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Status of Near-Shore Reefs of the Great Barrier Reef 2004

Hugh Sweatman, Angus Thompson,
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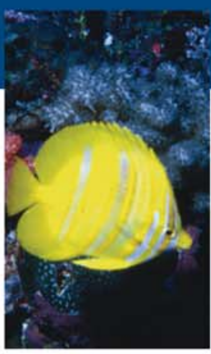


Australian Government
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Executive Summary

Near-shore reefs of the Great Barrier Reef (GBR) cover only a small part of the World Heritage Area, but they have disproportionate significance as signals of the condition of the ecosystem. These reefs are the most accessible to coastal communities and they are the most at risk from runoff. While there have been many studies of near-shore reefs, there has not been a large-scale systematic assessment of their status. This study had dual aims: (1) to assess the current status of a large sample of near-shore reefs along the GBR coast; and (2) to assemble a list of past studies and incorporate their findings as appropriate.

In 2004, we surveyed the benthic communities at 33 reefs in six regions between Cape Tribulation (16°S) and Keppel Is (23°S). Where topography allowed, two depths were surveyed at replicate sites at each reef giving a total of 63 locations. Surveys measured benthic cover, community composition, diversity of coral species and size-structures of coral communities.

Principal findings were as follows:

- The near-shore reef communities were very variable in 2004.
- Coral cover was extremely high in some locations: shallow parts of the reef slopes on the backs of Middle Is, Halfway Is and Humpy Is (Keppel region) had more than 80% cover of living hard coral. Nearly a quarter of the locations had more than 50% cover of hard corals. Coral cover was less than 10% at ten locations. Over all, the average cover of living hard coral was 33%. This is slightly higher than the average cover of 30% from 36 reefs in middle and outer regions of the GBR lagoon that were surveyed by the Australian Institute of Marine Science (AIMS) in 2004/2005.
- The number of species of hard corals ranged widely. There was an average of 22 spp. per location on the shallow slopes of some reefs in the Keppel region whereas there were more than 100 spp. in some locations in the Whitsunday region. The overall average number of species was 69.
- Densities of large coral colonies (definition of “large” was species-specific) varied by a factor of more than forty. Densities were lowest on the shallow slope of Wentworth Reef (Cairns region) and the deeper slope on the front of the Frankland Is (Innisfail region). The highest densities of large colonies were found on shallow slopes of reefs at Cape Tribulation (Cairns region) and Nelly Bay (Townsville region).
- Densities of small colonies (<10 cm maximum dimension, density corrected for the area of suitable substrate) ranged from a mean of less than 1 per m^2 on the shallow reef slope on the back of Keswick Is (Mackay region) to more than 40 per m^2 in deeper parts of the reef slope of King Reef (Innisfail region) and at the back of Dunk Is (Innisfail region). The overall mean density was 15.6 small colonies per m^2.
- Three broad community types were recognised: *Acropora* dominated communities, *Porites* dominated communities and mixed communities. Communities dominated by *Acropora* were common in the Keppel region while *Porites* communities were most common in the Innisfail region. Variation in community structure was correlated with the grainsize of sediment at the locations (an indicator of the resuspension/ deposition regime). There was only a weak relationship with an estimate of risk of exposure to runoff. The divergent communities in the Keppel and Innisfail regions contributed substantially to both these relationships.
- After correcting for differences in structure of coral communities among regions, there were substantial differences in community composition between shallow and deeper sites on reef slopes. This difference was influenced by variation in either settlement or early

survival as the differences in abundance of a number of coral genera between depths was due to variation in the numbers of small colonies.

- Past studies giving information on status of near-shore reefs are collated in an appendix. Examination of the few long-term data sets on near-shore reefs showed that coral cover changed dramatically in many of the sites. Most of the changes in communities over time were due to changes in cover of Acroporidae and, to a lesser extent, Pocilloporidae. Rates of recovery varied widely, depending on the disturbance. After a cyclone, coral cover on reefs at Cape Tribulation recovered quickly, increasing by >5% a year, presumably through regrowth of damaged colonies and the growth of fragments. In other instances, recovery was minimal after several years, presumably because recovery depended on recruitment of new individuals. It is clear that the coral bleaching in 1998 had widespread and severe effects on coral communities of near-shore reefs. Mortality associated with bleaching has been partially responsible for the decline in condition of some near-shore reefs in recent years. By killing corals over a wide area, bleaching is also likely to have reduced the regional supply of potential recruits on which recovery depended. In 2004 many near-shore reefs had substantial densities of small colonies that would have recruited after 1998. This suggests that general recruitment failure, which is one of the predicted results of excessive exposure to polluted runoff, was not widespread.
- Surveys in 2004 provided a baseline for assessing future changes in coral communities on near-shore reefs, but also raise many questions about factors that determine the structure of the coral communities, about their dynamics and their likelihood of persistence in the long term. Accurate measurements of biophysical variables at the survey sites, in combination with information on disturbance history, could explain some of the fine-scale variation in community structure. The few long-term data on coral communities on near-shore reefs show strong effects of several kinds of disturbance. For coral communities to persist they must recover during intervals between disturbances. Rates of recovery will vary with the kind of disturbance but there are few estimates of the rates of recovery that can be expected under different conditions. Recruitment of new colonies is essential for community resilience, so the presence of numbers of small colonies of several genera in many sites is a positive sign, but without information on survival and growth rates under truly representative conditions it is impossible to say whether even the highest densities of recruits that were recorded will be sufficient to replace adults in the long term. The Reef Water Quality Protection Plan provides an opportunity to monitor near-shore reefs over several years so as to relate community dynamics to local environmental conditions and to disturbance in order to provide answers to these questions.

1. Introduction

The near-shore reefs of the Great Barrier Reef (GBR) coast represent a relatively small proportion of GBR reefs: they account for less than 5% of the area of coral reef in the GBR province (Williams 2001). However, they have disproportionate significance for two reasons. Firstly, they include the most accessible reefs; these are recreational resources for coastal communities as well as supporting a number of tourism enterprises (e.g. Low Isles, Fitzroy Is, Magnetic Is). Secondly, among the coral reefs of the GBR, near-shore reefs are most directly at risk from effects of development in the coastal hinterland. It is generally accepted that the development of agriculture in the past 150 years in the coastal catchments has altered the quantities of sediment, nutrients and other pollutants entering the streams that discharge into the GBR lagoon (summarised by Furnas 2003) and most is likely to be retained in the near-shore zone.

For the purpose of this study the near-shore zone is defined as that area of the GBR lagoon that lies roughly within 20 km of the coastline and in waters shallower than 20 m (Williams 2001). Reef development in this near-shore zone of the GBR is restricted to the limited areas of hard substrate on continental islands or rocky headlands, though in a few cases, reefs have developed over coarse-grained alluvial deposits and even mud (Larcombe *et al.* 2001, Kennedy and Woodroffe 2002). The regular occurrence of low salinity conditions, high turbidity and high sedimentation rates prevents development of coral reefs close to river mouths, even where there is suitable substrate. Being in shallow areas close to the coast means that reefs in the near-shore zone are frequently exposed to flood plumes and to sediment that is resuspended from the shallow bottom by wave action (Larcombe and Wolfe 1999). Rainfall in the GBR region is strongly seasonal and intense periods of heavy rain associated with tropical cyclones contribute most of the volume of runoff to the GBR. The resulting flood plumes, particularly the first floods after the dry season, carry large quantities of sediment and nutrients and other pollutants, along with enormous quantities of fresh water, into the GBR lagoon. In most areas, prevailing winds and Coriolis forces spread the plumes northwards and keep them close to the coast (Devlin *et al*. 2001, King *et al.* 2001). This means that near-shore reefs are bathed in flood plumes far more frequently than those further offshore. Because freshwater floats on the denser seawater only the shallow parts of the reefs will experience low salinity, though turbidity associated with plumes will reduce light penetration to greater depths.

Coastal populations are expanding and coastal land use is changing in many parts of the world and there have been a number of studies from other tropical regions correlating such terrestrial changes with degradation of coral reefs. There is also a body of laboratory studies of the effects of components of runoff on reef organisms. This field has been reviewed recently by Williams (2001) and Fabricius (2005). As well as listing studies of changes in communities with increased exposure to runoff, Fabricius summarised the effects of the main components of runoff on survival and growth of adult corals (Figure 1.1), on coral reproduction, larval settlement and growth and survival of juveniles (Figure 1.2) as well as on organisms that interact with corals (Figure 1.3). It is clear that sediment has the most general direct deleterious effects on adult and juvenile coral colonies.

Laboratory and field studies have shown that coral species vary in their ability to tolerate sedimentation (Stafford-Smith and Ormond 1992, Stafford-Smith 1993) and reduced salinity (van Woesik *et al.* 1995). Coral diversity generally declines with increasing exposure to runoff, as species that are less tolerant of turbidity, sediment and nutrients are excluded and competitors (tolerant corals, macroalgae, filter-feeders) or other deleterious organisms (borers) become more abundant. On this basis, composition of coral communities should change with degree of exposure to runoff. Fabricius *et al.* (2005) found consistent changes in the benthic communities along gradients in water quality (potentially related to runoff) in two regions in the northern GBR and found that 60% of hard coral taxa showed a relationship with a composite index of water quality. The total coral cover, on the other hand, showed no relationship with the index of water quality; it was mostly dependent on the time since a major disturbance. As Fabricius' (2005) review makes clear, recruits of many species are more sensitive to components of runoff than are adults, so the abundance and diversity of coral recruits may be a particularly sensitive indicator of exposure to runoff.

	DIN	DIP	POM	Light reduction	Sedimentation
Calcification	↓	↓	↑	↓	↓
Tissue thickness	–	–	↑	↓	↓
Zooxanthellae density	↑	–	↑	↑	↓
Photosynthesis	↑	↑	↑	↓	↓
Adult colony survival	–	–	↑	↓	↓

Figure 1.1. Synthesis of documented direct effects of the four main parameters of terrestrial runoff on the growth and survival in adult corals, based on published studies or known biological properties and processes. The arrows indicate the relative strength and direction of the response (arrows pointing up or down = increasing or decreasing, thick arrow = strong, medium=moderate, thin = weak effect); a dash indicates that a response is unlikely; empty cells indicate that insufficient data are available. Reprinted from Marine Pollution Bulletin, Vol. 50, Fabricius, K. E., Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis, 125-146, Copyright (2005), with permission from Elsevier.

	Dissolved inorg. nutr.	POM	Light reduction	Sedimentation
Fecundity	↓		↓	↓
Fertilization	↓	↓	–	–
Embryo develop./ larval surv.	↓	↓	–	–
Settlement / metamorphosis	↓	↓	↓	↓
Recruit survival			↓	↓
Juvenile growth / survival			↓	↓

Figure 1.2. Synthesis of documented direct effects of the four main parameters of terrestrial runoff on the six main processes associated with coral reproduction and recruitment. Symbols as in Fig. 2.1. Reprinted from Marine Pollution Bulletin, Vol. 50, Fabricius, K. E., Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis, 125-146, Copyright (2005), with permission from Elsevier.

	Dissolved inorg. nutr.	POM*	Light reduction	Sedimentation
Crustose coralline algae	↓			⬇
Bioeroders	↑	⬆		↓
Macroalgae	⬆	↑	⬇	↓
Heterotrophic filter feeders		⬆	⬆	↓
Coral diseases	↑			↑
Coral predators		⬆		

* including phytoplankton

Figure 1.3. Synthesis of effects of the four main parameters of terrestrial runoff on the five main groups of organisms that affect coral cover. High abundances crustose coralline algae as settlement substrata promote coral populations, whereas high abundances of the other groups are assumed to negatively affect coral populations. Symbols as in Fig. 2.1. Reprinted from Marine Pollution Bulletin, Vol. 50, Fabricius, K. E., Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis, 125-146, Copyright (2005), with permission from Elsevier.

Formation of the present near-shore fringing reefs of the GBR began 6-7,000 years ago (Johnson 1985) following sea level rise at the start of the present interglacial period and there must always have been gradients in salinity, nutrients and sediment where rivers discharge into the GBR. However, runoff has probably changed both qualitatively and quantitatively since European settlement began along the GBR coast in the middle of the 19th Century. Prior to European settlement there were an estimated 1,200,000 ha of rainforest on coastal lowlands, eastern slopes of ranges and much of the Tablelands between Townsville and Cooktown (Cassells and Gilmour 1978), while drier areas were covered with open eucalypt and acacia forests. Extensive clearing occurred soon after colonisation: by 1906, much of the coastal lowlands and the northern part of the Atherton Tablelands had been cleared by 1906 and most of the rest of the Tablelands had been cleared by 1918 (Pringle 1986). After exploiting the accessible flat and fertile terrain, the rate of clearing then slowed until the 1950s, when it increased with mechanisation and the advent of new farming techniques for marginal soils as well as government development initiatives (Australian Greenhouse Office (AGO) 2000). Clearing continued at a high rate for the rest of the 20th Century. While the overall extent of changes to vegetation has been estimated by region (e.g. Furnas 2003), there is no comprehensive reconstruction of the time course of settlement and change in land use in the GBR catchments over the past 160 years [but see Neil (1994) Rayment and Neil (1997) for the Tully River catchment]. This would allow estimation of the timing of potential impacts on coral reefs from changes in sediment and pollutant inputs to the GBR lagoon.

Estimates of sediment inputs from catchments discharging to the GBR lagoon are necessarily approximate and have been derived in various ways, usually from models of erosion in catchments or from estimates of sediment per volume of water and river flows. Furnas (2003) gives estimates of current sediment exports to the GBR of 12.1-14.4 tonnes per year, though other estimates have been as high as 28 million tonnes (Belperio 1983). Estimates of pre-1850 levels are 1.0-4.4 million tonnes (Furnas 2003). These estimates of increases in sediment are based on changes on the land; there is also some direct evidence from the GBR lagoon. McCulloch *et al.* (2003) found an increase in barium/calcium ratios, a proxy for fine sediment discharge, in coral cores from the Palm Is group, suggesting a rise in discharge of fine sediment from the Burdekin River starting in about 1870. That date corresponds to the introduction of sheep and cattle to the region within a decade of the first European settlement. From changes in the relationship between barium/calcium ratios and river flow, the authors estimated that fine sediment output from the Burdekin River has increased 5-10 fold since European settlement.

While changes on the land have not been comprehensively documented, there is almost no historical information on the coral communities on near-shore reefs. One of the first major studies of coral reefs anywhere, the Great Barrier Reef Expedition of 1928, studied the relatively accessible near-shore reefs at Low Isles. However, there were few scientific descriptions of near-shore reefs and there were no systematic, long-term studies that allow assessment of the condition of any coastal reefs of the GBR until the early 1980s, and very few such studies since then. This means that major changes in land use had occurred several decades before any studies of the condition of the reefs that were most likely to be affected, though land clearing has continued and there have been considerable changes in types and practices of agriculture in the GBR hinterland since the 1980s. A primary motivation for this project was to establish a long-overdue quantitative baseline for near-shore reefs in several regions of the GBR, from which to track subsequent changes.

The objectives of this study were twofold:

1. To describe near-shore reefs of the Great Barrier Reef province and assess their status in 2004; and
2. To collate information on the past condition of near-shore reefs, particularly from grey literature, with an emphasis on comparison with current status.

The status of near-shore reefs is of concern largely because they are the part of the GBR that is most at risk from runoff. The most deleterious effects of runoff on corals appear to be caused by sediment. Coral reproduction and the early survival of juveniles are the population processes that are most likely to be affected. For these reasons, the descriptions of the study reefs include not only measures of coral cover, but also estimates of species diversity and measures of size-frequency of colonies – attributes that indicate the stage that a reef community has reached in its development.

About this report:

- Section 2 describes the survey locations, survey methods and analyses;
- Section 3 gives general description of the spatial variation among the survey reefs;
- Section 4 gives more detailed descriptions and interpretation of dynamics for each survey location; and
- Section 5 summarises the survey findings with a simple index of comparative reef status.

2. Surveys and Methods

2.1. Survey Locations

Prospective near-shore coral reef sampling locations were initially selected from six broad geographic regions of the GBR: Cairns, Innisfail, Townsville, Whitsunday, Mackay, and Keppel. Each of these regions has a unique combination of climatic regime, coastal and shelf topography and the characteristics of adjacent catchments.

The first consideration in selection of sampling locations was that we aimed to sample “coral reefs” as opposed to “coral communities”. We made the distinction following Van Woesik and Done (1997): coral reefs are communities of coral reef organisms growing on a significant layer of carbonate material substantially made up of the skeletons of their immediate predecessors. Coral communities on the other hand are communities of reef corals that grow on a substrate that is not formed by accretion of coral skeletons (e.g. granite, eroded beach rock, etc.).

To account for possible differences in community composition or dynamics resulting from the physical environment (particularly exposure to waves) our intention was to make surveys in both the front reef (i.e. the zone exposed to prevailing SE trade winds) and back reef (i.e. the zone protected from the SE) of each island or patch reef. However, in practice coral reefs did not occur on both the exposed and sheltered sides of many islands. Mainland fringing reefs were also problematic in this regard.

Within each region, a number of locations were selected based on presence of a reef. All locations were categorised as either front reef or back-reef in the field, but there was a continuum of exposure among the locations. The survey locations within each region were a haphazard selection of available reef development. A secondary consideration was to select reef locations that had been surveyed previously. The list of reef locations are presented in Table 2.1, Figure 2.1 and on maps included in Section 6. GPS waypoints for sites are given in Appendix 4.

Two replicate sites were surveyed at each survey location. Ideally each site consisted of five 20 m transects, separated by about 5 m, laid along depth contours on the reef slope at each of two depths: 2 and 5 metres below Lowest Astronomical Tide (LAT). At several locations there were no coral communities at or deeper than 5 m below LAT and therefore only the 2 m depth stratum was sampled. At Pandora Reef an additional depth of 8m was sampled. Four types of data were gathered on these transects:

1. Benthic cover: Cover of benthic organisms was estimated from five 20 m video point intercept transects. Points were identified to highest possible taxonomic resolution governed by image quality (Abdo *et al.* 2003). The video footage was taken along the upslope side of the transect line such that the tape marking the line was not included in the field of view.
2. Community demographics: Hard and soft coral colonies falling wholly or partially within a 0.34 m (slate width) wide belt were recorded in the first 10 m of each of the five 20 m long transects. These five sections were summed for analysis, ensuring that sampling was spread across the site. Each colony was assigned to one of the following size categories: <5 cm, 5 cm to <10 cm, 10 cm to <20 cm, 20 cm to < 50 cm, 50 cm to < 100 cm and greater than 100 cm.
3. Species lists: An observer spent about 50 min searching in the vicinity of the transects, listing all hard coral species. When an observer could not identify a particular coral to species in the field, the colony was photographed for comparison with coral identification

texts and the image was saved in a database. If identification was still questionable, corals were only identified to genus. In such cases, the number of unidentified species within a genus was noted.

4. Agents of coral mortality: The perceived cause of all new scars (patches of bare white skeleton) were recorded in a belt 2 m wide, 20 m long and centred on the five 20 m transects. Potential agents of mortality included *Drupella* spp., crown-of-thorns starfish and several groups of coral disease. Cases where the agent responsible could not be identified were recorded as "unknown". The proportion of colonies affected by coral bleaching or scarring were scored as follows: 0 = no colonies; 0+ = a few colonies; 1 = 1-10% of colonies; 2 =10-30% of colonies; 3 = 30-50% of colonies; 4 = 50-75% of colonies and 5 = >75% of colonies.

Table 2.1. Survey locations. At each zone there are two replicate sites. Numbers in the depth field indicate the depth contours surveyed, an asterisk indicates that that depth was only surveyed at one of the two sites at that location.

Region	Location	Reef number	Reef zone	Depth (m)
Cairns	Cape Tribulation Nth Reef	15069/16001	front	2
	Cape Tribulation Sth Reef	16003	front	2
	Snapper Is	16006	front & back	2&5
	Wentworth Reef	16037	front	2&5
	Double Is	16047	front	2&5
Innisfail	High Is	17009	front & back	2&5
	Frankland Is	17012	front & back	2&5
	King Reef	17048	front	2&5
	Dunk Is	17053	front & back	2&5
Townsville	Pandora Reef	18051	back	2,5&8
	Geoffrey Bay	19009	front	2&5
	Middle Reef	19011	front	2
	Nelly Bay	19009	front	2&5
Whitsunday	Black Currant Is	20010	front	2
	Manta Ray Is	20010	front	2&5
	Daydream Is	20035	back	2&5
	Shute Is	20048	front	2&5
	Pine Is	20061	back	2&5
	Cow and Calf Is	20065	front	2&5
Mackay	Keswick Is	20277	back & 2*fronts	2&5
	St. Bees Is	20279	back	2&5
Keppel	Nth Keppel Is	23004	front	2&5
	Middle Is	23010	back	2&5*
	Halfway and Humpy Is	23014	front & back	2&5
	Pelican Is	23017	back	2&5
	Peak Is	23026	front	2&5

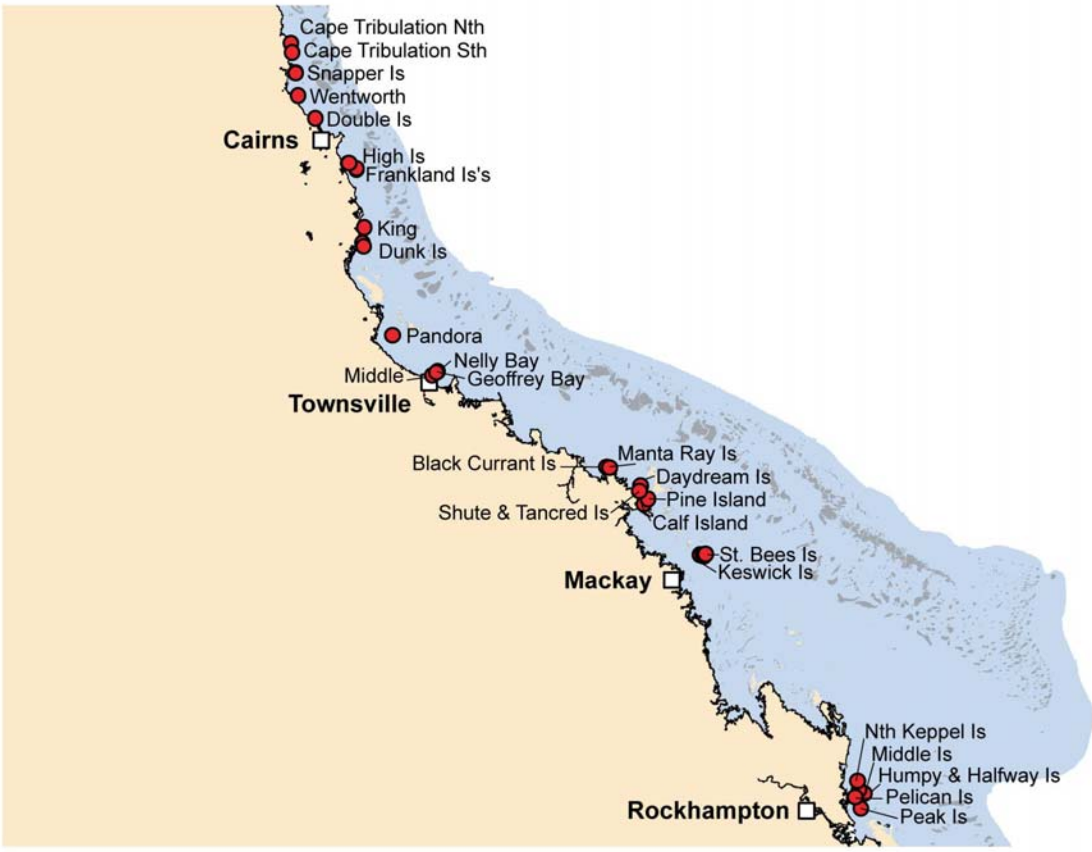

Figure 2.1. Map of survey locations.

In addition, voucher specimens of some species of uncertain identity were collected and lodged with the Museum of Tropical Queensland for identification and future reference. Colonies were photographed *in situ* prior to collection. These photographs are archived in a database and included on a searchable DVD housed along with the collection at the museum.

Sediment samples were collected from 23 near-shore reefs as part of a separate investigation during 2005. Thirteen of these samples were from locations that were surveyed 2004. They provided the basis for categorical classification of local sediment composition that was as an explanatory variable in a redundancy analysis. At each location, four 10 mm deep by 28 mm diameter plugs of surface sediment were collected from patches of sediment haphazardly spread over 100 m along the 5 m contour. The composition of these samples were categorised visually following Table 2.2. For the remaining locations, sediment composition was estimated from notes and by interpolation from the 23 locations where sediment was collected.

Table 2.2. Description of environmental factors used in redundancy analysis of the coral community data.

Factor	Justification	Description
Region	This factor aims to investigate the variation among the various survey regions as part of the overall sampling design of the project	Categorical with one value for each of the six regions visited: Cairns, Innisfail, Townsville, Whitsunday, Mackay, and Keppel
Sediment composition	The grainsize of the sediments found close to the sites; this is a general proxy for the local hydrodynamic regime.	Hierarchical 1 fine mud/silt 2 mud with some fine sand 3 sand with some mud 4 coarse sand
Depth	The depth of a community will affect light availability, the balance between sediment deposition and resuspension, as well as exposure to certain disturbances (low salinity, waves).	Depth of the transects: either 2 m or 5 m below Lowest Astronomic Tide
Adjacent depth	Turbidity may impact coral communities. Depth of the seabed adjacent to reefs will effect the period and intensity of resuspension.	Max depth of seabed within 3 nautical miles of the reef as read from marine charts
Exposure to runoff	Proximity to river along with flood periodicity and intensity and the measures of catchment modification were combined into an “Ecosystem Risk Index” (ERI) by Devlin *et al.* (2003) in an attempt to estimate the risk of exposure to river borne contaminants experienced by particular locations	Continuous with values calculated from formulae and river pollution indices published by Devlin *et al.* (2003).
Exposure	The aspect of a site in combination with the fetch to windward (SE) will affect the exposure to wave energy that may inturn affect community structure and/or sedimentation regime	Hierarchical 1: aspect between 250 and 20 degrees or fetch <5 km 2: aspect between 20 & 50 or 220 & 250 degrees or fetch 5-15 km 3: aspect between 50 & 90 or 220 & 180 degrees or fetch 15-30 km 4: aspect 90-180 degrees and fetch >30 km
Fetch	Proximity to nearest reef, coast or Island in the direction of prevailing wind (SE)	Hierarchical 1: <10 km, 2: 10-20 km, 3: 20-30 km, 4 :>30 km
Distance to land	There is generally a shift in community structure as one moves away from the coast.	Distance in km of the reef from the nearest point of mainland

2.2. Statistical Analysis

Univariate analyses

In the sampling design, multiple locations (the number varied among regions) were nested within each of the six survey regions, and two sites were nested within each reef. At each site, multiple transects were sampled along each of two depth contours (Figure 2.2). Prior to analysis, data were averaged (or summed) over transects, therefore this term does not feature in any subsequent analyses. For estimates based on demographic surveys data were aggregated over sites and therefore the term for site was not included in the model for these data.

$$\cfrac{\begin{pmatrix} Region_6^F \\ | \\ Location_?^r \\ | \\ Site_2^r \end{pmatrix} * Depth_2^F}{\begin{array}{c} | \\ Transect_5^r \end{array}}$$

Figure 2.2. Schematic representation of the sampling design. Terms link by an asterisk are crossed and the hierarchy of nested terms linked by a bar. The superscript *F* indicates a fixed effect and *r* indicates a random effect; subscripts represent the number of levels of the factor terms.

The algebraic representation of the model terms is as follows:

$$y_{ijkl} = \mu + R_i + l_j(R_i) + s_k(l_j(R_i)) + D_l + RD_{il} + l_j(R_i)D_l + \varepsilon_{ijkl}$$

where R = regions (i = 1,…,m), l = locations (j = 1,…,n), s = sites (k = 1,..,o), and D = depth (q = 1,..,p) and ε_{ijkl} = residual error. The Region and Depth terms and their interaction were fixed effects in the model. The error term for the fixed region differences was the location within region variation. The error term for both fixed depth differences and the depth by region interaction was the variation among locations within regions crossed with depth. The random effects represented sources of variability among locations within regions and sites within locations, the interaction of locations with depth and the mean square error. Linear mixed-effects models (Laird and Ware 1982; Pinheiro and Bates 2000) were used to estimate the fixed effects and the components of variance due to the random effects in the multilevel sampling design. Model parameters were estimated using restricted maximum likelihood. The random-effects in the model result in scalar variance estimates for between sampling unit variation. The estimated variance components are presented for each random effect in the model. The significance of variation associated with these random-effects was assessed by tests that the variance components differed significantly from zero. Such tests were conservative as they test against a null hypothesis that is on the boundary of the parameter space (i.e. H_0: $\sigma_r^2 = 0$), and some authors suggest that the observed *P*-value should be halved to achieve the nominal error rate under asymptotic assumptions (Self and Liang 1987). No adjustment was made here so the tests remain conservative. Unplanned pair-wise multiple comparisons were used to explore significant differences between the levels of fixed effects. Bonferroni corrections to the observed *P*-values were used to adjust the family-wise Type I error rate for multiple comparisons and therefore the interpretation of differences was conservative. Estimates of fixed effects are presented (and plotted) with 95% confidence intervals.

Several univariate response variables representing various aspects of the benthic environment were examined. These variables included the percent cover of hard coral, soft coral and macroalgae, and the species richness of hard corals. We also examined the density of hard corals in the small-recruit size-class (i.e. <5 cm) and in the large-recruit size-class (i.e. <10 cm), as well as the proportion of colonies in the <5 cm size-class representing small recruits, the proportion of colonies in the <10 cm size-class representing all recruits, and the proportion of large colonies. The limits of the “large” size class varied among genera, see Appendix 3. Estimates of the density of recruit-sized colonies included a standardisation for the area of available substrate at a given site. Data from the video transects were used to estimate the proportion of the substrate that was suitable for recruitment. This excluded areas covered by hard coral, soft coral or sand/mud. In addition, the proportion of demography belt transect area occupied by recruit sized colonies was estimated by calculating the planar area of recruit-sized colonies at each site as the number of colonies multiplied by the area of a circle 7.5 cm in diameter, representing the mid point of the 5-10 cm size class. This proportion of the substrate was added to the video estimates of available substrate. No correction was made for the <5 cm recruits because the low numbers of these colonies and their small planar area meant that the space they occupied was negligible.

Variation in some responses increased with their mean values. Square root or natural logarithm transformations were used to stabilise the mean-variance relationship and these transformed data used as the response where appropriate. As a result, the precision of estimates of these responses on the raw scale varied depending on the value of response. To present the precision of estimates, confidence intervals for estimates on the transformed scale were back-transformed to the raw scale.

Index of relative reef status

To summarise the survey results, we calculated an Index of Relative Reef Status. This index combines observed values for coral cover, species richness, density of coral recruits and the density of large coral colonies as an indication of how each site compared with others.

To calculate the Index, recorded values of the four variables for each depth at each location were ranked and assigned to quartiles. The lowest 25% of values for each combination of depth and location were given a score of zero and the highest 25% were given a score of 3. These scores where then summed for each combination of depth and location, giving an index with a possible range from zero (if values of all four variables at a particular location were within the lowest quartile), through to 12 if all values of all four variables were in the highest quartile of observations. The resulting values seek to present the relative status of coral reefs at all the survey locations, higher values representing reefs with higher “status”. More detailed assessments of the reefs in each location are given in Section 5.

Multivariate analysis of community structure

Estimates of the percent cover of each hard coral genus were used to investigate multivariate patterns in the structure of the coral community. Data were averaged over sites for each depth at each surveyed location. Percent cover values were square root transformed for all multivariate analyses in order to down-weight abundant genera. Euclidean distances were used to calculate the dissimilarity between reefs. This measure estimates the dissimilarity between two locations as the sum of the squared differences in percent cover over all genera.

Groups of locations with similar coral community types were then identified from hierarchical cluster analysis using the complete linkage method. The optimal number of clusters was defined from the cluster solution that minimised the average silhouette width (Rousseeuw 1987, Kaufman and Rousseeuw 1990).

Redundancy Analysis (RDA; van den Wollenberg 1977) was used to examine linear relationships between multivariate benthic community structure and spatial and environmental variables. RDA is a constrained ordination method that reduces the multivariate benthic percent cover data to a set of uncorrelated derived variables (or dimensions) which account for the maximum amount of variability in the data that is explained by given explanatory (i.e. constraining) variables. This method partitions the variance associated with individual terms in any linear model. The first two dimensions of the RDA solution were displayed in the form of a biplot. The biplots produced are a Euclidean representation, in low dimensional space, of the first two constrained components. Biplots allow the visualisation of association between explanatory variables and the component genera of the benthic community. The variation explained by a variable after accounting for other explanatory variables was assessed using partial redundancy analysis (PRDA). That is, the partial contribution of differences between locations to the total variance in community composition was removed before assessing the additional variance explained by depth differences.

Nonparametric multivariate permutation tests (Anderson 2001, ter Braak and Smilauer 2002) were used to test for the significance of linear relationships between community structure and the spatial and environmental variables listed in Table 2.2. The spatial and environmental variables used to examine differences in community structure represented values for locations and therefore permutation tests were used after the percent cover of each genus had been averaged over depths. Data were permuted under the full model (Anderson and ter Braak 2003). The full data was used to test for depth differences, however, average region and location differences were first partialled out in the analysis. Accordingly, data were permuted under the reduced model to test community differences between depths (Anderson and ter Braak 2003). Many of the environmental variables were simply derived from information on marine charts to approximate environmental factors that are known to affect coral reef communities (Table 2.2). These somewhat crude approximations were necessary because of a lack of available data on environmental variables at the survey locations.

2.3. Data Location

All data generated by this project is stored in an Oracle® database at AIMS (server: Oracle, port: 1521, SID: REEF, schema: REEFMON). The relevant tables are SAMPLE, WAYPOINTS, SAMPLE_TYPES, DEMOG, TAXON, RM_VPOINT, VPOINT_CODES, SPECIES, GENUS, FAMILY, BENTHOS, GROUP, SPECIES_LIST, PHOTO, PHOTO_GROUP, PHOTO_TAXA, SCUBA_SEARCH. Within these tables records relating to this project are identified as SAMPLE.P_CODE = 'IS'.

2.4. Comparison of Species Present in 2004 with Past Surveys

There are two sources of species presence data that can be compared with data collected in 2004.

1. Data collected in 1985 from an unspecified number of sites along Daintree coastal fringing reefs. The data are reported as a species list that includes qualitative estimates of abundance (Veron 1986). Taxa listed as common or abundant in 1985 and absent from the four sites surveyed in 2004 are discussed.
2. Data collected between 1994 and 1997 by Dr Lyndon DeVantier from a number of rapid coral community assessments that included species lists (DeVantier *et al.* 2006). Seventeen sites from this data set were from similar locations and depths to sites surveyed during 2004. Species lists are compared and those species occurring more commonly in the earlier surveys presented and discussed.

3. Results

3.1. *Spatial and Depth Differences in the Benthos*

Variation in the cover in groups of benthic organisms

Regional variation in cover of benthic organisms

The percent cover of hard coral differed among regions: hard coral cover was significantly higher in the Keppel region (53%) than in all other regions except Townsville (35%), (Figure 3.1a). In addition to the variation among regions, hard coral cover varied on a local scale between locations within regions and between sites within locations (Appendix 1). As an extreme example, two sites separated by a few hundred metres at North Keppel Island had coral cover values of 79.2% and 18.6%. The median difference in hard coral cover among sites on the same stretch of reef slope across all locations was 9.2%.

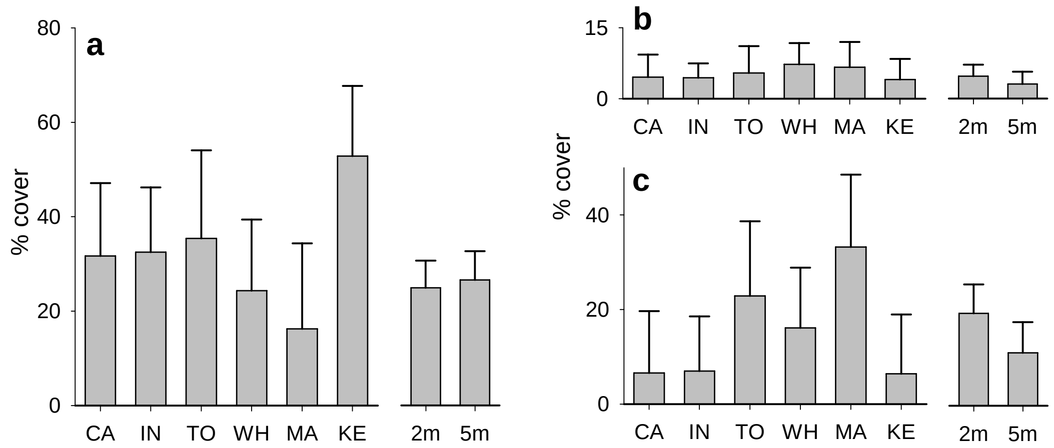

Figure 3.1. Estimated mean percent cover (a) hard coral, (b) soft coral and (c) macroalgae per location in each region and at each depth. Errors are 95% confidence intervals. Labels on the x-axis are abbreviations for the regions specified in Table 2.1 and are simply the first two letters of the names of the regions.

The average cover of soft corals did not differ substantially among regions or among locations within regions (Figure 3.1b), but was highly variable between sites separated by just 100s of metres (Appendix 1).

The cover of macroalgae differed among regions but once again, variability within regions was high (Appendix 1). The cover of macroalgae was significantly higher at locations in the Mackay region than in the Cairns, Innisfail or Keppel regions (Figure 3.1c). There was also significant variation in macroalgae among locations within regions, but variation among sites within locations was small (Appendix 1).

Variation in cover of benthic organisms with depth

Cover of hard coral did not differ on average between depths (Appendix 1).

The cover of soft corals also did not differ on average between depths, but there was substantial variability between depths among locations (Appendix 1). Cover of macroalgae was significantly higher on the shallow relative to the deeper sites; a pattern consistent among regions (Figure 3.1c; Appendix 1).

Variation in species richness of hard corals

The number of species of hard corals varied substantially among regions and was consistently higher in deep sites than in shallow sites (Figure 3.2; Appendix 1). Species richness in the Whitsunday region (mean of 98 per site), was significantly higher than in the Townsville, Mackay or Keppel regions (Figure 3.2). Species richness at sites in the Keppel region ($\bar{X}$ =36) was significantly lower than in all other regions (Figure 3.2).

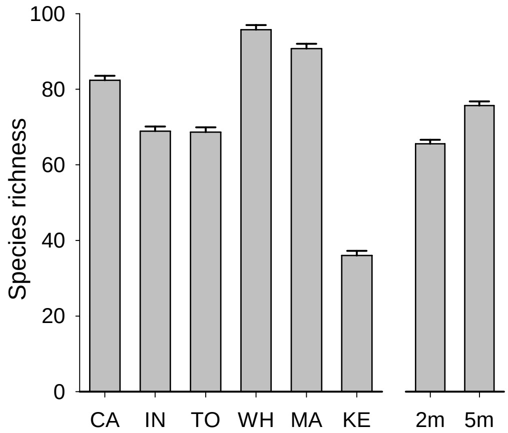

Figure 3.2. Observed mean species richness of hard corals per location in each region. Errors are 95% confidence intervals.

Variation in the abundance of hard and soft coral colonies

The average number of hard coral colonies recorded in the demography transects varied among regions but not with depth (Appendix 1). The average number of hard coral colonies per unit area was lowest in the Mackay region, and was significantly higher in all regions to the north. In contrast to the higher coral cover at locations in the Keppel region, the number of colonies on these reefs was lower than at locations in the Whitsunday region and regions to the north (Figure 3.3a). The abundance of soft coral colonies did not differ significantly among regions or with depth (Figure 3.3b; Appendix 1).

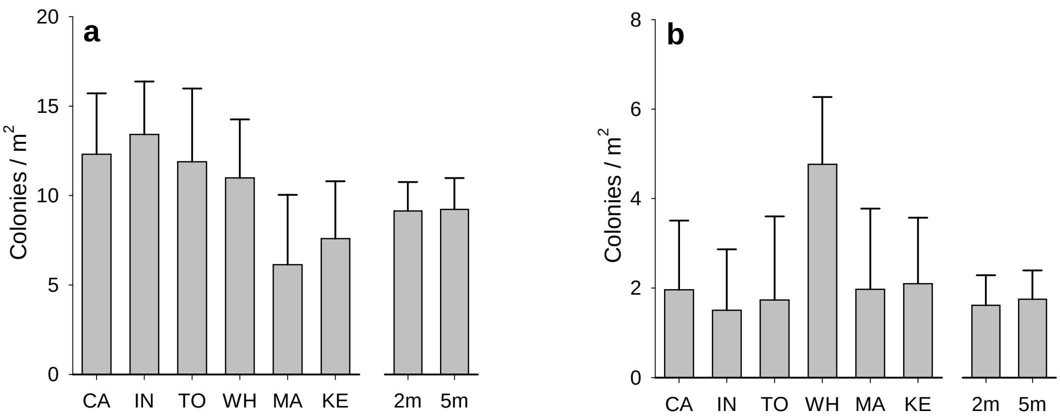

Figure 3.3. Estimated mean density of (a) hard coral and (b) soft coral colonies on demographic belt transects for each region and depth. Errors are 95% confidence intervals.

3.2. Regional Abundance of Individual Genera

Differences in the abundance of colonies of the more common genera between regions and depths were also investigated. Forty-one genera of hard corals and ten genera of soft corals were analysed, representing taxa that had ≥50 colonies recorded over all the surveys (Appendix 2.1). The abundance of colonies of 12 genera of hard corals and four soft coral genera differed among regions (P<0.05), mainly due to the low numbers of colonies in the Keppel region compared with other regions (Table 3.1). Most (92%) of the hard coral genera that differed in abundance among regions were least abundant or absent at locations in the Keppel region. No hard or soft coral genus had significantly higher abundance of colonies in the Keppel region than in other regions. Similarly, the abundance of eight of the 12 common hard coral genera and three of the four common genera of soft corals were significantly higher in the Whitsunday region than in at least one other region. However, for some of the genera, such differences were due to just one location where a genus was exceptionally abundant. Two genera (*Goniastrea* and *Briareum*) showed significant differences in abundance among regions but there was an interaction between region and depth effects, indicating that regional differences were not consistent for both depths. In each case the abundance of colonies was more variable at 2 m and regional differences were less at 5 m.

Table 3.1. Summary of pair-wise comparisons among regions for genera showing differences in average density of colonies among regions (P<0.05). A "**+**" indicates that the density of colonies was higher in that region than at least one other region; a "**–**"indicates the density of colonies was lower in that region than in at least one other region. Double symbols indicate the significance of the difference of pair-wise comparisons was P<0.05; a single symbol indicates P<0.1. Error rates were adjusted for multiple tests. "**na**" indicates that the genus was not observed in that region

Hard Corals	**Region**					
Genus	CA	IN	TO	WH	MA	KE
Coscinaraea		– –			++	–
Favia	+	++	++	++	++	– –
Favites		++		++		– –
Fungia	++		+		– –	– –
Goniastrea	– –	++	–			
Leptastra	++	++		++		– –
Lobophyllia	++	++	–	++	++	– –
Montipora	++					– –
Mycedium		– –		++		na
Oxypora	na	– –		++		na
Podabacia	+	– –	– –	++	– –	na
Porites	++	++	++	++	++	– –
Total - or na	2	4	3	0	2	11
Total +	7	6	3	8	4	0

Soft Corals	**Region**					
Genus	CA	IN	TO	WH	MA	KE
Briareum	++					– –
Klyxum	–			++		– –
Sarcophyton	– –	– –	– –	++		
Sinularia	– –	–	– –	++		– –
Total -	3	2	2	0	0	3
Total +	1	0	0	3	0	0

Abundance of individual genera by depth

Out of the 51 genera, the abundance of colonies of 17 genera of hard corals and one soft coral genus differed significantly between depths (Appendix 2.1). In most cases abundance was higher at deeper sites (Figure 3.4). A further nine hard coral and two soft coral genera also showed some trend toward higher abundance at deeper sites (Figure 3.4; Appendix 2.1). Depth distributions of five genera differed among the regions (significant depth x region interactions, Appendix 2.1). The abundance of these genera did not differ significantly between depths in most regions; where differences did occur, abundance was consistently lower in shallow sites than in deep sites.

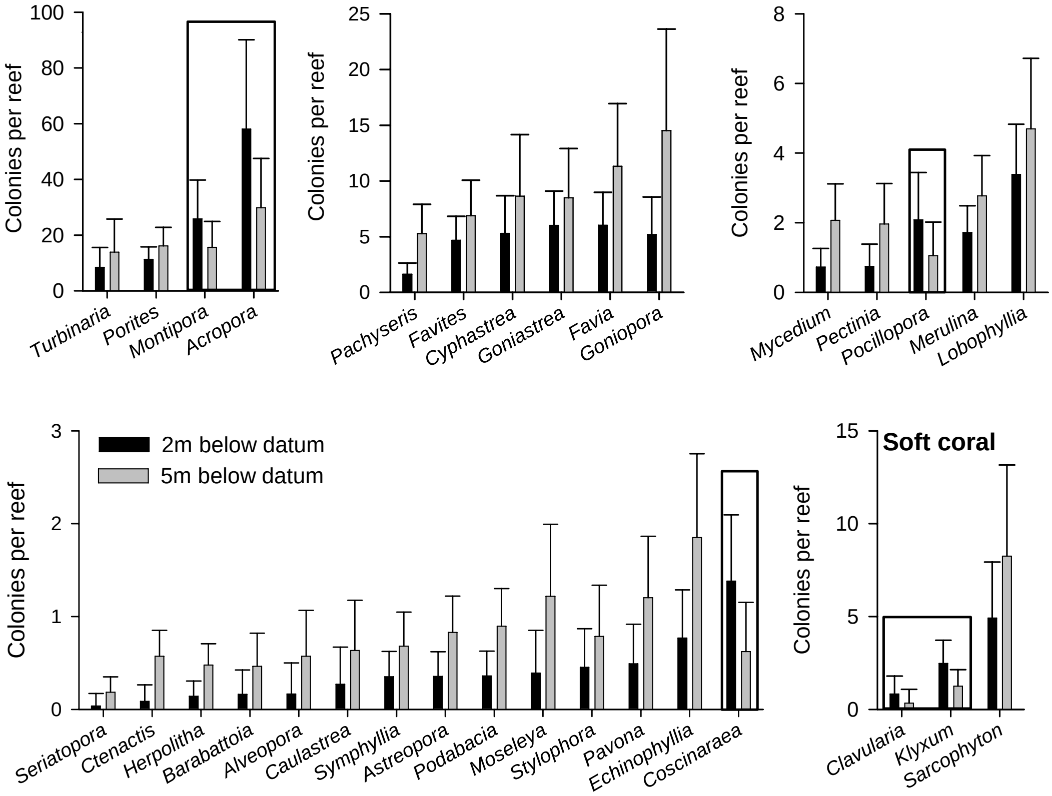

Figure 3.4. Mean abundance of colonies per location for genera whose mean densities differed between 2 m and 5 m depth (P<0.1). Error bars are 95% confidence intervals, data are back-transformed model estimates from the log-transformed data included in ANOVA models. Boxes identify those few genera that are more abundant at 2 m than 5 m depth. Note the different scales on Y-axes; genera are grouped by abundance in separate plots for ease of visual comparison.

Variation in the size distributions of hard and soft coral colonies

Regional patterns

There were regional differences in the average proportion of “large” colonies (see Appendix 3) within the hard coral communities (Appendix 1). The proportion of large colonies was significantly lower in the Innisfail region (12.3%) than in the Mackay or Keppel regions. The proportion of large colonies in the Keppel region (29.5%) was also higher than in the Cairns and Whitsunday regions (Figure 3.5). The high proportion of large colonies in the Keppel region explains how coral cover could be high in that region while the abundance of colonies was low. There were no significant differences in the proportion of small (<5 cm), or larger

(<10 cm) recruits in the hard coral communities among regions (Appendix 1) though the proportion of each was highest in the Innisfail region (Figure 3.5).

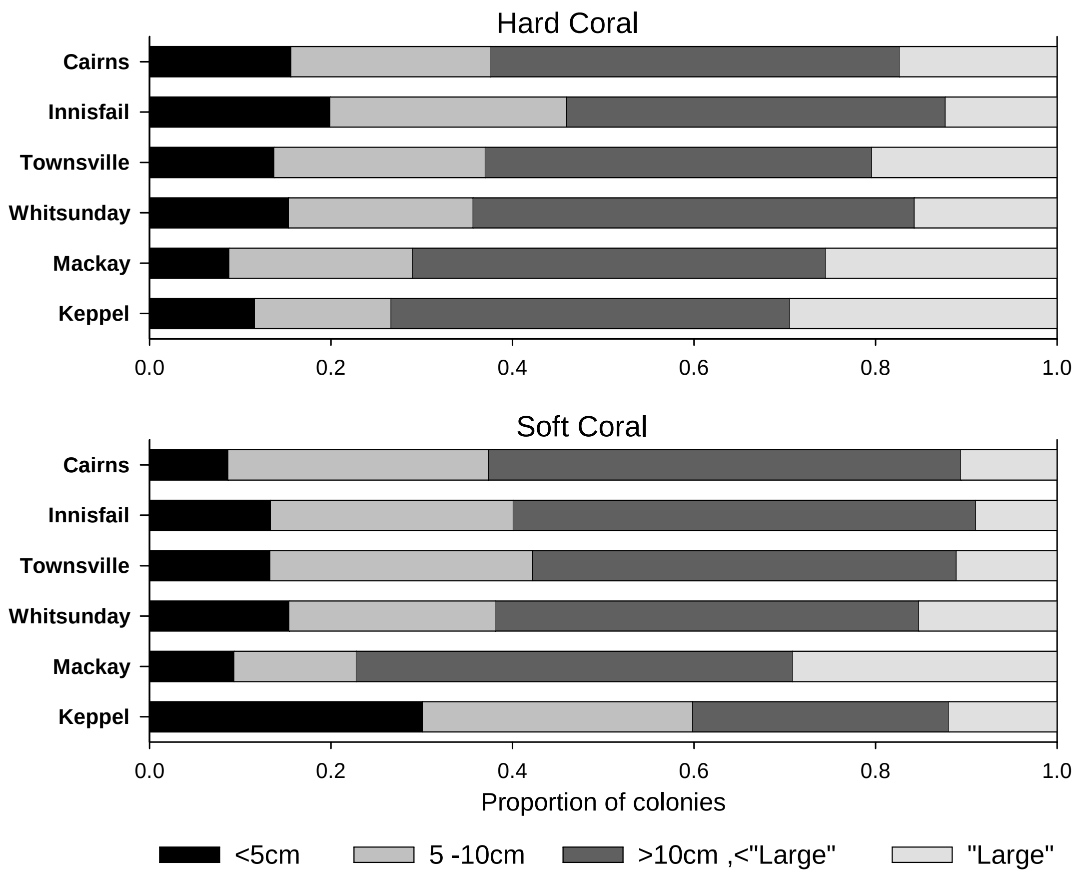

Figure 3.5. Overall proportions of hard and soft coral colonies in each size class recorded on demography transects in each region.

There were also regional differences in the average proportion of large colonies among the soft corals (Appendix 1; see Appendix 3 for designation of a large colony of each genus). The soft coral communities in the Mackay region had the highest proportion of large colonies (29%) and this was significantly higher than the Innisfail region where only 9% of colonies were large (Figure 3.5). The high proportion of large colonies in the Mackay region is reflected in the low proportion of recruit-sized colonies there. The proportion of colonies <5 cm in diameter was significantly higher in the Keppel region (30%) than in either the Cairns or Mackay regions (9%). Considering all colonies ≤10 cm in diameter further highlighted differences in the size structure of the communities between the Mackay and Keppel regions, with 60% of colonies in this size range in the Mackay region being significantly higher than the 23% observed in the Keppel region (Figure 3.5; Appendix 1).

There were no significant differences in the proportions of either large or recruit-sized colonies between depths for either the hard coral or soft coral communities (Appendix 1).

Size distribution of colonies by genus

Differences in the size structure of colonies between depths and among regions were only estimated for a few hard coral or soft coral genera because most genera were too rare to allow a reasonable estimate of their size distribution. We limited analyses to those genera for which (1) at least ten colonies were observed at both depths at a location and (2) one or more locations in at least three regions met the first criterion. Eleven genera met these conditions (Appendix 2.2). There were regional differences in the average proportion of large *Acropora*, *Galaxea* and *Sinularia* colonies (Figure 3.6, Appendix 2.2). The proportion of large colonies of *Favia* and *Sarcophyton* differed between depths but this was inconsistent among regions for *Favia* (Figure 3.6, Appendix 2.2). There were differences in the proportion of small *Goniastrea* colonies among regions and in the proportion of small *Sinularia* and *Turbinaria* colonies between depths (Figure 3.7, Appendix 2.2).

Setting abundance criteria for inclusion in the analysis meant that only a small number of locations in each region were considered for most genera. The limited number of locations within regions made interpretation of regional differences difficult because differences in size structure may depend on just one or a few locations. For example, *Galaxea* (Figure 3.6) was the dominant genus at Pine Island in the Whitsunday region where the proportion of large colonies (67%) was very high. This cannot be generalised to a high proportion of large colonies of *Galaxea* in the Whitsunday region because no other locations in that region met the criteria for inclusion in the analysis. Similarly, the high proportion of recruit-sized *Goniastrea* colonies in the Innisfail region was heavily influenced by large numbers of small colonies at both the front and back-reef locations at one reef: Dunk Island. There was one exception: large colonies of corals in the genus *Acropora* were common on all the locations in the Keppel region that were included in the analysis (Figure 3.6).

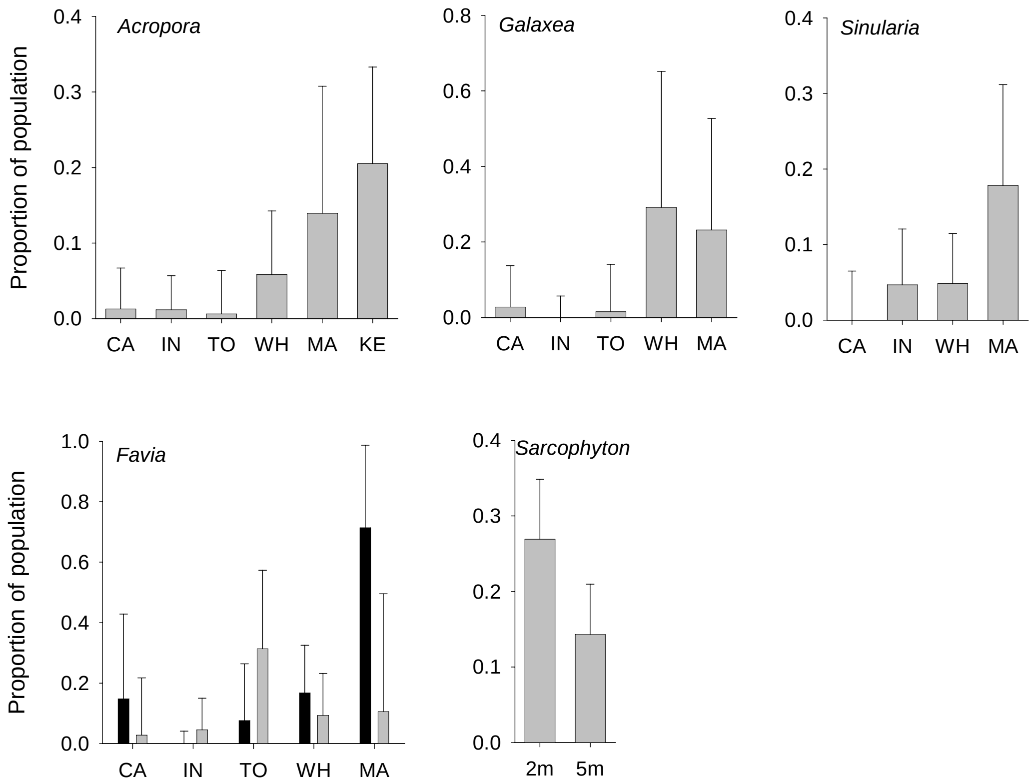

Figure 3.6. Proportion of large colonies of genera showing significant regional differences (*Acropora*, *Galaxea* and *Sinularia*), region by depth interactions (*Favia*) or depth differences (*Sarcophyton*) in colony size. Data are back-transformed values of arcsine-transformed proportions of the colonies per reef and depth (see Appendix 3).

