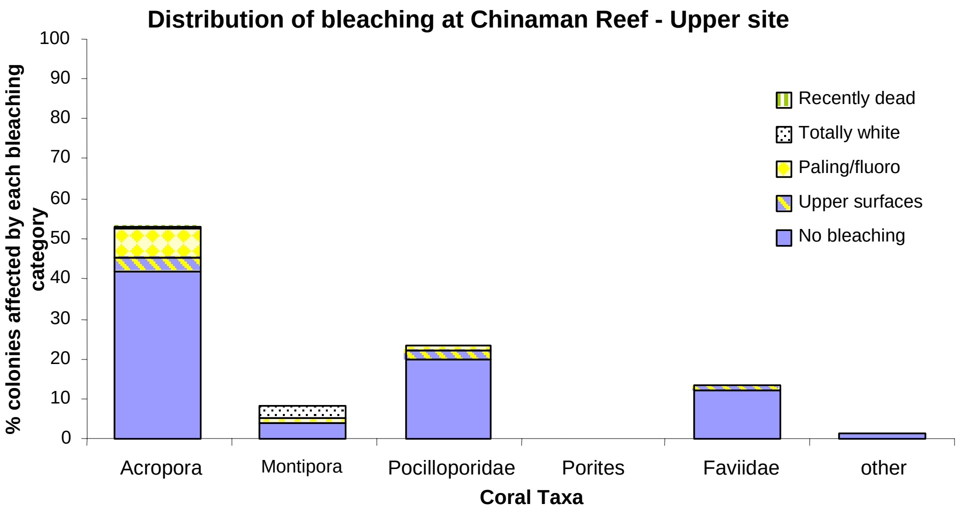


Figure 23. Distribution of bleaching among major coral groups at Chinaman Reef

Gannet Cay

Gannet Cay is a small planar mid-shelf reef. The coral community has declined over the last two decades due to the almost continuous presence of Crown of Thorns Starfish and coral cover in 2005 was recorded at just nine per cent, with filamentous turf algae dominating the substrate (LTMP 2005). The Coral Bleaching Response Plan survey site is on the eastern flank of the reef.

The hard substrate of the reef flat and shallow crest is dominated by filamentous turf algae (48 per cent, Figure 24). Coral cover is moderate (25 per cent), patchily distributed and comprised primarily of tabulate and bushy *Acropora* sp., and bushy Pocilloporids (Figure 25). The reef slope has a moderate gradient and, at the time of surveys, was composed of hard substrate with large patches of consolidated rubble. Filamentous turf algae is common (33 per cent) and soft corals, mainly *Xenia* sp., are common on the lower reef slope (35 per cent). Coral cover is moderate (22 per cent, Figure 24) and the community composition, similar to the upper reef slope, consists of bushy *Acropora* sp., *Pocillopora* sp. and *Seriatopora hystrix*. A variety of less common corals includes *Fungia* sp. and *Hydnophora* sp.

Bleaching impacts were similar on the upper and lower reef slopes (shallow 28 per cent, deep 26 per cent, Figure 26). Bleaching impacts were mainly confined to *Acropora* sp. and Pocilloporid and 'minor paling' was the most common bleaching category observed. *Seriatopora* sp. was affected the most severely, but is known to be among the most susceptible coral types to bleaching.

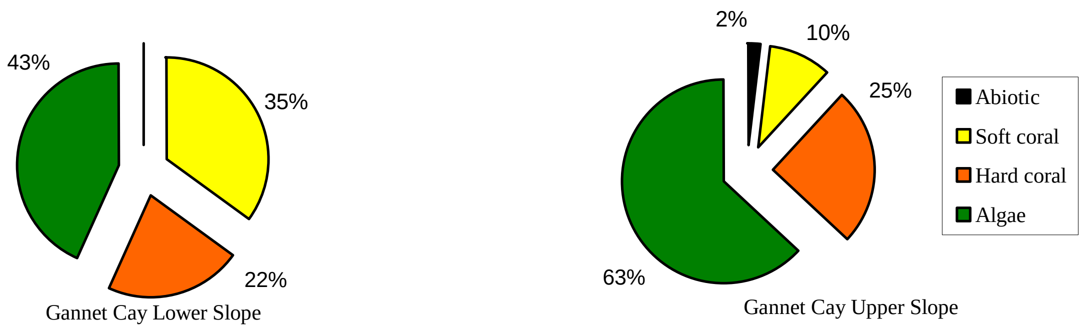


Figure 24. Substrate cover estimates at Gannet Cay

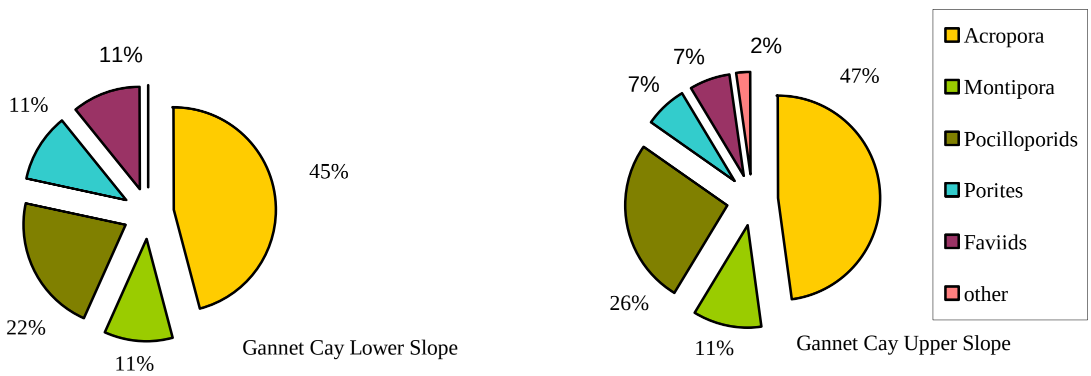
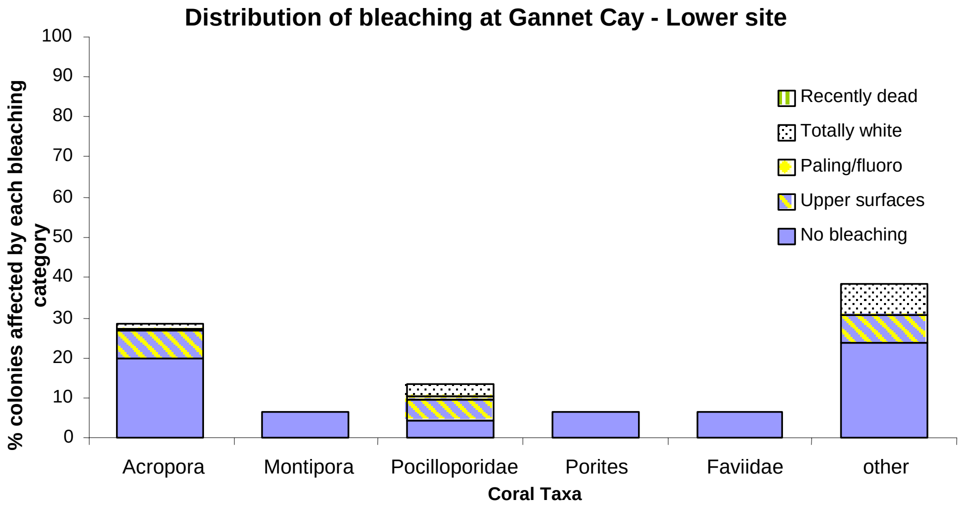


Figure 25. Coral community composition at Gannet Cay at the time of surveys

A. Lower Site



B. Upper Site

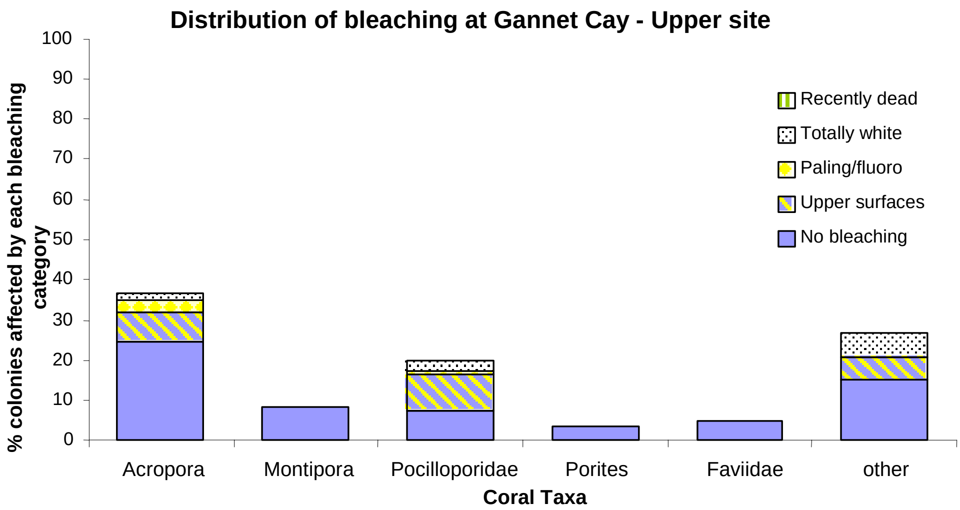


Figure 26. Distribution of bleaching among major coral groups at Gannet Cay

Reef 21-529

The Swains Reefs in the Far Southern Region is a tight complex of coral reefs over 100km from the mainland. Despite the distance from shore, reefs in the western sector of the Swains Reefs have the protection and habitat commonly associated with mid-shelf reefs in this region.

Reef 21-529 is a small mid-shelf crescent reef. Coral cover was reported to have increased steadily since 1998 to 51 per cent in 2005, with no outbreaks of Crown of Thorns Starfish and a drop in the level of disease observed (LTMP 2005). The Coral Bleaching Response Plan survey site is on the eastern flank of the reef. The reef flat and shallow crest area has high coral cover (80 per cent, Figure 27) dominated by foliose *Montipora* and branching *Acropora* sp. with Pocilloporid and bottlebrush *Acropora* sp. common (Figure 28). Filamentous turf algae, crustose coralline algae and *Halimeda* were also common at the time of surveys. The lower reef slope had a similar community composition (Figure 28), with high coral cover (77 per cent, Figure 27), with the addition of encrusting and massive *Porites* sp. as well as *Acropora bueggmani*.

Bleaching impacts were observed among hard corals on both the upper and lower reef slope (15 per cent, Figure 29), mostly as paling among branching, tabulate and bottlebrush *Acropora* sp. colonies.

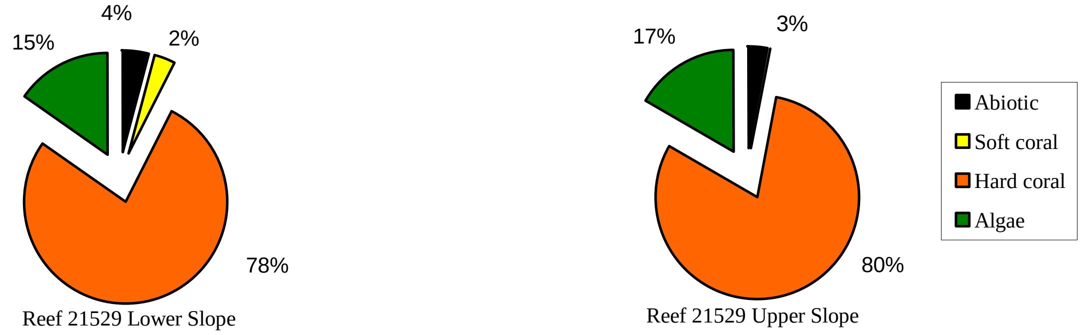


Figure 27. Substrate cover estimates at Reef 21-529

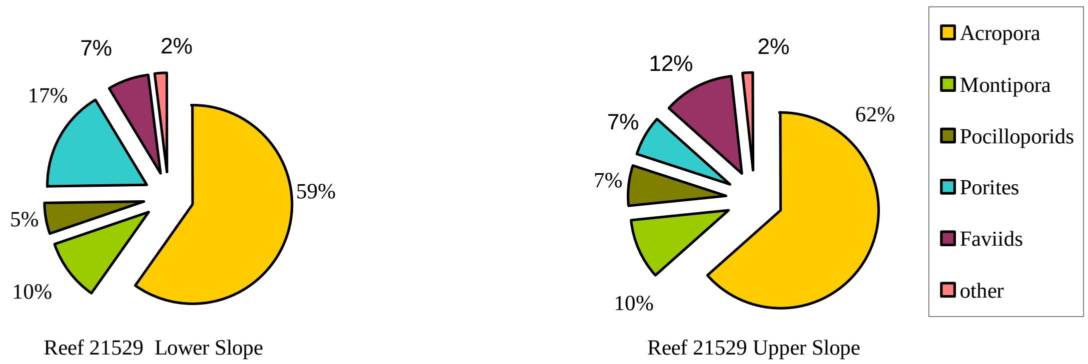
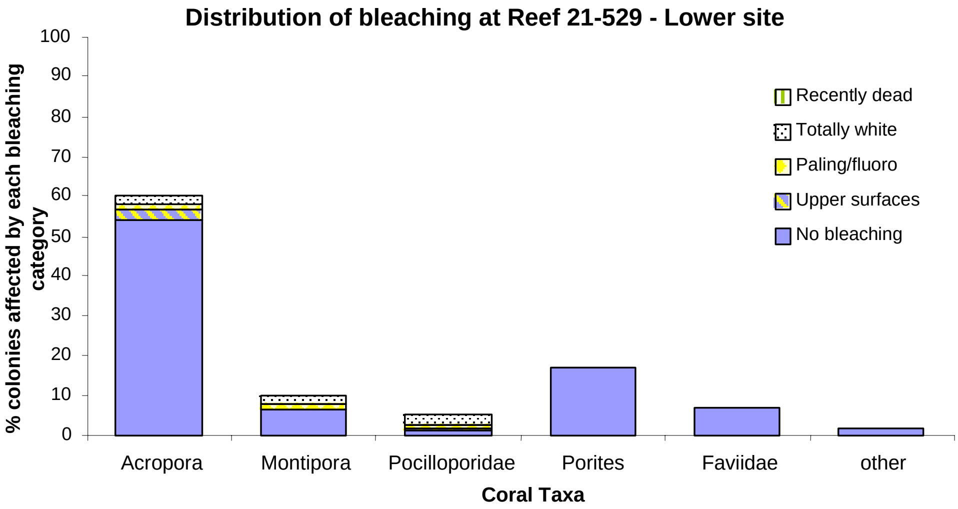


Figure 28. Coral community composition at Reef 21-529 at the time of surveys

A. Lower Site



B. Upper Site

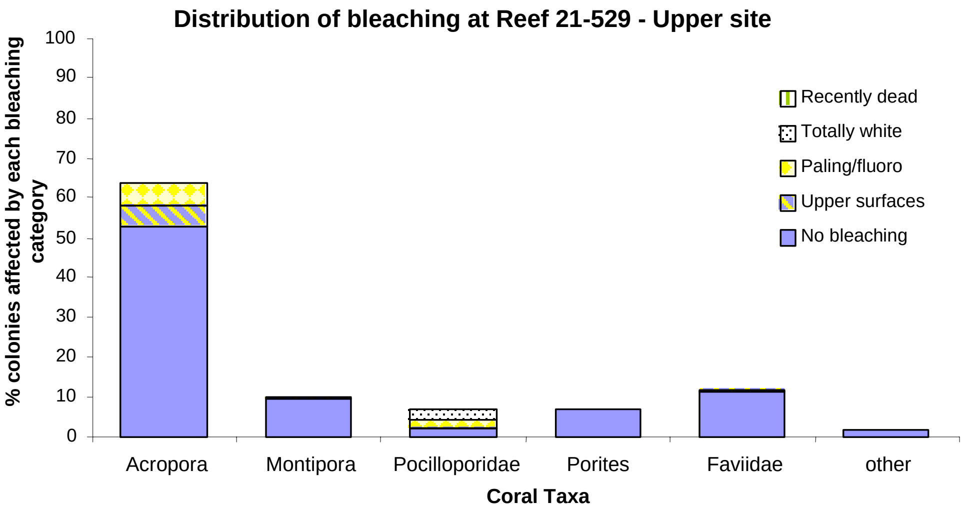


Figure 29. Distribution of bleaching among major coral groups at Reef 21-529

Southern Region

Summary

Table 4. Summary of Southern Region bleaching surveys

Reefs surveyed		Hard coral cover	Bleaching level
Inshore	Langford Island	intermediate	nil
	Hayman Island	high	low
	Border Island	moderate	nil
Mid-shelf	Reef 19-131	intermediate	nil
	Reef 19-138	moderate	nil
	Reef 20-104	high	low

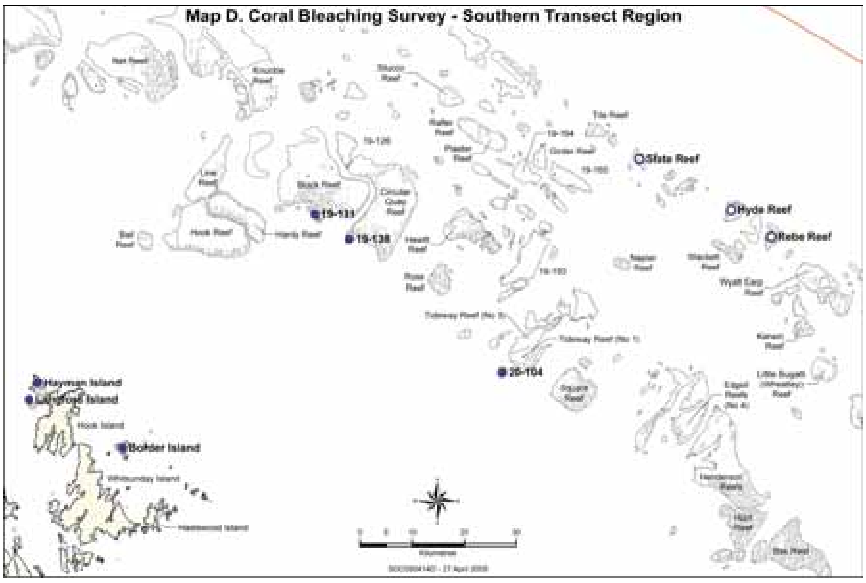
Key: Nil – 0 per cent, Low – 1-10 per cent, Moderate – 11-30 per cent, Intermediate – 31-50 per cent, High – 51-75 per cent
Very high or severe – 76-100 per cent

Assessments of individual sites with graphs of benthic cover, coral community composition and distribution of bleaching for reefs surveyed in the Southern Region can be found below.

