ECOLOGY OF CORAL ASSEMBLAGES ON CONTINENTAL ISLANDS IN THE SOUTHERN SECTION OF THE GREAT BARRIER REEF, AUSTRALIA.

Thesis submitted by

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Robert van Woesik
10 December 1991

DEDICATION

This thesis is dedicated to my mother and father: to her for her eternal optimism, and my father who taught me to view nature with an open mind, ensuring unlimited scope for research and the maintenance of a humble approach.

ACKNOWLEDGMENTS

First, I would like to thank the Australian Research Council for funding a major part of this study, and the Great Barrier Reef Marine Park Authority for funding the project to completion.

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Finally, to my special friends and colleagues Tim Ward and Lyn De Vantier, who know the finer aspects of this thesis better than anyone. Many thanks to them for their editorial comments which improved the final presentation of this work, and the many late nights we discussed philosophical aspects of coral reef ecology.

ABSTRACT

This study assessed the distribution of coral assemblages on coral reefs fringing continental islands between 20°S and 23°S on the Great Barrier Reef, Australia. Two questions were investigated. What is the composition and distribution of the coral assemblages and how are they influenced by ambient environmental conditions and episodic disturbance events, both natural and anthropogenic?. The study was conducted at four island groups; the Whitsunday (20°00'S), Cumberland (20°30'S), Northumberland (21°00'S), and the Keppel Islands (23°00'S).

Sixteen coral assemblages which recurred largely as a function of habitat and regional conditions were identified. Direct gradient analysis of 102 taxa and eight environmental gradients indicated that variation in coral composition was correlated with depth, exposure, tidal amplitude, distance from the mainland and the presence of seasonal macrophytes.

There was a lack of fringing reef development in the vicinity of 21°S and a restricted range of coral growth forms and species. Reef decline was not constrained by latitude, as fringing reefs were prolific at 23°S, but significantly correlated with extreme tidal fluctuations (10m); which induce high turbidity and reduce the euphotic zone. Major framework builders, massive and branching corals, dominated reefs north of 21°S but significantly declined at 21°S. Fast-growing, plate-like, encrusting and columnar forms dominated reefs at 21°S, suggesting coral growth rates and reef accretion are not directly related. High turbidity appears to have influenced coral composition and coral morphology to such a degree that poor reef development has occurred through the Holocene period.

Biological assemblages are also a product of episodic disturbances. Two case studies examined effects of disturbance; a major flood and the discharge of secondary sewage. The prolonged reduction in salinity, associated with the 1991 Queensland floods (cyclone'Joy'), caused a considerable decline in live coral biomass in the Keppel Islands. The dominant coral genus *Acropora* was most affected. Shallow corals in the Whitsunday Islands suffered minimal mortality, however many deep water pocilloporids (eg. *Seriatopora hystrix*) were killed. Low light levels associated with the monsoonal conditions may have caused the mortality.

Acropora spp. and pocilloporid corals appear most vulnerable to physico-chemical stress. Mild disturbance events (as in the Whitsunday Islands) tend to eliminate monospecific stands of these opportunistic corals. Suppressing space monopolisation by periodic exclusion may be

essential in maintaining regional diversity over long time scales. Large disturbances (Keppel Islands) tend to reduce regional diversity.

Effects of sewage on the coral assemblages at Hayman Island were investigated. Results suggest an impact 20-40 m from the outlet. Elevated nutrient levels reduced coral cover, suppressed colonization and induced community instability. It is important to understand the scale of impact from such influences as the inshore environment is most susceptible to anthropogenic interference.

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CHAPTER 1. INTRODUCTION.

1.1 Rationale and objectives

Hopley (1982) stated that fringing reefs were poorly developed south of 21°S. However, further investigations indicated that extensive fringing reefs do in fact occur south of 21°S, namely at the Keppel Islands at 23°S (pers. obs.). Clearly, latitudinal effects *per se* do not directly suppress reef development. The degree of reef development is determined partly by pre-Holocene foundations and partly by Holocene coral recruitment and growth. This study sought to determine the composition and distribution of contemporary coral assemblages on fringing reefs in the southern Great Barrier Reef and relate these assemblages to geological foundations and physical environmental conditions in order to elucidate why Holocene fringing reef growth has been limited at 21°S. The geological work of J.Kleypas (1992) and oceanographic work of S.Blake (1992) conducted in parallel with this study is acknowledged here.

The poor reef development around 21°S may be a consequence of many factors acting on coral colonies at various levels in their life-history. The development of coral reefs and the distribution of coral species are ultimately constrained by physical parameters (eg. temperature, light and salinity [Veron 1974; Mayer 1918; Hedley 1925]). Competition (Lang 1973), and predation (Pearson and Endean 1969) are biological processes which also influence the relative abundance of corals. This study examines coral assemblages on continental islands and assesses whether distribution patterns reflect regional environmental gradients.

Coral assemblages were defined on the basis of coral composition, abundance, colony morphology and size. Distribution and abundance patterns were compared with environmental gradients in four different regions (the Whitsunday, Cumberland, Northumberland and Keppel Islands) using multivariate statistics. Gradients included depth, exposure, distance from the mainland, distance from river mouths, local shelf depth, tidal amplitude, turbidity and inorganic nutrient concentrations.

Biological assemblages are not only a long-term response to the prevailing regional conditions, as episodic disturbances alter benthic communities (Woodley *et al* 1981; Van Woesik *et al* 1991) and have long lasting effects on community structure (Hughes 1989). Case studies were undertaken on natural and anthropogenic disturbance effects. These were associated with cyclone 'Joy' (1991), and the effects of secondary sewage at Hayman Island. The scale of influence by both disturbances was of interest, as cyclones are frequent in the study area and a study on the effect of locally elevated nutrients may lead to an understanding of the extent of mans impact on the nearshore environment.

More specifically this study sought to:

1 Examine the biological composition of coral assemblages in the vicinity of 21°S;

2 Assess the relationships between benthic composition and environmental gradients;

3 Describe the effect of a severe weather event, the passage of a monsoonal trough, on coral assemblages;

4 Investigate the effect of secondary sewage discharge on coral assemblages.

1.2 Factors affecting coral distribution - Physical parameters

As most corals broadcast their gametes (Harrison *et al* 1984), potentially, they allow their distribution range to be extended, distribution and abundance patterns of benthic organisms can be related to hydrodynamic corridors (Dight *et al* 1988). Isolation of larval pools was suggested as a major determinant structuring coral distribution patterns across the continental shelf (Done 1982). However, it has been postulated that distribution patterns may be not a prime consequence of inefficient dispersal (Jackson *et al* 1985; Veron 1985) but largely dependent on the physical environment (this thesis).

Temperature

Coral growth occurs within the range 11°C - 40°C, with an optimum around 23°C - 29°C (Fagerstrom 1987), restricting hermatypic coral growth to tropical seas. A decrease in mean sea surface temperature below 18°C tends to reduce calcification rates (Grigg 1981) to a point where coral growth becomes restricted (Wells 1956; Gladfelter *et al* 1978). Coral diversity (Veron 1974), larvae survivability (Kinne 1970; Rosen 1975) and reproductive potential (Jokiel and Guinther 1978) also decline with decreasing temperature. Similarly, elevated temperatures are detrimental to coral growth and survival (Glynn 1988). Temperature records and satellite imagery data (Kleypas 1992) will determine whether the region in the vicinity of 21°S experiences temperature anomalies.

Light

Light availability is considered most important for successful reef growth (Mayer 1918; Roos 1967; Chappell 1980) and light attenuation with depth restricts the distribution of hermatypic corals to shallow environments. Light intensity directly affects the rate of photosynthesis and calcification (Chalker 1985). Corals are most efficient at these metabolic processes when solar irradiance is relatively low, during early morning and late afternoon, where gross photosynthesis (P) is directly proportional to irradiance (I). As irradiance increases the rate of photosynthesis declines and approaches an asymptote (light-saturation), however these rhythms function as a controlling mechanism which provide corals with a relative constant supply of photosynthetic carbon (Chalker and Taylor 1978; Chalker 1985).

Inhibition of photosynthetic and calcification processes are apparent at very high and low light conditions (Barnes and Taylor 1973; Buddemeier *et al* 1974), which rarely occurs for corals that grow at moderate depths (Chalker 1985). However successful colonization on reef flats and upper slopes can be restricted because corals differ considerably in their ability to tolerate harmful ultra-violet light (Jokiel 1980). Light availability decreases most rapidly in the first 3m of water and below 5m linear growth rates decline considerably (Dustan 1975). Limited vertical distribution on deep slopes may be simply a consequence of a coral's inability to compensate its photosynthetic rate (McCloskey *et al* 1978).

Photoinhibition is exacerbated by an input of suspended sediment along the inshore environment. Indeed, low light associated with high turbidity may change metabolism to such a degree that carbon fixation is suppressed (Dana 1976; Spencer Davies 1977). To maximise light utilisation a coral's adaptation appears to operate at many levels: behaviourially (by increasing zooplankton intake, Lasker 1976); physiologically (Wethy and Porter 1976), symbiotically (Dustan 1975; Kevin and Hudson 1979; Falkowski and Dubinsky 1981) and morphologically (Dustan 1975; Veron 1986).

Corals growing in turbid waters have elevated zooxanthellae counts and enhanced pigmentation (pers. obs.). However they are not entirely passive in terms of zooxanthellae regulation and may control their densities (Kevin and Hudson 1979). These environments also induce some corals to adopt encrusting and laminar growth forms (Veron 1986). The areal exposure of the zooxanthellate polyp is increased by adopting such growth forms (Hubbard and Scaturo, 1985), thereby maximising light absorption. A corollary to this is reef growth may be restricted in low light environments by the lack of framework builders - large massive and arborescent colonies - and a dominance in laminar growth forms.

In some coral species colony shape is not genetically distinct as considerable phenotypic plasticity exists - a direct physiological response to environmental stimuli. However, some corals are entirely restricted by one growth form, for example *Pavona cactus* (Forskal 1775) as reported by Willis and Ayre (1985). These constraints may limit this species to specific habitat requirements.

Turbidity and sedimentation

Sub-optimal light availability may be a consequence of consistently high turbidity, induced by strong winds and high tidal fluctuations (pers. obs.). High turbidity does not necessarily suggest high sedimentation rates as water movement may prevent sediment falling out of suspension. This is common in exposed nearshore environments. Most corals can withstand a low sediment supply, however, very high sedimentation rates are lethal and corals do not survive burial for more than a few hours (Marshall and Orr 1931). Corals vary in their ability to remove sediment particles from their tissues (Hubbard and Pocock 1972). These rejection processes cause an energy drain on the corals (Dodge and Vainys 1977). Stafford Smith (1990) tested 42 scleractinian species for their sediment rejection capabilities. Some corals (faviids, mussids) actively remove sediments, whereas others (poritids) have low rejection capabilities although they can withstand extensive sediment supply.

Sedimentation rates as low as 0.45 to 1.1 mg cm^{-2} day^{-1} were reported from Jamaica by Aller and Dodge (1974). Rates of 1-21 mg cm^{-2} day^{-1} for Caribbean reefs led to sublethal effects on some corals (Rogers 1979). Cortes and Risk (1985) indicated stress resulted if sediment fallout was greater than 30 mg cm^{-2} day^{-1}. Studies undertaken more recently within the nearshore environment of the Great Barrier Reef region by Mapstone *et al* (1988) and Hopley *et al* (1990) show high sedimentation rates on nearshore fringing reefs (Hopley *et al* average of 80 mg cm^{-2} day^{-1}, Magnetic Island, Queensland). The underlying reefs, however, support diverse coral assemblages.

Data on regional variation in suspended sediment concentration was collected by collaborative researchers. The first was measured directly, by repeated field sampling in the Whitsunday region (S. Blake), and the second indirectly (J. Kleypas) via satellite imagery. The possible influence of different suspended sediment concentrations on coral species was assessed by univariate and multivariate analyses undertaken by the present author.

Nutrients

A continuous and sufficient supply of nutrients is an essential requirement for metabolic processes to ensure homeostasis, growth and reproduction of animal-plant symbionts. The supply of nutrients affects not only zooxanthellae productivity in hermatypic corals but also the productivity of phytoplankton, seagrasses, benthic macro- and filamentous algae. Conservation of nutrients within a coral reef system is essential as nutrients are generally in limited supply, and slight (3-4%) elevations may be sufficient to sustain a coral reef in a relatively nutrient poor environment (Kinsey 1990).

Although nitrates are usually not limiting on coral reefs (Wiebe *et al* 1975; Wilkinson and Sammarco 1983), phosphates frequently are (Johannes *et al* 1972; Littler *et al* 1991). Unlike nitrogen, phosphorus is not being exchanged between ocean and atmosphere, and it is the delivery of phosphorus, not nitrogen, which limits net production of organic material (Smith 1984).

A small increase in phosphorus within a coral reef system will substantially increase primary productivity to a level above other systems examined (Smith 1988) primarily due to the high Redfield ratios of reef epilithic algae C:N:P - 550:30:1 (Atkinson and Smith 1983). This value is three times that of tropical phytoplankton.

Nutrient concentrations are greater near continental landmasses than on outer reefs due to discharge from river systems and the constant agitation of bottom sediments releasing adsorbed nutrients into the shallow nearshore environments (Furnas 1990). It has been shown that increased nutrient levels enhance the assimilation of algal biomass, as a consequence brown (Phaeophyta) macrophytes and epilithic algae are particularly common on fringing reefs.

Changes in water quality around coral reefs are known to influence algal productivity and the precipitation of calcium carbonate (Smith and Kinsey 1976; Kinsey and Davies 1979). Productivity is enhanced and calcification is directly reduced by elevated phosphorus levels (Kinsey 1979; Simkiss 1964). This has been demonstrated to be competitively disadvantageous to hermatypic corals.

Several studies on the effects of elevated nutrients on coral reefs (Tomascik and Sander 1985, 1987; Smith *et al* 1981) have demonstrated that raising nutrient levels above ambient changes the fundamental structure of the benthic assemblages (Smith *et al* 1981). River catchments and local sewage discharge have this potential (Yellowless 1990).

Relatively low coral recruitment has been reported on nearshore environments compared with mid and outer shelf reefs (Sammarco 1991). Effects on colonization success may be a consequence of processes acting directly on the larvae before settlement, or via chemical cues making the substrate unsuitable for settlement (Morse *et al* 1988). Low recruitment rates and high post-settlement mortality may also be a consequence of high nutrient concentrations in nearshore environments (Sammarco 1991). However, the direct influence of nutrients at early settlement has never been tested.

Indirect stress (associated with nutrient increases) may increase colony mortality because of a disproportionate amount of resources are allocated to maintenance, effectively reducing survival because of metabolic exertion (Edmunds and Spencer Davies 1989). Edmunds and Spencer Davies (1989) showed that the small polyped *Porites* spp. growing under stress became completely autotrophic. Large polyped corals may lack the nutritional flexibility observed in small polyped species and may be selected against under stress. Tomascik and Sander (1987) also described predominantly small polyped species in polluted and high sediment environments.

1.3 Factors affecting coral distribution - Biological parameters

Competition

Dense algal mats reduce both opportunities for coral settlement and may reduce survival in coral spat which do establish, through competition (Maragos 1972; Birkeland 1977). Locally elevated nutrient concentrations may sustain macroalgae assemblages for extended periods (Hatcher 1984), leading to reef demise if dominance is maintained (Hallock and Schlager 1986). Competition between macroalgae and corals seems most prevalent nearshore and at high latitudes (Wilson and Marsh 1979; Hatcher 1985). In fact the dominance of macroalgae has been considered a major controlling factor of reef development at high latitudes (Johannes *et al* 1983). High algal biomass correlate well with periods of high concentrations of dissolved nutrients, for example at the Houtman Abrolhos Islands, Western Australia (Crossland *et al* 1984), where orthophosphate (DIP) concentrations were the highest ever recorded for an unpolluted reef (Crossland 1983). On these reefs, calcification rates were similar to low latitude reefs (Smith 1981), however coral growth was depressed because of direct competitive interactions with macroalgae (Hatcher 1991).

Massive soft corals *Lobophytum* spp., *Sarcophyton* spp., and *Sinularia* spp. can also inhibit hard coral (scleractinia) growth, although some hard corals can inhibit small soft corals (Benayahu and Loya 1977). Contact between colonies is not essential for inhibition, as toxins play a vital role in competitive interference strategies, inducing complex competitive networks (Jackson and Buss 1975).

Inter-specific competition between hard coral colonies has been frequently demonstrated (Lang 1973; Jackson 1977). However, many authors argue that coral neighbours are mostly random and the degree to which inter-colony aggression structures assemblages seems negligible and only operates on a very localised scale (Wellington 1980; Bradbury and Young 1981; Cope 1981; Bak *et al* 1982; Reichelt and Bradbury 1984).

Connell and Keough (1985) reviewed the literature on benthic competition. They concluded that assymetrical competition, whereby one species continually wins over another, only occurred in one instance when species were in the same phylum. Bryozoans and tunicates showed more asymmetry than corals and sponges. Competitive outcomes was more a consequence of size, where large colonies usually won over small ones due to their ability to vertically project.

Space maintenance is not only dependent on competitive traits but may be effective through different life-history strategies. Opportunistic corals (after Jackson and Hughes 1985) may allocate considerable energy toward the production of gametes and colony growth, with minimal resources toward maintenance. These traits induce a ephemeral existence although it allows corals to maintain regional space. In contrast, low fecundity, high colony upkeep and slow growth assures the maintenance of local space.

Predation

Over the past twenty five years two population outbreaks of crown-of-thorns starfish *Acanthaster planci* (Linnaeus 1758), have caused a considerable reduction in scleractinian biomass on many reefs of the Great Barrier Reef (Pearson and Endean 1969; Endean 1974; Done 1985; Moran 1986 for review). It is clear that the starfish is an old inhabitor of the reef ecosystem (Lucas *et al* 1985). What is equivocal is whether or not they have been in similar plague proportions during the Holocene period (Walbran 1989; Keesing *et al*, in press). Whilst sedimentology studies have found evidence of starfish activity on the Great Barrier Reef (Walbran 1989), the size and ecological effect of the populations remain unclear. Research on slow growing, massive corals suggests that disturbances of this magnitude have not occurred on a regular basis in the past (Done 1987; Cameron *et al* 1991). An apparent southward trend in intense predatory activity, is being attributed to the transport of planktonic larvae from populations aggregated "upstream" in surface currents (Kenchington 1977), a proposal supported by more recent modelling studies (Reichelt *et al* 1990).

Small populations of *Acanthaster planci* were located in the northern extreme of the Whitsunday Islands in 1989 (Van Woesik *et al* 1989), which is in agreement with the general southward trend along the Great Barrier Reef. A programme was undertaken by the Great Barrier Reef Marine Park Authority which eradicated several thousand starfish. Although no historic data exists on *A. planci* for the study region, some circumstantial evidence indicates that the area has not been subject to extensive predation pressure at least in the last several hundred years:

1 judging by the present southward extent of *A. planci* (large populations have been observed just to the north of the Whitsunday Islands in 1992);

2 the frequency and abundance of large, slow growing, coral colonies indicates a lack of predation for a considerable period.

1.4 Episodic disturbances

Intermittent exclusion of benthic organisms via disturbance has been proposed by some authors as a necessity for the stability or persistence of species on long time scales (Dayton 1971; Lewin and Paine 1974; Sale 1977; Connell 1978; Sousa 1979). These disturbance events, depending on their magnitude, may maintain variability by preventing competitive exclusion and space monopolisation among species - enhancing diversity on a local scale. On the other hand, large scale events may eliminate entire assemblages, including large persistent corals which may lead to a decrease in diversity.

Physical damage

Some habitats and geographic locations may only suffer occasional, and mild, physical disturbance. Other regions are subjected to intense disturbance via cyclones, with return periods of 10-15 years for a given 100km (Lourenz 1981). An example of such a biotype is the outer edge of the Great Barrier Reef (Van Woesik *et al* 1991). Episodic disturbances cause high colony mortality and these habitats seem to support predominantly fast-growing and highly fecund coral species (eg. *Acropora* spp., *Efflatournaria* spp. and *Xenia* spp.). Slow growing massive species are uncommon, dominant only on the sheltered back slopes some 100m to the lee. On the other hand, fringing reefs are relatively protected by continental islands although severe cyclones can considerably alter the benthic assemblages (Collins 1978), and have lasting effects on the community structure (Hughes 1989).

Freshwater runoff

Optimal coral growth occurs at salinities around 34 - 36 parts per thousand (ppt), although corals appear to tolerate intermittent conditions around 27 - 48 ppt (Fagerstrom 1987). Periodic reductions in salinity are common on fringing reefs near large river catchments during the passage of monsoonal troughs. The effect of reduced salinity on a coral reef has been recorded on a number of occasions (Hedley 1925; Rainford 1925; Goreau 1959; Cooper 1966; Collins 1978; Lovell 1989). If exposure to these conditions is extensive corals expel their zooxanthellae and coral death is imminent. Death arises due to irreversible osmotic exchange although corals differ considerably in their tolerance to such conditions (chapter 6).

1.5 Anthropogenic impact

Although human influences clearly have the capacity to alter the fundamental nature of marine systems, they are not always harmful to coral reefs (see review by Brown and Howard 1985; Grigg and Dollar 1990). The degree of impact is very dependant on the type of pollutant and the duration of impact (Van Woesik *et al* 1990). However, it has been shown that the continuous input of elevated nutrient concentrations, via city sewage, altered the benthic communities within an entire Bay on Oahu, Hawaii (Smith *et al* 1981; Maragos *et al* 1985), effectively suppressing community calcification and enhancing primary productivity (Kinsey 1979). While it is widely recognised that severe eutrophication changes the character of coral reefs, the response of Great Barrier Reef biota to slight nutrient increases is unknown. Therefore, a study was undertaken which assessed the effect of secondary sewage discharge on community composition and coral growth.