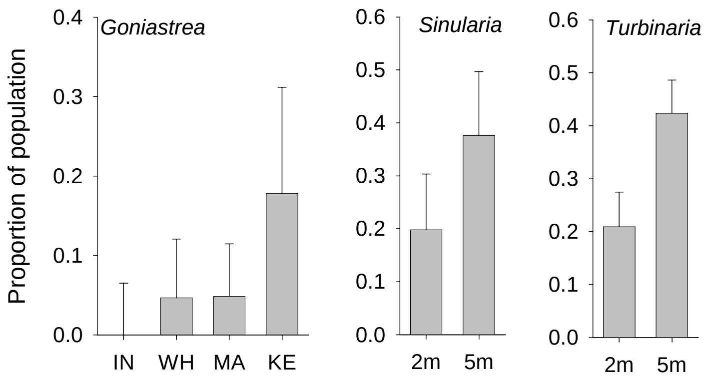

Figure 3.7. Proportion of colonies <10 cm in diameter of genera showing significant regional (*Goniastrea*), or depth differences (*Sinularia, Turbinaria*) in proportions of recruit-sized colonies, based on mixed model ANOVA. Data are back transformed from arcsine-transformed proportions

Variation in the density of recruit-sized coral colonies

The standardised density of hard coral recruits <5 cm in diameter varied among regions and there was some evidence of variation among depths (Figure 3.8a, Appendix 1). The difference among regions was similar when recruits up to 10 cm in diameter were included (Figure 3.8b, Appendix 1). The difference in density of recruits among depths was significant when <10 cm colonies were included. The highest mean density of recruits was recorded in the Innisfail region; this was significantly higher than the density in the Keppel region. The density of recruits at 5 m depth was higher than at 2 m (Figure 3.8a; Appendix 1).

The standardised density of soft coral colonies <5 cm in diameter also varied among regions (Figure 3.8c, Appendix 1). The density of small soft coral colonies was highest in the Whitsunday region and low in all other regions except for the Keppels. The density of colonies <10 cm in diameter did not differ significantly among regions and the density of either <5 cm or <10 cm size class colonies did not differ between depths (Figures 4.8c and d, Appendix 1).

Differences in density of recruits <10 cm in diameter were investigated for 31 hard coral genera and six soft coral genera (Appendix 2.3). The density of recruits of 11 hard coral genera and one soft coral genus differed between depths (Figure 3.9). Of these, only *Acropora* had a higher density of recruits at 2 m than 5 m (Figure 3.9). Depth distributions of three genera, *Echinophyllia*, *Pachyseris* and *Pavona,* showed regional inconsistencies (Appendix 2.3); in those regions where differences were obvious, the density at 5 m was always higher than at 2 m. The density of recruits of 16 out of 31 hard coral genera (52%) and three of seven soft coral genera differed between regions (Table 3.2, Appendix 2.3).

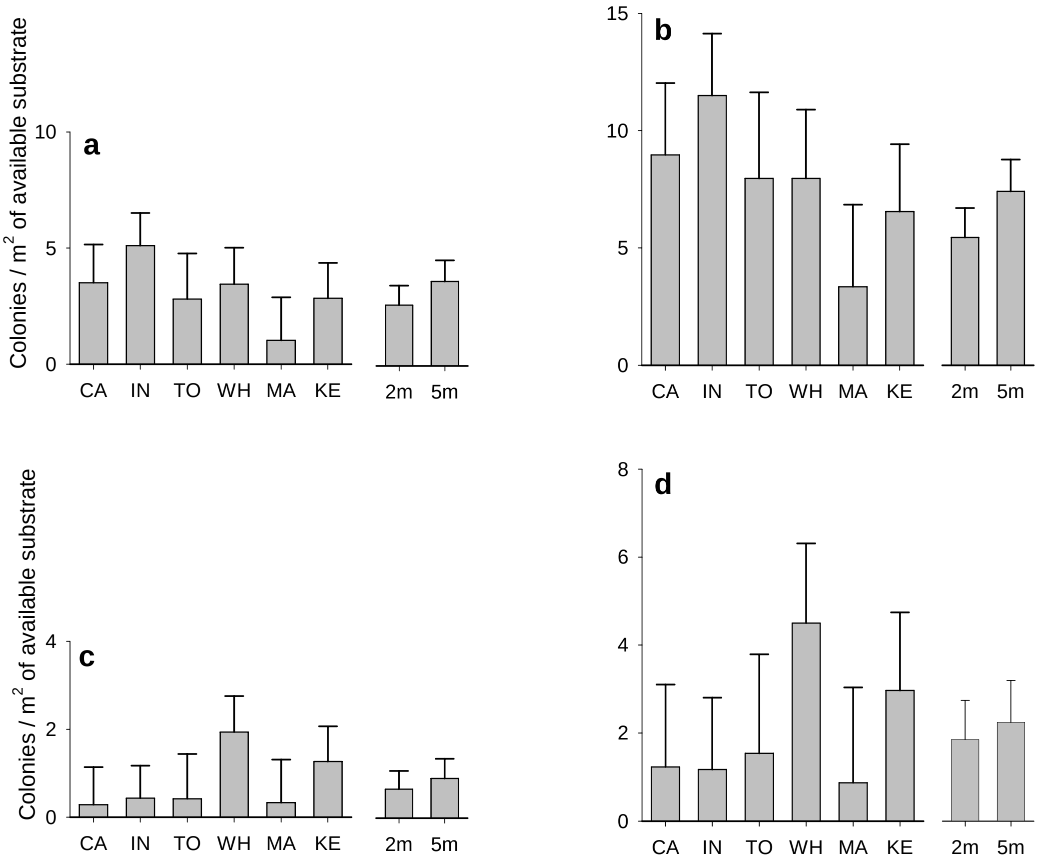

Figure 3.8. Density of small colonies of hard and soft corals in two size classes in each region and at the two survey depths. (a) Hard corals <5 cm diameter; (b) hard corals<10 cm diameter (c) soft coral colonies <5 cm diameter; (d) soft corals<10 cm diameter. Plots for each group have the same scale on the y-axes to allow comparison between recruits of different sizes.

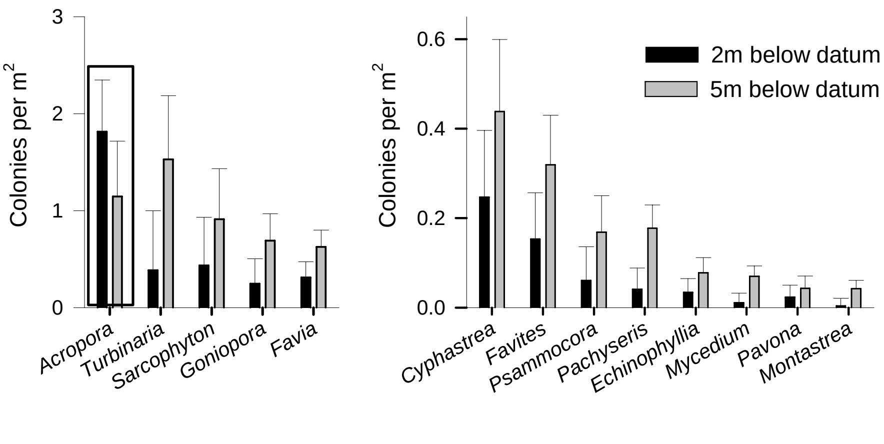

Figure 3.9. Average density of recruit-sized colonies per location at 2 m and 5 m depth. Genera are those showing significant differences in density among depths (P<0.05). Note the difference in direction of depth effect for *Acropora* compared to all other genera (in box).

Table 3.2. Summary of pair-wise comparisons for those genera for which the density of colonies <10 cm diameter differed among regions. A "**+**"indicates that the density of colonies was higher in that region than at least one other region; a "**–**"indicates the density of colonies was lower in that region than in at least one other region. Double symbols indicate *P*<0.05 while single symbols *P*<0.1. Error rates were adjusted for multiple pair-wise comparisons.

Hard Corals	**Region**					
Genus	CA	IN	TO	WH	MA	KE
Acropora	- -	- -			- -	++
Caulastrea	++	- -	- -	- -	- -	- -
Favia		++	++		-	- -
Favites		+				
Fungia	+				-	
Galaxea	++	++		-		- -
Hydnophora		++				- -
Leptastrea		+	-			-
Lobophyllia	- -	- -	- -	++		- -
Montipora	++			-		- -
Pachyseris			++			- -
Pectinia		- -		++	-	- -
Platygyra	- -	++	- -			
Pocillopora						
Podabacia		- -	- -	++	- -	- -
Porites		++			-	- -
Total -	3	5	5	3	7	12
Total +	4	7	2	3	0	1

Soft Corals	**Region**					
Genus	CA	IN	TO	WH	MA	KE
Sarcophyton	-	- -		++		
Sinularia	- -	- -	-	++	-	- -
Xenia	-	-	-	-	-	+
Total -	3	3	2	1	2	1
Total +	0	0	0	2	0	1

Significant depth by region interactions for the hard coral genera *Caulastrea* and *Pachyseris* suggest that regional differences were not consistent among depths. In both cases the interaction arose because these genera were abundant at only one depth in a single region and were generally rare or absent elsewhere. Only *Acropora* had a higher density of recruits in the Keppel region than in at least one other region: densities in the Keppels were higher than in the Cairns, Innisfail or Mackay regions. Density of recruits in the Mackay region was also conspicuously low: no genus had a significantly higher (P<0.05) density of recruits in the Mackay region than in least one other region. Conversely, the Innisfail region had the highest number of genera with recruit densities that were higher than in at least one other region (Table 3.2).

The Whitsunday region stands out for its relatively high density of recruit-sized soft corals of the genera *Sarcophyton* and *Sinularia* (Table 3.2).

Summary of univariate analyses

There is substantial regional variability in cover of hard coral, soft coral and macroalgae. For hard coral and macroalgae there are relatively constant differences among regions, however there was substantial variability at finer spatial scales as there was for soft corals. Hard coral cover and soft coral cover varied quite a lot between sites within locations (separated by just 100-200 m). By contrast cover of macroalgae did not vary so much among sites within locations, but did vary among locations within regions. Similarly the density of hard and soft coral colonies, both overall and for various size classes, was very variable among sites largely masking regional differences. The strongest regional effect was detected in species richness, though again finer scale variation was great. Such fine scale variation suggests that any processes influencing coral communities are operating at fine scales. Interestingly the density of hard coral recruits showed consistent differences among regions with relatively little finer scale variation. This discrepancy suggests that post recruitment processes (disturbances) had yet to substantially impact this section of the community at specific locations.

Salient regional differences

Keppel region had the highest cover of hard corals and highest proportion of large hard coral colonies (including the highest proportion of large *Acropora* colonies). This high cover was due the presence relatively few, very large colonies. Being the southern most region it was not surprising that the average species richness was substantially lower than in other regions.

The Mackay region had the lowest cover and density of hard coral colonies as well as the lowest density of hard coral and soft coral recruits. Recruits also comprised the lowest proportion colonies of all the regions. This region had highest proportion of large soft coral colonies and highest cover of macroalgae.

The Whitsunday region had the highest cover and density of soft coral colonies and also the highest density of soft coral recruits. Species richness of hard corals was highest in this region.

The Townsville region had relatively high coral cover and density of colonies but the lowest proportion of large *Acropora* colonies. *Acropora* colonies of recruit size were present in average densities.

The Innisfail region had the highest density of hard coral recruits, the highest proportion of hard coral recruits and the highest density of hard coral colonies. In contrast, large colonies were relatively rare within the region that had the lowest proportion of large colonies of both hard corals and soft corals. Cover of macroalgae was low, as was the overall density of soft coral colonies.

The Cairns region's coral communities were not exceptional compared to the other regions. The cover of macroalgae was low.

Several measures of the community differed consistently between shallow and deep sites. Species richness and density of hard coral recruits both tended to increase with depth and cover of macroalgae was generally lower in deeper sites. There were marked differences in the abundance of colonies between depths that were masked by pooling over all taxa. Most genera were more abundant at 5 m than at 2 m.

3.3. Analysis of Community Structure

Locations were classified into six broad community types based on the percent cover of 65 hard coral genera (Figure 3.10). The most divergent community types were dominated by corals in the genera *Acropora* and *Montipora* (i.e. Family Acroporidae) or by *Porites* compared with communities at locations that had low cover of these genera (groups 4, 5 and 6 vs. groups 1, 2 and 3, in Figure 3.10, Table 3.3). Within the former group of locations, communities in groups 4 and 5 were characterised by high proportions of *Acropora* spp; the groups differed primarily in that group 5 had relatively high cover of the branching growth form of *Acropora* whereas group 4 had a more mixed representation of forms and included a high proportion of *Montipora*. The locations dominated by branching *Acropora* were in the

Keppel Island region, with the single exception of the shallow communities on the back-reef at Dunk Island (Figure 3.10). Communities dominated by branching *Acropora* had the highest average coral cover, highest proportion of large colonies and lowest species richness of the six community types (Figure 3.11). The mixed *Acropora*- and *Montipora*-dominated community type was found in several regions, though these genera were relatively species-rich. Being based on genera, this group almost certainly included communities that would be distinct in terms of the constituent species.

Table 3.3. Average percentage of the community made up of each genus in each cluster group identified in the dendrogram in Figure 3.10. Only those genera with a maximum average proportion in any cluster group of >2% are included. Only values greater than 1% in any cluster group are reported for clarity of presentation. Shading of cells relate to the value of that cell compared to the maximum average proportion observed in any cluster group for that genus as follows; Black >75% of maximum, Dark Grey 50-75% of maximum, Light Grey 25-50% of the maximum, white <25% of the maximum.

Genus	Cluster Group					
	1	2	3	4	5	6
Galaxea	21	1.1	1.6			1
Pachyseris	19	8.4	3.4	5		1.9
Pectinia	7.8	1.4				1.9
Merulina	3.6	1.9	2			
Lobophyllia	3.5		1.1			1.4
Podabacia	2.7					
Mycedium	2.6		1.4			
Goniopora	5	52	4.8	2.6		3.2
Echinopora	2.2	5.3	1.7			1.1
Leptoseris		3.3				
Montipora	6.6	2.7	17		3.5	21
Turbinaria		6.1	13		1.5	3.7
Psammocora			4.1			
Cyphastrea			4			1.6
Goniastrea			3.8			
Favites	1.5		2.7			
Hydnophora	1.5		2.6			
Favia	1		2.6			
Alveopora			2.4			
Porites sub-massive				28		
Porites branching		1.8		18		
Porites massive		5.7	4.2	17		1.9
Heliopora				7.3		
Caulastrea				2.9		
Porites encrusting			1.7	2.8		
Acropora branching		1.7	5.5	1.5	67	20
Acropora tabulate	1.9	1	3.7	2.3	17	19
Acropora other	7.7		5.1		6.8	11

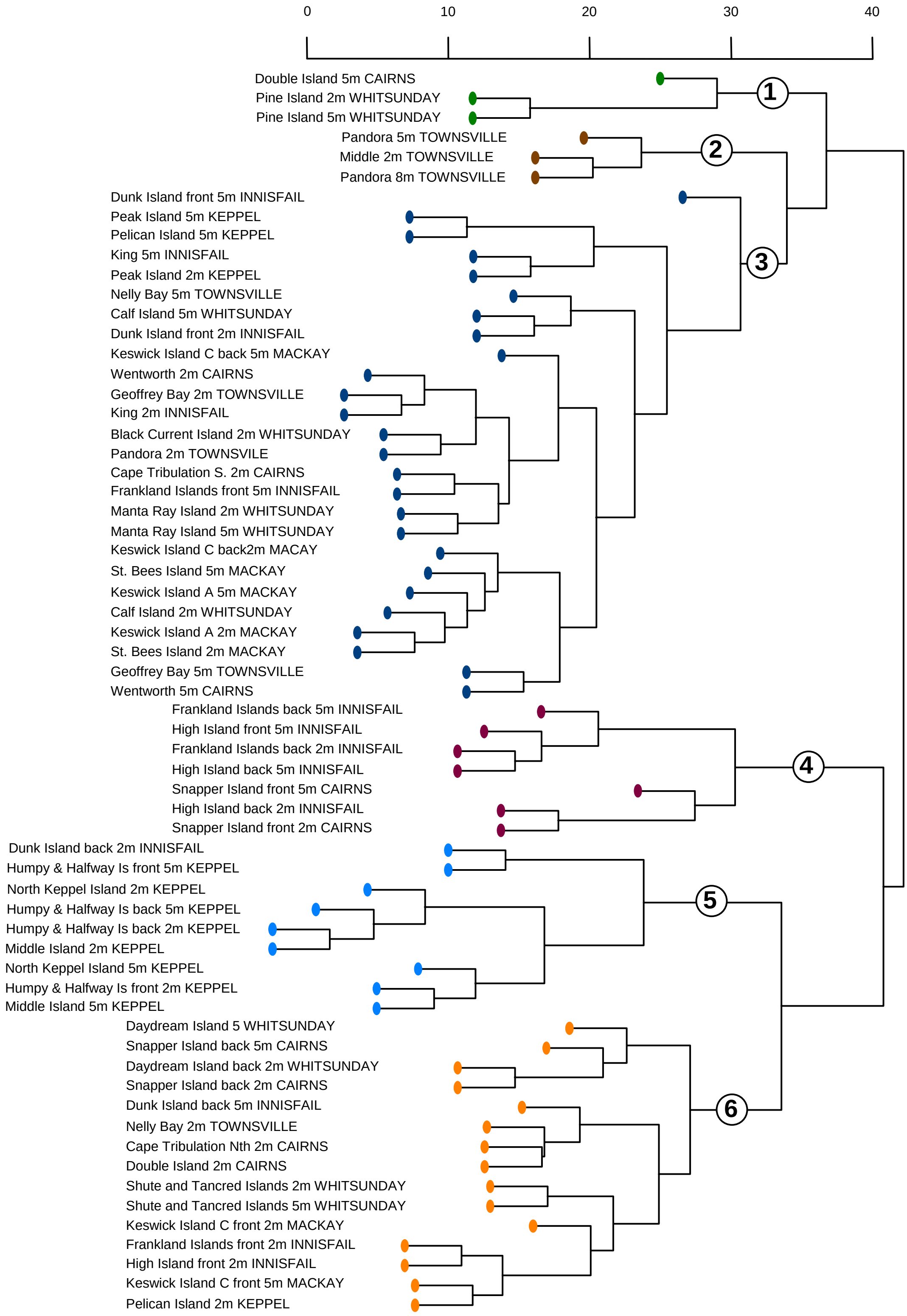

Figure 3.10. Dendrogram of community composition based on genera, using percent cover estimates from demography transects (square root transformed) and the Manhattan metric. The optimal number of cluster groups was determined by minimising group silhouettes (Kaufman, L. and Rousseeuw, P. J., 1990). Numbering of cluster groups is arbitrary and included to allow ease of reference in the document.

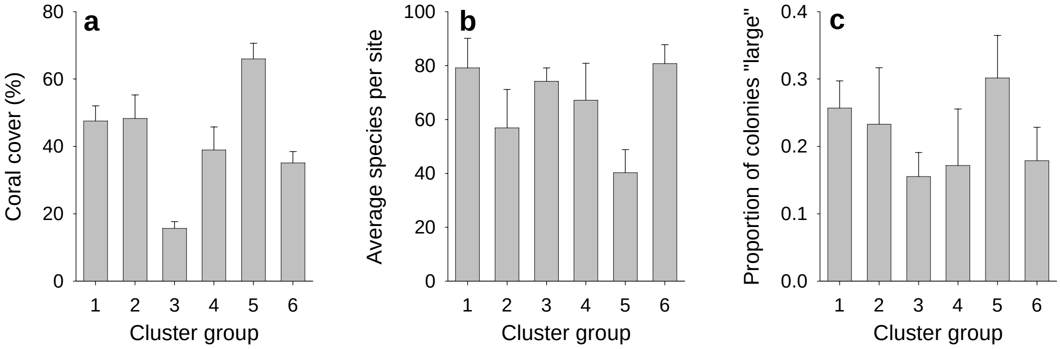

Figure 3.11. Mean coral community summary statistics for cluster groups, (a) percent cover of hard coral, (b) species richness and (c) the proportion of colonies that were in the large size category for their genus. Errors are 95% confidence intervals.

Communities dominated by *Porites* spp had a more restricted distribution, occurring at High Island, in the back-reef zones of the Frankland Islands in the Innisfail region, and in the southern area of Snapper Island in the Cairns region. Among the communities that had low proportional cover of *Acropora*, *Montipora* or *Porites*, group 1 was dominated by *Galaxea* and/or *Pachyseris* and group 2 by *Goniopora* (Figure 3.10; Table 3.3). Both of these community types were relatively rare, being represented on three reef-depth combinations each (out of the 63 that were surveyed). Communities in groups 1 and 2 typically had high coral cover (Figure 3.11); in contrast, community type 3 represented locations with low total coral cover ($\bar{X}$ = 16%) that were not dominated by any particular taxa (Figure 3.10; Table 3.3). These mixed, low cover communities were widespread; they had the lowest proportion of large colonies of any group (Figure 3.11c) and may represent other community types that had been degraded or were in the process of recovery.

Association between benthic community structure and environmental and spatial variables

We did not find any interactions among environmental variables that were associated with differences in community structure so environmental variables are therefore discussed independently (Table 3.4).

Table 3.4. F-ratios and *P*-values from multivariate permutation tests of association between the coral community structure and spatial and environmental variables estimated using redundancy analysis. df, degrees of freedom. The proportion of variance in community composition explained by each variable was estimated from the redundancy analysis.

Environmental variable	F	df	*P*-value	Proportion of community variance explained (%)
Region	2.29	5, 27	<0.005	29.8
Sediment composition	2.59	3, 29	0.005	21.1
Adjacent depth	2.07	1, 31	0.037	6.3
Ecosystem Risk Index (ERI)	1.78	1, 31	0.076	5.4
Exposure	1.20	3, 29	0.120	11
Fetch	0.83	1, 31	0.530	2.6
Distance to shore	0.76	1, 31	0.650	2.4
Depth	3.11	1, 28	<0.005	2.3

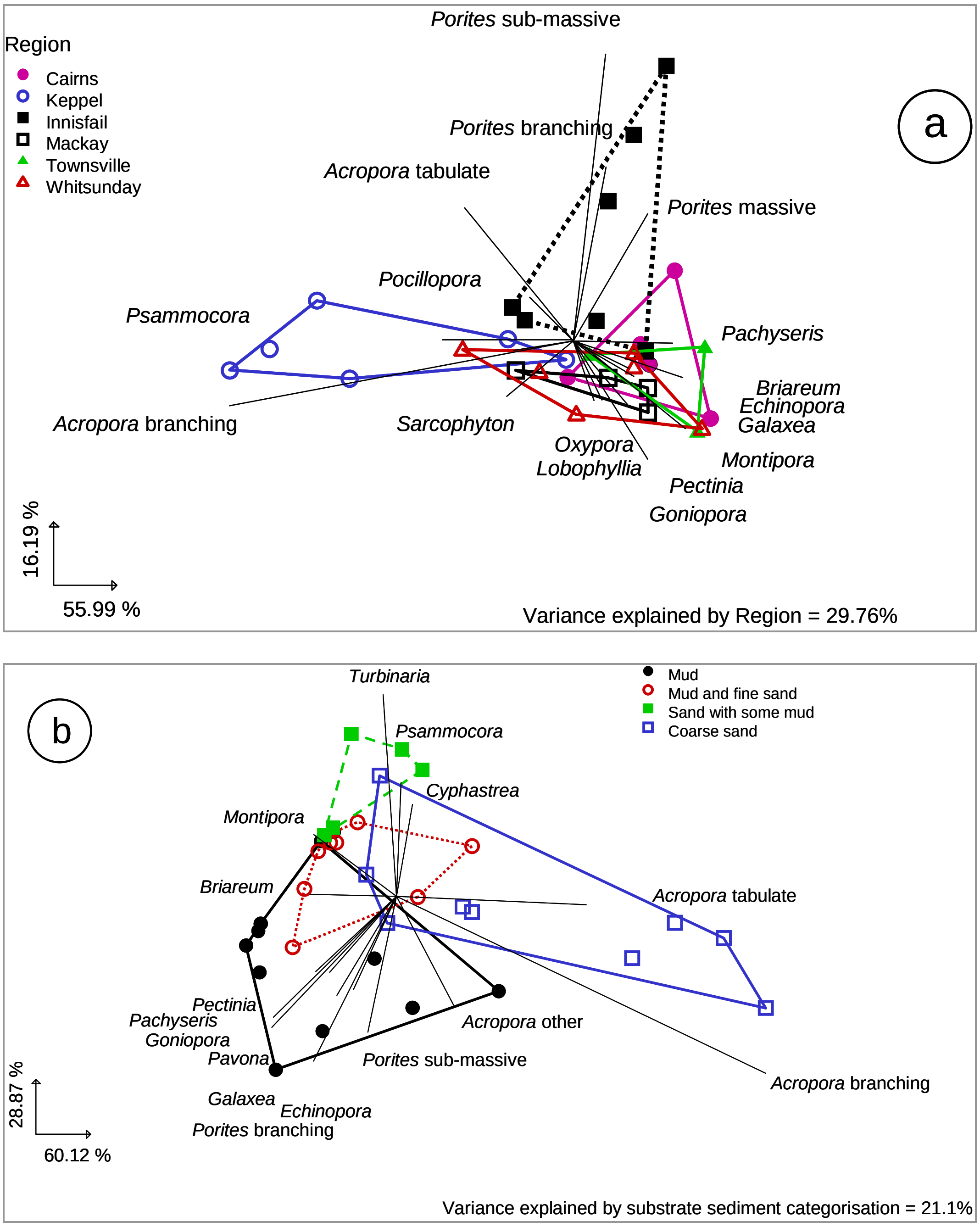

Figure 3.12. Redundancy analysis biplots for categorical environmental variables for which there were significant differences in community composition, (a) differences in the coral community among regions and (b) differences in the coral community associated with sediment composition. Vectors for the 15% of taxa that contributed most to variation among categories are shown.

Regional differences in community structure accounted for almost 30% of the total multivariate variation among genera between locations (Table 3.4). Communities in the Keppel region generally had higher cover of branching *Acropora* compared with the other regions. The Innisfail region was also distinct from the other regions in having higher cover of *Porites*. There was high overlap in community types in the other regions (Figure 3.12a).

Differences in the benthic community also covaried with sediment composition (Table 3.4). The pattern was strongly influenced by four locations from the Keppel region that were dominated by branching *Acropora* spp. and were distinct in having sandy sediments. There was a secondary gradient associated with the mud content of the substrate, ranging from predominantly fine mud though to a mud sand mix. There were also a number of genera with higher relative abundance in muddier settings, e.g. those in the lower left of Figure 3.12b.

Both depth of adjacent waters and estimated risk of exposure to runoff (ERI) showed some evidence of association with coral community composition ($p<0.1$ in Table 3.4). Branching *Acropora* spp were relatively more abundant where ERI was low, but this was primarily due to communities in the Keppel Island group that were dominated by *Acropora* spp. and where ERI was relatively low. By contrast the genus *Porites* was relatively more abundant in locations with high ERI values, though again this resulted from just a few locations (High Island and the back-reefs of the Frankland Island group). However, these same *Porites*-dominated reefs were also surrounded by deeper water than most locations in this study, and contributed to the association between coral communities and the depth of adjacent waters.

There were also significant differences in coral communities between the shallow and deep sites (Table 3.4). This reflects the differences in abundance of colonies of a number of genera at the two depths (Figure 3.4).

In summary we identified six community types on near-shore reefs. Three of these (groups 2, 4 and 5 in Table 3.3) include a high proportion of just one or a few genera, in the case of group 5 in Table 3.3, a single growth form of a single genus (branching *Acropora*). Two community types (groups 1 and 2) were quite rare, each being found at only two locations, and were dominated by a very few genera (see groups 1 and 2 of Figure 3.10 and Table 3.3) while community types represented by groups 3 and 6 were more wide spread and included a wider range of genera. Group 3 was the most common community type identified. This mixed community typically had low cover and the lowest proportion of large colonies (Figure 3.11).

Unlike the mixed community, communities dominated by both branching *Acropora* and *Porites* (groups 4 and 5) showed some regional limits to their distribution. Communities dominated by branching *Acropora* were largely restricted to the Keppel region while those dominated by *Porites* were restricted to the Innisfail and Cairns regions. The distributions of these two community types were the basis of the regional differences in community composition. The strong association between branching *Acropora* communities and sandy substrates in the Keppel region contributed substantially to the association between community composition and sediment composition. There were also a number of other genera that were relatively abundant in locations with muddy substrates: communities dominated by *Porites* spp were all situated close to river mouths and were also surrounded by relatively deep water. This contributed substantially to the observed associations between these variables and community composition.

3.4. Species Distributions

The surveys in 2004 recorded 315 species from 65 genera and 14 families of Sceleractian hard corals (Appendix 5). Few species were ubiquitous in the near-shore zone. Around 30% of species occurred in less than 10% of the survey locations compared to less than 2% that occurred in more than 90% of locations (Figure 3.13). This predominance of rare, or at least patchily distributed, species resulted in great variation in species lists between sites and depths in the same location. On average 124 species (max 171, min 53) were recorded from all sites and depths at a location. However, on average 66% of the species recorded at a given location were not found at both 2 m and 5 m depths, while 62% where not found at both sites at a given depth.

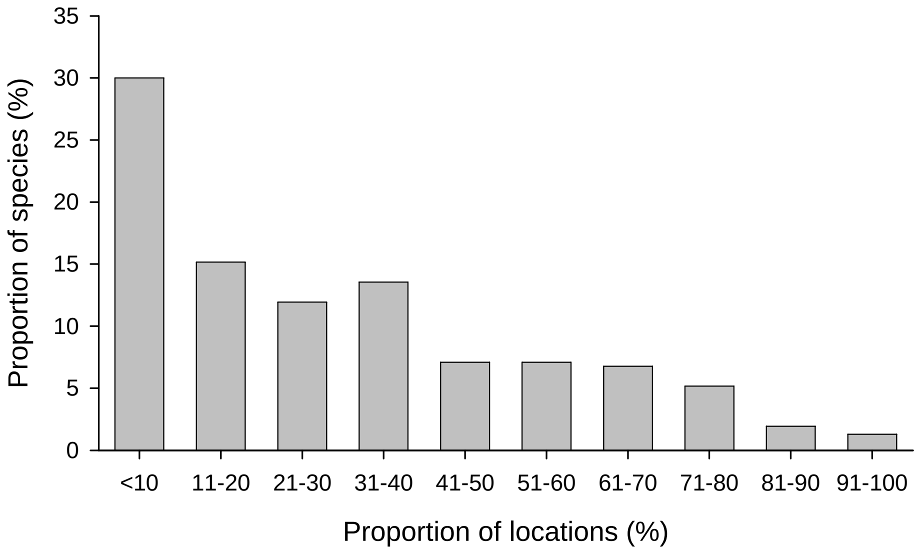

Figure 3.13. Proportional representation of 233 coral species among 33 locations, based on surveys in 2004. Thirty percent of species were only recorded in 10% or less of the survey locations.

The average number of species per location was underestimated, as species that could only be identified to genus were not included. Such cases were most common in the genera *Acropora*, *Montipora*, *Goniopora* and massive forms of *Porites*.

Changes in species distributions over time

One possible result of changes in conditions in the near-shore waters of the GBR lagoon would be a shift in the species composition of coral communities as species that were adapted to the prior conditions were replaced by more generalist species or those adapted to the changed conditions. Substantial changes could be revealed in comparisons with past lists of species from near-shore locations

There are lists of coral species from rapid assessments at a number of sites made between 1994 and 1997 (DeVantier *et al.* 2006). Seventeen of these sites could be matched by location and depth with sites surveyed in 2004. The rapid assessments recorded a maximum of 116 species, a minimum of 17 species and a mean of 42 per site from a species pool of 176. The comparable sites in 2004 yielded a species pool of 233 species, a minimum of 18, a maximum of 112 and an average of 72 species per site. Higher species richness in 2004 is most likely a product of the survey technique as the 2004 surveys involved up to twice the search intensity and observers were not required to perform as many tasks at the same time as in the rapid assessments.

Between 10% and 62% (average 43%) of the species recorded during the mid-1990s surveys were not observed on similar sections of reef in 2004. Little can be concluded from this comparison other than that these results are within the range of differences among sites observed in 2004 and so could reflect minor differences in site location rather than changes in species composition. The greater sampling effort in 2004 could be expected to lead to more species being recorded at sites, but species that were recorded in more of the sites in the earlier surveys could indicate community changes. Species that were recorded on at least three more of the 17 comparable sites in the earlier survey than in 2004 are listed in Table 3.5. While it is possible that all these species decreased in abundance in the interval, some species may have been confused with similar species (Table 3.5).

Table 3.5. Species that were present in three or more of the 17 comparable sites in 1994-97 and 2004. The number of sites in which a species was observed in one survey but not the other is given in the second and third columns. Possible reasons for observed differences are given in the final column.

Species	2004	1994-97	Possible reason for difference
Acropora aculeus	0	10	Confusion with *A. latistella*
Acropora micropthalma	1	6	Reduction or not well distinguished in 2004
Acropora vaughani	2	6	Reduction?
Montipora hispida	0	3	Genus *Montipora* not consistently identified to species level in 2004 surveys, though some species are prone to coral bleaching.
Montipora informis	2	5	
Montipora tuberculosa	0	8	
Montipora undata	0	3	
Astreopora gracilis	0	5	Confusion with A. listeri or A. moretonensis
Herpolitha limax	7	10	No distinction from *H. weberi* in 1994-97
Hydnophora exesa	1	4	Confusion with other *Hydnophora* species
Lobophyllia corymbosa	2	5	No distinction from *L. dentatus* in 1994-97
Porites nigrescens	2	5	Reduction?
Goniopora tenuidens	0	5	Lack of species level identification for many colonies of this genus in 2004
Stylophora pistillata	2	5	Reduction?
Symphyllia recta	0	3	Reduction?

Data collected on reefs in the Cape Tribulation area in 1985 (Veron 1986) were compared with surveys of similar sites in 2004. The data from 1985 were aggregated over an unspecified number of sites but Veron (1986) gave an indication of how common each species was. Of the 141 species recorded in 1985, 44 were not among the 143 recorded in 2004. Thirty-six of these were either rare or uncommon in 1985, so small changes in location or depth of surveys may account for their omission. The greater range of depths surveyed in 1985 may well account for the differences in abundance of the remaining eight species that were recorded as “common” or “very common” in 1985 (Table 3.6). Once again our inability to identify some species of *Montipora* in 2004 may also have resulted in differences, as the abundance of this genus has not changed markedly on these reefs (Ayling and Ayling 2005). The absence of *Seriatopora hystrix* from the surveys in 2004 may indicate a reduction in the occurrence of the species on the Cape Tribulation reefs.

Table 3.6. Species recorded as "common" on Cape Tribulation coastal fringing reefs by Veron in 1985 but absent from the four sites surveyed in 2004.

Species	1985	Explanation of absence in 2004
Cyphastrea micropthalma	common	Possible confusion with *C. chalcidicum*
Fungia repanda	common	Possible confusion with *F. concinna*
Goniastrea retiformis	common	Range generally shallower than 2004 transects
Leptastrea purpurea	common	Possible confusion with *L. transversa*
Montipora hispida	very common	Lack of resolution among *Montipora sp.*
Montipora nodosa	common	Lack of resolution among *Montipora sp.*
Polyphyllia talpina	common	Range generally deeper than 2004 transects
Seriatopora histrix	common	Likely reduced abundance

3.5. Review of Long-term Data Sets from Near-shore Reefs

In assessing the status of near-shore reefs, the 2004 surveys need to be considered in context of the existing knowledge of the dynamics of near-shore reefs. An extensive list of sources of information relating to the status of coral communities on near-shore reefs of the GBR in the past is given in Appendix 6. There are several studies involving repeated surveys over time that provide historical comparisons (Table 3.7). Changes in hard coral cover through time (Figure 3.14-3.16) highlight the frequency of disturbance events: substantial reductions in coral cover that can be associated with specific disturbances were recorded at least once on almost all near-shore reefs that were surveyed. Coral bleaching, floods, cyclones or crown-of-thorns starfish (COTS) have all caused substantial reductions in coral cover as summarised below.

<u>Bleaching</u>: This was the most frequent source of disturbance to near-shore coral communities. Of the 31 reefs monitored 29 had declines in coral cover that were attributed to elevated sea surface temperatures in summers of either the 1998 or 2002. Only three reefs were monitored over the 1987 summer and three different reefs were monitored over the summer of 1993, but reductions in coral cover that were attributed to bleaching occurred on all three reefs in each period (Ayling and Ayling 2005). The impacts of these bleaching events varied widely among reefs ranging down from a reduction in cover of 93% at Cattle Bay, Orpheus Island in 1998 down to a loss of just 1.3% of the coral cover at Nelly Bay, Magnetic Island also in 1998. Lesser reductions or a lack of increase during bleaching years were not included in these figures. Averaging bleaching disturbances over all reefs and years (Table 3.8) shows that reefs have lost at least 5% of their coral cover every 5-6 years with drastic reductions (>40% of cover lost) approximately every two decades.

<u>Cyclones</u>: Impacts from cyclones are the second most frequent disturbance to near-shore communities. Reductions of greater than 5% of the coral cover occurred 16 times over all reefs and years surveyed, this equates on average to once every 14-15 years. The most severe disturbance observed o reefs surveyed occurred on the northern sites at Snapper Island where cyclone Rona reduced coral cover by 74% (from 66% to 17% absolute cover).

<u>Crown-of-thorns starfish</u>: Predation of corals by COTS was observed on 9 of the 31 reefs surveyed with no reef south of Townsville impacted. The most severe disturbance was recorded at Fitzroy Island where cover was reduced by 79% (31.9% to 6.8% cover of the substrate). Other reefs at which COTS caused marked reductions in coral cover were Green Island where 57% of the cover was removed over three years (1996-1999), Eastern reefs of

the Frankland Island group (54% reduction in cover) and Daintree fringing reefs south of Cape Tribulation (45% reduction in cover).

Floods: Direct impacts of flooding were the least common cause of reduction in coral cover recorded on near-shore reefs. Only sites at Snapper Island had reductions in coral cover attributed to flooding. In 1996 a flood of the Daintree River reduced coral cover from 88% to just 12%. The impact of floods to near-shore reefs in this data set is likely to be under-represented as the majority of sites are at least 2m below datum which is deeper than the typical penetration of low salinity in flood plumes (Devlin *et al.* 2001). Shallower areas of reef than those monitored would be exposed more frequently.

Table 3.7. Summary of long-term studies with repeated surveys of near-shore reefs on the GBR.

Organisation	Location	Method	Temporal replication	Reference
Sea Research	Daintree mainland fringing reefs	3 locations each with 4 sites of 5x20 m fixed Line Intercept transects	15 visits between 1985-2004	Ayling A.M and Ayling A.L (2005)
	Snapper Island	2 habitats each with 3 sites of 5x20 m fixed Line Intercept transects	10 visits 1994-2004. Additional sample from 1988 for Northern reef	
	Frankland Island Group	2 habitats each with 3 sites of 5x20 m fixed Line Intercept transects	8 visits 1998-2005. Additional sample from 1995 for Western reef.	
	Magnetic Island	4 bays with a variable number of sites each 4x20 m Line intercept or video transects)	15 visits 1989-2005	
AIMS	Decapolis	3 sites each with 5x50 m video transects	Nominally 13 visits between 1992/3 and 2005	Sweatman *et al.* (2005)
	Low Isles			
	Fitzroy Island			
	Pandora			
	Havannah Is			
	Middle Reef			
	Pandora	4 habitats with 10-13x1 m stereo photo belt transects at each	7 visits between 1981 and 2005	Not yet reported (manuscript in prep.)
QDEH /AIMS	Pelorus Is	5 x 50 m fixed video transects	8-10 visits between 1994/7 and 2005	Thompson and Malcolm (1999)
	Orpheus Is (Cattle Bay)			
	Orpheus Is (NE Bay)			
	Orpheus Is (Yanks Jetty)			
	Acheron Is			
	Herald Is			
QPWS	North Keppel Is.	5x50 m fixed video transects	6-7 visits between 1993/96 and 2002	Not yet reported
	Middle Is.			
	Halfway Is.			

Combining all disturbance types (Table 3.8) highlights the frequency of disturbance to near-shore reefs. Impacts that remove at least 5% of the coral cover have occurred on average once every 3-4 years with severe impacts (removing at least 40% of the coral cover) occurring approximately once every 11 years. Not included in these figures are instances of relatively minor disturbance that act only to retard increases in cover. A high proportion of disturbances occurred in the mid- to late 1990s. This, followed by bleaching in 2002, resulted in low coral cover in the period 2000-2002. With the exception of a flood that affected the southern reef of Snapper Island in 2004, reefs have been relatively disturbance-free since 2002, allowing coral cover to increase.

Table 3.8. Observed incidence of disturbance events of varying intensity from long-term studies of near-shore reefs. Frequency of disturbance is calculated as the total number of annual observations (235, summed over all reefs monitored) divided by the incidence of disturbance, resulting in a particular proportional reduction in coral cover (Reduction in coral cover column).

Reduction in cover	Incidence of disturbance					Frequency of disturbance (yrs)	
	Bleaching	Cyclone	COTS	Flood	Combined	Bleaching	Combined
>5%	42	16	12	3	73	5.6	3.2
>10%	31	14	8	3	56	7.6	4.2
>20%	21	8	7	2	38	11.2	6.2
>40%	11	4	4	1	20	21.4	11.7

Disturbance events may have considerable effects on quite small areas: the disparate disturbance histories for locations on the northern and southern sides of Snapper Island are a good example (Figure 3.15). Here, flooding of the Daintree River in 1996 and 2004 killed a high proportion of the coral community on the southern side of the island, especially corals in the family Acroporidae,. Northern reefs of Snapper Is were only marginally affected but these were severely damaged by Cyclone Rona in 1999 (Ayling and Ayling 2005). Even reductions in coral cover due to broad-scale disturbances such as the severe coral bleaching in early 1998 may vary markedly between nearby reefs.

In addition to varying spatially, disturbance can also vary with depth. When of the Fitzroy River flooded in January 1991, the effects of freshwater were limited to the upper few metres of the slope in the Keppel Islands (van Woesik *et al.* 1995). Similarly, when the Daintree River inundated sites on the southern side of Snapper Island, communities that were more than 3 m below low tide were largely unscathed, while corals at less than 3 m depth suffered almost total mortality (Ayling and Ayling, 1997).

Coral taxa also vary in their susceptibility to different types of disturbance with the Acroporidae and Pocilloporidae being most generally susceptible (Figure 3.17b). On average, changes in the cover of Acroporidae account for almost three quarters of the observed change in hard coral cover (Figure 3.17a). Cover of these taxa declined by >90% of its maximum value in over half the locations that were surveyed in the long-term studies. This compares with the median reduction of <60% for the least affected family, Poritidae. This means that disturbances may shift community composition towards less susceptible taxa in the short-term, though there is little evidence that these shifts are maintained in the longer term (Ayling and Ayling 2005).

Rates of recovery depend on the nature of the disturbance. Regrowth from damaged portions of existing colonies (remnants or fragments typical of cyclone damage) can be rapid;

it will be more protracted when whole-colony mortality occurs and recovery is reliant on the settlement and subsequent survival and growth of new individuals (Ayling and Ayling 2005). The long periods with little or no recovery following severe bleaching of sites in the Palm and Rattlesnake island groups in 1998 and an unknown disturbance 1995-1997 (Figure 3.16) are examples of recovery that was reliant on recruitment. Investigating family level cover estimates shows that cover of the family Acroporidae was reduced to zero in six of the seven shallow sites on reefs in Halifax Bay surveyed by QDEH/AIMS. The near complete removal of the *Acropora* community from shallow areas, which was the local brood stock, reduced the supply of potential recruits in subsequent years. In addition, coral recruits younger than two years old are unlikely to be recorded on video due to their very small size and often cryptic nature.

The intensity and frequency of combined disturbances to near-shore coral communities must be considered when considering the status of any observed community. This is especially true of populations of the more vulnerable taxa. It is clear that reefs should be expected to suffer occasional reductions in cover so any designation of status should consider not only the current community but also the capacity for recovery in periods free from disturbance.

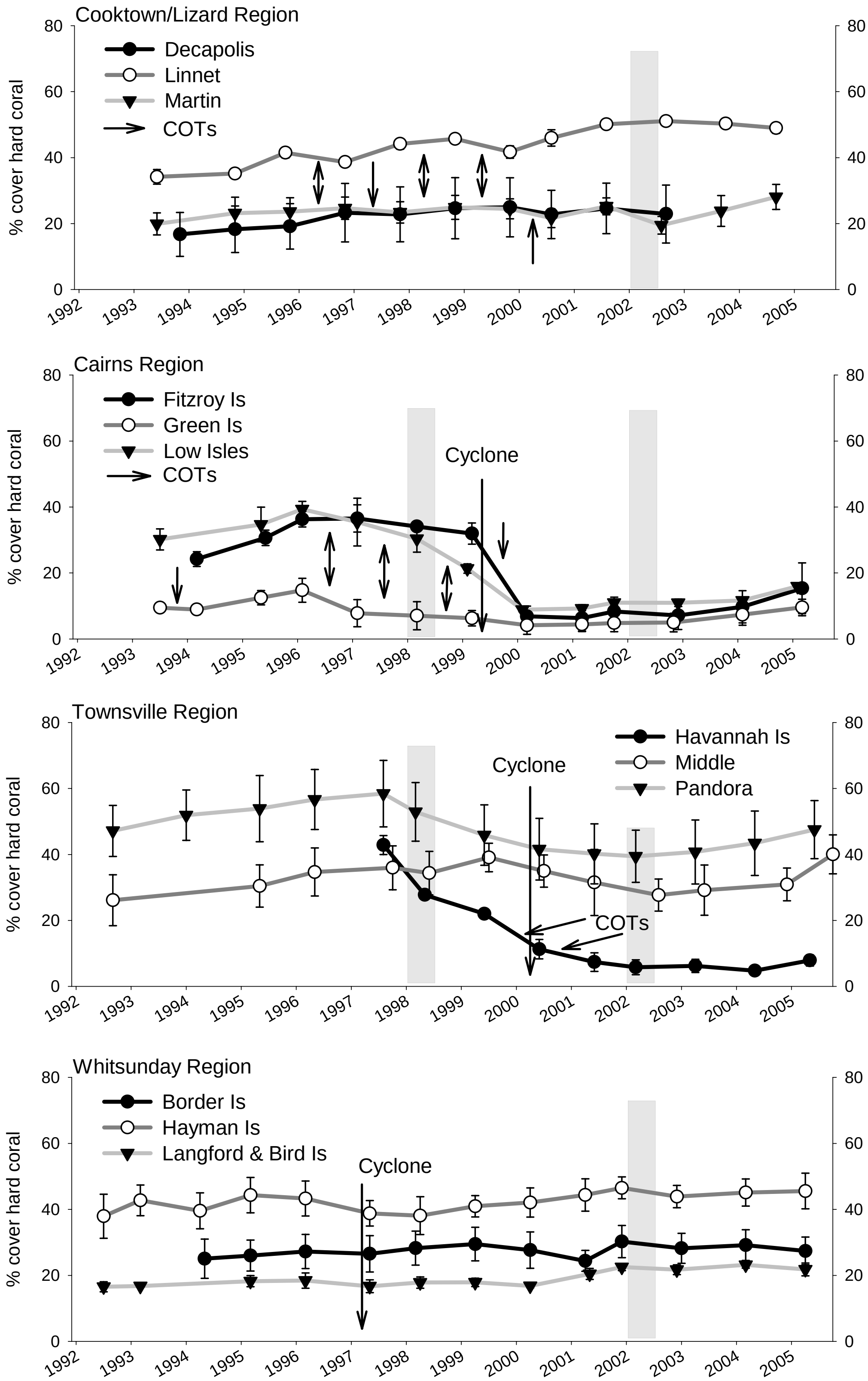

Figure 3.14. Changes in cover of hard coral on near-shore sites monitored by AIMS. Plots show mean percent cover and standard errors based on video transects from three sites at each reef are shown. Known impacts are indicated by either arrows (crown-of-thorns starfish and cyclones) or shaded bars for coral bleaching years.

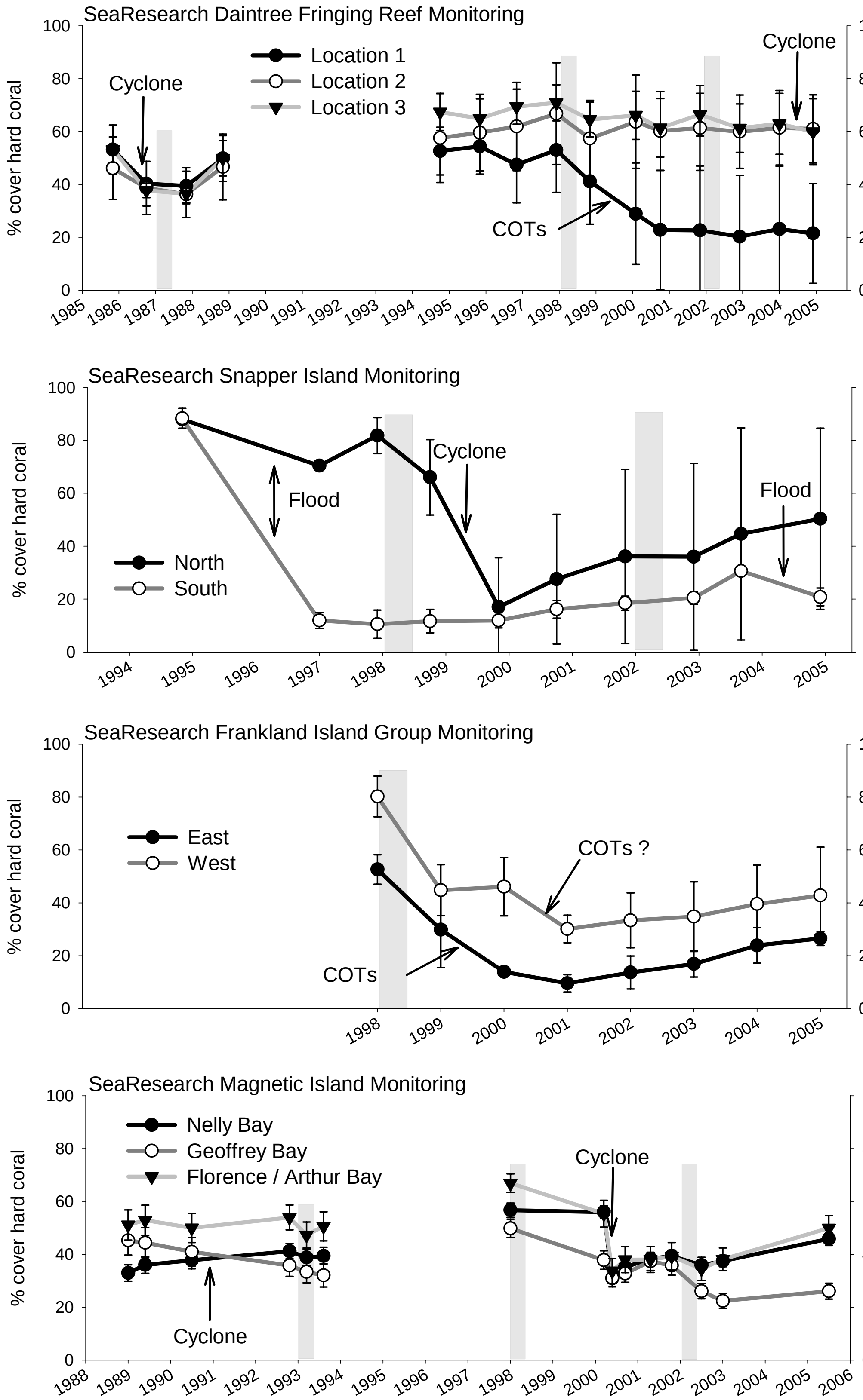

Figure 3.15. Changes in cover of hard coral on near-shore sites monitored by Sea Research. Mean percent cover and standard errors are shown. Known impacts are indicated by either arrows (crown-of-thorns starfish, floods and cyclones) or shaded bars for coral bleaching.

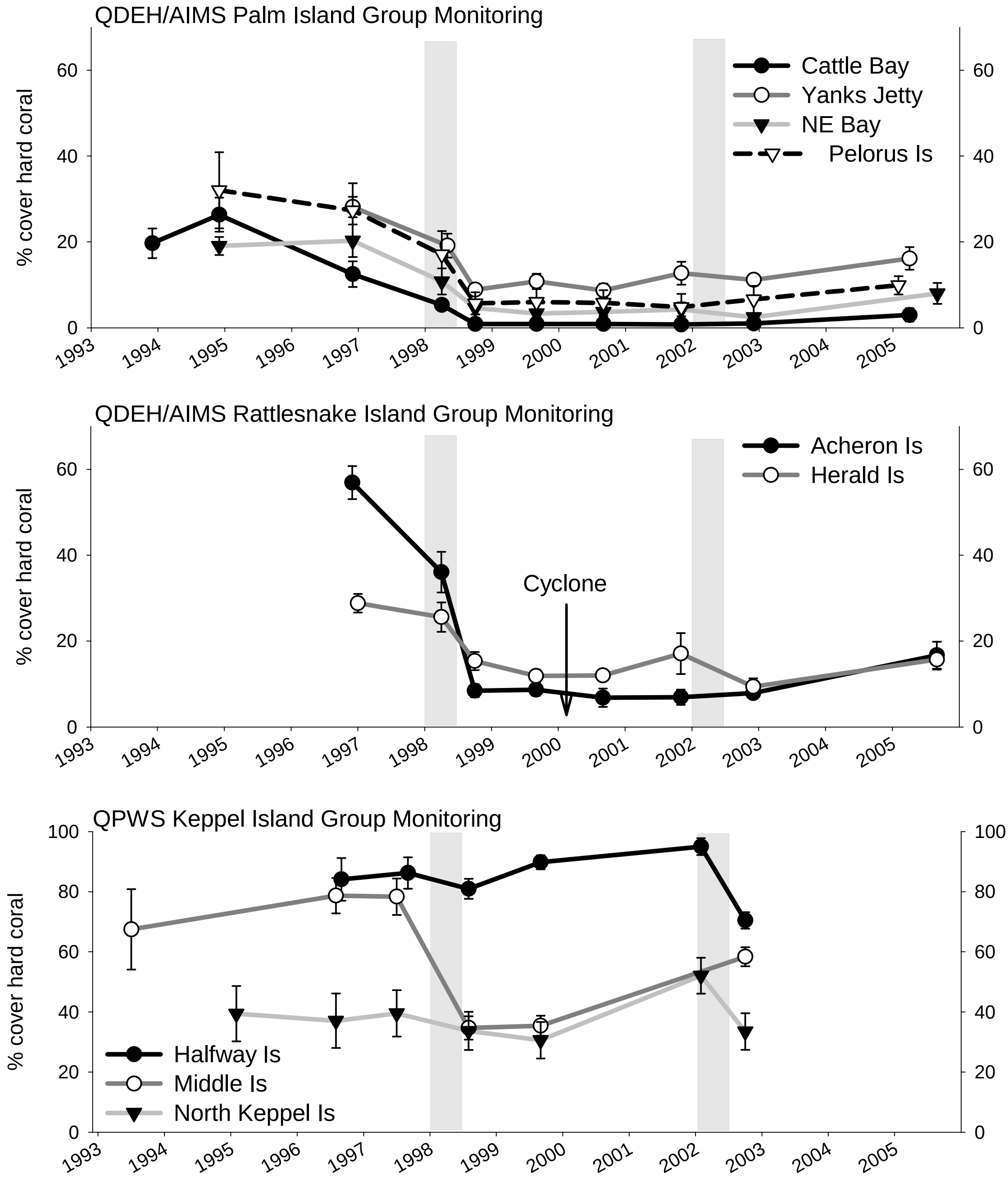

Figure 3.16. Changes in cover of hard coral on near-shore sites monitored initially by the Queensland Department of Environment and Heritage and subsequently by either the Queensland Parks and Wildlife Service or AIMS. Mean percent cover and standard errors based on three sites at each reef are shown. Known impacts are indicated by either arrows (crown-of-thorns starfish and cyclones) or shaded bars for coral bleaching.