The survey locations contained two distinctive habitat types: fringing reefs bordering continental islands and patch reefs protected by much larger adjacent reefs. Only inner and mid-shelf reefs were surveyed in this sector as deteriorating weather conditions prevented surveys of the outer reefs.

Coral cover varied widely among both inshore and mid-shelf locations in this region at the time of surveys. This region has a history of disturbances including cyclones, crown-of-thorns starfish, floods and coral bleaching. Higher than average coral cover was observed at both Hayman Island and Reef 20-104 (predominately rapidly colonising *Montipora* and *Acropora* corals), while Border Island had moderate coral cover (predominately of resilient but slower growing *Porites* corals).

Bleaching impacts were extremely minor and patchily distributed within this region, confined to the occasional individual colony or those corals known to be most sensitive to anomalously warm temperatures.



Map 2. Surveyed sites in the Southern Region, Great Barrier Reef. Filled circles are sites surveyed. Empty circles are proposed survey sites

Border Island (A)

Border Island is an inshore continental island located to the east of Whitsunday Island. The Coral Bleaching Response Plan site, Border Island (A), refers to the fringing reef on the west side of Border Island. Coral cover and diversity (including both hard and soft corals) on this reef has fluctuated in response to the bleaching events of 1998 and 2002 and hard coral cover was reported as 27 per cent in 2005 (LTMP 2005).

The reef flat has a slight gradient to seaward and the benthic community is composed mostly of soft corals (*Lobophytum*, *Sinularia*) with the occasional hard corals (*Montipora*, Fungiids, *Acropora* and Pocilloporids). The slope of the reef flat becomes moderate at the crest area and is composed of rubble gutters with outcrops of consolidated substrate supporting the coral community. Soft corals are numerous (48 per cent, Figure 30), mostly *Lobophytum*, *Sinularia* and *Sarcophyton sp*. (Figure 31). Hard coral cover is moderate (23 per cent, Figure 30), patchily distributed and includes branching *Porites cylindrica* and *Seriatopora hystrix*, encrusting *Montipora* sp. and *Mycedium elephantotus* (Figure 31). The reef slope has a moderate gradient with a substrate of rubble and sand. As on the upper reef slope, the coral community is dominated by soft coral (45 per cent) with *Sinularia*, *Sarcophyton sp*. common. Hard coral cover is low–moderate (18 per cent, Figure 30) with large colonies of submassive *Goniopora* sp. being the most common.

Bleaching impacts were extremely minor with only *Seriatopora hystrix*, a coral known to be among the most susceptible to bleaching, affected.

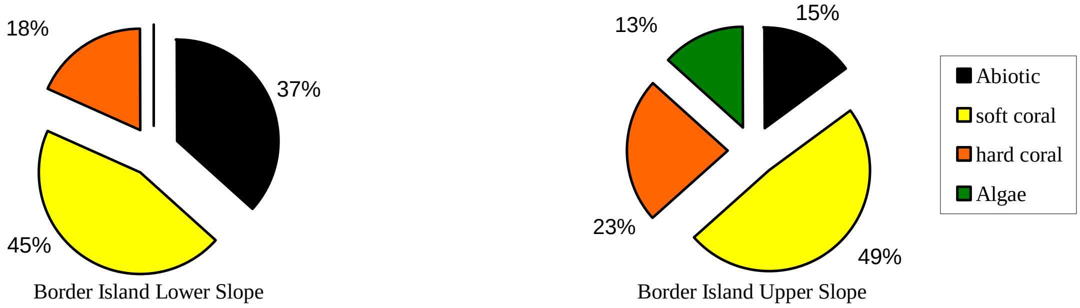


Figure 30. Substrate cover estimates at Border Island

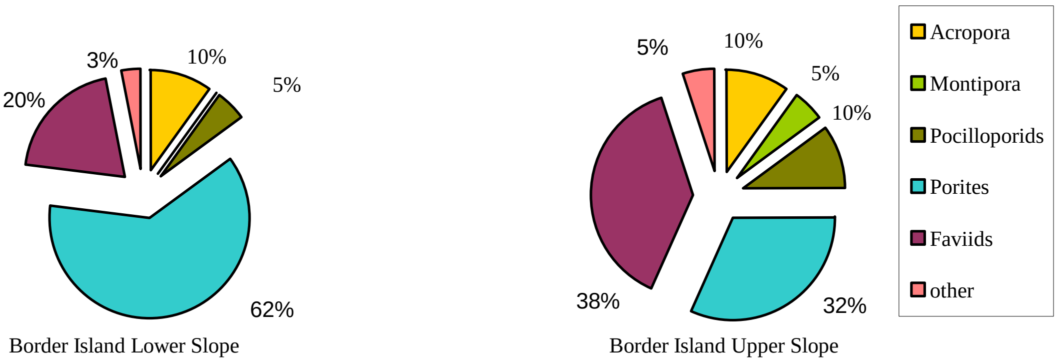


Figure 31. Coral community composition at Border Island at the time of surveys

Langford Island

Langford Island is a small rocky island connected by a sweeping sand bar and broad reef flat to Bird Island, an even smaller collection of rocky substrate. Both hard coral cover and soft coral cover have risen to moderate levels over recent years (22 per cent and 23 per cent respectively), while the prevalence of white syndrome disease and coralliviorous snails remains low (LTMP 2005). The Coral Bleaching Response Plan survey site is on the north-eastern flank of Langford Island.

The reef flat is dominated by soft corals and small *Porites* massives. The crest and upper reef slope are topographically complex and include small gullies and ridges. Hard coral cover was moderate (40 per cent, Figure 32), with the coral community profile skewed by the presence of large stands of branching *Porites cylindrica* and sub-massive *Goniopora sp*. (Figure 33). Soft coral was common (33 per cent). Coral cover, at the time of surveys, was moderate (33 per cent, Figure 32), and a large variety of *Faviid* sp. was noted (Figure 33). Soft corals (32 per cent) were abundant on the reef slope.

Bleaching did not impact most corals. However, paling was noted in a couple of colonies; a large branching *Acropora* colony and a *Turbinaria* colony.

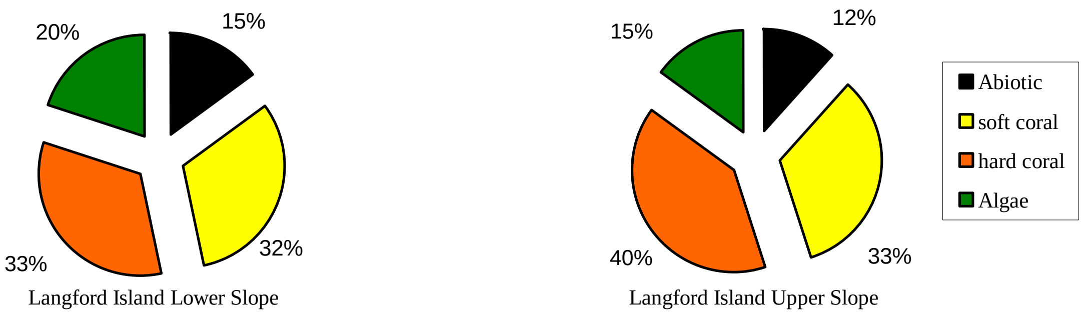


Figure 32. Substrate cover estimates at Langford Island

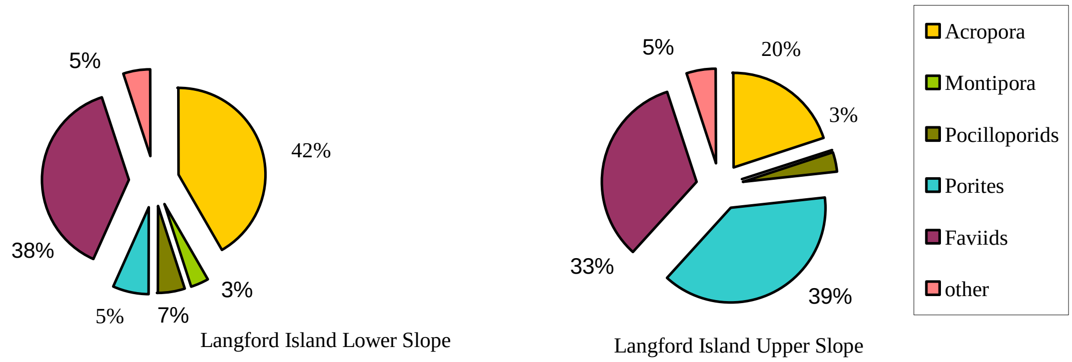


Figure 33. Coral community composition at Langford Island at the time of surveys

Hayman Island

Hayman Island is a small continental island adjacent to Hook Island in the Whitsunday group. A broad fringing reef extends from the eastern shore and is protected in part by Hook Island. Despite slight damage from several cyclones, patchily distributed white syndrome disease and minor bleaching over recent years, average hard coral cover on this fringing reef has gradually increased during the last decade to 45 per cent, driven by increases in the percent cover *Montipora* and *Acropora sp.* (LTMP 2005). The Coral Bleaching Response Plan survey site is on the eastern extremity of this fringing reef.

The reef flat and crest support a moderately high hard coral cover (62 per cent, Figure 34), principally of tabulate and branching *Acropora* sp. colonies. The reef slope is steep and a sheer wall in places. Coral cover is also moderately high on the lower reef slope (53 per cent) with a variety of corals including an abundance of foliose and encrusting *Montipora* sp. (Figure 35) .

Bleaching was restricted to a few colonies of the hard corals *Goniopora* sp. (upper surfaces) and *Seriatopora hystrix*.

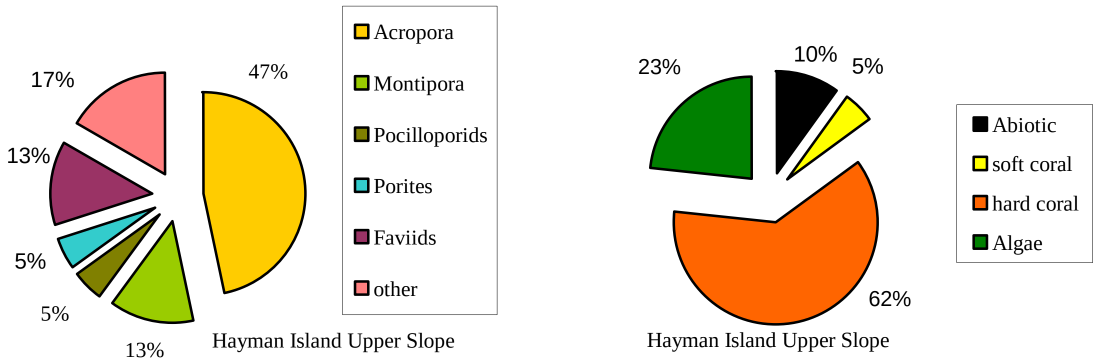


Figure 34. Substrate cover estimates at Hayman Island

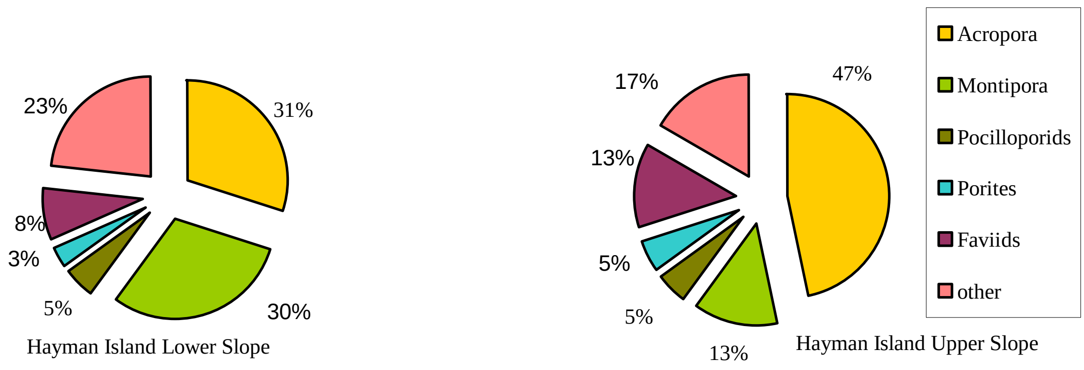


Figure 35. Coral community composition at Hayman Island at the time of survey

Reef 20-104

Reef 20-104 is a small planar reef adjacent to the south-west end of Tideway Reef. The coral community has experienced cycles of impact (Crown of Thorns Starfish, Cyclone Justin, bleaching) and recovery over the last decade and, although coral cover was reported to have increased recently, there is the potential threat of another Crown of Thorns Starfish outbreak (LTMP 2005).

The upper reef slope has a solid foundation of hard substrate with varied topography and a reef crest forming a wall along some of its length indicating a reef exposed to high wave energy. Coral cover is moderately high on the upper slope (55 per cent, Figure 36) with numerous tabulate and bushy *Acropora* colonies. Filamentous turf algae (43 per cent, Figure 37) occupies a significant proportion of colonisable space. The lower slope has high coral cover (70 per cent) with the coral community dominated by large branching and tabulate *Acropora* colonies. A variety of corals were observed at the time of surveys including foliose *Montipora* and *Mycidium* sp., massive *Porites* sp. and Faviids (Figure 37).

Bleaching impacts were restricted to a few pale branching *Acropora* and bushy *Pocillopora* sp. colonies.

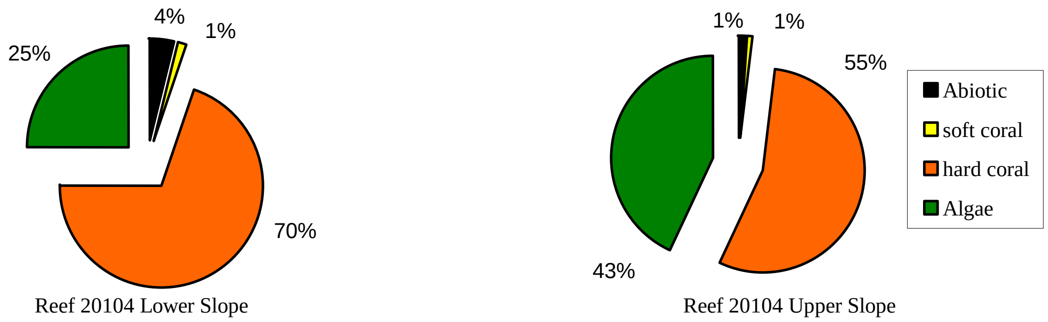


Figure 36. Substrate cover estimates at Reef 20-104

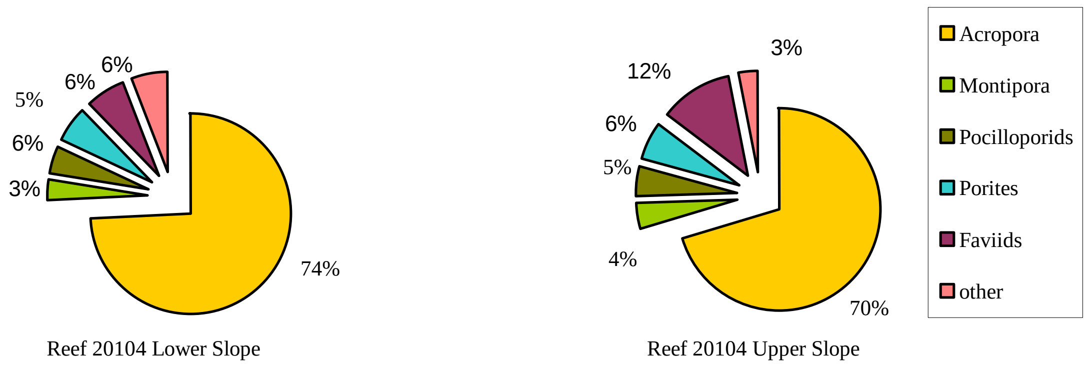


Figure 37. Coral community composition at Reef 20-104 at the time of surveys

Reef 19-138

Reef 19-138 is a small mid-shelf lagoonal reef adjacent to the south-west side of Circular Quay Reef. The coral community has a history of repeated impacts and recovery including Cyclone Justin in 1997 and bleaching in 2002, with coral cover reported to be moderate-high (40 per cent) in 2005 (LTMP 2005). The Coral Bleaching Response Plan survey site is on the south-east edge of Reef 19-138.

Crustose coralline algae and the hydroid Millepora dominate the reef flat area. Gullies frequently cross the reef flat to empty at the reef crest. The steep walls of the gullies provide shelter and support for abundant colonies of tabulate *Acropora* sp. Overall, coral cover on the upper reef slope is moderate at 25 per cent (Figure 38) with *Acropora* dominating the community (Figure 39). The reef slope has a moderate to steep gradient and is compose of hard substrate giving way to rubble at 10m. Coral cover on the lower reef slope is moderate (22 per cent, Figure 38) and, as on the upper reef slope, *Acropora* dominates the coral community.