A focus on fringing reefs is becoming increasingly necessary in order to understand the inshore reef ecosystem most commonly influenced by terrestrial factors and contemporary man. In contrast to mid and outer shelf coral reef assemblages, fringing reefs were originally described as simplistic (Steers and Stoddart 1977). However, more recently certain fringing reefs have been recognised for their diversity (Veron 1986), high coral cover (pers. obs.) and high coral and geomorphological growth rates (Isdale 1981; Hopley 1982).

CHAPTER 2. PHYSICO-CHEMICAL ENVIRONMENT OF THE STUDY AREA.

2.1 Location

The study area was situated off the central coast of Queensland, Australia, along the southern section of the Great Barrier Reef (Figure 2.1). Thirty-four continental islands were examined from 20°05'S to 23°10'S (Appendix 1). The area was divided into four major sections: the Whitsunday Islands; Cumberland Islands, Northumberland Islands and the Keppel Islands. The total area is approximately 6000 km^2.

2.2 Geology

The Whitsunday, Cumberland and Northumberland Islands are volcanic in origin (Clarke *et al* 1971). Some of the islands are classified as granitic, however most are basaltic, andesitic, dacitic and rhyolitic in composition (Ewart *et al* 1990). Volcanism is inferred to have occurred throughout the island range in the Cretaceous period (145 million years ago). The volcanic deposits appear to have erupted from multiple vents. The volcanics are cut by numerous dykes ranging from dolerite through to rhyolite in composition. The Keppel Islands are also volcanic, although there are also large areas of unconsolidated Quaternary sediments.

2.3 Reef geomorphology

Three general fringing reef types were classified by Hopley and Partain (1986) based on geomorphological foundations (Figure 2.2):
Type 1. Reefs formed on the foundation of rocky shores during the Holocene transgression. Reef flat development is limited as most transgressional growth has been to low water mark from deep rocky foundations (eg. Figure 2.2i, Figure 2.3a);
Type 2. Reefs on pre-existing sedimentary structures. Reefs can develop over relatively unstable terrigenous sedimentary deposits, consolidation can be rapid and progradation extensive, although only thin (eg. Figure 2.2ii, Figure 2.3c);
Type 3. Reefs on old carbonate foundations. An initial framework isolated offshore filled in by terrigenous and biogenic carbonate deposits (eg. Figure 2.2iii, Figure 2.3b).

Figure 2.1. The study area: A Whitsunday Islands, Cumberland Islands, C Northumberland Islands, D Keppel Islands.

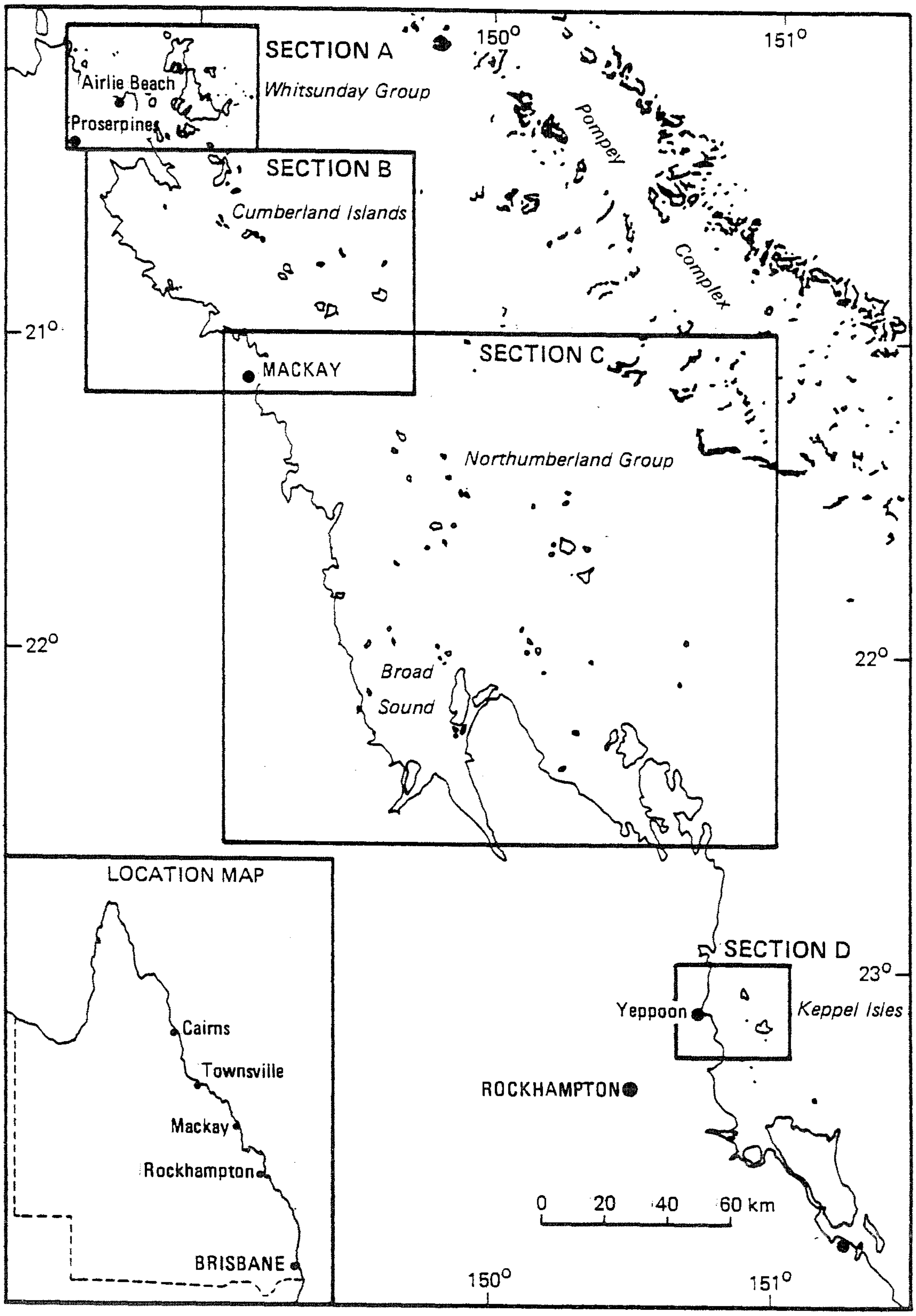
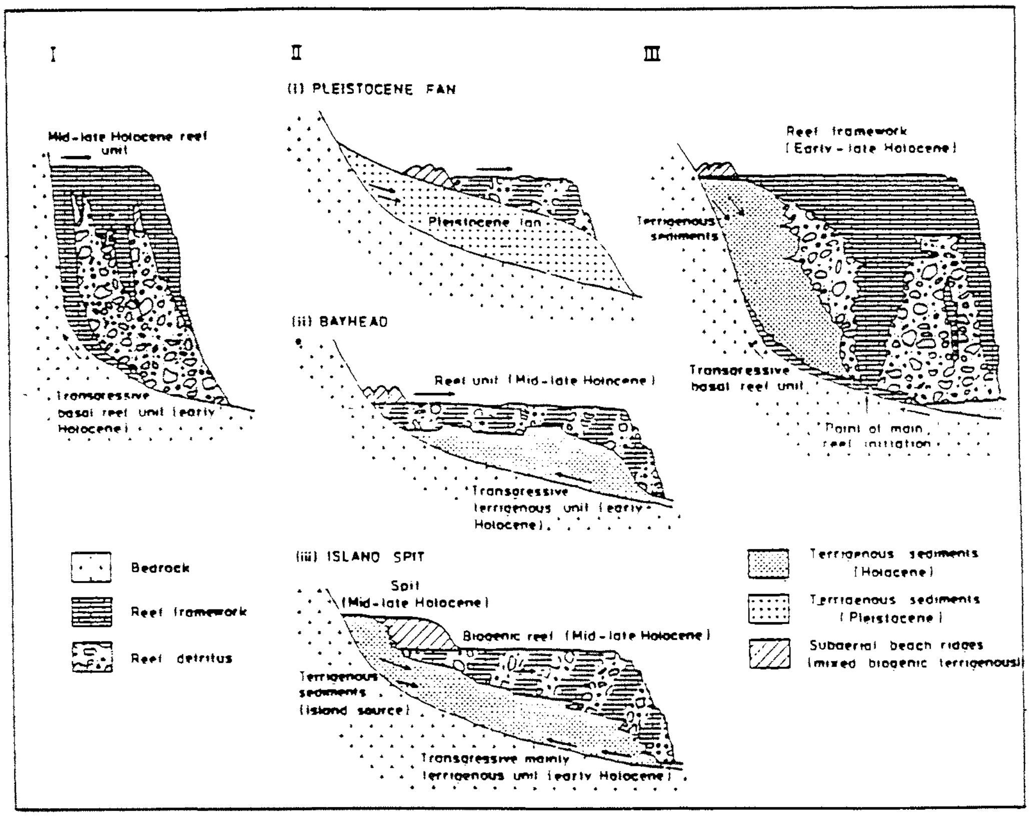


Figure 2.2. Geomorphology of three fringing reef types as classified by Hopley and Partain (1986), 1 on rocky foundations, 2 on pre-existing sedimentary structure, 3 on old carbonate foundation.



a.

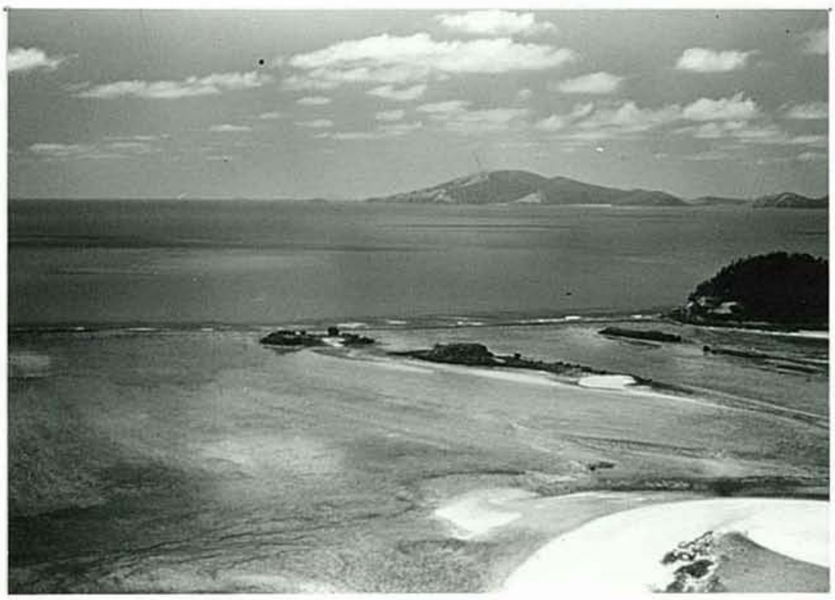
Figure 4.2 Varying degrees of fringing reef development .

a Poor reef development, South Percy Island, Northumberland islands.

b Intermediate development, Prudhoe Island, Northumberland islands.

c Extensive development, Cockermouth Island, Cumberland islands.

b.



c.

Table 2.1. Degree of reef development for island groups; 1 (poor development), 2 (intermediate development) and 3 (extensive development), as described in Figure 2.2. Reef development based on Great Barrier Reef Gazetteer, Hopley (1982), Hopley *et al* (1989).

Region	Latitude	Island group	Reef type	Sites (n)
1	20°05'S	Hayman Is.	3	3
2	20°06'S	Langford region	3	3
3	20°10'S	Hook Island inlet	2	2
4	20°18'S	Molle Islands	2	5
5	20°20'S	Shute Harbour	3	4
6	20°22'S	Long Is.	1	3
7	20°18'S	Whitsunday Is.	2	4
8	20°21'S	Hamilton Is.	2	5
9	20°33'S	Thomas Is.	1	2
10	20°40'S	Goldsmith Is.	1	20
11	20°48'S	Carlisle/Brampton Islands	2	16
12	20°46'S	Cockermouth Is.	3	6
13	20°52'S	Scawfell Is.	3	12
14	21°01'S	Penrith Is.	3	9
15	21°20'S	Prudhoe Is.	2	2
16	21°36'S	Curlew Is.	1	3
17	21°30'S	Digby Is.	1	5
18	21°40'S	Percy Islands	2	10
19	23°10'S	Keppel Islands	3	8

Reef distribution

Type 1 reefs occur along the windward side of the Whitsunday, Cumberland and Keppel Islands (Table 2.1). The inner Cumberland and Northumberland Islands have minimal reef flat development which increases offshore. Type 2 reefs occur on Hayman and Cockermouth Islands and Type 3 reefs are located on the lee of most of the Whitsunday, Cumberland and Keppel Islands. Leeward reefs in the Northumberland Islands are sparse.

Clearly reef development is poor in the vicinity of 21°S (Hopley 1982). Hopley *et al* (1989) summarised the frequency of reef types by latitude (Hopley *et al* 1989, Table 5). Incipient reefs (Type 1 reefs), with no extensive reef flats, were most common between 21°S and 23°S.

Eighty incipient reefs were reported between 21°S and 22°S, in contrast to the Whitsunday Islands where only 20 such reefs were reported. In fact 73% of incipient reefs found on the Great Barrier Reef were located between 21°S and 23°S (Hopley *et al* 1989).

A drilling programme on six reefs in the Cumberland and Northumberland Islands (Kleypas, 1992) indicated that Holocene reef initiation took place within a narrow time period some 7200-8000 years before present. These results are consistent with initiation of other reefs in the Great Barrier Reef (Davies *et al* 1985) and in the Indian Ocean (Montaggionni 1988). It appears that reefs throughout this study region have been close to modern sea-level for approximately 6000 years before present (ie. the end of the post glacial transgression) and growth has been mainly through lateral extension. However, reefs on Middle Percy Island (in the Northumberland region) appear to date back only to 3720 years before present. This delayed "turn-on" (Buddemeier and Hopley 1988) may be a consequence of harsh regional conditions for reef initiation.

All reefs investigated were underlaid with Pleistocene reef, eolianite or crystalline rock (Kleypas 1992). By contrast, fringing reefs in the central GBR have developed primarily over terrigenous foundations (Hopley 1982). Holocene reefs in the Cumberland group were classified as detrital by Kleypas (1992), because a large proportion of the reef being made of fragmented corals such as *Acropora* spp. and pocilloporids. Framework components, massive corals and algal bindstone, were consistently confined to the upper 1-2m.

2.4 Oceanography

Tides and currents

Tidal fluctuations have a distinct latitudinal component along the Great Barrier Reef (Figure 2.4). The tides are semi-diurnal and vary considerably in range throughout the study region (Table 2.2). To the south of Mackay the tides are the highest on the east coast of Australia, ranging to 10 meters in Broad Sound (22°S). The extreme fluctuations in tide height have been of interest for a considerable period (Flinders 1814; Maxwell 1967; Pickard *et al* 1977; Bode and Stark 1983; Middleton *et al* 1983). Through field observations and mathematical models they concluded that (in agreement with Flinders 1814) because of the dense nature and broad expanse of the outer reefs very little tidal movement is directed across the reefs. Most of the input of tidal energy, into this region of the GBR lagoon, is propagated through the Capricorn Channel to the south and Hydrographers Passage to the north. Maximum tides in Broad Sound are a consequence of local resonance amplifying tidal range within these narrow passages (Middleton *et al* 1983).

Table 2.2. Regional location of islands surveyed and three environmental variables; extent of tidal fluctuation, distance from mainland (km) and distance from nearest river (km). Each island was allocated a number between 1 and 5, in accordance with mean tidal amplitude, where - 1 is 3-4m, 2 is 4-5m, 3 is 5-6m, 4 is 6-7m and 5 is 7-8m (data derived from Queensland Official Tide Tables, 1990, Department of Harbours and Marine).

ISLAND	REGION	TIDE	DIST.MAIN	DIST.RIVER
Hayman	Northern Whitsunday	1	24km	80km
Langford	Northern Whitsunday	2	22km	76km
Hook	Northern Whitsunday	2	15km	71km
Molle	Inner Whitsunday	2	3km	55km
Daydream	Inner Whitsunday	2	3km	57km
Shute	Inner Whitsunday	2	0.5km	53km
Long	Inner Whitsunday	4	1km	45km
Pine	Inner Whitsunday	4	5km	43km
Whitsunday	Central Whitsunday	2	15km	55km
Hamilton	Central Whitsunday	2	12km	50km
Thomas	Cumberland	3	18km	40km
Goldsmith	Cumberland	3	35km	49km
Carlisle	Cumberland	3	28km	40km
Brampton	Cumberland	3	25km	36km
Cockermouth	Cumberland	3	40km	46km
Scawfell	Cumberland	3	45km	52km
Penrith	Outer Northumberland	3	74km	80km
Prudhoe	Northumberland	4	42km	56km
Curlew	Northumberland	5	40km	80km
Digby	Northumberland	5	48km	90km
N.Percy	Northumberland	4	64km	88km
S.Percy	Northumberland	4	48km	74km
Keppel	Keppel	2	14km	30km

Figure 2.4 Tidal fluctuations along the Great Barrier Reef. The full line describes the coastal tides and the dashed line the outer reef tides. A higher amplitude occurs inshore (after Pickard *et al* 1977).

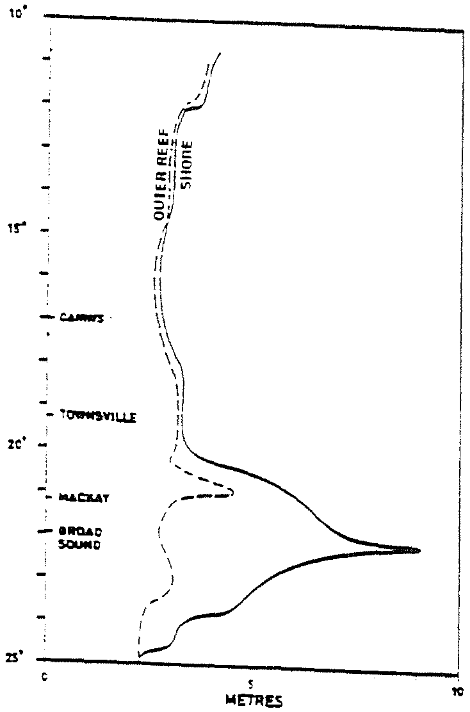
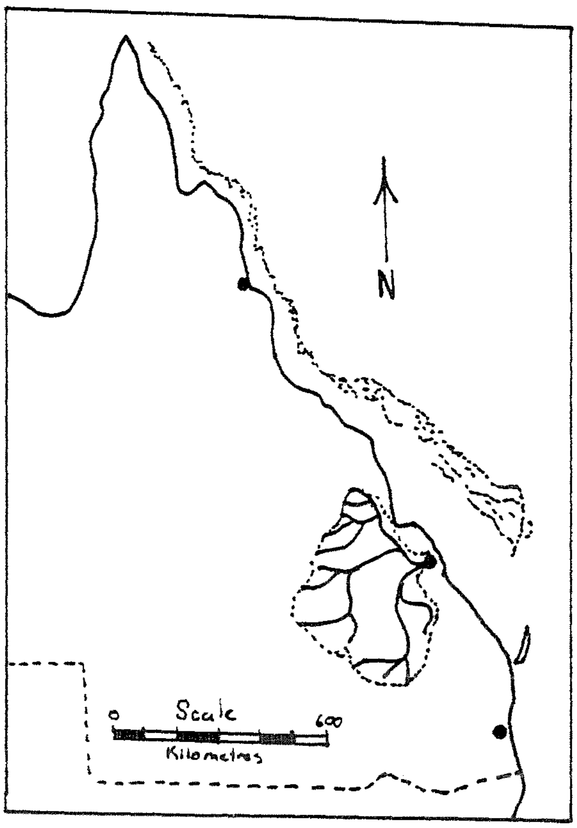


Figure 2.5 Area of the Fitzroy River catchment, 140,000km2, the largest catchment area in Queensland.



Away from constrictions to flow, current velocities average 0.5 ms^{-1} in the Whitsunday Islands. The close proximity of the islands induces complex current patterns and eddies behind bayheads (Parnell 1987). Current velocities increase towards Broad Sound in accordance with increasing tidal amplitude. Velocities and direction are substantially modified between island passes and currents exceeding 5 ms^{-1} have been recorded.

Waves

Outer reefs block oceanic swells and suppress wave development in the Great Barrier Reef lagoon. A two month investigation within the study area, conducted by the Beach Protection Authority (1979), recorded highest waves at 4.02m. Wave heights greater than 2 m occurred for only 2% of the observation period and > 1m for 22% of the time. However, the deployment period occurred in September/October, when trade winds are generally calm (Bureau of Meteorology, Brisbane). Although wave height is restricted by the relatively sheltered nature of the inner lagoon, waves at 3-4 m are common for extensive periods (pers. obs.).

Sea Temperature

In the study area sea surface temperature fluctuate from 28°C in February to 20.5°C in July (Pickard *et al* 1977). Average temperatures are around 24.5°C. However, in early September (1990) 18.9°C was recorded in Repulse Bay (unpubl. data), and 24.0°C on the outer reefs. Cross-shelf differences are maintained throughout the winter months (May-August) by low frequency longshore currents which act as an effective barrier to cross shelf mixing (Wolanski and Ridd 1990).