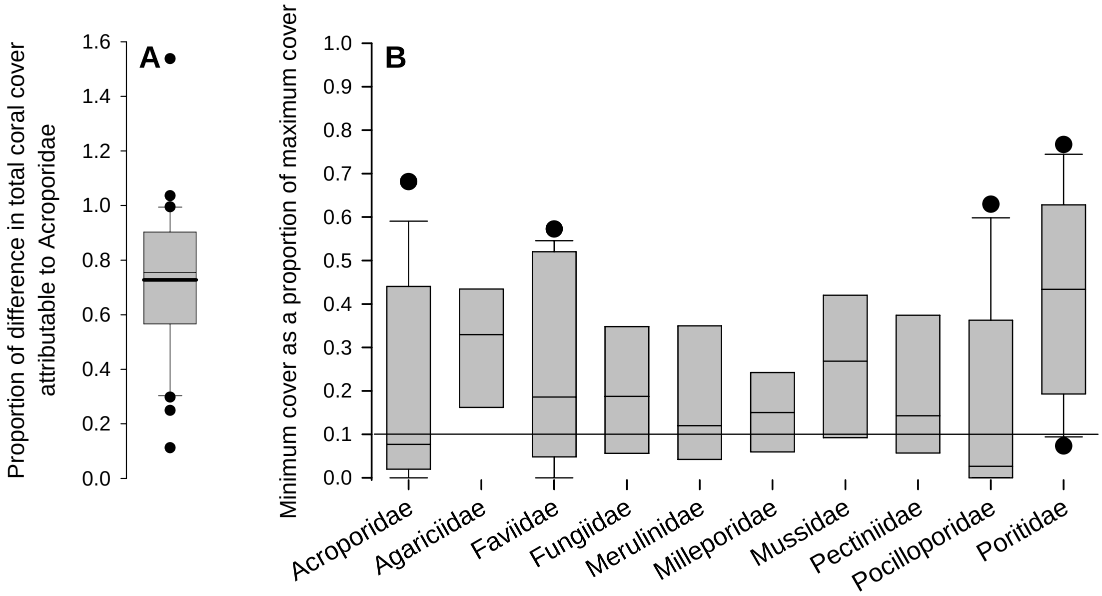

Figure 3.17. Temporal variability in cover estimates of hard coral families. (A) Distribution of the proportion of change in hard coral cover attributable to Acroporidae. (B) The range of cover observed in the different families, expressed as the minimum cover as a proportion of the maximum cover recorded at a reef. Data are from the monitoring data sets listed in Table 3.8. Data were only used from those reefs where the maximum observed cover of a family was greater than 2%. Boxes represent the 25th to 75th percentiles along with the median line (and bold mean line in A), whiskers give the 10th and 90th percentiles and data beyond these limits are represented as dots. Plot B includes a reference line for visual purposes only.

4. Detailed Descriptions of Reef Communities in Each Survey Location

4.1. How to Read Reef Pages

These ”reef pages” present a summary of the coral communities at each survey location in 2004. As there were often differences between communities in the shallow (2 m below Lowest Astronomic Tide [LAT]) and deep (5 m below LAT) surveys, data for each depth are presented separately.

Within the text, reference to “% cover” refers the proportion of the substrate that is occupied by a particular component of the benthic community. This should not be confused with reference to the makeup of specific components of the benthic community for example a statement such as “of the hard coral cover, 90% was *Acropora*” is not implying the *Acropora* occupied 90% of the substrate rather that, of the *x*% hard coral cover, 90% of colonies belonged to the genus *Acropora*.

Reference to “Incidence of current disturbance” relates to data collected in scuba searches (see methods section); the sum of observations from all transects at a depth is presented.

When there have been previous surveys at a site, these are compared with the results from surveys in 2004. Where possible, historical data on communities and disturbance events at the survey locations and others nearby are used in combination with the 2004 results to interpret recent community dynamics.

Cape Tribulation North

A mainland fringing reef north of Cape Tribulation that borders a rainforest-backed beach. The broad reef flat leads to a moderate reef slope 10-20 m wide that extends to sand 4-5 m. As this was a relatively shallow reef community, no deep sites were surveyed in 2004. Sites coincide with 'location 2, sites 5 and 7', monitored by Sea Research from1985-88 and then annually from 1994 (Ayling and Ayling 2005). Sites were surveyed in July 2004.

Shallow surveys

Hard coral cover (48%) was well above average (Figure A). The coral community was patchily distributed within the location and dominated by *Montipora* spp. (16%), as numerous large colonies of foliose and encrusting coral. *Acropora* spp. were also common (11%), principally as tabulate colonies. Soft coral cover (10%) was slightly above average and included eight genera, while cover of macroalgae was low at the time of survey.

From the demographic survey, colony numbers were dominated by *Montipora* spp. (31%), *Acropora* spp. (29%) and *Turbinaria* spp. (7%) (Figure D). *Montipora* spp. and *Turbinaria* spp. were represented by larger colony sizes with 33 and 15 colonies >1 m in maximum dimension respectively. Although there were 17 tabulate *Acropora* colonies >1 m in maximum dimension, most (63) were around 50 cm size. Density of recruits per area of available substrate was low particularly in <5 cm size-class (Figure C). Coral species richness (84) was above average (Figure B). Diversity of *Acropora* (16 species) and *Montipora* (7 species) where similar to average (15 and 5 respectively) while the family Faviidae, with 11 genera and 25 species was slightly below the average of 15 genera and 28 species.

Incidence of recent or current disturbance was low, with nine *Drupella* gastropods, only one instance of 'white syndrome' disease and minor bleaching among individual colonies.

Summary

The location owes its high coral cover to the dominant large colonies of *Montipora* spp. and *Acropora* spp. an observation consistent with observations over the past 20 years. Detailed descriptions of the community dynamics of this location over the period November 1985 to January 2004 are provided in Ayling and Ayling (2005) and provide the longest running data set on near-shore reefs. From these data we see that in the period 1985 to 1988 coral cover was reduced by damage associated with Cyclone Manu in 1986, then again by a bleaching event in early 1987, by November 1988 rapid growth of Acroporid species had returned cover to levels similar to those in 1985. Hard coral cover between October 1994 and January 2004 was higher than in the 1980s and ranged between a maximum of 66.7% in 1997 to a minimum of 57.4% the following year, the result of a severe bleaching event in early 1998. Cover again increased following this event. Interestingly throughout the cycles of disturbances and recovery the community type has not changed. The low levels of recruitment recorded in this survey, coupled with generally large colony size and persistent community composition suggest that the resilience of this community results from recovery and growth of colonies suffering partial mortality rather than the settlement and subsequent growth of new colonies. Severe disturbances that cause total mortality of colonies might lead to slower recovery and/ or community change.

Cape Tribulation North

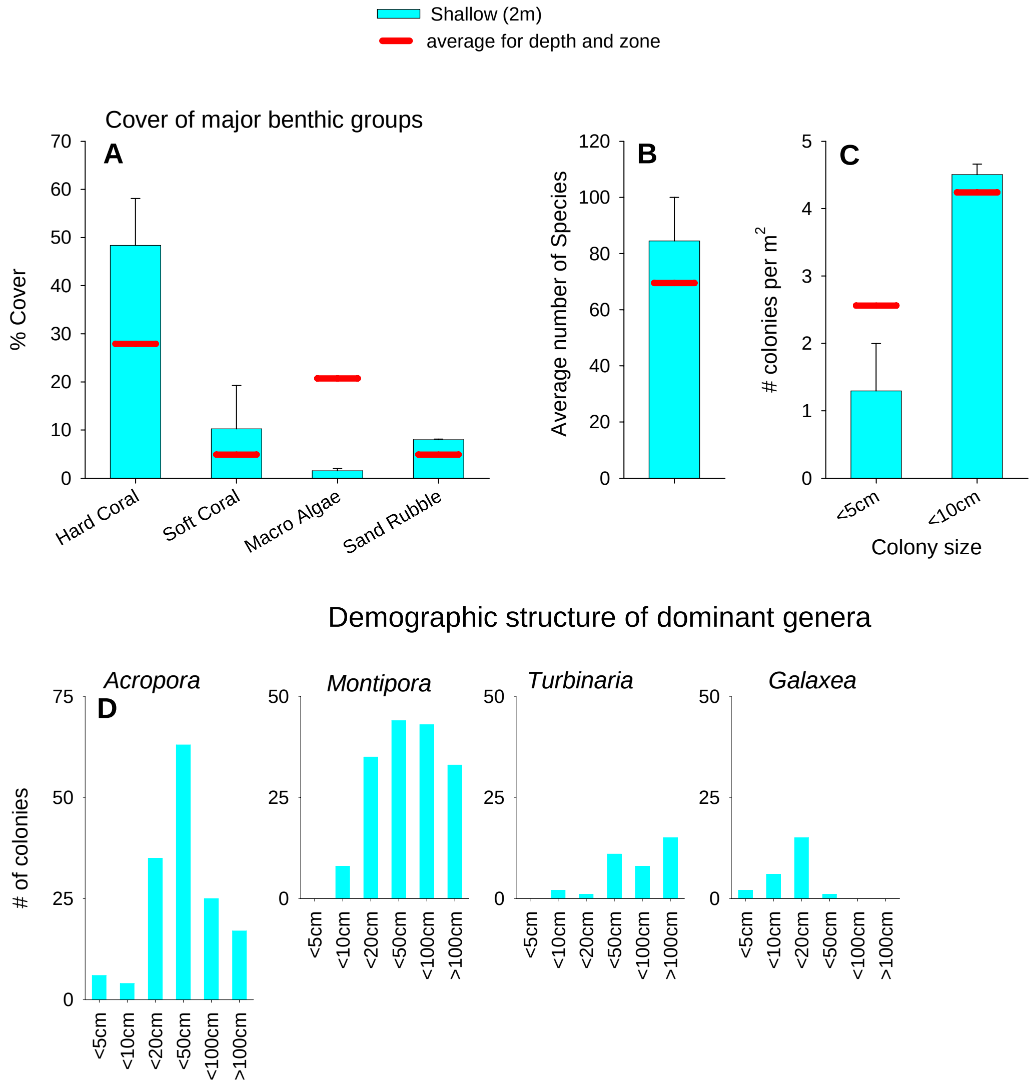

Figure A: The average percent cover of major benthic groups at each depth from video transects.
Figure B: The average species richness recorded during swim searches at each depth.
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Figure D: The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Cape Tribulation South

A mainland fringing reef just south of Cape Tribulation. The moderate reef slope extended to a sand base at 4-5 m. This location coincides with ‘Location 1, sites 1 and 3’, monitored by Sea Research from 1985-88 and then annually from 1994 (Ayling and Ayling 2005). Sites were surveyed in July 2004.

Shallow surveys

The reef slope is patchily constructed of solid substrate and loose rubble. At the time of survey, the sediment load in the water was markedly higher than at Cape Tribulation North and the visibility was reduced to 3 m. Hard coral cover (8%) was among the lowest recorded during this study (Figure A), soft coral cover at 6% was around average while macroalgae cover (5%) was low. The substrate was dominated by turf algae (75%).

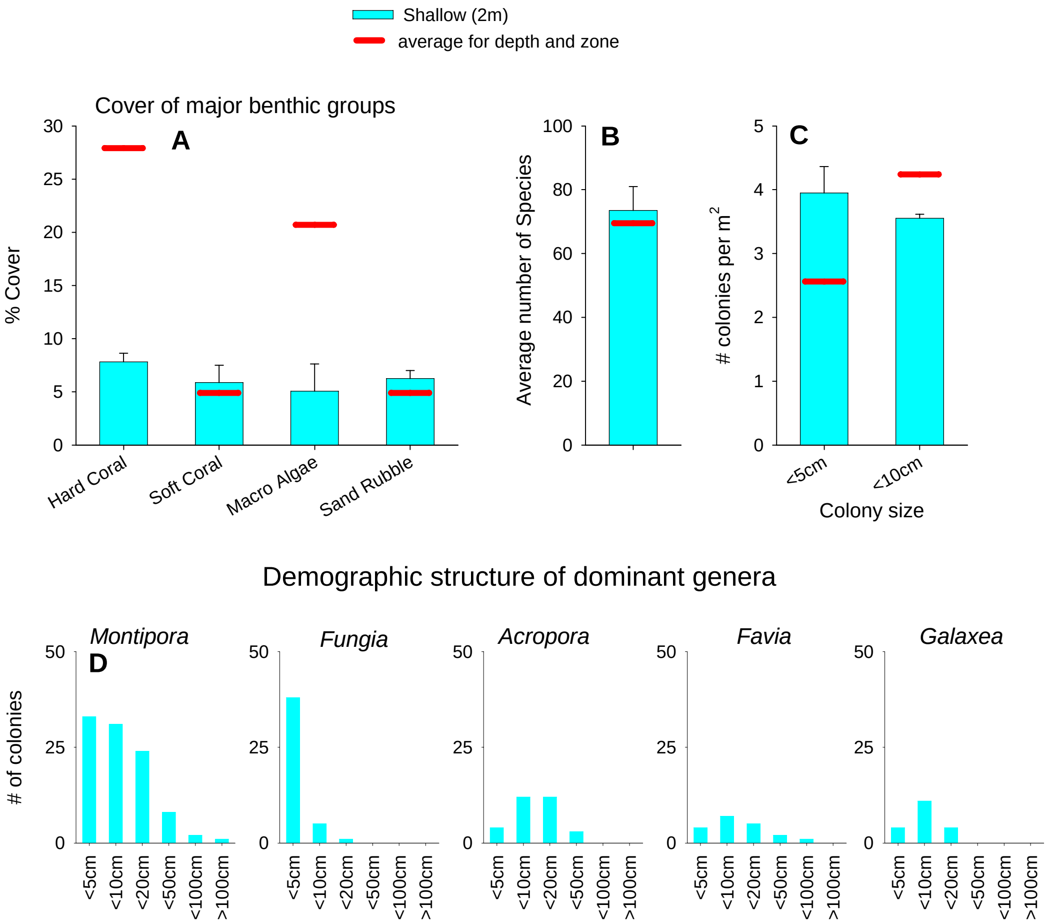
Demographic surveys show colony numbers were among the lowest for any location in the surveys in 2004. Few coral colonies were over 20 cm in size (Figure D). The dominant coral type (encrusting and foliose *Montipora* spp) covered only 2% of the substrate. The density of small recruits (<5 cm) at 3.9 per square metre of available substrate was above average (Figure C) with the density of larger (<10 cm) recruits average. Despite low colony numbers species richness (73) was slightly above average and dominated by species of the genus *Acropora* (11 species) and the family Faviidae (20 species).

Incidence of recent disturbance was low with only a few individual colonies showing signs of bleaching or physical breakage.

Summary

Past surveys of this location record a steady decline in coral cover following the 1998 bleaching event, a subsequent period of crown-of-thorns starfish infestation and a further bleaching event in 2002 (Ayling and Ayling 2005). Despite these severe impacts, there are similarities between the suite of coral species seen here and those at the Cape Tribulation North location. This, along with the dominance of the community by small colonies of the fast growing *Montipora* spp. and *Acropora* spp. and above-average recruit density suggest cover may increase rapidly in the absence of further severe disturbance.

Cape Tribulation South



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Snapper Island (front reef)

A well developed fringing reef lying along the southern shore of the island. The slope consists of large live and dead massive coral colonies interspersed with consolidated and loose rubble and becomes increasingly silty with depth. The coral community gives way to sand and silt below 6-8 m. The survey sites in 2004 coincided closely with sites monitored annually by Sea Research (Ayling and Ayling 2005) with our Site 1 corresponding to 'South Site 3' and our Site 2 corresponding to 'South Site 1'. Sites were surveyed in July 2004.

Shallow surveys

The benthic community was dominated by turf algae (70%). Soft corals were widely scattered and cover low (4%) while macroalgae were not recorded (Figure A). Hard coral cover (22%) was slightly below average and dominated by massive *Porites* species (15%), while *Acropora* spp.(3%) occurred principally as scattered small corymbose colonies. Other corals groups present, such as the Faviidae collectively occupied only 2% of the substrate.

While there were some *Porites* massive colonies and a few 'blue coral' *Heliopora* colonies that were >1 m across, the majority of colonies (72%) were under 20 cm, with almost half (43%) being recruits (<10 cm) (Figure D). These recruits included the genera *Porites*, *Acropora, Favia, Galaxea,* and *Pocillopora*. Despite a high proportion of recruit-sized colonies, the large amount of available substrate for recruitment meant that recruit density was below average (Figure C). Species richness (73) was slightly above average (69), including 13 species of *Acropora* (mostly small corymbose colonies) and 27 species of Faviidae, representing nine genera. Of the rare species, *Coeloseris mayeri* was identified from only one other location in 2004 surveys.

Recent disturbance to coral colonies was limited to the observation of 10 *Drupella* gastropods with associated scarring, and two instances of 'white syndrome' disease. Recent mortality of corymbose *Acropora* colonies had occurred as indicated by the observation of a number of lightly fouled dead colonies.

Deep surveys

The coral community at 5 m was patchily distributed on hard substrate among areas of rubble and sand. Hard coral cover (34%) was and higher than in the shallows (Figure A). The community included large *Porites* bommies and a few large colonies of *Goniopora, Caulastrea, Lobophyllia* and *Heliopora* amongst generally smaller encrusting, sub-massive and foliose forms. Soft coral cover (13%) was above average and higher than at 2 m.

The density of recruits was above average (Figure C) with almost 30% of the larger (5-10 cm size) recruits being either *Goniopora* spp. *or Porites* spp.

Species richness was high (95) and markedly higher than on the shallower slope (Figure B). Impressively, there were 12 genera of Faviidae, represented by 33 species (35% of species richness). Fungiidae (six genera and 11 species) and Poritidae (2 genera and 12 species) were also diverse. Soft corals were represented by three genera of Alcyoniidae, two of Nephtheidae and single Briareidae and Xeniidae. *Acropora* spp. (7) were fewer than average (12). A few rare corals were found at this location. *Coscinaraea wellsi* was only found at this location in 2004 surveys and *Astreopora ocellata* was recorded at only two other reefs.

Recent levels of colony disturbance were low with eight *Drupella* gastropods and associated scarring, partial bleaching on individual colonies, a single case of 'black death' and a small number of physically damaged colonies.

Summary

Past observations on the shallow front reef of Snapper Island date back to 1994 with annual surveys from 1997 through to 2004, a full description of these surveys is to be found in Ayling and Ayling (2005). In 1994 hard coral cover was very high at almost 90% and dominated by corals of the genus Acropora (59% of the hard coral community). In March 1996 a flood of the Daintree River caused high mortality with almost 100% mortality of Acroporid corals and major mortality of most other taxa with Porites spp. the least effected. There was a strong depth effect with the majority of the damage occurring above 3 m. By 2003 only Porites spp. had cover at pre-1996 levels, although several other genera, including Acropora, had begun to increase over this period. The Daintree River flooded again just months prior to our survey, affecting the Acropora community. This is consistent with the presence of recently killed colonies. This contrasts with the deeper coral community, where average hard coral cover and above-average species richness and recruit densities, as well as broad demographic distributions for a range of genera, all suggest a diverse and stable community.

Snapper Island (front reef)

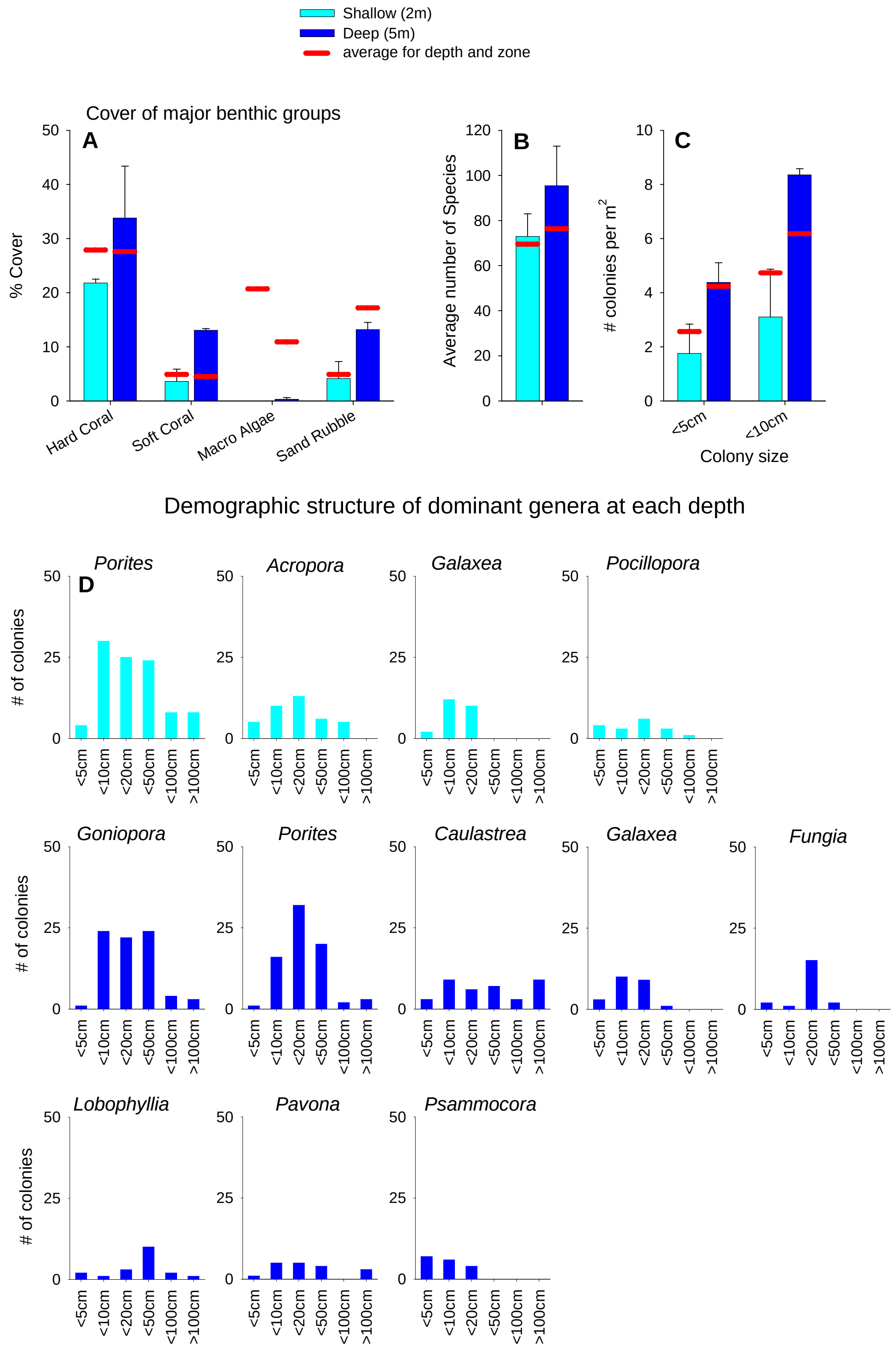

Figure A: The average percent cover of major benthic groups at each depth from video transects.
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Snapper Island (back reef)

A well-developed fringing reef lying along the northern shore of the island. The back reef slope varied from gently sloping *Acropora* spp. thickets to rubble banks or areas of steep consolidated substrate. The coral community gives way to sand or silt at depths ranging from 3 to >8 m. The sites in 2004 surveys coincide closely to sites monitored annually by Sea Research (Ayling and Ayling 2005) with our Site 1 corresponding to 'North Site 1' and our Site 2 corresponding to 'North site 3'. Sites were surveyed in July 2004.

Shallow surveys

Hard coral assemblages were patchily distributed with cover at Site 1 (73%) considerably higher than Site 2 (10%) resulting in a slightly above-average cover (Figure A). Overall the coral assemblage was dominated by *Acropora* spp. (72%), principally large stands of branching and bottlebrush colonies at Site 1. Other contributing coral groups included foliose *Montipora* spp., *Echinopora* spp., and sub-massive *Porites* spp. Soft coral cover (3%) was low. Filamentous turf algae and macroalgae (not *Sargassum* spp.) were patchily distributed.

Over 48% of colonies were *Acropora* spp. with a large number of branching and bottlebrush colonies >1 m in size (Figure D). Recruit densities overall were above average though densities of colonies <5 cm are low (Figure C) *Acropora* spp. and *Montipora* spp. together contributed to 60% of the recruitment (<10 cm size). Species richness at this location (64) was slightly higher than the overall location average. The dominant *Acropora* spp. were predominately of the bottlebrush growth form (*A. elseyi* and *A. longcyathus*).

A low level of disease was present with two colonies suffering 'white syndrome' and three colonies with 'brown band' and several unidentified scars.

Deep surveys

As at 2 m, the coral communities differed among sites. Site 1 ran along the lower portion of a gently sloping *Acropora* spp. dominated 'thicket' while Site 2 ran among isolated massive corals at the base of a steep consolidated slope. At Site 2 hard coral cover (28%) was almost half that of Site 1 (51%). Contrasts in general coral assemblages exist between sites. Site 1 was dominated by *Acropora* spp. and *Montipora* spp. while Site 2 was dominated by *Galaxea* and *Porites*. Soft coral and macroalgae cover were low at both sites.

Several taxa included a wide range of colony sizes, with *Acropora*, *Montipora, Galaxea* and *Pachyseris* each having several colonies over a metre in maximum dimension as well as recruits <5 cm (Figure D). The density of both <5 cm and <10 cm recruits was above average (Figure C) though for the <5 cm size-class this result was driven by *Turbinaria* spp. which were exclusive to Site 2.

Species richness of hard corals (98) was high. The Faviidae were particularly well represented with 11 genera and 27 species. The genus *Acropora* was also well represented (15 species). The only colony of *Anacropora matthaii* seen during the 2004 surveys was found at this location.

Minor levels of disease were recorded, six colonies having 'white syndrome' and two having 'black death'. Four *Drupella* gastropods were recorded with associated scarring, along with a few scattered bleached colonies.

Summary

Differences in coral communities among sites can be partially explained by differing disturbance histories. Site 1 was on the northern side of the island while Site 2 was on the northeastern tip. Historical records of the shallow communities indicate that these sites faired quite differently in past disturbance events (Ayling and Ayling, 2005). In 1997 both sites were dominated by *Acropora* spp. and had coral cover exceeding 75%, bleaching in 1998 caused a reduction of 15 - 22% cover on both sites. The main difference occurred in 1999 when cyclone Rona reduced cover at Site 1 to 38% from which point it has rapidly recovered, Site 2 was far harder hit with a reduction to less than 4% cover and little subsequent recovery. The difference between the recovery profiles of these sites probably reflects the level of disturbance. Site 1 was able to recover rapidly as all that was required was regrowth of existing damaged colonies. *Acropora* spp. were almost totally removed from Site 2, so recovery has depended on the settlement and subsequent growth of new individuals. The large numbers of *Turbinaria* recruits at Site 2 where no larger colonies were recorded may indicate a shift in community structure, at least in the short term.

Snapper Island (back reef)

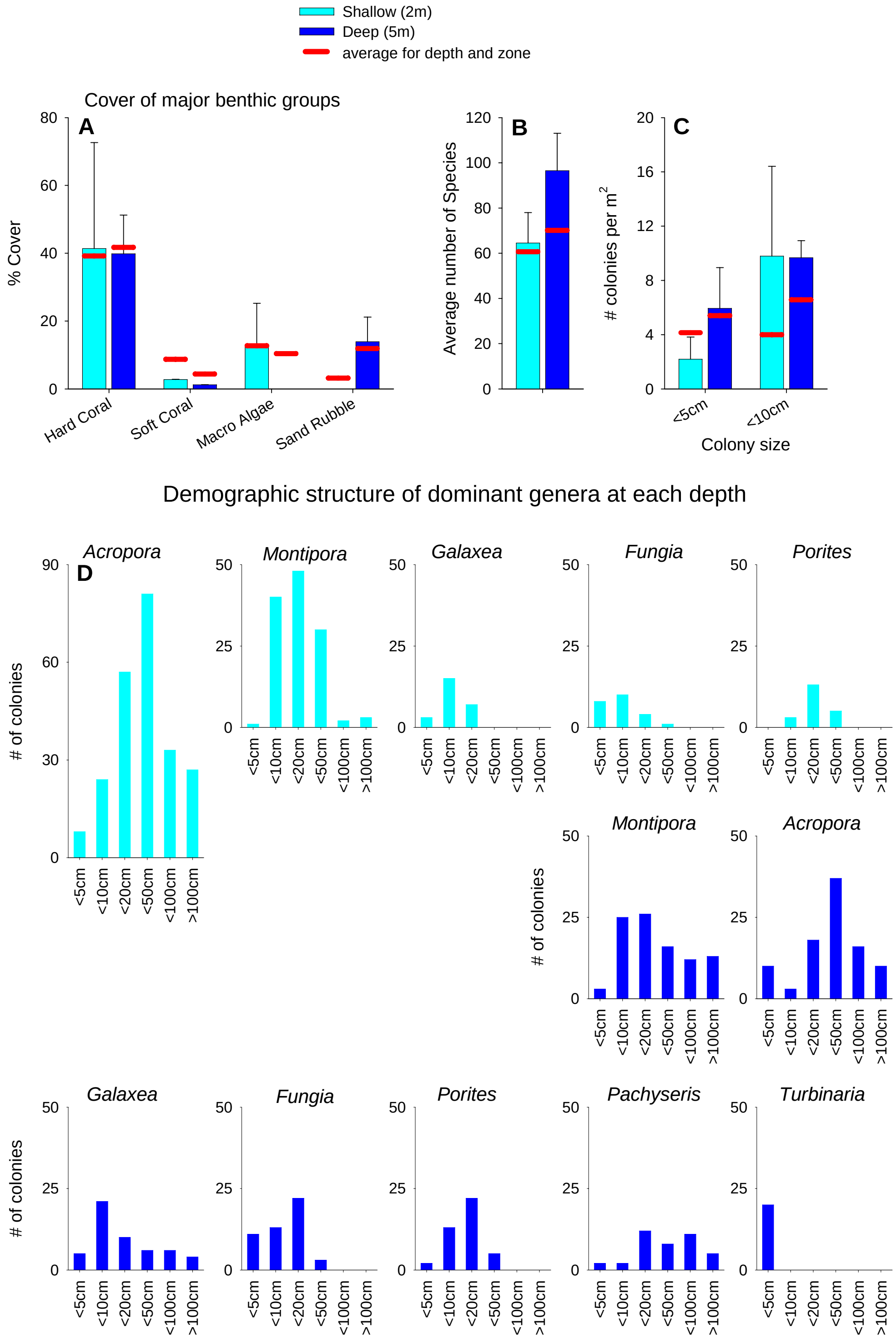

Figure A: The average percent cover of major benthic groups at each depth from video transects.
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Wentworth Reef

The sites were on the eastern edge of a shoal-reef some 5 km off the coast to the south of Port Douglas. The reef slope was generally gentle with a few steeper sections extending down to sand and silt at 6-7 m. The substrate was a mixture of hard reef framework and consolidated rubble with a coral assemblage scattered among large areas of algae. Sites were surveyed in July 2004.

Shallow surveys

The shallow slope was dominated by macroalgae (55%) (Figure A), particularly *Sargassum* spp., that was thickly overgrowing dead branching and massive corals. Cover of both hard coral (6%) and soft coral (0.75%) were well below average (Figure A). What few corals were present were mainly small *Montipora* spp., *Acropora* spp. and *Porites* representing 40%, 19% and 9% of the coral assemblage respectively. Filamentous turf algae (38%) covered the remaining substrate.

Species richness (63) and density of coral recruits are also both below average (Figures B and C). *Montipora venosa* was only recorded twice in 2004 surveys, the other location being on the deep slope of this reef.

The impoverished state of the coral assemblage was further underlined by the demography. *Montipora* spp. represent 43% of the colonies with only three colonies >1 m in size. Over all taxa, 98% of colonies were under 50 cm in maximum dimension, 48% being recruits <10 cm. Of the 93 recruits, 29 were *Montipora* spp. and 23 were *Acropora* spp.

Observations of recent sources of coral mortality or damage were restricted to minor physical damage and bleaching of a few individual colonies.

Deep surveys

Macroalgae gave way to filamentous turf algae (67%) as the dominant biota at 5 m. Cover of both hard coral (9%) and soft coral (0.9%) was low and patchy (Figure A). The most coral colonies were encrusting and foliose *Montipora* spp. and corymbose *Acropora* spp., though each of these accounted for only 12.5% of the community. As in the shallow community, the great majority of coral colonies (98%) were under 50 cm size (Figure D). Recruit density was markedly higher than at 2 m especially in the <5 cm size-class (Figure C). Although there was moderate recruitment of *Montipora* spp., *Acropora* spp., *Porites* spp. and the family Faviidae, the majority of recruits (40%) were *Turbinaria* spp. There were no *Turbinaria* colonies that were >10 cm (Figure D).

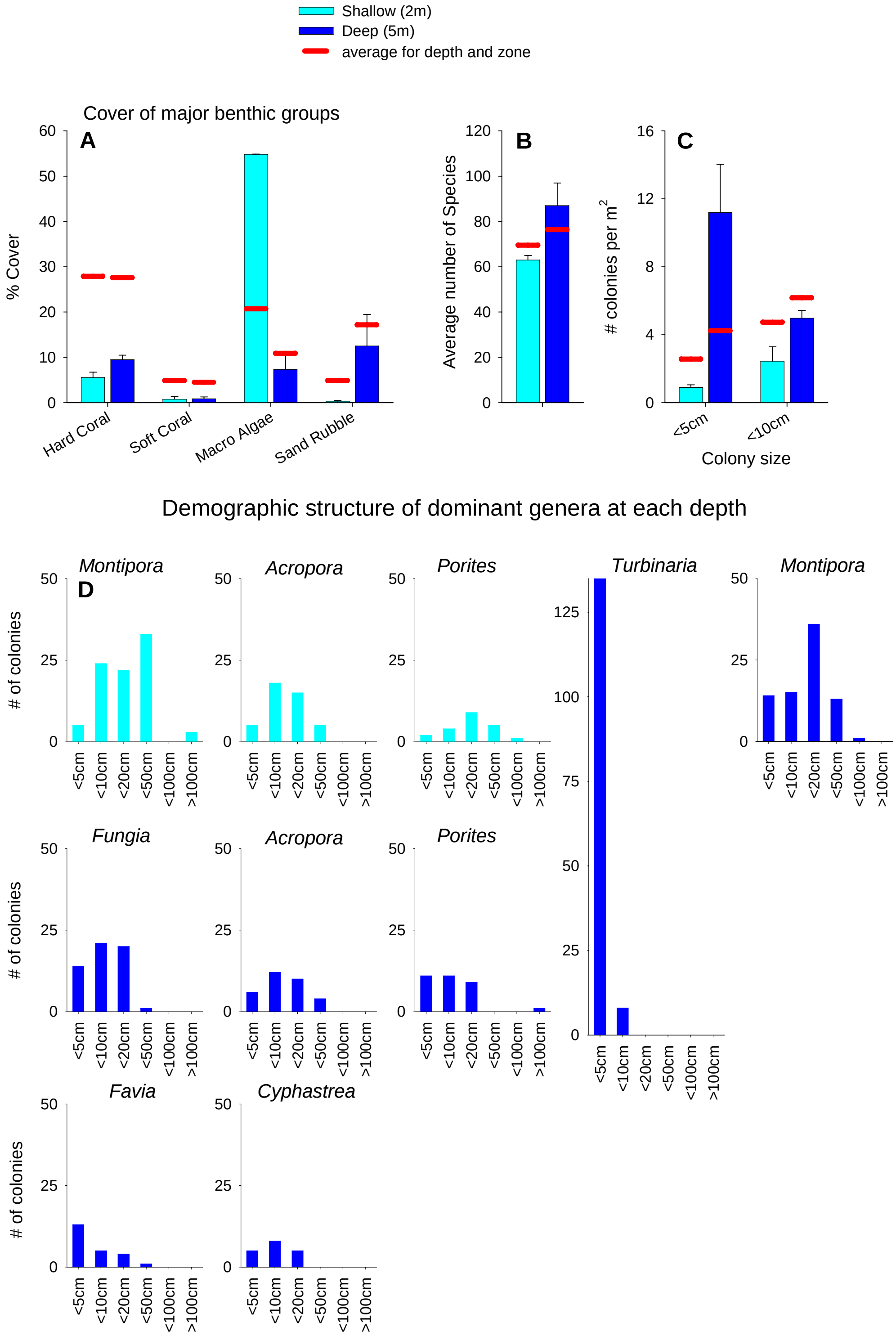
Despite low cover, species richness was well above average and markedly more diverse than on the shallow slope. Diverse groups included *Acropora* (11 species), *Montipora* (7 species), and Faviidae (29 species in 12 genera).

Observations of recent sources of coral mortality or damage were restricted to minor physical damage to a few colonies.

Summary

With very few large colonies and low cover the coral community appeared to have suffered one if not repeated impacts in recent years. Based on observations of disturbance to nearby Snapper Island these likely include bleaching in 1998, Cyclone Rona (1999) and possibly predation by *Acanthaster planci* that was common on mid shelf reefs in the Cairns region in the late 1990s. While the extensive cover of macroalgae is a potential barrier to re-colonisation and growth of corals in the shallows, the deep slope community appeared to have a diverse coral assemblage and scope for recruitment, so coral cover may increase rapidly in the absence of future disturbance.

Wentworth Reef



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Double Island

Sites were on the eastern edge of a well-developed fringing reef linking Double and Haycock Islands. The slope substrate was mostly hard reef framework and had a moderate gradient to a depth of 5-7 m where it met a silt substrate. The coral community is extensive throughout the reef slope. The water clarity often deteriorates due to tidal resuspension of sediment so that visibility was reduced to 1 m despite very calm conditions. Sites were surveyed in August 2004.

Shallow surveys

Hard coral cover (47%) was high (Figure A). Cover of soft coral at 7% was average. Cover of macroalgae (9%) was below average and patchily distributed. The hard coral assemblage was characterised by large colonies of foliose/encrusting *Montipora* spp. that comprised 50% of the cover, *Acropora* spp. (mostly branching) accounted for a further 22%. The remaining coral community was mixed with individual taxa accounting for only low portions of the overall cover.

Montipora spp. made up a high proportion of individual colonies (53%) with many of these (35%) large at >1 m in maximum dimension (Figure D). This community had the highest density of large *Montipora* spp. colonies in the 2004 surveys. There were also some large (branching) *Acropora* spp. colonies, though corymbose colonies of 20-50 cm diameter were most abundant. Overall recruit density was average though the density of the smaller <5 cm colonies was low (Figure C). *Acropora* spp. and *Montipora* spp. were the most common recruits. Species richness of hard corals (63) was slightly below average (Figure B) though *Acropora.* (16 species) and *Montipora* (8 species) were reasonably represented. The only report of *Caulastrea echinulata* in the 2004 surveys was at this reef, as was one of only two observations of *Montipora foveolata.*

Observations of recent coral damage were low, with six *Drupella* gastropods and associated scarring being recorded, along with four coral colonies with 'white syndrome' disease and some minor physical damage.

Deep surveys

Descending the reef slope, the coral cover increased to 56%, macroalgae cover declined and soft corals were absent (Figure A). *Pachyseris speciosa* and *Galaxea* spp were the dominant components of the coral community accounting for 39% and 18% of the overall cover. In contrast to the shallow slope *Montipora* spp. (3%) and *Acropora* spp. (1%) made up only minor portions of the community.

Pachyseris speciosa and *Galaxea* spp. included a high proportion of very large colonies (Figure D). Overall recruit density was average, though low numbers in the smaller <5 cm size-class a little low (Figure C).

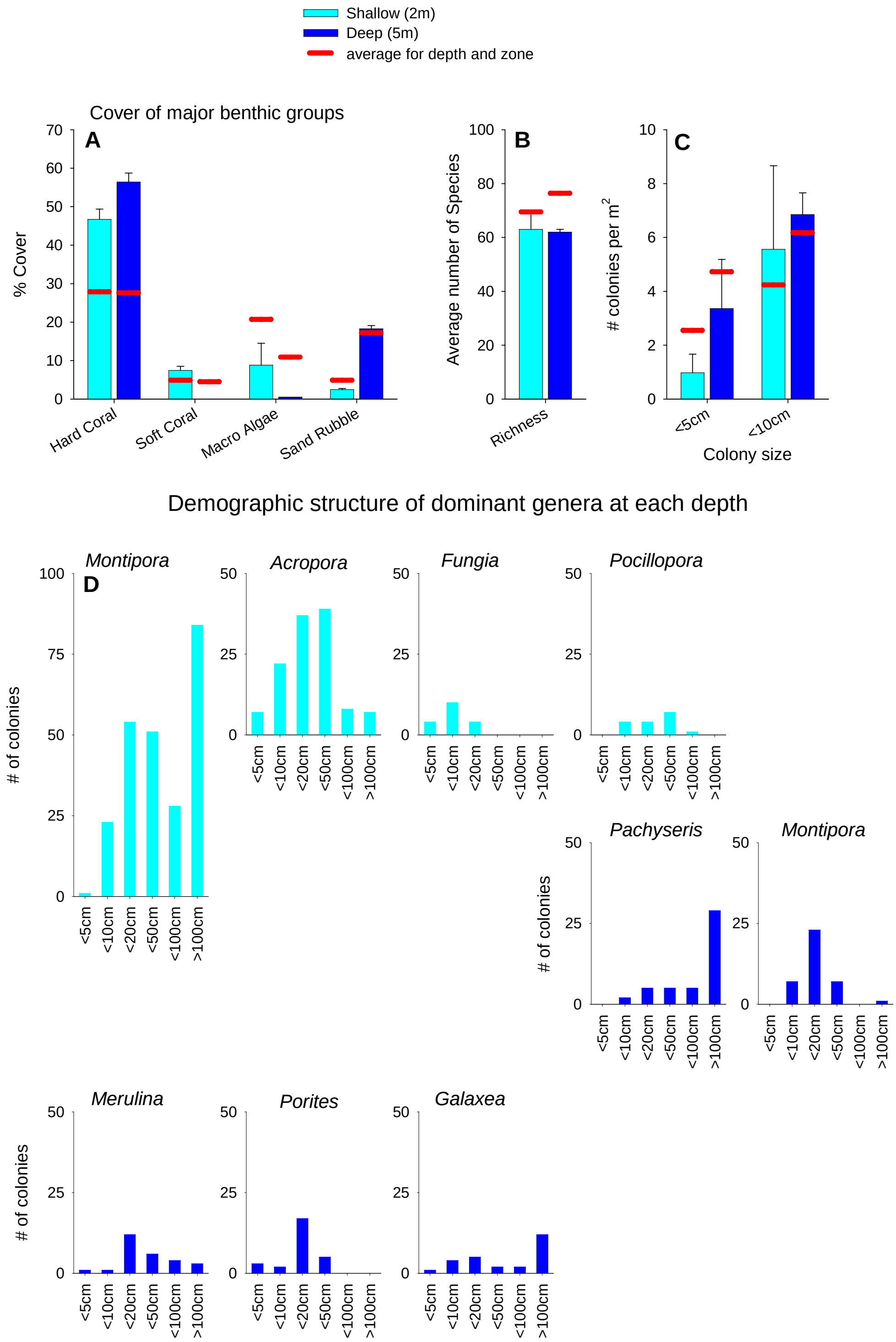
Species richness was slightly below average (Figure B). The number of *Acropora* spp. and Fungiid species decreased with depth, but this was compensated for by increases in a range of taxa including species from the families Caryophylliidae, Faviidae, Mussidae and Pectiniidae.

Recent incidence of colony damage was limited to the observation of partial bleaching of a small number of colonies.

Summary

The marked shift in community composition from the shallow community largely dominated by Acroporidae to the more diverse deeper slope community is typical of communities in such turbid environments where light attenuation is rapid. The dominance of a few rapidly growing coral genera, the truncation of the size range of *Acropora* spp. and the disrupted growth form of the larger *Montipora* spp. colonies at 2 m, suggests a community recovering from past impact. Conversely the high cover and proportion of large colonies at 5 m suggest limited disturbance over a long period on the deeper slope.

Double Island



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High Island (front reef)

A fringing reef without well-developed reef flat lying along the eastern face of the island. The slope was moderate with hard substrate and coral communities extending well below the deep site (5 m). Sites were surveyed in March 2004.

Shallow surveys

Turf algae (58% cover) were the dominant component of the benthic community, covering most of the outcrops of hard substrate and rubble. Soft coral cover was average (Figure A) and dominated by the genus *Sinularia*. Hard coral cover varied among sites; (16% Site 1, 37% Site 2). *Acropora* spp., predominantly tabulate and corymbose forms, was the dominant group of hard corals contributing 66% of the overall coral cover.

The coral community included few colonies larger than 50 cm (Figure D) but had above-average density of recruit-sized colonies. Species richness was slightly above average (Figure B) with the genus *Acropora* (20 species), and the family Faviidae (9 genera, 28 species) most diverse.
Evidence of recent disturbance to the coral community included the observation of two *Drupella* gastropods with associated scarring, five colonies infected with 'white syndrome' disease, and several colonies were partially bleached.

Deep surveys

Cover of turf algae was high at 56%. In contrast cover of hard coral was low (Figure A) though it did vary among sites (36% Site 1 vs. 12% Site 2). The coral community was dominated by *Porites* spp. (63% of the hard coral community), particularly *Porites rus* at Site 1 where some particularly large colonies contributed to the higher cover at this site. In contrast to the shallower slope *Acropora* spp. (6%) and *Montipora* spp. (4%) are minor components of the coral community.

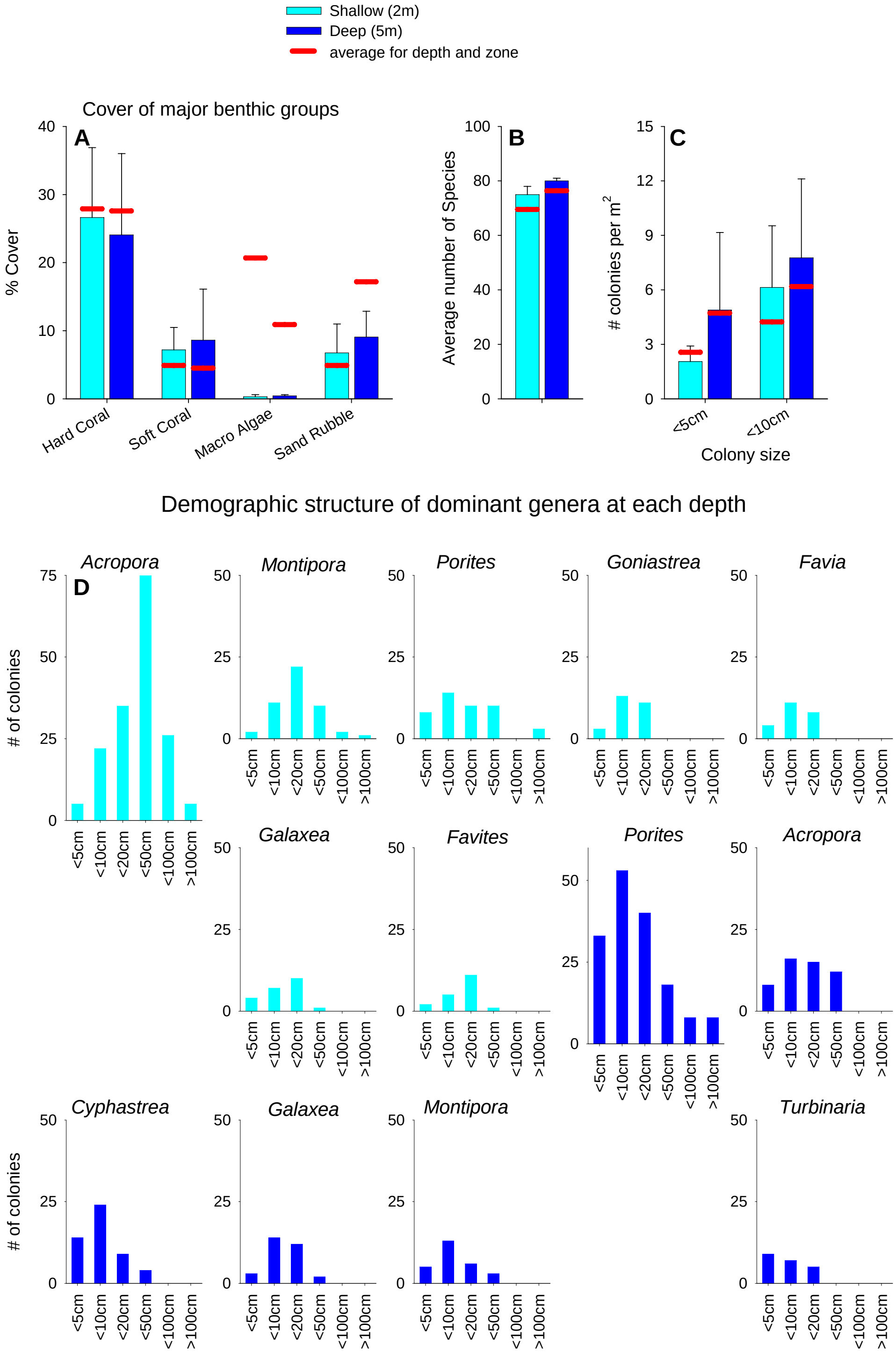
The size structure of the coral community was skewed toward smaller colonies with 96% less than 50 cm in maximum dimension and above-average density of the recruit-sized categories (Figures C and D). Recruitment was occurring across a number of genera though *Porites* recruits were most common representing 31% of colonies <10 cm size. Species richness was slightly above average (Figure B) with diverse groups including *Acropora* spp. (17 species) and the family Faviidae (30 species from 10 genera)

Evidence of recent disturbance to the coral community included the observation of one *Drupella* gastropod and associated scarring, three colonies infected with 'white syndrome' disease, and a few colonies were partially bleached.

Summary

The overall impression from this location is of a community with a history of disturbance (few corals larger than 50 cm, low coral cover). The only large colonies were quick growing (*Acropora* spp. and *Montipora* spp.) or resilient (*Porites* spp) species. As density of recruit-sized colony was above average and included a diversity of taxa, overall cover is expected to increase in the near future in the absence of further disturbance events.

High Island (front reef)



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High Island (back reef)

A fringing reef with well-developed reef flat lying along the western side of the island. The slope was steep and composed predominantly of living and dead massive *Porites* colonies interspersed with patches of rubble and silt. The slope gave way to silt below 6-8 m. Sites were surveyed in March 2004.

Shallow surveys

Hard coral cover was high (Figures A) though differed markedly among sites (73% Site 1, 38% Site 2). High coral cover at Site 1 included extensive stands of massive *Porites* (41%) and the branching *Porites cylindrica* (24%), with only small pockets of other corals. Site 2, while still retaining *Porites* spp. (25%) had a broader representation of other coral groups. Cover of soft coral (7%) was average (Figure A) and comprised predominantly of *Sinularia*. Macroalgae cover was very low.

The coral community included a high proportion of large colonies of the genus *Porites* with 50% of colonies in that genus >1 m in size (Figure D). Despite the prevalence of large *Porites* colonies, recruit density was above average (Figure B) with 47% of individual colonies >10 cm in size and these recruits spread among 23 genera. Species richness was also well above average (Figure B), due largely to the diverse *Acropora* (17 species, and Faviidae (32 species from 10 genera).

Incidence of recent disturbance to the coral community included observation of nine *Drupella* gastropods and associated scarring, a few individual coral colonies exhibiting bleaching and several instances of anchor damage.

Deep surveys

Hard coral cover was on average moderately low (Figure A) though again this differed among sites (Site 1 49% vs. just 6% at Site 2). *Porites* spp. was the dominant coral group making up 87% of the coral cover and comprised mainly of branching *P. cylindrica* and sub-massive *P. rus,* with a few large massive colonies also. Soft coral cover (5%) was average (Figure A).

The demographic study revealed that only 9% of the colonies were greater than 50 cm in size with 82% of these being in the genus *Porites*. The vast majority of colonies (80%) were less than 20 cm. This predominance of small colonies was reflected in the higher than average recruit density (Figure C). Of note is that all of the 33 genera of hard coral recorded had at least one individual within the recruitment size range of less than 10 cm though 39% of all recruits belonged to the three most abundant genera *Porites*, *Galaxea*, and *Favia*. Species richness was average (Figure B) with diverse groups including the family Faviidae (11 genera and 27 species), Fungiidae (4 genera and 8 species) and seven species of both Agariciidae and Poritidae.

Incidence of recent damage or mortality was limited to a few partially bleached colonies and some minor anchor damage.

Summary

The lack of large colonies in all but the resilient genus *Porites* indicate past mortality of a large section of the community. The abundance of small colonies, higher than average density of recruits and moderate species richness indicated that recovery was well underway. Although undocumented, it is highly likely that this reef was severely affected by coral bleaching in 1998 though flood plumes and crown-of-thorns starfish may well have caused additional mortality.