No bleaching impacts were observed at this site.

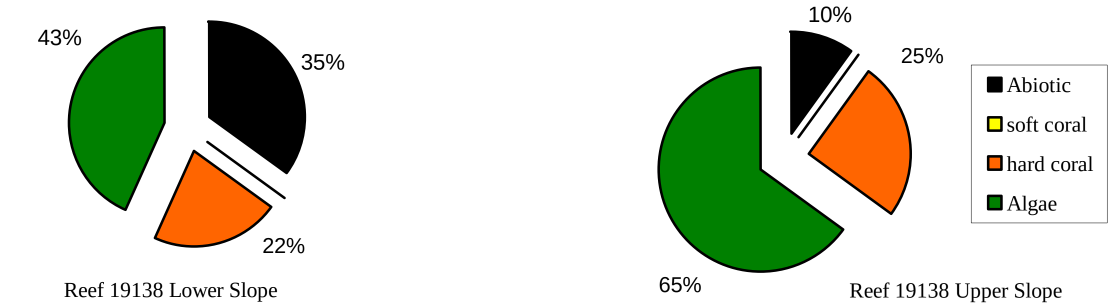


Figure 38. Substrate cover estimates at Reef 19-138

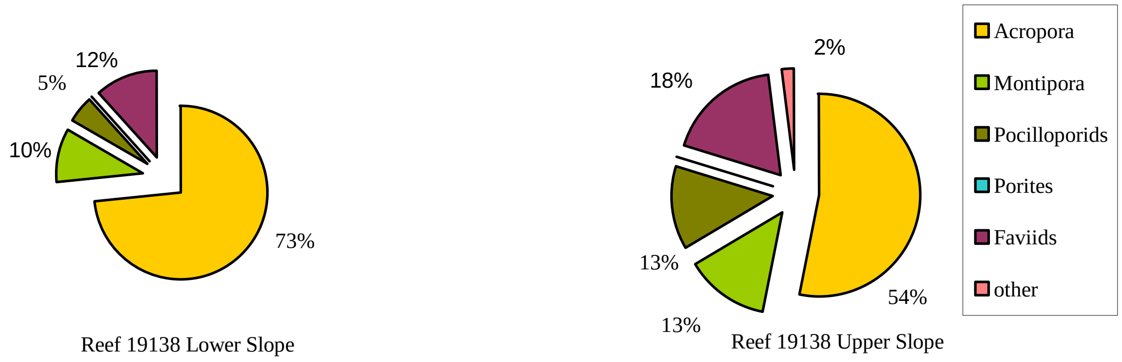


Figure 39. Coral community composition at Reef 19-138 at the time of surveys

Reef 19-131

Reef 19-131 is a small mid-shelf lagoonal reef adjacent to the much larger Block Reef. The coral community has a history of recovering from impacts such as Cyclone Justin (1997) and bleaching (2002) with coral cover reported to be moderately high (40 per cent) in 2005 (AIMS LTMP 2005). The Coral Bleaching Response Plan survey site is on the south-east edge of Reef 19-131.

The reef flat is composed of hard substrate with filamentous turf algae and crustose coralline algae. Coral colonies are patchily distributed. The upper reef slope has a larger population of corals, with a mix of *Acropora*, *Montipora* and Faviid corals (Figures 40, 41). Tabulate and branching *Acropora* colonies are of a similar size (40-50cm) suggesting many in the coral community are of the same age. Overall coral cover on the upper reef slope was moderately high, at the time of surveys (52 per cent, Figure 40). Disease was observed among some tabulate *Acropora* sp. The reef slope has a steep gradient to 12m. Both filamentous turf algae and crustose coralline algae are common on the solid substrate. The coral cover decreases on the lower reef slope (42 per cent, Figure 40). The coral community is dominated by *Acropora* and Faviid corals (Figure 41).

No bleaching impacts were observed at this site.

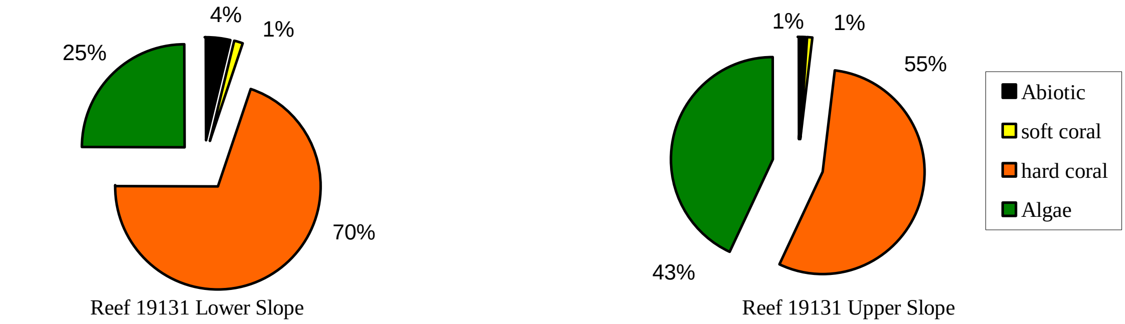


Figure 40. Substrate cover estimates at Reef 19-131

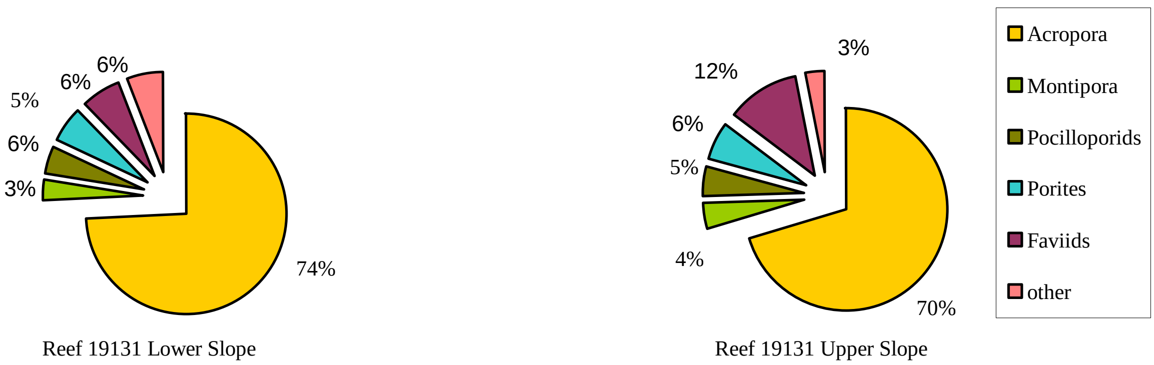


Figure 41. Coral community composition at Reef 19-131 at the time of surveys

Central Region

Summary

Table 5. Summary of Central Region bleaching surveys

Reefs surveyed	Hard coral cover	Bleaching level
John Brewer Reef	low	nil
Rib Reef	low	low

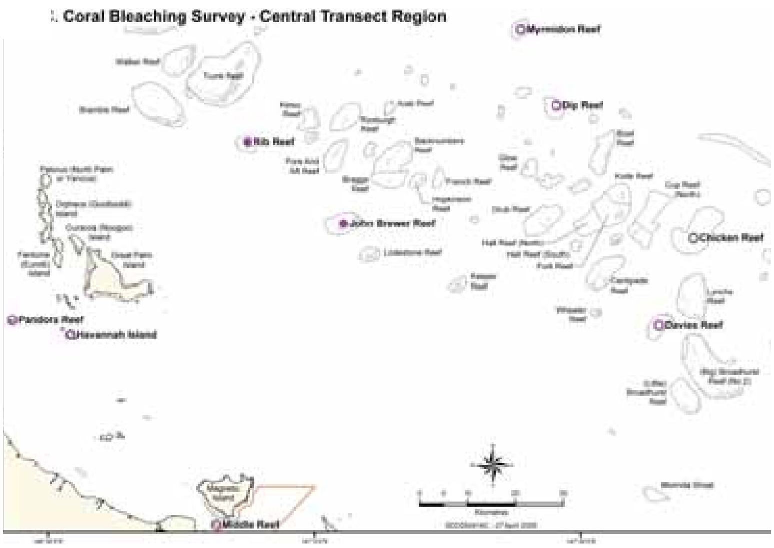
Key: Nil – 0 per cent, Low – 1-10 per cent, Moderate – 11-30 per cent, Intermediate – 31-50 per cent, High – 51-75 per cent
Very high or severe – 76-100 per cent

Assessments of individual sites with graphs of benthic cover and coral community composition and distribution of bleaching for reefs surveyed in the Central Region can be found below.

Only two reefs were surveyed for coral bleaching in the Central Region as the focus of the expedition turned to post-cyclone damage assessment following the passage of Tropical Cyclone Larry through this region two days before these surveys were undertaken.

Coral cover and diversity at both reefs was low due to a protracted history of crown-of-thorn starfish impacts, and overall hard coral cover ranged between five per cent and 10 per cent. There were some large individuals of the massive *Diploastrea heliopora* and *Pavona* sp. observed. Bleaching was confined to a few individuals of *Goniopora*, *Seriatopora*, both of which are known to be sensitive to anomalously warm temperatures, and a few soft corals.

The main impacts in the central reefs that were surveyed was from the passing of Cyclone Larry. This took the form of old debris being swept from the reef crest down across the reef slope, and large areas of reef surface removed or broken open to expose the holes and crevices used for shelter by reef-dwelling creatures. This damage to reef infrastructure is an important but often unobserved aspect of cyclone impacts because, after a few weeks, the fresh indications of damage are masked by the colonisation of turf algae. A full account of the effects of Cyclone Larry is available as a separate report (Chin et al 2006).



Map 3. Surveyed sites in the Central Region, Great Barrier Reef. Filled circles are sites surveyed. Empty circles are proposed survey sites.

John Brewer Reef

John Brewer Reef is a mid-shelf planar reef north of Townsville. The coral community has been subjected to a series of impacts over the last 20years including cyclone (1997), bleaching (1998/1999) and Crown of Thorns Starfish (1984, 2001-2003), with a 2005 survey reporting very low coral cover (two per cent, LTMP 2005). The Coral Bleaching Response Plan site is on the south-east side of the reef.

The reef flat and crest are dominated by filamentous turf algae and crustose coralline algae. The reef flat is crossed by broad gutters that empty into the crest area. Coral cover on the upper reef slope, at the time of surveys was very low (<five per cent, Figure 42) and the coral community is composed mainly of Pocilloporid, *Montipora* and *Acropora* corals (Figure 43). Branching and encrusting *Millepora* sp. (fire coral) were common in patches. There were a few recruiting tabulate *Acropora* sp. observed in the crest area. The reef slope has a moderate gradient and is composed of outcrops of hard substrate and patches of rubble. Coral cover is low on the lower reef slope (<five per cent, Figure 42) and the coral community is made up of more Faviid sp. than were observed on the upper reef slope, including the occasional large colony of *Diploastrea heliopora*. The most striking observation was the amount of damage caused to the reef infrastructure (and some of the remaining live corals) by the passage of Cyclone Larry only two days before. This included reef gutters filled with excavated reef matrix, smashed corals and sections of reef edge having collapsed. The debris was widely scattered on the reef slope.

No bleaching impacts were observed at this site.

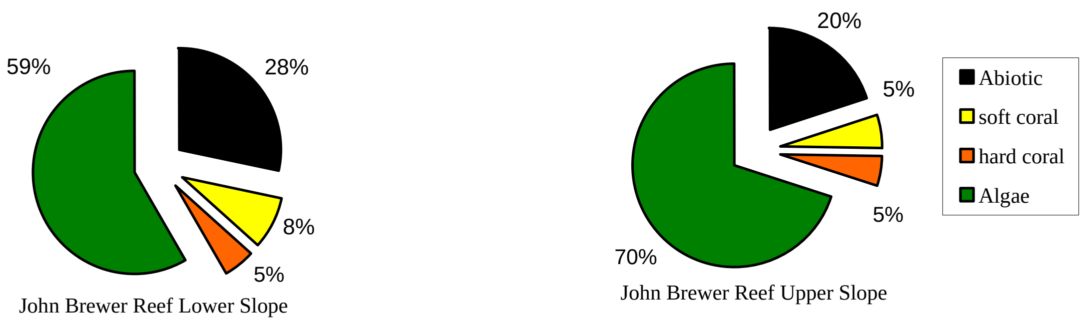


Figure 42. Substrate cover estimates at John Brewer Reef

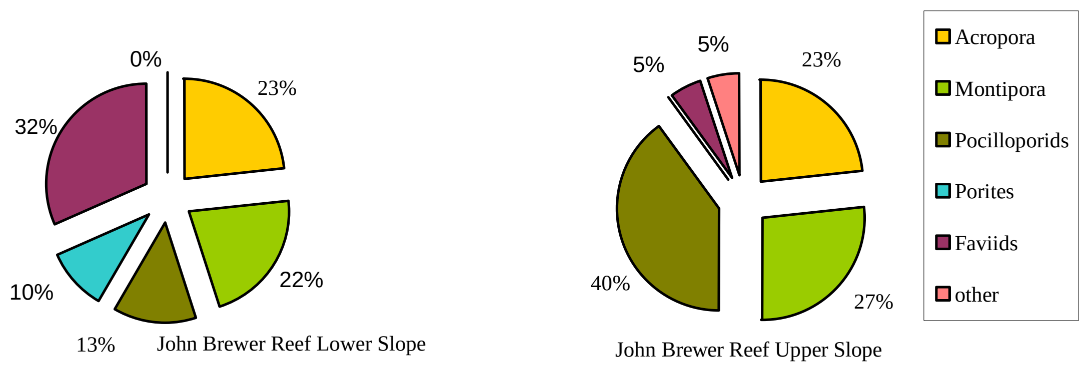


Figure 43. Coral community composition at John Brewer Reef at the time of surveys

Rib Reef

Rib Reef is a small mid-shelf planar reef to the north of Townsville. Following a series of recent impacts (Cyclone Justin 1997, Crown of Thorns Starfish outbreaks 1999-2004), the coral community is reported to be recovering, with low coral cover (five per cent) in 2005 (AIMS LTMP 2005).

The reef flat is dominated by turf algae and calcareous algae, intersected by gullies leading to the crest. The crest site had a moderate drop to the reef slope. Overall coral cover on the upper reef slope was low at the time of surveys (10 per cent, Figure A44) and a mix of mainly *Acropora* and Pocilloporid corals (Figure A45). Disease was observed in a few *Acropora* and *Goniastrea* colonies. The reef slope, composed of conglomerate rubble, is moderately steep to a sand base at 15m. Coral cover is low on the lower reef slope (10 per cent, Figure A44) with the coral community composed mainly of *Acropora*, *Montipora* and Faviids (Figure A45). Filamentous turf algae dominated the substrate on the lower reef slope.

Minor coral bleaching was observed among a few individual hard corals and soft corals on the upper reef slope. Minor bleaching was even more apparent on the reef slope with a small number of *Acropora* and Pocilloporid colonies showing signs of paling and/or fluorescing. The most striking feature of Rib Reef on this survey was the impact of Cyclone Larry just three days prior. The gullies at the crest were either full of excavated debris or scoured clear, revealing long-buried substrate. Only a few branching corals were broken, however many sponges and soft corals were peeled from the substrate.

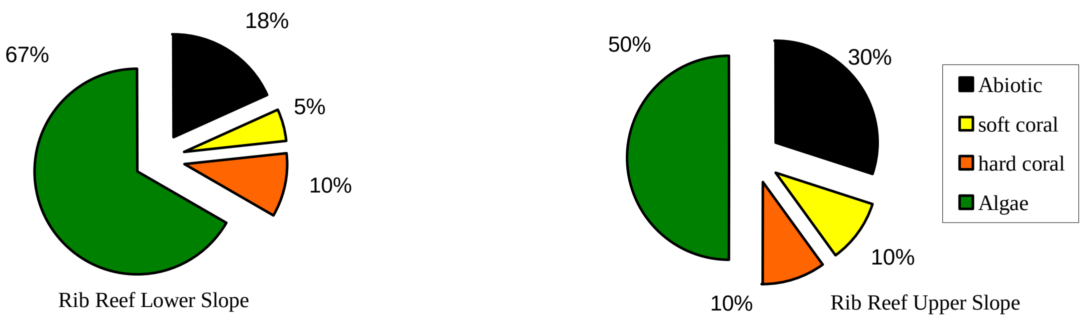


Figure 44. Substrate cover estimates at Rib Reef

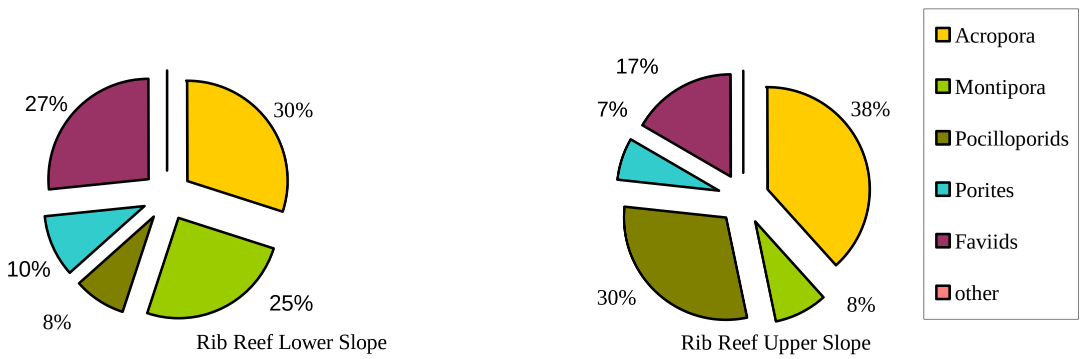


Figure 45. Coral community composition at Rib Reef at the time of surveys

Northern Region

Summary

Table 6. Summary of Northern Region bleaching surveys

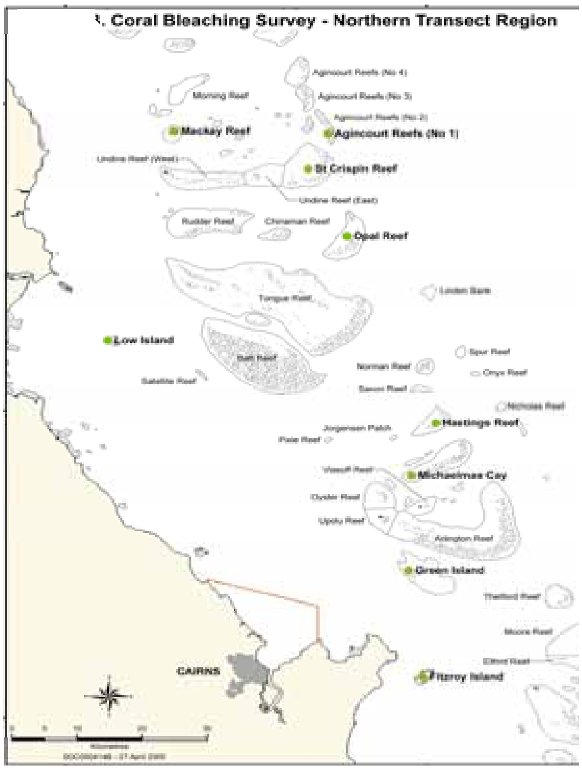
Reefs surveyed		Hard coral cover	Bleaching level
Inshore	Fitzroy Island	moderate	nil
	. Green Island	moderate	nil
	Low Isles	moderate	low
Mid-shelf	Michaelmas Cay	intermediate	nil
	Hastings Reef	intermediate	nil
	Mackay Reef	intermediate	nil
Outer	Opal Reef	moderate	nil
	St Crispin Reef	intermediate	nil
	Agincourt No.1 Reef	intermediate	nil

Key: Nil – 0 per cent, Low – 1-10 per cent, Moderate – 11-30 per cent, Intermediate – 31-50 per cent, High – 51-75 per cent
Very high or severe – 76-100 per cent

Assessments of individual sites with graphs of benthic cover and coral community composition and distribution of bleaching for reefs surveyed in the Northern Region can be found below.