2.5 Climate

The climate is tropical; ie. generally warm, wet and humid in summer and mild and dry in winter. The air temperature fluctuates from a daily average maximum of 31°C in January to 23.5°C in July. The prevailing winds are from the south east. In summer however, the monsoon line moves southwards into northern Australia. The summer trades are generally weak as they pass over warm equatorial waters and absorb large quantities of moisture. Rains at times pre-empt or coincide with the formation of tropical cyclones in the Coral Sea. Tropical cyclones take erratic courses although they generally move in a south-east direction (Lourenz 1981), and periodically cause damage to coral reefs (Van Woesik *et al* 1991). Fifty three cyclones have passed within 400km of the study area within the last 80 years (Table 2.3).

Table 2.3. Frequency of cyclones within 400km of the study area over the last eighty years, excluding cyclone 'Joy' 1991.

Period	Number
1909-1920	5
1921-1930	4
1931-1940	6
1941-1950	13
1951-1960	4
1961-1970	5
1971-1979	4
1981-1990	12

The elevation of the Whitsunday Islands and adjoining mainland (peaks to 1000m) is such that it orographically induces high rainfall. Mean annual rainfall in the Whitsunday area is 2000 mm per year and the average over the Mackay region, for a period of one hundred years up to 1982, was 1700 mm per year (data supplied by the Bureau of Meteorology, Brisbane).

Monsoonal troughs at times extend over the entire study region, inducing intense rainfall and flooding of the major river catchments. Such an event occurred in January 1991 in association with cyclone 'Joy'. Periodic flooding considerably decreases nearshore surface salinity from the normal 35 ppt to as low as 15 ppt (see Chapter 6).

2.6 Major river systems

Three major river systems flow into the study area. The Fitzroy River is the largest river in Queensland (Figure 2.5). Its catchment area is 140,000 km^2 and it runs through Rockhampton and discharges into Keppel Bay. The Fitzroy has a mean annual discharge rate of 0.65 10^{10} m^3 per year, which is the third highest in Queensland behind the Burdekin (1.2 10^{10} m^3 per yr) and the Normanby (0.82 10^{10} m^3 per yr) (Pickard *et al* 1977). The Pioneer River, which runs through Mackay, has a substantially smaller catchment area of 1375 km^2 (discharge rate 0.1 10^{10} m^3 per yr). The third river system is a combination of the Proserpine and O'Connell rivers, which have a combined catchment area of 12,245 km^2 and discharge (0.25 10^{10} m^3 per yr) into Repulse Bay in the southern Whitsunday Islands (Figure 2.6). All river plumes are subjected to predominant south east winds and swell, causing a residual movement of discharge to the north.

2.7 Nutrients

Waters from terrestrial run-off are usually charged with macro-nutrients. River plumes dissipate rapidly along the inshore region of the Great Barrier Reef (Wolanski and Ridd 1990). During the wet season concentrations of NO_3, NH_4 and $Si(OH)_4$ decrease logarithmically with increasing distance from the Proserpine/O'Connell river system (Figure 2.7) (nb. raw data was collected by S. Blake with methodology outlined in Chapter 3). There appears to be a significant negative correlation with the concentration of NO_2 and the distance from the mainland during the wet season (Figure 2.8). During the dry season concentrations of PO_4, $Si(OH)_4$ and suspended sediments logarithmically increase with an elevation in tide range (Figure 2.9).

2.8 Suspended sediments

Between Broad Sound and the Whitsunday Islands suspended sediments are mainly quartz, clays and calcite (Kleypas 1992). Some predictive estimates were made from the suspended sediment data, presented above (Figure 2.9 and appendix 9), and tidal fluctuations for the Northumberland region, where tidal ranges are exceptionally high and reef development is poor. Predictive estimates were made using a least squares regression analysis. For 8m tidal fluctuations, which occur regularly in Broad Sound, suspended sediment concentrations were 78.52mg/l^{-1}. This value is very similar to data collected by Kleypas (1992) on 11/10/90 in Broad Sound. Three replicates (84.20, 89.43, 62.21) averaged to 78.61 mg/l^{-1} (Kleypas 1992, Table 5.5). These findings indicate that not only do large tidal fluctuations enhance suspended sediment concentrations but tidal range appears directly proportional to suspended sediment concentrations.

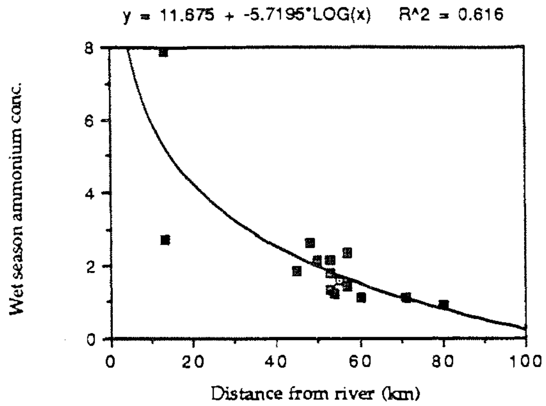
The shallow inner shelf between the Fitzroy River and the Cumberland Islands has been reported as being devoid of fine muds (< 1%) (Maxwell 1968). Shallow bathymetry and constant exposure to predominant winds prevents fine sediment from settling around these islands because of continued re-suspension. As a consequence, fine muds remain in suspension producing consistently high turbidity. However, the Whitsunday Islands act as a barrier, whereby the migration of southern mud ceases (Figure 2.1). Fine muds are prominent in leeward embayments in the Whitsunday Islands (40-60%, Maxwell 1968). Any residual drift of fine sediments north of here is minimal (Maxwell 1968).

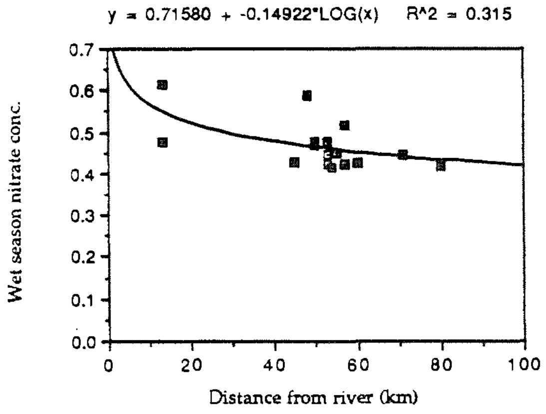
2.9 Overview of study area

It is evident that the study region has some anomalous characteristics and supports coral assemblages along several macroscale gradients. Tidal amplitudes (10m) are higher than anywhere else on the Great Barrier Reef inducing high suspended sediment levels. The geological foundation of reefs in the Northumberland region is considerably different from all other areas drilled on the Great Barrier Reef, because their initiation was delayed some 4000 years. Considerable variation in the distribution of continental islands along environmental gradients (eg. distance from three river systems, distance from mainland, shelf depth) provides an ideal study area for comparative analyses on reef assemblages. Whether benthic assemblages reflect environmental gradients is investigated using direct gradient analysis techniques.

Figure 2.6 Discharge from the Proserpine/O'Connell river into the southern Whitsunday islands, 1990.

Figure 2.7. Nutrient species (NH_4, NO_3, $Si(OH)_4$) decreasing in concentration with increasing distance from the Proserpine/O'Connell River system. Samples are mean concentrations taken over 9 sampling periods during the wet season (December-March). Raw data collected by S. Blake. All nutrient concentrations are in micromoles.





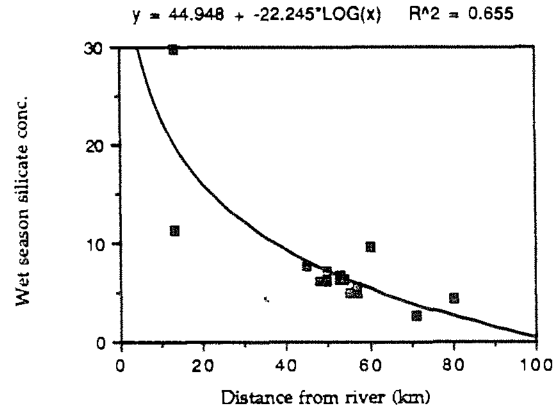


Figure 2.8. Nitrite (NO_2) decreasing with increasing distance from the mainland. Samples are mean concentrations taken over 9 sampling periods during the wet season (December to March). Concentration in micromoles. Raw data collected by S. Blake. All nutrient concentrations are in micromoles.

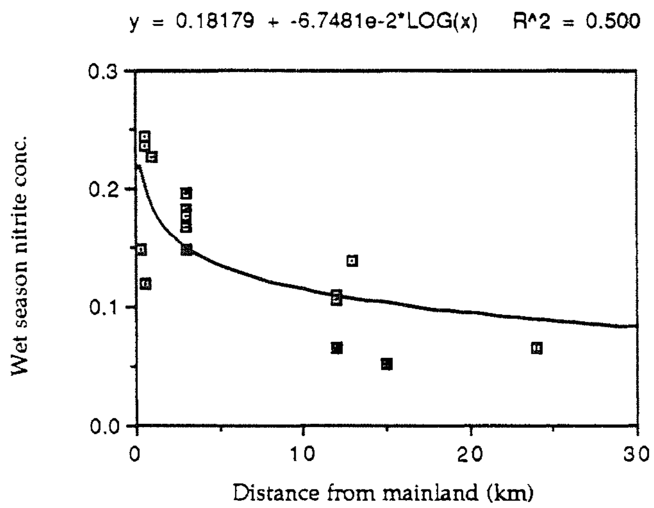
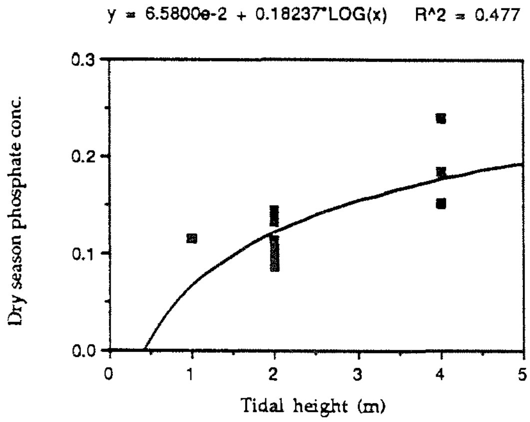
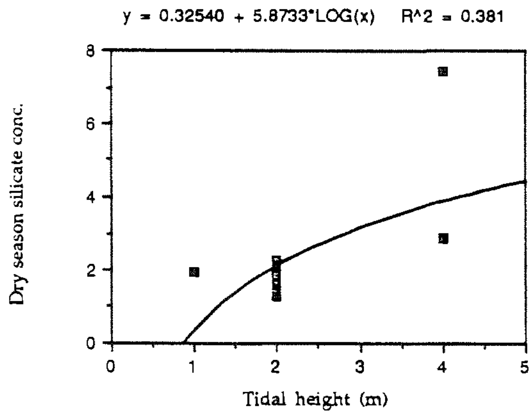
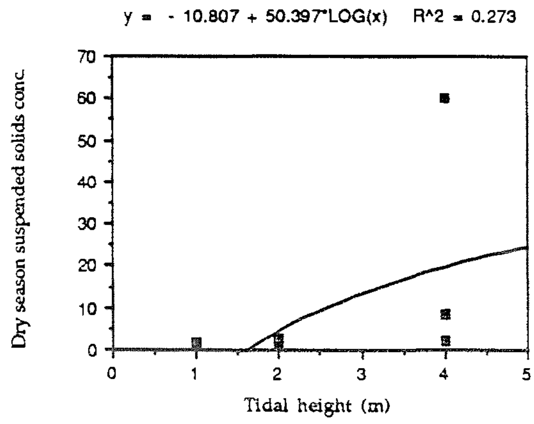


Figure 2.9. Nutrient species (PO_4, $Si(OH)_4$) and suspended solids increasing with tidal amplitude. Samples are mean concentrations taken over 9 sampling periods during the dry season (April - November). Nutrient concentrations are in micromoles and suspended sediment in milligrams per litre. Raw data collected by S. Blake. All nutrient concentrations are in micromoles.







CHAPTER 3. METHODS

3.1 Interpretation and analysis of multivariate data

Background

Before the influential paper by Bray and Curtis (1957) discussing the continuum concept, environmental gradients were recognised *a priori* and sampling was undertaken in accordance with these gradients (Whittaker 1956). Analyses were then undertaken to distinguish if certain species complied with these gradients. Information gained distinguished certain species response patterns. However the causative gradients were defined *a priori*.

It is evident that this community gradient approach is tautological. The continuum approach however, perceives overall patterns by ordering sites using, for example, their species composition or abundance. Gauch and Whittaker (1972) introduced the Gaussian curve as a simple model of a species response to environmental variables. This curve is not unlike a normal distribution curve, however they emphasised that the curve represents a response function not a probability distribution. In other words unimodal models represent, in principle, a 'mean' response along a continuum of physiological tolerance.

There are numerous options available to analyse multivariate datasets using unimodal models. The following brief overview considers the properties of some of the main options. On the basis of trials, Multi-Dimensional Scaling and (partial and full) Canonical Correspondence Analysis were chosen.

Ordination and clustering

Both ordination (Whittaker 1967) and clustering techniques (Clifford and Stevenson 1975) have been used extensively to describe distribution patterns in nature. They distinguish differences between sites and assist in narrowing down the number of variables that might be determining distribution patterns. However, the influence of specific environmental parameters is difficult to test directly. Problems can be envisaged using these techniques in isolation, since a lack of understanding or stratification of the environment under investigation may lead to the masking of any patterns that may exist.

Multi-Dimensional Scaling

Multi-Dimensional Scaling (MDS) is a non-linear ordination technique (Kruskal and Wish 1978; Minchin 1987; Jongman *et al* 1987; Ter Braak and Prentice 1987). It produces a configuration of points, for example representing sites, where their distance apart reflects similarity based on species composition. The input dissimilarity matrix is based on rank-order. A measure of goodness-of-fit of the distances apart, and their overall orientation, is judged by a stress coefficient. Stress is based on a scale from 0 to 1 where values below 0.2 express a reasonable confidence in the ordination profiles. More specifically a stress factor is a measure of dispersion along the monotonic regression function, which is normally expressed as an eigenvalue in linear ordination techniques.

Direct gradient analysis

Erroneous environmental gradients may be identified if indirect gradient analyses are used in isolation (Austin 1985). Canonical Correlation Analysis is a direct gradient analysis technique which tests species composition against environmental gradients. However, the procedure suffers from multi-colinearity problems when the number of species approaches the number of sites (McArdle pers. com.). This is often the case on diverse coral reefs. An alternative technique, Canonical Correspondence Analysis (Ter Braak (1986), is also a direct gradient analysis procedure. It is a combination of an ordination and a multiple regression. It extracts the dominant pattern of variation in community composition from the species data. It then attempts to relate the first few ordination axes with the environmental variables. As a result the ordination axes appear in order of explained variance by linear combinations of environmental variables. The resultant species response curves are unimodal with centroids identifying the optimum of the curve. These are displayed in relation to the ordination axes (eigenvalues). The first two eigenvalues are constrained and the second two are independent of the first, or unconstrained. These analyses lead to ordination diagrams - biplots - which optimally display similar sites in terms of composition, and orientate sites in terms of environmental gradients. The significance of eigenvalues can be tested via Monte Carlo permutation tests. If only one environmental gradient is tested at any one time, via a partial Canonical Correspondence Analysis (defining other gradients as covariables), then a significance test on the eigenvalue will be similar to a significance test on the correlation between the environmental gradient and species distribution and abundance patterns (centroids).

The Monte Carlo test

The Monte Carlo test is based on the principles of permutation and randomisation (Hope 1968). It uses the similarity matrix to test the significance of the canonical axes (eigenvalues). This test gives rise to a random data set within the confines of the estimated correlation matrix. It randomly permutes a link between the species data and the environmental data. For each random dataset an eigenvalue is calculated. The number of random permutations was restricted to 99 for all these analyses. If the set of species correlate with the environmental variable then the calculated test statistic, in the actual analysis, will be larger than the majority of the test statistics that were calculated from the random dataset. If the observed value is among the 1% or 5% of the highest values then the benthic assemblage can be said to be significantly related to the environmental variable(s) at a $p < 0.01$ or $p < 0.05$ level.

Models, philosophy and interpretation

In nature however, there is no reason why species response curves cannot take another form to that of a Gaussian curve. Indeed, Greig-Smith (1983) discussed the concept that species response curves may not necessarily be symmetrical and Austin and Smith (1989) and Minchin (1989) recently argued that these (unimodal) types of models lack a sound biological basis and are not representative of physiological response patterns. They add that realistically most response patterns are skewed for populations measured.

Logarithmic transformations and standardising may remove that skewness (Okland 1986). However, one will be testing the median values as opposed to the mean values of the population (LaBarbera 1986). If there is a response of a population along an environmental gradient the response of the population mean is most valuable, not the median value. For this reason species abundances were not transformed using multivariate non-parametric analyses, and a unimodal response model is assumed around the mean. Notably, such an argument would be invalid for parametric analyses, such as analysis of variance, as a major assumption is a normally distributed population. Any skewness beyond normality needs rectifying via transformations.

Indeed, the usefulness of any model, in practice, relies on the robustness against violations of the model conditions. The robustness of correspondence analysis has been tried and tested extensively and found to be considerably robust (Hill and Gauch 1980; Ter Braak 1985). The analyses can test variables directly and falsify any inappropriate or non-correlating parameters thereby allowing a more definitive exploration of nature.

3.2 Field methods for regional study (chapters 4 and 5)

One hundred and twenty-five study sites were examined on thirty four continental islands (Appendix 1). Aerial photographs were used to aid selection of study sites. The position of each site was fixed using compass bearings on headlands and other landmarks. Each site measured 20m by 10m and was divided into 5m by 5m subsections to enhance recording accuracy. Sites were primarily located on shallow reef slopes (approximately 2m below Low Water Datum, LWD), with the longitudinal axis oriented along the depth contour. The 20m by 10m quadrats were used to identify coral composition, abundance, size and morphology. In addition, line transects were run across the quadrat to estimate gross cover of major benthic components. Surveys were conducted on SCUBA.

The size and identity of all the scleractinian corals (Veron and Pichon 1976; 1980; 1982; Veron and Wallace 1984; Veron 1986) and alcyonarian corals (Bayer *et al* 1983) were recorded (Appendix 2). At the beginning of this study it was not possible to distinguish all scleractinian colonies within the genera *Acropora, Montipora* and the family Poritidae. However through the course of this work species level identification became more familiar (Chapter 6). On the other hand, alcyonarian corals were recorded to genus throughout. For the purposes of analysis 102 Operational Taxonomic Units, OTUs (Sneath and Sokal 1973) outlined in Appendix 2 were used.

Each coral colony was allocated to one of five size classes based on maximum diameter: A 1-10cm; B 11-50cm; C 51-100cm; D 101-300cm, E > 301cm, at all sites except those in the Cumberland region (sites 32-88) where size class A and B were combined. This region was investigated first. The data are reported to lowest resolution in Appendix 2, however multivariate analyses undertaken in chapter 4 and 5 utilised the four size classes: A 1-50cm; B 51-100cm; C 101-300cm; D > 300cm.

Estimates of percentage cover of hard coral, soft coral, macroalgae, turf algae on carbonate substrate, dead coral and sand were made at each site using a 20m fibreglass tape measure (Appendix 3). The tape was laid along the centre of each site, and the point of transition of each benthic component under the tape was recorded. Generally macroalgal biomass is higher in spring/summer than in autumn/winter on nearshore reefs in Queensland (Ngan and Price 1980). To reduce seasonal variation most surveys were conducted during winter months.

Environmental variables

To determine whether coral distribution patterns are reflected along macroscale gradients (10's of kms), the following information was recorded for each site (Appendix 4): distance to mainland; distance to nearest river; annual mean tidal range; shelf depth; depth (relative to Low Water Datum, LWD); region of study. Each site was also allocated a number, either 0 or 1, based on a whether the site was sheltered by a bayhead or not. This was termed an exposure index (Appendix 4).

Oceanographic variables

Quantitative measurements of dissolved inorganic nutrients, suspended solids, bottom sediments and hydrodynamic patterns were collected between April 1988 and July 1991 at sixteen sites by S. Blake (Appendix 9). Collaborative research was initiated in 1988 and water quality sites were chosen which directly corresponded to benthic study sites. The present author analysed the raw data. Data presented are mean concentrations for the wet (December to April) and dry season (May to November). Water samples were extracted 10-30m from the reef edge, at three depths in duplicate (1 m and 4m below the sea surface, and 1 m above the seafloor). Samples were collected in five litre Niskin bottles, filtered using 0.45 micrometer disposable cellulose acetate filters and stored in acid-washed plastic tubes. Samples were immediately frozen. The concentrations of dissolved inorganic nutrients, NO_2, NO_3, PO_4, NH_4, $Si(OH)_4$ were measured with a multi-channel segmented flow auto-analyser at the Australian Institute of Marine Science, Townsville. The amount of suspended solids in the water column was determined by slowly filtering duplicate 500ml samples of seawater collected in a Niskin bottle, onto Whatman GF/C filters, drying at 60°C, desiccating and re-weighing.