High Island (back reef)

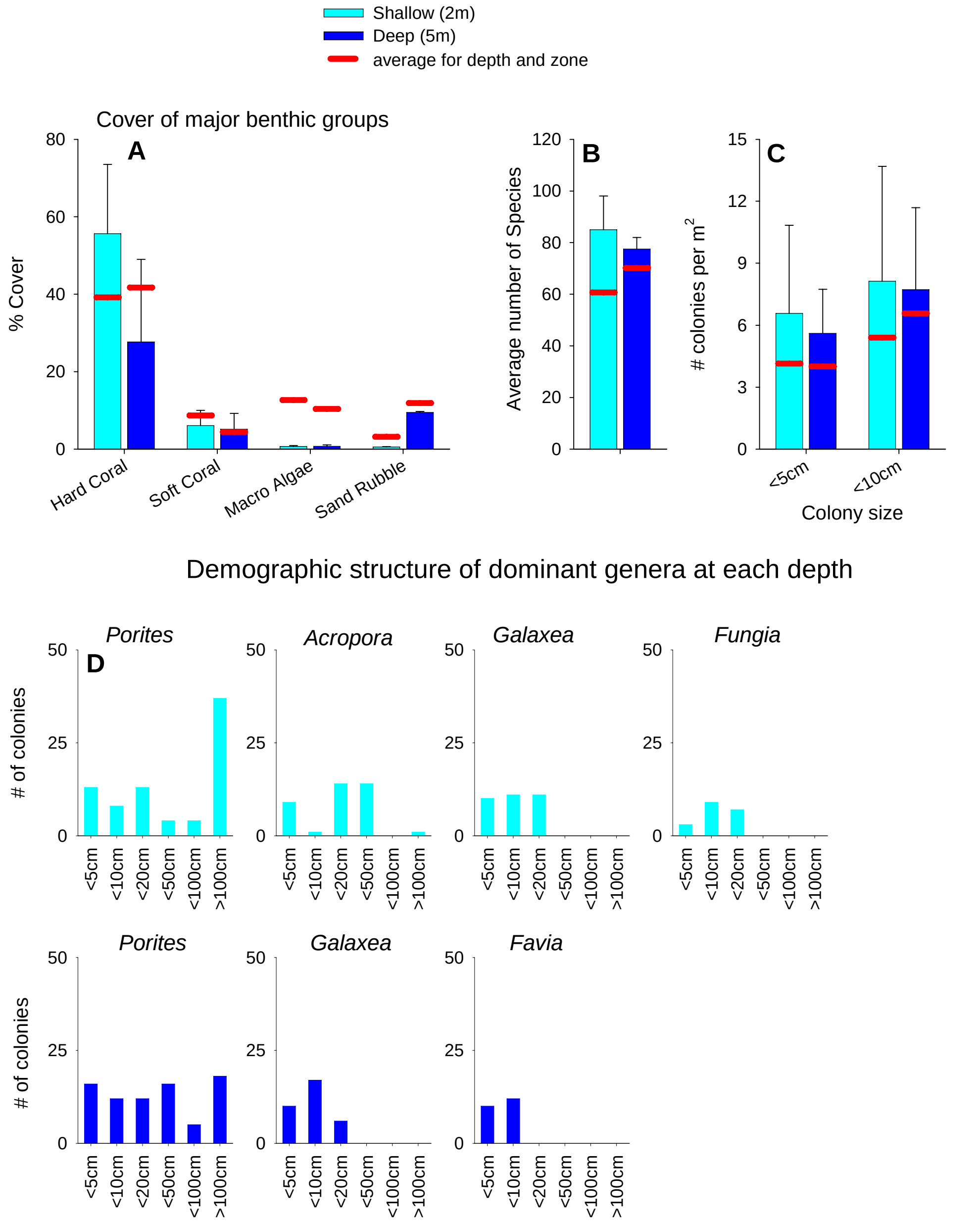

Figure A: The average percent cover of major benthic groups at each depth from video transects.
Figure B: The average species richness recorded during swim searches at each depth.
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Figure D: The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Frankland Islands (front reef)

One site was surveyed on the northeastern corner of the fringing reefs of each of Normanby Island and Round and Russell Islands, constituting the Frankland Islands front reef location. These sites correspond closely to monitoring sites that have been surveyed annually by Sea Research (Ayling and Ayling 2005). Our Site 1 equated to “East 1” and our Site 2 equated to “East 3”. In both cases, the depth of Sea Research transects was between our shallow (2 m) and deep (5 m) transects. At both sites the reef slope was gently inclined and composed of large blocks of reef framework interspersed with areas of both loose and consolidated rubble. The slope broke up into a sandy substrate below the level of our deep transects. Sites were surveyed in March 2004.

Shallow surveys

Hard coral cover at 35% was slightly above average, soft coral cover was low and macroalgae absent (Figure A), turf algae occupied the majority of the remaining substrate. *Acropora* spp. accounted for 76% of the total hard coral cover. This dominance was reflected in the community structure where 47% of colonies are of the genus *Acropora* including a number of colonies >1 m in size (Figure D). Other well-represented genera included *Porites* and *Montipora*. The density of recruit-sized colonies was average (Figure C) with the more common genera all showing reasonable levels of recruitment (Figure D). Coral species richness was average (Figure B) with *Acropora* and *Montipora* the most diverse genera.

Incidence of recent coral damage was low with only one *Drupella* gastropod with associated scar, two colonies with ‘white syndrome’ disease, a few partially bleached colonies and minor anchor damage in the form of overturned tabulate *Acropora* colonies.

Deep surveys

Filamentous turf algae occupied 80% of the substrate on the deeper sites. Hard coral cover (10%) was well below average and soft coral cover (8%), while patchily distributed, was above average (Figure A). The coral community was dominated by the genus *Acropora* (75%). Coral species richness was slightly lower than average. As with the shallow slope *Acropora* represented by 15 species was the most diverse genus.

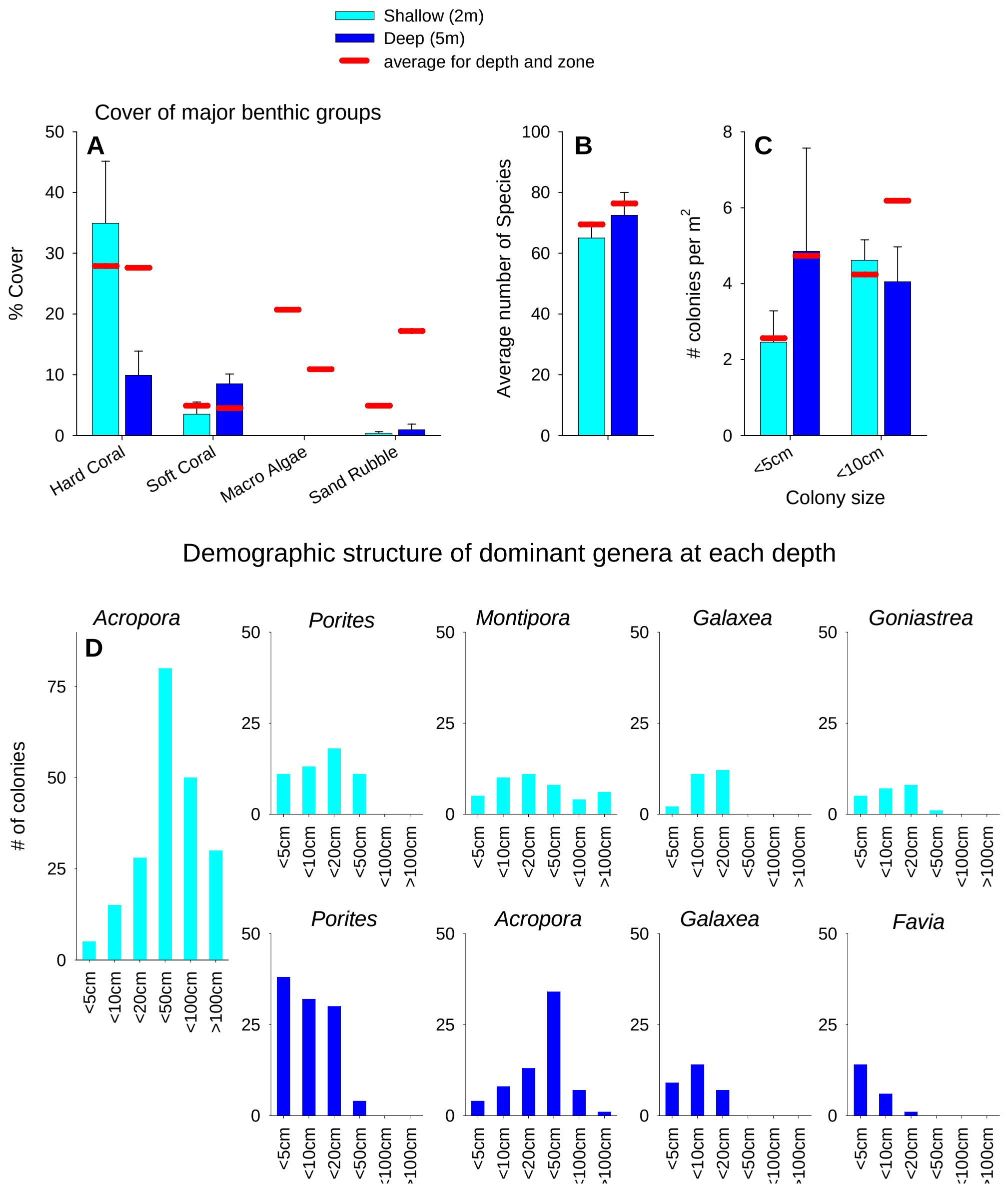
The coral community demographics highlighted a lack of large colonies with very few colonies >50 cm (Figure D). The density of recruit-sized colonies was slightly below average with recruits of the genus *Porites* most abundant (Figures C and D).

Incidence of recent coral damage included the observation of 19 *Drupella* gastropods and associated scarring, and a low number of partially bleached colonies.

Summary

Past observations show declines in coral cover caused by bleaching (1998) and crown-of-thorns starfish (1999-2001, Ayling and Ayling 2005). Certainly the low coral cover, lack of large colonies (especially on the deeper slope and shallow Site 2) and reduced species richness are consistent with these past observations of disturbance. The higher cover and presence of a number of large *Acropora* spp. colonies at the shallow Site 1 suggested that the impacts were not as severe at this site since these colonies survived both impacts. Low recruit density indicated a slow recovery, perhaps due to a lack of mature corals nearby. Cover of *Montipora* spp. and *Pocillopora* were two components of the community decreased drastically following the disturbances. Low to moderate numbers of *Montipora* spp. recruits (24 colonies <10 cm) were recorded, suggesting that this genus may increase. Only two *Pocillopora* recruits (<10 cm diameter) were recorded and there were low numbers of mid-sized colonies (20-50 cm). As this species has brooded larvae, it is capable of rapid local increases in cover if adult colonies are present.

Frankland Islands (front reef)



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Frankland Islands (back reef)

One site was surveyed on the slope of well-developed fringing reefs on the western sides of Normanby and Russell Islands; combined these form the Frankland Islands back reef location. These sites correspond closely to monitoring sites that are surveyed annually by Sea Research (Ayling and Ayling 2005) : our Site 1 equates to “West 3” and our Site 2 equates “West 2”. Our shallow sites were at a depth similar to permanent transects that are monitored by Sea Research. The reef slope at these sites was typically shallow down to 2-3 m then moderate to steep below that. The substrate consisted of both loose and consolidated rubble amongst large (living and dead) coral bommies. The hard substrate and coral communities gave way to silt at 6-8 m. Sites were surveyed in March 2004.

Shallow surveys

There was high cover of turf algae (50%) growing on long-dead coral skeletons. Cover of both hard coral (38%) and soft coral (9%) were marginally above average (Figure A). Unusually, the coral community was dominated by *Porites* spp. (75%), mostly branching *P. cylindrica, P. nigrescens,* and sub-massive *P. rus*. *Pachyseris rugosa* was the only other common coral taxon. The *Porites* community was well represented across all size-classes including recruit-sized colonies and with some of the larger colonies well in excess of 1 m (Figure D). Overall the density of recruit-sized colonies was very low (Figure C). Species richness was also well below average (Figure B), with only 8 species of *Acropora* and 9 species within 5 genera of Faviidae, both low values for these taxa.

Incidence of recent coral damage was limited to the observation of 11 *Drupella* gastropods and associated scarring.

Deep surveys

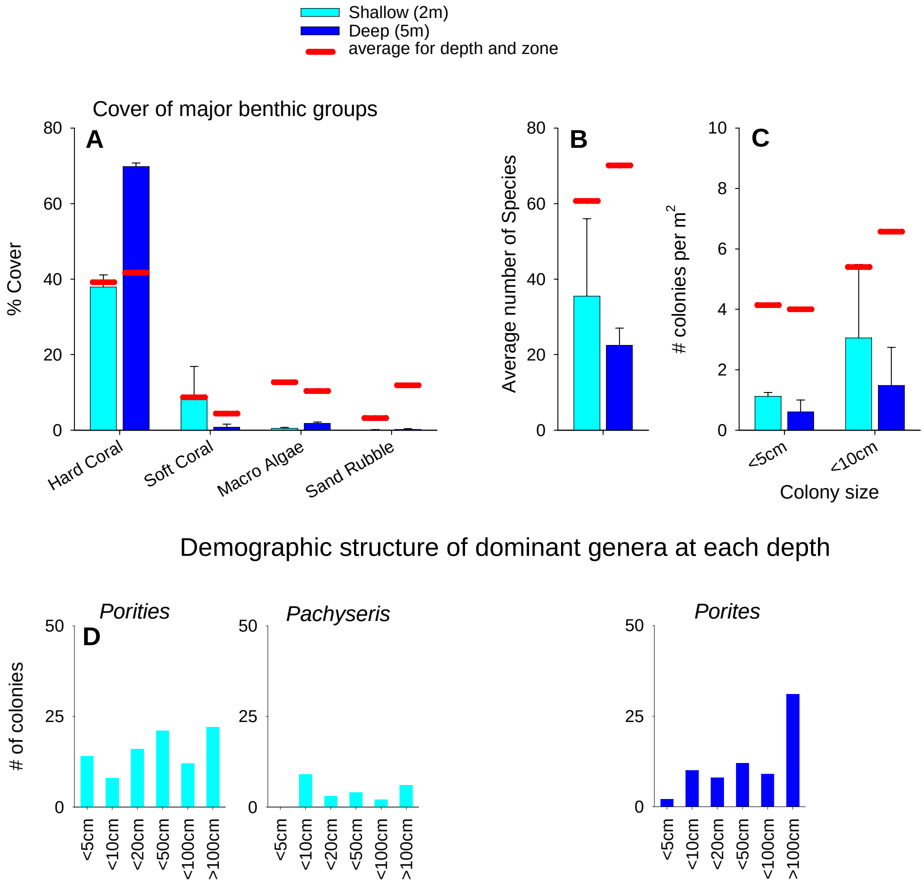
Hard coral cover at 70% was very high (Figure A). The coral community was dominated by large colonies of *Porites rus* with *P. cylindrica* also common and together accounting for 96% of the coral cover. Over 43% of *Porites* colonies were greater than 1 m across (Figure D) with several colonies in excess of 4 m. Sub-massive and branching *Porites* were dominant in this location. Recruit density was very low (Figure C) with only 16 recruits (<10 cm), 12 of which were *Porites* spp. Species richness was also very low with only 22 species of coral recorded (Figure B) making this location one of the least diverse communities in the surveys in 2004.

Incidence of recent coral damage was limited to the observation 4 *Drupella* gastropods with associated scarring, and a minimal amount of anchor damage.

Summary

While cover was high on the deeper slope the overall effects of bleaching and likely crown-of-thorns starfish infestation between 1998 and 2000 are evident in the very low species richness and dominance by *Porites*, a genus resilient to bleaching and not favoured by COTS. The very low recruit density, the low species richness and continued very low cover of *Acropora* spp. (a group that dominated the shallow slope prior to bleaching in 1998; Ayling and Ayling 2005) suggested that low recruitment shaped the community at this location. The reasonable proportion of recruit-sized *Porites* colonies may result either from higher larval supply via self-seeding or from fragmentation.

Frankland Islands (back reef)



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King Reef

A mainland fringing reef extending toward the coast in the lee of two isolated rocky outcrops some 5 km from the shore. We investigated areas along the edges of the main reef platform and found surrounding depths of only 2-3 m and very little evidence of living coral communities. Our sites were situated on the seaward (eastern) faces of the two offshore rocky outcrops. The slopes here consisted mainly of rock substrate with only small areas of solid carbonate substrate. There were areas on the deep slope where the substrate was mainly rocky boulders <50 cm in maximum dimension. The rocky substrate gave way to sand at 6 m. Sites were surveyed in May 2004.

Shallow surveys

The main component of the benthic community was macroalgae (41% cover) with cover of both hard coral (5.5%) and soft coral (0.1%) extremely low (Figure A). The remaining substrate was rock with a covering of turf algae. Of the hard coral community the genus *Turbinaria* showed the highest cover though this occupied less than 2% of the available space.

The hard coral community was dominated by small colonies (Figure D) with only 2% of colonies >50 cm and none >1 m. Recruit density was slightly below average (Figure C) with *Turbinaria* spp. accounting for 40% of all colonies <10 cm in maximum dimension. Species richness was also below average (Figure B).

Incidence of recent damage to the coral community included the observation of just one *Drupella* gastropod with associated scarring, very minor anchor damage and a few partially bleached colonies.

Deep surveys

Hard coral cover increased with depth though at 23% was still below average (Figure A). Correspondingly cover of macroalgae decreased with depth to below-average cover of 7%. As on the shallow slope the genus *Turbinaria* (11%) had the highest cover of any hard coral genus, and here, accounted for almost half the coral community cover.

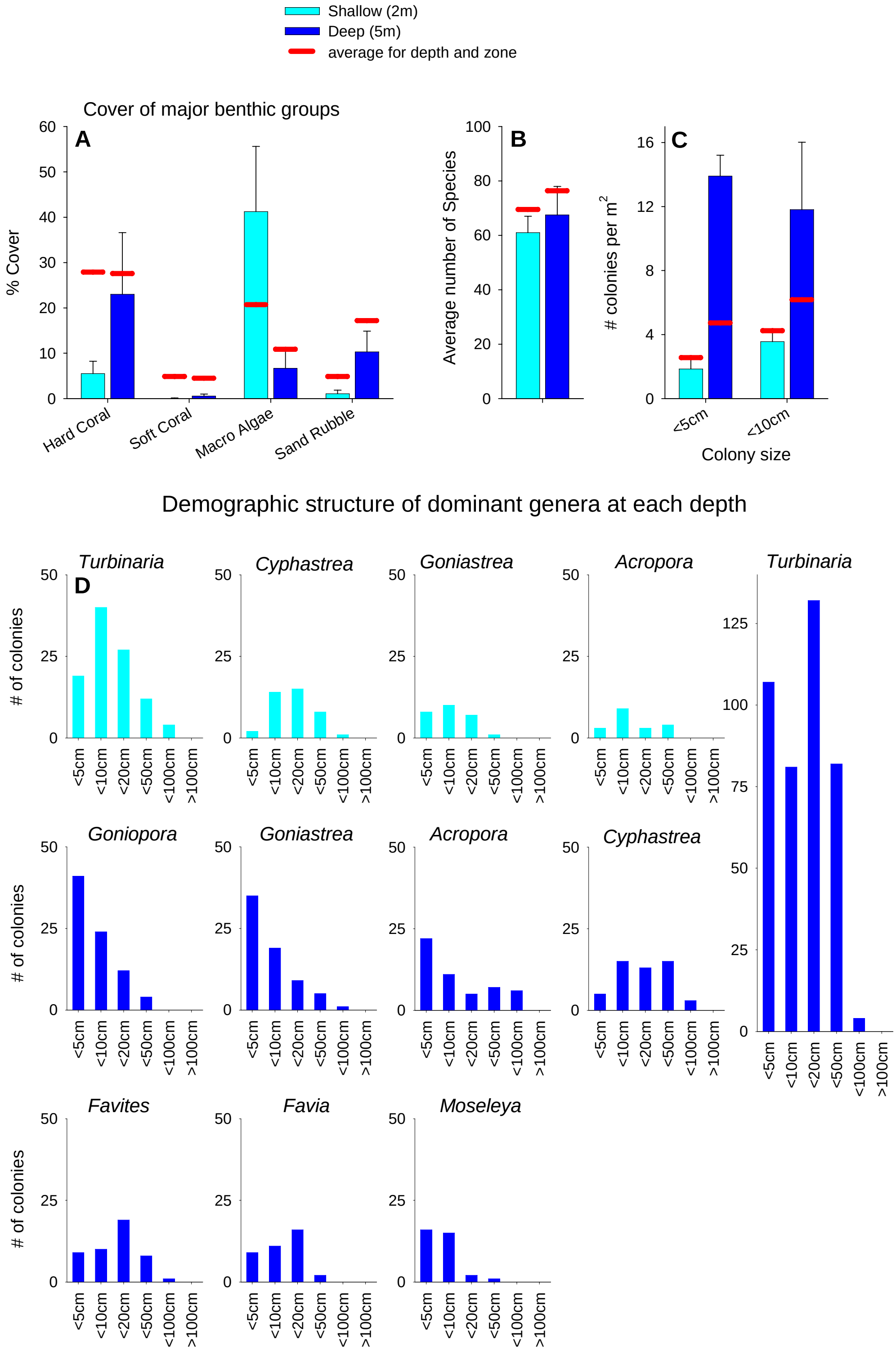
As on the shallow slope, the coral community was dominated by small colonies with only 2% of colonies >50 cm in maximum dimension and none >1 m. A small number of large *Diploastrea* were recorded in close proximity to the site. Recruit density was the highest of any location surveyed due to exceptionally high densities of *Turbinaria*, though several other genera had reasonable recruit densities (Figure C and D). Species richness was slightly below average.

Incidence of recent mortality and damage was moderate with 25 Drupella gastropods and associated scarring, 7 colonies infected with “white syndrome” and 4 with “brown band disease” along with low numbers of colonies showing partial bleaching and anchor damage.

Summary

The low coral cover and truncated size structure of the community indicates a community that has been recently and severely disturbed. The very high recruit density, near average species richness, and spread of colonies across at least several of the smaller size-classes indicates that this location can support complex coral communities. The lack of substantial carbonate substrates suggests that coral communities at this site, while obviously viable in the short term, are subject to periodic removal. There are consistent anecdotal reports that this location supported a rich coral community, including large stands of branching *Acropora* spp., as recently as the 1980s. During this study only a few very small colonies of branching *Acropora* spp. were recorded on our sites and a broad reconnaissance of the general reef area did not locate any other stands of this coral type. In the absence of further disturbance the coral community should continue to develop as the abundant small colonies grow and others recruit. There was little evidence of a return to the *Acropora* dominated community reported from the past.

King Reef



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Dunk Island (front reef)

Fringing reef on the southern side of the island with well-developed reef flat. The moderate slope has outcrops of reef frame work in the form of large live and dead massive coral colonies supporting diverse coral communities, interspersed with patches of sand, silt and rubble. The coral community runs to a silty substrate between 5 and 7 m. Sites were surveyed in May 2004.

Shallow surveys

Macroalgae, principally *Sargassum* spp., was the most noticeable component of the benthic community, accounting for 32 % cover (Figure A), filamentous turf algae (39%) was also high. Cover of both hard coral (20%) and soft coral (0.7%) were below average (Figure A) though these may have been underestimated due to the cover of macroalgae. Tabulate, branching and corymbose forms of the genus *Acropora* combined were the most common component of the coral community representing approximately a third of the cover. Massive *Porites* spp. and encrusting *Montipora* spp. were also well represented (15% each). Species richness was above average (Figure B) with the genus *Acropora* (14 species) and the family Faviidae (24 species from 10 genera) well represented.

Acropora spp. colonies were the most numerous and represented across all size-classes with 13% >1 m in maximum dimension. Other genera with large numbers of colonies included *Cyphastrea, Favites, Favia, Galaxea, Montipora* and *Porites* (Figure D). That 45% of colonies were under 10 cm size resulted in the well above-average recruit density (Figure C).

Incidence of recent impacts to the coral community was limited to a few instances of anchor damage.
Deep surveys

Cover of macroalgae declined markedly from 32% to 4.4% between the shallow and deep sites (Figure A). Hard coral cover (38%) was above average (Figure A). The coral community was diverse with a number of taxa well represented though none was dominant. The main components of the community were *Porites* (11%), *Turbinaria* (10%), *Montipora* spp. (9%) and *Favia* spp (8%). Species richness was above average (Figure B) with the families Faviidae (33 species from 12 genera), and Fungiidae (9 species from 6 genera) notably diverse.

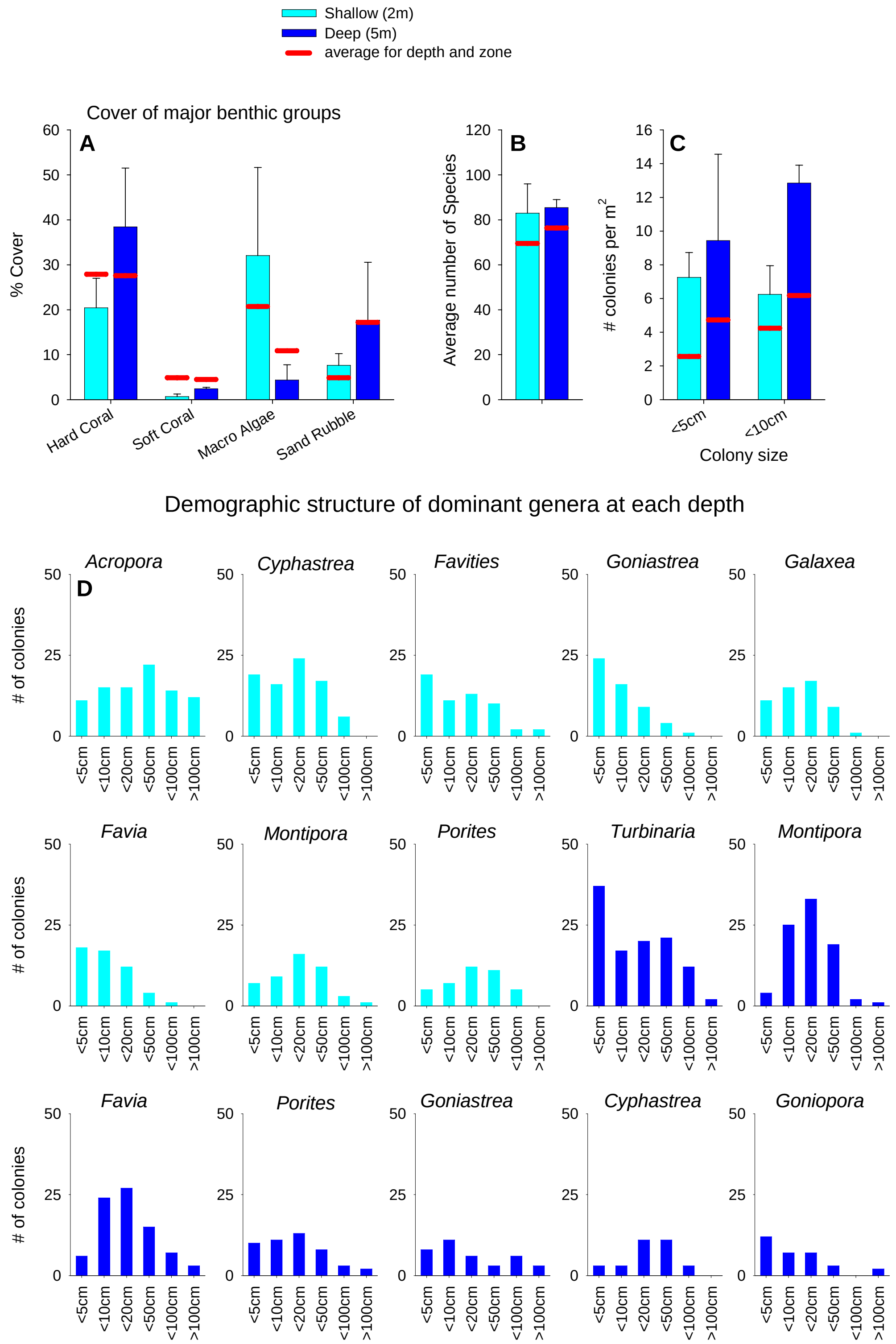
With no one taxa dominant, a number of genera were represented by large numbers of individual colonies (Figure D). Size of colonies was mostly less than 1 m though several very large colonies of *Pachyseris speciosa* and one colony of *Caulastrea furcata* that exceeded 5 m were recorded. Recruit density was well above average (Figure C) with a number of genera including numbers of recruit-sized colonies (Figure D).

Incidence of recent impacts to the coral community was limited to minor bleaching of a few colonies at one site.

Summary

The relatively low proportion of >1 m size colonies at this location indicates disturbance within the last decade. The level of recruitment along with the abundance and taxonomic diversity of colonies suggests the coral assemblage is slowly expanding at the expense of the algal community on the shallow slope. In the absence of further severe impact these same community attributes, along with the already moderately high coral cover, give a prognosis for the maintenance of a diverse coral community on the deeper slope.

Dunk Island (front reef)



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Dunk Island (back reef)

Fringing reefs lacking substantial reef development. Sites included the northeast corner of Purtaboi Island and a section of the northern side of Dunk Island. The substrate was predominantly granite at both sites, with a thin veneer of living corals and dead coral skeletons interspersed with sand silt and rubble. With increasing depth the rocky structure gave way to rubble beds and gorgonian gardens; sloping towards a base of sand, silt and seagrass at 5-7 m. Sites were surveyed in May 2004.

Shallow surveys

The coral community at each back-reef site reflected the different habitats found along the sheltered side of Dunk Island. At Site 1, turf algae was dominant (56%) and hard coral cover was moderate (38%), while at Site 2 (Purtaboi Is) hard coral cover was high (70%). Cover of both soft corals and macroalgae was very low at both sites (Figure A). Within the coral assemblage cover of tabulate and branching *Acropora* spp. accounted for a high proportion of the community at 41% and 31% respectively.

Coral colony numbers were high with *Acropora* spp. the most abundant, though several other genera were well represented (Figure D). A large number of large *Acropora* spp. (>1 m) indicates some resilience to past disturbance, particularly at Site 1. Recruit density was high (Figure C) particularly among species of *Goniastrea* and *Turbinaria* (Figure D) with the majority of recruits (75%) found in Site 1. Species richness was also above average (Figure B) with *Acropora* (19 species) particularly diverse.

Evidence of recent impacts to the coral community included the observation of 10 *Drupella* gastropods with associated scarring, two colonies with ‘white syndrome’ disease and a few colonies showing signs of bleaching.

Deep surveys

Hard coral cover decreased with depth to be below average at 27%, conversely cover of both soft coral and macroalgae were higher than on the shallow slope (Figure A). The hard coral community was a mixture of *Montipora* spp., *Acropora* spp., and *Turbinaria* with 52% of colonies belonging to these three genera.

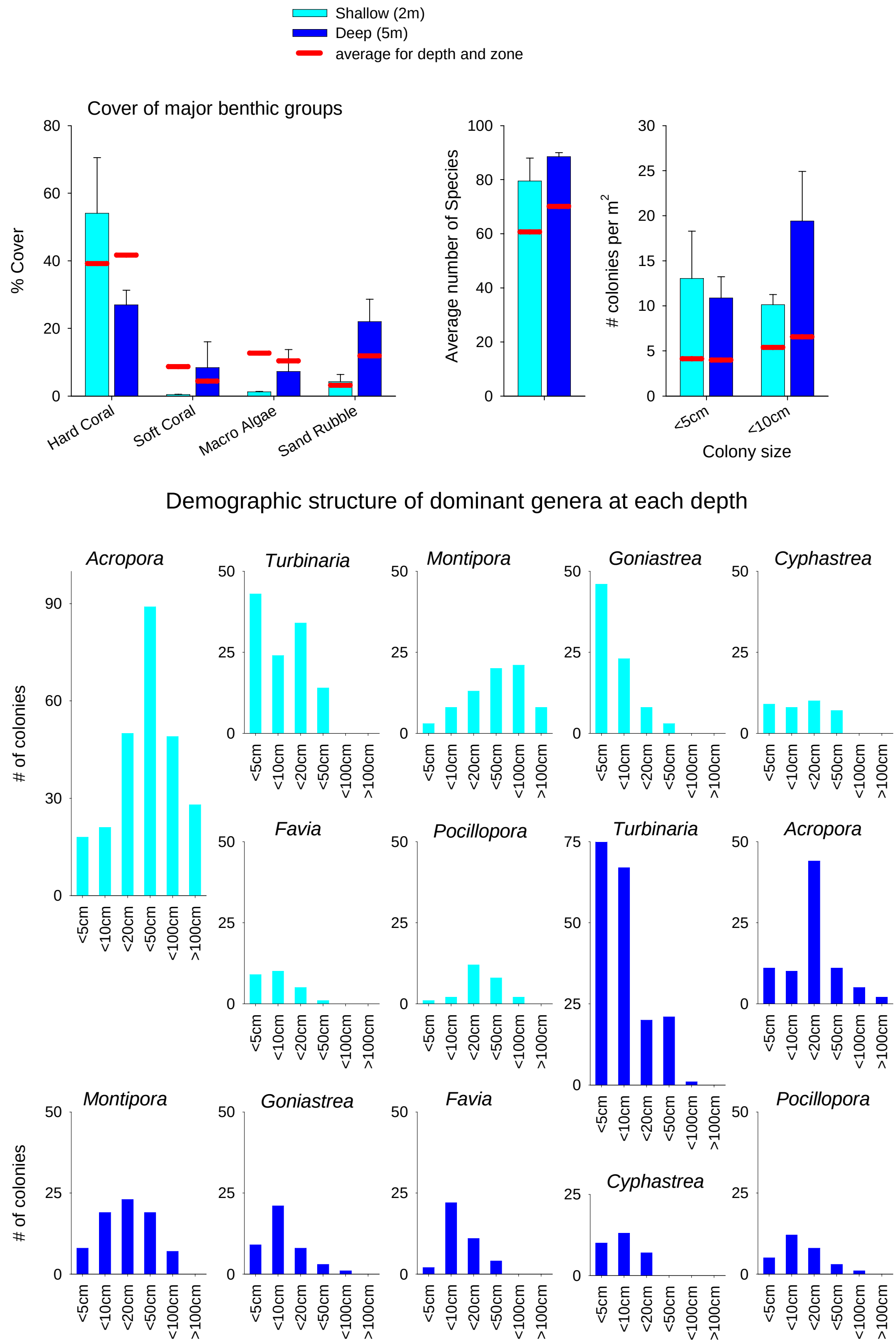
There were few colonies greater than 50 cm (Figure D), suggesting mortality among the coral assemblage within the last five to ten years. Species richness and recruit density were both above average (Figures B and C). *Turbinaria* had by far the highest number of recruit-sized colonies though a large number of 10-20 cm *Acropora* colonies suggests a good recruitment pulse for this genus several years ago (Figure D). Numbers of species in the genera *Acropora* and *Montipora* and the family Faviidae are all higher than average.

Incidence of recent coral mortality included observation of 8 *Drupella* gastropods with associated scarring, a coral colony with ‘black death’ disease, a few partially bleached colonies and anchor damage to a small number of colonies

Summary

The site at Purtaboi Island revealed a very healthy coral community especially on the shallow slope with high cover and average colony size, particularly within the genus *Acropora*. Although the shallow site on Dunk Island itself and the deeper slope had lower coral cover the high recruit density across a range of taxa indicate the potential development of a diverse coral community. The lack of reef development along with anecdotal observations of disturbance from as early as the early 1900s (Banfield 1908) indicate that coral communities in this location are at best transient.

Dunk Island (back reef)



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Pandora Reef

A small isolated reef sheltered between the Palm Islands and mainland. The back reef slope continues a moderate gradient to a depth of 12 m and is primarily composed of small patches of hard substrate amongst mounds of rubble with patches of silt increasing with depth. The unusual depth of the coral community afforded the survey of an addition 8 m depth at this reef. Sites lie along the northern slope of the reef and correspond to AIMS long-term monitoring sites such that Site 1 (5 m) of this study is adjacent to Site 2 AIMS LTMP and Site 2 (8 m) of this study is adjacent to AIMS LTMP site 3. The shallow sites also correspond to a similar habitat surveyed by Dr Terry Done (AIMS) for the last two decades. Sites were surveyed in March 2004.

Shallow surveys

Hard coral covered just 9% of the total substrate with soft coral (40%), turf algae (28%) and macroalgae (17%) all common (Figure A). Of the soft coral community encrusting *Briareum* sp. and *Clavularia* sp. made up 62% and 37% of the cover respectively. The hard coral community consisted mainly of scattered colonies of the genera *Fungia*, *Turbinaria*, and fewer *Acropora* and *Porites*.

There were few large colonies amongst the hard coral community with (97%) of colonies less than 50 cm diameter. The density of recruit-sized colonies was high (Figure C) though a high proportion of these were *Fungia* (Figure D) , which limits the possible increase in cover from growth of these small colonies. Species richness was low (51 species) across all coral groups.

A scuba search reported no coral predators, disease or damage.

Deep surveys

With increasing depth the cover of soft coral was markedly reduced (Figure A) though composition was similar to the shallow slope with *Briareum* sp. (67%) and *Clavularia* sp. (17%) the main components. Hard coral cover showed the opposite trend, increasing to 35% (Figure A) though cover was patchy (65% at Site 1 vs. 5% at Site 2). The difference in hard coral cover between sites was largely reflected in differences in macroalgae cover (1.5% Site 1 vs. 60% Site 2). High hard coral cover at Site 1 was largely the result of very large colonies of *Goniopora* with 59% of the hard coral cover made up of this genus. *Porites* (16%) and *Turbinaria* (12%) were also major components of the community at this depth.

While 11% of the individual hard coral colonies were >1 m in maximum dimension (including *Goniopora*, *Porites* and *Turbinaria*), this figure obscures the dominance of the community by these large colonies as some of the large *Goniopora* colonies were in excess of 4 m. These large colonies at Site 1 along with the high macroalgae cover at Site 2 no doubt influence the low estimate of species richness (Figure B). Recruit density was very low (Figure C) particularly considering that of the few recruits present 36% were free-living *Fungia.*

A scuba search recorded partial bleaching in a few *Goniopora* colonies and only three instances of 'white syndrome' disease.

Very deep surveys (8 m)

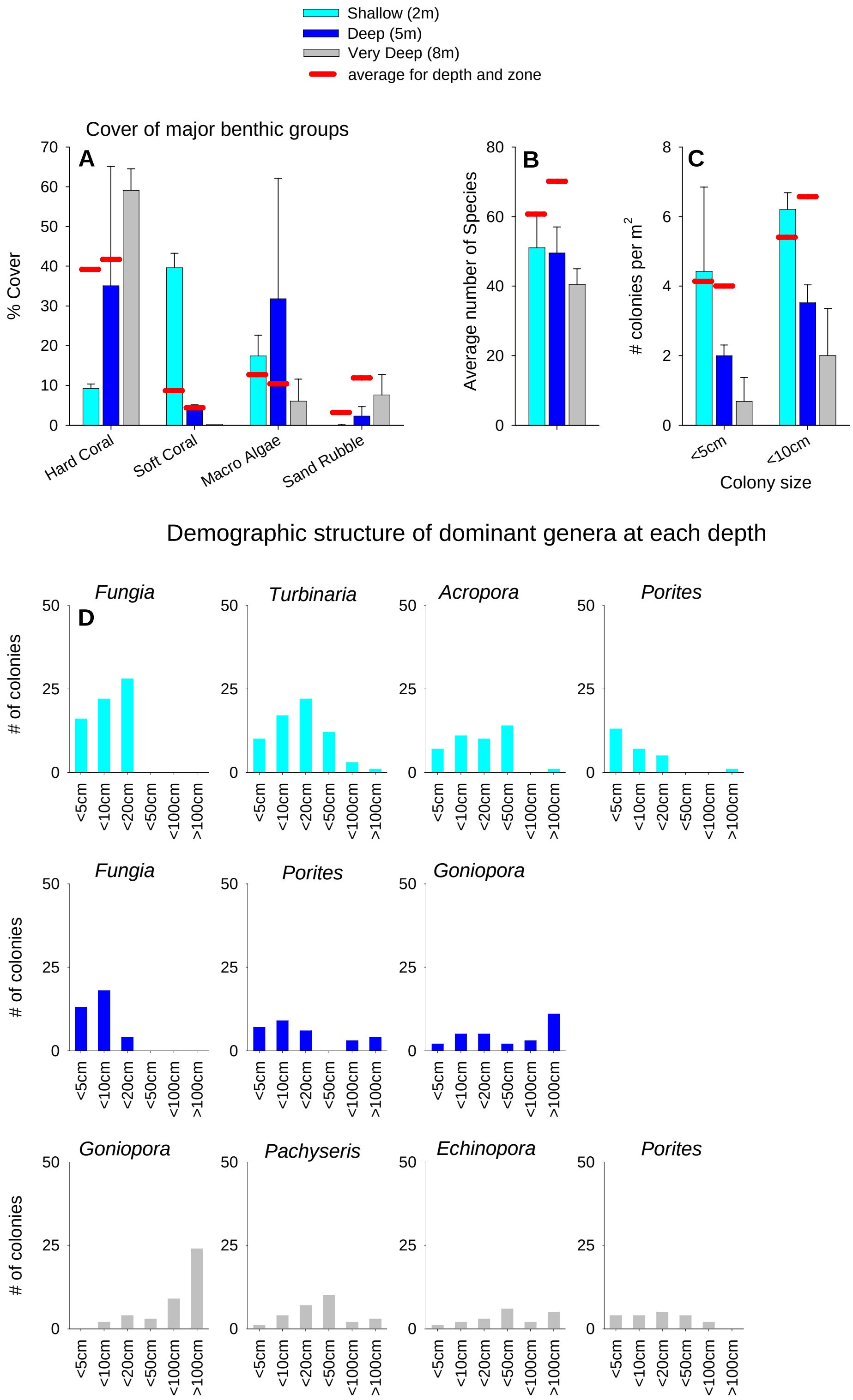
Hard coral cover was very high (59%) continuing the trend for increased cover with depth, similarly the decrease in cover of soft coral was also maintained with cover extremely low (0.25%) (Figure A). Hard coral cover was dominated by large colonies including *Goniopora* (61%), *Leptoseris yabei* (18%), *Echinopora* (7%) and *Pachyseris speciosa* (5%)

The hard coral community size structure skewed toward larger colonies because of these large colonies, with 25% of all colonies >1 m in size. Conversely the smaller size-classes are poorly represented (Figure D). This low proportion of smaller size-classes is reflected in a very low recruit density (Figure C). Species richness is also very low compared to the averages for shallower locations.

Summary

Increasing coral cover and colony size with depth fits with observations of past disturbance, particularly the 1998 bleaching event, when large stands of *Acropora* spp. and *Montipora* spp. that dominated the coral community on the shallow slope were killed (T. Done unpublished data). Overall mortality on deeper LTMP monitoring sites was lower though cover of the genus *Acropora* was greatly reduced. Even after the 1998 bleaching, coral cover on the deep slope continued to decline, possibly as a result of the passage of Cyclone Tessi in 2000. The higher recruit density on the shallow slope should see this community recover, though low numbers of the previously abundant *Acropora* and *Montipora* species may indicate a community shift, at least in the short term. The very large colonies on the deeper slope indicate a long period with little disturbance; should a disturbance occur, the relatively low recruit density and low species richness suggest recovery may be very slow.

Pandora Reef



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Nelly Bay

A large bay-head reef with extensive reef flat. The slope of this reef is gentle and mostly made up of loose coral rubble though there are areas of harder substrate formed by large massive corals. The slope extended to a sand-silt substrate at 5-6 m. Sites were surveyed in May 2004.

Shallow surveys

Macroalgae (mainly *Sargassum*) is seasonally dominant and still covered 23% of the bottom in this winter survey. Hard coral cover was high (56%, Figure A) and dominated by large colonies of foliose *Montipora* spp. that made up 56% of the cover. Branching and tabulate forms of *Acropora* spp. (23% combined) and foliose *Turbinaria* (12%) were also common components of the community.

The dominance in cover of the genera *Montipora, Acropora* and *Turbinaria* was reflected in the abundance of colonies with these genera representing 88% of colonies recorded. Further, the size structure of the community shows many large colonies of the genera *Montipora* and *Turbinaria* (Figure D). Lower numbers of small colonies give slightly below-average recruit density (Figure C). The low numbers of recruits at this location was surprising given the number of adult *Turbinaria* as at some other locations *Turbinaria* dominate the recruit population. Species richness was below average with the families Faviidae (9 species) and Poritidae (4 species) particularly low, there was a strong complement of *Acropora.* (19 species), *Montipora* (7 species) and *Turbinaria* (4 species).

Levels of recent or ongoing disturbance were moderate with a scuba search recording 12 *Drupella* gastropods, three colonies with 'white syndrome' disease, seven colonies with 'Brown Band' disease, scattered bleached colonies and signs of anchor damage.

Deep surveys

Towards the base of the reef slope (5 m) the gradient flattened out and the proportion of sand and rubble increases. Hard coral cover while still high (42%) was lower than on the shallow slope (Figure A). The coral community was dominated by the genus *Turbinaria* (55%) with *Porites* (13%), *Montipora* (11%) and *Acropora* (10%) also reasonably common. Macroalgal cover (10%) was also lower than on the shallow slope (Figure A).

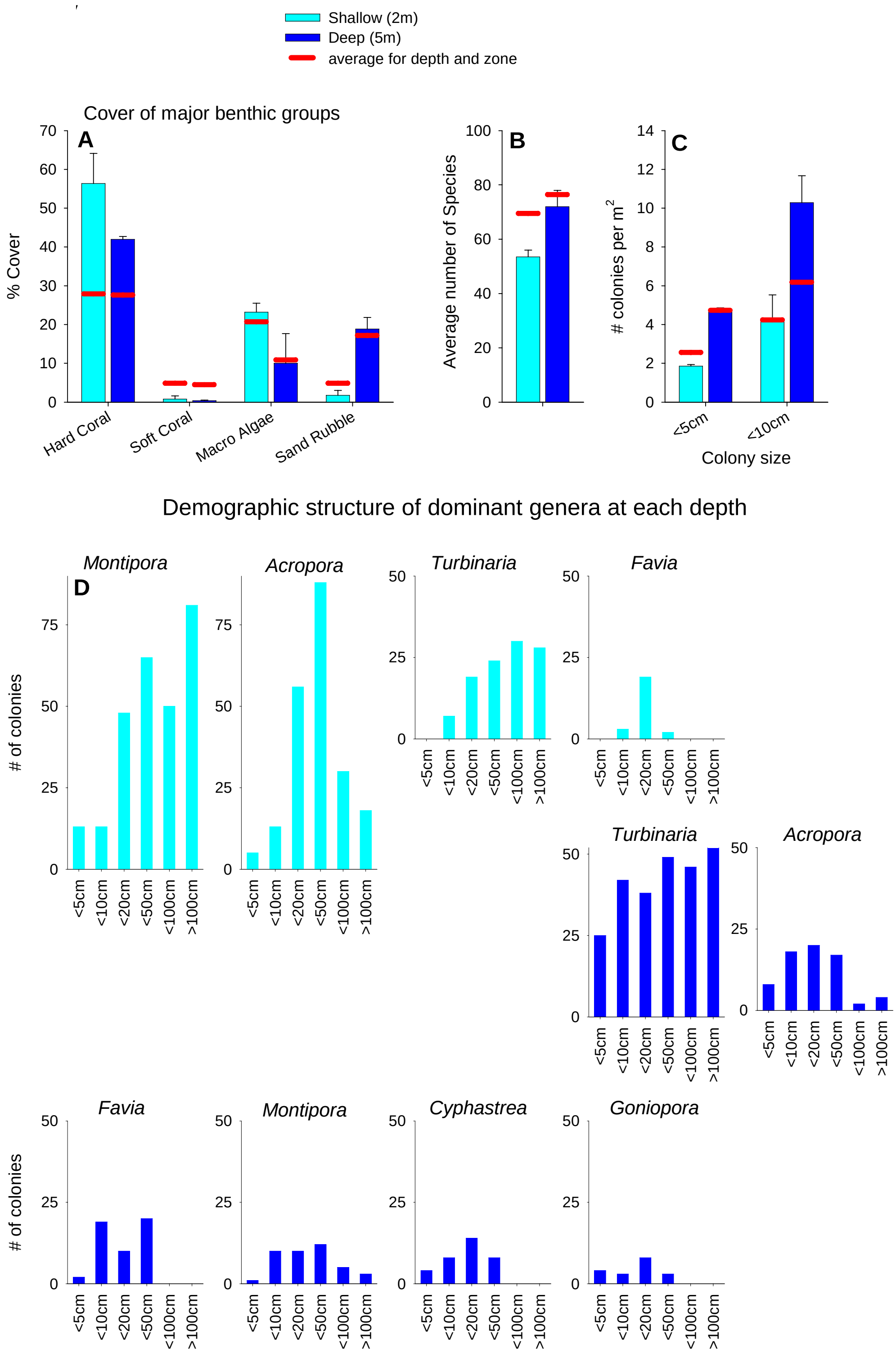
Turbinaria was the most common genus representing (46%) of the colonies. The genus included many large colonies as well as large numbers of recruits (Figure D) and largely accounts for the above-average recruit density (Figure C). While *Acropora* spp. (tabulate and corymbose) and *Montipora* spp. (encrusting) were also represented across the size categories, they were much less common than on the shallow slope (Figure D). Species richness was slightly below average (Figure B).

A scuba search of the location recorded a moderate number of *Drupella* gastropods (26) with associated scarring, one colony with 'Brown Band' disease, some individual colonies exhibiting bleaching, and minor anchor damage.

Summary

Nelly Bay has been monitored since 1989 (Ayling and Ayling 2005). Over the period 1989 to 1998 coral cover increased from 30-40% to over 60% due largely to increases in *Acropora* spp. and *Turbinaria* spp. Cyclone Tessi in early 2000 reduced cover to 1989 levels. Cover again increased over a short period before a further though minor setback due to bleaching in 2002. Interestingly the impact of bleaching and disease has generally been lower at Nelly Bay than the adjacent Geoffrey Bay. This is reflected in comparatively larger colony sizes and higher coral cover. Good coral cover, along with moderate recruit density and a history of recovery, give confidence in the resilience of the coral community in this bay.

Nelly Bay



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Geoffrey Bay

A large bay-head reef. The sites are situated along the slope of a broad reef flat. The reef slope has a gentle gradient down to 6 m and, though there are small areas of solid substrate, the majority of the slope is composed largely of unconsolidated piles coral rubble, interspersed with patches of sand that become more common with depth. Sites were surveyed in August 2004.

Shallow surveys

The most striking feature of the shallow community was the macroalgae cover (66%), mainly prostrate *Dictyota* spp. Hard coral cover at 11% was low (Figure A) and composed mostly of foliose and encrusting *Montipora* sp. (54% of the coral cover). Branching, tabulate and corymbose *Acropora* spp. (combined 12%) and massive *Porites* (12%) also contributed to the cover. While some large colonies of *Montipora* spp. were present the majority of hard corals (89%) were less than 50 cm in maximum dimension (Figure D). Recruit density was slightly above average (Figure C) with *Montipora* spp., *Acropora* spp. and *Cyphastrea* spp accounting for 60% of the recruit-sized colonies. Species richness is slightly lower than average (Figure B), and while both *Acropora.* (15 species) and *Montipora* (9 species) are reasonably diverse richness of the family Faviidae (12 species) is particularly low.

A scuba search of the location recorded two *Drupella* gastropods, and several *Montipora* spp. colonies exhibiting patches of bleaching under pockets of sediment.

Deep surveys

As on the shallow slope macroalgae was dominant (37%) (Figure A), here composed of a decaying brown algae (*Sporochnus* sp.) that presents as a fibrous green mass clinging to parts of the substrate and coral colonies. Hard coral cover was low (17%). The coral assemblage was mixed, with the genera *Turbinaria* (19%), *Acropora* (11%), *Porites* (10%) and *Favia* (8%) contributing most to cover estimates. Low coral cover was an artefact of the generally small colony size rather than low number of colonies with 90% of the colonies less than 50 cm in size (Figure D). Large colonies were limited to a few foliose *Montipora* sp. and *Pachyseris speciosa* though some large *Porites* were observed adjacent to the transects. The density of recruit-sized colonies was slightly above average, though colonies <5 cm were underrepresented (Figure C). Species richness was higher than on the shallow slope (Figure B) due mainly to high diversity of the Faviidae (32 species).

A scuba search of this location recorded seven *Drupella* gastropods and associated scarring, while some *Montipora* spp. colonies had patches of bleaching beneath pockets of sediment.

Summary

Reef slope communities in Geoffrey Bay have been monitored since 1989 (Ayling and Ayling 2005). The pertinent observations over this time are repeated declines in coral cover following coral bleaching events in 1992, 1998 and 2002, Cyclone Tessi in 2000 and most recently disease through 2002 and at least early 2003. In the period 1993 through to 1998 (the longest period without disturbance) the cover of all major coral groups showed marked increases. These increases were then eroded over the period 1998- 2003 with high mortality across a number of the larger deep slope coral species. The low numbers of large colonies and low coral cover in 2004 are a result of this period of disturbance, though the combination of reasonably high coral diversity and numerous small colonies indicate the potential for recovery at this location.

Geoffrey Bay

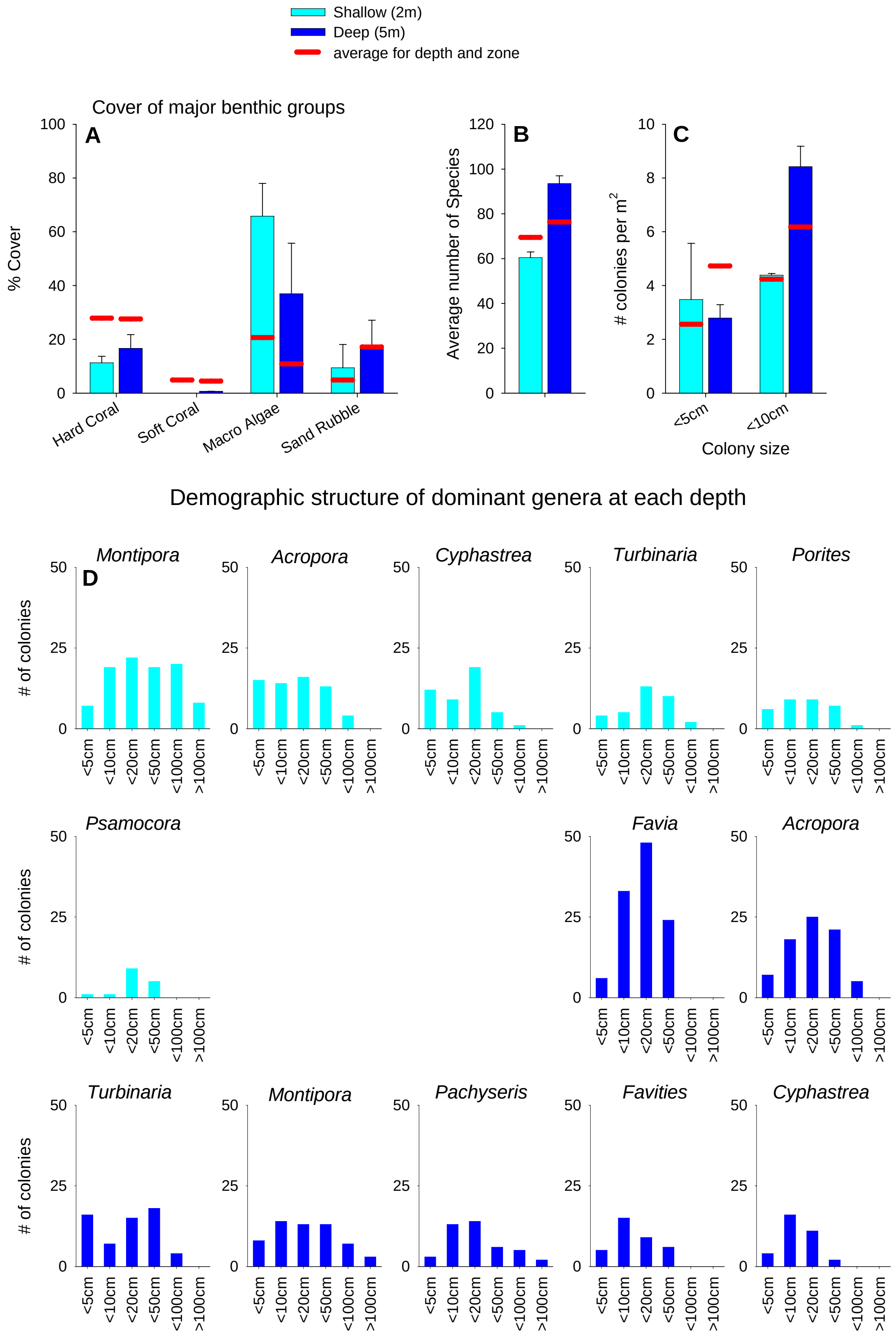


Figure A: The average percent cover of major benthic groups at each depth from video transects.
Figure B: The average species richness recorded during swim searches at each depth.
Figure C: The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm.
Figure D: The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Middle Reef

Sites were situated along the northern slope of this small patch reef. Surrounding waters are shallow with the reef slope meeting a silty bottom at 3-4 m and as such only shallow slope sites were sampled. The sites correspond to location of AIMS LTMP sites 1 and 2, though LTMP sites are deeper (3-4 m). The sites run along the top or side of large outcrops of hard substrate, predominantly formed by individual coral colonies, with areas of silt in between. Sites were surveyed in August 2004.