The reef communities show typical variation associated with inshore, mid-shelf and outer-shelf habitats. Of note was the dominant soft coral community on the upper reef slope of Opal and St Crispin reefs - outer-shelf habitats that would have been expected to have dominant hard coral communities. Low coral cover at these sites is likely the result of outbreaks of Crown of Thorns Starfish through this area in 2000, and now the ability of hard corals to return to previous levels is being impeded by the soft corals now dominating the available substrate. Agincourt Reef had a more equal distribution of hard and soft coral within the reef community. Mackay Reef was unusual in that it was a mid-shelf reef with good coral cover and diversity.

The reefs surveyed showed little signs of bleaching. At most reefs a few colonies of plate *Montipora* and branching Pocillopriid corals were fluorescent or pale, however the proportion of the community that this represents is very low (< one per cent).



Map 4. Surveyed sites in the Northern Region, Great Barrier Reef. Filled circles are sites surveyed. Empty circles are proposed survey sites.

There were some signs of Cyclone Larry having passed to the south at Fitzroy and Green Islands, and at Michaelmas Cay, tumbled tabulate *Acropora* and some broken branching *Acropora* were observed. No severe or extensive damage was observed at any of the sites surveyed.

Fitzroy Island

Fitzroy Island is a continental island close to Cairns, surrounded by a narrow fringing reef. Since regular surveys began, (1986) the coral community has fluctuated due to impact and recovery from floods, Crown of Thorns Starfish and bleaching (LTMP 2005). The Coral Bleaching Response Plan site is on the sheltered western side. The reef slope is steep with a mixture of silt/sand, rubble, and solid outcrops.

The coral cover is low to moderate (25 per cent-33 per cent, Figure 46) on both the upper and lower reef slopes. The reef-flat has a high proportion (30 per cent, Figure 47) of soft corals (in particular *Sinularia*, *Lobophytum* and *Briareum*). The coral community is patchy on the reef flat and more expansive on the crest with large *Acropora* tabulate colonies and some *Acropora* branching sp. Newly broken corals were sighted, the breakages attributed to the recent passing of Cyclone Larry. The lower reef slope has scattered *Porites* massives and solid outcrops supporting a variety of corals in addition to those corals observed in the shallows. These include *Physogyra*, *Pachyseris* and *Lobophyllia* sp. (Figure 47).

On the reef crest and flat bleaching was restricted to the occasional Pocilloporid coral. On the reef slope, bleaching was observed among Pocilloporiids, and on the upper branches of some *Acropora* sp.

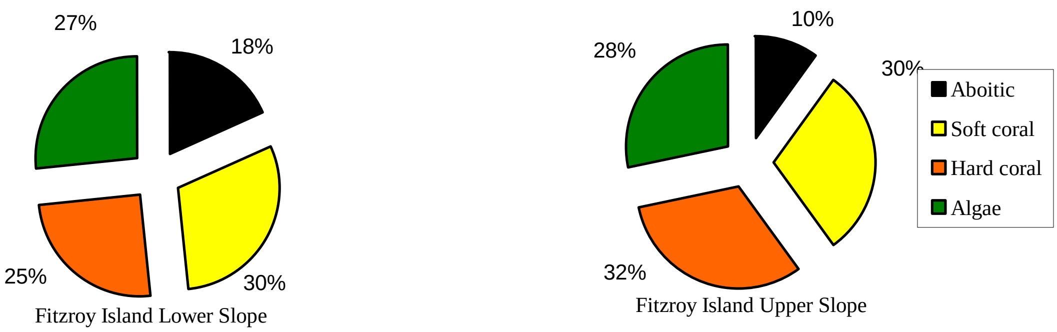


Figure 46. Substrate cover estimates at Fitzroy Island

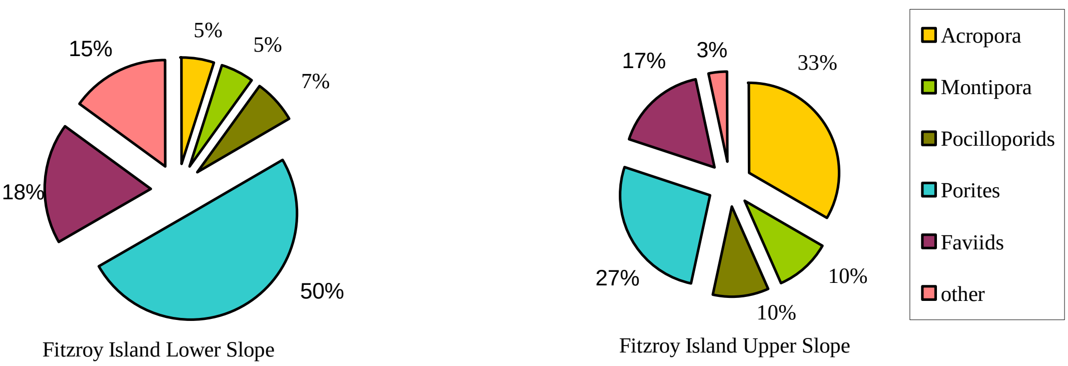


Figure 47. Coral community composition at Fitzroy Island at the time of surveys

Green Island Reef

Green Island is an inshore planar reef with a large sand cay, located east of Cairns. A history of Crown of Thorns Starfish outbreaks has left coral cover generally low and only slowly recovering, reported as nine per cent on the reef slope in 2005 (AIMS LTMP 2005). The Coral Bleaching Response Plan site is on the southern edge of Green Island reef.

The reef flat is a mixture of solid substrate and rubble, covered with filamentous turf algae. Gullies from the reef flat empty onto the wall-like crest area. Coral cover on the upper reef slope is low to moderate (23per cent, Figure 48). The coral community consists of scattered outcrops which have tiers of *Acropora* tabulates and medium-sized (1-2m) *Porites* bommies, with only a few other coral types (Figure 49). There was some evidence of cyclone damage with recently broken or knocked over branching *Acropora* sp. colonies. The reef slope drops steeply to a sand base at 11m and consists of hard substrate covered with filamentous turf algae. Large ‘boulders’ mostly devoid of either hard or soft corals (though some coral recruits were observed) were common. Coral cover is low on the lower reef slope (10per cent, Figure 48) and scattered among slope and boulders. Some large colonies of branching *Acropora* and massive *Lobophyllia* were observed (Figure 49).

Bleaching in the shallows was confined to the sensitive Pocilloporid group and a few colonies of branching *Acropora* sp. and foliose *Montipora* sp. Minor bleaching on the reef slope was observed as paling in the upper branches of a few *Acropora muricata* and *A. valencianessi* colonies.

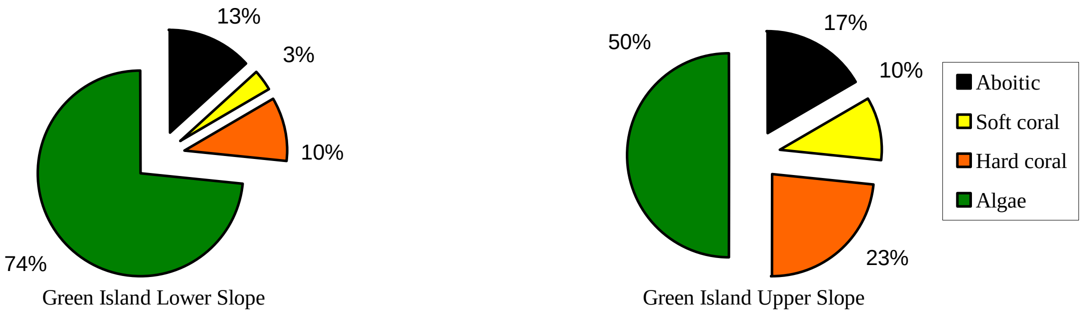


Figure 48. Substrate cover estimates at Green Island

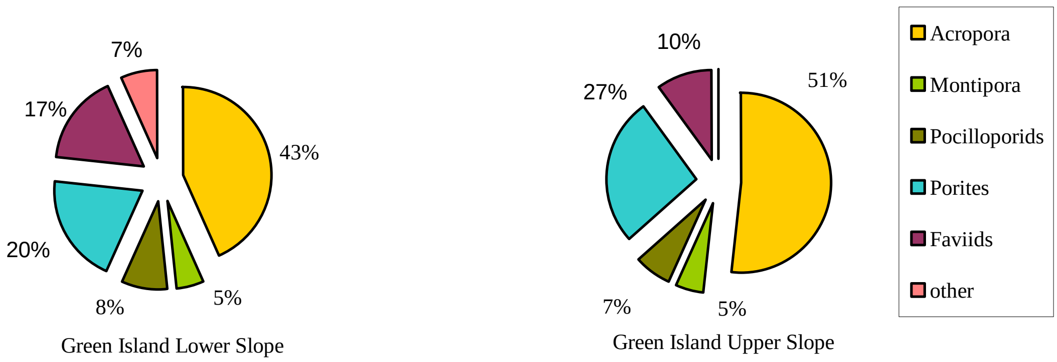


Figure 49. Coral community composition at One Tree Island at the time of surveys

Low Islets Reef

Low Islets Reef is a small inshore planar reef with a sand cay, adjacent to Woody Islet and located east of Port Douglas. The coral community is making a slow recovery from the combined impact of Crown of Thorns Starfish, bleaching and Cyclone Rona (1998 to 1999) and in 2005 coral cover was reported as 16per cent (LTMP 2005). The Coral Bleaching Response Plan site is located on the east side of Low Islets Reef.

The reef flat is a broad undulating area with a scattered population of *Porites* bommies. The upper reef slope has a base of rubble with isolated outcrops of hard substrate supporting a moderate (20 per cent, Figure 50) but varied coral community. On the rubble base there is a patchy distribution of ‘branching’ *Acropora* sp. and foliose corals including *Turbinaria*, *Montipora* and *Echinopora* sp (Figure 51). The reef slope has a moderate gradient and is composed of loose rubble and outcrops of hard substrate. Although the coral cover was low to moderate (15 per cent, Figure 50) the high algal cover on the slope (53 per cent) suggests there is room available substrate for coral recruits. As on the upper reef slope, the proportion of *Porites* sp. on the reef slope (both massive and branching forms) is equal to that of the *Acropora* sp. corals, which are usually more dominant. Some disease was observed on a few branching *Acropora* sp.

Bleaching was confined to a few colonies of *Stylophora* and *Montipora* sp. on the reef slope and was minor.

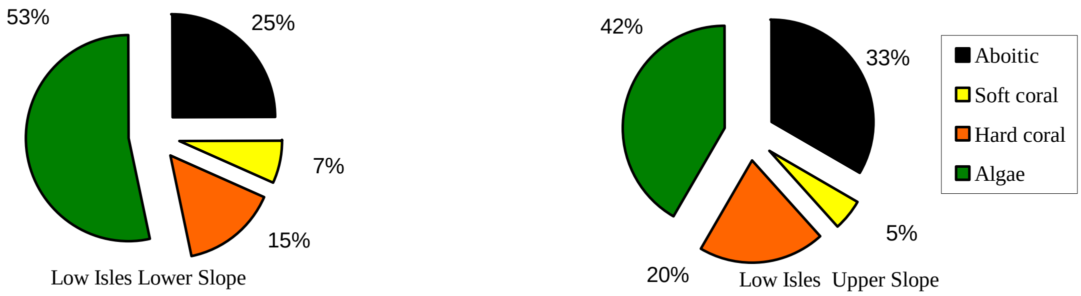


Figure 50. Substrate cover estimates at Low Islets Reef

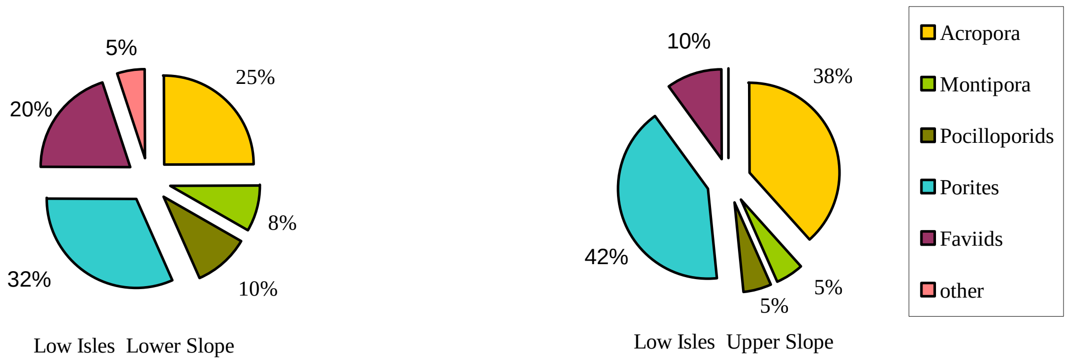


Figure 51. Coral community composition at Low Islets Reef at the time of surveys

Michaelmas Reef

Michaelmas Reef is a large elongate mid-shelf reef with a sand cay on the south-west extremity. Coral cover has fluctuated due to crown-of-thorns starfish activity and was an average of 23 per cent of the substrate in 2005 (LTMP 2005). The Coral Bleaching Response Plan site is on the exposed north-east section of reef.

The reef slope becomes a false front with a reef flat at 4m and a broad gulley behind leading to the main reef. The upper reef slope was characterised by very high coral cover at this site at the time of these surveys (70 per cent, Figure 52) with an abundance of branching and tabulate *Acropora* sp. and a large proportion of Pocilloporids (Figure 53). Crustose coralline algae are common (30 per cent), and soft coral cover is low (Five percent, Figure 53). The reef slope is steep and wall-like in places. The slope wall convolutes along its length, providing localised topographic refuges for attached coral colonies. Coral cover on the lower reef slope is less than half that of the upper (33 per cent, Figure 52) and there is a greater abundance of soft corals (32 per cent). Soft corals include *Lobophytum* and *Sinularia* sp., with a large amount of encrusting forms. The hydroid *Millepora* sp. was also very common in both encrusting and branching form.

Bleaching impacts were confined to the upper reef slope, were minor and were limited to the upper surfaces of the occasional branching *Acropora* sp.