3.3 Data analysis for regional study (Chapter 4).

Species data were directly compared with environmental variables using the multivariate packages PATN (Belbin 1987), CANOCO (Ter Braak 1987), ECOPAK (Minchin 1986) and DECODA (Minchin 1990). Transformations to the species data were not applied (for reasons explained above), while environmental variables were standardised by dividing by the standard deviation. Standardisation was considered essential since the environmental variables were measured at a number of scales (eg. tide 1-5, depth 1-3). These manipulations gave the variables equal weight in the analyses. Analyses were undertaken on matrices containing both hard and soft corals, and on independent matrices for hard and soft corals.

In order to objectively test environmental variables which have a significant correlation with the biological assemblages a series of partial Canonical Correspondence Analyses (Ter Braak 1988) were undertaken. Testing was performed in an iterative manner. Firstly, one variable was tested, for example depth, against the species dataset. The first canonical axis derived from this analysis was then tested for variation from random via a Monte Carlo permutation test. If found significant it was defined as a covariable, to regress out its effect, and used in combination with the following variable to test its significance. This process was repeated for all eight variables. All significant variables were then utilised within a full Canonical Correspondence Analysis.

Analyses produced canonical coefficients which express the degree of change in community composition per unit change in an environmental variable (or a suite of environmental variables simultaneously). These correlations are linear combinations of environmental variables where all variables are held constant. However the analyses also produced intraset coefficients, which are correlation coefficients between environmental parameters and the ordination axis produced when the environmental variables are assumed to covary. Canonical coefficients and intraset coefficients give the same information only in the special case when environmental variables are mutually uncorrelated. The later coefficients however do not suffer from multi-colinearity problems when variables are related (Ter Braak 1986), therefore interpretation focused on these coefficients.

Results were displayed graphically as biplots, where species or sites were represented as points in a 2-dimensional array and similarities in abundance or composition were the main criteria for their positioning. Environmental variables can be displayed as vectors, although only presented in this manner in chapter 5. The angle of each vector was the greatest variance explained by the environmental variable juxtaposed on species responses to that variable. Vectors with long axes were most correlated with biological composition.

3.4 Analysis of regional data on coral abundance, size and morphology (Chapter 5).

In order to compare the abundance and size of corals in the Whitsunday and Northumberland region a two factor analysis of variance (ANOVA) was considered initially (using size and region as factors). Significant interaction terms in such an analysis would be of particular interest as interaction terms have been defined by Underwood (1986) as terms which elucidate emergent properties (although difficult to test in an *a posteriori* manner). Significant interaction terms would signify that regional conditions influence the size to which corals can grow. However, such an analysis would violate the laws of independence as a site is $200m^2$ (ie. a defined space) and the abundance of many large corals may restrict recruitment of small corals. Therefore the size and abundance of the corals in each site are not independent.

Therefore, a t-test was used to examine the null hypothesis that the two regions (Whitsunday and Northumberland Islands) supported a similar number of coral colonies. One of the critical assumptions in these analyses is the normality of data and homogeneity of variances. Normality was examined via a Wilk-Shapiro statistical test (Shapiro and Francia 1972). Several preliminary tests indicated that variances were often unequal. This problem was overcome with a test adopted from Snedecor and Cochran (1980) that does not require equal variances. Furthermore, degrees of freedom are expressed to one decimal point, which was calculated using the Satterthwaite's approximation (Snedecor and Cochran 1980).

In order to balance the design, ten sites were selected randomly from the Whitsunday region as only 10 sites were surveyed in the central Northumberland group (Curlew, Digby and Henderson Island). Analyses were undertaken for total scleractinian corals, 'fast growing', 'massive', and 'arborescent' scleractinian corals and soft corals. Variation in size structure was examined graphically.

The extent of carbonate development was compared at the same 20 sites mentioned above, using reef area as a comparative index. Reef area was derived from the Great Barrier Reef Gazetteer. Similar t-tests were applied to the data in order to determine whether reef development significantly varied between the Whitsunday and Northumberland Island sites.

3.5 Natural disturbance: the January 1991 floods (Chapter 6).

Permanent sites were established on the Keppel Islands in 1989. Severe flooding of the Fitzroy River led to hyposaline conditions in Keppel Bay for 15 days (O'Neill *et al* 1992). Most permanent sites in Keppel Bay had experienced absolute coral mortality during the flood event. A depth stratified sampling strategy was undertaken in order to assess the vertical extent of damage and any differential mortality. On the other hand, nine sampling sites in the central Whitsunday Islands were re-examined after the monsoonal conditions using the same sampling strategy.

Keppel Islands survey

Post flood surveys were undertaken in February 1991. At each site, a vertical profile was run perpendicular to the reef crest. Sampling was conducted every 1.0m vertical depth. At each depth, three 15m line transects measured live coral, recently dead coral and bleached coral. Eight sites were surveyed in this manner (Figure 3.1; Figure 3.2). At each site, detailed searches were undertaken within a $50m^2$ area to observe any differential survival of species. Each coral colony was allocated to one of three categories - dead, damaged (bleached or partially bleached) or alive and unaffected. Colony depth and observation time were recorded to retrospectively assess the response of different species relative to LWD.

Histopathology

Terminal polyps from ten partially bleached colonies (5 Acropora formosa, 2 *Acropora secale*, 1 *Acropora latistella*, 1 *Pocillopora damicornis* and 1 *Seriatopora hystrix*) were collected from two locations on the Keppel Islands (Clam Bay and Barren Island) in February 1991 at depths ranging from 1 to 3m below Low Water Datum. With each fragment intended for histology, an attempt was made to sample the border between normal and bleached tissue. All tissues were fixed in 10% seawater formalin. The following histological preparations were undertaken by J. Glazebrook (Deakin University). A photographic record kept of each specimen prior to decalcification with formic acid (0.5 to 5%). The remaining soft tissues were then embedded in paraffin wax, cut to a thickness of 5-6 u and stained by Haematoxylin and Eosin, Periodic Acid Schiff and Trichome.

Whitsunday Islands survey

In order to examine the effects of the monsoonal conditions on reefs in the Whitsunday Islands nine sites surveyed in December 1990, on Hamilton, Dent, Plum Pudding and Henning Islands (Figure 3.3), were re-surveyed in May 1991. Site re-location was facilitated by compass bearings, however sites were not permanently marked. Sites were stratified at four pre-determined depths; reef flat, 3m, 6m, and 10m LWD. These depths were chosen after a pilot study of the region identified four major habitats. Benthic assemblages were quantitatively measured using four 20m line transects at each depth. Changes in total cover were analysed via a three factor analysis of variance (ANOVA) with factors being: time (random), site (random) and habitat (fixed) and transects nested within habitat (acting as replicates). Data were log (x + 1) transformed.

3.6 Anthropogenic disturbance: effects of secondary sewage (Chapter 7).

To determine regional variation an examination was made on the composition, abundance, morphology and size of coral colonies (Chapter 4 and 5). A similar examination was made on a temporal scale near a sewage outlet to assess whether coral assemblages responded to elevated nutrient levels. Coral cores from the genus *Porites* spp. were also examined at varying distance from the outlet in order to assess the influence of discharge on coral growth. This coral was chosen as it possesses skeletal banding (Buddemeier and Kinzie 1976) and has previously been used in palaeo-environmental studies (Isdale 1984; Boto and Isdale 1985).

Discharged effluent

Effluent has been discharged off the reef crest at the Hayman Island, Whitsunday Islands (Fig. 3.4) since 1960. Relatively high concentrations of contaminants were discharged prior to 1972: 400 mg/l BOD_5 (Biological Oxygen Demand for five days incubation) and 200-500 mg/l NFR (Non-Filterable Residue) (Bell 1989). Considerable improvement occurred with implementation of a secondary treatment plant in 1981 which removes BOD but little or no nutrients. This installation allowed the resort to discharge effluent concentrations well within the requirements of their discharge licence: 20 mg/l BOD_5, 10-20 mg/l NFR, total nitrogen (mainly in the form of nitrate) 20 mg/l and total phosphorus 10 mg/l. Effluent is periodically discharged to marine waters via a 9cm plastic pipe at a maximum discharge rate of 500 m^3/day.

Field Methods

Field work was conducted on Hayman Island in the Whitsunday Islands in December 1986 and October 1988 (Figure 3.4). Three permanent study locations were established: 'potential impact', 'location 2' (approximately 300 m to the east of the outlet) and 'location 3' (approximately 300 m to the west of the outlet) (Figure 3.4). There were three contiguous sites at each location. Another location was established in October 1988 at Blue Pearl Bay. This location was named a 'control' - as it was located well outside the potential influence of sewage discharge. At each site 20 m by 10 m quadrats were made at a fixed depth of ca. 2m LWD. The transects encompassed the lower reef crest and slope, where the majority of coral biota were concentrated. Each site was divided into eight 5 m by 5 m subplots which were marked with steel posts and pins. Corals and other benthic organisms were recorded to species level where possible, some colonies were later amalgamated to genera and growth form. Each colony was allocated to a size class (A 1-50cm, B 51-100cm, C 101-300cm, D > 301cm). Hard corals were also assessed for recent tissue damage (estimated visually to the nearest 10 % of colony surface). At each site estimates of percent cover were made for gross biotic (hard and soft corals, turf algae) and abiotic variables (sand and rubble) using three 20 m line transects laid parallel to the reef crest (inset Figure 3.4). These data were not quantitatively analysed because of low replication.

Coral cores

Coral cores (diameter 35 mm; length 120 - 290 mm) were taken from six *Porites* spp. corals by the author using a hand-held pneumatic drill. A 35mm by 600mm core barrel and stainless steel tip was made by the author specially for small core extraction. Single cores were taken from sites 3 (sewage outlet) and 4, two cores from site 7 (one dead and one live colony) and two from the control location. All cores were taken from corals 2 - 3 m below LWD. Cores were cut longitudinally into 2 slabs, 5 mm and 7 mm thick, parallel to the growth axis. The 5 mm slabs were viewed and photographed under ultra-violet (UV) light at the Australian Institute of Marine Science under the supervision of Dr. P Isdale and the 7 mm sections were X-rayed at the Townsville Hospital.

Each dark-light couplet was assumed to represent one year of growth (Buddemeier and Kinzie 1976). Growth rates were determined by averaging the lengths of each dark-light couplet along three transects drawn parallel to the growth axis on the X-radiographs. Years of high fluorescence were noted.

Small fragments of the cores (2 mm, 2mm and 0.5mm thick) were prepared for viewing under an electron microscope. Fragments were taken from the dense and light couplets (representing 1981) from each core, adhered to a glass slide and covered in carbon. These slides were viewed under a Philips SEM 505 scanning electron microscope and photographed.

Three cores, from sites 3, 7 and 1, were analysed for porosity via the mercury intrusion technique (Gregg and Sing 1967) using a micromeritics autopore 9200 system at the University of Queensland. The basis of the mercury porosymmetry technique is that an excess pressure (P) is required to force the liquid mercury into capillaries within a solid (coral) (Gregg and Sing 1967). In this manner the radius of the capillaries (assumed cylindrical) and the surface tension of the liquid is measured. A mercury porosimeter is a device which is capable of generating suitably high pressures and measuring simultaneously both the pressure and the volume of mercury taken up by the pores.

Analytical methodology

Hybrid Multidimensional Scaling analysis (HMDS) (Kruskal and Wish 1978), applying the Bray-Curtis dissimilarity coefficient (Bray and Curtis 1957), was used to examine relative change in species composition at each site over time. The technique was applied to examine similarities between both spatial and temporal datasets simultaneously. The control site data was added to the HMDS analyses, as a 2-D reference. A two-way analysis of variance, using time and location as factors (sites nested within location), was used to test the null hypothesis that coral abundance did not vary between the two time periods or between locations. Several taxonomic levels were examined in this manner. Non-parametric Mann-Whitney Wilcoxon tests, for unpaired samples, were used to compare the temporal change in the amount of partial mortality on massive *Porites* spp. and caespitose *Acropora* spp.. Comparisons were restricted to these corals because they were common and their morphology, growth rates and longevity are near the extremes of variation for scleractinian corals.

Figure 3.1 Location map of the Fitzroy River mouth and the Keppel Islands.

Figure 3.2. Study sites on the Keppel Islands.

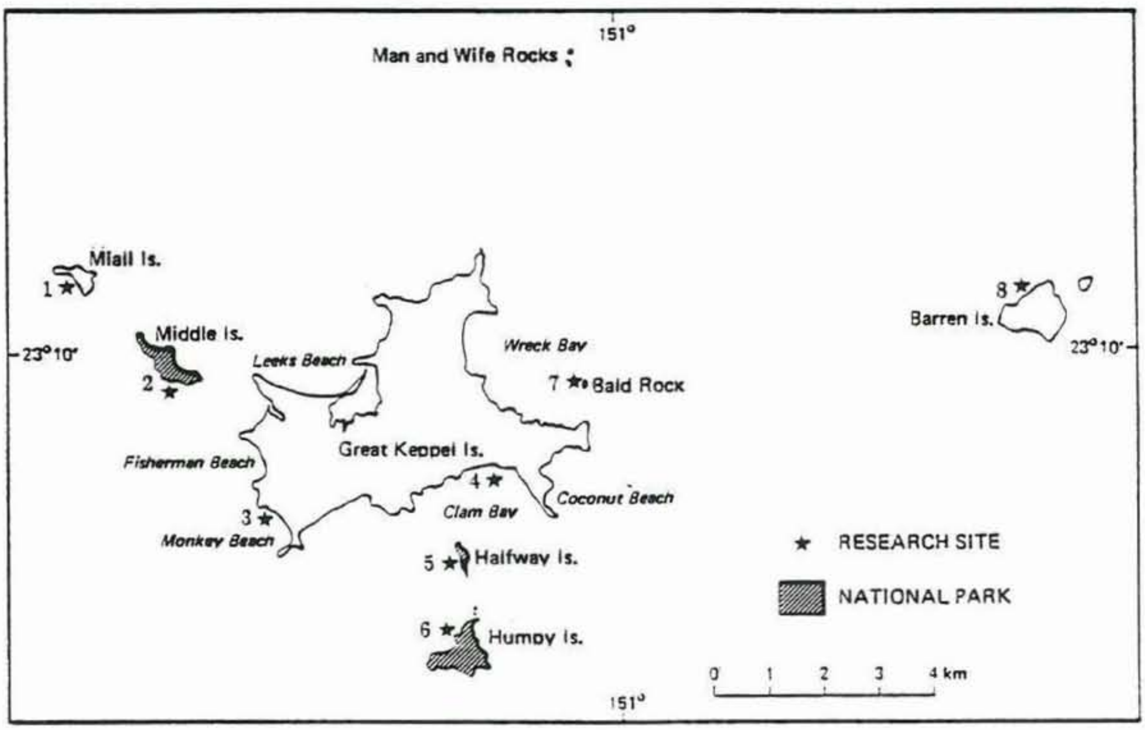


Figure 3.3. Location of study sites in the Hamilton Island region. These sites were surveyed at four different depths before and after the January 1991 floods.

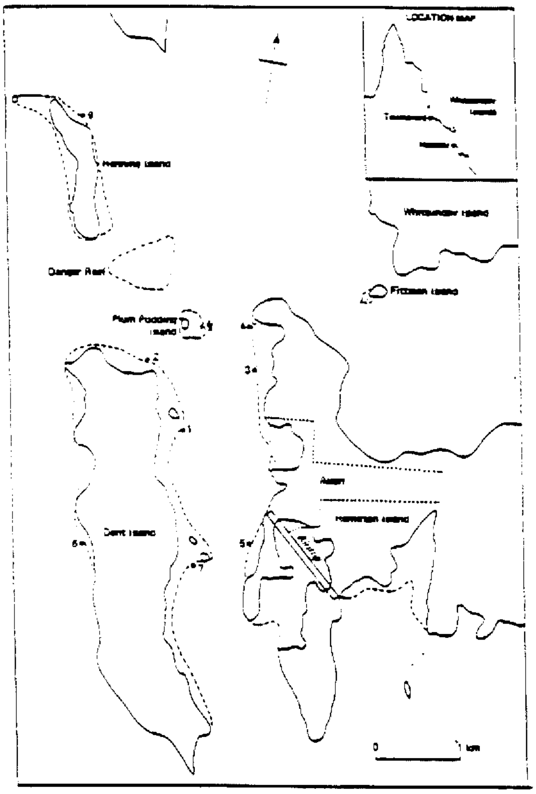
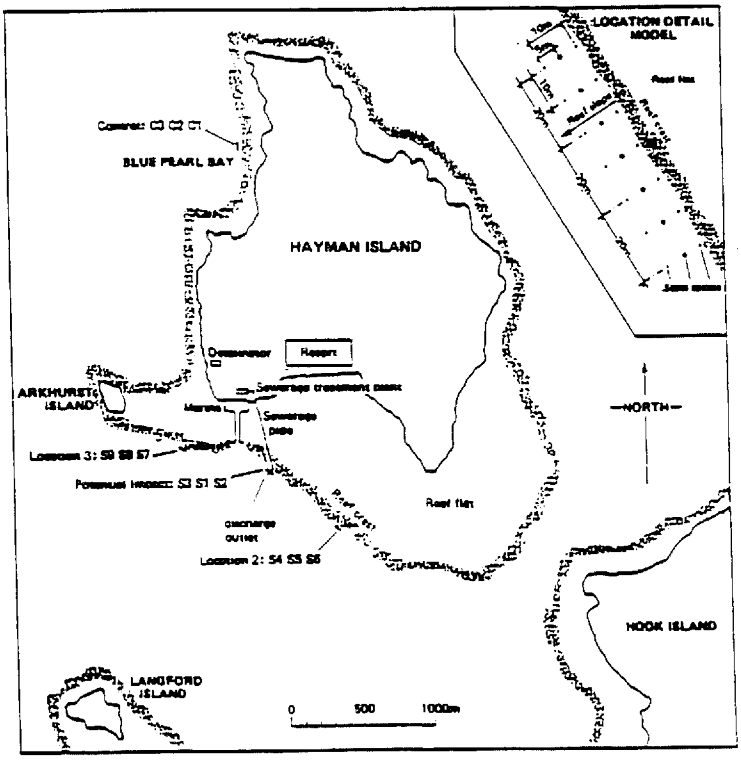


Figure 3.4. Location of study sites at Hayman Island, with inset showing location layout (three 20m by 10m sites).



CHAPTER 4. REGIONAL VARIATION IN CORAL DISTRIBUTION

4.1 Introduction

Fagerstrom (1987), in his review of the palaeontological literature on corals reefs, defined a coral community as a suite of species with characteristic composition, which can be objectively mapped (due to obvious spatial boundaries) and is generally coincident with strong environmental gradients. This concept is tested on contemporary data.

In this chapter the regional variation in major coral and macroalgal taxa are examined. Correlations between coral assemblages and environmental gradients are assessed, and recurrent assemblages are described.

4.2 Overall Composition

A total of 90 taxa from scleractinian corals, alcyonarian corals and the hydrozoans *Millepora* spp. are used to describe the variation in composition between the four regions; Whitsunday, Cumberland, Northumberland and Keppel Islands. The outer Whitsunday and Cumberland Islands were most diverse. The number of taxa declined south of 21°S (Table 4.1).

Table 4.1. Regional variation in taxa.

Island Group	Number of OTUs	Latitude
Whitsunday Islands (north)	77	20°05'S
Whitsunday Islands (central)	79	20°18'S
Whitsunday Islands (south)	73	20°22'S
Cumberland Islands (inner)	73	20°40'S
Cumberland Islands (outer)	78	20°52'S
Northumberland Islands	65	21°30'S
Percy Islands	58	21°40'S
Keppel Islands	38	23°10'S

Family

Faviidae was the most common family, occurring at 97% of the sites (Table 4.2). Acroporidae was also widespread with the highest overall mean. Poritidae and Pocilloporidae were also common at most sites. Other scleractinian families were less prolific.

Table 4.2 Relative abundance of Scleractinian corals, where frequency of occurrence is expressed as FREQ., MEAN is the overall mean abundance calculated over sites. Mean values are presented for each region separately. Penrith Island data are not included because of the island's mid-shelf location and the lack of slope data.

TAXA	FREQ.	MEAN	Whit. Is.	Cumb. Is.	North. Is.	Keppel Is.
Acroporidae	96.5	60.4	67.1	47.3	76.9	85.0
Faviidae	97.4	41.5	85.6	20.4	39.6	22.4
Poritidae	93.0	30.5	65.9	13.4	34.2	3.8
Pocilloporidae	90.4	18.5	31.0	14.3	6.8	28.7
Dendrophylliidae	63.5	7.6	6.7	2.7	23.7	5.5
Mussidae	79.1	6.8	13.3	5.3	3.9	0.5
Agariciidae	66.1	6.8	7.2	6.1	10.3	1.4
Fungiidae	59.1	5.0	12.5	2.9	0.7	0.6
Pectiniidae	57.4	3.8	6.7	3.1	2.6	-
Merulinidae	67.8	3.3	4.8	3.3	1.9	1.1
Oculinidae	50.4	2.8	4.2	3.2	0.4	-
Caryophylliidae	37.4	1.1	2.3	0.8	0.6	-
Siderastreidae	13.0	0.4	0.4	0.3	0.7	-

Species-genus

Overall, the most widespread scleractinian genera were *Favia, Goniastrea, Favites, Platygyra, Acropora, Porites, Montipora* and *Goniopora*, respectively. The mean abundance and frequency of *Acropora* spp. was marginally higher than *Montipora* spp. (30.3 and 27.8 mean number of colonies per 200m^2). Pocilloporids (mainly *Pocillopora damicornis* and *Stylophora pistillata*) were also prolific. Highest mean number of colonies per site was recorded for the genera *Montipora, Goniastrea, Favites, Porites* 'massive', *Favia* and *Goniopora*, respectively (Appendix 5).