Shallow surveys

Hard coral cover was high at 51% (Figure A) and dominated by large colonies of *Goniopora* (63% of hard coral cover, with 43% of *Goniopora* colonies >1 m size), and *Pachyseris speciosa* (17% of hard coral cover, with 36% of *Pachyseris* colonies well >1 m in size). The majority of coral colonies (81%) were under 50 cm in size, most likely a factor of available space between these enormous colonies of *Goniopora* spp and *Pachyseris* spp. Recruit density was average (Figure C) with the majority of recruits (<10 cm size) of the genus *Acropora* (24%), *Favia* (16%) and *Turbinaria* (10%), suggesting the potential for a slight diversification of the community as these colonies grow.

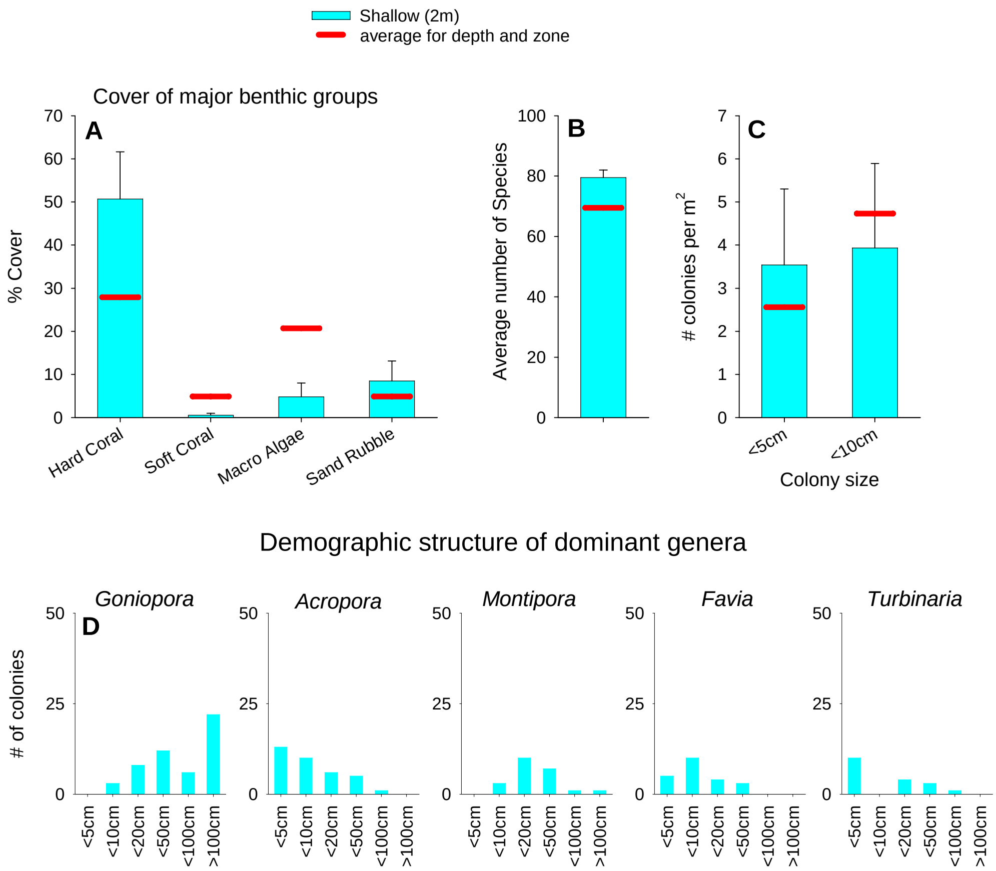
Species richness was slightly above average (Figure B) with the community including species more often found on the deeper slope. This may be an artefact of typically turbid waters and sheltered conditions.

Evidence of recent coral damage was limited to one colony infected with “white syndrome”, one other with ‘black death’ disease and a few small scars of unknown origin.

Summary

The coral cover on the shallow slope was slightly higher than on the adjacent AIMS LTMP sites a metre or so deeper, where coral cover has ranged between 27% in 2002 and 42% in 1999. The reduction in coral cover on the LTMP sites was probably caused by bleaching in early 2002 and Cyclone Tessi in 2000. The shallow slope community would have been similarly if not more severely impacted by these events. The presence of very large colonies of *Pachyseris* and *Goniopora* indicate the resilience of these colonies to these disturbances. The large number of *Acropora* spp. recruits suggests this group may rapidly increase on the shallow slope to add diversity to the community now dominated by large colonies of other genera. High cover of *Acropora* spp. occurred at these sites as recently 1997 when there was high mortality of *Acropora* spp. colonies from unknown causes (A Thompson, pers. obs.).

Middle Reef



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Black Currant Island

Black Currant Island is attached at low tide to the mainland at the northern end of Dingo Beach. The two sites run along the slope of separate sections of coastal fringing reef to the north (Site 1) and south (Site 2) of this island. The reef is characterised by a moderate to steep, solid carbonate slope leading down to rubble and silt at 3-4 m. Only shallow surveys were possible because of the limited depth at the reef base. Site 1 corresponds to “Champagne Bay” while Site 2 is some 200 m south of “Hideaway Bay”; these sites visited in December 1994 and reported in DeVantier *et al.* (1997). In these 1994 survey two depths, 0-2 m and 4-6 m were surveyed and as such it is likely the surveys reported in this present study were undertaken between these two depths. Comparisons to these earlier surveys included below represent the average of the two depths surveyed in 1994. These sites are also in the general area of sites visited by van Woesik and DeVantier (1992). Sites were surveyed in May 2004.

Shallow surveys

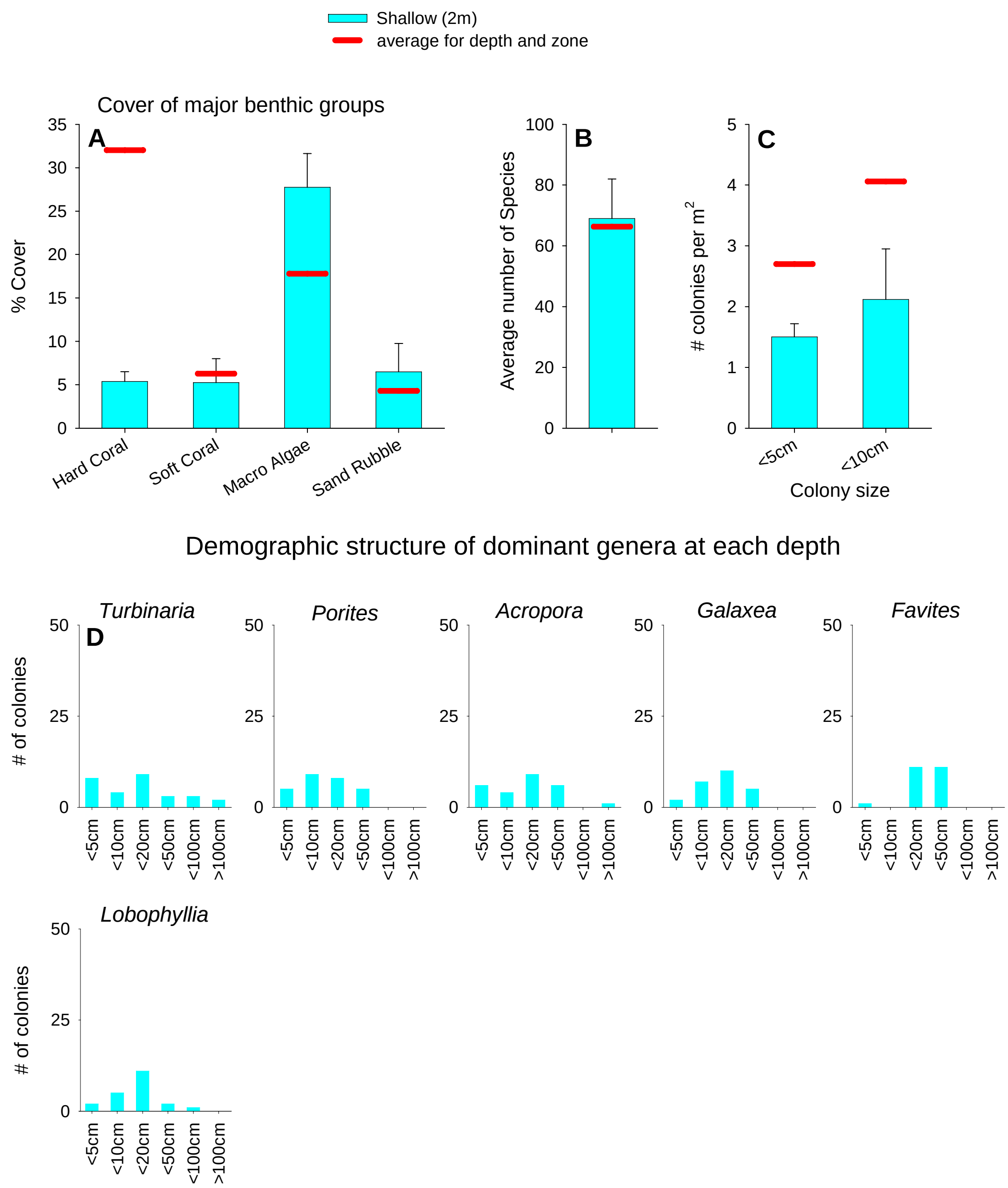
In the present survey, and both 1992 and 1994 surveys, the benthic community was dominated by macroalgae, (*Sargassum sp*.). The two earlier surveys recorded slightly higher cover (average greater than 40% vs. 28% (Figure A) though this was probably a seasonal artefact rather than a real decline in cover over the intervening decade.

Hard coral cover was very low (5%, Figure A). This value was lower than in either 1992 or 1994 when cover in similar areas averaged between 17% and 22%. The hard coral cover was not dominated by any one species, but contained similar proportions of *Turbinaria, Porites*, *Acropora* spp. *and Galaxea*. Comparison of data from Site 1 (2004) and Champagne Bay (1994) indicates reductions in the genera *Acropora* and *Montipora* that together accounted for over 70% of the hard coral cover in 1994 compared with just 7% in 2004.

Summary

The most likely cause of reduced coral cover over the decade 1994 to 2004 is coral bleaching associated with elevated sea surface temperatures in 1998 and possibly 2002. While total density of coral recruits is low (Figure C), over 70% of colonies are under 20 cm indicating some, albeit slow, recovery. *Montipora* spp. colonies, once dominant in the area, were conspicuously rare as were large colonies in general. Only 7% of colonies were over 50 cm (Figure D). This lack of large colonies may well be influencing the availability of recruits and as such rate of recovery. Despite the low coral cover and recruitment rate species richness was average (Figure B).

Black Currant Island



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Manta Ray Island

A fringing reef on the southern side of the island. Site 1 corresponds closely to Pelican Is. as reported in DeVantier *et al.* 1997, while Site 2 corresponds closely to Site 4 in van Woesik and DeVantier 1992. The sites had a shallow slope of consolidated rubble and dead *Acropora* spp. branches leading down to sand and silt at 5 m. Sites were surveyed in May 2004.

Shallow surveys

Turf algae occupied the highest proportion of the benthos (68%). Overall hard coral cover (12%) was low (Figure A). Of the hard coral community the genus *Acropora* accounted for the majority of coral cover (71%) and also a high proportion (42%) of coral colonies (Figure D). *Turbinaria* was the second most abundant genus in terms of colony density, though it only represented 8% of the coral cover. The density of coral recruits was low (Figure C) and while 15 genera were recruiting, 67% of recruits were either *Acropora* spp. or *Turbinaria*. Soft coral cover was slightly above average and dominated by *Sarcophyton* (46%). Species richness was very high compared to other shallow sites (Figure B). Diverse groups included the families Faviidae (44 species from 13 genera), Fungiidae (9 species from 5 genera), Mussidae (10 species from 2 genera), Pectiniidae (6 species from 4 genera), and genus *Turbinaria* (7 species).

Only a small proportion of colonies (14%) were greater than 50 cm in maximum dimension, the majority of these (69%) belonging to the genus *Acropora*.

Scuba search surveys revealed large numbers of Drupella and associated scarring and just one infection of “white syndrome”.

Deep surveys

The hard coral cover was slightly higher than at 2 m though at still low at 14% (Figure A). Again the coral community included a high proportion of branching and tabulate *Acropora* spp. that together accounted for 67% of the cover. Between coral colonies were large stands of *Sargassum* (macroalgae 28.5%, Figure A). Hard coral species richness was high (Figure B), with particularly diverse groups including *Acropora* (30 species), *Turbinaria* (9 species) and the family Faviidae (41 species from 11 genera).

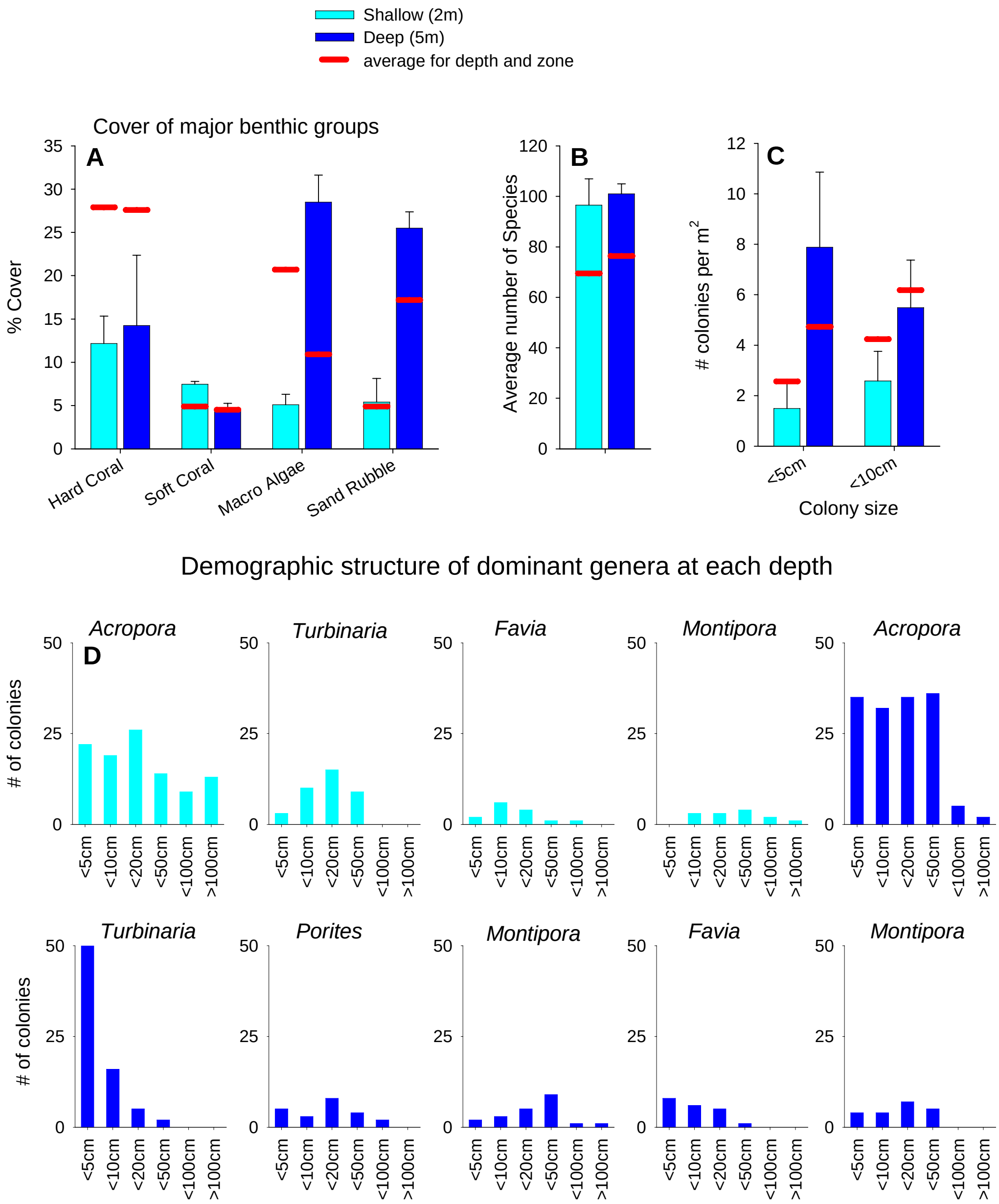
Density of recruit-sized colonies was well above average (Figure C) and included individuals from a wide range of taxa (28 genera). This high recruit density is reflected in the demographic structure of the coral community with 54% of individuals less than 10 cm in maximum dimension compared to just 4% greater than 50 cm diameter. 52% of the recruit-sized colonies where in the genera *Acropora* or *Turbinaria*.

Incidence of recent coral damage was low with 3 *Drupella* and associated scarring, 8 small scars of unknown origin and one case of “white syndrome”.

Summary

There has been a marked reduction in coral cover at site one from between 55% and 49% recorded in 1992 and 1994 respectively to the 15% estimated in 2004. DeVantier *et al.* (1997) reported the community having been dominated by *Acropora* spp. (93%) and while in 2004 the cover had been reduced, the dominance by *Acropora* spp. was maintained. It is likely that coral bleaching in 1998 caused the decline. Coral cover on the deeper slope in 1992 and 1994 was lower than at 0-2 m, with estimates of 40% and 16% respectively, while in 2004 the cover at 5 m was 22% and higher than at 2 m. While some of this variability is likely due to slight differences in depth and transect placement the results suggest that the deeper community was less disturbed or is recovering faster than the shallower slope community, higher recruitment rate and rarity of colonies >50 cm may indicate the latter.

Manta Ray Island



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Daydream Island

A narrow fringing reef without a fully developed reef flat along the NW side of the island. The sites were characterised by a shallow to moderate rubble slope at the base of rocky outcrops leading down to a silt below 8 metres. The sites coincide with sites 1 and 2 videoed by GBRMPA in April 1998 in response to coral bleaching. The shallow sites also coincide with the general area surveyed as site 6 in Fisk (1991). Sites were surveyed in May 2004.

Shallow surveys

The hard coral cover on the shallow sites (30%) was low average for near-shore shallow reef sites (Figure A). *Acropora* spp. (mostly branching) and *Montipora* spp. were the main components of the coral community accounting for 80% and 18% of the cover respectively. Cover of *Lobophyllia* and *Favia* was far lower than *Montipora* spp. despite higher colony densities (Figure D). This discrepancy reflected the relatively small size of these colonies (63% of *Lobophyllia* were under 10 cm while two thirds of *Montipora* spp. colonies were greater than 50 cm). Density of recruits was average (Figure C) with 34% of recruit-sized colonies in the genus *Acropora*.

Species richness was above average (Figure B) with particularly diverse groups including *Acropora* spp. (20 species), *Euphyllia* (4 species), Pectiniidae (7 species from 4 genera) and Faviidae (35 species from 14 genera).

A scuba search for damage to corals recorded 23 colonies with some form of partial mortality including nine with “brown band disease”, three with “white syndrome” and 11 with scarring of unknown cause. The scuba search also reported low numbers of the gastropod *Drupella*.

Cover of soft corals (10%) was slightly above average and mainly consisted of the genera *Sinularia* and *Sarcophyton*.

Deep surveys

The hard coral cover on the deep sites was high (56%, Figure A). As on the shallow slope the community was dominated by *Acropora* spp. (75%) and *Montipora* spp. (13%). In between colonies were patches of silt (8%) and turf algae (31%). The size of the *Acropora* spp. colonies was generally large with 40% of the colonies counted >1 m (Figure D). There were also large numbers of *Acropora* spp. recruits with 20% of colonies smaller than 10 cm; this contributing strongly to the above-average density of recruit-sized colonies (Figure C). Species richness was higher at this site than any other deep site visited with richness of *Acropora* spp. (29 species) and Faviidae (40 species from 12 genera) particularly high.

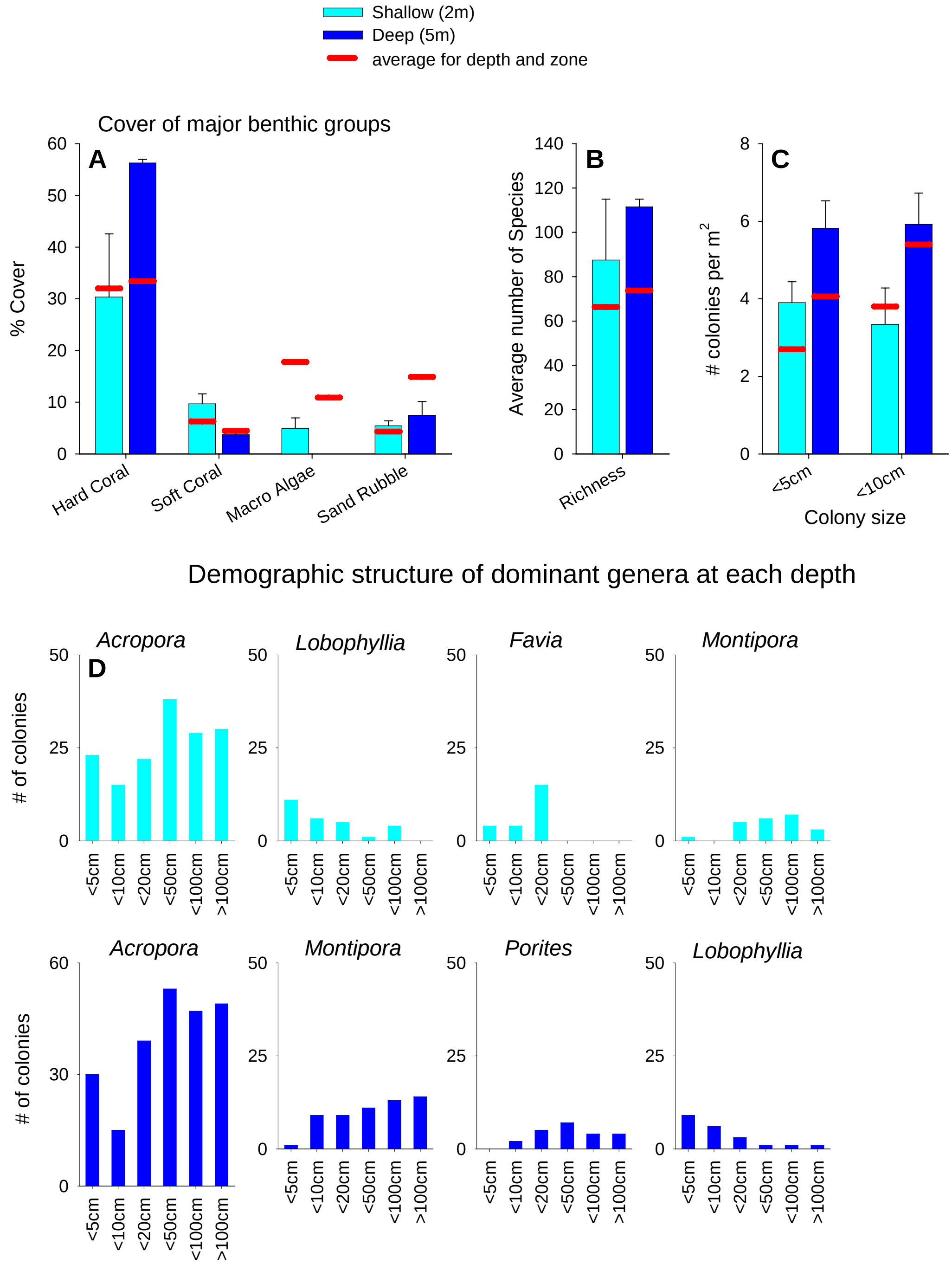
Incidence of damage to corals was high with 57 colonies on scuba search transects showing some form of partial mortality including 12 with “brown band disease”, 15 with “white syndrome” and 30 with scarring of unknown origin.

Summary

In 1990 surveys of the shallow reef slope (2-3 m) in the general area covered by these sites reported a community with 44.5% coral cover that was dominated by branching *Acropora* spp. (Fisk 1991). At this time damage to the coral community from anchoring was noted. In April 1998 cover was down to 36% though given the possibility of slightly different transect depth and position this is not considered substantial. By September 1998 cover was down to 20% due to mortality associated with the 1998 thermal bleaching event. By 2004 cover had increased to 30%. The level of disease, together with unexplained scarring may be reducing the overall rate of recovery.

The deep community was not affected by bleaching in 1998, with cover estimates similar in April (60%) to post bleaching in September (65%). The reduction to 56% cover may be due to slight differences in transect positioning though the high incidence of disease and unexplained scarring may have contributed to this decline.

Daydream Island



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Shute and Tancred Islands

A single fringing reef site on the southern tip of each island was selected and these combined to form the survey location. The reef slope had a moderate gradient and consisted of both loose and consolidated rubble slope with some coral outcrops. The coral community gave way to sand and silt below 5-7 meters. Site 1 and 2 shallow correspond to sites 30 (closely) and 31 (general area) sampled in 1992 and reported by van Woesik and DeVantier 1992. Sites were surveyed in May 2004.

Shallow surveys

The benthic community consisted of almost even proportions of hard coral (30%), soft coral (28%) and turf algae 30% with sand and rubble making up the remainder (Figure A). Macroalgae were noticeably absent. *Acropora* spp. (44%) and *Goniopora* (24%) dominated the hard coral community though a number of other genera were moderately represented (Figure D). The size structure of the coral community showed colonies spread over a range of size-classes (Figure D) with both small recruits and larger sized individuals present, and a high density of coral recruits (Figure C). The diversity of the coral community was high with the average of 100 species per site (Figure B). *Sinularia* (50%) and *Sarcophyton* (29%) dominated the soft coral community.

Incidence of ongoing mortality was low with only eight colonies recorded with partial mortality. Two colonies were infected with “white syndrome”, three colonies had “skeletal eroding band”, two scars of unknown origin and the feeding scar of one *Drupella* gastropod.

Deep surveys

At 24% hard coral cover was below average and lower than on the shallow slope. Cover of hard coral would be limited by the high proportion (29%) of soft sediment (plotted as sand and rubble, Figure A). *Acropora* spp. was the main component of the hard coral community accounting for 27% of the coverage with the remaining community comprised of a number of moderately abundant genera including *Porites* (9%), *Goniopora* (8%), *Montipora* (8%), *Pachyseris* (6%), *Pectina* (6%), *Lobophyllia* (5%) and *Pavona* (4%). The presence of a wide range of genera is reflected in the high species richness (Figure B). Recruit density is low (Figure C) as reflected in size structures of the most common genera where numbers of <5 cm and <10 cm individuals are low. Soft coral cover (10%) while above average (Figure A) was lower than on the shallow slope though similarly composed of mainly *Sarcophyton* (44%) and *Sinularia* (25%). Macroalgae was absent.

Summary

Comparison of the shallow community at Site 1 with 1992 indicates cover of both hard and soft coral in 2004 was very similar to that recorded in 1992. The slightly above-average coral cover, high diversity and high recruitment all indicate the potential for future increases in coral cover at this location. On the deep sites the high diversity and numerous genera that include large individuals attest to the lack of recent disturbances and the ability of corals to survive in this environment. The below-average coral cover and low recruit density suggest that recruitment is limited. If this is the case, recovery from any future disturbance event may be slow.

Shute and Tancred Islands

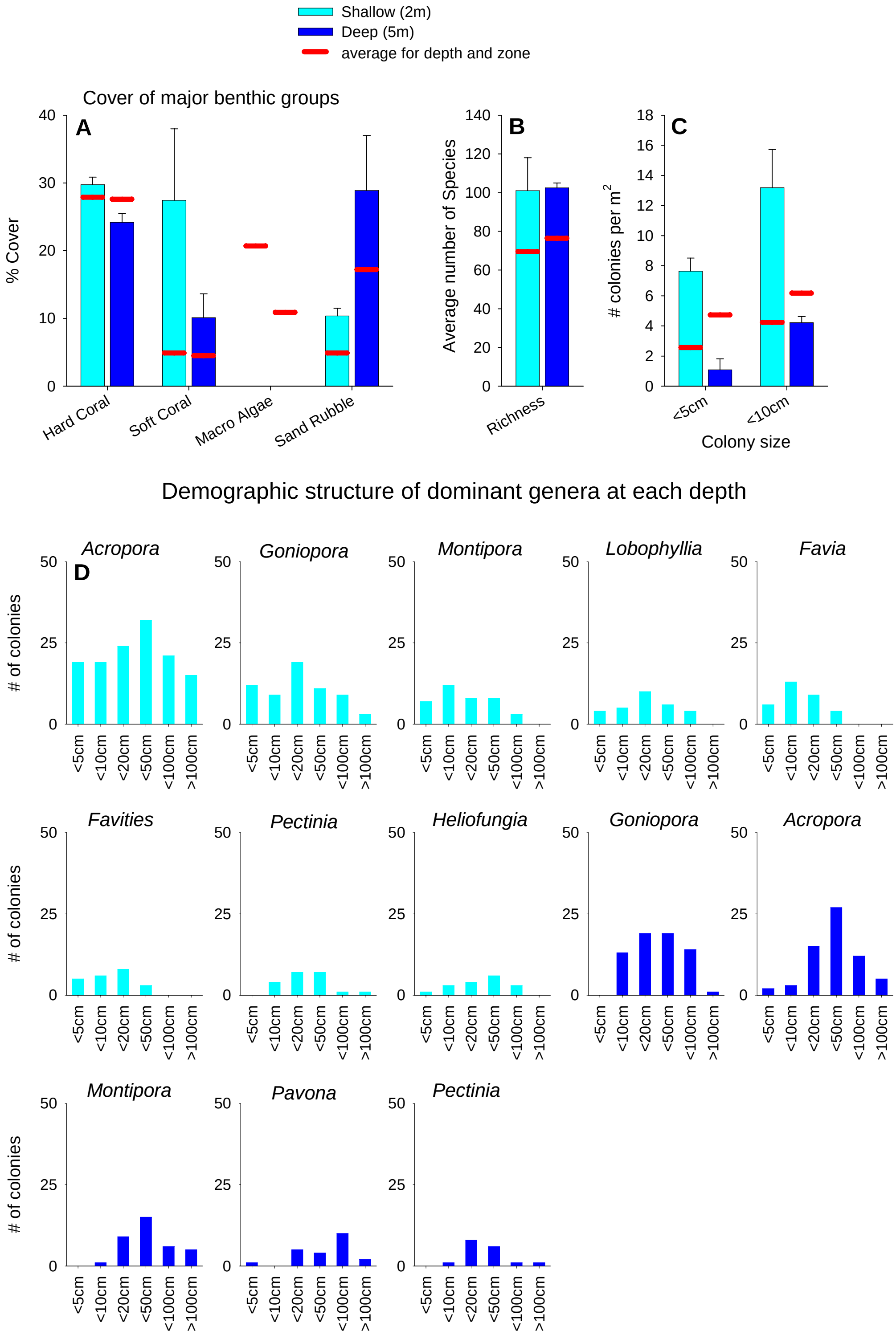


Figure A. The average percent cover of major benthic groups at each depth from video transects. **Figure B.** The average species richness recorded during swim searches at each depth. **Figure C.** The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm. **Figure D.** The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Pine Island

Sites were on a fringing reef with a narrow (15-40 m) reef flat extending from a boulder-strewn shoreline on the western side of the island. From the reef crest the slope dropped steeply into at least 20 m of water. The coral community gave way to silt below 8 m. Sites were surveyed in May 2004.

Shallow surveys

The benthic community was mostly turf algae (45%) and hard coral (44%) with low cover of soft coral, macroalgae and sand/rubble (Figure A). Cover of hard coral varied substantially from 24% at Site 1 to 64% at Site 2. The main components of the coral community were *Galaxea* (54%), *Acropora* spp. (18%) and *Montipora* (7.5%). 46% of the *Galaxea* colonies were greater than 1 m, with several exceeding 3 m. This explains how 9% of the individual colonies made up 54% of the total coral cover. In contrast *Porites* colonies were small with 71% less than 10 cm so although this genus had most individual colonies (Figure D) they made up only 2% of the coral cover. Moderate numbers of *Acropora* spp. and *Porites* recruits contribute to the above-average density of recruit-sized colonies (Figure C).

Species richness was well above average (Figure B) with Euphyllidae (5 species), Faviidae (32 species), Fungiidae (9 species) and Pectiniidae (9 species) families with above-average species richness estimates.

Incidence of disease was low with 8 colonies infected with “white syndrome” and two with “black death”. A further 5 had scarring of unknown origin.

Deep surveys

As with the shallow sites the benthic community was mostly of turf algae (48%) and hard coral (42%) with c very low over of soft coral and macroalgae (Figure A). Again hard coral cover varied among sites (31% Site 1 vs. 53% Site 2). The coral community was diverse with a number of genera contributing including; *Galaxea* (20%), *Goniopora* (15%), *Pectinia* (12%), *Pachyseris* (10%), and *Acropora* (9%). The size distributions of the various genera differed markedly with *Galaxea* and *Pachyseris* and to a lesser degree *Pectinia* mainly represented by large colonies while *Acropora*, *Goniopora* and *Porites* included many recruit-sized colonies (Figure D).

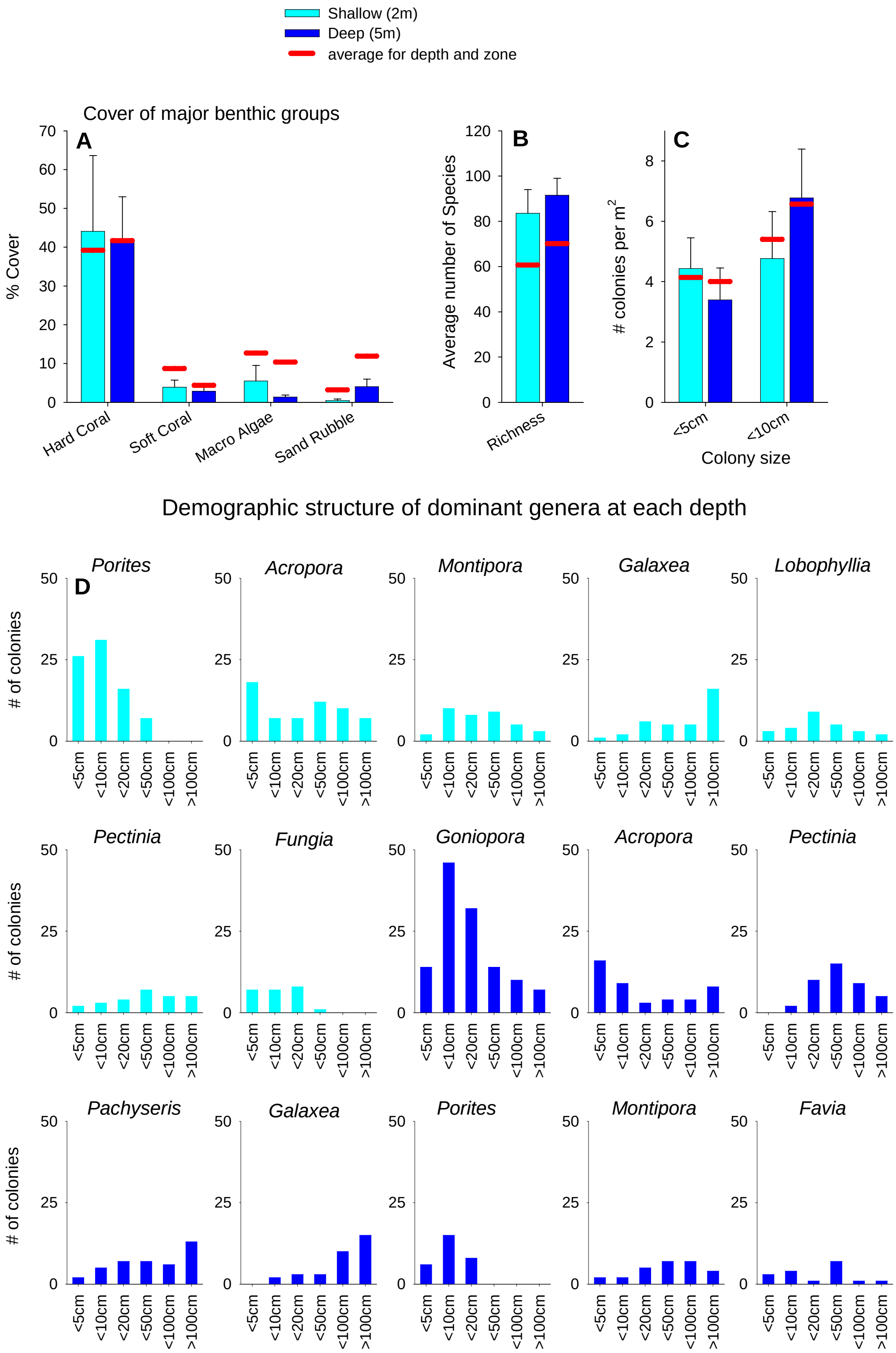
Species richness in deeper sites was well above average (Figure B) with Euphyllidae (5 species), Faviidae (33 species), Fungiidae (11 species) and Pectiniidae (7 species) well represented.

Incidence of coral recent mortality was low with 4 colonies infected with “white syndrome”, one with scarring of unknown origin, and a few partially bleached colonies.

Summary

The two sites at this reef had totally different coral communities although they were only a few hundred meters apart and in very similar physical settings. Site 2 was dominated by large *Galaxea* colonies that had been relatively undisturbed for many years, whereas the rubble slope of Site 1 showed evidence of dominance of *Acropora* spp. in the past. The numbers of recruit-sized colonies at each site suggested that the differences in community would be maintained with recruitment at Site 1 showing a return to an *Acropora/ Montipora/ Porites* community. Of the 50 *Acropora* spp. recruits (<10 cm), 84% were found at Site 1 with similar disproportions in recruitment for *Porites* spp. (88% Site 1), *Montipora* spp. (92% Site 1) and *Goniopora* spp. (95% Site 2). At the opposite end of the size spectrum, there were colonies >1 m from 11 genera, although only four genera were common among sites. This location is an example of the differences in community type that can occur over very small distances.

Pine Island



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Calf Island

Calf Island shares a reef flat with Cow Island that extends from the mainland. The reef slope had a shallow to moderate gradient and consisted mostly of small granite boulders with rubble and silt between. The boulders and associated coral community gave way to silt below 6 m. These sites are located between sites 45 and 46 as reported in van Woesik and DeVantier 1992. Sites were surveyed in May 2004.

Shallow surveys

The benthic community was dominated by macroalgae (74%), predominantly *Sargassum,* with very low cover of both hard coral (7%) and soft coral (1%) (Figure A). The high cover of *Sargassum* will have caused some underestimate in the cover of the coral community due to overshadowing on the video image. Field observations suggest that coral cover was very low irrespective of algal cover. The demographic structure of the community (Figure D) highlights the predominance of small individuals with 67% of colonies under 20 cm compared to less than 2% >1 m. The fact that the recruit density is below average even though a high proportion (34%) of colonies are classified as recruits is testament to the depauperate coral community. Despite low cover and colony numbers species richness is slightly above average (Figure C). High species richness in the family Faviidae (34 species in 9 genera) and the genera *Goniopora* (6 species) and *Turbinaria* (8 species) contribute to this result.

Incidence of recent or current mortality was limited to two colonies with scarring of undetermined origin.

Deep surveys

While still high, cover of macroalgae (29%) decreased with depth. Sand/silt and rubble (29%) and turf algae (24%) were well represented, while cover of soft corals (6%) was average for deep slope sites (Figure A). Hard coral cover on the deep slope (9%) was also very low (Figure A). *Porites* (2% of the reef surface) accounted for 22% of the coral community. *Goniopora,* the only other genus covering more than 1% of the reef surface, made up 14% of the community. The size structure of the coral community was skewed toward small colonies with 82% of individuals less than 20 cm (Figure D). This is reflected in slightly above-average recruit density (Figure C). *Turbinaria*, *Goniastrea* and *Goniopora* were all recruiting well at this depth (Figure D). Large colonies were very rare with only 2 *Porites* and 1 *Acanthastrea* colony measuring >1 m in maximum dimension.

Incidence of recent or current mortality was limited to 3 colonies with scarring of undetermined origin.

Summary

Surveys in 1992 in similar depths but at sites on either side of those described above reported a similar dominance of macroalgae (van Woesik and DeVantier 1992). At that time coral cover was very low with estimates of 1-2% at the four site/depth combinations. Given these results there is the potential that, although low, coral cover may have increased slightly since 1992. Certainly the levels of recruitment should lead to higher cover in future years. The low numbers of large colonies and limited accumulation of carbonate substrate on the granite suggests that the coral community here develops opportunistically between disturbance events rather than persisting for long periods of time.

Calf Island

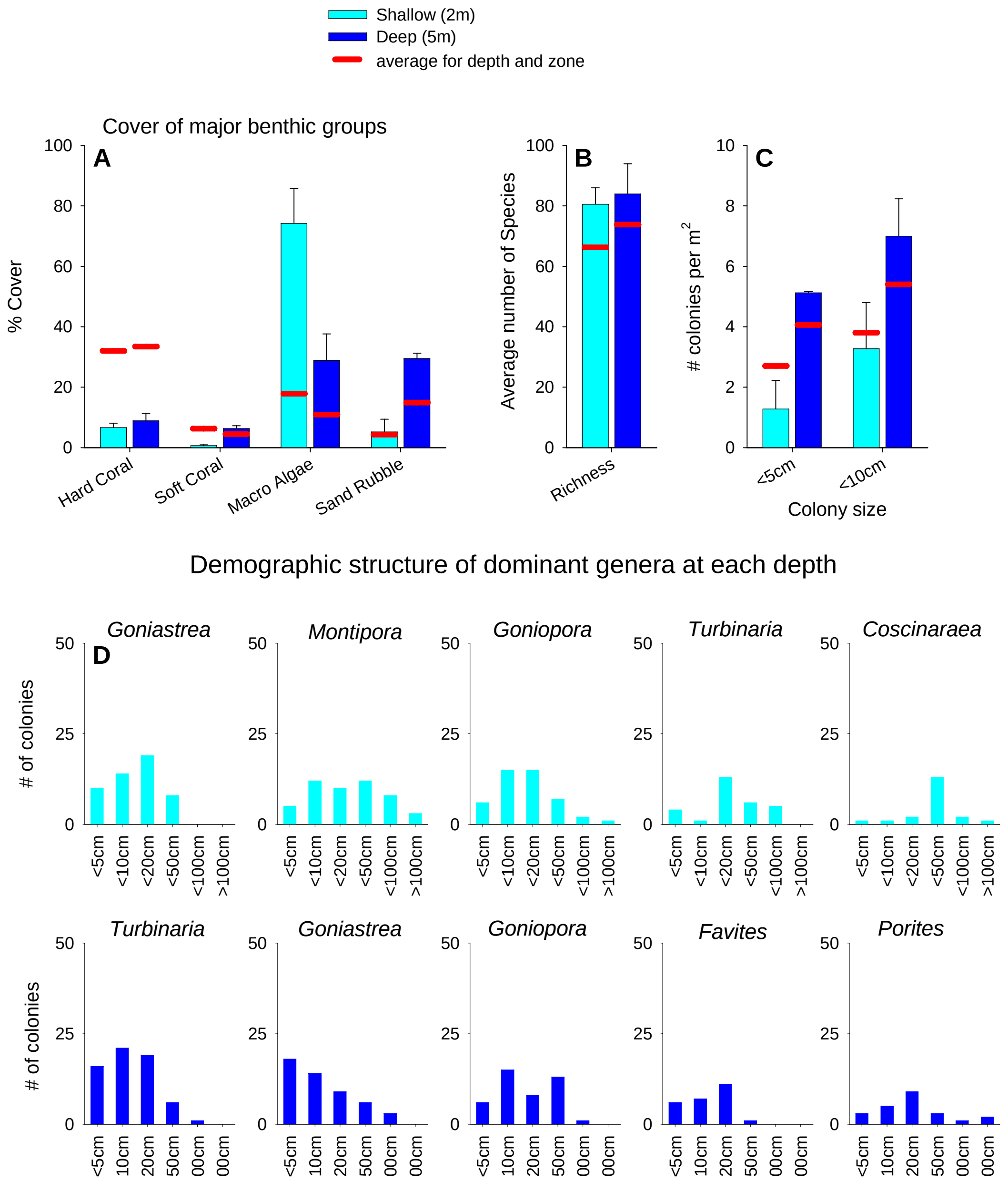

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Figure C. The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm.
Figure D. The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

St. Bees Island

A fringing reef that extended a variable distance from the northern side of the island. The shallow depth at Site 1 ran across a deep reef flat with scattered bommies. The deeper slope at this site was moderate. Site two ran along a convoluted section of reef slope made up mostly of the vertical sides of large bommies with many overhangs and a sandy floor at 7 m. Sites were surveyed in June 2004.

Shallow surveys

The dominant components of the benthic community were macroalgae (46%) and turf algae (27%). Hard coral cover was well below average at 8% (Figure A). Soft coral was also low at 5% and mainly in the *Briareum / Rhytisma* group (66%). The genera *Porites* (38%) and *Montipora* (23%) were the main constituents of the hard coral community though these only covered 3% and 2% of the substrate respectively. No other coral genera covered more than 1% of the reef surface. The size structure of the coral community was not obviously skewed toward either large or small colonies (Figure D), rather there were low numbers of colonies in each size-class. This is reflected in a very low density of coral recruits (Figure C). With such low coral cover it is not surprising that incidence of damage to the coral community on scuba search transects was low, with only 3 scars of unknown origin and 2 colonies infected with “white syndrome” recorded.

In contrast to low cover, species richness of hard corals was well above average (Figure B). Higher than average richness within the families Agariciidae (4 species), Faviidae (36 species) and Mussidae (6 species) contributed to this.

Deep surveys

The deep slope benthic community also had high cover of both macroalgae (45%) and turf algae (22%). Cover of both hard coral (13 %) and soft coral (4%) was low (Figure A). From video transects *Merulina* (15%), *Montipora* spp. (13%) and *Acropora* spp. (11%) made up the highest proportions of hard coral cover, though *Merulina* covered a maximum of 1.8% of the reef surface, so could hardly be considered a dominant part of the community. From the demographic transects *Merulina* was present as just a few large colonies. This predominance of large colonies was evident throughout the limited coral community with over half the genera recorded on demographic transects including individuals in excess of 50 cm. The only genus with over 20 individuals recorded on demographic surveys was *Montipora* though several of these were large individuals (Figure D). Recruit density was very low (Figure C). With such low coral cover it is not surprising that incidence of damage to the coral community on scuba search transects was low, with only 2 scars of unknown origin and 1 colony infected with “white syndrome” recorded.

In contrast to low cover, species richness of hard corals was well above average (Figure B). Higher than average richness within the families Agariciidae (5 species), Faviidae (39 species), Mussidae (8 species) and the highest richness at any site for Siderastreidae (5 species) contributed to this result.

Summary

The low coral cover and low recruit density suggest this reef may be severely recruitment limited. This interpretation is further supported by high species richness and diversity of large individual colonies both of which suggest that once corals recruit the environment will support a diversity of species through to large size. The geographic isolation of this, and the neighbouring Keswick Island, may be partly responsible for low recruitment.

St. Bees Island

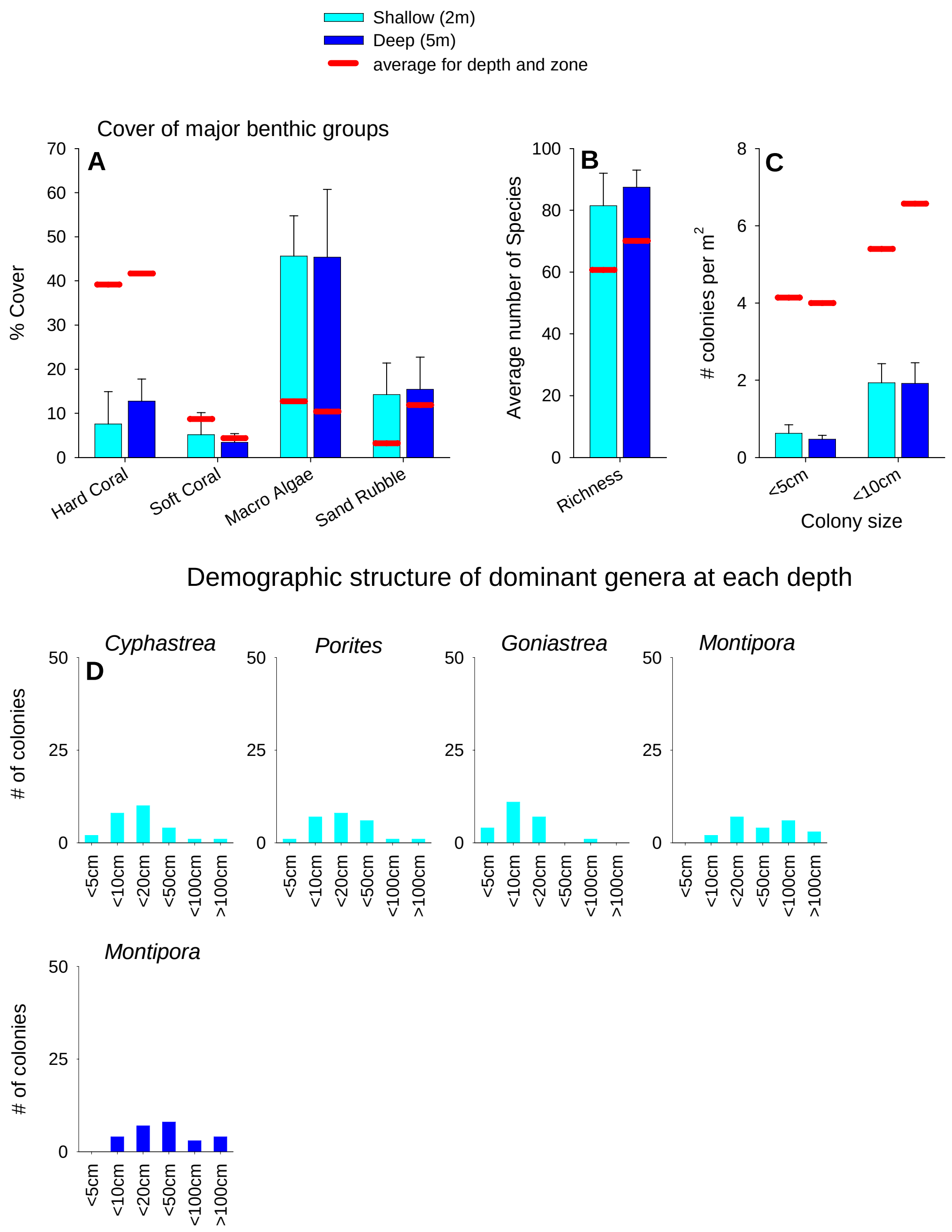

Figure A. The average percent cover of major benthic groups at each depth from video transects.
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Keswick Island A, Singapore Bay

Singapore Bay is on the southwestern edge of Keswick Island. Sites were located on the slope of the extensive bay head reef. The reef slope gradient was variable ranging from a gentle slope to scattered steep-sided outcrops. The substrate was solid carbonate reef framework that ran to sand at 6 m. Sites were surveyed in June 2004.

Shallow surveys

Cover of hard coral (10%) and soft coral (3%) was very low, though these values were almost certainly underestimated due to the high cover of macroalgae (52%, Figure A). Encrusting and foliose *Montipora* spp. (29%), *Porites* (17%) and *Acropora* spp. (15%) were the main constituents of the coral community. The size structure of the coral community was slightly skewed toward smaller colonies with only 17% of colonies larger than 50 cm. The majority of these were *Montipora* (Figure D). While 32% of colonies where less than 10 cm in maximum dimension and thus classed as recruits, recruit density was well below average (Figure C). Species richness was above average (Figure B). Higher than average richness in the families Faviidae (37 species), Mussidae (9) and Poritidae (11 species) contributed to this.

Incidence of damage to the coral community recorded during scuba search survey was low, with only 3 scars of unknown origin and 1 colony with “white syndrome”.

Deep surveys

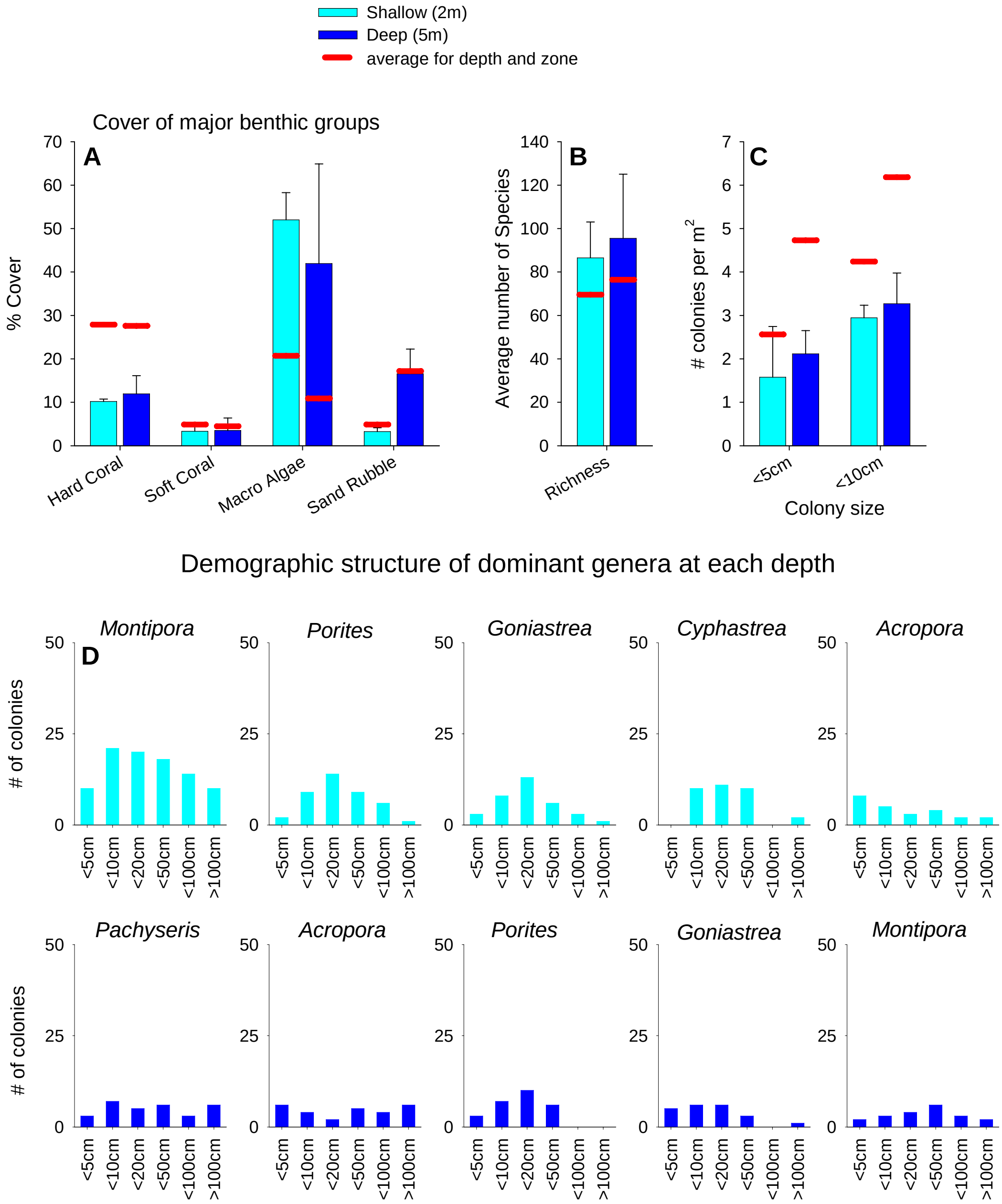
Cover of hard coral (12%) and soft coral (3%) was similar to the shallower slope (Figure A). While cover of macroalgae was lower (42%) than in shallower water this reduction was largely due to increased areas of sand toward the reef base (Figure A). Of the total hard coral cover *Acropora* spp. (20%), *Goniopora* (16%), *Montipora* spp. (14) and *Pachyseris* (8%) made up the greatest proportions. With the exception of *Goniopora* these same genera also had the highest number of individual colonies (Figure D). The size structure of the community as a whole showed a high proportion (43%) of colonies to be less than 10 cm diameter though larger colonies were recorded for most of the more common genera (Figure D). Despite a high proportion of recruit-sized individuals overall recruit density was low (Figure C) reflecting the low numbers of colonies. Species richness was high despite low scores for other aspects of the coral community. Higher than average richness in the families Mussidae (14 species) and Poritidae (11 species) contributed to this result.