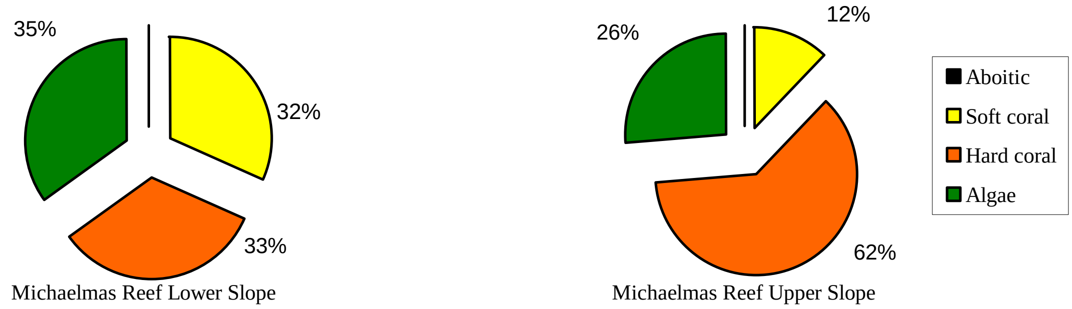


Figure 52. Substrate cover estimates at Michaelmas Reef

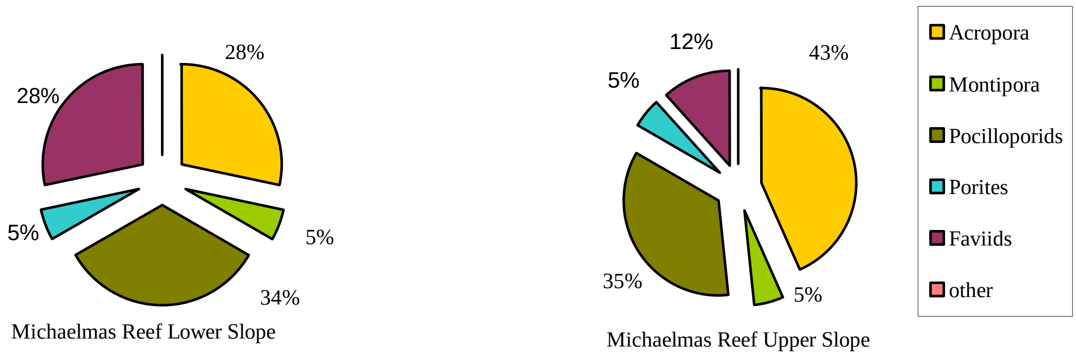


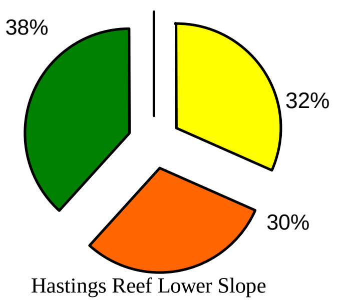
Figure 53. Coral community composition at Michaelmas Reef at the time of surveys

Hastings Reef

Hastings Reef is an elongate mid-shelf reef to the north-east of Cairns. The coral community is recovering from a decline in 2002 following an outbreak of Crown of Thorns Starfish, with surveys in 2005 reporting 24 per cent coral cover (LTMP 2005).

At the time of these surveys the reef flat and upper reef slope had a moderately high hard coral cover (48 per cent, Figure 54). Soft corals are noticeably prolific (32 per cent), especially large colonies of *Lobophytum* sp (Figure 55). The reef slope has a moderate gradient to depth with a tall ridge rising from 10m. Hard coral cover is lower on the lower reef slope than on the upper (30 per cent) and in almost equal proportion to soft coral. Filamentous turf algae were more common on the lower reef slope (38 per cent, Figure 54). *Acropora*, Pocilloporidae and Faviidae made up the majority of the coral community on the upper and lower slopes (Figure 55). There was evidence of the recent passing of Cyclone Larry, with several newly tumbled tabulate *Acropora* colonies on the reef slope.

Minor bleaching was observed and consisted of paling among a few branching *Acropora* sp. and foliose *Montipora* sp. corals on the lower reef slope.



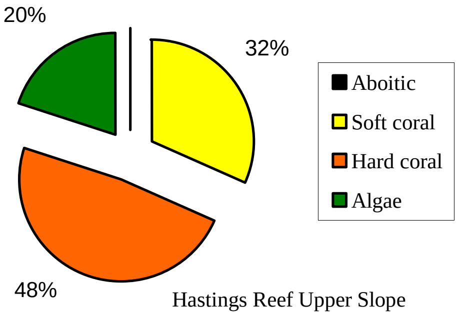
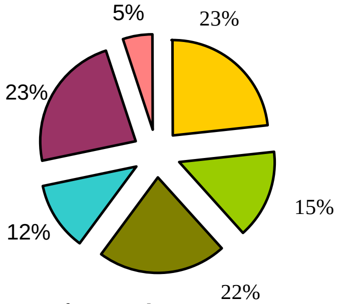


Figure 54. Substrate cover estimates at Hastings Reef



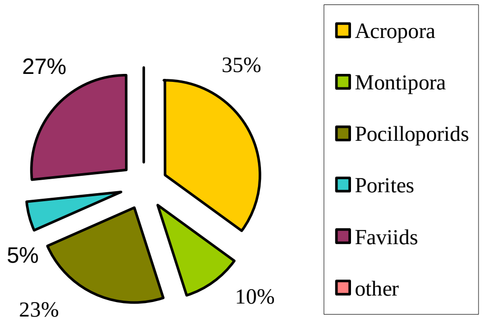


Figure 55. Coral community composition at Hastings Reef at the time of surveys

Opal Reef (No. 2)

Opal Reef is an elongate outer-shelf reef east of Port Douglas. The coral community is recovering from a Crown of Thorns Starfish outbreak in 2000, with a 2005 survey reporting hard coral cover at 21 per cent and soft coral cover at 33 per cent (LTMP 2005). The Coral Bleaching Response Plan site is at the north-east side of Opal Reef.

The coral community on the reef flat is composed of scattered hardy *Acropora* corals including *A. humulis* and *A. palifera* on a solid foundation of crustose coralline algae. The reef flat is crossed by many channels and gullies, providing refuge to a few *Montipora* sp. and Pocilloporid corals. This rugged coral community continues onto the upper reef slope with an increase in soft coral cover (27 per cent). Overall hard coral cover in the on the upper reef slope is moderate (30 per cent, Figure 56). The reef slope undulates down to a broad terrace at 10m. Large outcrops and ridges at 10m form a second barrier or false front. Soft corals dominate the lower reef slope substrate (65 per cent, Figure 57) while overall hard coral cover remains moderate (27 per cent, Figure 56).

No bleaching was observed among the coral community at this site.

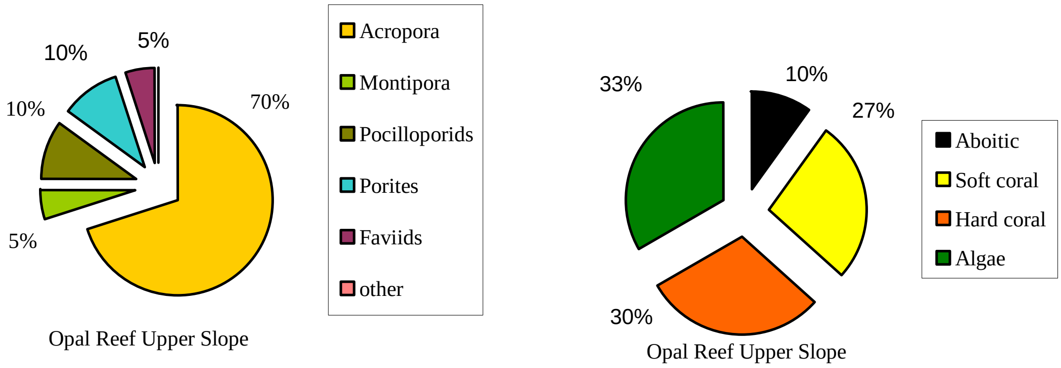


Figure 56. Substrate cover estimates at Opal Reef

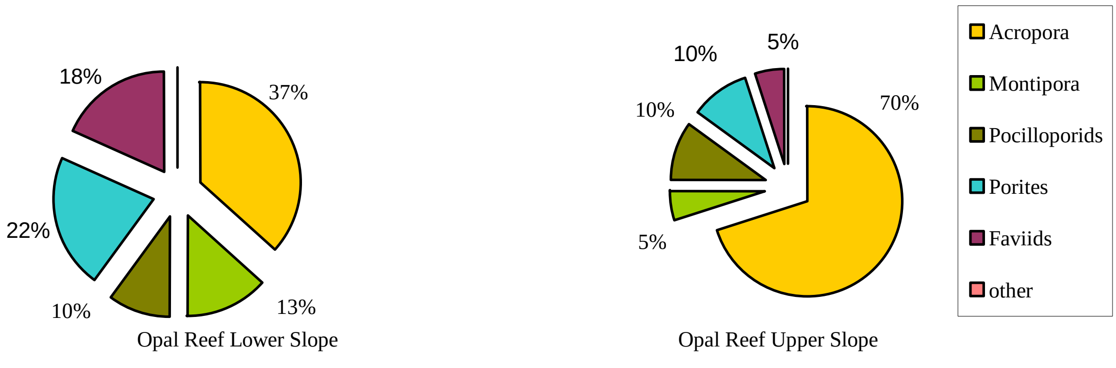


Figure 57. Coral community composition at Opal Reef at the time of surveys

St. Crispin Reef

St. Crispin Reef is an elongate outer-shelf reef to the east of Cape Tribulation. Past surveys suggest that changes in coral cover over the last 20 years have been modest at this reef, with coral cover on the reef slope reported as 27 per cent in 2005 (LTMP 2005). The Coral Bleaching Response Plan site is located on the northeast side of St. Crispin Reef.

The reef flat has numerous low profile hardy corals including *Acropora palifera, A.humulis* and *A. gemmifera* on a solid base of crustose coralline algae. This community continues on to the upper reef slope area with an increase in the number of large tabulate *Acropora* sp. colonies. Overall, coral cover in the shallows is moderate (38 per cent, Figure 58). The soft coral community (30 per cent) is dominated by large encrusting *Lobophytum* sp. on the reef flat and numerous *Xenia* sp. on the upper reef slope. The reef slope has a moderate gradient to depth. The soft coral community dominates (55 per cent, Figure 58) the lower reef slope at St. Crispin, with *Efflatounaria* sp. being very common at the time of surveys. While coral cover on the reef slope is lower (25 per cent) than in the *Acropora* dominated shallows, there is an increase in coral diversity, including Faviids and Pocilloprids (Figure 59).

No bleaching was observed within the coral community at this site.

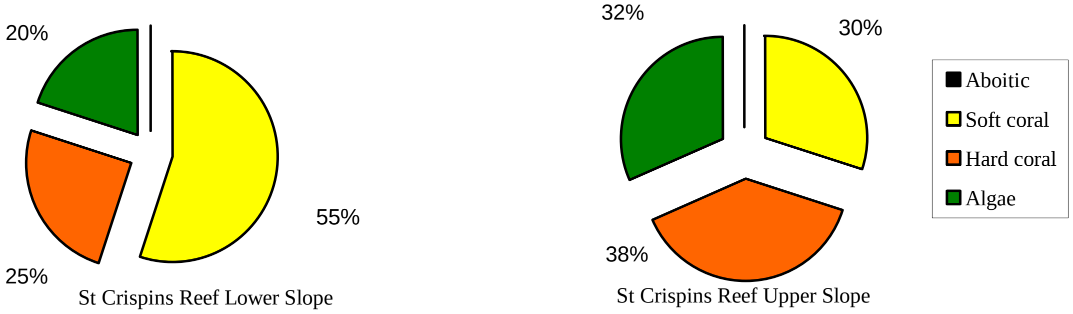


Figure 58. Substrate cover estimates at St Crispins Reef

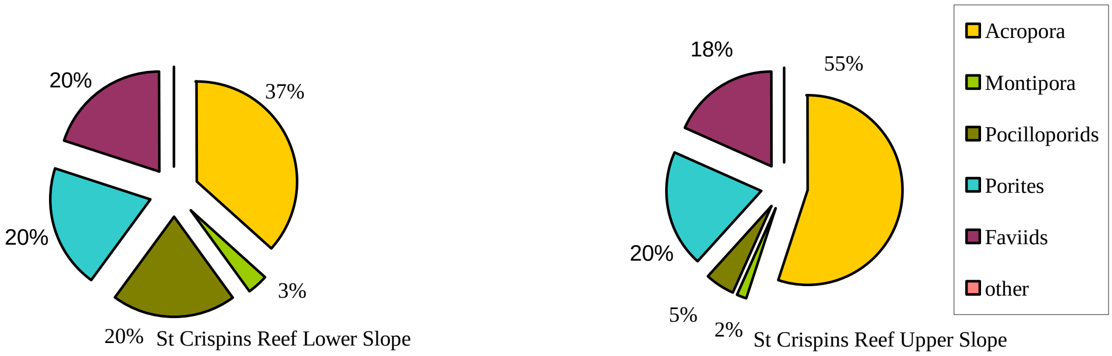


Figure 59. Coral community composition at St Crispins Reef at the time of surveys

Agincourt Reef No.1

Agincourt Reef is an elongate reef on the outer edge of the Great Barrier Reef. Average coral cover around the reef has fluctuated over the last ten years (20-40 per cent) without signs crown-of-thorn starfish or episodes of bleaching (LTMP 2005). The Coral Bleaching Response Plan site is on the semi-exposed north-eastern side of the reef.

The reef-front is broad and deep, and is probably a 'false front'. A false front can be a common feature of exposed reefs and consists of a large buttress section leading up from the main reef slope in front of the reef flat. A broad shallow gully usually separates the false front from the reef proper. Coral cover is high on the upper reef slope (46 per cent, Figure 60) and dominated by low profile, hardy *Acropora* and Pocilloporiid corals. *Acropora palifera*, *A.monticulosa A. humulis* and *Pocillopra* sp are common (Figure 61). Crustose coralline algae are also common and indicates the exposure to wave energy at this location.
Coral cover is moderate to high on the lower reef slope (40 per cent, Figure 60) with *Acropora* dominating the coral community (Figure 61). *Acropora palifera* is abundant in encrusting and sub-massive forms and further underlines the exposure of this location. Soft corals are very abundant, almost equal in density to hard corals.

Minor bleaching was observed on both the reef flat and reef slope with some fluorescing *Pocillopora* and *Montipora* colonies, and some pale *Stylophora* colonies. Visibility at this location was at least 15m.

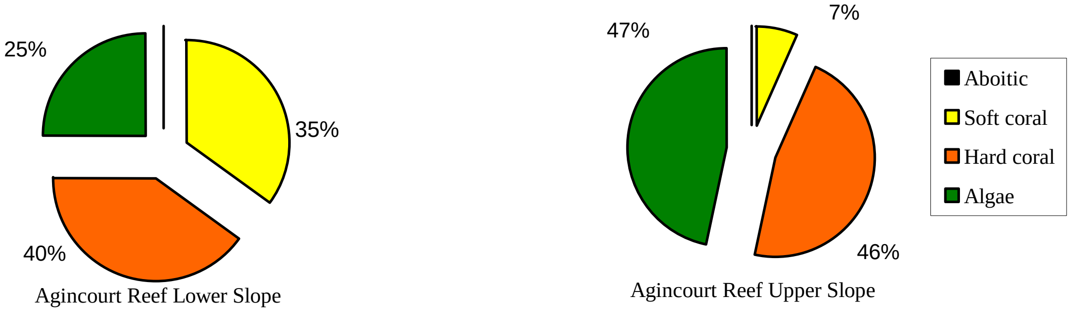


Figure 60. Substrate cover estimates at Agincourt Reef

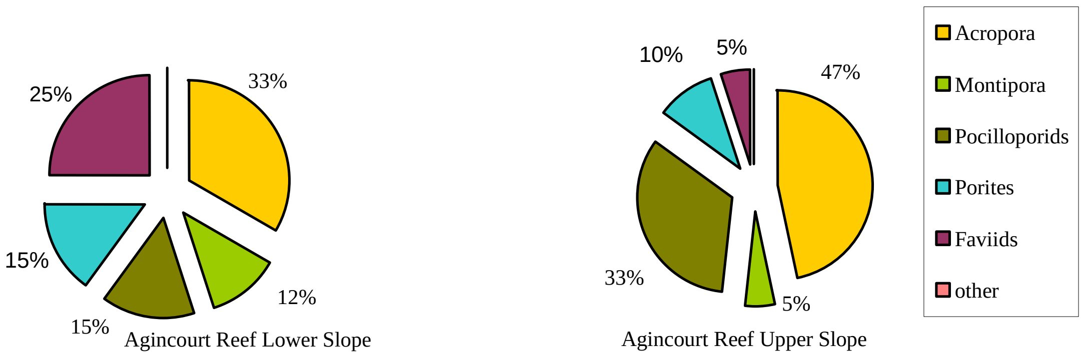


Figure 61. Coral community composition at Agincourt Reef at the time of surveys

Mackay Reef

Mackay Reef is a small mid-shelf reef to the east of Cape Tribulation. The coral community is reported to be making a slow but steady recovery from the effects of Crown of Thorns Starfish (1998) and Cyclone Rona (1999), with a moderate coral cover (27 per cent) recorded in 2005 (LTMP 2005). The Coral Bleaching Response Plan site is on the eastern side of Mackay Reef.

The reef flat has patchily distributed coral cover (mainly branching *Acropora*) among old rubble. The upper reef slope has a shallow gradient and supports large colonies of a diverse range of corals (Figure 62) including branching and tabulate *Acropora* sp., foliose *Montipora* sp., massive *Porites* sp., and massive *Diploastrea* sp. (Figure 63). There are also numerous colonies of *Turbinaria* sp. Overall, coral cover on the upper reef slope is 38 per cent (Figure 62). The reef slope has a moderate gradient and is composed of patchily distributed loose rubble with a complex of ridges and gullies. The slope consists of only coral rubble below 7m. Coral cover on the lower reef slope is 30 per cent (Figure 62), with *Acropora*, *Turbinaria*, *Lobophyllia* and Faviidae sp. all contributing to a diverse community.

There was no bleaching observed on the upper reef slope at this site, even among the sensitive species of Pocilloporids and *Montipora.* On the lower reef slope bleaching was limited to a few pale *Stylophora* and *Montipora* colonies.