Ninety six percent of the sites supported soft corals with a mean abundance of 122.3 colonies per site. Fourteen alcyonarian genera were recorded for quantitative analysis. Some rare soft corals were observed although not included in the overall analysis due to taxonomic problems. Most common and abundant soft corals were from the genera *Sarcophyton, Xenia, Alcyonium, Sinularia* and *Lobophytum* (Appendix 2).

Macroalgae

The inshore reefs of the Whitsunday, Cumberland, Northumberland and Keppel Islands supported abundant macrophytes, although macrophytes were rare on outer islands. Phaeophyta were the dominant algae throughout the study area (with highest biomass in summer). Most common were *Sargassum* spp., *Lobophora variegata, Dictyota* spp. (*D. paradalis* and *D. volubilis*), and *Padina* spp., *Hormophysa triquetra*. Other common phaeophytes were *Cystoseira trinodis, Stypopodium flabelliforme, Hydroclathrus clathratus, Colpomenia sinuosa, Chnoospora implexa* and *Dictyopteris australis.*

Rhodopytes were generally less prolific and most common on the outer islands, especially in the Whitsunday and Cumberland Islands. *Plocamium hamatum* was abundant between crevices on outer island slopes. *Hypnea pannosa, Laurencia* spp., *Galaxaura oblongata* and *Acanthophora spicifera* were more abundant inshore. Erect calcareous algae were conspicuously rare (*Amphiroa* sp., *Jania adhaerens*), however variants of calcareous encrusters (*Lithophyllum* sp. and *Peyssonnelia* sp.) were plentiful under fleshy macrophytes.

Macroalgae abundance and reef development

In order to examine regional trends in the relative abundance of hard corals and macroalgae, data from line transects were used and sites at each island were pooled to provide a comparative measure (Table 4.3; Figure 4.1). Each group of sites was classified into one of the following rankings:

1 Poor reef development - incipient reefs (Figure 4.2a);

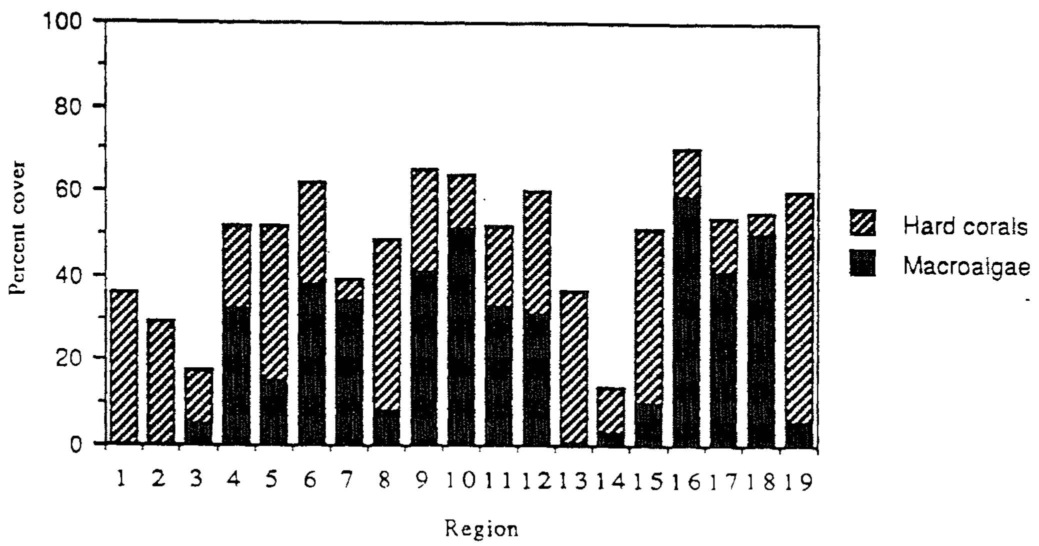
2 Intermediate reef development (Figure 4.2b);

3 Extensive reef development (Figure 4.2c).

Table 4.3. Island groups, their latitude, degree of reef development and pooled mean estimates for percent macroalgae, hard coral and soft coral cover. Where Reg. is region and Lat. is latitude.

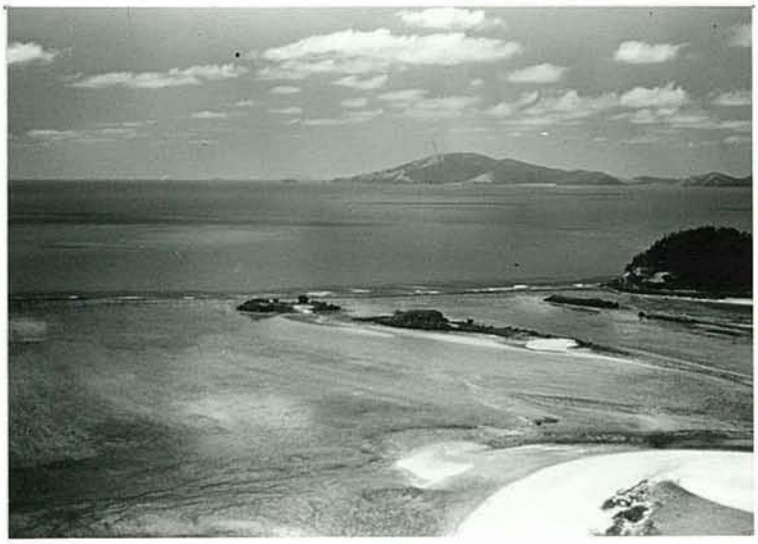
Reg.	Lat.	Island group	Reef type	Sites (n)	% Macroalgae	% Hard coral	% Soft coral
1	20°05'S	Hayman Is.	3	3	0	36.0	13.6
2	20°06'S	Langford region	3	3	0	29.0	21.0
3	20°10'S	Hook Island inlet	2	2	5	13.0	13.0
4	20°18'S	Molle Islands	2	5	32.4	19.6	3.6
5	20°20'S	Shute Harbour	3	4	15.0	37.0	16.3
6	20°22'S	Long Is.	1	3	37.6	23.6	4.7
7	20°18'S	Whitsunday Is.	2	4	34.3	4.8	8.3
8	20°21'S	Hamilton Is.	2	5	7.8	41.4	6.0
9	20°33'S	Thomas Is.	1	2	40.5	24.0	3.0
10	20°40'S	Goldsmith Is.	1	20	50.8	13.4	1.6
11	20°48'S	Carlisle/Brampton Islands	2	16	32.9	19.4	2.8
12	20°46'S	Cockermouth Is.	3	6	30.7	28.7	7.0
13	20°52'S	Scawfell Is.	3	12	0.7	36.3	24.6
14	21°01'S	Penrith Is.	3	9	3.3	11.1	12.2
15	21°20'S	Prudhoe Is.	2	2	10.0	41.0	18.5
16	21°36'S	Curlew Is.	1	3	58.6	11.0	4.0
17	21°30'S	Digby Is.	1	5	40.6	13.2	2.2
18	21°40'S	Percy Islands	2	10	49.6	5.3	1.2
19	23°10'S	Keppel Islands	3	8	5.7	54.3	0.3

Figure 4.1. Regional variation in hard coral and macroalgal cover. Regions are specified in Table 4.3. Cover estimates are pooled mean estimates derived from 20m line transects.



a.

b.



c.

Figure 4.2 Varying degrees of fringing reef development .

a Poor reef development, South Percy Island, Northumberland islands.

b Intermediate development, Prudhoe Island, Northumberland islands.

c Extensive development, Cockermouth Island, Cumberland islands.

There was a highly significant negative correlation between the amount of reef development and the amount of macroalgae present (Spearmans rank correlation 0.8157, $p < 0.001$).

4.3 Regional variation in benthic assemblages

The Whitsunday and Cumberland regions were dominated by acroporids, faviids, poritids and pocilloporids. In the Northumberland region however, Acroporidae and Dendrophylliidae became dominant; specifically the genera *Montipora* and *Turbinaria*. Acroporidae (mainly *Acropora* spp.) was most common in the Keppel Islands.

Whitsunday Islands

On a site by site basis, massive *Porites* spp. were the most abundant and frequently occurring corals in the Whitsunday Islands (90% of sites). Massive faviids were also widespread and abundant, especially *Favia* spp. (mean colony number per 200m^2 site = 23), *Favites* spp. (n = 22) and *Goniastrea* spp. (n = 21) species (Appendix 3). *Montipora* spp. was the 5th most abundant taxa, followed by *Goniopora* spp., (hydrocoral) *Millepora tenella*, *Seriatopora hystrix*, *Stylophora pistillata*, *Lobophyllia hemprichii* and *Porites cylindrica*. The soft corals *Sarcophyton* spp. were ubiquitous (in 80% of sites examined) although *Alcyonium* spp. and *Xenia* spp. had the highest mean abundance per site (n = 101 and 50).

Cumberland Islands

Macroalgae cover was exceptionally high on inner islands but decreased offshore. Coral cover and diversity increased in accordance with lack of macrophytes (Figure 4.1). Although the faviids, *Favia* spp. and *Favites* spp., occurred at most sites, fast growing corals were most prolific, caespitose *Acropora* spp., encrusting *Montipora* spp., *Goniopora* spp., *Pocillopora damicornis* and *Seriatopora hystrix* were also common throughout the region. *Sarcophyton* spp. were found at 62% of the sites and had the highest mean abundance (n = 15.9). *Xenia* spp., *Lobophytum* spp. and *Briareum* spp. were also frequent.

Northumberland Islands

Penrith Island was an anomaly due to its distance offshore (74km). Although strong winds and swell prevented quantitative data collection from windward slopes, qualitative searches indicated slopes were largely dominated by massive faviids on the shallow crest and arborescent *Acropora* spp. on the slopes. It was more akin to a mid-shelf reef in terms of composition and geomorphology (pers. obs.). In complete contrast the inner islands supported minimal arborescent or massive colonies. *Montipora* spp. and *Turbinaria* spp. corals were dominant (mean colony number per site, n = 35 and 21 respectively), followed by *Goniopora* spp. and encrusting *Porites* spp.. *Pocillopora damicornis* and *Goniastrea* spp. were well dispersed throughout the region although their abundance was low. Most common alcyonarian corals were *Capnella* spp., *Briareum* sp. and *Lobophytum* spp.

In comparison to reefs further north, the Northumberland Islands did not appear to support any particular species not found elsewhere, except for *Duccanopsammia axifuga*. However many species found north of 21°S were not found in the Northumberland Islands. These include: *Diploastrea heliopora, Astreopora* spp., *Leptoseris* spp., *Catalaphyllia jardinei, Plerogyra sinuosa, Physogyra lichtensteini,* some fungiids (*Heliofungia actiniformis, Herpolitha* sp., *Polyphyllia talpina), Pavona cactus, Millepora tenella.* Notably only 2 colonies of *Porites cylindrica* were recorded in the Northumberland Islands.

Keppel Islands

The Keppel Islands were dominated by *Acropora* spp.: *A. formosa, A. microphthalma* and *A. millepora*. Leeward reefs were shallow, supporting large monospecific stands of *Acropora* spp. and small colonies of *Pocillopora damicornis* and *Sarcophyton* spp. Exposed slopes lacked reef flats although coral diversity was high. Faviids, and the soft corals *Xenia* spp. and *Sinularia* spp. were more common on these slopes.

4.4 Environmental gradients

Some environmental factors, for example salinity, temperature and nutrient loading cause a measurable physiological response in a coral colony and can influence its spatial distribution (Yonge and Nicholls 1930). Others, such as water depth, have no direct effect on corals. Rather the consequences of depth (attenuation of ambient light and wave exposure) substantially influence the vertical distribution of coral types (Dustan 1982; Bradbury and Young 1981, respectively). The primary objective of this chapter was to compare sites with similar composition and abundance and assess whether distribution patterns are reflected in the environmental gradients. The gradients assessed were depth, exposure, (local or regional) location, tidal amplitude, distance from mainland, distance from the nearest river and shelf depth.

When assemblages were defined at the taxonomic level of scleractinian family no significant eigenvalues were evident (Table 4.4, Table 4.5). When taxa were distinguished at species-genus level the environmental variables depth, distance from mainland and exposure all had significant eigenvalues (from partial Canonical Correspondence Analysis, Table 4.6). A further two environmental variables, tide and island location, were significantly correlated with benthic composition when species-genus and colony size were assessed (Table 4.7). The latter results are used in chapter 5 where further analyses are undertaken on regional variation in colony size and morphology.

Table 4.4 Results of Monte Carlo test on the eigenvalues derived from a series of partial Canonical Correspondence Analyses using family level data for both hard and soft corals (with colony size classes identified). Environmental variables are outlined in chapter 3.2. Each environmental variable was tested independently via the Monte Carlo permutation test to determine whether the 1st eigenvalue was significant.

Depth	Unique	Region	Tide	D.main	D.river	Sh.dep	Expo
0.39	0.96	0.90	0.57	0.18	0.70	0.53	0.32
ns	ns	ns	ns	ns	ns	ns	ns

Table 4.5a Results of Monte Carlo test on the eigenvalues derived from a series of partial Canonical Correspondence Analyses using family level data for scleractinian corals and eight environmental variables (size classes amalgamated). **4.5b.** For scleractinian corals and soft corals. Specifics as in Table 4.4.

a.

Depth	Unique	Region	Tide	D.main	D.river	Sh.dep	Expo
0.13	0.84	0.64	0.27	0.28	0.56	0.99	0.61
ns	ns	ns	ns	ns	ns	ns	ns

b.

Depth	Unique	Region	Tide	D.main	D.river	Sh.dep	Expo
0.57	0.97	0.84	0.77	0.28	0.95	0.34	0.58
ns	ns	ns	ns	ns	ns	ns	ns

Table 4.6 Results of Monte Carlo eigenvalue tests from a series of partial Canonical Correspondence Analyses using the species-genus data (both hard and soft corals) and eight environmental variables. Specifics as in Table 4.4.

Depth	Unique	Region	Tide	D.main	D.river	Sh.dep.	Expo
0.03	0.26	0.29	0.09	0.02	0.42	0.18	0.04
*	ns	ns	ns	*	ns	ns	*

Table 4.7. Results of Monte Carlo eigenvalue tests from a series of partial Canonical Correspondence Analyses using the species-genus data (both hard and soft corals), colony size and eight environmental variables. Specifics as in Table 4.4.

Depth	Unique	Region	Tide	D.main	D.river	Sh.dep	Expo
0.05	0.05	0.24	0.03	0.02	0.31	0.10	0.03
*	*	ns	*	*	ns	ns	*

Distance from the mainland

Significant gradients in Table 4.6 were used in a full Canonical Correspondence Analyses. Distance from mainland was highly correlated with coral distribution patterns (Table 4.8). Most species were widespread, however some species were more prolific nearshore: *Goniastrea* spp., *Cyphastrea* spp., *Leptastrea* spp., *Diploastrea heliopora, Moseleya latistellata, Pseudosiderastrea tayamai, Astreopora* spp., *Herpolitha limax, Polyphyllia talpina, Alveopora* spp., *Goniopora* spp., *Podabacia crustacea, Porites cylindrica, Catalophyllia jardenei, Palauastrea ramosa, Seriatopora hystrix, Clavarina triangularis* (rare), *Turbinaria* spp., *Plerogyra sinuosa.* Few scleractinian species were restricted to offshore locations, although overall coral abundance increased offshore. Alcyonarian corals were more irregularly distributed although *Alcyonium* spp., was most common nearshore and *Efflatournaria* sp. were restricted to offshore locations.

Table 4.8. Canonical Correspondence Analysis using the species-genus dataset, both hard and soft corals (size classes pooled). The Monte Carlo permutation test indicated that the first eigenvalue was significantly different from random at $p < 0.01$.

	Axis 1	Axis 2	Axis 3	Axis 4
CCA Eigenvalue	0.280	0.110	0.051	0.510
Correlation Coefficient	0.856	0.624	0.656	0.000

Variable	Canonical Coefficient		Intraset Correlation Coefficient	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	-0.276	0.088	-0.759*	-0.153
Mainland	0.432	0.077	0.722*	0.157
Exposure	0.191	-0.332	0.322	-0.576*

Vertical distribution

Throughout the study area most scleractinian corals were found in distinct habitats, ie. had a negative correlation with depth (Table 4.8), although some species were found at all depths (Table 4.9). Variation in the vertical distribution of corals is thought to be mainly a consequence of aerial exposure, light availability and water movement (see Sheppard 1982 and Done 1983 for review).

On reef flats of the outer Whitsunday Islands faviids, small encrusting *Porites* spp. and stout *Acropora* spp. predominated (*Acropora millepora* and *Acropora aspera*). The inner island reef flats supported abundant macroalgae. Coral assemblages were mainly composed of *Montipora* spp., *Turbinaria* spp., *Porites* spp., *Pavona varians*, and several *Acropora millepora* and *Acropora valida*. Reef crests were often occupied by a small number of species which form large monospecific stands, especially massive *Porites* spp., *Acropora* spp. and *Sinularia* spp.. This zone extends to some 3m (LWD). The upper slope generally supports the highest diversity of corals and is classified as the *Acropora* spp./mussid zone. Below 6-10m, light levels are highly attenuated and slopes support mainly cryptic pectiniid, agariciid and caryophylliid corals.

Soft corals were evenly dispersed with depth although Nephthiid type corals (*Nephthea* spp., *Dendronephthea* spp. and *Stereonephthea* spp.) were mainly found on deep slopes. *Anthelia* spp. and *Efflatournaria* spp. were generally found at mid depth (0-3m), and *Sinularia* spp. and *Lobophytum* spp. on shallow slopes and crests.

Table 4.9. Vertical distribution of scleractinian species.

SHALLOW HABITAT > 0m LWD. *Goniastrea spp., Leptastrea spp. Porites* 'encrusting', *Acropora millepora, Acropora aspera, Astreopora spp., Coscinaraea spp., Pavona varians.*
0 - 3m LWD. *Platygyra spp., Plesiastrea versipora, Lobophyllia spp., Porites cylindrica, Porites 'massive', Porites annae, Alveopora spp., Goniopora spp., Acropora* 'tabulate', *Acropora formosa, Pocillopora damicornis, Seriatopora spp., Stylophora pistillata, Herpetoglossa simplex, Fungia spp., Polyphyllia talpina, Herpolitha limax, Plerogyra sinuosa, Cynarina lacrymalis, Pachyseris rugosa, Palauastrea ramosa, Duccanopsammia axifuga, Catalaphyllia jardinei, Clavarina triangularis,* (hydrocoral) *Millepora tenella.*
> 3m LWD. *Echinopora spp., Caulastrea spp., Diploastrea heliopora, Leptoria phrygia, Moseleya latistellata, Oxypora spp., Pachyseris speciosa, Pavona cactus, Leptoseris spp., , Echinophyllia spp., Euphyllia spp., Pectinia spp., Podabacia crustacea, Merulina ampliata, Acanthastrea spp., Archelia horrescens, Sandalolitha robusta, Physogyra lichtensteini, Scolymia spp., Pseudosiderastrea tayamai.*
ALL DEPTHS. *Favites spp., Favia spp., Oulophyllia crispa, Cyphastrea spp., Acropora palifera, Acropora valida, Symphyllia spp., Galaxea spp., Mycedium elephantotus, Hydnophora spp., Montipora spp., Turbinaria spp., Heliofungia actiniformis.*

Exposure

Degree of exposure (Appendix 4) was consistently correlated with benthic composition (Table 4.8) although more strongly weighted toward soft than hard corals (Table 4.10a and 4.10b). At exposed sites predominant species were fast growing corals with opportunistic life-history strategies (after Jackson and Hughes 1985): *Acropora humilis, Porites cylindrica, Porites annae, Stylophora pistillata, Pocillopora damicornis, Seriatopora hystrix,* (hydrocoral) *Millepora tenella, Acropora* 'tabulate', and the soft corals *Sinularia* spp., *Efflatournaria* sp., *Alcyonium* spp.

Table 4.10a Canonical Correspondence Analysis on species-genus data and environmental variables, for hard corals only. Monte Carlo permutation test indicated that the first and second canonical axes were significantly different from random at $p < 0.01$.

	Axis 1	Axis 2	Axis 3	Axis 4
CCA Eigenvalue	0.207	0.08	0.062	0.457
Correlation Coefficient	0.764	0.608	0.521	0.000

Variable	Canonical Coefficient		Intraset Correlation Coefficient	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	-0.277	0.255	-0.685*	0.704
Mainland	0.360	0.190	0.890*	0.526
Exposure	-0.127	-0.065	-0.320	-0.184

Table 4.10b. Canonical Correspondence Analysis of species-genus data and environmental variables, for soft corals only. Monte Carlo permutation test indicated that the first and second canonical axes were significantly different from random at $p < 0.01$.

	Axis 1	Axis 2	Axis 3	Axis 4
CCA Eigenvalue	0.374	0.065	0.029	0.488
Correlation Coefficient	0.786	0.427	0.336	0.000

Variable	Canonical Coefficient		Intraset Correlation Coefficient	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	-0.310	-0.118	-0.482	-0.200
Mainland	0.403	0.084	0.629*	0.143
Exposure	0.397	-0.230	0.677*	-0.428

Nutrient concentrations

The results outlined below are part of a collaborative study undertaken with S. Blake, who collected the nutrient and suspended sediment data. A north-south gradient was identified in the Whitsunday region for NO_3, NH_4 and $Si(OH)_4$ concentrations (Chapter 2.7, 3.2). These nutrient species significantly declined away from the Proserpine/O'Connell Rivers in the wet season. However, distribution and abundance of coral assemblages did not correlate with any nutrient or suspended sediment concentrations (Table 4.11, Table 4.12). Oceanographic parameters used in the correspondence analyses were mean values collected over 9 sampling periods (Appendix 9). Similar results were obtained when seasonal concentrations (wet and dry) were utilised.