Incidence of damage to the coral community included a moderate number of colonies (14) with scars of unknown origin and 5 colonies infected with “white syndrome”.

Summary

The low coral cover and low recruit density combined with the presence of large individuals from a number of species may indicate that these coral communities are a product of chronic low recruitment. It is possible that the high cover of *Sargassum* plays some role in limiting the coral community though the mechanism is unknown.

Keswick Island A, Singapore Bay



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Keswick Island C (back reef)

A section of fringing reef in Egremont Passage between Keswick Is. and St. Bees Is. The reef slope was characterised by large, steep sided, carbonate outcrops and smaller coral bommies leading to a sandy bottom at 6 metres. Sites were surveyed in June 2004.

Shallow surveys

Macroalgae (33%) and turf algae (24%) were the main components of the benthic community. Cover of soft coral was also high (19%, Figure A) with *Sinularia*, *Sarcophyton* and *Briareum* all common. In contrast, hard coral cover (14%) was well below average (Figure A). Of particular note is the extremely low recruit density of hard corals (Figure C). The community structure was skewed toward large colonies with 41% of colonies greater than 50 cm in maximum dimension compared to just 6% classed as recruits. Large colonies (>1 m diameter) were represented by 16 genera compared to just 6 genera with recruit-sized individuals (<10 cm). The only measure of the hard coral community that was above average was species richness (Figure B). High richness in the families Faviidae (34 species) and Mussidae (9 species) out-weighed lower than average richness of the typically diverse *Acropora* spp. (8 species) to give this result.

Very little recent disturbance to the coral community was noted with only 2 scars of unknown origin, 1 colony infected with “white syndrome” and a few colonies with partial bleaching recorded.

Deep surveys

Cover of macroalgae (31%) was marginally lower than on the shallower slope though this difference was due more to a higher proportion of sand and rubble than lower density of algal cover (Figure A). Soft coral cover (5%) was markedly lower than on the shallower slope and was about average for deep sites, in contrast hard coral cover (23%) was higher though still below average (Figure A). The genera *Goniopora* and *Alveopora* combined (these genera are difficult to separate on video transects) accounted for 67% of the coral cover and along with *Porites* (10%) meant that the family Poritidae dominated the hard coral community. *Goniopora* and *Alveopora* also had the highest number of individuals on demographic transects and both had size distributions skewed toward larger individuals (Figure D). While higher than on the shallower slope, recruit density of hard coral was still well below average (Figure B). Species richness was the only measure of the coral community to be above average for deep locations with higher than average richness in the families Poritidae, Faviidae, Euphyllidae and Mussidae all contributing to this result.

Incidence of recent disturbance to the coral community recorded during scuba search survey was limited to a very few partially bleached (slightly pale) colonies and one individual infected with “white syndrome”.

Summary

As with back reef sites at St. Bees Is. and the front reef site in Singapore Bay, Keswick Is, the coral communities in this location showed signs of chronic low recruitment, with low coral cover, very low recruit densities and coral populations skewed toward larger colonies. These sites all had high cover of macroalgae, this algal community may limit coral recruitment or early survival. Anecdotal reports from residents of Keswick Is suggested that algal cover increased dramatically toward the end of 2001 and has been seasonally abundant since.

Keswick Island C (back reef)

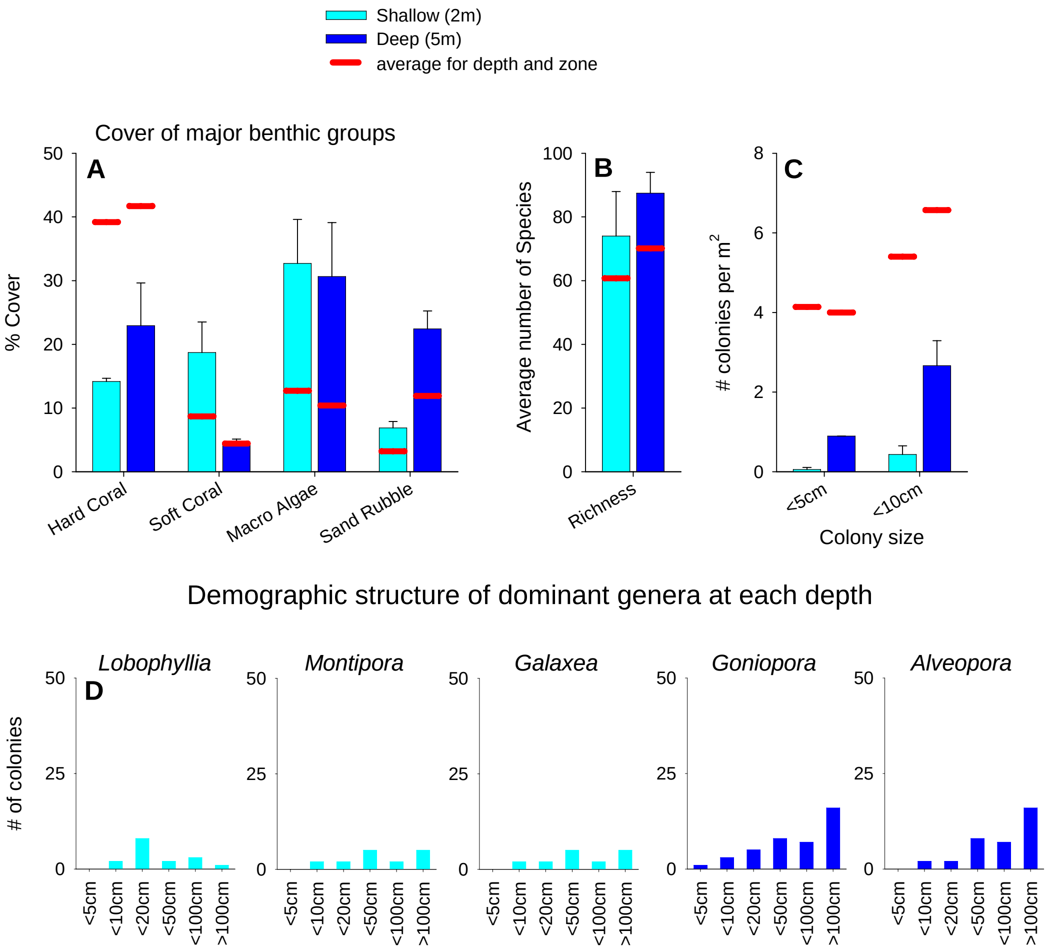

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Figure C. The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm.
Figure D. The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Keswick Island C (front reef)

A narrow fringing reef running into the southern end of Egremont Passage near the end of the Keswick Island runway. The reef slope was characterised by a shallow gradient with a few coral outcrops leading down to sand and rubble with scattered coral colonies at 4 to 5 m. Sites were surveyed in June 2004.

Shallow surveys

Of the four locations around Keswick and St. Bees Is, this was the only location where hard coral cover (36%) was above average (Figure A). It was also the only location were the genus *Acropora* dominated the coral community, accounting for 82% of the overall coral cover. Soft coral cover (10%) was also above average, while macroalgae cover was below average (13%, Figure A) in contrast to other nearby locations. The density of recruits was average (Figure C), which again sets this location apart from others in the area were recruit densities were very low. As in nearby locations, there was a high proportion of large colonies with 20% of colonies greater than 50 cm in maximum dimension. The majority of these large colonies (69%) belong to genera *Acropora* and *Montipora* (Figure D). Species richness was also above average and again it was *Acropora* with 32 species that contributed most.
The high cover of *Acropora* spp. has not gone unnoticed with scuba search surveys finding 69 *Drupella* (a coral eating gastropod), the highest density recorded at any location in 2004 surveys. Nine scars of indeterminate origin and 7 colonies infected with “white syndrome” made up the balance of recent impacts to the coral community.

Deep surveys

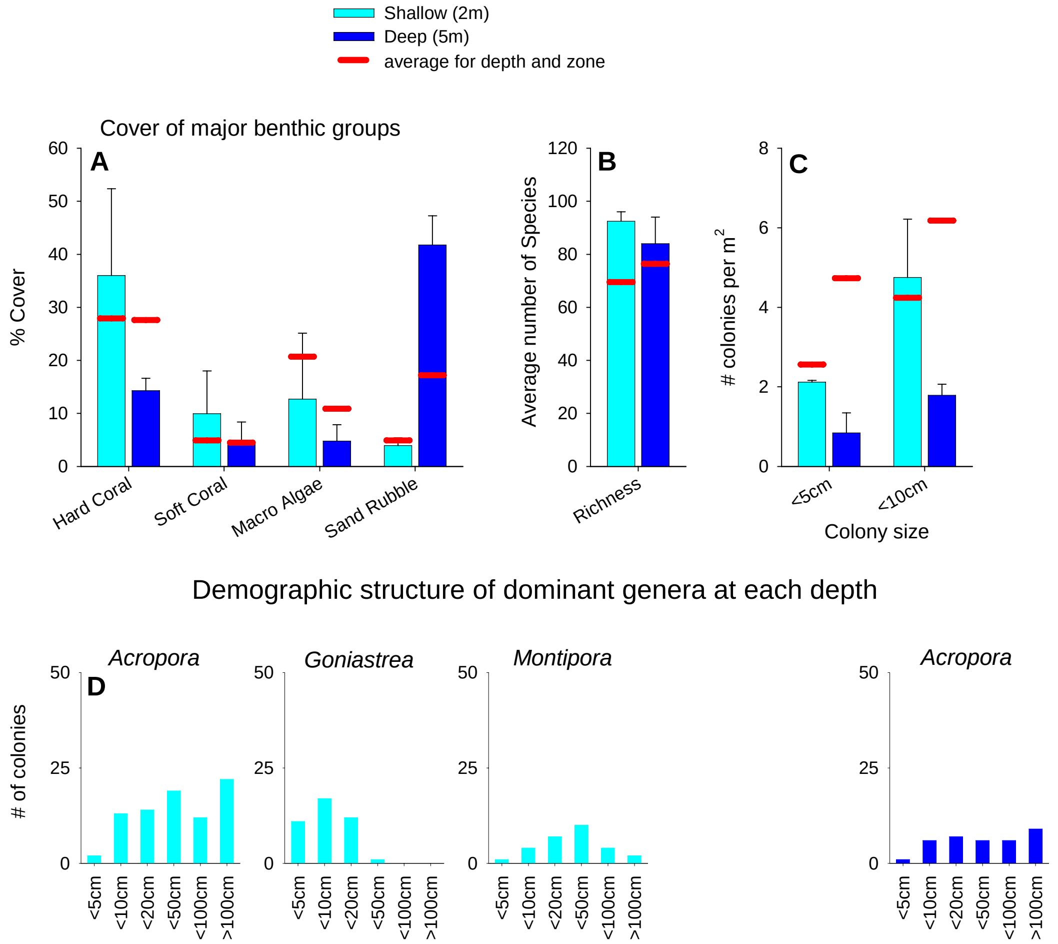
The deep sites ran through an area dominated by sand and rubble (Figure A) with only scattered coral colonies. This dominance of sand and rubble produced the low cover of hard coral (14%), soft coral (4%) and macroalgae (5%) as suitable substrate was limited. Even with the reduced area of habitat for hard corals, species richness was slightly above average (Figure B) with above-average richness in genus *Acropora* (29 species) contributing most. The level of sand and rubble cannot explain the low recruit density indicated (Figure C) as estimates were corrected for the area of available habitat, so excluding sand. 76% of the hard coral cover was made up of the genus *Acropora*. The size structure of *Acropora* spp. (Figure D) represents the site in general, with low numbers of recruits though several individuals attained a diameter >1 m.

Incidence of coral damage was lower than in the shallows with 11 *Drupella*, 5 scars of unknown origin, 1 colony infected with “white syndrome” and 1 with “brown band disease”.

Summary

The higher coral cover and dominance of the coral community by *Acropora* spp. set this location apart from others in the area. Recruit density was moderate to low and this combined with the level of disease and predation by *Drupella* may have kept the coral cover low.

Keswick Island C (front reef)



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North Keppel Island

The survey location is along the edge of a wide fringing reef within a bay on the southern side of the island and sheltered from the SE trade winds by Pumpkin Island to the south. The reef slope had a moderate gradient and was composed predominantly of sand and rubble, the coral community extended to 6-7 m and a sandy substrate. The deeper transects at Site 2 coincide closely to a site surveyed since 1995 by QPWS staff. Sites were surveyed in April 2004.

Shallow surveys

Hard coral cover was high (52%, Figure A). 97% of the hard coral cover was from the genus *Acropora* and of this 98% was of a branching growth form. Very low species richness (Figure B) and low cover of both soft coral and macroalgae (Figure A) further reflect the dominance of branching *Acropora* spp. Free living *Fungia* represented the only other genus with more than a handful of colonies at this depth. In general colony size was large with more colonies >1 metre in maximum dimension than in any of the smaller size-classes (Figure D). Density of recruits was low (Figure C) though this did not take into account the propensity for vegetative reproduction via fragmentation of branching *Acropora* spp. or that recruits of branching *Acropora* colonies would rapidly exceed the 10 cm maximum dimension used to classify an individual as a recruit.

Incidence of disease was high with 65 observations of “white syndrome” constituting the highest level recorded on any survey of near-shore sites included in this report. Some of this “disease” may have been due to a shut down of sections of tissue on the lower branches, a phenomenon common amongst branching *Acropora* spp. and possibly a response to shading as the colony grows. A moderate number of *Drupella* (14) were also recorded.

Deep surveys

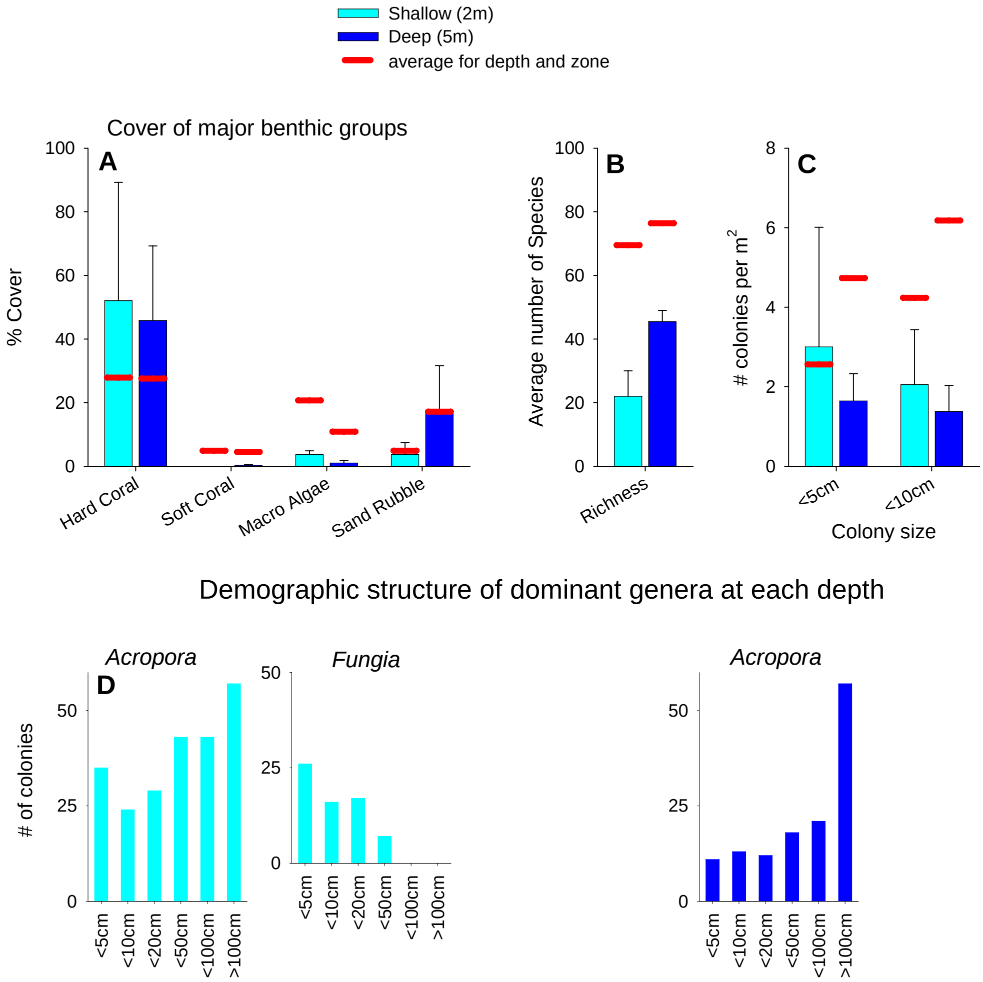
The deep slope community was very similar with high hard coral cover (46%) and very low soft coral and macroalgae cover (Figure A). Again the coral community was dominated by *Acropora* spp. making up 91% of the community, 92% of which was branching in growth form. The community was skewed toward large colonies with 37% of individuals having a diameter >1 m (Figure D), an observation that indicates a long period without major disturbance. Recruit density was low (Figure C). Species richness, while still low, was higher than on the shallower slope (Figure B) due to the inclusion of a number of massive and encrusting species (mostly in the families Faviidae and Mussidae) where the branching *Acropora* community on the slope met sandy substrate at the reef base.

Drupella numbers were higher than at 2 m with 35 individuals recorded during scuba search surveys. “White syndrome” was also very common with 44 colonies infected, though again this may have been confused with a non-infectious shut down of tissue common amongst branching *Acropora* spp..

Summary

Results of monitoring at this reef are presented in Figure 3.15 of this report. From the first observation in 1995 through to 1997 cover on these sites was around 39%. Following a bleaching event in 1998 there was a slight decline so that by August 1998 cover was down to 34%. By February 2002 cover had increased to the highest recorded from this site (52%) but was then hit again by another bleaching event so that by October 2002 cover was down to 33%. Periodic bleaching has obviously affected the coral community over the last decade, though observations in 2004 indicated that a number of the large colonies survived these events. Further, our cover estimates were higher than those following the 2002 bleaching and this, along with increases between the 1998 bleaching and 2002 indicate the ability of the coral community to recover from these disturbances.

North Keppel Island



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Middle Island

The survey sites are located along a fringing reef developed around a rocky outcrop on the NE side of the island. This location coincides closely with a site monitored since July 1993 by QPWS staff. The reef slope has a shallow to moderate gradient and reaches sand at 4 -5 m. Only one deep site was surveyed as the reef slope did not extend to 5 m at Site 2. The composition of the underlying slope was difficult to determine due to the almost complete coverage of branching *Acropora* spp. thickets. Sites were surveyed in April 2004.

Shallow surveys

At 82% hard coral cover at this location was the highest recorded from any site in 2004 surveys. With such high coral cover other components of the community including soft coral and macroalgae were very low (Figure A). The very low species richness (Figure B) reflects the dominance of just a few species of branching *Acropora* with 99.9% of the community composed of *Acropora* spp. of which 98% were branching growth forms. Recruit density was above average on the small remaining area of available habitat (Figure C). In fact the size structure of the community was split between large colonies>1 m and colonies <20 cm in maximum dimension (Figure D). Colonies in the 20 cm to <1 m size-classes may possibly have been killed by bleaching events in 1998 and 2002 (see below).

As is often the case with branching *Acropora* spp. a number of colonies (48) had scars of unknown origin around the base of branches though only 5 were considered be infected with either “white syndrome” (4) or “brown band disease” (1). A single *Drupella* gastropod and minor anchor damage were also noted during scuba search survey.

Deep surveys

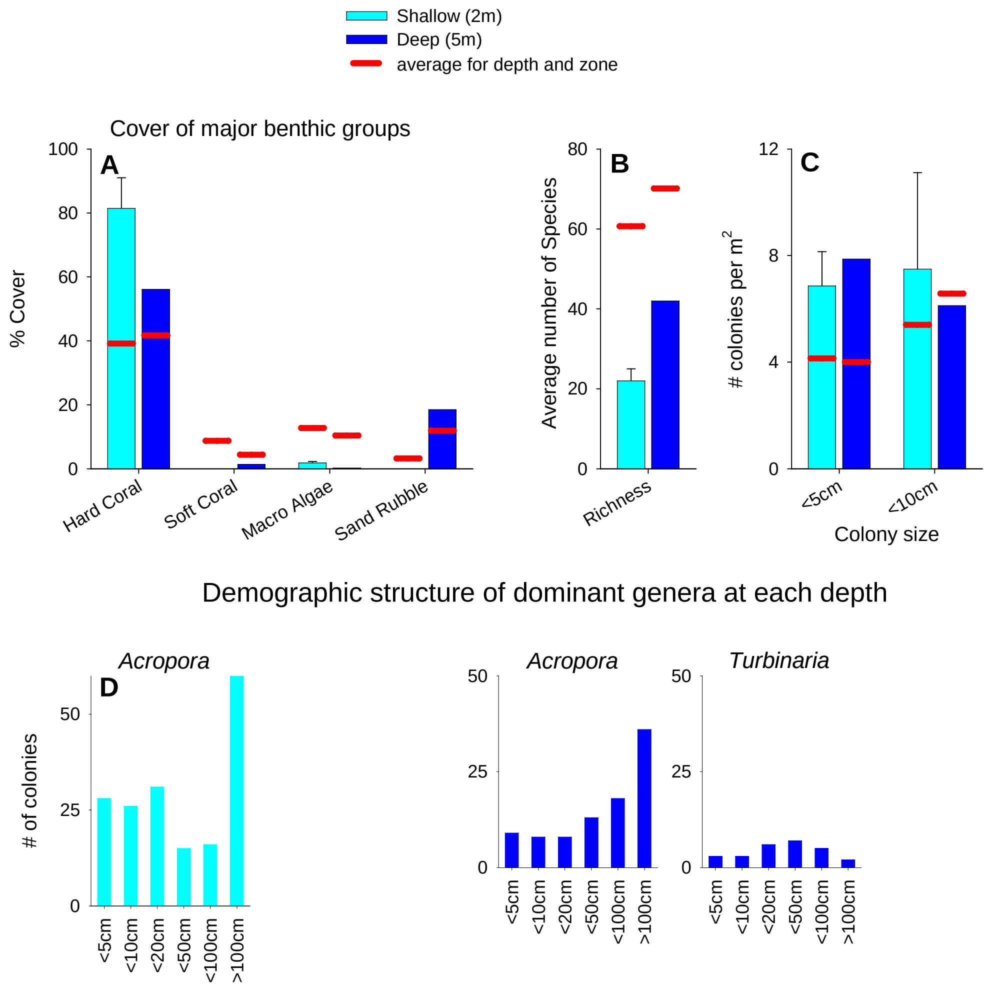
Cover of hard coral (56%) was lower than on the shallower slope though this was due in part to transects lying along the coral / sand interface and so including areas of sand (Figure A). The coral community became more diverse along the interface with the sand (Figure B) including several species that were not present on the shallower slope. Richness of Faviidae and *Turbinaria* was notably higher. *Acropora* was still by far the most abundant genus making up 89% of the cover compared with just 5% for *Turbinaria*. Recruit density was above average (Figure C), though the size structure of the community was skewed toward large corals >1 m in maximum dimension (Figure D).

Incidence of damage to corals was lower than on the shallower slope with scuba search transects including only 11 colonies with scarring of unknown origin and a single colony infected with “white syndrome”.

Summary

Data from surveys undertaken by QPWS since 1993 (Figure 3.15 this report) showed that this reef has been dominated by stands of branching *Acropora* spp for the past decade. In the period July 1993 through to July 1997 cover increased from 67% to 78%. By August 1998 cover had declined to 35%, almost certainly as a result of coral bleaching earlier in 1998. Cover again increased to over 70% by February 2002 before falling to 58% by that October, again the decline almost certainly due to mortality from coral bleaching. The high cover and recruitment rate recorded in 2004, along with documented recoveries after bleaching events show the resilience of this community.

Middle Island



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Humpy and Halfway Islands (back reef)

One site was surveyed on the leeward fringing reef of each island. The reef slope at each site was moderate, though at Site 1 (Humpy Island) the slope extended well below the depth of our transects while at Site 2 (Halfway Island) the slope ran to sand at about 6 m. Site 2 coincided with a site visited in 1991 (van Woesik 1992). At each site the slope was composed mostly of *Acropora* rubble with occasional areas of more consolidated carbonate substrate. Site 2 was on the same section of reef as a site that has been surveyed by QPWS staff since 1996, though it was several hundred metres away. Sites were surveyed in April 2004.

Shallow surveys

Hard coral was very high (81%) leaving little room for soft coral or macroalgae both of which had very low cover (Figure A). The dominance of the coral community by branching *Acropora* spp. (98% of the coral cover) meant species richness was low (Figure B). The size structure of the coral community was skewed toward large colonies with 45% of colonies >1 m in maximum dimension (Figure D). Density of recruits was low (Figure C) though this did not take into account the capacity of branching *Acropora* spp. to reproduce via fragmentation or that recruits of branching *Acropora* spp. would rapidly exceed the 10 cm maximum dimension used to classify an individual as a recruit. Scuba search surveys documented a large number (78) scars of unknown origin, these mostly small patches of mortality on lower branches a phenomenon common to branching *Acropora* spp..

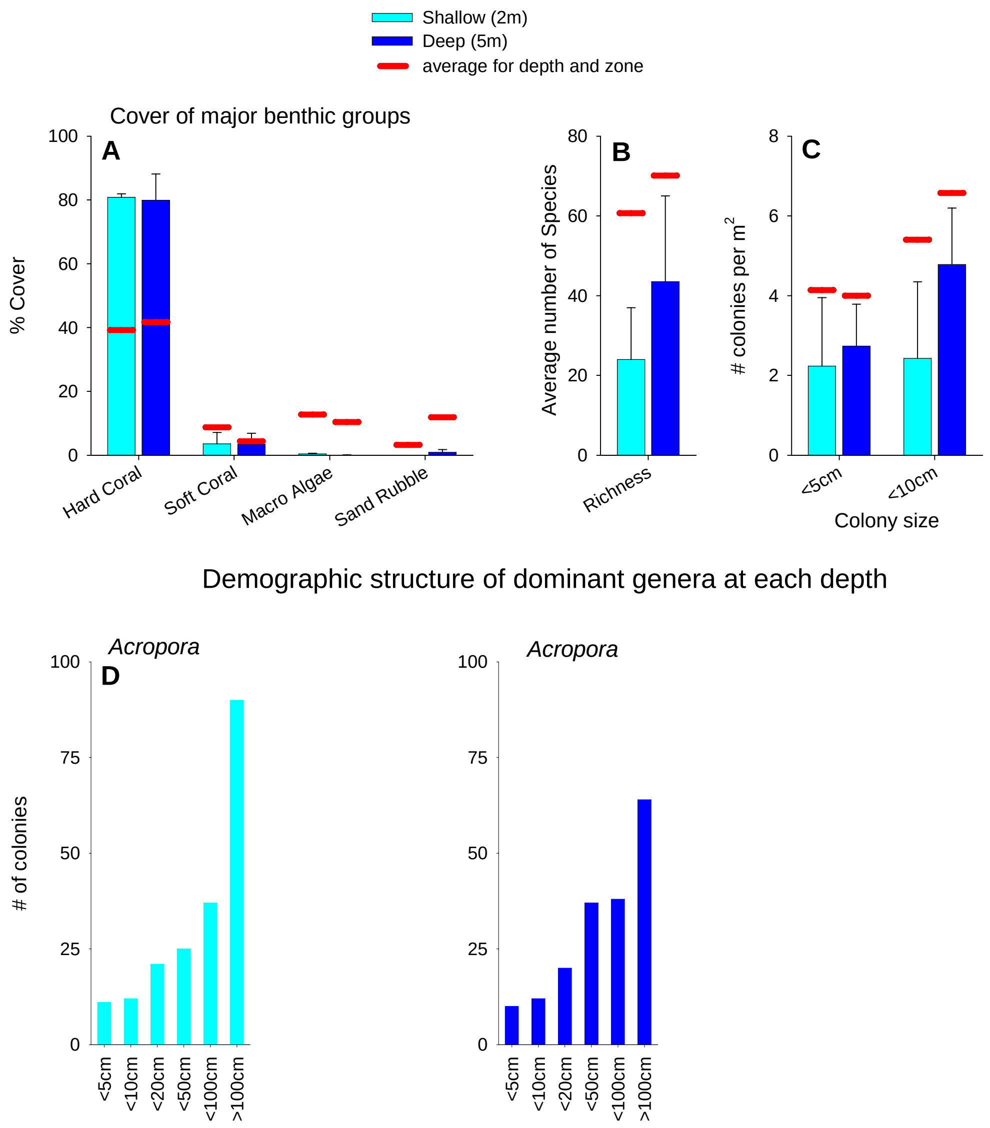
Deep surveys

The benthic community at 5 m was very similar to that at 2 m, with very high hard coral cover (80%) and low cover of both soft coral (3%) and macroalgae (0.1%) (Figure A). The hard coral cover was again mostly *Acropora* spp. (99%) of which 96% were branching forms. The size structure of the community was skewed toward large colonies (Figure D), which contributed to the below-average density of recruits (Figure C). Recruit density did not take into account the capacity of branching *Acropora* spp. to reproduce via fragmentation or that recruits of branching *Acropora* spp. would rapidly exceed the 10 cm maximum dimension used to classify an individual as a recruit. Species richness, while still low, was higher than at 2 m (Figure B) due mainly to higher richness of the families Acroporidae and Mussidae and the genera *Porites*, *Psammocora* and *Turbinaria*. Scuba search transects revealed a very large number of colonies (125) with scars of unknown origin, these were mostly small patches of mortality on lower branches, a phenomenon common to branching *Acropora.*

Summary

Van Woesik (1992) reported almost total mortality of corals above 1.5 m following a flood of the Fitzroy River in 1991. He also noted that below this depth the flood had little observable effect. Monitoring on a nearby section showed a small reduction in the very high coral cover following bleaching in 1998, followed by an increase to the extremely high level of 95% prior to another bleaching event in 2002 that reduced cover to 70% (Figure 3.15 this report). Our observations of very high coral cover and large colony size at both depths indicated effects of bleaching have been relatively minor.

Humpy and Halfway Islands (back reef)



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Humpy and Halfway Islands (front reef)

One site was surveyed on the windward fringing reef of each island. The reef slope differed substantially between sites. At Site 1 (Halfway Island) the slope was broad with a shallow gradient and comprised a branching *Acropora* spp. thicket standing on a bed of *Acropora* rubble with occasional solid carbonate outcrops. At Site 2 (Humpy Island) the slope consisted of a convoluted rocky substrate with limited carbonate accretion. Sites were surveyed in April 2004.

Shallow surveys

Hard coral cover was very high (71%) while soft coral cover (4%) was average for shallow sites and macroalgae almost no existent (0.2%, Figure A). *Acropora* spp. accounted for the majority of the hard coral cover (86%). The size structure of the coral community was skewed toward large colonies (Figure D) with 30% of colonies having a maximum dimension of greater than 1 m. A high representation of large colonies is reflected in lower than average recruit density (Figure C). This figure does not take into account the propensity for vegetative reproduction via fragmentation for branching *Acropora* spp. or that recruits of branching *Acropora* colonies would rapidly exceed the 10 cm maximum dimension used to classify an individual as a recruit. Scuba search surveys recorded a large number of colonies (55) with scarring of an unknown origin. Scarring was mostly limited to small patches at the base of otherwise healthy branching *Acropora* colonies: a phenomenon common to these corals. Incidence of “white syndrome” was also high with 27 colonies infected. High cover of branching *Acropora* spp. leaves no space for other species causing below-average species richness (Figure B).

Deep surveys

The benthic community at 5 m was very similar to that at 2 m, with very high hard coral cover (73%), near average cover of soft coral and almost no macroalgae (0.1%, Figure A). *Acropora* spp. were again the main component of the coral cover (85%) with *Montipora* spp. (4%) and *Pocillopora* (4%), while the next most abundant, relatively rare. Of the *Acropora* community, branching growth forms (78%) were dominant though less so than on the shallower slope. This reduction was due to presence of tabulate growth forms that made up 21% of the *Acropora* spp. cover. The size structure of the community was skewed toward large colonies (Figure D) with 27% of individuals having a maximum dimension greater than 1 m. Both recruit density (Figure C) and species richness (Figure B) were slightly higher than at 2 m though still below average. Scuba search revealed a very large number of colonies (105) with scars of unknown origin. Scarring was mostly evident as small patches of mortality on lower branches, a phenomenon common to branching *Acropora* spp. Incidence of disease was also high with 43 colonies infected with “white syndrome”, three with “brown band disease” and 7 with “skeletal eroding band”.

Summary

The high coral cover and large colony size indicated a coral community that has not been severely disturbed for a long period of time.

Humpy and Halfway Islands (front reef)

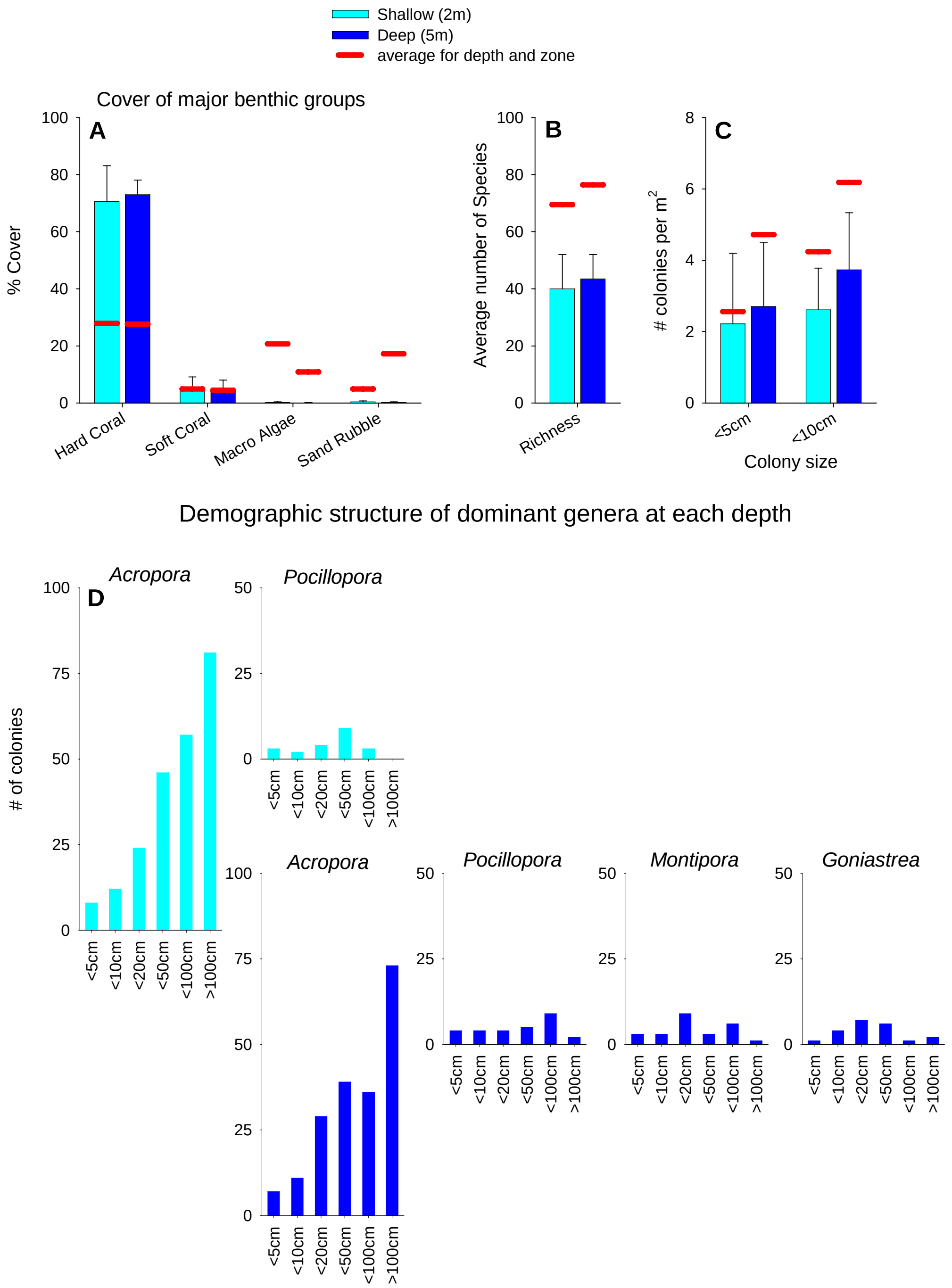

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Figure D. The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Pelican Island

Sites surveyed were on the northern (leeward) side of the island. The reef slope had a shallow gradient the substrate had low relief and was a mixture of rocky outcrops, sand and rubble. The slope ran to sand and silt at around 6 m. Sites were surveyed in April 2004.

Shallow surveys

Hard coral cover (14%) and soft coral cover (6%) were both below average, in contrast to the high cover of macroalgae (Figure A). The dominant hard coral genus was *Acropora* (69% of the coral cover) with branching (44%) and tabulate (28%) growth forms the most common. The most common soft coral genus was *Sarcophyton* that made up two thirds of the soft coral cover. Species richness was well below average (Figure B) with *Acropora* the only genus with above-average representation. The size structure of the community was skewed toward small colonies with 83% of colonies having a maximum dimension of less than 20 cm. The majority of these small colonies were *Acropora* spp. (Figure D). Density of recruit-sized colonies was above average (Figure C).

Incidence of recent mortality was very low with only one colony exhibiting a scar of unknown origin.

Deep surveys

Hard coral cover (31%) was approximately double the cover at 2 m (Figure A). The hard coral community was distinctly different from that at 2 m. Major components included the family Faviidae (24%) and genera *Hydnophora* (32%),and *Goniopora* (20%). *Acropora* spp. were not recorded on the video transects. While *Turbinaria* colonies were the second most abundant genus, cover was low giving this genus only 5% of the cover. Species richness was low with below-average richness of the family Acroporidae and absence of Fungiidae contributing to this result. Soft coral cover (13%) was higher than at 2 m with the majority of the cover represented by *Sarcophyton* (36%) and *Sinularia* (27%). Cover of macroalgae (5%) was markedly lower (Figure A). The size structure of the community was skewed toward small colony size (Figure D) with only 8% of colonies along demographic transects having maximum dimensions greater than 1 m while 38% of colonies were in the under 10 cm size-class and as such classified as recruits. As such recruit density was above average.

Summary

Below-average coral cover and few large colonies may indicate past disturbance. The above-average recruit density suggests good recovery potential in the short term. A lack of substantial carbonate accretion suggests that persistence of coral communities may be short lived with periodic disturbance the norm.

Pelican Island

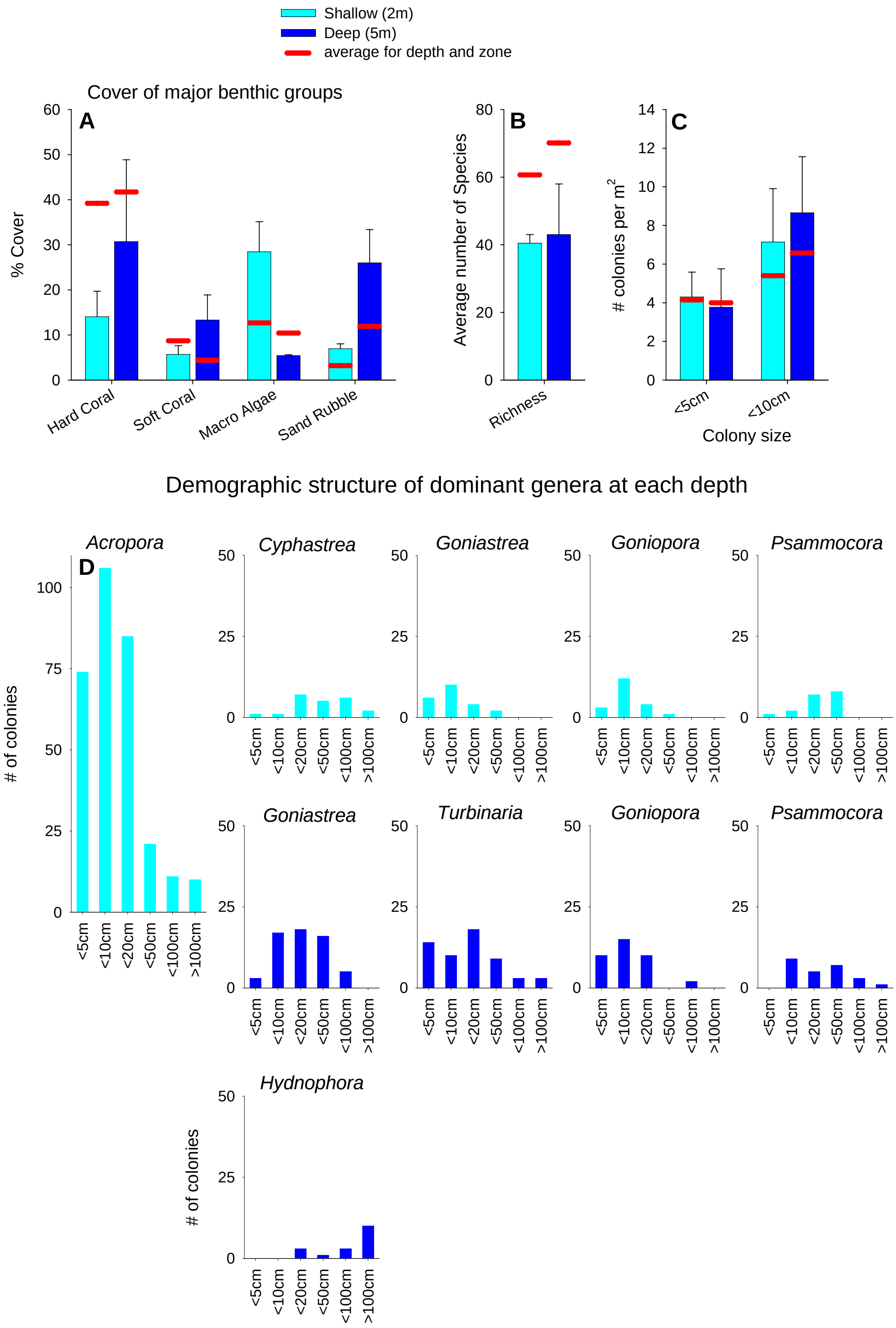

Figure A. The average percent cover of major benthic groups at each depth from video transects.
Figure B. The average species richness recorded during swim searches at each depth.
Figure C. The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm.
Figure D. The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

Peak Island

Very high turbidity made it difficult to locate sites at this location. Site 1 was on the northeastern side of the island, Site 2 was on the eastern side of a small rocky outcrop to the south of the main island. The reef slope at both sites was mainly composed of rock with a thin veneer of coral though at Site 1 there was some accumulation of coral rubble and carbonate rock at 5 m. The substrate at the reef base at around 6 m was of sand and silt. Sites were surveyed in April 2004.

Shallow surveys

Given the high turbidity and proximity to the mouth of the Fitzroy river it was surprising to find hard coral cover (27%) was close to average. Less surprising was the slightly above-average cover of macroalgae (21%, Figure A). Another surprise was the presence of large coral colonies that had obviously survived for a substantial period of time with 13% of colonies having maximum dimensions in excess of 1 m. Recruit density (Figure C) and species richness (Figure B) were low, which supported initial impressions that this was a marginal coral habitat. The hard coral community was not dominated by any one genus rather *Montipora* (23%), *Psammocora* (20%), *Pocillopora* (11%), *Goniopora* (12%) all made up a proportion of the cover. Cover of *Acropora* spp. (3%) was low in comparison to the number of colonies due to the high proportion (58%) of colonies in the <10 cm size-classes. In the absence of disturbance in the near future proportional representation may shift toward this fast growing group.

While incidence of disease or scarring was limited to just four scars of unknown origin a high proportion of the *Montipora* spp. colonies at Site 2 were partially bleached. No mortality associated with this bleaching was recorded.

Deep surveys

Hard coral cover was moderate (23%) though slightly lower than at 2 m (Figure A). Species richness (Figure B) and density of coral recruits (Figure C) were very low. Low species richness reflects the absence of several families that were recorded on most other reef fronts including Agariciidae, Euphyllidae, Fungiidae, Oculinidae and Pectiniidae as well as the lack of any species of the common genus *Acropora*. It should be noted that while no *Acropora* species were recorded in the surveys of species richness, one small colony was recorded in demographic surveys. The genera *Psammocora* (47%), *Turbinaria* (20%), *Goniopora* (8%) and the family Faviidae (17%) were the main components of hard coral cover. The coral community had a high proportion of large colonies with 24% over 50 cm. High turbidity was reflected in the low spreading growth form of the majority of colonies. Cover of soft corals (8%) was above average with the community composed of a mixture of genera the most common being *Sarcophyton* (24%) and *Sinularia* (22%), species loosely grouped as “Gorgonian like” including sea fan and whip forms of soft corals were also an obvious component of the community (25%).

Summary

Moderate cover and generally large colony size show that conditions were suitable at least for the limited suite of species that occur there. Low recruitment may limit coral community development and slow recovery from disturbance. Very high turbidity was reflected in the growth form of corals at 5 m with predominantly encrusting or flattened morphologies. With the exception of bleached *Montipora* spp. colonies (that appeared to be recovering) the coral community looked very healthy with few observations of scarring and no disease.

Peak Island

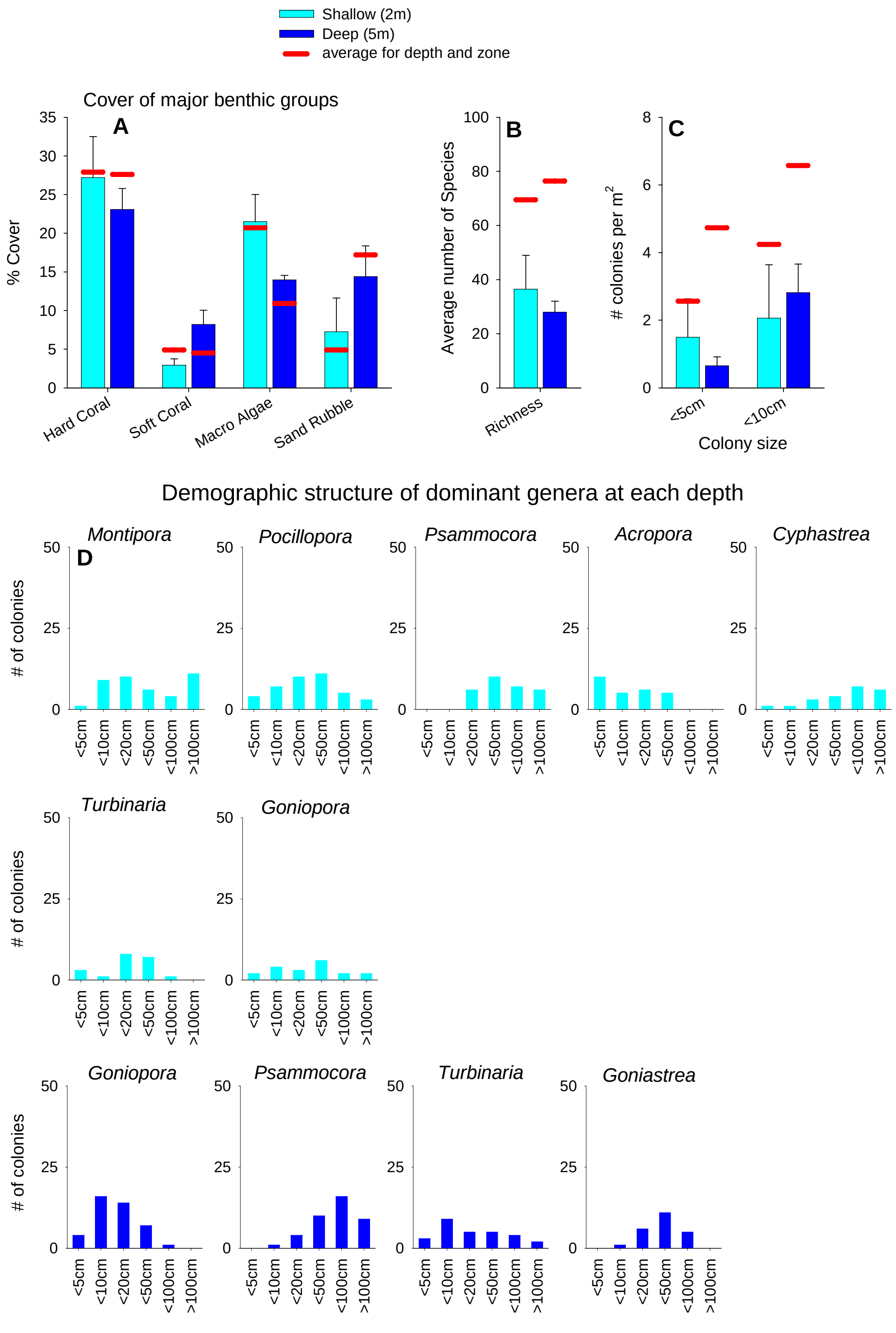

Figure A. The average percent cover of major benthic groups at each depth from video transects.
Figure B. The average species richness recorded during swim searches at each depth.
Figure C. The average density (colonies per m^2 of substrate that was available to recruits) for hard coral colonies in the size classes 0-5 cm and 0-10 cm.
Figure D. The number of colonies of the most abundant genera at each depth in each size class. Error bars represent the standard error of the mean estimate from the two sites at each depth. The mean values for each summary statistic from all survey locations are shown as reference lines. In all plots, darker shading represents data from the 5 m below LAT transects.

5. Relative Status of Near-shore Reefs

As a synthesis of the main data sets collected from each reef we calculated a naïve reef health index as a summary statistic for the surveys undertaken. This index combines observed values for coral cover, species richness, coral recruit density and the density of large coral colonies to give a relative indication of how each site compares to others visited. These variables represent different aspects of the coral community and are specifically selected to include components of community resilience. Reduced species richness of hard corals can indicate of environmental stress as less tolerant species are excluded from the community as conditions change along water quality gradients (Fabricius *et al.* 2005). Coral cover is often scorned as an indictor of environmental health on the grounds that low cover may simply be the result of a recent disturbance, but high cover must indicate the adequacy of the setting for those species that are present. Similarly, the presence of many large colonies in the community is a result of their long-term persistence and so indicates the maintenance of favourable conditions for those species. Critical to any coral community is the ability to regenerate following disturbance; here we use the density of recruit-sized colonies, standardised to the area of available substrate, to indicate recovery potential.

To calculate the reef health index, values the four variables: coral cover, species richness, coral recruit density and the density of large coral colonies were ranked then sorted and assigned to quartiles of the population. The lowest 25% were assigned a value of 0 and the highest 25% were given a value of 3. These values where then summed for each reef, giving a relative health index with a possible range from 0, if values for all variables at a particular location were within the lowest quartile of values recorded, through to 12 if values for all variables were in the highest quartile of observations. Scoring the values for each variable involves judgement as to what is “good” or “bad” in terms of the status of a coral community. We consider higher values of each variable to be better than lower values. We emphasise that the results represent a naïve estimate of relative status as no attempt was made to weight the four variables. For example, high cover of hard corals may indicate a positive state, but low cover may simply reflect a recent disturbance and as such should perhaps not carry the same weighting as the density of recruits that may reflect the recovery potential of the community. Natural differences among community types will occur and we did not attempt to correct for these. Nor do we attempt to weight the variables as to do so would be based on conjecture rather than evidence.

The resulting categorisations for each reef and depth are presented as colour coded site markers on Figures 5.1-5.6 and a brief description of the coral community status is given in Table 5.1. This representation highlights the striking lack of consistency in categorisation both among neighbouring reefs and between depths at the same reef. In some instances these differences almost certainly reflect differences in disturbance history as shown by monitoring data and by observations from Snapper Island. At 16 (73%) of the 22 reefs where the categorisations differed between depths, the community at 2 m scored lower. The differences among depths were not due to one community measure being consistently lower at 2 m: each measure was lower on roughly equal numbers of reefs where there was a difference.

Reefs that scored in the lowest categories occurred in each region. The only regions where there were no reefs in the highest categories are the Mackay and Keppel regions. Density of recruit-sized colonies and cover of hard corals were generally low in the Mackay region: species richness was the only community variable for which any reef was represented in the highest quartile. This suggests that, while the environmental conditions can support a wide range of species, the process of replenishment of the coral communities has been compromised in some way. Very low species richness compared to other regions prevented reefs in the Keppel Island Group reaching higher categories. The extensive stands of live branching *Acropora* on these reefs may limit the space available to other species. The density of recruits was also low on several reefs in this region, especially at Peak Island.

For more detailed descriptions of the benthic communities at each reef we direct the reader to the “reefpages”, section 4 of this report.

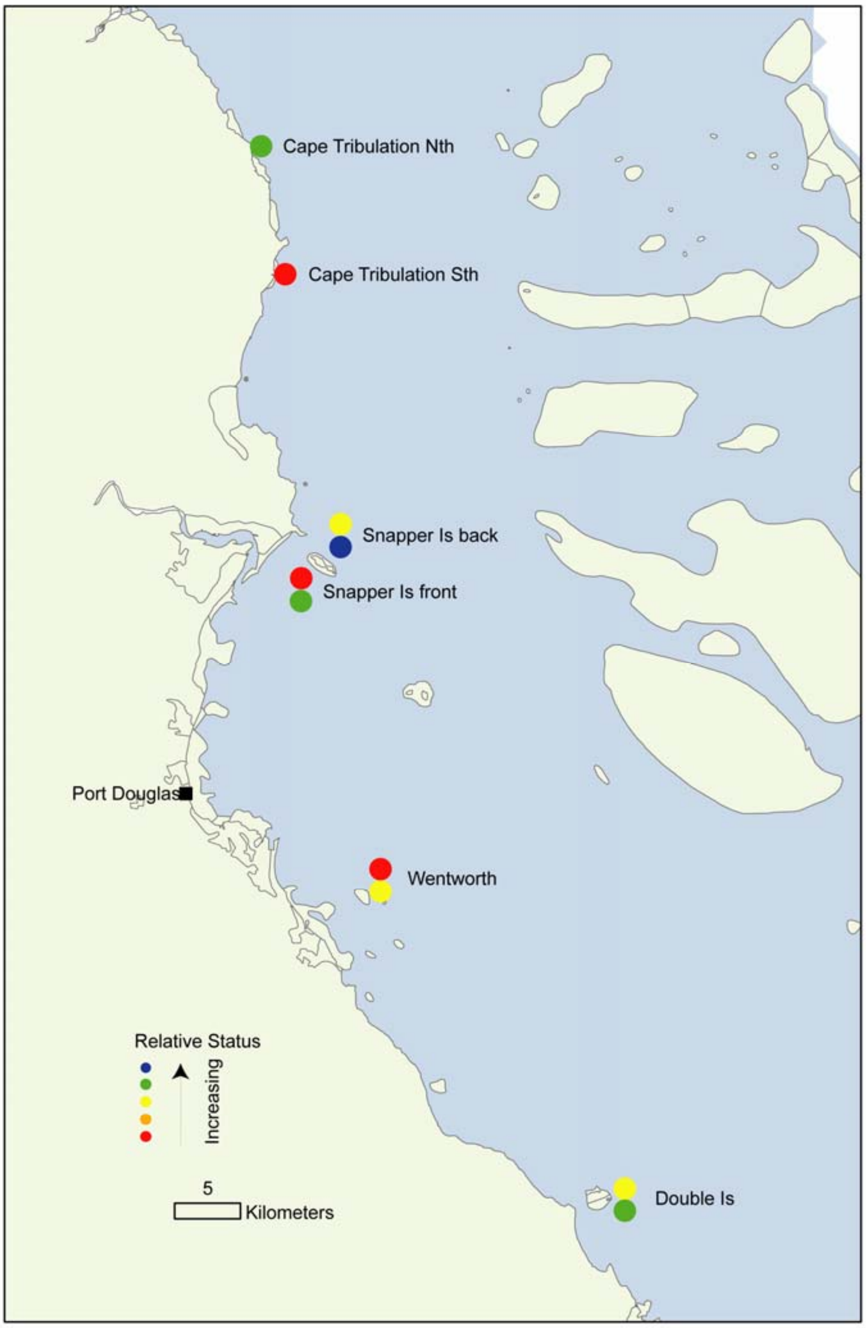

Figure 5.1. Survey locations in the Cairns region colour-coded by value index of relative status at each depth.