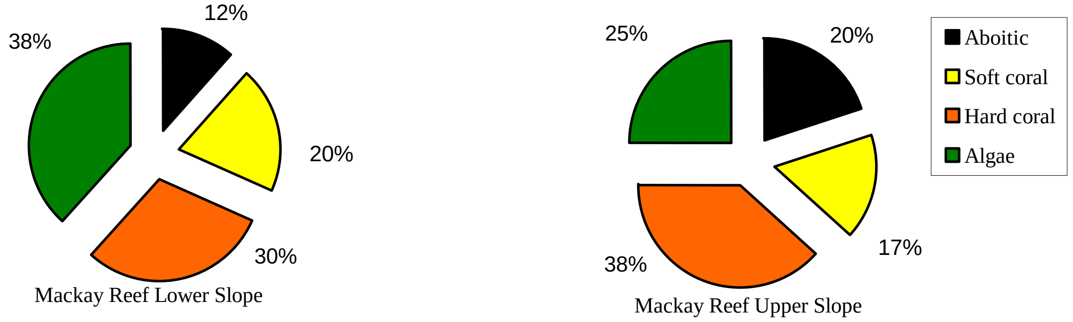


Figure 62. Substrate cover estimates at Mackay Reef

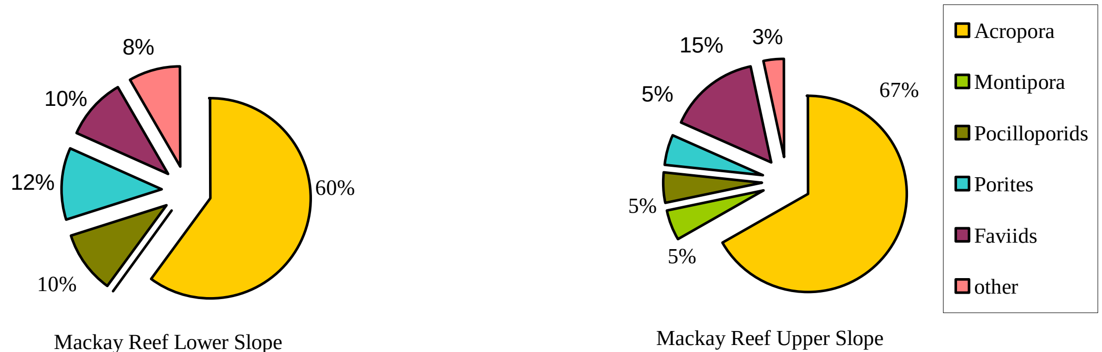


Figure 63. Coral community composition at Mackay Reef at the time of surveys

Far Northern Region

Summary

Table 7. Summary of Far Northern Region bleaching surveys

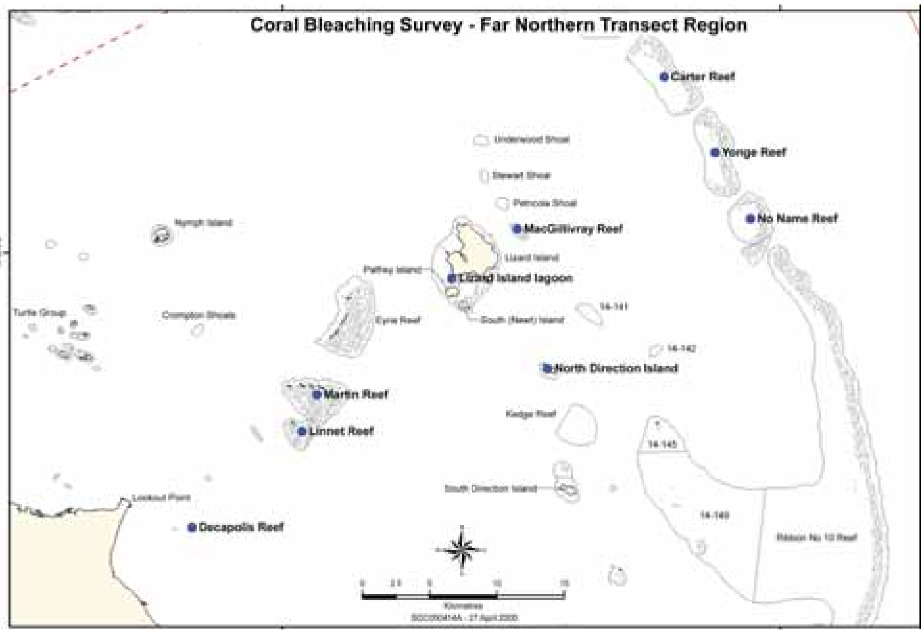
Reefs surveyed		Hard coral cover	Bleaching level
Inshore	Martin Reef	intermediate	low
	Linnet Reef	intermediate	low
	Decapolis Reef	high	nil
Mid-shelf	North Direction Island	intermediate	low
	Lizard Island	moderate	low
	MacGillivray Reef	intermediate	low
Outer	Carter Reef	moderate	nil
	Yonge Reef	moderate	nil
	No Name Reef	intermediate	nil

Key: Nil – 0 per cent, Low – 1-10 per cent, Moderate – 11-30 per cent, Intermediate – 31-50 per cent, High – 51-75 per cent
Very high or severe – 76-100 per cent

Assessments of individual sites with graphs of benthic cover and coral community composition and distribution of bleaching for reefs surveyed in the Far Northern Region can be found below.

In general, coral communities of the inshore and mid-shelf reefs in this region were abundant and diverse. The outer reefs of Carter and Yonge had front slopes dominated by crustose coralline algae, with low to moderate hard coral cover. No Name Reef had slightly higher coral cover and coral diversity than the other locations surveyed in this region.

The reefs surveyed showed few signs of bleaching, confined to only a few patches of paling and fluorescing corals at the mid-shelf reefs of Lizard Island and MacGillivray Reef, and at the inshore reefs of Martin and Linnet. These were predominately *Pocillopora damicornis* and *Stylophora pistilata* colonies as well as a few encrusting *Montipora* sp., all of which are known to be among the most susceptible coral types to the stresses that cause bleaching.



Map 5. Surveyed sites in the Far Northern Region, Great Barrier Reef. Filled circles are sites surveyed. Empty circles are proposed survey sites.

North Direction Island

North Direction Island is a mid-shelf continental island with a broad fringing reef. Average live coral cover was reported as moderately high (30-40 per cent) in 2005 with a low occurrence of disease and a high concentration of Drupella sp. (LTMP 2005). The Coral Bleaching Response Plan site is on the eastern side of the reef.

The hard substrate of the broad reef flat has a mix of filamentous turf algae and crustose coralline algae with patchily distributed small bushy *Acropora sp.* colonies. The reef flat is crossed by broad gullies leading to the reef crest. Foliose *Montipora* sp. corals were observed in some gullies. At the crest area the gullies opened to the reef slope. The walls of the gullies had large colonies of *Echinopora lamellosa* and *Coscinaria collumna*. The upper reef slope, at the time of surveys, had high hard coral cover (70 per cent, Figure 64), dominated by large stands of branching *Acropora*, principally *A. robusta* (Figure 65). The reef slope is steep to 7m then becomes more moderate. The substrate cover is a rubble/sand mix with patchily distributed outcrops of hard substrate. Coral cover on the lower reef slope is lower than at the upper (23 per cent, Figure 64) and coral diversity is confined to the outcrops. The outcrops are often three metres high and support numerous coral colonies. Large beds of *A. longicyathus* and *Echinopora horrida* were observed on the rubble slope.

Minor bleaching was observed on the upper reef slope and was confined to a few pale or fluorescent blue colonies of *Montipora* sp.

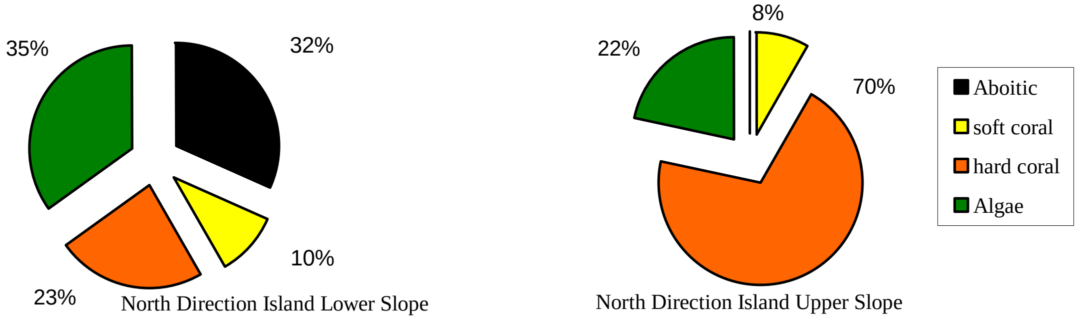


Figure 64. Substrate cover estimates at North Direction Island

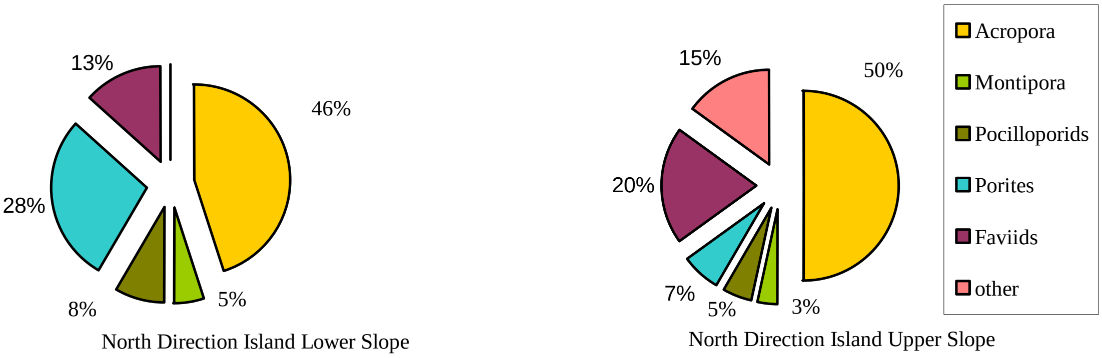


Figure 65. Coral community composition at North Direction Island at the time of surveys

MacGillivray Reef

MacGillivray Reef is a small planar mid-shelf reef to the north-east of Lizard Island. The reef has a history of variable coral cover associated with impact and recovery from Crown of Thorns Starfish outbreaks, with coral cover in 2005 averaging 21 per cent on the reef slope (LTMP 2005). The Coral Bleaching Response Plan survey site was on the east side of this small reef.

The upper reef slope at this site, at the time of surveys, had a moderate coral cover (42 per cent, Figure 66) with varied habitats at both reef flat and reef crest. The reef flat is composed of a variety of small colonies *Acropora* digitates / branching corals, and Pocilloporids. Adding to this coral garden are the occasional extensive soft coral 'combs' of *Sinularia* sp. The reef crest area drops as a short wall from the reef flat and supports most of the coral cover here including *Acropora* branching and tabulate corals, massive *Porites* as well as Faviids (Figure 67). The reef slope has a moderate gradient, with broken outcrops separated by rubble leading onto sand at nine metres. Coral cover is low to moderate (20 per cent, Figure 66). Large colonies of massive *Porites* and *Merulina ampliata* are common. Coral disease was noted but patchily distributed.

Minor bleaching was observed among some branching *Acropora* sp. colonies on the reef flat and upper reef slope but was limited to the paling of upper branches.

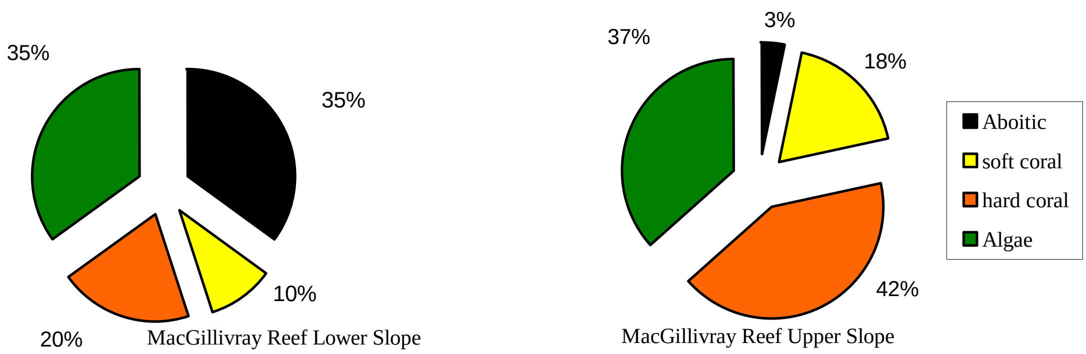


Figure 66. Substrate cover estimates at MacGillivray Reef

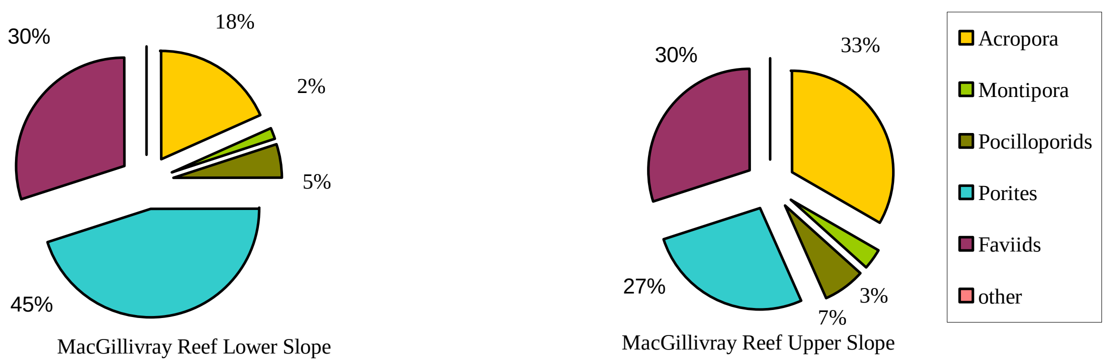


Figure 67. Coral community composition at MacGillivray Reef at the time of surveys

Lizard Island lagoon reef

Lizard Island is a mid-shelf continental island with a broad fringing reef enclosing a coral lagoon. The coral community has been recovering from the protracted impacts of Crown of Thorns Starfish and in 2005 average coral cover was reported as a low to moderate 17 per cent (LTMP 2005). The Coral Bleaching Response Plan site was located in the Lizard Island reef lagoon.

At the time of these surveys, the upper reef slope coral community was made up of numerous but scattered colonies less than one metre in diameter (Figures 68, 69). Overall, coral cover was moderate (33 per cent, Figure 68). The reef slope has a moderate gradient with a hard substrate base that turns to sand with hard outcrops at 12m. The coral community on the lower reef slope is relatively diverse but of low abundance (17 per cent cover). *Porites* and Faviid corals were common (32-33 per cent, Figure 69). Turf algae on hard substrate were abundant on the upper (52 per cent) and lower (42 per cent) reef slopes.

Bleaching impacts were confined to the upper reef slope community and limited to completely bleached Pocilloporid coral with the occasional branching *Acropora* and *Leptoria phrygia* being pale on upper surfaces.

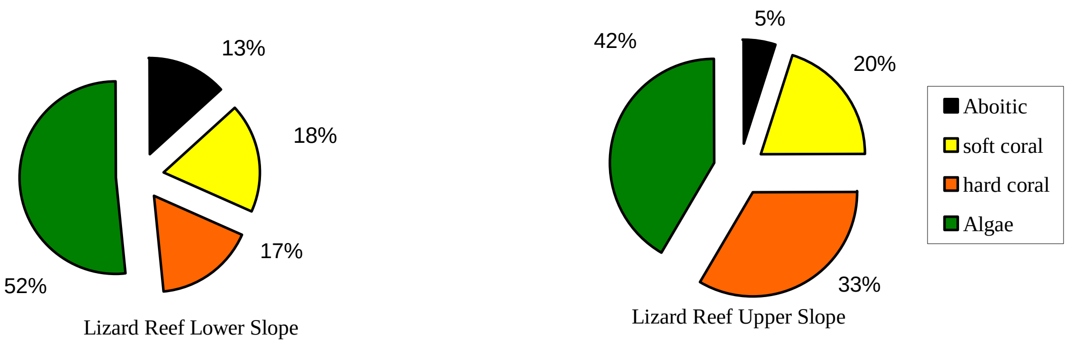


Figure 68. Substrate cover estimates at Lizard Reef

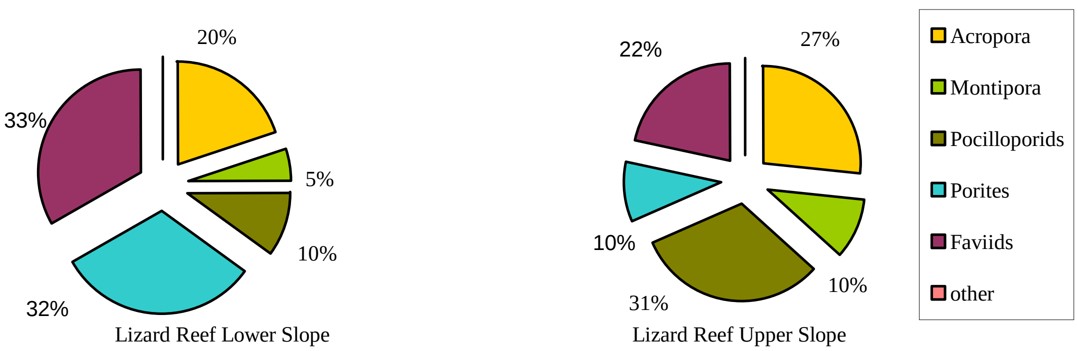


Figure 69. Coral community composition at Lizard Reef at the time of surveys

Carter Reef

Carter Reef is an elongated outer-shelf reef located northeast of Lizard Island. Corals at this site have been affected by CROWN OF THORNS STARFISH , cyclones (especially Cyclone Ivor 1990), disease and *Drupella* sp., and was reported at 39 per cent in 2005 (LTMP 2005).

At the time of surveys, the upper reef slope community consisted of a range of hardy corals, including *Acropora palifera, A. monticulosa, Pocillopora damicornis* (Figures 70, 71). Coral cover is moderate (32 per cent, Figure 70) on a substrate dominated by crustose coralline algae (60 per cent, Figure 71). Soft coral cover is minimal (five per cent). The lower reef slope is steep, with patchily distributed coral and lower overall cover than on the upper slope (15 per cent, Figure 70). Soft coral cover was noticeably higher (10 per cent). Disease was noted on a small number of tabulate *Acropora* colonies.