Table 4.11 Results of Monte Carlo eigenvalue tests from a series of partial Canonical Correspondence Analyses using 16 sites (including colony size). The concentration of six nutrient concentrations (and all nitrogen species combined) were tested (Appendix 9). NO_2 is nitrite, PO_4 is phosphate, NH_4 is ammonia, NO_3 is nitrate, $Si(OH)_4$ is silicate, SS is suspended solids.

NO_2	PO_4	NH_4	NO_3	$SI(OH)_4$	SS	NO_2*NH_4 *NO_3
.98	0.53	0.62	0.79	0.99	0.97	0.97
ns	ns	ns	ns	ns	ns	ns

Table 4.12 Results of Monte Carlo eigenvalue tests from a series of partial Canonical Correspondence Analyses using 16 sites and species composition data (size classess pooled).

NO_2	PO_4	NH_4	NO_3	$SI(OH)_4$	SS	NO_2*NH_4 *NO_3
.95	0.57	0.54	0.79	0.91	0.38	0.40
ns	ns	ns	ns	ns	ns	ns

4.5 Recurrent coral assemblages

Quantitative analysis

In order to assess the spatial relation of sites with similar (species-genus) composition an analysis was sought which explained a considerable proportion of the overall variance. The correspondence analysis in Table 4.8 was used because the first and forth ordination axes explained 79% of the overall variance (axis 1 and 4, 0.28 + 0.51 = 79%). The first (constrained) and fourth (unconstrained) eigenvalues were simultaneously plotted. These results differ considerably from preliminary analyses using more conventional ordination techniques (eg. Principal Component Analysis), where only 28-31% of the variance was explained.

The sites fall into groups which have been enclosed by subjective boundaries based on proximity, they have been labelled A to O (Figure 4.3). Rarely did all the sites of any particular island group together, except those on Penrith and Hayman Island. Figure 4.4 is a superimposed version of Figure 4.3, illustrating site clusters and dominant species-genera. The position of each taxon, however, is not restricted to each (exact) 2-D location, rather it illustrates it's relative position in terms of frequency of occurrence and abundance.

Group A sites were assemblages dominated by macroalgae (Table 4.11; Figure 4.5a,b,c)[1], *Montipora* spp., *Turbinaria* spp., encrusting *Porites* spp. and (less common) encrusting *Acropora* spp., *Alveopora* spp. and the soft coral *Briareum* sp.. These assemblages were located on the inner islands of the Northumberland group, and less frequently on upper slopes of the Whitsunday and Cumberland Islands (Figure 4.7).

Group B was similar to A although not dominated as much by macrophytes. Caespitose *Acropora* spp. colonies and agariciids were common (Figure 4.5d). These assemblages were widespread throughout the study area.

Group C were assemblages composed of massive *Porites* spp. and *Goniopora* spp. (Figure 4.5e). These corals dominated the Whitsunday Islands and were found on upper and lower slopes of the Cumberland and Northumberland Islands respectively (Figure 4.7). Group D was similar to C, although arborescent corals were found in association with poritids (Figure 4.5f). These assemblages were exclusive to the Whitsunday and Cumberland Islands.

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[1] Figures 5.5 and 5.6 are photos of each assemblage which are explained more fully in Table 4.11.

The degree of regional exposure decreases from right to left in Figure 4.3 and 4.4 (this type of exposure is different than the [local] exposure variable used in the previous analyses). The most exposed assemblages were found on Penrith Island reef flat, assemblage L. Assemblage E and J were crest and upper slope assemblages dominated by *Acropora* spp. and *Pocillopora damicornis* (Figure 4.5g, Figure 4.6c). Assemblages F and G were generally depauperate in composition, they were common on inner Cumberland Islands (Goldsmith and Carlisle, Figure 4.5h and 4.6a). The reefs supporting these assemblages were poorly developed (incipient). Faviid and *Acropora* spp. corals dominated assemblage H. This is a very general assemblage found on slopes of the Keppel, Cumberland and Whitsunday Islands.

Transient or interchangeable assemblages are evident near the centre of Figure 4.4 (G,H,I,J and K), and stable or predictable assemblages are most evident near the periphery. Diversity tends to be high in groups M, N and O, and low in groups A,B and C, indicating that diversity increases from top to bottom in Figure 4.4. Notably surveys were restricted to < 10m, due to extensive bottom time (SCUBA) required to collect data. However, deep habitats were consistently observed to support foliose and encrusting pectiniids and agariciids (assemblage P). In overview, these findings indicate that distinct or extreme environments (habitat or region) may promote the existence of characteristic species groups, and away from extremes species distribution patterns become unpredictable.

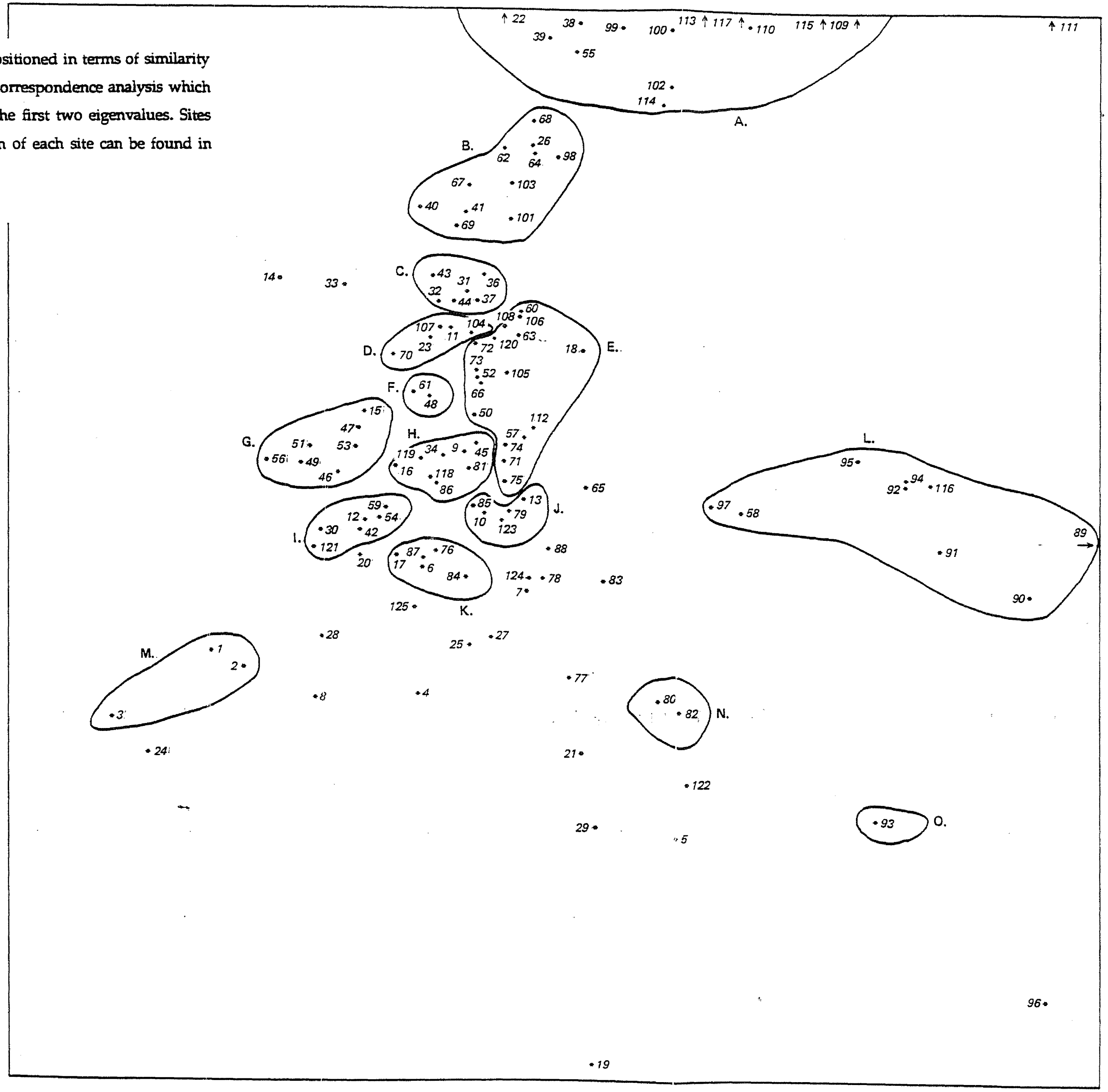


Figure 4.3. Schematic representation of all 125 study sites positioned in terms of similarity in composition and abundance of hard and soft corals. The correspondence analysis which produced this figure accounted for 79% of the variance in the first two eigenvalues. Sites have been grouped into 15 clusters labelled A to O (location of each site can be found in Appendix 1).

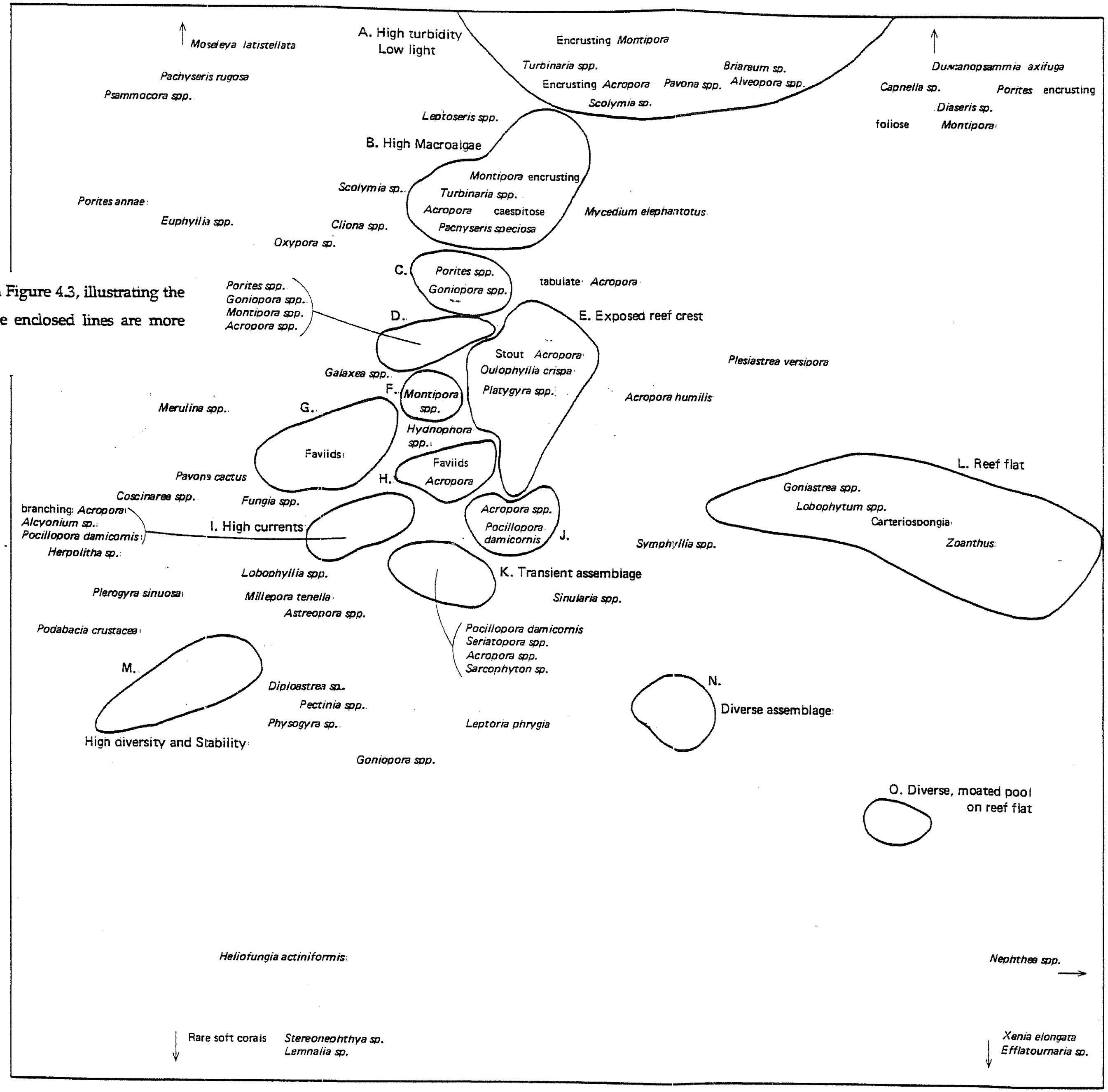
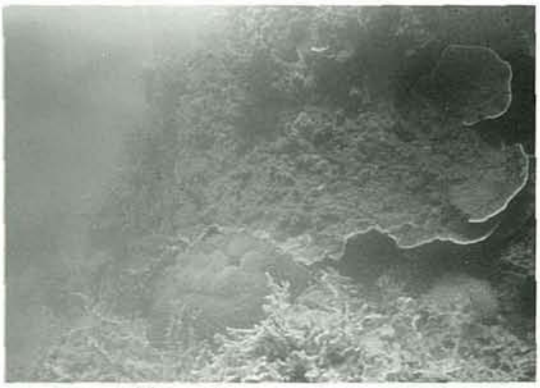


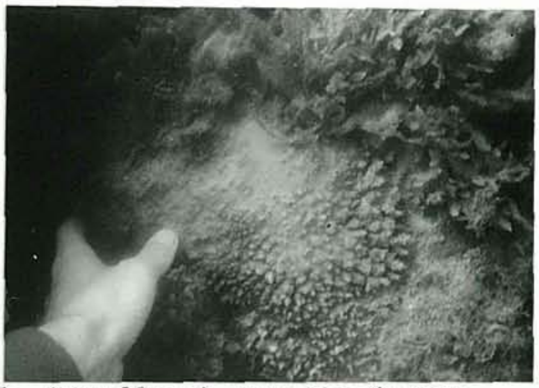
Figure 4.4. Schematic overlay of site groups labelled A to O from Figure 4.3, illustrating the relative position of major coral taxa represented. Corals outside enclosed lines are more loosely associated with the groups.

Table 4.11. Assemblage groups defined by canonical correspondence analysis (see Figures 4.5 and 4.6 for photos).

	Species composition	Description and general location
A	*Montipora* spp., *Turbinaria* spp., *Briareum* sp., *Pavona venosa*, encrusting *Acropora* spp. and *Porites* spp. (*Sargassum* spp., *Padina* spp.).	Incipient reef slopes, Northumberland Islands
B	*Montipora* spp., *Turbinaria* spp., encrusting *Porites* spp., caespitose *Acropora* spp., *Pachyseris speciosa*.	Upper slope assemblage - Whitsunday and inner Cumberland Islands
C	Massive *Porites* spp., (*P.lutea*, *P.mayeri*, *P.lobata*) and *Goniopora* spp. (*Sinularia* spp.)	Poritidae: Widespread, leeward and windward
D	*Porites* spp., *Goniopora* spp., *Montipora* spp., *Acropora* spp.	Poritidae and Acroporidae: Leeward assemblage
E	*Acropora* spp. (*A.palifera*, *A.humilis*, *A.millepora*, *A.secale*), *Oulophyllia crispa*, *Platygyra* spp.	Exposed reef crest
F	Foliose *Montipora* spp., *Acropora* spp.	Acroporidae: NW slope, Cumberland Islands
G	*Favia* spp., *Favites* spp., *Cyphastrea* spp., *Leptastrea* spp., *Echinopora* spp., *Galaxea astreata*, *Galaxea fascicularis*, *Fungia* spp., *Merulina ampliata*.	Faviidae, Oculinidae and Fungiidae: Depauperate assemblage, leeward Whitsunday and Cumberland Islands
H	Faviids and *Acropora* spp.	Faviidae and Acroporidae, Widespread
I	*Millepora tenella*, *Alcyonium* spp., *Pocillopora damicornis*, *Stylophora pistillata*.	Pocilloporidae, Alcyonarian and Hydrocorals: High current area (pers. obs.)
J	Pocilloporidae, *Acropora* spp.	Fast growing corals, widespread
K	*Pocillopora damicornis*, *Seriatopora hystrix*, *Acropora valida*, *Sarcophyton* sp., *Sinularia* spp.	Fast growing, transient, early successional corals (pers. obs.)
L	*Goniastrea* spp., *Lobophytum* spp., Carteriospongia, *Zoanthus* sp., *Acropora aspera*.	Reef flat - Penrith Island, Percy Island
M	*Porites annae*, *Porites lutea* *Porites mayeri*	Hayman Island - Poritidae
N	*Acropora* spp.	Scawfell Island- Acroporidae
O	Outlier: Diverse assemblage	Penrith Island, moated pool.
P	Pectiniid and Agariciid corals.	Deep slopes below 10m LWD.

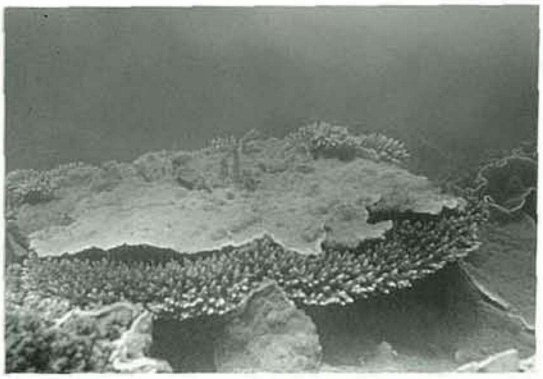


a. Assemblage A.



b. Assemblage A, encrusting *Acropora*.

c. Assemblage A, encrusting *Porites*.



d. Assemblage B, *Montipora* and *Acropora*.

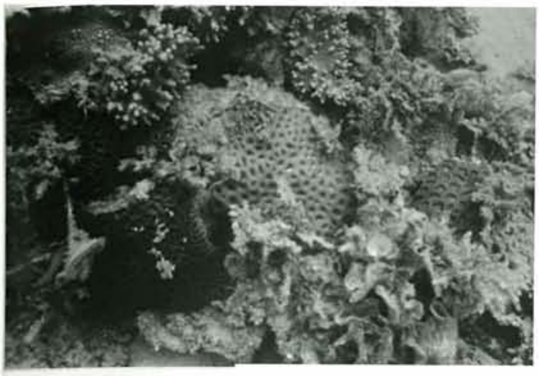
e. Assemblage C, massive *Porites*.

f. Assemblage D, *Porites* and *Acropora*.

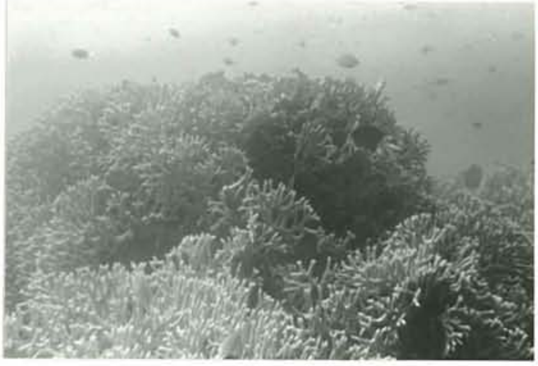
g. Assemblage E, outer island reef crest.

h. Assemblage F, *Montipora* and *Acropora*.

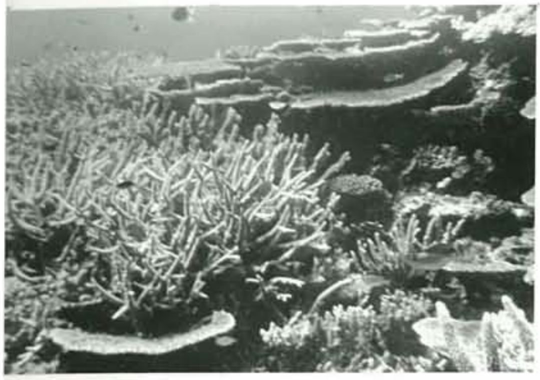
Figure 4.5 Assemblage groups defined in Table 4.11.



a. Assemblage G.



b. Assemblage I, *Millepora* colonies.

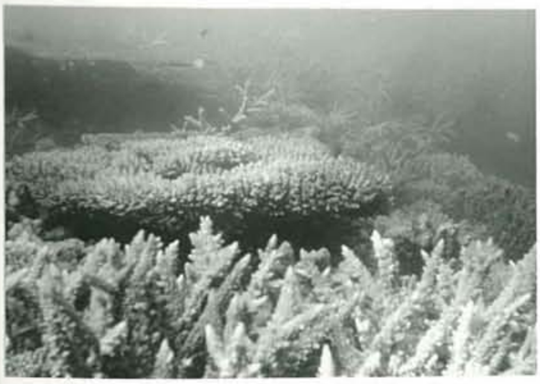


c. Assemblage J, fast growing corals.

d. Assemblage K, transient assemblage.

e. Assemblage L, reef flat *Goniastrea.*

f. Assemblage L, Carteriospongia.