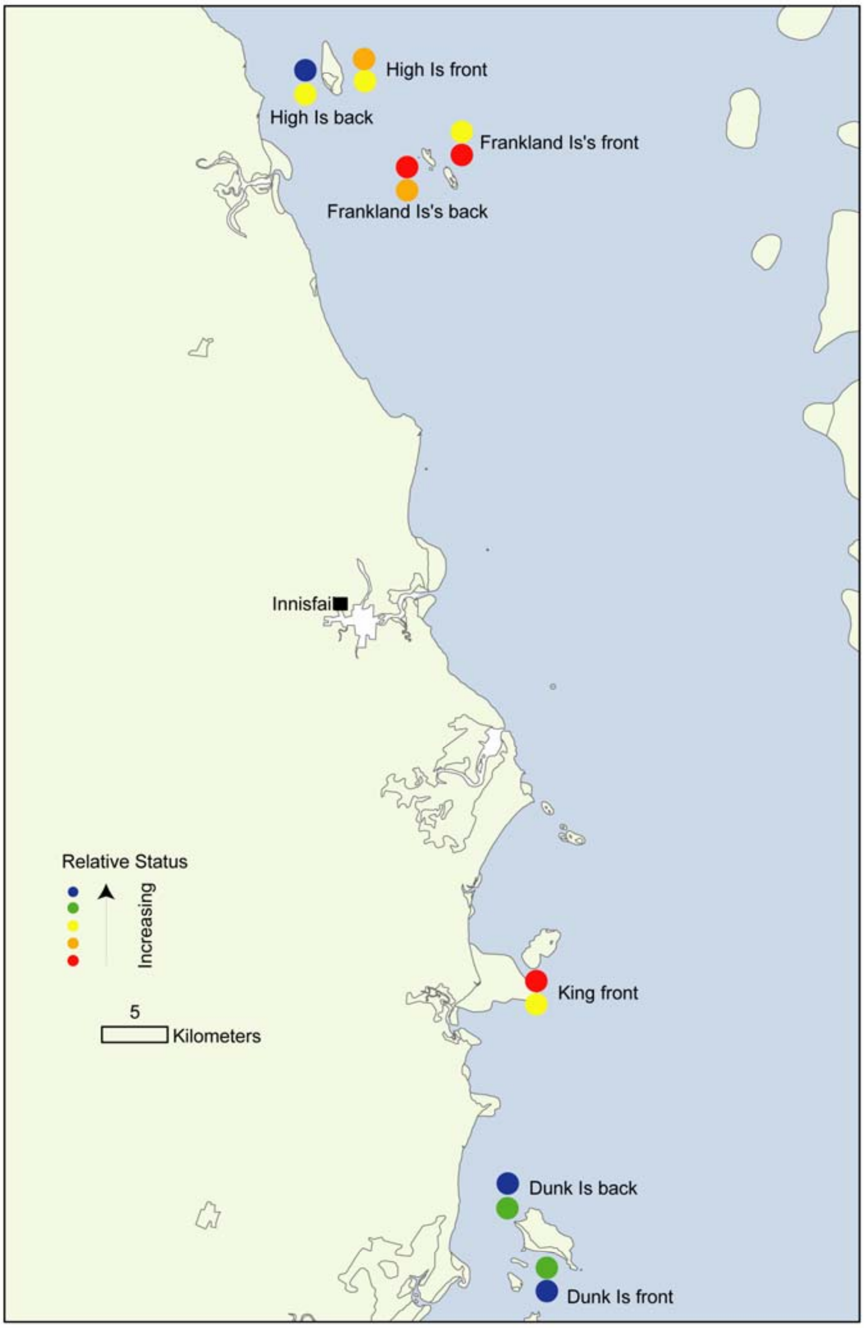

Figure 5.2. Survey locations in the Innisfail region colour-coded by value index of relative status at each depth.

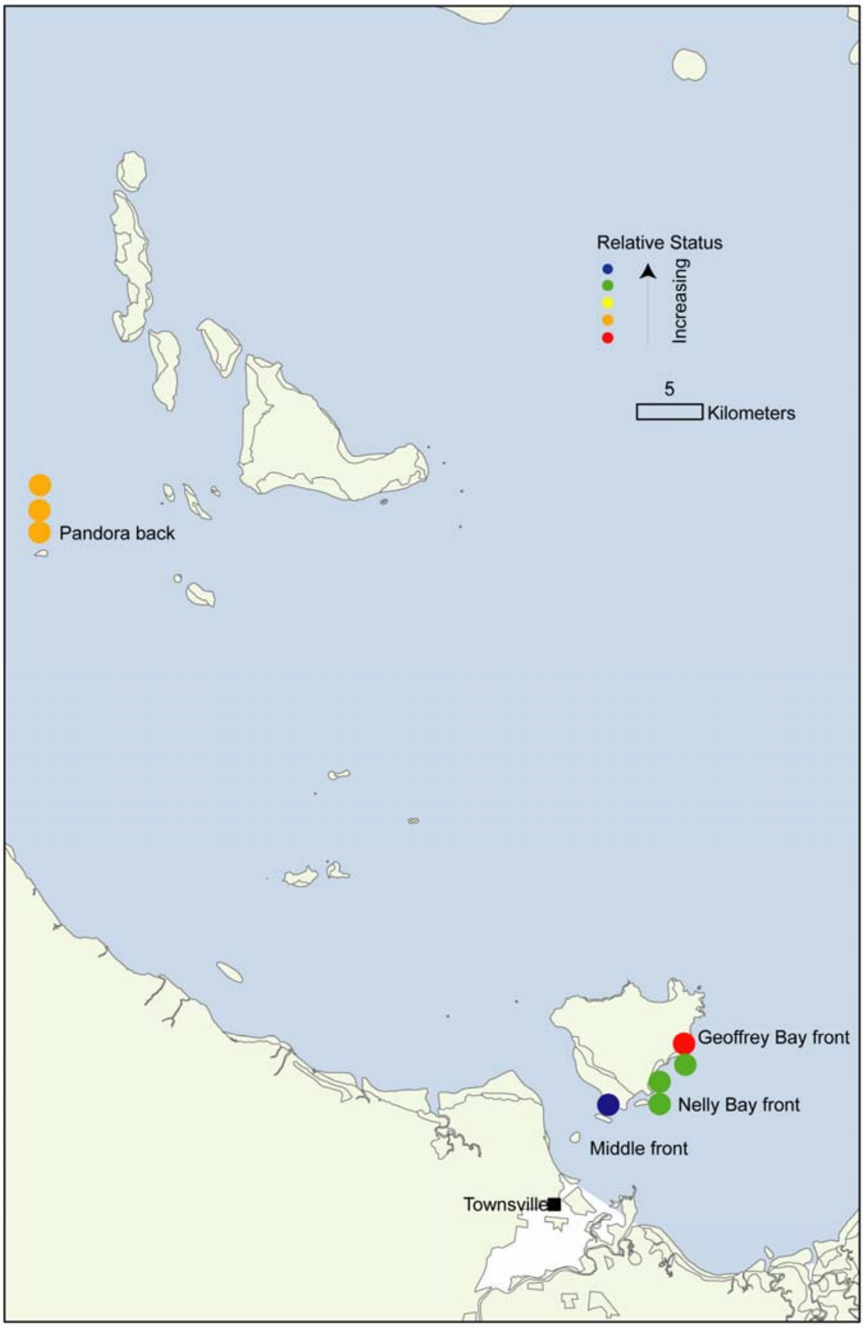

Figure 5.3. Survey locations in the Townsville region colour-coded by value index of relative status at each depth.

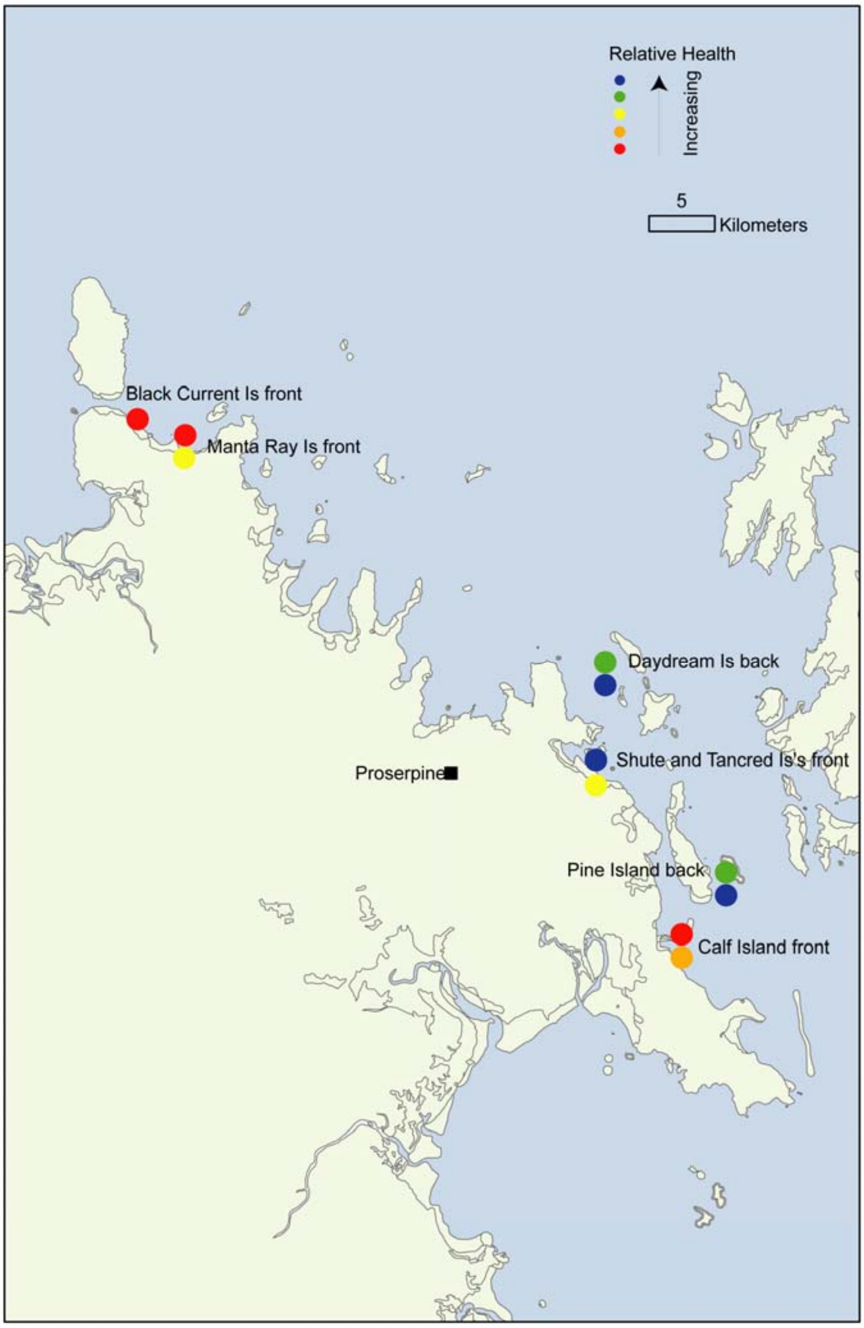

Figure 5.4. Survey locations in the Whitsunday region colour-coded by value index of relative status at each depth.

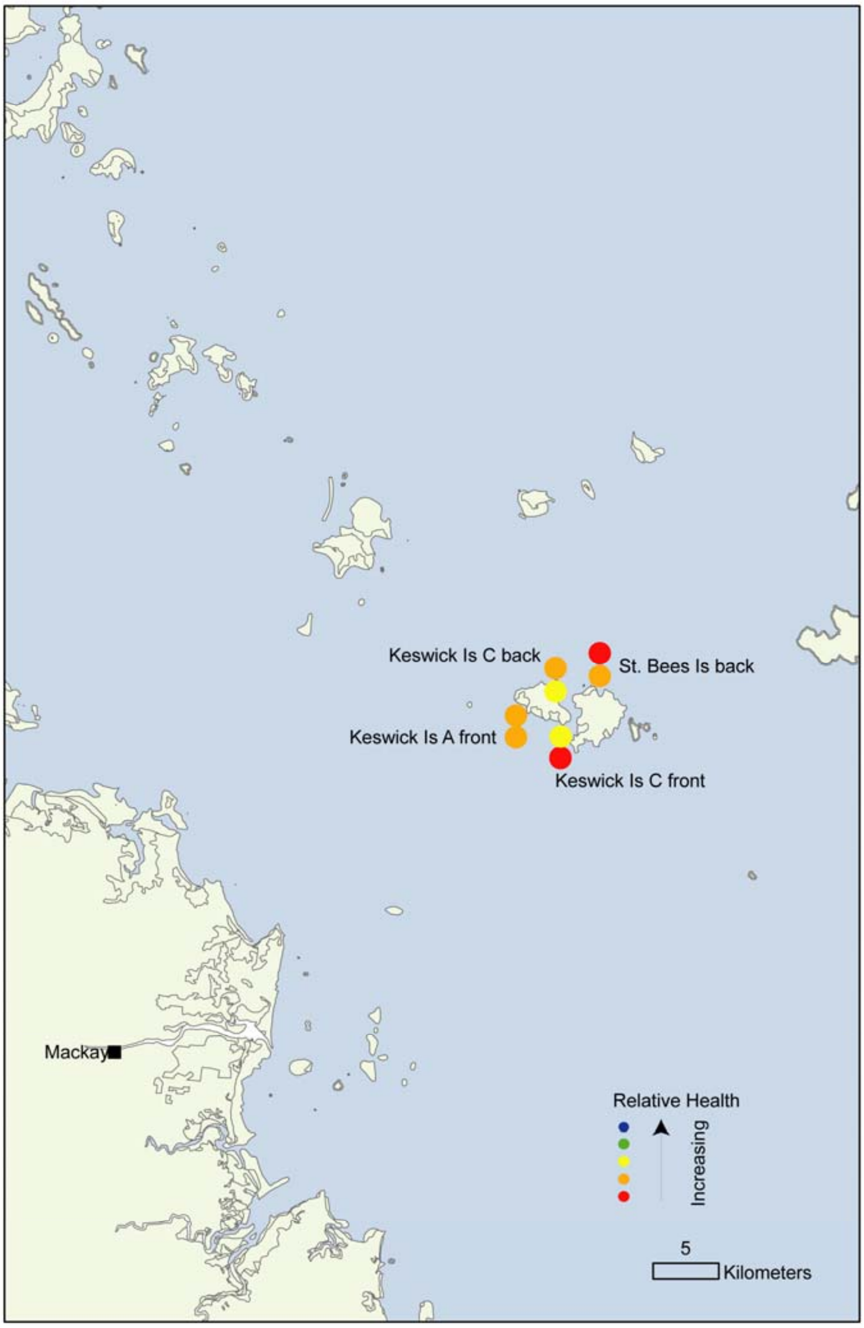

Figure 5.5. Survey locations in the Pompey region colour-coded by value index of relative status at each depth.

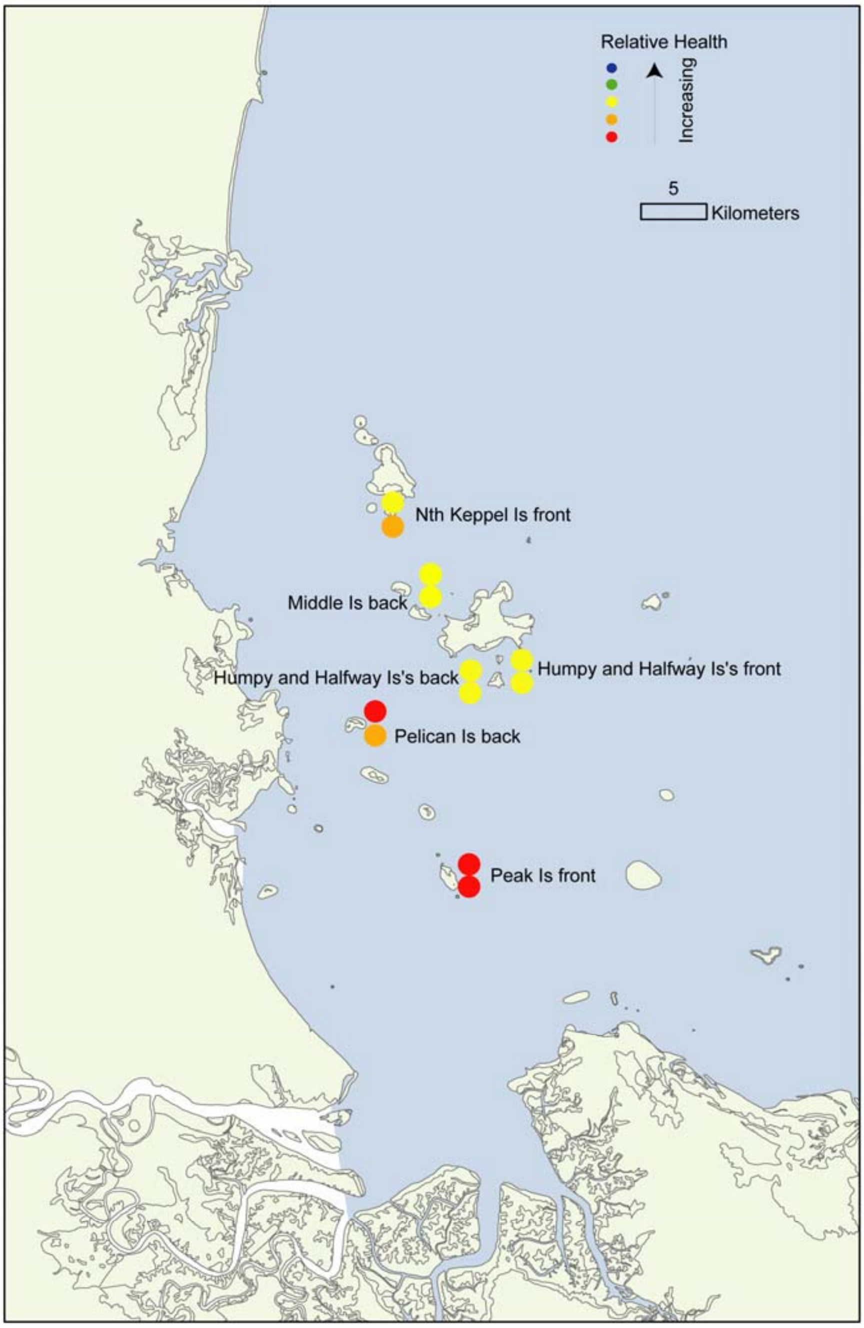

Figure 5.6. Survey locations in the Keppel region colour-coded by value index of relative status at each depth.

Table 5.1. Status categorisation of near-shore reefs, including brief explanation of basis for categorisation. Full descriptions of communities at each reef are presented in "reef pages" in Appendix 1. Status is relative ranging from lowest 🔴 through 🟠 🟡 🟢 to highest 🔵.

Cairns Region	Cape Tribulation Nth	2m	🟢	Monitoring indicates a long period without major disturbance, this is reflected in high coral cover and a community including a high density of large colonies.
	Cape Tribulation Sth	2m	🔴	Coral cover was low following bleaching in 1998 and a COTS outbreak in 1999. That the density of recruit sized colonies is above average and includes a high proportion of the fast growing genus *Montipora* indicates recovery potential.
	Snapper Is. Back	2m	🟡	At 2m the status is lowered by severe impacts of bleaching in 1998 and cyclone Rona in 1999, though the high numbers of small sized *Acropora* and *Montipora* colonies along with increasing cover observed in monitoring data show recovery is progressing. While coral cover at 5m is similar to that observed at 2m, species richness is substantially higher, there is a higher density of large colonies and the density of recruit sized colonies is also higher.
		5m	🔵	
	Snapper Is. Front	2m	🔴	Differential status between 2m and 5m reflects the higher exposure to flood events at 2m. Monitoring shows that the 2m location was recovering from a flood in 1996 prior to a second flood just months before this survey. Low cover and density of recruit sized individuals are almost certainly the result of these floods. The 5m community was largely unimpacted and remains a flourishing coral community.
		5m	🟢	
	Wentworth Rf.	2m	🔴	Coral cover was very low. At 2m the very high cover of macroalgae along with low density of recruit sized colonies suggest limited recovery. At 5m the community was more diverse and macroalgae cover lower. This along with slightly above average density of recruit sized colonies suggest cover should increase.
		5m	🟡	
	Double Is.	2m	🟡	Coral cover at 2m was high with the community including a high density of large colonies. Particularly low species richness limited status score though low species richness may be expected given the very turbid setting. At 5m the community differed in composition though again cover was very high and included many large colonies indicating long term persistence.
		5m	🟢	
Innisfail Region	High Is. Back	2m	🔵	Coral cover at 2m was high and though dominated by large *Porites*, species richness was high as was the density of recruit sized colonies. Coral cover was lower at 5m and with the exception of *Porites* large colonies very rare suggesting past disturbance. The high density of recruit sized colonies showed some recovery potential though the majority were relatively slow growing genera.
		5m	🟡	
	High Is. Front	2m	🟠	Moderate coral cover and relatively few large colonies, with the exception of *Porites,* at both depths were indicative of past disturbance, with COTS and bleaching observed at the nearby Frankland Island Group both possible causes. Moderate densities of recruit sized colonies including numbers of the fast growing *Acropora* and *Montipora* indicate recovery was progressing and especially at 2m.
		5m	🟡	
	Frankland Group Back	2m	🔴	The coral community was dominated by large colonies of the genus *Porites* with very few other taxa contributing to the very high cover at 5m or moderate cover at 2m. Monitoring showed that this reef was severely impacted by bleaching in 1998 with further reductions in 2000 likely due to COTS. These disturbances removed a high proportion of the community at 2m and in particular the genus *Acropora*. Very low species richness and density of recruit sized colonies suggest limited recovery from these disturbances.
		5m	🟠	
	Frankland Group Front	2m	🟡	At 2m recovery from impacts noted in monitoring data was well underway due predominantly to the presence of high numbers of *Acropora* colonies. At 5m recovery was not as obvious with coral cover very low and while the density of recruit sized colonies was higher at 5m than at 2m a high proportion of these are slower growing taxon thus not contributing to a rapid increase in cover. Slightly below average species richness should increase as species recruit into the reef as part of the recovery process.
		5m	🔴	
	King Rf.	2m	🔴	Low recruitment density and high cover of macroalgae suggest the low coral cover at 2m is unlikely to change in the short term. This is in stark contrast with the community at 5m where coral cover should increase rapidly in the absence of future disturbance due to the high density of recruit sized colonies.
		5m	🟡	
	Dunk Is. Back	2m	🔵	Although there is little reef accretion, high coral cover, species richness, density of recruit sized colonies and density of large colonies indicate a flourishing coral community at 2m. Hard coral cover declines rapidly with depth though a high density of recruit sized colonies including rapidly growing *Turbinaria, Acropora* and *Montipora* should see cover increase.
		5m	🟢	
	Dunk Is. Front	2m	🟢	Even though coral cover at 2m was moderately low and cover of macroalgae high the density of recruit sized colonies and high species richness indicate potential for future increase. At 5m all indications are for a resilient coral community with cover at 38% made up of a diverse assemblage of species and poised to increase due to the high density of recruit sized colonies.
		5m	🔵	

Table 5.1. continued.

Townsville Region	Pandora Rf.	2m		Coral cover increased with depth from very low (9%) at 2m down to 59% at 8m. While this may reflect variable exposure to bleaching in 1998, aims unpublished data (Done pers. comm.) suggest the *Acropora* dominated community at 2m had been in decline prior to this event. While density of recruit sized colonies at 2m was near average a large number of these are solitary *Fungia* and as such will not result in substantial increase in cover. Density of recruit sized colonies at 5m and 8m was very low, and along with the high representation of large colonies suggest resilience of the community may rely more on survival of existing corals rather than recovery via recruitment and growth of new colonies. The very large size of some existing colonies does however suggest substantial resilience to local conditions for these corals.
		5m		
		8m		
	Middle Rf.	2m		Coral cover was high and large colonies numerous. This along with a moderate density of recruit sized colonies and moderate species richness all indicated a resilient community. This is supported by observations from monitoring showing an overall increase in coral cover between 1992-2005.
	Nelly Bay	2m		Coral cover was moderate at 5m and high at 2m with the community including a number of large colonies at each depth. The density of recruit sized colonies at 2m was marginally below average though included moderate numbers of the fast growing *Acropora* and *Montipora. A* t 5m the density of recruits was high and as such increases in cover are likely. Monitoring data that shows coral cover increased during periods between disturbance events and no substantial change in community composition has occurred during the period 1988-2005.
		5m		
	Geoffrey Bay	2m		Monitoring data indicate that the observed low coral cover and few large colonies result from disturbance associated with bleaching in 1998, again in 2002 and an intervening cyclone in 2000. Prior to these disturbances cover had increased from a low point in 1993. Average densities of recruit sized colonies including the fast growing *Acropora* and *Montipora* should allow increases in cover in the absence of further disturbance.
		5m		
Whitsunday Region	Black Currant Is.	2m		The coral community was in very poor condition. Coral cover was very low and macroalgae cover high, coupled with a low density of recruit sized colonies substantial change in the near future is unlikely
	Manta Ray Is.	2m		Previous surveys indicate a marked reduction in coral cover between 1994 and present. The cause of this reduction is unknown though thermal bleaching in 1998 is likely. Coral cover was low at both depths. The density of recruit sized colonies at 2m was also low suggesting limited recovery potential in the short term. At 5m the density of recruit sized colonies was higher and included moderate densities of the fast growing *Acropora* suggesting recovery at this depth was underway. A complication however may be the very high cover of macroalgae at 5m.
		5m		
	Daydream Is.	2m		The coral community was dominated by large branching and bottlebrush *Acropora* colonies that became more patchily distributed in the shallows. The density of recruit sized colonies and also species richness were lower at 2m all resulting in the lower status score for 2m compared to the flourishing community observed at 5m. One concern at 5m was a high incidence of coral disease.
		5m		
	Shute and Tancred Is.	2m		Coral cover at 2m was slightly above average and the community included a number of large colonies, had very high species richness and an abundance of recruit sized colonies all suggesting a flourishing coral community. At 5m the cover was partially limited by a lack of hard substrate at one site where the reef community gives way to mud at this depth. Density of recruit sized colonies on the available hard substrates at 5m was very low and as such increase in cover reliant more on growth of existing colonies than recruitment of new individuals, this may limit recovery from any future disturbance event.
		5m		
	Pine Is.	2m		Communities differed markedly between sites. One had very high coral cover dominated by large individuals of the genus *Galaxea*, the second had low coral cover and no large *Galaxea* colonies. This second site had moderate to high levels of recruit sized colonies indicating cover may increase. Difference in status score was due to higher species richness and density of large colonies at 5m.
		5m		
	Cow and Calf Is.	2m		Cover of macroalgae was very high and that of corals correspondingly low. The community was not substantially different to that observed in a previous survey in 1992 though coral cover may have increased slightly. Very low density of recruit sized colonies at 2m suggests little scope for change in the near future while higher densities at 5m may see an increase in coral cover at this depth though this would be slow given the predominance of slow growing taxa. That there were very few large colonies and observations from 1992 and 2004 both record very limited coral communities may suggest this location is not conducive to supporting substantial coral communities.
		5m		

Table 5.1. continued.

Pompey Region	St. Bees Is.	2m	🔴	Macroalgae cover was very high. Although species richness was high at both depths no taxa were particularly common. Coral cover was low at both depths. Very low density of recruit sized colonies suggests limited scope for substantial increase in coral cover.
		5m	🟠	
	Keswick Is. Back	2m	🟠	The benthic community at both depths included high cover of macroalgae with soft corals also common at 2m. The hard coral community showed signs of severe recruitment limitation with very low densities of recruit size colonies and a high proportion of the corals present in larger size classes. High species richness at both depths contrasted the low cover. The community at 5m was unique amongst reefs visited during this study due to the relatively high number of large *Alveopora* colonies.
		5m	🟡	
	Keswick Is. C Front	2m	🟠	Coral cover was moderate at 2m with the community including moderate numbers of large colonies and high species richness. At 5m coral cover was low cover due in part to the mobile sandy substrate limiting suitable coral settlement substrate. It is possible that the low density of recruits at 5m is due to the mobility of the sand around areas of hard substrate such that available hard substrate is periodically buried. The limited available space at 5m may also limit species richness and the number of large colonies thus overly influencing the status score.
		5m	🔴	
	Keswick Is. A	2m	🟠	Low coral cover in combination with low density of recruit sized colonies and high cover of macroalgae indicate limited prospects of a rapid change in the status of the coral communities at either depth.
		5m	🟠	
Keppel Region	North Keppel Is.	2m	🟡	Both depths were dominated by large colonies of branching *Acropora* . Cover was lower at 5m due to this being the lower limit of the reef slope at which point the coral communities give way to sand. Species richness was low as is typical of reefs in this region. Density of recruit sized colonies was also low though the relative importance of sexual recruitment verses fragmentation as a reproductive strategy in *Acropora* thickets such as these is unknown.
		5m	🟠	
	Middle Is.	2m	🟡	The coral community was dominated by large colonies of branching *Acropora.* At 2m the cover was the highest of any location included in this survey (81%). At 5m cover was slightly lower due to the inclusion of sand patches at the reef base. At both depths the density of recruit sized colonies was above average and this along with high cover, abundance of large colonies and past monitoring showing substantial increase in cover following disturbance all indicate a resilient community. It is only low species richness that lowers the status score.
		5m	🟡	
	Humpy and Halfway Is. Back	2m	🟡	The reef slope at both depths was dominated by stands of large branching Acropora colonies resulting in very high coral cover. Status was limited only by low species richness and low density of recruit sized colonies. Monitoring and our observations indicate a flourishing coral community.
		5m	🟠	
	Humpy and Halfway Is. Front	2m	🟡	Hard coral cover was high at both depths and included a high number of large colonies. Low species richness (typical of this region) and slightly below average density of recruit sized colonies limit our status score. Indications were that this coral community was flourishing
		5m	🟡	
	Pelican Is.	2m	🔴	Hard coral cover and species richness were both low at 2m, however a high number of recruit sized colonies of *Acropora* should see cover increase in the near future. At 5m coral cover was moderate and there were a higher number of large colonies and also a moderate density of recruit sized colonies. A lack of substantial reef development suggests that although the coral community shows signs of resilience it may be transient in the longer term.
		5m	🟡	
	Peak Is.	2m	🔴	This reef exists in a highly turbid setting as reflected in the prostrate growth form of colonies at 5m. Hard coral cover was near average and included a high proportion of large colonies with density of recruit sized colonies correspondingly low. The community was unique among reefs included in this survey due to relatively high numbers and large size of *Psammocora* colonies. Species richness was low. That there was almost no evidence of reef formation suggests coral communities at this location may develop advantageously between major floods of the Fitzroy river.
		5m	🔴	

6. Discussion

The first objective of the study was to make an extensive and detailed comparative assessment of the status of near-shore reefs across a large area of the Great Barrier Reef province at one time. Sections 4 and 5 contain detailed descriptions of the coral communities on near-shore reefs by region and for each location. These attributes are then combined into an index of relative reef status (Section 5).

To fulfil the project's second objective, an extensive list of sources of information relating to the past status of coral communities on near-shore reefs of the GBR is given in Appendix 6.

Based on surveys in 2004, the salient characteristic of near-shore reef communities of the GBR was their variability: they varied in taxonomic composition and extent of development. Coral cover varied from unusually high values compared with other reefs of the GBR at shallow sites in the Keppel region to obviously sparse cover in the Mackay region. Small colonies were present in most locations, indicating recruitment in recent time. This and the few long-term data that are available for near-shore reefs suggest that near-shore reefs are like other reefs of the GBR in experiencing cycles of disturbance and recovery, with variable recovery rates that depend on the composition of the benthic communities

In other ways, near-shore reefs appeared to be more variable than other reefs of the GBR: locations that are relatively close to each other, and so might be expected to experience similar environmental conditions and be subject to the same disturbances, supported distinct communities of corals and had different relative status index scores (Section 6). Some of this variation is a product of the near-shore environment. Reef development in the near-shore zone consists mainly of veneers over loose substrates in bayheads or leeward shores or as fringing reefs on islands or headlands (Hopley *et al.* 1983).The convoluted nature of island and headland shores has two effects. First it means that the hydrodynamic environment can vary over short distances. Hydrodynamics will largely determine the local sedimentation/ resuspension regime (Parnell 1988, Wolanski *et al.* 2005). High levels of fine sediment affect corals and coral communities in several deleterious ways (Williams 2001, Fabricius 2005). Secondly, minor differences in location and aspect can also affect exposure to disturbance events, as shown by the changes in hard coral cover in the different sites at Snapper Is (Figure 3.15), where differences in aspect resulted in substantial differences in exposure to cyclone-induced waves in one instance and to inundation with freshwater from flooding in another (Ayling and Ayling 1997). These are all ways in which the near-shore environment enhances small-scale variability in both the types of communities that develop at sites and in the extent of their development at a particular time.

This study was descriptive and all attempts to relate aspects of the coral communities to environmental variables were *a posteriori* and correlative. Estimates of variables describing the physical setting of each location (Table 2.2) based simply on geography and exposure to the prevailing SE trade winds (Exposure and Fetch) explained little variation in communities. The relative grain-size of the sediment (reflecting the local resuspension/ deposition regime) did explain a proportion of variation in the coral communities. The genera that were more abundant in locations with fine-grained sediments (Figure 3. 12b) are known to shed sediments (Stafford-Smith and Ormond 1992, Stafford-Smith 1993) relatively efficiently, while those with poor sediment shedding capability were associated with sandier areas.

There were consistent differences in the relative abundance of a number of genera between the 2 m and 5 m depths. This difference with depth may also be related to sedimentation. Several of the genera that were more abundant in deeper transects were also associated with muddier sediments. In contrast the genus *Acropora* was better represented in the less muddy environments and, with *Montipora*, was more common in shallower sites.

Resuspension of fine sediments is a function of wave height relative to depth, so resuspension attenuates with depth (Wolanski *et al.* 2005) while deposition increases. This means that the rate of sedimentation of fine particles at a location will increase with depth.

Any increase in fine sediment in the near-shore zone may have asymmetric effects on coral communities. Wave action will continue to remove the additional sediment from the shallow resuspension zone at a location, while the extra sediment will accumulate in the deeper deposition zones. This implies that communities associated with deposition zones will suffer extra stress with increased sedimentation, while other habitats, where continual resuspension occurs, will change little. The counter-intuitive result would be that the sediment-tolerant species could be most affected by increases in sedimentation rates or increased contamination. This is speculative, but points to the need for further investigation into the links between communities, sedimentation and local scale hydrodynamics.

Frequency of inundation with freshwater will also vary with depth. The relationship between variation in coral communities and exposure to low salinity conditions was not assessed directly, but river flow volumes, flood periodicity and distance from river-mouths are all components of the Ecosystem Risk Index (ERI, Devlin *et al.* 2003) which explained some variation in coral community structure (Table 3.4). Tolerance of corals to low salinity has not received the same attention as the effects of sedimentation, but Kerswell and Jones (2003) showed that some species bleach and die after exposure to low salinity levels that occur routinely in flood plumes (Devlin *et al.* 2001). Field observations following two GBR flood events (van Woesik *et al.* 1995, Ayling and Ayling 1997) suggested that *Acropora* spp. and *Pocillopora* spp. were less tolerant of low salinity than are *Porites* spp. These more susceptible genera (*Acropora* and *Pocillopora*) were common in shallow transects (2 m below LAT) in 2004, implying that diluted flood plumes rarely penetrate even to 2 m depth in many sites. This is consistent with the limited depth penetration of low salinity conditions within flood plumes (Devlin *et al.* 2001). We did not sample communities in shallower sites on reef crests or flats; but these would be expected to suffer salinity stress more frequently, with associated mortality.

Considering the longstanding concern about the effects of runoff on the status of the GBR in general and of near-shore reefs in particular, there is a surprising lack of relevant data on water quality for the GBR. No systematic measurements of water quality variables were available at the scale of our individual survey sites on near-shore reefs. We used the ERI (Devlin *et al.* 2003) as an estimate of likely exposure to runoff at survey reefs. While it is the best available, the ERI is a crude index, based on a River Pollution Index (RPI) that includes a simplistic estimate of sediment loads and weights all proxies for pollution (except for urban development) equally on linear scales. The RPI is combined with rough estimates of flood plume extents and a simplistic linear dilution factor to give the ERI. While the resulting estimates show qualitative correspondence to preconceptions of risk to near-shore communities from terrestrial runoff, the scaling of ERI values is very dubious. Knowledge of the effects of components of runoff on reef organisms (as summarised by Fabricius 2005) should be used to scale the component functions in the RPI. The revised RPI should then be combined with basic hydrodynamic models for the GBR lagoon to give more realistic estimates of ecosystem risk.

6.1. *The Status of Near-shore Reefs*

Assessment of the status of near-shore coral reefs must take account of the range of environmental settings in which near-shore coral communities exist and how these affect community composition. Species composition alone is not an indication of condition as differences may simply reflect variation in the natural environmental setting (Done 1982). Proxies of environmental variables explained some of the variation in communities among survey locations, but much variability remained unexplained. Part of this unexplained variability results from the crudeness of these proxies, but it is clear from the few long-term studies (Figures 4.14-4.16) that near-shore coral communities are dynamic and subject to severe disturbances. This means that the timing of surveys relative to disturbance events can drastically influence assessments of the status of communities. In this way, assessment of coral cover at one point in time (e.g. van Woesik *et al.* 1999) may give a misleading impression of the status of a given community without the context of the recent disturbance history. A more informative assessment of status must include evidence of resilience - the regenerative capacity of the community following disturbance. An overall lack of small individuals or recruitment of a different set of species from the established colonies could indicate low community resilience. Density estimates of recruit-sized colonies were an important component of these surveys. While recruit-sized coral colonies were recorded in most locations in 2004 and estimates of density ranged considerably, the absence of information on local survival rates under prevailing conditions means that it is impossible to know if even the highest recorded densities would exceed mortality rates and so be sufficient to ensure perpetuation of communities.

Annual temperature ranges, tidal amplitude and proximity to mid- and outer shelf reef communities all vary among regions. Terrestrial inputs to the near-shore zone will also vary as local catchments vary in size, rainfall, soil type and land use, all of which will greatly alter the period, intensity and water borne components of flood events (eg. ERI) as well as the nature of accumulated sediments (Furnas 2003, Devlin *et al.* 2003). The index of relative reef status showed few consistent regional differences; most regions included locations with a wide range of relative status scores (section 6). Three regions stand out: reefs in the Mackay region collectively appeared to be the least “healthy” on the basis of low cover of hard corals and low density of recruit-sized hard coral colonies. By contrast, locations of the Innisfail region had high densities of recruits of a number of genera but low densities of large colonies, suggesting that these reefs were recovering from past disturbances. Reefs in the Keppel region were different again: hard coral cover was very high, but the density of recruits and species richness were low.

Communities at some sites had high coral cover but were dominated by very large individuals (>2 m diameter) of very few species. These include Pine Island (*Galaxea*), Middle and Pandora Reefs (*Goniopora*) and back-reefs of the Frankland Is group and High Island (*Porites*). It is possible that large colonies are relics of past environmental conditions at a site, having recruited and survived juvenile stages in a more hospitable setting than the current one. Thus while stands of large colonies must have persisted to have reached such large size this does not mean that the same community would regenerate following a disturbance. Such communities typically show low species richness though this may be because the space available for the recruitment and growth of other species was limited by large individuals of the dominant species.

The index of relative reef status was based on the combination of four unweighted attributes of each location. This is simplistic, as the relative importance of the constituent variables will almost certainly differ and will also vary from one community type to another. For example, species richness is likely to be low in highly turbid areas as few species are capable of persisting in such conditions. Also, each component variable is scaled to the range of values that were recorded in our 2004 surveys; we do not know how these values compare with pre-colonisation values from 150 years ago, or whether high values of the index do actually correlate with community persistence or low values indicate stress. The dynamics of communities can only be assessed by monitoring them over appropriate time scales.

6.2. Comparison with Species Lists from Previous Surveys

Veron (2002) lists 403 species of zooxanthellate scleractinian corals from eastern Australia, of which at least 315 species were recorded during these surveys in 2004. This number is probably a slight underestimate as several species of *Montipora*, and *Porites* could not be distinguished in the field. While this suggests that a high proportion of the available species pool can survive on near-shore reefs, many were very rare and possibly transient. A few species were ubiquitous, but most were rare: approximately one third of species were observed on less than 10% of the sites. Considering the abundance of colonies for each genus, 63 genera were recorded in demographic surveys but 33% of those genera contributed <1% of colonies. The patchy distribution and rarity of a number of species, as shown by the low overlap of species between sites within locations, suggests that many species occur in small and isolated stands. Maintenance of these sub-populations will depend on the disturbance regime and on the connectivity among near-shore reefs and between the near-shore and populations on reefs further off shore. When brood stock is severely depleted over a wide area, there may be protracted periods with no apparent recovery, as in the Palm Island group following bleaching in 1998 (Figure 3.16). Indications from gene flow among populations (Ayre and Hughes 2004) also suggest limited movement of larvae across the “shipping channel” that separates the mid-shelf reefs from the near-shore zone, especially in the southern regions of the GBR.

Our attempts to compare our records with past species lists were complicated by the fine-grained patchy distributions of species at local scales. Similar areas of a reef may have been surveyed but changes in the community over time could not be distinguished from effects of small differences in location. Taxonomic inconsistencies were an added problem. The accurate GPS locations for our sites and precise location of transects by depth, along with specimens and the database of photographs of colonies *in situ* that have been lodged in the Museum of Tropical Queensland collection should aid future comparisons.

With these considerations, comparison of species lists from 17 sites in 2004 and surveys from similar locations in the mid 1990s indicated a number of species that may have suffered reductions in distribution over a 7-10 year period. Two severe bleaching events occurred between the two sets of surveys, so species that were susceptible to thermal bleaching may have been lost. Comparison with communities on fringing reefs along the Daintree coast in 1985 also identified a small number of species that may have seen local declines in abundance or distribution. The apparent reduction in *Seriatopora hystrix* on the Cape Tribulation reefs is interesting because the species is particularly susceptible to thermal bleaching (Marshall and Baird 2000) and gene flow estimates suggest it has very low connectivity among sub-populations (Ayre and Hughes 2004).

6.3. Review of Temporal Data Sets from Near-shore Reefs

Long-term replicated surveys on near-shore reefs highlight the dynamic nature of these coral communities, with crown-of-thorns starfish, flooding, cyclone waves and thermal bleaching all causing large reductions in coral cover in various locations since monitoring began in the mid 1980s. These studies provide the clearest basis for assessment of status of near-shore reefs as they provide data on recovery following disturbance. In the long-term, status can only be considered “good” if there is evidence that coral cover and diversity can be maintained through recruitment and growth in periods of low disturbance that compensate for mortality from disturbances.

Pooling proportional changes in cover from all historical surveys in the near-shore zone showed that the Acroporidae and Pocilloporidae were among the most susceptible taxa to disturbances that affect near-shore reefs. These taxa are also capable of relatively rapid increase. The cover of *Acropora* spp. on reefs in the Palm and Rattlesnake groups was reduced to very low levels, if not completely removed from these reefs in the mid to late 1990s. Coral bleaching in 1998 was probably responsible for most of the reduction. While there is no evidence for substantial recruitment of other coral taxa onto these reefs, that might indicate a shift in composition, there has been little evidence of recovery of the *Acropora* community either. Bleaching and other unknown impacts killed whole coral colonies, so recovery will depend on recruitment and growth of new individuals. This is slow compared with recovery through regrowth of colonies that have suffered only partial mortality or growth of coral fragments (Ayling and Ayling, 2005). Bleaching killed a large proportion of the shallow water *Acropora* communities throughout Halifax Bay; these communities probably supplied the bulk of larvae to the Palm Is reefs. Corals that bleach extensively but survive have lower reproductive output for at least one year (Ward *et al.* 2002), so surviving colonies would have had lower fecundity in the summer of 1998-9 and possibly 1999-2000. Settled juveniles take 2-3 years to become visible in video records, so little record of recovery would be expected until at least 2001-02. All this, combined with additional bleaching in 2002, means that the lack of substantial recovery of the *Acropora* community by 2004 was not unexpected.

6.4. Knowledge Gaps and Future Directions

The surveys in 2004 found a great deal of local variability in benthic communities on near-shore reefs. Communities are likely to vary among locations for two kinds of reasons: firstly the local biophysical environment restricts the suite of species that can live in a site and secondly, the recent disturbance history determines the extent of benthic cover and the spectrum of colony sizes. The lack of accurate, local measurements of any biophysical variables meant that there was little possibility of explaining much of this variability among sites. Given the concern about the effects of runoff on near-shore reefs, the absence of any substantial data on water quality regimes at the great majority of locations is particularly striking. Systematic local measurements and more sophisticated modelling of environmental variables are could explain more of the variation. The variability in the communities implies either that the differences in environmental conditions that affect community structure occur on a surprisingly fine scale or, more likely, that chance plays a significant role in the structure of the community that develops at any particular location.

The few long-term studies of benthic communities on near-shore reefs show that they are dynamic and are regularly subject to major disturbances on a timescale of a decade. The high frequency of disturbances, combined with the observation that many anthropogenic changes on land can lead to adverse effects on reproduction and recruitment of corals, focuses attention on rates of recovery of reef communities. The size-distribution of colonies from a single survey allows some inference of past history at a location (with a number of assumptions) and size-distributions can be compared among locations, but they give no information on rates of recovery. Estimates of larval supply from settlement plates would reveal the number of potential recruits and some information on their diversity. Repeated estimates of colony size-structure in combination with measures of benthic cover would allow rates of growth and survivorship to be estimated. These vital rates could show whether the observed levels of recruitment will lead to increases in coral cover or not, and may possibly also allow rates of recovery to be estimated.

Surveys in 2004 recorded at least 315 species of hard corals in swim searches around the survey sites at 33 reefs. Most of these were recorded in low numbers at few sites. Studies based on intensive sampling on a limited area of transects emphasise common species and will not give useful information on the dynamics of these rare species: Are they transient and the result of infrequent transportation of larvae from another habitat? Are they a small but regular component of benthic communities under certain biophysical conditions? Is their presence an indicator of conditions within a particular range? These surveys provide a benchmark for future changes, but are only a small start in describing the status and functioning of coral communities on near-shore reefs.

7. References

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Appendix 1

Summary analysis table of *F*-tests for fixed effects and estimates of random variance components in for a variety of univariate summaries of the coral community estimated from linear mixed effects models. The error term for Region was Reef (Region), and the error term for Depth and Depth*Region was Depth*Reef(Region). The denominator degrees of freedom were estimated by a Sattherthwaite approximation and are rounded up to the nearest integer. Models for estimates derived from demographic structure of the community do not include the random variable "site" as data is aggregated over sites at each depth on each reef.

Cover of hard coral

Source	df	F	P	Variance Component	P
Region	5, 27	2.56	0.051		
Reef (Region)				170.6	0.072
Site(Reef(Region))				117.6	0.014
Depth	1, 24	0.22	0.65		
Depth* Region	5, 24	0.33	0.89		
Depth*Reef(Region)				99.8	0.053
Residual				125.2	<0.001

Cover of soft coral

Source	df	F	P	Variance Component	P
Region	5, 26	0.39	0.85		
Reef (Region)				2.69	0.785
Site(Reef(Region))				11.4	0.021
Depth	1, 25	1.54	0.23		
Depth* Region	5, 26	1.19	0.34		
Depth*Reef(Region)				30.8	0.005
Residual				12.1	<0.001

Cover of macroalgae

Source	df	F	P	Variance Component	P
Region	5, 27	2.47	0.058		
Reef (Region)				137.9	0.038
Site(Reef(Region))				29.4	0.13
Depth	1, 25	7.32	0.012		
Depth* Region	5, 25	0.19	0.96		
Depth*Reef(Region)				98.3	0.017
Residual				77.2	<0.001

Species richness of hard corals

Source	df	F	P	Variance Component	P
Region	5, 27	13.8	<0.001		
Reef (Region)				0.021	0.213
Site(Reef(Region))				0.036	0.018
Depth	1, 24	10.9	0.003		
Depth* Region	5, 24	1.24	0.32		
Depth*Reef(Region)				0.005	0.58
Residual				0.042	<0.001

Proportion of hard coral colonies that are "Large" (see Appendix 3)

Source	df	F	P	Variance Component	P
Region	5, 27	2.89	0.033		
Reef (Region)				0.006	0.01
Depth	1, 24	0.58	0.45		
Depth* Region	5, 24	0.13	0.98		
Residual				0.004	0.001

Proportion of hard coral colonies that are <10 cm in diameter

Source	df	F	P	Variance Component	P
Region	5, 25	1.95	0.12		
Reef (Region)				0.009	0.056
Depth	1, 23	2.31	0.14		
Depth* Region	5, 23	0.61	0.7		
Residual				0.011	0.001

Proportion of hard coral colonies that are <5 cm in diameter

Source	df	F	P	Variance Component	P
Region	5, 24	1.64	0.19		
Reef (Region)				0.002	0.37
Depth	1, 23	1.29	0.27		
Depth* Region	5, 23	0.86	0.52		
Residual				0.006	0.001

Proportion of soft coral colonies that are "Large" (see Appendix 3)

Source	df	F	P	Variance Component	P
Region	5, 24	3.06	0.029		
Reef (Region)				0.004	0.14
Depth	1, 21	1.54	0.23		
Depth* Region	5, 21	0.21	0.95		
Residual				0.007	0.002

Proportion of soft coral colonies that are <10 cm in diameter

Source	df	F	P	Variance Component	P
Region	5, 26	2.79	0.038		
Reef (Region)				0.012	0.16
Depth	1, 24	1.69	0.21		
Depth* Region	5, 24	1.05	0.42		
Residual				0.026	0.001

Proportion of soft coral colonies that are <5 cm in diameter

Source	df	F	P	Variance Component	P
Region	5, 28	3.22	0.02		
Reef (Region)				0.004	0.18
Depth	1, 26	2.44	0.13		
Depth* Region	5, 26	0.64	0.67		
Residual				0.012	0.001

Density of hard coral colonies

Source	df	F	P	Variance Component	P
Region	5, 27	2.84	0.034		
Reef (Region)				4.92	0.294
Site(Reef(Region))				5.6	0.037
Depth	1, 25	1.02	0.32		
Depth* Region	5, 26	0.6	0.7		
Depth*Reef(Region)				9.15	0.023
Residual				8.49	<0.001

Density of soft coral colonies

Source	df	F	P	Variance Component	P
Region	5, 27	2.63	0.045		
Reef (Region)				1.65	0.075
Site(Reef(Region))				0.74	0.067
Depth	1, 26	0.05	0.82		
Depth* Region	5, 26	1.7	0.17		
Depth*Reef(Region)				1.45	0.021
Residual				1.31	<0.001

Density of hard coral recruits <5 cm standardised to area of available substrate

Source	df	F	P	Variance Component	P
Region	5, 27	2.82	0.036		
Reef (Region)				0.13	0.913
Site(Reef(Region))				1.71	0.062
Depth	1, 27	3.96	0.057		
Depth* Region	5, 27	1.19	0.34		
Depth*Reef(Region)				2.94	0.029
Residual				3.16	<0.001

Density of hard coral recruits <10 cm standardised to area of available substrate

Source	df	F	P	Variance Component	P
Region	5, 27	3.22	0.021		
Reef (Region)				3.46	0.377
Site(Reef(Region))				3.81	0.148
Depth	1, 26	7.19	0.012		
Depth* Region	5, 27	1.00	0.436		
Depth*Reef(Region)				7.24	0.053
Residual				10.17	<0.001

Density of soft coral recruits <5 cm standardised to area of available substrate

Source	df	F	P	Variance Component	P
Region	5, 27	2.64	0.045		
Reef (Region)				0.28	0.336
Site(Reef(Region))				0.34	0.010
Depth	1, 26	1.35	0.26		
Depth* Region	5, 26	0.28	0.92		
Depth*Reef(Region)				0.74	0.005
Residual				0.33	<0.001

Density of soft coral recruits <10 cm standardised to area of available substrate

Source	df	F	P	Variance Component	P
Region	5, 27	2.35	0.067		
Reef (Region)				1.82	0.186
Site(Reef(Region))				1.71	0.020
Depth	1, 26	1.33	0.259		
Depth* Region	5, 26	0.66	0.656		
Depth*Reef(Region)				2.46	0.018
Residual				2.10	<0.001

Appendix 2

Appendix 2.1.

Summary of regional and depth differences based on mixed model ANOVA using the natural log transformed abundance of colonies for individual genera. Genera were included in the analyses if at least 50 colonies were recorded along demography transects. Only those regions where at which at least one colony was observed were included in the model for each genus. Probability values <0.05 are shown in boldface.

Hard Corals

Genus	Region	Depth	Region* Depth
Acanthastrea	0.099	0.173	0.797
Acropora	0.232	0.001	0.117
Alveopora	0.143	0.067	0.72
Astreopora	0.058	0.008	0.013
Barabattoia	0.771	0.051	0.289
Caulastrea	0.317	0.028	0.392
Coscinaraea	0.041	0.066	0.203
Cyphastrea	0.258	0.037	0.789
Echinophyllia	0.059	0.003	0.077
Echinopora	0.094	0.298	0.049
Euphyllia	0.36	0.108	0.244
Favia	0.001	0.01	0.428
Favites	0.01	0.067	0.381
Fungia	0.002	0.714	0.527
Galaxea	0.175	0.687	0.097
Goniastrea	0.004	0.083	0.005
Goniopora	0.222	<0.001	0.167
Heliofungia	0.181	0.148	0.102
Heliopora	0.837	0.567	0.31
Hydnophora	0.406	0.194	0.481
Leptastrea	0.002	0.428	0.246
Lobophyllia	<0.001	0.096	0.149
Merulina	0.465	0.047	0.046
Montastrea	0.072	0.101	0.316
Montipora	0.021	0.053	0.705
Moseleya	0.311	0.002	0.408
Mycedium	0.032	0.007	0.633
Oxypora	0.004	0.247	0.055

Genus	Region	Depth	Region* Depth
Pachyseris	0.402	0.001	0.027
Pavona	0.116	0.003	0.05
Pectinia	0.082	0.003	0.935
Platygyra	0.067	0.13	0.044
Plesiastrea	0.65	0.695	0.176
Pocillopora	0.096	0.022	0.095
Podabacia	<0.001	0.026	0.121
Porites	<0.001	0.03	0.944
Psammocora	0.737	0.857	0.057
Pseudosiderastrea	0.267	0.406	0.769
Stylophora	0.059	0.078	0.286
Symphyllia	0.8	0.059	0.969
Turbinaria	0.278	0.017	0.214

Soft Corals

Genus	Region	Depth	Region * Depth
Briareum	0.018	0.122	0.009
Capnella	0.22	0.489	0.152
Clavularia	0.784	0.095	0.914
Efflatournaria	0.377	0.608	0.654
Klyxum	0.012	0.085	0.677
Lobophytum	0.168	0.165	0.329
Nephthea	0.352	0.107	0.317
Sarcophyton	0.006	0.007	0.399
Sinularia	0.003	0.92	0.8
Xenia	0.289	0.395	0.024

Appendix 2.2.