No bleaching was observed at this reef site.

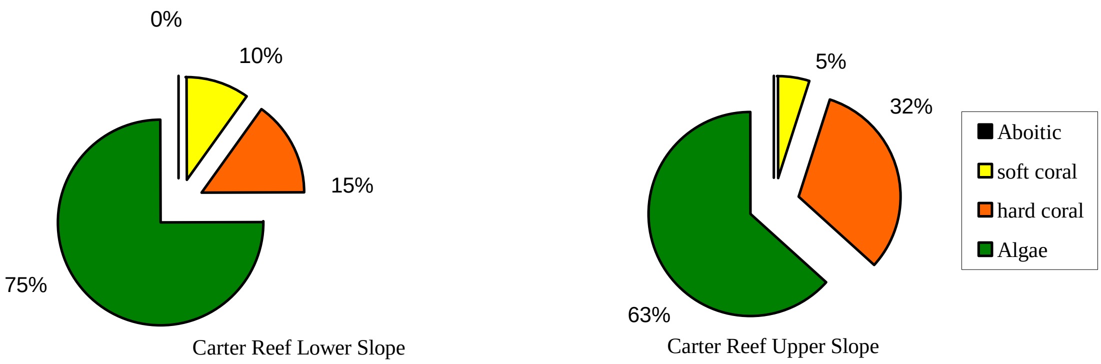


Figure 70. Substrate cover estimates at Carter Reef

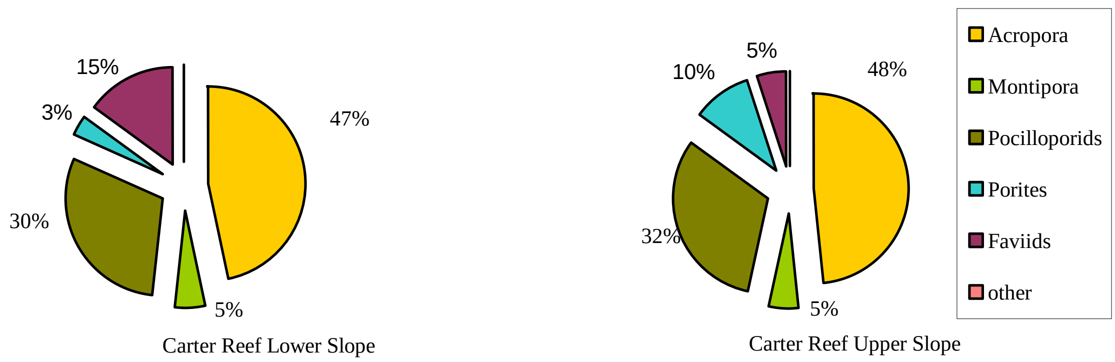


Figure 71. Coral community composition at Carter Reef at the time of surveys

Yonge Reef

Yonge Reef is a large planar reef on the outer edge of the Great Barrier Reef. Coral cover is generally high (48 per cent) despite the presence of low-level coral disease and Drupella sp. (LTMP 2005). The Coral Bleaching Response Plan site is on the semi-exposed north-eastern side of the reef.

The reef slope has a moderate gradient and is terraced at 10m. The broad reef flat and upper reef slope has a community of hardy corals (30 per cent, Figure 72) including *Acropora palifera*, *A. monticulosa*, *A. gemmifera*, and Pocilloporiid corals (Figure 73). The crest area showed signs of collapse in some places, an impact attributable to cyclone activity. Coral cover on the lower slope is moderate (25 per cent, Figure A72) and the broad terrace at 10m has numerous large *Acropora* tabulate colonies (Figure 73). Crustose coralline algae and filamentous turf algae were both abundant.

No bleaching was observed among the coral communities at this location.

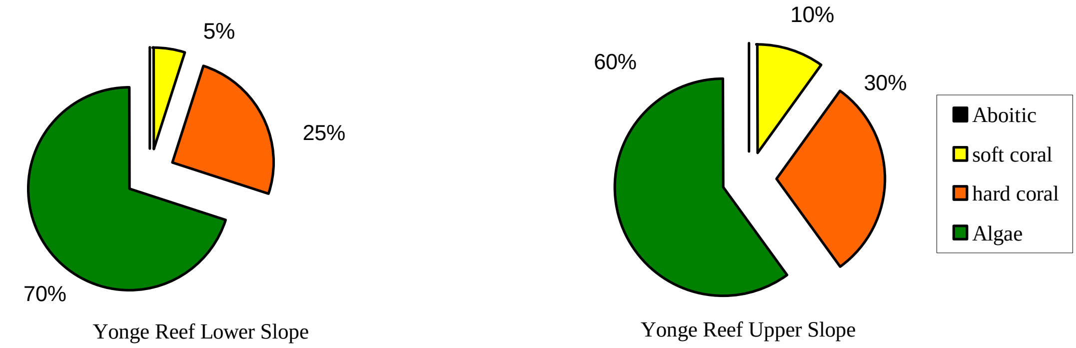


Figure 72. Substrate cover estimates at Yonge Reef

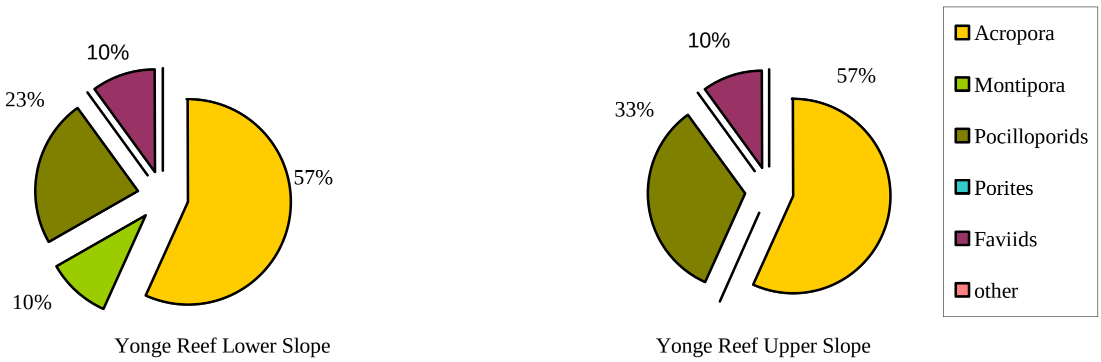


Figure 73. Coral community composition at Yonge Reef at the time of surveys

No Name Reef

No Name Reef is an outer-shelf reef to the east of Lizard Island. The coral community has a history of strong recovery from impacts (Crown of Thorns Starfish, cyclones, disease, Drupella). A moderate hard coral cover (38 per cent) was reported for 2005 following the decline in observed incidences of coral disease (LTMP 2005).

At the time of these surveys, the upper reef slope had a moderate diversity of corals on a hard substrate base (Figures 74, 75). Hard coral cover is 40 per cent on the upper reef slope and made up primarily of small *Acropora* tabulates and Pocilloporids. The lower reef slope is very steep with less coral cover (32 per cent) than the upper and an increase in *Montipora* sp. and *Porites* sp. corals. Patches of sand and rubble are common. Large boulders were observed below the survey depth, and could be a result of recent cyclone activity.

No bleaching impacts were observed at this site.

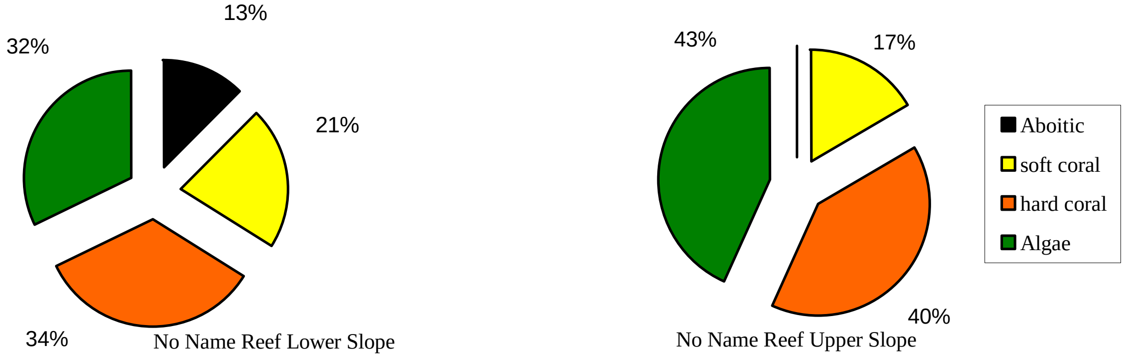


Figure 74. Substrate cover estimates at No Name Reef

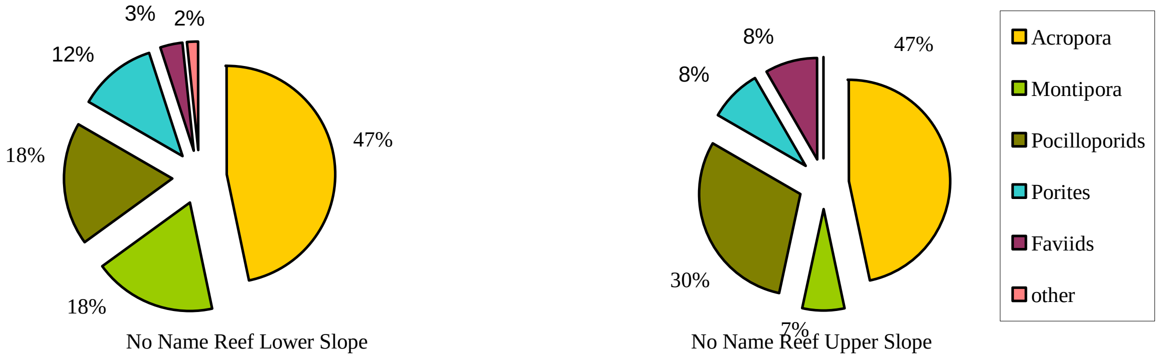


Figure 75. Coral community composition at No Name Reef at the time of surveys

Martin Reef

Martin Reef is a square-shaped inshore planar reef to the east of Cape Flattery. The coral community has remained fairly stable through minor impacts over the years (Crown of Thorns Starfish, bleaching, disease), with coral cover at 28 per cent in 2005 (AIMS LTMP 2005).

At the time of these surveys, coral cover on the upper reef slope was high (73 per cent), and the coral community was dominated by large fields of branching *Acropora* with only a small amount of rubble, indicating no recent storm damage (Figures 76, 77). The reef slope has a slight gradient and is composed of rubble and sand, levelling off to a sand base at 8m. The coral community is confined to scattered outcrops of hard substrate and overall coral cover on the lower reef slope is low (18 per cent, Figure 76).

Bleaching impacts were limited to the paling of the tips of some *Acropora* sp, colonies on the upper reef slope.

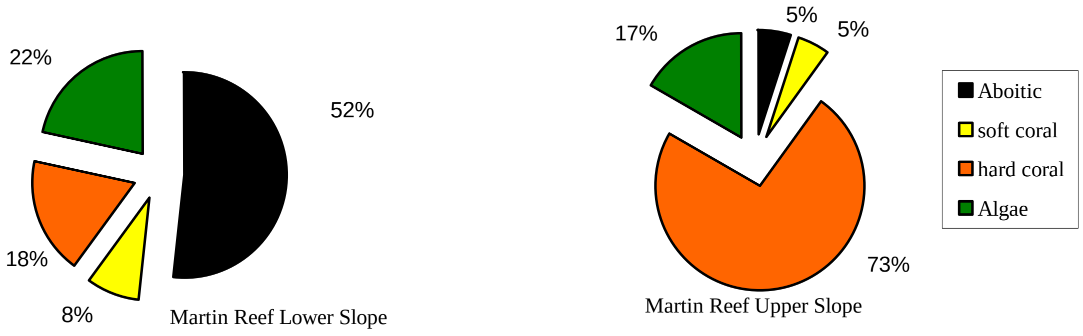


Figure 76. Substrate cover estimates at Martin Reef

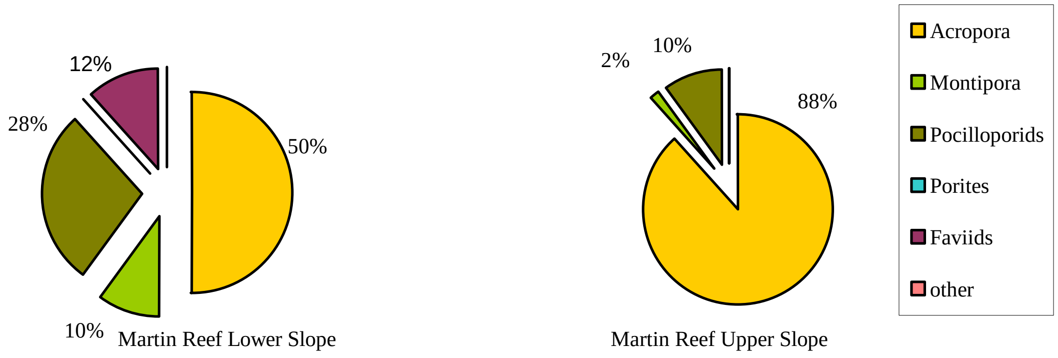


Figure 77. Coral community composition at Martin Reef at the time of surveys

Linnet Reef

Linnet Reef is a small planar reef adjacent to the south end of Martin Reef. The reef has recovered well from past Crown of Thorns Starfish outbreaks and coral cover in 2005 was recorded at 42 per cent on the reef slope (LTMP 2005). The Coral Bleaching Response Plan site is on the east side of the reef.

At the time of these surveys, coral cover in the shallows is moderate to high (50 per cent, Figure 78), with large colonies of branching *Acropora* sp. corals around the crest and upper reef slope (Figure 79). The reef flat has extensive coral rubble covered with turf algae, which is indicative of the level of exposure at this site. The lower reef slope has a moderate gradient and is composed mainly of rubble and sand with a few outcrops of hard substrate, large massive *Porites* sp. colonies and stands of branching *Acropora* sp. Coral (Figure 79). Coral cover on the lower reef slope was recorded as low to moderate (35 per cent, Figure 78).

Bleaching impacts were minor at this location and were limited to *Seriatopora hystrix*.

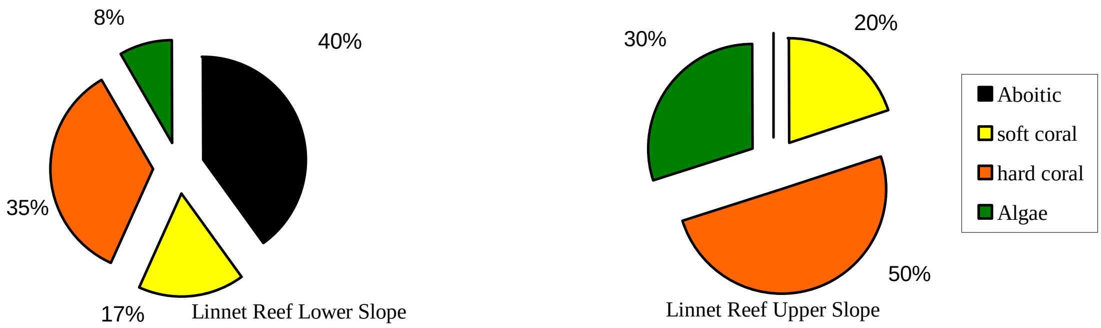


Figure 78. Substrate cover estimates at Linnet Reef

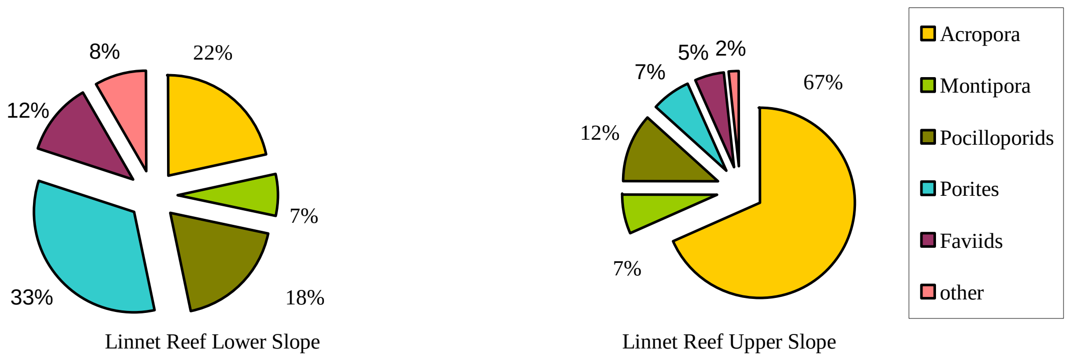


Figure 79. Coral community composition at Linnet Reef at the time of surveys

Decapolis Reef

Decapolis Reef is a small inshore planar reef off Cape Flattery. Coral cover has remained stable for several years of surveys with a reported average of 23 per cent in 2003; the year that coral disease was first reported here (LTMP 2003).

The reef crest has extensive beds of branching *Acropora* sp. and little overall diversity. At the time of these surveys, coral cover on the upper reef slope was very high (87 per cent, Figures 80, 81). In contrast, the lower reef slope had higher coral diversity but reduced coral cover (37 per cent, Figure 80). The reef slope had a moderate to steep gradient comprised of large outcrops of hard substrate on fine silt. These outcrops support a diversity and abundance of coral groups, including *Pachyseris* sp., *Echinophyllia* sp., and *Turbinaria* sp. (Figure 81). Disease was noticeable among the *Montipora* corals on the reef slope. Fine silt was present over all hard substrate.

No bleaching was observed at this site.