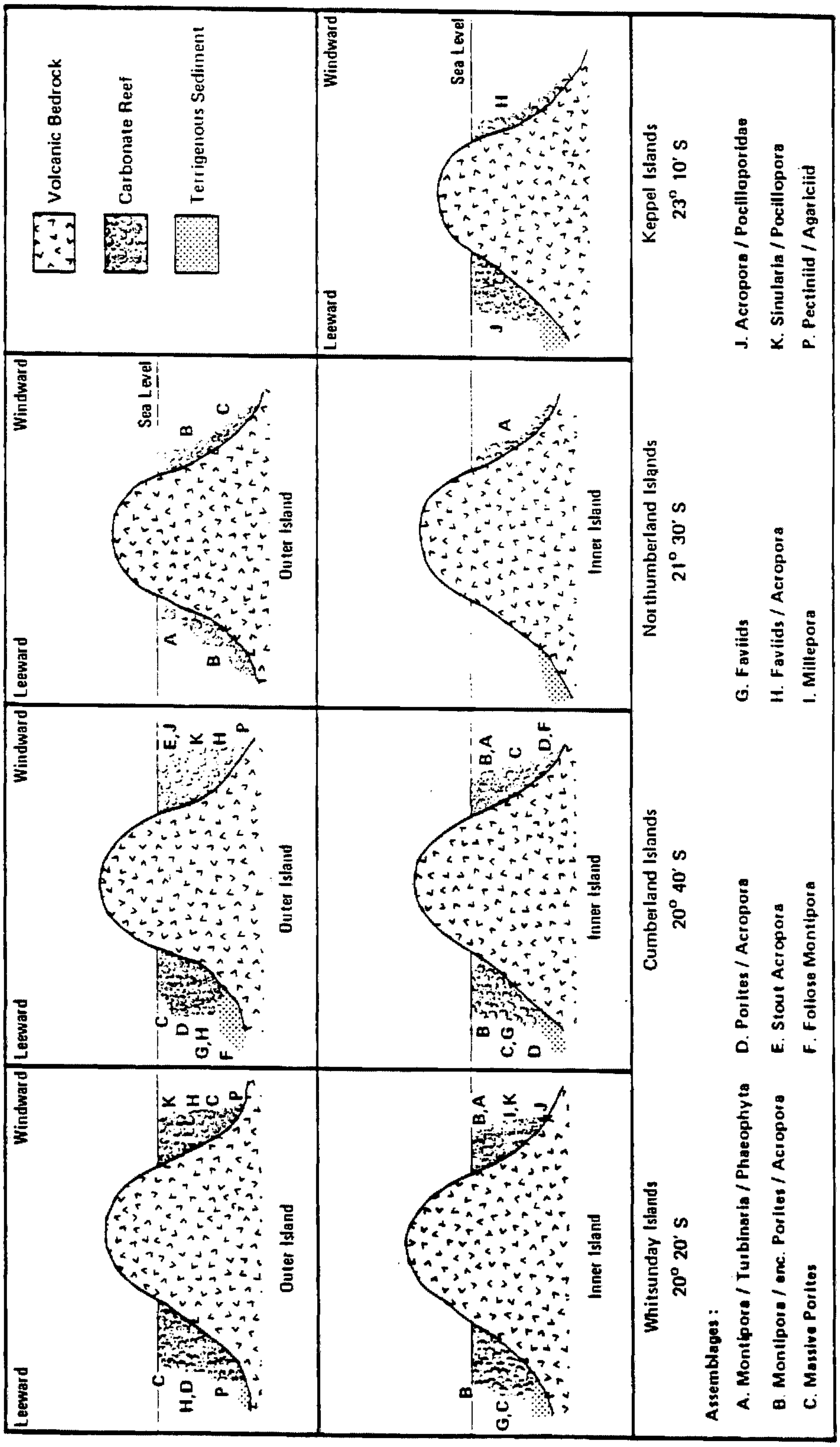


g. Assemblage N, Scawfell Island *Acropora.*

h. Assemblage P, deep water Agariciids.

Figure 4.6 Assemblage groups defined in Table 4.11.

Figure 4.7 Spatial distribution of major coral assemblages in the Whitsunday, Cumberland, Northumberland and Keppel Islands.



4.6 Discussion

Regional variation

This study suggests that the composition and dominance of benthic assemblages on fringing reefs varies considerably between regions: *Porites* spp. and faviids dominated the Whitsunday Islands; Acroporidae and Pocilloporidae the Cumberland Islands; *Montipora/Turbinaria* assemblages the Northumberland Islands; and *Acropora* spp. the Keppel Islands. These contemporary findings are consistent with results from the geological drilling programme, which show considerable geographic variation in reef composition (Keypas 1992).

Environmental correlates

Depth, and distance from the mainland significantly correlated with coral composition. Vertical distribution patterns appeared to be largely a function of tolerance to aerial exposure and regional and local light conditions. Faviids and *Porites* spp. were most common on reef flats and upper slopes. Acroporids and mussids dominated mid slopes and agariciids and pectiniids the lower slopes. The four major zones described for the Whitsunday Islands were recognised in the Cumberland Islands, although coral cover was generally lower on reef crest assemblages. In the Northumberland Islands, reef crest assemblages were completely absent and corals found at depth (8-10m) in the Whitsunday and Cumberland Islands were found in 3-4m in the Northumberland Islands. This finding suggests a reduction in light transmission and a narrowing of the photic zone. Zones generally expanded further offshore.

The degree of shelter by bayheads (exposure variable) also correlated with distribution and abundance patterns. The incidence of fast growing opportunistic corals in exposed sites appears to be a consequence of intermittent disturbance through lack of shelter by a headland. No anomalous temperature gradients were observed through the 1988-1991 period for the Northumberland Islands (NOAA AVHRR satellite imagery, Kleypas 1991), refuting the possibility that differences in temperature may reduce reef development at 21^0S. Furthermore, the size of an island, *per se*, does not appear to limit reef development, as some very small islands in Shute Harbour (Whitsunday Islands) support large reef flats and large islands in the Cumberland group (Goldsmith and Thomas) support small reefs.

Nutrient and suspended sediment concentrations did not significantly correlate with the coral assemblages based on 16 sites analysed in the Whitsunday Islands. The nutrient concentrations among these islands are higher than those recorded anywhere else on the Great Barrier Reef (for unpollluted locations) (S. Blake, pers. com.). However, only dissolved nutrients were measured in this study, which does not account for nutrients stored in organic or particulate form, nor those stored in the sediment. Understanding quantitative fluxes between these forms and the sediment is necessary in order to assess changes in productivity and assimilation of the associated benthos.

Coral communities

The 16 recurrent assemblages described were largely a function of regional and local constraints. Regional constraints were most obvious for the Northumberland Islands, supporting relatively low coral diversity. *Montipora* spp. and *Turbinaria* spp. dominated these reefs. Diversity increased towards the Cumberland and Whitsunday Islands. There was a distinct lack of major framework builders - large massive and branching corals - in the Northumberland Islands. This is examined further in Chapter 5. (Notably, some soft corals, more specifically *Sinularia* spp., also considerably add to reef framework. These corals form hard spicule rock [pers. obs.] which can dominate upper reef crests and slopes. For this reason alcyonarian and scleractinian corals were often analysed simultaneously).

Stout coral morphologies dominated outer island reef crests (assemblages E), induced by wave activity. Species unable to change growth form were not found in these habitats. Dominance of macroalgae and associated epiphytes also restricted the growth and survival of coral colonies on reef flats and upper slopes (assemblage B). Few coral species occupied the macroalgae understorey (faviids, small *Porites* spp., *Montipora* spp. and occasionally *Acropora* spp.), presumably due to consistently low light levels and abrasion. Plasticity and resilience of these corals in a variety of habitats appears to be a major consequence of their ubiquity both on a local and regional scale.

The highly significant negative correlation between the amount of reef development and abundance of macroalgae suggests that consistently high algal biomass may suppress net reef growth. Similar findings were reported by Hallock and Schlager (1986), who assessed ancient reefs and discussed transformations towards depauperate coral assemblages and complete reef demise in the presence of abundant macroalgae.

Away from extreme conditions (Whitsunday Islands) diverse assemblages were recorded with colonies often larger than 2m diameter. Colonization may be unrestricted and colony growth indeterminant in these environments. However in harsh regions (Northumberland Islands), determinant growth may occur and environments appear more select in terms of which species survive.

Community theory

Coral distribution patterns are consistent with theoretical concepts described by MacArthur and Wilson (1967) and Gauch and Whittaker (1972), where abundance is a construct of major and minor genera (and families) varying as a consequence of regional circumstances. Major groups vary regularly and in accord with habitat and some environmental gradients. Whereas minor groups vary more or less irregularly. Major scleractinian groups are *Acropora* spp., *Montipora* spp., poritids, faviids, pocilloporids, dendrophylliids and agariciids. Alcyonarian corals include *Sinularia* spp., *Lobophytum* spp., *Sarcophyton* spp., *Briareum* spp., *Alcyonium* spp. and *Xenia* spp.. Minor groups include merulinids, oculinids, pectiniids, mussids, fungiids, and caryophylliids.

Since similar habitats and regional conditions may recur in space and time, successional processes may be repeated in forced or constrained environments and may cause similar taxa to dominate or be associated. In relation to Fagerstrom's (1987) definition of coral communities mentioned in the introduction of this chapter (communities have characteristic composition, are able to be objectively mapped and are coincident with environmental gradients), it appears that only some assemblages fall into this rigorous categorisation and only when environments are extreme. Other coral assemblages are more diffuse and transient and are regulated by apparently stochastic events.

Driving processes

Distribution patterns have also been defined across the central Great Barrier Reef (GBR) for hard corals (Done 1982) and soft corals (Dinesen 1983). Done described 4 assemblage types from 2 inshore reefs. Many assemblages described on mid-shelf reefs in the central GBR were similar to those described in this chapter (assemblage D, E, H, J, K). Done's study, which incidentally covered the same geographic area as the present study, 6000km^2, suggested cross shelf isolation and larval availability was the process driving cross-shelf variability. This may be correct for patterns across the GBR, however, along the GBR connectivity is evident (Bode and Stark 1983; Dight *et al* 1988). Since distribution patterns vary considerably along the inshore region, a scenario which Done refuted may be more appropriate in explaining the distribution patterns observed along fringing reefs in the southern GBR "The larval pool is thoroughly mixed and recruits to a given reef include many species not represented as adults. Differences between reefs are determined by a differential post-settlement survival in favour of species already present" (Done 1982). Whether the patterns are determined by pre or post-settlement selection is unclear, however they appear to be a consequence of regional conditions.

CHAPTER 5. REGIONAL VARIATION IN CORAL ABUNDANCE, SIZE AND MORPHOLOGY.

5.1 Introduction

Holocene reef development varies between geographic regions and is considerably limited in the Northumberland Islands at 21°S (Hopley 1982; Hopley *et al* 1989). The growth potential of a coral reef may be restricted by the capacity of the reef to support abundant corals. In order to determine whether the Whitsunday and the Northumberland Islands supported, on average, the same number of coral colonies, of the same size structure, 10 sites in each region were compared. Reef growth may also be restricted by the lack of framework builders - large massive and arborescent colonies (Davies 1983). Comparative analyses were undertaken to determine whether the regions differed in the abundance of massive and branching colonies. A regional comparison was also made for fast-growing scleractinian corals and hydrozoans (*Millepora* spp.), and for total alcyonarian corals (Table 5.1). Notably, minimal overlap occurs in the categorisation of massive and branching corals, however corals can be both branching and fast-growing.

Table 5.1. Morphological groups used in comparative analyses, exclusions within each family are listed separately in tables to follow. References identify morphological criteria.

	MASSIVE CORALS	ARBORESCENT CORALS	FAST GROWING CORALS
SPECIES	Faviidae, Poritidae, Agariciidae, *Galaxea* spp., Mussidae, *Pectinia* spp., Siderastreidae, Caryophylliidae.	*Acropora* spp., *Porites cylindrica*, *Porites nigrescens*, Pocilloporidae, *Millepora tenella*.	*Acropora* spp., *Montipora* spp., Pocilloporidae, *Millepora tenella*, *Turbinaria* spp.
REFERENCES	Isdale 1981, Done 1982, pers. obs.	Pers. obs.	Oliver *et al* 1983, Simpson 1988, pers. obs.

5.2 Coral abundance and morphology

There was no significant difference in overall coral abundance between the two regions (Table 5.2c). However, a comparison of means (*a posteriori* Tukeys test) indicated that the Whitsunday Islands supported more corals than the Northumberland Islands (Whitsundays mean = 480.0, SE 95.64, and Northumberland mean = 288.0, SE 47.65). Small corals (between 1-10cm) were considerably more abundant in the Whitsunday Islands (Figure 5.1). The abundance of fast-growing corals did not differ significantly between regions (Table 5.3c), although the Northumberland Islands did support, on average (Tukey test), more fast growing corals (Northumberlands mean = 193.5, SE 41.86 and the Whitsundays mean = 98.60, SE 24.99). Coral colonies between 11-50 cm in size were most abundant, and considerably more common in the Northumberland Islands (Figure 5.2).

In contrast, the Whitsunday Islands supported significantly ($p = 0.016$) more massive colonies than the Northumberland Islands (Table 5.4c). The abundance of small colonies (1-10cm and 11-50cm) was considerably greater in the Whitsunday Islands (Figure 5.3). The Whitsunday Islands also supported significantly ($p = 0.026$) more arborescent corals than the Northumberland Islands (Table 5.5c). Colony abundance was greater for all size classes, especially colonies between 11-50cm (Figure 5.4). The abundance of alcyonarian corals did not significantly differ between the two regions (Table 5.6c), although considerably more small corals (1-10 cm) were recorded in the Whitsunday Islands, especially at sites 2 and 5 (Table 5.6a, Figure 5.5).

Table 5.2a. Total abundance of all corals within sites for the Whitsunday islands.

SITE	2	5	11	12	13	14	15	20	23	26
1-10cm	747	331	94	13	38	155	12	273	57	38
11-50cm	331	419	310	265	93	448	294	199	210	116
51-100cm	63	15	9	70	2	19	34	24	69	8
101-300cm	9	0	4	12	2	2	4	9	0	9
> 300cm	0	0	0	0	0	0	1	0	0	0
TOTAL	1150	765	417	360	135	624	345	505	336	171

Table 5.2b. Total abundance of all corals within sites for the Northumberland islands.

SITE	98	99	100	101	102	103	104	105	106	107
1-10cm	14	130	116	0	120	30	29	4	17	1
11-50cm	65	203	334	146	176	386	293	161	300	35
51-100cm	4	29	23	9	43	32	29	5	81	23
101-300cm	0	0	1	0	0	0	1	6	15	17
> 300cm	0	0	0	0	0	0	0	0	0	2
TOTAL	83	362	474	155	339	448	352	176	413	78

Table 5.2c. Results of t-test (for unequal variances, see chapter 3.6) which tested the null hypothesis that the Whitsunday and Northumberland islands supported the same number of corals. The approximate Wilk-Shapiro statistic, which assessed whether the distribution was normal, was 0.8567 (ie. normal).

T	DF	P	**Significance**
1.80	13.2	0.094	NS

Figure 5.1. Total coral abundance and size in the Whitsunday and Northumberland Islands. Error bars are 1 standard deviation.

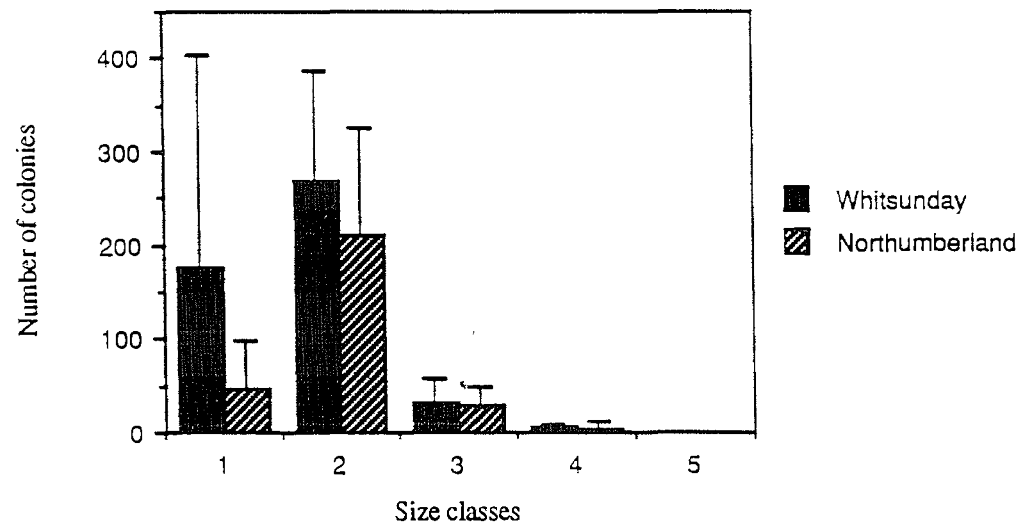


Table 5.3a. Total abundance of fast growing corals (*Acropora spp., Montipora* spp., Pocilloporidae, *Millepora spp., Turbinaria spp.*) in the Whitsunday region.

SITE	2	5	11	12	13	14	15	20	23	26
1-10cm	55	30	21	11	5	5	1	65	4	22
11-50cm	59	87	60	208	9	45	27	69	58	30
51-100cm	9	2	14	72	1	2	3	0	1	0
> 101cm	1	0	8	0	2	0	0	0	0	0
TOTAL	124	119	103	291	17	52	31	134	63	52

Table 5.3b. Total abundance of fast growing species in the Northumberland region.

SITE	98	99	100	101	102	103	104	105	106	107
1-10cm	7	123	106	0	20	41	14	0	10	1
11-50cm	50	154	269	68	130	303	112	66	152	27
51-100cm	1	28	12	7	34	38	22	5	86	16
> 101cm	0	0	0	0	0	0	0	6	16	11
TOTAL	58	305	387	75	184	382	148	77	264	55

Table 5.3c. Results of t-test which tested the null hypothesis that the Whitsunday and Northumberland islands supported the same number of fast growing corals. The approximate Wilk-Shapiro statistic, which assessed whether the distribution was normal, was 0.8621 (ie. normal).

T	DF	P	Significance
-1.95	14.7	0.071	NS

Figure 5.2. Abundance and size of fast-growing coral species in the Whitsunday and Northumberland Islands. Error bars are 1 standard deviation.

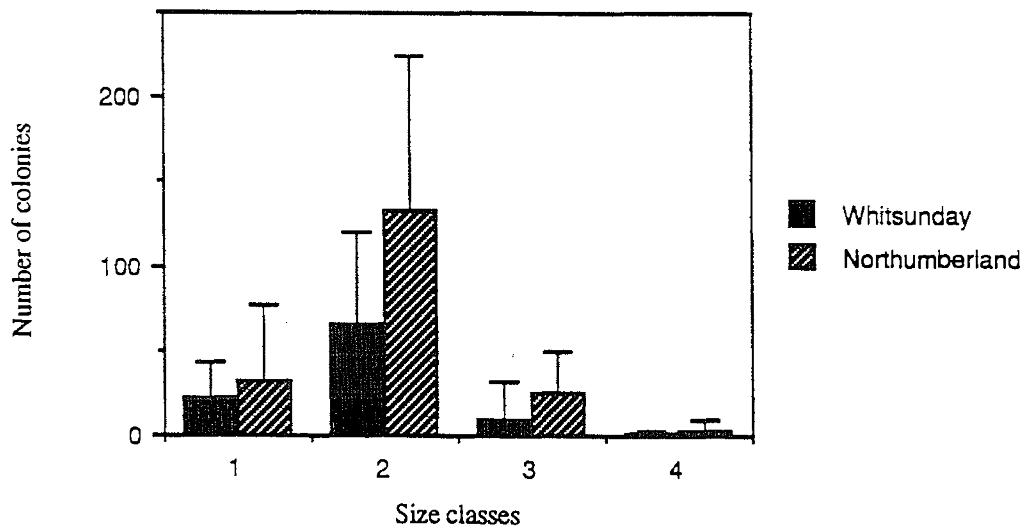


Table 5.4a. Total abundance of 'massive' colonies (Faviidae, Poritidae, Agariciidae, *Galaxea spp.*, Mussidae, *Pectinia spp.*, Siderastreidae, Caryophylliidae (excluding *Echinopora lamellosa, Porites cylindrica, Porites nigrescens, Pavona cactus, Hydnophora rigida, Echinophyllia* spp. and *Oxypora* spp.) within select sites in the Whitsunday region.

SITE	2	5	11	12	13	14	15	20	23	26
1-10cm	121	40	34	3	9	110	2	184	20	2
11-50cm	221	210	133	85	69	355	213	141	110	21
51-100cm	54	10	0	1	1	6	19	24	66	1
101-300cm	18	0	0	0	0	0	4	9	0	0
> 300cm	0	0	0	0	0	0	1	0	0	0
TOTAL	414	260	167	89	79	471	239	358	196	24

Table 5.4b. 'Massive' colonies within the Northumberland region.

SITE	98	99	100	101	102	103	104	105	106	107
1-10cm	5	19	0	0	5	2	5	0	8	0
11-50cm	21	56	54	46	44	151	155	82	159	9
51-100cm	1	4	5	1	6	7	7	2	6	4
101-300cm	0	0	0	0	6	0	1	0	1	1
> 300cm	0	0	0	0	0	0	0	0	0	0
TOTAL	27	79	59	47	61	160	168	84	174	14

Table 5.4c. Results of t-test which tested the null hypothesis that the Whitsunday and Northumberland islands supported the same number of massive corals. The approximate Wilk-Shapiro statistic, which assessed whether the distribution was normal, was 0.8824 (ie. normal).