Summary of differences among regions and depths for genera that were sufficiently abundant and widely distributed to compare proportion of the populations in two size classes: “large” or <10 cm (recruits). Probability values are from mixed model ANOVA using arcsine transformed proportions. A genus was included if at least 10 colonies were observed at both depths of at least two reefs in three or more regions.

Genus	Proportion "large"			Proportion <10 cm		
	Region	Depth	Region by Depth	Region	Depth	Region by Depth
Acropora	<0.001	0.647	0.200	0.777	0.340	0.054
Cyphastrea	0.193	0.558	0.473	0.335	0.415	0.642
Favia	0.485	0.048	0.047	0.213	0.932	0.471
Galaxea	<0.001	0.078	0.076	0.128	0.267	0.431
Goniastrea	0.394	0.695	0.91	0.022	0.738	0.894
Goniopora	0.349	0.295	0.066	0.429	0.626	0.856
Montipora	0.064	0.141	0.480	0.067	0.186	0.232
Porites	0.522	0.583	0.937	0.717	0.253	0.058
Sarcophyton	0.145	0.019	0.207	0.310	0.063	0.631
Sinularia	0.040	0.92	0.749	0.203	0.028	0.199
Turbinaria	0.327	0.211	0.479	0.131	0.013	0.055

Appendix 2.3.

Summary of differences among regions and depths in the density of juvenile colonies (<10 cm diameter). Density is based on the area of available substrate at each site. Probability values are from mixed model ANOVA. Taxa were included in the analysis if >50 colonies <10 cm diameter were recorded in the surveys.

Hard Corals	Region	Depth	Region* Depth
Acanthastrea	0.120	0.150	0.337
Acropora	0.004	0.026	0.131
Barabattoia	0.503	0.152	0.396
Caulastrea	0.027	0.086	0.031
Cyphastrea	0.081	0.049	0.548
Echinophyllia	0.124	0.050	0.032
Euphyllia	0.215	0.657	0.120
Favia	0.006	0.007	0.488
Favites	0.041	0.016	0.545
Fungia	0.036	0.219	0.638
Galaxea	0.002	0.429	0.082
Goniastrea	0.058	0.444	0.111
Goniopora	0.527	0.015	0.828
Heliopora	0.698	0.210	0.779
Hydnophora	0.024	0.111	0.297
Leptastrea	0.011	0.097	0.399
Lobophyllia	0.001	0.260	0.905
Merulina	0.409	0.060	0.154
Montastrea	0.074	0.001	0.293
Montipora	0.014	0.213	0.220
Moseleya	0.230	0.058	0.801
Mycedium	0.190	0.002	0.067
Pachyseris	0.040	0.002	0.008
Pavona	0.077	0.031	0.003
Pectinia	0.014	0.177	0.742
Platygyra	0.004	0.099	0.053
Pocillopora	0.050	0.464	0.408
Podabacia	<0.001	0.195	0.515
Porites	0.013	0.159	0.070
Psammocora	0.396	0.041	0.301
Stylophora	0.211	0.215	0.687
Turbinaria	0.310	0.002	0.538

Soft Corals	Region	Depth	Region* Depth
Briareum	0.263	0.510	0.277
Capnella	0.376	0.328	0.865
Clavularia	0.542	0.342	0.309
Klyxum	0.751	0.974	0.156
Sarcophyton	0.031	0.036	0.304
Sinularia	0.006	0.176	0.994
Xenia	0.019	0.168	0.220

Appendix 3

Criterion of "large" for each genus, based on the size spectra encountered over all sites in the surveys and in other diving on the GBR. Any colony in the listed size class or larger was considered to be "large".

5-10 cm	10-20 cm	20-50 cm	50-100 cm	>100 cm
Cynarina	*Denronephthya*	*Acanthastrea*	*Alveopora*	*Acropora*
Pseudosiderastrea	*Fungia*	*Anacropora*	*Astreopora*	*Briareum*
Scolymia	*Heteroxenia*	*Barabattoia*	*Caulastrea*	*Diploastrea*
	Lithophyllon	*Capnella*	*Cespitularia*	*Pachyseris*
	Litophyton	*Catalaphyllia*	*Cladiella*	*Pavona*
	Moseleya	*Coeloseris*	*Clavularia*	*Porites*
	Stereonephthya	*Ctenactis*	*Coscinaraea*	
		Cyphastrea	*Ctenocella*	
		Duncanopsammia	*Echinophyllia*	
		Euphyllia	*Echinopora*	
		Favia	*Efflatournaria*	
		Favites	*Galaxea*	
		Gardineroseris	*Goniastrea*	
		Heliofungia	*Goniopora*	
		Herpolitha	*Heliopora*	
		Lemnalia	*Hydnophora*	
		Leptastrea	*Klyxum*	
		Leptoria	*Leptoseris*	
		Montastrea	*Lobophyllia*	
		Nephthea	*Lobophytum*	
		Paralemnalia	*Merulina*	
		Polyphyllia	*Montipora*	
		Rhytisma	*Mycedium*	
		Sandalolitha	*Oulophyllia*	
		Sarcophyton	*Oxypora*	
		Scapophyllia	*Palauastrea*	
		Seriatopora	*Pectinia*	
		Stylocoeniella	*Physogyra*	
		Stylophora	*Platygyra*	
		Tubipora	*Plerogyra*	
		Xenia	*Plesiastrea*	
			Pocillopora	
			Podabacia	
			Psammocora	
			Sinularia	
			Symphyllia	
			Turbinaria	
			Acropora	
			Briareum	

5-10 cm	**10-20 cm**	**20-50 cm**	**50-100 cm**	**>100 cm**
			Diploastrea *Pachyseris* *Pavona* *Porites*	

Appendix 4

Waypoints for survey sites. GPS datum is WGS84. At many sites, a waypoint was only recorded for one depth (usually 5 m); in such cases the transects at the other depth were located perpendicularly up or down slope from the given position. Positions given are the start of transect 1 for the given depth, from this point transects were numbered in a clockwise direction around the reef. The exception was Middle Island (Keppel region) where transects were numbered in an anti-clockwise direction.

Region	Reef	Site	Depth	Latitude	Longitude
Cairns	Wentworth	1	2	16 30.809S	145 31.543E
	Wentworth	1	5	16 30.795S	145 31.557E
	Wentworth	2	2	16 30.908S	145 31.526E
	Wentworth	2	5	16 30.912S	145 31.555E
	Double Island	1	5	16 43.619S	145 41.373E
	Double Island	2	5	16 43.758S	145 41.536E
	Snapper Island (back)	1	5	16 17.544S	145 29.813E
	Snapper Island (back)	2	5	16 18.11S	145 30.418E
	Snapper Island (front)	1	5	16 18.127S	145 30.118E
	Snapper Island (front)	2	5	16 17.985S	145 29.76E
	Cape Tribulation Nth	1	2	15 59.876S	145 26.547E
	Cape Tribulation Nth	2	2	16 1.8S	145 27.716E
	Cape Tribulation Sth	1	2	16 5.242S	145 28.24E
	Cape Tribulation Sth	2	2	16 6.475S	145 27.875E
Innisfail	King	1	5	17 46.471S	146 9.546E
	King	2	5	17 46.72S	146 9.337E
	Dunk Island (back)	1	5	17 55.565S	146 8.749E
	Dunk Island (back)	2	5	17 55.399S	146 8.234E
	Dunk Island (front)	1	5	17 57.666S	146 9.782E
	Dunk Island (front)	2	5	17 57.44S	146 8.631E
	High Island (back)	1	5	17 9.603S	146 0.345E
	High Island (back)	2	5	17 9.729S	146 0.419E
	High Island (front)	1	2	17 9.489S	146 0.882E
	High Island (front)	1	5	17 9.507S	146 0.895E
	High Island (front)	2	2	17 9.794S	146 0.749E
	High Island (front)	2	5	17 9.817S	146 0.779E
	Frankland Islands (back)	1	5	17 13.618S	146 5.422E
	Frankland Islands (back)	2	5	17 12.747S	146 4.557E
	Frankland Islands (front)	1	2	17 12.243S	146 4.608E
	Frankland Islands (front)	2	2	17 13.195S	146 5.458E

Region	Reef	Site	Depth	Latitude	Longitude
	Frankland Islands (front)	2	5	17 13.168S	146 5.494E
Townsville	Pandora	1	5	18 48.694S	146 25.803E
	Pandora	2	2	18 48.692S	146 25.943E
	Pandora	2	5	18 48.642S	146 25.959E
	Nelly Bay	1	5	19 9.821S	146 51.274E
	Nelly Bay	2	2	19 10.278S	146 50.926E
	Nelly Bay	2	5	19 10.29S	146 50.95E
	Middle Reef	1	2	19 11.681S	146 48.635E
	Middle Reef	2	2	19 11.762S	146 48.808E
	Geoffrey Bay	1	5	19 9.301S	146 52.108E
	Geoffrey Bay	2	5	19 9.413S	146 51.734E
Whitsunday	Calf Island	1	5	20 25.506S	148 50.933E
	Calf Island	2	5	20 25.655S	148 51.036E
	Pine Island	1	5	20 22.682S	148 53.306E
	Pine Island	2	5	20 22.525S	148 53.185E
	Daydream island	1	5	20 15.205S	148 48.731E
	Daydream island	2	5	20 15.134S	148 48.763E
	Manta Ray Island	1	5	20 4.867S	148 30.831E
	Manta Ray Island	2	5	20 4.767S	148 30.898E
	Black Currant Island	1	2	20 3.94S	148 28.86E
	Black Currant Island	2	2	20 4.811S	148 29.834E
	Shute and Tancred Islands	1	5	20 18.104S	148 48.193E
	Shute and Tancred Islands	2	5	20 18.051S	148 47.898E
Mackay	St. Bees Island	1	5	20 54.207S	149 25.92E
	St. Bees Island	2	5	20 54.224S	149 26.585E
	Keswick Island A	1	5	20 54.709S	149 23.449E
	Keswick Island A	2	5	20 54.673S	149 23.313E
	Keswick Island C (back)	1	5	20 54.445S	149 25.044E
	Keswick Island C (back)	2	5	20 54.633S	149 25.005E
	Keswick Island C (front)	1	5	20 55.555S	149 25.418E
	Keswick Island C (front)	2	5	20 55.641S	149 25.279E
Keppel	Peak Island	1	5	23 20.474S	150 56.21E
	Peak Island	2	5	23 21.178S	150 56.509E
	Middle Island	1	5	23 9.737S	150 55.261E
	Middle Island	2	2	23 9.878S	150 55.406E
	Pelican Island	1	5	23 14.326S	150 52.471E

Region	Reef	Site	Depth	Latitude	Longitude
	Pelican Island	2	5	23 14.495S	150 52.711E
	North Keppel Island	1	5	23 5.191S	150 54.325E
	North Keppel Island	2	5	23 5.113S	150 54.104E
	Humpy and Halfway Islands (back)	2	5	23 12.158S	150 58.182E
	Humpy and Halfway Islands (front)	1	5	23 11.796S	150 58.348E
	Humpy and Halfway Islands (front)	2	5	23 12.444S	150 58.478E

Appendix 5

Appendix 5.1.

Species recorded from near-shore reefs. Numbers in brackets indicate the number of surveys in which the species was observed. There were a total of 129 surveys (combinations of reefs, sites and depths).

Acroporidae

Acropora abrolhosensis (1)
A. abrotanoides (6)
A. aculeus (22)
A. acuminata (1)
A. anthocercis (10)
A. aspera (4)
A. austera (6)
A. brueggemanni (15)
A. bushyensis (1)
A. carduus (1)
A. cerealis (10)
A. clathrata (2)
A. cytherea (40)
A. dendrum (4)
A. digitifera (46)
A. divaricata (76)
A. donei (9)
A. elizabethensis (4)
A. elseyi (50)
A. florida (3)
A. gemmifera (26)
A. glauca (20)
A. grandis (33)
A. granulosa (7)
A. horrida (20)
A. humilis (29)
A. hyacinthus (48)
A. intermedia (54)
A. kirstyae (3)
A. latistella (81)
A. longicyathus (31)
A. loripes (27)
A. microclados (18)
A. microphthalma (61)
A. millepora (65)
A. monticulosa (3)
A. multiacuta (2)
A. muricata (82)
A. nana (3)
A. nasuta (25)
A. palifera (33)
A. paniculata (2)
A. polystoma (4)
A. prostrata (21)
A. pulchra (14)
A. robusta (7)
A. rosaria (20)
A. samoensis (32)
A. sarmentosa (38)
A. secale (47)
A. selago (18)
A. solitaryensis (18)
A. striata (1)
A. subglabra (3)
A. subulata (41)
A. tenuis (76)
A. torresiana (8)
A. valenciennesi (17)
A. valida (105)
A. vaughani (11)
A. verweyi (2)
A. willisae (4)
A. yongei (7)
A. sp1 (68)
A. sp2 (37)
A. sp3 (16)
A. sp4 (7)
A. sp5 (1)
Anacropora matthai (1)
Astreopora gracilis (21)
A. incrustans (1)
A. listeri (11)
A. moretonensis (11)

A. myriophthalma (42)
A. ocellata (3)
A. sp1 (16)
Montipora aequituberculata (61)
M. angulata (1)
M. caliculata (4)
M. confusa (2)
M. corbettensis (16)
M. crassituberculata (39)
M. danae (14)
M. digitata (2)
M. floweri (1)
M. foliosa (24)
M. foveolata (2)
M. grisea (27)
M. hispida (4)
M. hoffmeisteri (2)
M. incrassata (11)
M. informis (22)
M. millepora (1)
M. mollis (2)
M. monasteriata (4)
M. nodosa (4)
M. peltiformis (4)
M. spongodes (16)
M. spumosa (2)
M. stellata (35)
M. tuberculosa (6)
M. turgescens (38)
M. turtlensis (9)
M. undata (7)
M. venosa (2)
M. verrucosa (23)
M. sp1 (86)
M. sp2 (41)
M. sp3 (18)
M. sp4 (12)
M. sp5 (6)

Agariciidae

Coeloseris mayeri (3)
Gardineroseris planulata (3)
Leptoseris mycetoseroides (6)
L. scabra (5)
L. yabei (4)
L. sp1 (1)
Pachyseris rugosa (29)
P. speciosa (77)
Pavona cactus (20)
P. clavus (2)
P. decussata (23)
P. explanulata (13)
P. maldivensis (1)
P. minuta (2)
P. varians (36)
P. venosa (20)
P. sp1 (1)

Astrocoeniidae

Palauastrea ramosa (4)
Stylocoeniella armata (22)
S. sp1 (2)

Dendrophylliidae

Dendrophyllia spp (1)
Duncanopsammia axifuga (8)
Turbinaria bifrons (22)
T. frondens (44)
T. heronensis (7)
T. mesenterina (91)
T. patula (49)
T. peltata (62)
T. radicalis (29)
T. reniformis (81)
T. stellulata (31)
T. sp1 (3)

Euphyllidae

Catalaphyllia jardinei (4)
Euphyllia ancora (32)
E. cristata (14)
E. divisa (30)
E. glabrescens (23)
Physogyra lichtensteini (18)
Plerogyra sinuosa (28)

Faviidae

Barabattoia amicorum (28)
B. laddi (2)
Caulastrea curvata (3)
C. echinulata (1)
C. furcata (29)
Cyphastrea chalcidicum (43)
C. decadia (11)
C. microphthalma (51)

C. serailia (89)
C. sp1 (10)
Diploastrea heliopora (16)
Echinopora gemmacea (31)
E. horrida (12)
E. lamellosa (66)
E. pacificus (12)
Favia danae (20)
F. favus (88)
F. helianthoides (28)
F. laxa (2)
F. lizardensis (33)
F. maritima (74)
F. matthaii (57)
F. maxima (23)
F. pallida (37)
F. rosaria (41)
F. rotumana (35)
F. rotundata (20)
F. speciosa (43)
F. stelligera (1)
F. truncatus (8)
F. veroni (17)
F. vietnamensis (1)
F. sp1 (25)
F. sp2 (1)
Favites abdita (64)
*F. bestae (1)**
F. chinensis (23)
F. complanata (70)
F. flexuosa (19)
F. halicora (72)
F. pentagona (76)
F. russelli (62)
F. sp1 (18)
Goniastrea aspera (66)
G. australensis (85)
G. edwardsi (10)
G. favulus (71)
G. palauensis (67)
G. pectinata (58)
G. retiformis (26)
G. sp1 (10)
Leptastrea pruinosa (51)
L. purpurea (72)
L. transversa (33)
Leptoria irregularis (1)
L. phrygia (34)
Montastrea colemani (36)
M. curta (44)
M. magnistellata (19)
M. valenciennesi (9)
M. sp1 (2)
Moseleya latistellata (52)
Oulophyllia bennettae (6)
O. crispa (33)
Platygyra contorta (50)
P. daedalea (92)
P. lamellina (33)
P. pini (64)
P. ryukyuensis (48)
P. sinensis (42)
P. verweyi (63)
P. sp1 (15)
P. sp2 (3)
P. sp3 (1)
P. sp4 (1)
Plesiastrea versipora (46)

Fungiidae

Cantharellus spp (7)
Ctenactis albitentaculata (7)
C. crassa (17)
C. echinata (31)
Fungia concinna (24)
F. corona (1)
F. danai (11)
F. fungites (59)
F. granulosa (8)
F. horrida (17)
F. klunzingeri (14)
F. paumotensis (28)
F. repanda (34)
F. scabra (1)
F. scruposa (7)
F. scutaria (1)
F. sp1 (17)
F. sp2 (1)
F. sp3 (1)
Halomitra pileus (1)
Heliofungia actiniformis (30)

Herpolitha limax (41)
H. weberi (11)
Lithophyllon sp1 (1)
Podabacia crustacea (66)
P. motuporensis (1)
Podabacia sp1 (1)
Polyphyllia talpina (32)
Sandalolitha robusta (21)

Merulinidae
Hydnophora exesa (45)
H. grandis (6)
H. microconos (15)
H. pilosa (84)
H. rigida (21)
H. sp1 (1)
Merulina ampliata (78)
M. scabricula (48)
Scapophyllia cylindrica (2)

Milleporidae
Millepora exesa (2)
M. platyphylla (4)
M. tenella (1)
M. sp1 (14)

Mussidae
Acanthastrea bowerbanki (4)
A. echinata (27)
A. hemprichii (12)
A. hillae (12)
A. lordhowensis (19)
A. regularis (24)
A. rotundoflora (1)
A. sp1 (11)
A. sp2 (1)
Blastomussa wellsi (2)
Cynarina lacrymalis (8)
Lobophyllia corymbosa (27)
L. dentatus (28)
L. flabelliformis (5)
L. hataii (22)
L. hemprichii (91)
L. pachysepta (55)
L. robusta (40)
L. sp1 (11)
Micromussa amakusensis (1)
Scolymia australis (18)
S. vitiensis (19)
Symphyllia agaricia (5)
S. radians (22)
S. recta (10)
S. sp1 (3)

Oculinidae
Galaxea acrhelia (9)
G. astreata (68)
G. fascicularis (95)
G. paucisepta (2)

Pectiniidae
Echinophyllia aspera (52)
E. echinata (7)
E. echinoporoides (5)
E. orpheensis (22)
E. sp1 (4)
Mycedium elephantotus (68)
M. mancaoi (2)
Oxypora glabra (9)
O. lacera (66)
Pectinia alcicornis (20)
P. lactuca (61)
P. paeonia (38)
P. sp1 (2)

Pocilloporidae
Palauastrea ramosa (1)
Pocillopora damicornis (95)
P. danae (2)
P. eydouxi (1)
P. kelleheri (2)
P. verrucosa (17)
Seriatopora caliendrum (4)
S. hystrix (18)
Stylophora pistillata (50)

Poritidae
Alveopora allingi (11)
A. catalai (1)
A. gigas (3)
A. spongiosa (1)
A. tizardi (18)
A. sp1 (9)
Goniopora columna (39)
G. djiboutiensis (57)
G. eclipsensis (9)
G. fruticosa (11)

G. lobata (9)
G. minor (39)
G. norfolkensis (10)
G. palmensis (13)
G. pandoraensis (11)
G. pendulus (31)
G. somaliensis (4)
G. stokesi (3)
G. stutchburyi (47)
G. tenuidens (15)
G. sp1 (57)
G. sp2 (32)
G. sp3 (18)
G. sp4 (9)
G. sp5 (2)
Porites annae (8)
P. cylindrica (36)
P. evermanni (1)
P. lichen (5)
P. monticulosa (1)
P. nigrescens (5)
P. rus (23)
P. solida (2)
P. sp1 (107)
P. sp2 (75)
P. sp3 (26)
P. sp4 (3)
P. sp5 (1)

Siderastreidae

Coscinaraea columna (68)
C. exesa (7)
C. wellsi (1)
Psammocora contigua (24)
P. digitata (10)
P. haimeana (6)
P. nierstraszi (6)
P. obtusangula (25)
P. profundacella (10)
P. superficialis (46)
P. sp1 (9)
Pseudosiderastrea tayami (26)

Helioporidae

Heliopora coerulea (11)

Appendix 5.2.

List of specimens lodged with the Museum of Tropical Queensland. Numbers in brackets indicate the number of specimens for that species. At the time of reporting 15 specimens of the Genus *Acropora* remained to be identified.

Acroporidae

Acropora aculeus (9)
A. acuminata (2)
A. anthocercis (3)
A. aspera (1)
A. austera (3)
A. brueggemanni (1)
A. carduus (1)
A. cerealis (9)
A. cytherea (2)
A. digitifera (1)
A. divaricata (4)
A. donei (1)
A. elseyi (7)
A. florida (1)
A. glauca (10)
A. grandis (1)
A. granulosa (1)
A. horrida (4)
A. hyacinthus (8)
A. intermedia (7)
A. latistella (17)
A. listeri (1)
A. longicyathus (14)
A. loripes (6)
A. microclados (5)
A. microphthalma (5)
A. millepora (2)
A. muricata (4)
A. nana (1)
A. nasuta (10)
A. palifera (2)
A. paniculata (2)
A. pulchra (3)
A. samoensis (6)
A. sarmentosa (1)
A. secale (2)
A. selago (2)
A. striata (1)
A. subulata (4)
A. tenuis (1)
A. valida (24)
A. vaughani (6)
A. verweyi (2)
A. willisae (1)
A. yongei (1)
Anacropora matthai (1)
Montipora angulata (1)
M. crassituberculata (2)
M. danae (1)
M. foliosa (1)
M. grisea (4)
M. hoffmeisteri (1)
M. informis (2)
M. millepora (1)
M. monasteriata (1)
M. peltiformis (2)
M. stellata (1)
M. turgescens (1)

Dendrophylliidae

Turbinaria mesenterina (1)
T. reniformis (1)

Euphyllidae

Euphyllia glabescens (1)

Faviidae

Barabattoia amicorum (1)
B. laddi (1)
Cyphastrea microphthalma (1)
C. serailia (1)
Favia danae (1)

F. favus (4)
F. helianthoides (2)
F. laxa (1)
F. maritima (3)
F. matthaii (2)
F. maxima (1)
F. rosaria (3)
F. rotumana (1)
F. rotundata (2)
F. speciosa (4)
Favites acuticollis (1)
F. bestae (1)
F. flexuosa (3)
F. halicora (2)
F. pentagona (1)
F. russelli (3)
Goniastrea aspera (4)
G. australensis (3)
G. favulus (1)
G. palauensis (2)
G. pectinata (1)
Montastrea colemani (2)
M. magnistellata (1)
Moseleya latistellata (2)
Platygyra daedalea (5)
P. lamellina (3)
P. pini (6)
P. verweyi (1)

Fungiidae

Ctenactis crassa (1)
C. echinata (1)
Fungia concinna (2)
F. danai (1)
F. fungites (5)
F. horrida (2)
F. paumotensis (2)
F. repanda (2)
F. scruposa (1)
Halomitra pileus (1)
Herpolitha limax (1)
Sandalolitha robusta (1)

Merulinidae

Hydnophora grandis (1)
H. rigida (1)

Mussidae

Acanthastrea bowerbanki (1)
A. echinata (2)
A. regularis (2)
Lobophyllia corymbosa (1)
L. hataii (1)
L. hemprichii (1)
Micromussa amakusensis (1)

Oculinidae

Galaxea paucisepta (1)

Pectiniidae

Echinophyllia echinoporoides (1)
Mycedium elephantotus (1)
Oxypora lacera (1)

Pocilloporidae

Palauastrea ramosa (1)

Poritidae

Goniopora palmensis (1)
G. pandoraensis (1)
Porites annae (1)
P. cylindrica (1)
P. monticulosa (1)
P. rus (1)

Siderastreidae

Coscinaraea columna (1)
Psammocora superficialis (2)

Appendix 6

Compilation of past studies with relevance to status of near-shore reefs of the Great Barrier Reef.

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
AIMS	Cooktown/ Lizard - Cairns - Townsville – Whitsundays	12 near-shore reefs	1992 ongoing	GPS (marked transects)	Ongoing monitoring - high quality data. www.aims.gov.au/reef-monitoring	Annual survey of 15x50 m video transects at each reef
AIMS	Townsville	Pelorus, Orpheus (3 sites), Herald and Acheron Islands	1994-1996 ongoing	GPS (marked transects)	Ongoing monitoring - high quality data.	Annual survey of 5x50 m video transects at each reef
AIMS	Shoalwater Bay and north	44 reefs	First survey from 1986 to 2001	Approx.	Source of information for large sections of reef slope. Variations in tow path and limited visibility may impact comparisons among years for small sections of reef.	Manta tow surveys of entire reef perimeter
Ayling AM, Ayling AL. (1985) A preliminary survey of coastal reefs in the Cape Tribulation Region, Unpublished report to GBRMPA.	Innisfail – Whitsundays	44 reefs including 6 near-shore	1983-1984	no	Estimates of hard coral cover are presented for 4 near-shore reefs. However as the location of sampling sites and depth of samples is not explicit, comparison to future data would be difficult.	10x10 m LIT at each site, most at NW edge of reefs
Ayling AM, Ayling AL. (1985). A biological survey of selected reefs in the Central section of the Great Barrier Reef Marine Park. Unpublished report submitted to GBRMPA. 53 pp	Cairns	17 fringing reef sites around Cape Tribulation	1985	Marked	Baseline data for ongoing Cape Tribulation monitoring sites.	12 sites with marked 5x20 m LIT, 5 sites with 5x20 m random LIT

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Ayling AM, Ayling AL. (1986) Is silt run-off affecting coral communities on the Cape Tribulation fringing reefs? In Baldwin CL.(ed). Fringing Reef Workshop; Science Industry and Management. Great Barrier Reef Marine Park Authority Workshop Series No.9: 83-86.	Cairns	17 fringing reef sites around Cape Tribulation	1986	Marked	First update for ongoing Cape Tribulation monitoring sites. Includes assessment of the impact of Cyclone Manu to hard coral cover.	12 sites with marked 5x20 m LIT, 5 sites with 5x20 m random LIT
Ayling AM, Ayling AL. (1991) The effect of sediment run-off on the coral populations of fringing reefs at Cape Tribulation. Research Publication No. 26. Great Barrier Reef Marine Park Authority, Townsville.	Cairns	17 fringing reef sites around Cape Tribulation	1985-1988	Marked	The 12 fixed sites form the basis of high quality ongoing monitoring of these reefs and the longest running data set for near-shore reefs of the GBR (Ayling and Ayling 2005).	12 sites with marked 5x20 m LIT, 5 sites with 5x20 m random LIT
Ayling AM, Ayling AL. (1995) A preliminary survey of benthic communities on fringing reefs in the middle Cairns section. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville	Cairns - Innisfail	17 near-shore reefs between Cape Tribulation and the Frankland Island group	1995	GPS (~100 m est.)	Very good baseline data for the reefs included. Coral cover high (>65%) at all reefs.	5x20 m LIT at each of 2 sites per reef. Species list from 30 min. swim.
Ayling AM, Ayling AL. (1996). The biological status of fringing reefs in the Great Barrier Reef World Heritage Area. Unpublished report submitted to GBRMPA. 5 pp.	Cape Flattery to Keppel Island		1991-1996	NA	Synthesis of major quantitative studies on near-shore reefs to 1995.	
Ayling AM, Ayling AL. (1998) Magnetic Quays monitoring program benthic transects: A resurvey and methods comparison. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville	Townsville	Bays of Magnetic Island Including Nelly, Geoffrey, Arthur and Florence	1989-1998	Marked	Update report for long-term monitoring sites at Magnetic Island. Most recent report of this data can be found in Ayling and Ayling (2005). Includes comparison of LIT to Video technique to demonstrate comparability of methods.	Predominantly 4x20 m LIT per site. Number of sites varies among bays.

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Ayling AM, Ayling AL. (1998) The effect of the Daintree River flood plume on Snapper Island coral reefs. Research Publication No. 53. Great Barrier Reef Marine Park Authority, Townsville.	Cairns	Snapper Is, Black Rocks	1998	Marked	Effects of flooding of the Daintree River. Snapper Island data is mostly incorporated in to long-term monitoring data for this reef. Positions for sties at black rock not included.	4 sites on each of the north and south faces of Snapper Island, 2 sites at Black Rocks. 5x20 m LIT at each site
Ayling A.M, Ayling AL, Berkelmans R. (1998) Shoalwater Bay fringing reef resource assessment. Research Publication No. 54. Great Barrier Reef Marine Park Authority, Townsville.	Shoalwater Bay	18 Shoalwater Bay reefs	1995	no	Provides very good regional baseline of coral communities. At individual reef level data is less useful as sites impossible to relocate from information provided.	5x20 m LIT, 30 min. swim search for coral species and 90 min. demography search for large colonies at each of 2 sites per reef
Ayling AM, Ayling AL.(1999) The dynamics of Cairns section fringing reefs. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville.	Cairns - Innisfail	Franklin Island Cape Tribulation reefs, Snapper Island	1985-2005	Marked	Update reports for long-term monitoring sites on near-shore reefs from 7 reef-zone locations. High quality data that is well presented and considered.	multiple sites per reef, 5x20 m LIT per site
Ayling AM, Ayling AL. (1999) Medium-term changes in coral populations of fringing reefs at Cape Tribulation. Research Publication No. 59. Great Barrier Reef Marine Park Authority, Townsville.						
Ayling AM, Ayling AL. (2000) The dynamics of Cairns section fringing reefs: Part 2. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville						
Ayling AM, Ayling AL. (2001) The dynamics of Cairns section fringing reefs: 2001. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville						
Ayling AM, Ayling AL. (2002) The dynamics of Cairns section fringing reefs: 2002. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville	Cairns - Innisfail	Franklin Island Cape Tribulation reefs, Snapper	1985-2005	Marked	Update reports for long-term monitoring sites on near-shore reefs from 7 reef-zone locations. High quality data that is well presented and considered.	multiple sites per reef, 5x20 m LIT per site

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Ayling AM, Ayling AL. (2004) The dynamics of Cairns section fringing reefs: 2004. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville		Island				
Ayling AM, Ayling AL. (2005) The dynamics of Cairns section fringing reefs: 2005. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville						
Ayling AM, Roelofs AJ, McKenzie LJ, Lee Long WJ (1997).Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) . EcoPorts Monograph Series No. 5. Ports Corporation of Queensland, Brisbane.	Cooktown - Lizard	Cape Flattery area, Decapolis reef, Four Foot Rock	1996	GPS	Data provided are summaries for three reef types with coral cover to family and also species lists for each reef type. Good baseline data for this area though dangerous to repeat due to possibility of crocodile attack.	5x20 m LIT for benthos at each of 4 or 5 sites per reef type (near-shore, fringing, rocky)
Baird AH, Marshall PA. (2002). Mortality, growth and reproduction in scleractinian corals following bleaching on the Great Barrier reef. Mar Ecol Prog Ser Vol. 237: 133-141	Townsville	Orpheus Is - Pelorus Is	1998	NA	Differential mortality as a result of thermal bleaching in 1998 for a limited number of species. Useful to put observed changes in context.	Tagged colonies monitored
Berkelmans R. (2001) Bleaching, upper thermal limits and temperature adaption in reef corals. PhD thesis, Department of Marine Biology and Aquaculture, James Cook University, Townsville Australia	Townsville – Whit-sundays	12 near-shore reefs	May 1998 and Oct 1998	GPS (contact author)	Data presented in thesis as hard coral cover only though full analysis of videos stored on AIMS database. High quality data.	5x5 minute video transects at 2 depths and two sites per reef.
Berkelmans R, De'ath G, Kininmonth S, Skirving WJ. (2004). A comparison of the 1998 and 2002 coral bleaching events on the Great Barrier Reef: spatial correlation, patterns, and predictions. Coral Reefs 23: 74-83	GBR wide	entire GBR	1998 and 2002	NA	provides predicted impact of 1998 and 2002 bleaching events.	SST data analysis

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Berkelmans R, Oliver JK (1999) Large-scale bleaching of corals on the Great Barrier Reef. Coral Reefs, 18:55-60	GBR wide	entire GBR	1999	NA	Provides a detailed map of extent of bleaching from 1998.	Aerial and video ground truth surveys
Bull G. D. (1982) Scleractinian Coral Communities of Two Inshore High Island Fringing Reefs at Magnetic Island, North Queensland. Mar. Ecol. Prog. Ser. 7:267-272	Townsville	Geoffrey and Cockle Bay	1982	no	Good descriptions of coral communities along transverse transects. Exact locations not provided though adequate for broad comparison to future communities.	at least 5x30 m LIT per major habitat zone along a transverse section of the reef
Burns K, DeVantier L, McCook L, Turak E. (1995). Pilot study of the status of Brampton Island fringing reefs. Australian Institute of Marine Science and CRC: Reef Research.	Mackay	Brampton Island and Pelican Island	1995	GPS (~50 m est.)	Provides data adequate for rough future comparisons of hard and soft coral cover and cover of Sargassum and also size distribution of colonies. That depth is not explicitly stated would limit the interpretation of such comparisons.	Visual estimates, belt transects and video transects
Cheal AJ, Coleman G, Delean S, Fitzpatrick B, Miller I, Osborne K, Page C, Sweatman H. (2001). Status of fringing reefs and options for long-term monitoring in the Northumberland Islands, Southern Great Barrier Reef, Australia. AIMS Report No. 33. 65 pp. Australian Institute of Marine Science, Townsville.	Mackay	9 reefs of the Northumber-land Islands	2000	GPS	Broad descriptions based on manta tow data or spot snorkel survey for 9 reefs. Detailed video and fish transect data at two depths for 3 reefs that serve as a high quality baseline for these reefs.	Video, Manta-tow and spot checks for coral communities, visual census belt transects for fish communities
Chin A, Ayling T. (2000). Disturbance and recovery cycles: long-term monitoring on 'unlucky' inshore fringing reefs in the Cairns section of the GBRMP. Reef Research. 10(1): 5-8	Cairns - Innisfail	Cape Tribulation, Snapper Is, Franklands	1985-2000	NA	Synopsis of disturbance to near-shore reefs from monitoring data provided in Ayling and Ayling reports (2005 most recent)	
Collins J. Unpublished reef flat data. Department of Marine Biology. James Cook University.	Townsville	Geoffrey Bay	1976-1988	no	Difficult to interpret as transect placement changed among years. Evidence for a low point in cover following bleaching in 1982 with some subsequent recovery. Potentially valuable due to the rarity of data from this period.	LIT variably spaced perpendicular to a transverse transect across the reef flat. Length of LIT up to 1982 was 30 m then 10 m in 1986-88.

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
DeVantier L, Turak E. (1995) Surveys of coral community structure on the fringing reefs in the Whitsundays region, central Great Barrier Reef February - May 1995. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville.	Whitsundays	34 sites Gloucester to Repulse Bay	1995	GPS (~50 m est.)	Data adequate to allow detection of substantial change in cover or shifts in species composition. Regional comparisons would be more appropriate than individual reefs due to limited spatial extent of sampling and lack of replication at the reef level.	RAP species lists, categorical size distribution and benthic group cover estimates
DeVantier L, Turak E, Davidson J, Done T. (1997) Status of Fringing Reefs in the Dingo Beach Area, Whitsundays Region, Central Great Barrier Reef, 1994. Unpublished Report to the GBRMPA, Townsville.	Whitsundays	Hideaway Bay, Champagne Bay, Olden Island, Pelican Island	1994	GPS (~50 m est.)	Valuable data set for reef communities in the Dingo beach area prior to bleaching in 1998.	5x50 m video transects at each of two depths (0-2 and 4-6 below crest) and 2 sites per reef
DeVantier LM, van Woesik R, Steven ADL. (1992) Monitoring study of the coral communities of Middle Reef, Townsville, June 1991. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville.	Townsville	Middle Reef	1990-1991	detailed map	Provides a useful baseline data set for Middle Reef that compliments AIMS LTMP sites.	3x20 m LIT and belt transects for recruit sized colonies at each of 6 sites
DeVantier L, Turak E, Done TJ, Davidson J. (1997) The effects of cyclone Sadie on coral communities of near shore reefs in the central Great Barrier Reef, In Steven A. (ed). Cyclone Sadie flood plumes in the Great Barrier reef Lagoon: Composition and Consequences. Great Barrier Reef Marine Park Authority Workshop Series No.22: 65-88	Townsville - Innisfail	Brook Island, Pelorus Island, Pandora Reef	1997	GPS (~50 m est.)	Provides hard coral cover estimates for 4 sites and 3 depths from Pandora Reef however transects are unreplicated within sites hence future comparisons difficult. Adds another observation of response to disturbance for near-shore reefs.	video transects and species inventories
DeVantier LM, Barnes GR, Daniel PA, Johnson DB. (1986b) Studies in the assessment of coral reef ecosystems. 2. Phillips Reef. Australian Institute of Marine Science, Townsville.	Townsville	Phillips Reef	1984-1985	Approx. (compass bearings)	Detailed benthic community data to lifeform categories. Good baseline against which change could be assessed.	7x100 m LIT spread between three reef zones.

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
DeVantier, LM; De'ath, G; Done, TJ; Turak, E. (1998) Ecological assessment of a complex natural system: A case study from the Great Barrier Reef. Ecol. Appl. 8 no. 2:480-496.	Whitsundays	40 reefs in this region	1994-1995	NA	Provides a synthesis of results from data presented in other reports by these authors.	visual estimates, taxonomic lists, RAP methods
Smith L. Unpublished data. Australian Institute of Marine Science	Cairns - Innisfail	High Island, Fitzroy Island, Snapper Island, Russell Island	1999-2000	GPS (~50 m est.)	Data includes valuable post disturbance community cover, recruitment and Acropora size class information.	recruitment tiles, *Acropora* demography, video transects
Devlin M, Waterhouse J, Taylor J, Brodie J. (2001) Flood plumes in the Great Barrier reef: Spatial and temporal patterns in composition and distribution. Research Publication No. 68. Great Barrier Reef Marine Park Authority, Townsville.	GBR wide	Fitzroy River to Daintree river	1991-1999	NA	Excellent study into the seaward extent of flood plumes, their makeup (water quality parameters) and relationships with the land use in the adjacent catchment areas. Detailed mapping etc. of cyclone flood events	Plume mapping and water sampling
Dinesen ZD. (1983) Patterns in the distribution of soft corals across the central Great Barrier Reef. Coral Reefs 1:229-236.	Townsville	Cross shelf transect from near-shore to Coral Sea	1983	no	Identifies broad differences in soft coral communities. Difficult to compare to future data sets as methods semi quantitative and locations of sites not reported.	visual estimates of percent cover of soft coral genera
Done TJ. Unpublished data. Australian institute of Marine Science.	Townsville	Pandora	1981-2005	Marked	Valuable data set of photo quadrats spanning 25 years. Data yet to be fully worked up.	Photo quadrats
Done TJ (1982) Patterns in the Distribution of Coral Communities Across the Central Great Barrier Reef. Coral Reefs 1: 95-107.	Townsville	Pandora, Phillips	1982	Approx.	Broad description of coral communities at Pandora and Phillips reef. Difficult to utilise for comparison to later sampling as data is not presented and mostly subjective.	species lists and subjective estimates of relative cover at an unspecified number of sites, of unspecified size
Done TJ, Potts DC (1992). Influences of habitat and natural disturbances on contributions of massive *Porites* corals to reef communities. Marine Biology 144, 479-493	Townsville - Cairns	6 reefs including the near-shore Pandora reef	1984-1990	Approx.	Detailed maps of Porites community at Pandora that builds on area mapped in Potts *et al.* (1985).	mapping

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Fabricius K. E (1997) Reef Invasion by Soft Corals: Which taxa and which habitats. Proceedings of the Australian Coral Reef Society 75th Anniversary Conference, Heron Island. pp. 77-90	Central GBR	32 reefs	1996-1997	Approx. (contact author)	Manuscript based on extensive data set of soft coral distribution and abundance on near-shore reefs. The data is not reported in a form directly usable to infer changes in communities. The synthesis however provides insight into possible classification of reef communities based on "invasive" assemblages of soft corals.	4-5 rapid survey swims per site, variable number of sites per reef.
Fabricius KE, De'ath G (1997) Habitat optima of soft corals on the central Great Barrier Reef: niche characterisation using regression tree analysis. In: Proc of The Great Barrier Reef, Science, Use and Management: A National Conference, vol 2. Great Barrier Reef Marine Park Authority, pp 167-174	Central GBR		1997	Approx. (contact author)	Details environmental variables that help to explain distribution of soft coral communities within the GBR. While not presented in the manuscript the underlying data is a valuable baseline of Soft Coral communities.	4-5 rapid survey swims per site, variable number of sites per reef.
Fabricius K, De'ath G, McCook L, Turak E, Williams DMcB. (2005). Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef. Marine Pollution Bulletin Vol 51: 384-398.	Innisfail - Cairns - Princess Charlotte Bay	13 near-shore reefs	2000-2003 (assumed)	Approx.	Whilst not presented in the manuscript the underlying data provide useful snapshots of the various communities and may be available from the authors. Presentation of data useful in highlighting gradients in community composition for fishes, algae, hard corals and soft corals.	Plot less swims
Fisk, D. A, Harriott VJ. 1986. Recruitment and mortality of juvenile corals on the fringing reefs north and south of Cape Tribulation over one year. In Baldwin CL.(ed). Fringing Reef Workshop; Science Industry and Management. Great Barrier Reef Marine Park Authority Workshop Series No. 9: 87-99.	Cairns	Cape Tribulation	1985 - 1987	Approx.	Very good baseline data on coral settlement, juvenile density and survival (post cyclone).	6 x settlement plates and, 3x1m^2 quadrats for juvenile density at each of 6 reefs

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Fisk D. A. (1991) Daydream Island Monitoring study: Final Report on the post-development survey conducted from 28 August - 4 September 1990. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville.	Whitsundays	Daydream Is	1990	Approx.	While transects were marked it is unlikely that they would be still in place. The sampling intensity and approximate location of sites afforded by map provided make this data a useful baseline for major coral groups.	5x20 m LIT at two depths (reef flat and slope 2-3m) at each of 12 sites
GHD 2002. Nelly Bay Impact Monitoring Program – Baseline Report. Prepared on behalf of the Great Barrier Reef Marine Park Authority. 77 pp.	Townsville		2000	Marked	Includes broad taxonomic group cover from reef flat and slope for five bays. This is high quality data. The reef slope data are largely incorporated into long-term monitoring of Magnetic Island reefs (Ayling and Ayling 2005). Also provides impact of Cyclone Tessi.	4x20 m LIT per site there were a variable number of sites per bay
GHD (2003) Nelly Bay Impact Monitoring Program - Summary Report, Unpublished report to the Great Barrier Reef Marine Park Authority, Townsville.	Townsville	Magnetic Island	2002-2003	Marked	Includes detailed descriptions of coral communities from five bays and also observations of individual colonies. Community level data is mostly included in Magnetic Island monitoring study (Ayling and Ayling 2005)	4x20 m LIT per site there were a variable number of sites per bay, fine scale monitoring of mortality to individual colonies
GBRMPA (2002) Unpublished Bleaching Surveys. Contact Marshall P.	Palms, Whitsundays, Keppels	10 reefs	2002	GPS (contact GBRMPA)	High quality data not reported though stored on AIMS database	5x5 minute video transects at 2 depths at each site
Harriott VJ, Fisk DA. (1990) Techniques to survey anchor damage, and a preliminary report on the extent of anchor damage in the Whitsunday Islands. Unpublished report submitted to the Great Barrier Reef Marine Park Authority, Townsville.	Whitsundays	Hook Is (10), W. Molle	1989	Approx. (Hook Is sites only)	Limited use as a baseline due to broad cover categories, inability to relocate sites and small sample area.	qualitative estimates of coral cover
Hedley C. (1925) The natural destruction of a coral reef" Reports of the Great Barrier reef Committee. Vol 1:35-40	Mackay		1925	NA	Early record of flood damage to near-shore reefs. No quantitative information provided.	observational

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Johnson DB, Daniel PA, DeVantier LM, Barnes GR, (1986a) Studies in the assessment of coral reef ecosystems. 2. Pandora Reef. Australian Institute of Marine Science, Townsville.	Townsville	Pandora reef	1984-1985	Approx. (detailed map)	Detailed benthic community data to lifeform categories. Good baseline against which change could be assessed.	9x100 m LIT spread between three reef zones.
Kaly UL, Mapstone BD, Ayling AM, Choat JH (1994) Coral Communities. In: Benson LJ, Goldsworthy PM, Butler IR, Oliver JK (eds) Townsville Port Authority capital dredging works. 1993: Environmental monitoring programme. Townsville Port Authority.	Townsville	Middle Reef, Magnetic Island, Rattlesnake Island	1993	Marked	These data are predominantly incorporated into on going monitoring of Magnetic Island reefs (Ayling and Ayling 2005). The exception being sites at Middle Reef and Rattlesnake Island, the utility of these additional sites is limited as locations are not reported	fixed video transects
Larcombe P, Costen A, Woolfe KJ. (2001) The hydrodynamic and sedimentary setting of near shore coral reefs, central Great Barrier Reef shelf, Australia: Paluma Shoals, a case study. Sedimentology 48:811-835.	Townsville	Paluma Shoals, Phillips Reef	1995	Approx. (detailed map)	Moderate utility as a baseline for coral community at Paluma Shoal. Recruitment estimates of limited value as recorded on LIT.	10x10 m LIT
Lough JM, Barnes DJ. (1995) Centuries-long records of coral growth on the Great Barrier Reef. State of the GBR World Heritage Area Workshop. GBRMPA Workshop series 23. Pp 149-157.	Mostly Cairns and Whitsundays a few corals from further north	18 near-shore locations	1995	NA	Contextual evidence for variability in reef growth (calcification) over extended periods	coral cores
McCook LJ, De'ath G, Price IR, Diaz-Pulido G, Jompa J (2000) Macroalgal resources of the Great Barrier Reef: Taxonomy, distributions and abundances on coral reefs. Unpublished report to the Great Barrier Reef Marine Park Authority, Townsville.	Townsville	Nelly Bay and Geoffrey Bay	1988-1989	Marked	Detailed account of the coral communities of Magnetic island. Much of this data forms part of the long-term monitoring of Magnetic Island reefs (Ayling and Ayling 2005)	4x20 m LIT at each of 13 sites

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Mapstone BD, Choat JH, Cumming RL, Oxley WG. (1989) The fringing reefs of Magnetic Island: Benthic biota and sedimentation a baseline study. Research Publication #13. Great barrier Reef Marine Park Authority, Townsville	Lizard Island to Heron island	110 reefs including approx. 50 near-shore	?-1999	Approx.	Report provides a brief summary of algal community distributions. Submitted with report is a relational database of the raw data "GBR Algal Ecology Database" this stands as by far the most comprehensive data set for GBR algae.	RAP
GHD (2003) Nelly Bay Impact Monitoring Program - Summary Report, Unpublished report to the Great Barrier Reef Marine Park Authority, Townsville.	Townsville	Nelly, Geoffrey, Arthur and Florence Bays	2004	Marked	Reef slope data are largely included in Magnetic Island monitoring time series (Ayling and Ayling 2005). High quality for benthic community over 5 years. Contains effects of cyclone and bleaching with recovery evident at some sites. Also provides summary of detailed colony monitoring. Electronic version of report supplies links to interim reports for detailed descriptions of community impact and change.	4x20 m fixed LIT transects at each site, variable number of sites per bay
Oliver J. (1985) Recurrent seasonal bleaching and mortality of corals on the Great Barrier Reef. In Proceedings of the Fifth International Coral Reef Congress, Tahiti Vol. 5:201-206	Townsville	Includes information from 6 near-shore reefs	1985	no	Provides timing and limited spatial extent of 1982 bleaching event, limited indication of taxa most affected.	hotch potch
Potts DC, Done TJ, Isdale PJ, Fisk DA (1985). Dominance of a coral community by the genus *Porites* (Scleractinia). Mar. Ecol. Prog. Ser. Vol. 23: 79-84.	Townsville	Pandora	1982	Approx.	Very detailed description of the Porites spp. community on a small patch of reef.	Mapping of a 30x12 m plot
Saenger P. (1986) A reconnaissance account of the Rodney Island Fringing Reef and associated marine communities, Shelburne Bay. In Baldwin CL.(ed). Fringing Reef Workshop; Science Industry and Management. Great Barrier Reef Marine Park Authority Workshop Series No. 9: 70-76.	Shelburne Bay	Rodney Is	1984	no	Limited to qualitative descriptions and rough cover estimates of major groups.	anecdotal

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
Schaffelke B, Uthicke S, Klumpp DW. (2003) . Water quality, sediment and biological parameters at four near-shore reef flats in the Herbert River Region, central GBR. GBRMPA Research Publication No. 82. 64 pp.	Townsville	Palm Is, Fantome Is, North Is (Brook Island group)	1995-1997	Approx.	Provides a very good water quality baseline for the reefs included.	
Stafford-Smith MG, Kaly UL, Choat JH. (1994) Reactive monitoring (short term responses) of coral species. In: Benson LJ, Goldsworthy PM, Butler IR, Oliver JK (eds) Townsville Port Authority capital dredging works. 1993: Environmental monitoring programme. Townsville Port Authority.	Townsville	Magnetic Is, Rattlesnake Is, Bay Rock	1993	Approx.	Response of corals to dredging, provides context for effects of sedimentation. None of the corals at the impact site exceeded criteria that would suspend dredging.	Twice-weekly monitoring of 20 colonies of each of four species of coral. Environmental variables measured with sediment traps, light sensors and nephelometer
Stephenson W, Endean R, Bennett I. (1957). An Ecological survey of the marine fauna of Low Isles, Queensland. Australian Journal of Marine Freshwater Research 9: 261-318	Cairns	Low Isles	1950	Approx.	Detailed description of coral communities in a number of habitats against which future observation could be compared. Also provides a timeline of disturbance for Low Isles for the first half of the 20th century. Valuable primarily as one of only a few detailed descriptions from this period.	
Thompson AA,. Malcolm H. (1999) Benthic and fish monitoring of fringing reefs in the Brook, Palm and Rattlesnake Island groups: Status post 1998 coral bleaching event. Unpublished report submitted to the Queensland Parks and Wildlife Service.	Townsville - Innisfail	Brook Is, Pelorus Is, Orpheus Is, Acheron Is, Herald Is.	1995-1999	GPS (marked transects)	Update from ongoing long-term monitoring sites in the Palm and Rattlesnake Island groups and final data for Brook Island monitoring. Video data stored at AIMS.	8 sites with 5x50 m video transects at each
van Woesik R. (1988?)	Whitsundays	Long Is, Pine Is, Hook Is, Black Is, Langford & Bird Is	1987	Approx.	Limited spatial coverage of sites limits utility as baseline. However in combination would provide a regional baseline.	3 depths per site. Only 1x20 m LIT and one 1x10m^2 quadrat (community composition) per depth.

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
van Woesik R. (1991) Immediate impact of the January 1991 floods on the coral assemblages of the Keppel Islands. Research Publication #23. Great Barrier Reef Marine Park Authority, Townsville	Keppels	8 Reefs in the Keppel Island group	1991	Approx.	Effects of Fitzroy river flood, resurvey of some of his PhD sites provides a good observation of "natural disturbance", and a strong depth effect. Gives a list of species that survived the hyposaline conditions.	3x15 m LIT replicated at 1 m depth intervals down the slope at each reef.
van Woesik R, DeVantier LM. (1992) Resource assessment of near shore coral communities in the Whitsundays region. Unpublished report to the Queensland Department of Environment and Heritage.	Whitsundays	54 sites	1992	Approx.	Substantial data set on hard coral soft coral communities including average size, and some species level information. Cover estimates are semi quantitative. High number of sites would make temporal comparisons robust at regional level. Inability to exactly relocate sites may limit comparison of temporal data for individual reefs.	Scuba swims & visual cover est., RAP
van Woesik, R. (1992) Ecology of coral assemblages on continental Islands in the southern section of the Great Barrier Reef, Australia. PhD thesis, James Cook University of North Queensland, 227 pp.	Whitsundays to Keppels	125 sites from 34 Islands	1986-1991	Approx.	Limited value as base line at the individual site level due to very small size of sampling area and inability to relocate exact location. High number of sites would make regional level comparisons more appropriate.	LIT, species lists, size class categorisation of colonies, mostly 2 m below low water
van Woesik R, DeVantier LM, Glazebrook JS. (1995) Effects of Cyclone "Joy" on near shore coral communities of the Great Barrier Reef. Mar. Ecol. Prog. Ser. 128:261-270	Townsville – Whitsundays - Keppel	Middle, Whitsundays and Keppels	1995	Detailed maps	Effect of Cyclone Joy. Good baseline data for Middle Reef to family level cover 1990 and 1991 this presented in more detail in DeVantier *et al.* (1992). Whitsundays data pooled to depth over several reefs. Keppel data available from van Woesik 1991.	LIT data summaries to family level at Middle Reef sites. Various taxonomic reporting to regional level only for Whitsundays reefs. Descriptive results only for Keppel reefs

Source	Region	Reef	Survey date	Relocatable?	Relevance to reef health	Methods
van Woesik R, Tomascik T, Blake S. (1999) Coral assemblages and physico-chemical characteristics of the Whitsundays Islands: evidence of recent community changes. Mar. Freshwater Res. 50:427-440.	Whitsundays	Gradient of seven reefs away from Proserpine river mouth	1993-1994	Approx.	Identifies a mismatch between reef development and current reef development potential in the southern Whitsundays. A case for post European settlement reef degradation on reefs close to the river mouth.	species lists, water quality variables, recruitment, LIT,
Veron JEN. 1986. Checklist of corals from the Daintree Reefs. In Baldwin CL.(ed). Fringing Reef Workshop; Science Industry and Management. Great Barrier Reef Marine Park Authority Workshop Series No. 9: 99-103	Cairns	Daintree	1985	no	Provides an early estimate of species occurrence and relative abundance. Potentially useful for comparisons to future communities as can have high regard for identifications.	swim search
Wachenfeld DR. (1995). Long-term trends in the status of coral reef-flat benthos - The use of historical photographs. State of the GBR World Heritage Area Workshop. GBRMPA Workshop series 23. Pp 134 - 148.	Whitsundays to Cairns	14 sites	Various Historical until mid- 1990's	Approx.	The photographs listed in this manuscript provide the earliest observations against which current status can be compared. Unknown height of tide is a draw back to future comparisons	Landscape photos

Further information

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