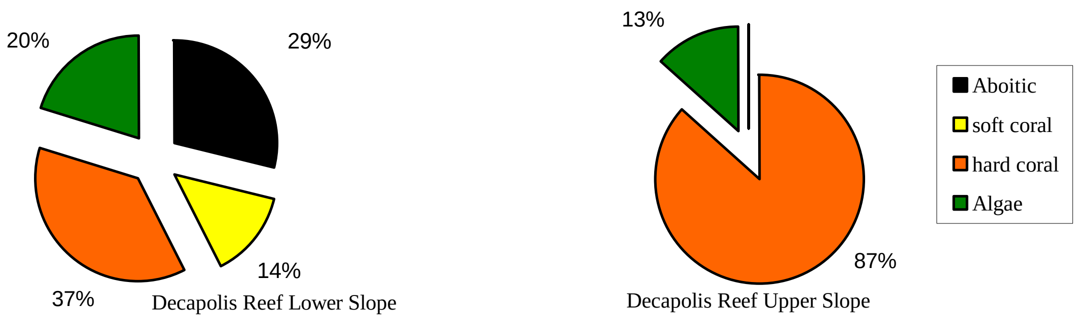


Figure 80. Substrate cover estimates at Decapolis Reef

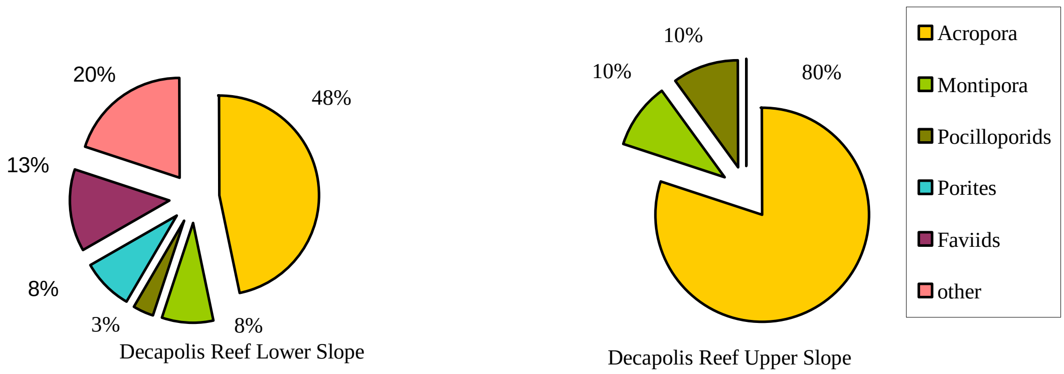


Figure 81. Coral community composition at Decapolis Reef at the time of surveys

Discussion

The coral communities of the Great Barrier Reef have been impacted historically by a range of disturbances. Over the last fifty years, researchers have documented impacts from river plumes, cyclones, crown-of-thorn starfish, *Drupella*, eutrophication and, more recently, disease and coral bleaching. While most impacts affect coral reefs at local or regional scales, only bleaching has the means to impact the Great Barrier Reef over large spatial scales. Factors influencing the bleaching patterns on large spatial scales (among regions) include the residence time of warm water masses and the extent to which the warm temperatures are maintained and reinforced. The bleaching events of 1998, 2002 and 2006 demonstrate that bleaching at large spatial scales on the Great Barrier Reef is not ubiquitous in extent or inclusion and that, for 2006, the stresses causing bleaching can be highly localised.

A number of factors, when combined, have been identified as imparting resilience to coral reef communities that experience thermal stress on the Great Barrier Reef (Done et al. 2003). These include: proximity to upwelling of cooler deep water, mixing and a large tidal range, shading by high islands or complex marine topography, acclimatisation through previous exposure to thermal stress, and genetic proclivity for thermal tolerance. In addition, other studies have demonstrated a gradation of sensitivity to thermal stress among a range of coral taxa (Marshall and Baird 2000, Done et al. 2003), suggesting the distribution of effects of thermal stress are varied in highly diverse coral communities. As a result, spatial patterns in bleaching responses during 1998, 2002 and 2006 varied on both local and regional scales.

The coral communities around the Keppel Islands are particularly vulnerable to changes in water quality. Reefs in the area are primarily of the shallow fringing variety and restricted in depth by a sand base at 10-15 m. The coral communities on many of the fringing reefs are dominated by extensive stands of branching and tabulate *Acropora* species. Corals in the community have shown themselves to be resilient through survival of and recovery from recent disturbances; notably the 1991 flood (van Woesik 1991) and the bleaching events of 1998 and 2002 (Berkelmans et al. 2004). The *Acropora* genus, and particularly the branching morphologies, is sensitive to thermal stress (Marshall and Baird 2000, Done et al. 2003) and severe bleaching responses (pale, fluorescing, white) were observed during 1998, 2002 and 2006. However, the high level of coral mortality following the 2006 regional bleaching event highlights the impact of physical factors and the vulnerability of coral communities with low biodiversity.

The Future

Sea surface temperatures are projected to rise over the coming decades due to global warming (IPCC 2007) with an increased frequency of bleaching events on the Great Barrier Reef (Hoegh-Guldberg et al. 2007, Hoegh-Guldberg 1999). The survivorship of corals will depend on several key factors that include:

- The ability of corals to adapt or acclimatise to higher sea temperatures
- The condition of corals prior to thermal stress
- The sustainability of discrete habitats that offer refuge to diverse corals due to cooler currents, shading and isolation from other impacts
- The maintenance of reproduction, recruitment and replenishment cycles that link reefs at regional spatial scales

Despite mechanisms of physiological and genetic adaptation, and opportunistic habitat selection, many coral species will be unable to survive projected temperature increases (Coles and Brown

2003). With thermal stress affecting both recruitment and survivorship in patterns varying across different spatial scales, coral communities may undergo shifts in community structure with more adaptive types dominating (Done 1999). These community shifts are likely to be accompanied by an overall loss in species diversity and such landscape changes will have an effect on the overall benthic community structure. This would be a particularly dramatic change for high abundance / low diversity communities. In addition, higher temperatures may stimulate higher growth rates and promote longer growth periods among the macroalgae. This would lead to a phase-shift in community structure where the dominance of macroalgae reduces the opportunity for coral settlement and exacerbates low coral recruitment (McCook 1999).

Studies on the effects of thermal stress and climate change on coral communities are important for developing management strategies that improve the chances of reefs surviving in the coming decades. The Coral Bleaching Response Plan has documented the distribution of bleaching among coral communities across the Great Barrier Reef during the 2005/2006 summer. Management plans to monitor the response of coral communities to increasing sea temperatures will continue to rely on early warning systems at both the institutional level (such as *ReefTemp*[1] and POAMA Great Barrier Reef SST forecasts[2]) and community level (such as BleachWatch).

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Appendix A: Comparison between March and June 2006 rapid assessment surveys in the Keppel Islands

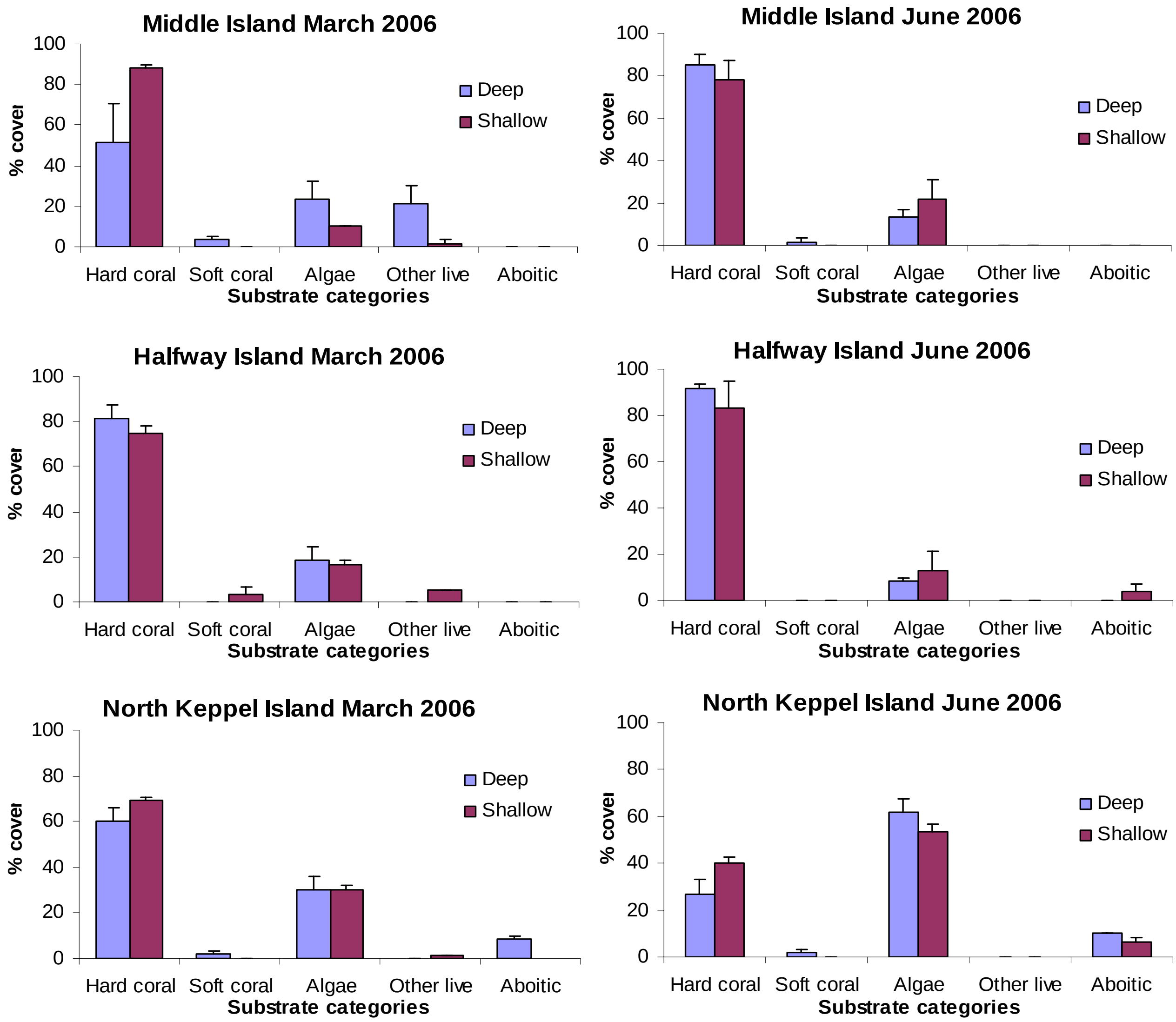
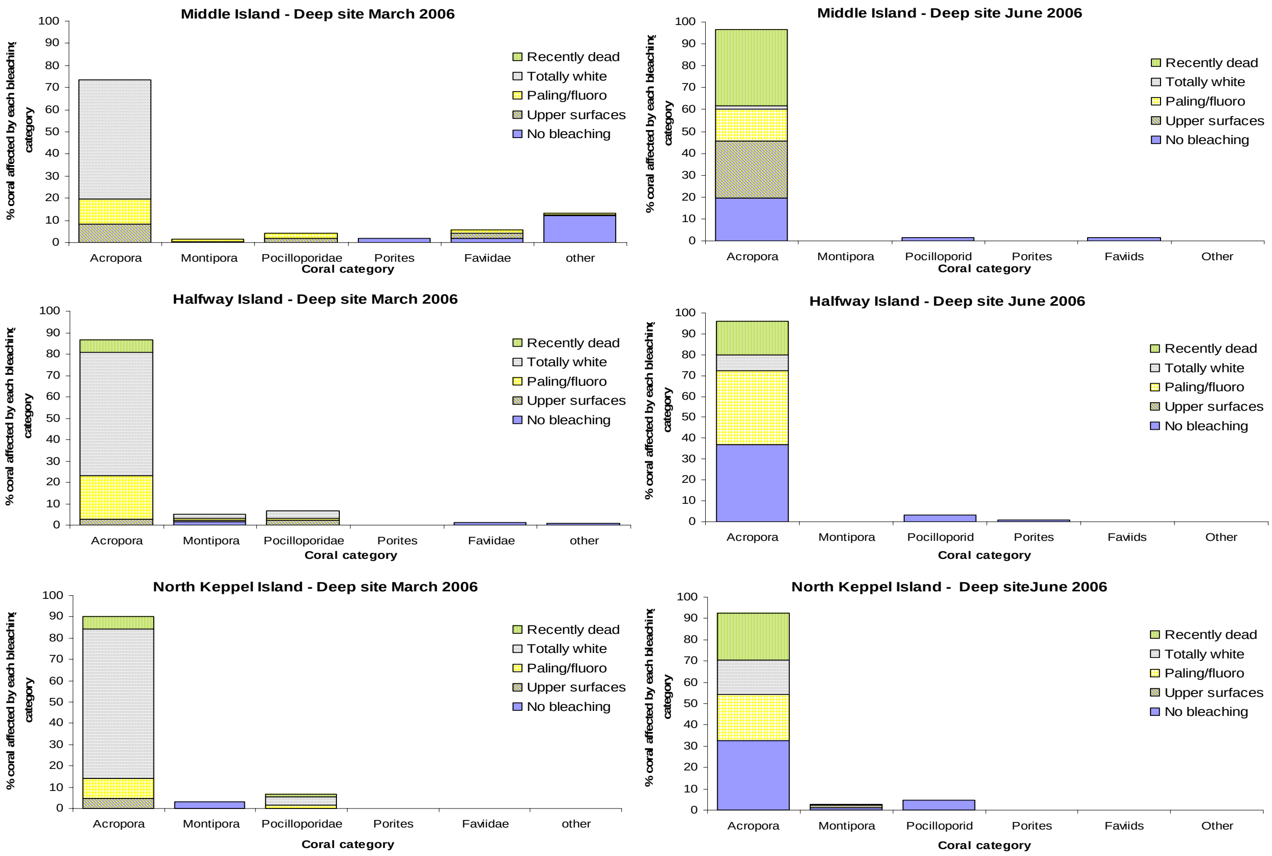


Figure A1. Benthic categories at three sites in the Keppel Islands; comparison between March and June 2006. Note for North Keppel Island the decrease in coral cover and increase in algal cover as corals succumb to bleaching stress and are colonised by turf algae.

A. Lower sites



B. Upper sites

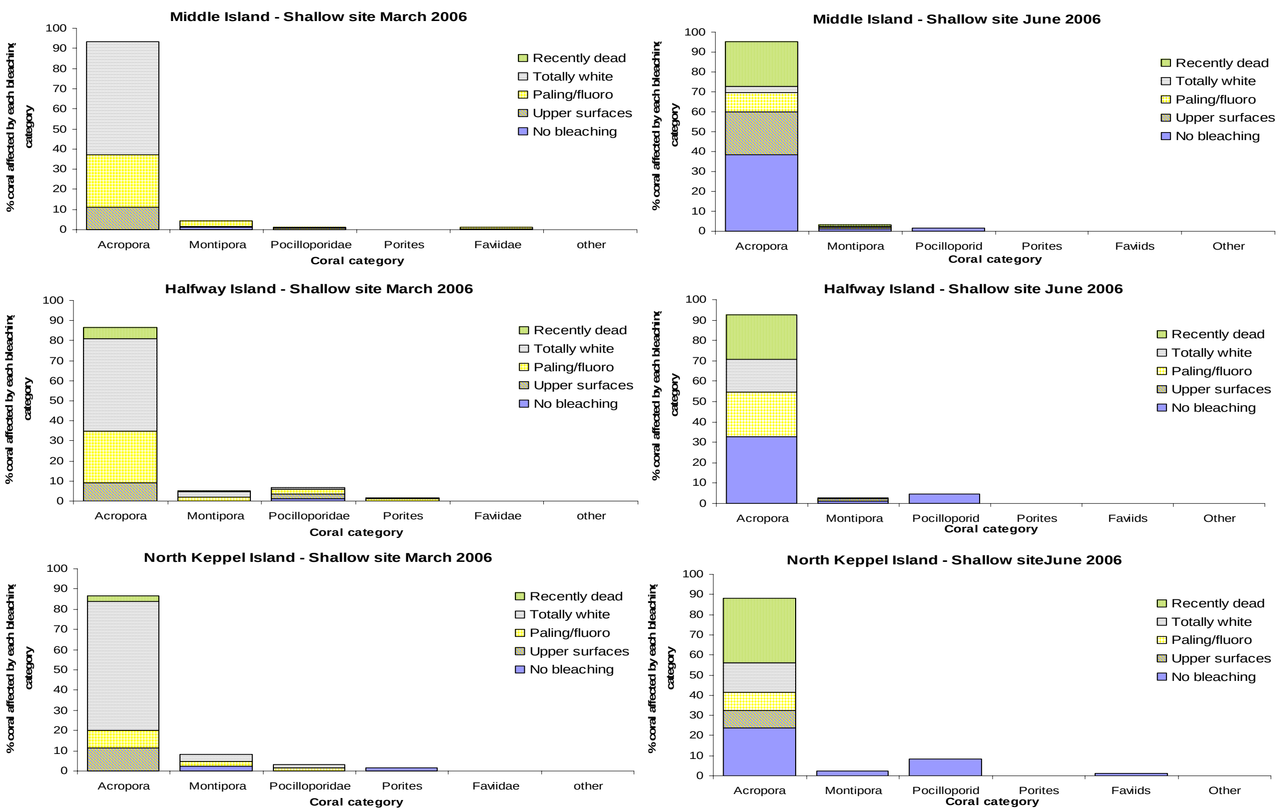


Figure A2. Distribution of bleaching affects among main contributing coral groups at three sites in the Keppel Islands; comparison between March and June 2006 for a) lower sites and b) upper sites. Note the progression of bleaching to either 'No bleaching' or 'Recently dead' states as corals recover or die, especially for the dominant *Acropora* group.