T	DF	P	Significance
2.81	11.8	0.016	*

Figure 5.3. Total abundance and size of massive coral species in the Whitsunday and Northumberland Islands. Error bars signify 1 standard deviation.

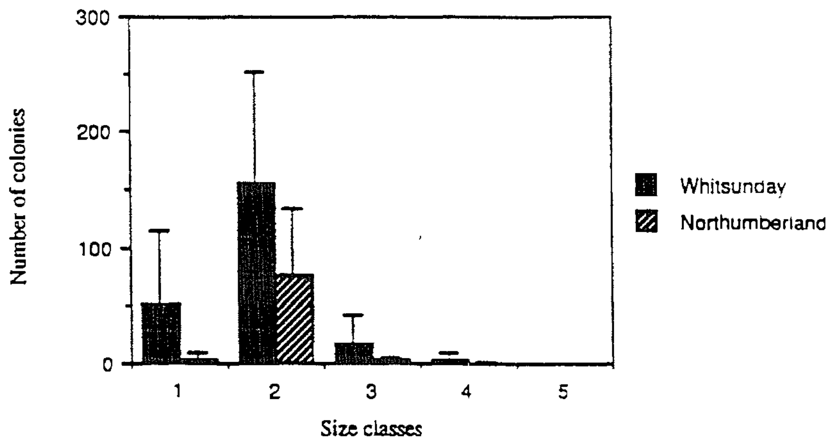


Table 5.5a. Total abundance of arborescent hard corals (*Acropora spp., Porites cylindrica, Porites nigrescens, Pocillopora damicornis, Seriatopora hystrix, Stylophora pistillata, Palauastrea ramosa, Millepora tenella*) in the Whitsunday region.

SITE	2	5	11	12	13	14	15	20	23	26
1-10cm	34	22	22	9	3	0	0	31	3	8
11-50cm	52	61	95	146	3	21	6	138	34	27
51-100cm	27	6	2	63	0	0	1	12	1	0
> 101cm	5	0	0	12	0	0	0	9	0	0
TOTAL	118	89	119	230	6	21	7	190	38	35

Table 5.5b. Total abundance of arborescent hard corals in the Northumberland region.

SITE	98	99	100	101	102	103	104	105	106	107
1-10cm	0	7	0	0	9	0	1	0	1	1
11-50cm	5	14	5	5	14	7	15	18	32	12
51-100cm	0	0	1	1	2	3	1	1	6	8
> 101cm	0	0	0	0	0	0	0	6	3	11
TOTAL	5	21	6	6	25	10	17	25	42	32

Table 5.5c. Results of t-test which tested the null hypothesis that the Whitsunday and Northumberland islands supported the same number of arborescent corals. The approximate Wilk-Shapiro statistic, which assessed whether the distribution was normal, was 0.7258 (ie. normal).

T	DF	P	Significance
2.64	9.5	0.026	*

Figure 5.4. Total abundance and size of arborescent coral species in the Whitsunday and Northumberland Islands. Error bars signify 1 standard deviation.

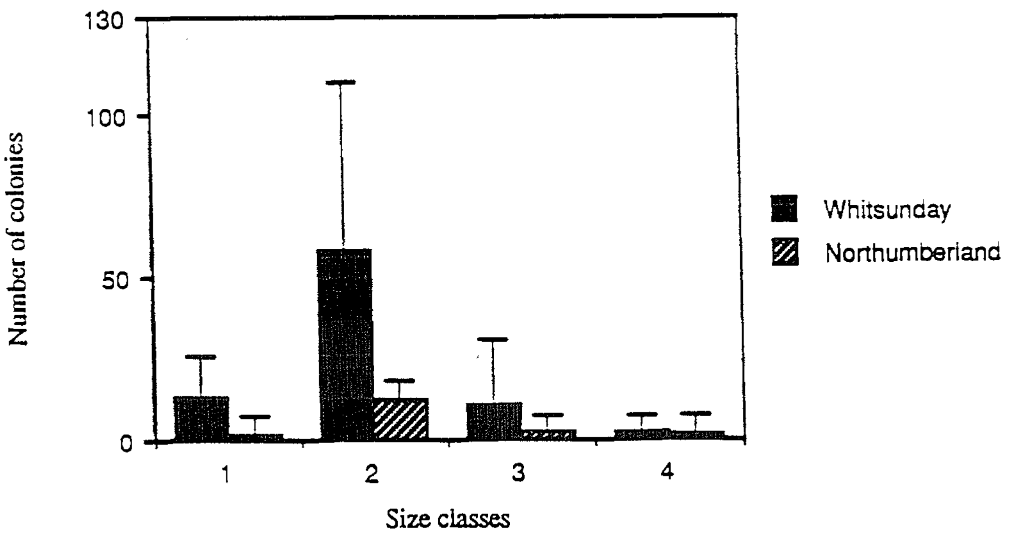


Table 5.6a. Total abundance of soft corals within the Whitsunday region.

SITE	2	5	11	12	13	14	15	20	23	26
1-10cm	574	267	5	0	24	40	7	38	33	21
11-50cm	42	131	13	0	14	50	51	3	47	59
51-100cm	0	0	0	0	0	11	9	0	1	5
> 100cm	0	0	0	0	0	2	0	0	0	9
TOTAL	616	398	18	0	38	103	67	41	81	94

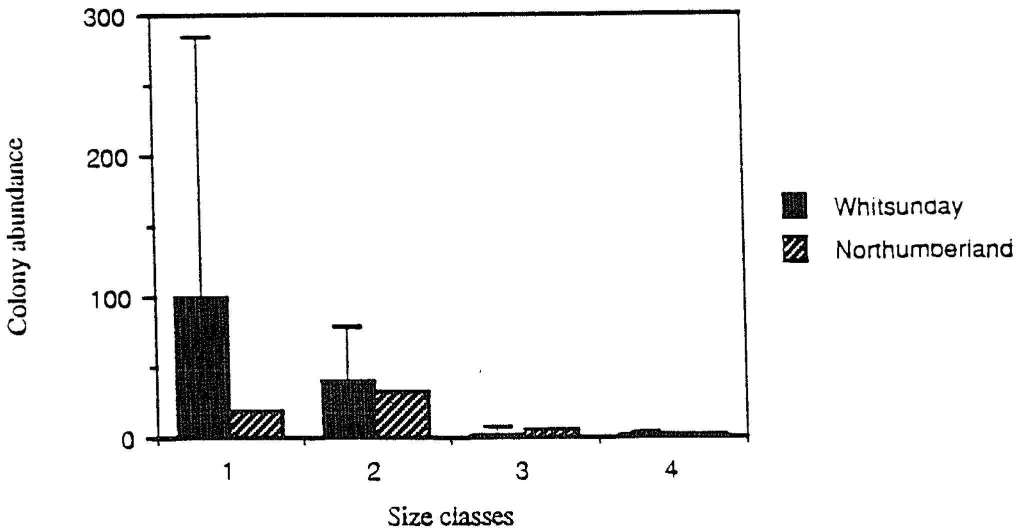
Table 5.6b. Total abundance of soft corals in the Northumberland region.

SITE	98	99	100	101	102	103	104	105	106	107
1-10cm	2	39	65	0	66	7	13	3	1	0
11-50cm	3	47	102	16	47	47	31	17	15	1
51-100cm	0	8	8	0	16	3	9	0	6	7
> 101cm	0	0	1	0	0	0	6	0	0	7
TOTAL	5	94	176	16	129	57	59	20	22	15

Table 5.6c. Results of t-test which tested the null hypothesis that the Whitsunday and Northumberland islands supported the same number of soft corals. The approximate Wilk-Shapiro statistic, which assessed whether the distribution was normal, was 0.6118 (ie. normal).

T	DF	P	Significance
1.31	10.5	0.218	NS

Figure 5.5. Total abundance and size of soft coral colonies in the Whitsunday and Northumberland Islands. Error bars signify 1 standard deviation.



5.3 Colony size and environmental gradients

Based on species components, similar sites were grouped independent of location *per se.*, and distribution patterns correlated with depth, exposure and distance from mainland. However, once colony size was included, there were some contrasting features (Table 5.7):

1. tidal range became an important variate in addition to distance from the mainland, depth and exposure;
2. adjacent sites tend to be more closely clumped together (within the 2-Dimensional configuration of the correspondence analysis, Figure 5.6), indicating similarities in not only faunistic composition but also in size structure of the coral colonies.

Ordinations based solely on faunistic composition reflect only major environmental gradients. However, analyses incorporating size have a strong location effect whereby neighbouring sites group together. Notably, intraset correlations were low when hard and soft corals were combined (Table 5.7), however the 'tide' and 'unique' variables (distinguishing tidal amplitude and location effect, respectively) were high for analysis on hard corals alone (Table 5.8). These results indicate that environmental conditions induced by high tidal fluctuations is effective on scleractinian corals but not on the growth capacity of soft corals.

The Northumberland Islands (groups A, B, E, Figure 5.6) and Pine Island (group C) were closely associated. Pine Island lies in the direct vicinity of the Proserpine/O'Connell river discharge, and had similar assemblages as Percy and Curlew Island. The slopes supported numerous small *Montipora* spp. and *Turbinaria* spp. colonies. This result suggests that extreme tidal conditions and river discharge have a similar influence on the settlement, survival and/or growth potential of coral species.

Colony size tended to increase north of the Northumberland Islands. In fact sites at the top of Figure 5.6 supported mainly small colonies, with abundance of large colonies increasing towards the bottom of the figure. The inner Cumberland Islands (group F,G,H and K) supported larger colonies, especially *Montipora* spp.. Groups M and N were located on the reef flat of Penrith and south Percy Island respectively. Growth is normally suppressed in these habitats, supporting only small faviids, encrusting *Porites* spp. and some Carteriosponges. Scawfell Island (group I), Keppel Islands (group J), and the southern slopes of Hamilton Island (group L) supported large monospecific stands of arborescent *Acropora* spp., whereas large *Porites* spp. dominated the northern Whitsunday Islands (group O and P).

Table 5.7. Full Canonical Correspondence Analysis on species-genus data and their size classes. The Monte Carlo permutation test indicated that the first and second canonical axes were significantly different from random, $p < 0.01$.

	Axis 1	Axis 2	Axis 3	Axis 4
CCA Eigenvalue	0.320	0.311	0.148	0.100
Correlation Coefficient	0.899	0.862	0.729	0.681

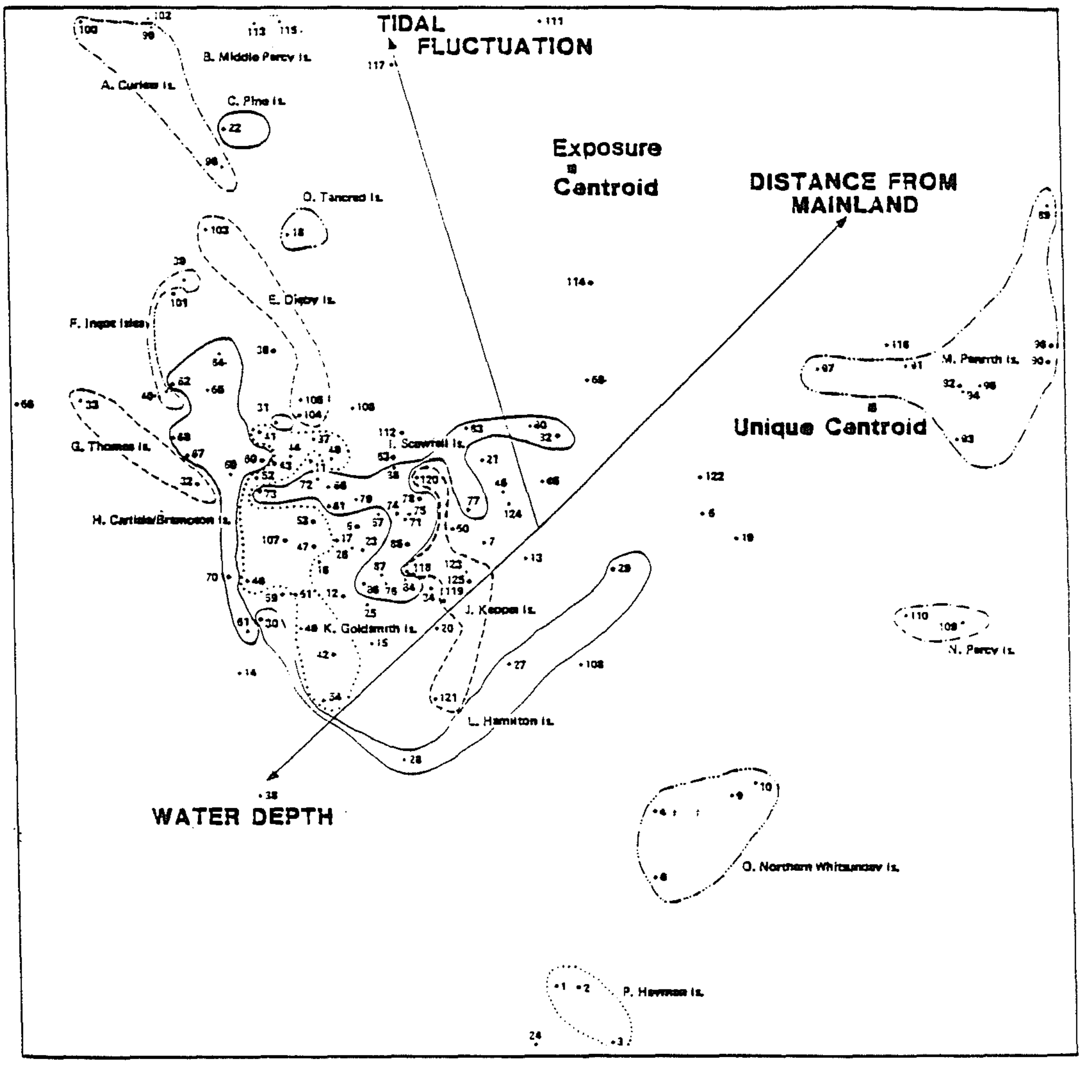
Variable	Canonical Coefficient		Intraset Correlation Coefficient	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	-0.158	0.141	-0.041	-0.031
Unique	0.296	0.008	0.075	0.002
Tide	-0.479	0.510	-0.130	0.116
Mainland	0.458	0.087	0.121	0.019
Exposure	0.054	0.183	0.017	0.049

Table 5.8 Canonical Correspondence Analysis undertaken on species-genus data and their size classes, for hard corals only. Monte Carlo permutation test indicated that the first and second canonical axes was significantly different from random at $p < 0.01$.

	Axis 1	Axis 2	Axis 3	Axis 4
CCA Eigenvalue	0.259	0.221	0.126	0.088
Correlation Coefficient	0.849	0.758	0.739	0.730

Variable	Canonical Coefficient		Intraset Correlation Coefficient	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	-0.233	-0.082	-0.582	-0.163
Unique	0.250	-0.005	0.631*	-0.011
Tide	-0.359	0.459	-0.877*	0.930*
Mainland	0.376	0.091	0.932*	0.181
Exposure	-0.110	0.016	-0.317	-0.037

Figure 5.6. Schematic biplot of all 125 sites, tested for similarity in composition, abundance and colony size, and the significant environmental variables.



5.4 Comparative reef growth

It has previously been stated that reef development is poor in the vicinity of 21°S, and incipient reefs, with no extensive reef flats, were most common between 21°S and 23°S (Hopley *et al* 1989). The extent of reef development was compared for the same sites analysed above. On this occassion sites were compared using reef surface area as an index for carbonate development (Table 5.9). This data was derived from the Great Barrier Reef Gazetteer. The surface area in each region was compared via a t-test, using region as the main factor of interest and sites as replicates. It was found that indeed the regions support significantly different carbonate development ($p = 0.023$).

Table 5.9. Comparative surface area for reefs surveyed in the Whitsunday and Northumberland Islands.

	SITE									
WHITSUNDAY ISLANDS	**2**	**5**	**11**	**12**	**13**	**14**	**15**	**20**	**23**	**26**
Surface area (km^2)	3.80	2.50	0.1	0.1	1.3	1.3	1.3	0.1	3.1	0.63
NORTHUMBERLAND ISLANDS	**98**	**99**	**100**	**101**	**102**	**103**	**104**	**105**	**106**	**107**
Surface area (km^2)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3

5.5 Discussion

Colony abundance and morphology

Total coral abundance did not significantly differ between the Whitsunday and Northumberland Islands although fast-growing corals were more abundant in the Northumberland Islands. The latter region supported mainly small massive, encrusting and plate-like coral colonies. Even the normally massive *Porites* spp. were predominantly encrusting. In contrast, the abundance of massive and arborescent colonies was significantly higher ($p < 0.05$) in the Whitsunday region.

Thickets of *Millepora tenella* and *Porites cylindrica* were rarely recorded on the slopes of the Northumberland Islands. Large monospecific stands of *Acropora* spp. (*A. formosa, A. nobilis, A. grandis*) were also relatively scarce, except on Prudhoe Island which is located in the northern extreme of the island group. However, *Acropora* spp. dominated the Keppel Island reefs and *Porites cylindrica* and *Millepora tenella* have been observed further south in the Capricorn Bunker group of reefs (23°35'S) (pers. obs.). Their decline, therefore, is not a direct restriction of latitude.

These findings do not suggest that *Acropora* spp. are absent in the Northumberland Islands, as many caespitose and tabular acroporids (*A. valida, A. divaricata, A. cerealis, A. bushyensis, A. carduus, A. latistella, A. cytherea* and *A. clathrata*) were found on Curlew and Digby Island. It suggests that there was a definite lack of major framework builders such as massive *Porites* spp. and large monospecific stands of *Acropora* spp. (Davies 1983). Total reef accretion may be markedly reduced through the absence of these corals.

Colony size

Most colonies in the Northumberland Islands were between 11 and 50cm. An absence of small and large colonies may signify low recruitment, high post-settlement selection, or suppressed growth (or a combination of these). Coral recruitment appears suppressed on fringing reefs compared to mid-shelf reefs (Sammarco 1991). A harsh regional environment, because of consistently high turbidity and high algal biomass may suppress recruitment further and cause considerable post-settlement mortality.

Regional conditions

High concentrations of suspended sediment (up-to $89mg/l^{-1}$) were consistently detected 75-100km from Broad Sound which impinged on the Northumberland Islands (Figure 5.7) twice monthly during spring tides. These observations were made by Kleypas (1992) via NOAA AVHRR satellite imagery. Channel 1 reflectance values correlated strongly with suspended sediment concentrations.

High turbidity has been shown to restrict coral growth because of sub-optimal light conditions and as a partial function of calcification efficiency (Cortes and Risk 1985; Barnes and Taylor 1973). Such changes may occur under macrophytic algae (Figure 5.8a). Consistently high turbidity may also induce such changes, and corals which are usually massive in morphology were mainly encrusting in the Northumberland Islands (Figure 5.8b). Furthermore, many corals which are normally open caespitose and platey, such as *Pocillopora damicornis* and *Turbinaria reniformis,* had tightly packed branches and were columnar (respectively) in the Northumberland Islands. The areal exposure of the zooxanthellate polyp is increased by adopting such growth forms. Hubbard and Scaturo (1985), reported a similar phenomena in highly turbid environments, and also indicated that such adaptations maximise light and minimise sediment build-up.

Reef growth

Carbonate development was significantly less in the Northumberland region. Extreme tidal fluctuations enhance aerial exposure on low tide and reduce light conditions on high tide. More precisely, an increase in tidal range effectively raises the Mean High Water Spring (MHWS), and lowers the Mean Low Water Neap (MLWN) and MLWS levels which normally regulate or restrict the vertical growth capacity of a reef. It is not the high tidal fluctuations alone which influence the corals, rather the consequences of the large fluctuations (10m) in the nearshore environment which cause high turbidity (as discussed above). Notably, reefs in the Pompey complex, located 150km offshore, are also affected by high tides but support prolific coral assemblages (pers. obs.).

Considering the dead reef at Marble Island (Appendix 1) the regional conditions in the Northumberland Islands appear, at times, so extreme that coral assemblages have a tendency to become locally extinct. The reef was in a destructive rather than a constructive phase of development, supporting no live coral but abundant shingle from *Acropora* spp. and

Turbinaria spp. and Phaeophytes. The reef has formed some time in the Holocene period as no recrystallisation of aragonite was evident (thin section analysis, Kleypas pers. comm.). Incidentally, a dead reef was also found at Digby Island, however this reef was radiocarbon dated at 38,090 years bp. This is the only recorded incident on the Great Barrier Reef where a Pleistocene foundation is exposed at sea-level.

The adverse conditions in the Northumberland Islands may have caused a time-delay in reef initiation (eg. Middle Percy Island) and assemblages which established were relatively transient (eg. Marble Island). The slopes may have supported major framework builders through the Holocene (eg. *Acropora formosa*). However, their vulnerability to episodic disturbance (Chapter 6) on top of stressful regional conditions allowed only temporary colonization. Contemporary assemblages appear transient with growth forms adapted to low light conditions. In summary, consistently high turbidity, induced by large tidal fluctuations, may have caused significantly less carbonate accumulation in the Northumberland region during the Holocene period.

Figure 5.7a . The Duke Island group (22°S), Northumberland islands, lack coral reefs.

Figure 5.7b. Consistently high turbidity in the Northumberland region, a consequence of 8-10m diurnal tidal fluctuations.

Figure 5.7c. Highly turbid waters in the lee of Curlew Island, Northumberland islands.

Figure 5.7d. The Northumberland islands lack reef development, a probable consequence of consistently high turbidity. Wild Duck Island.

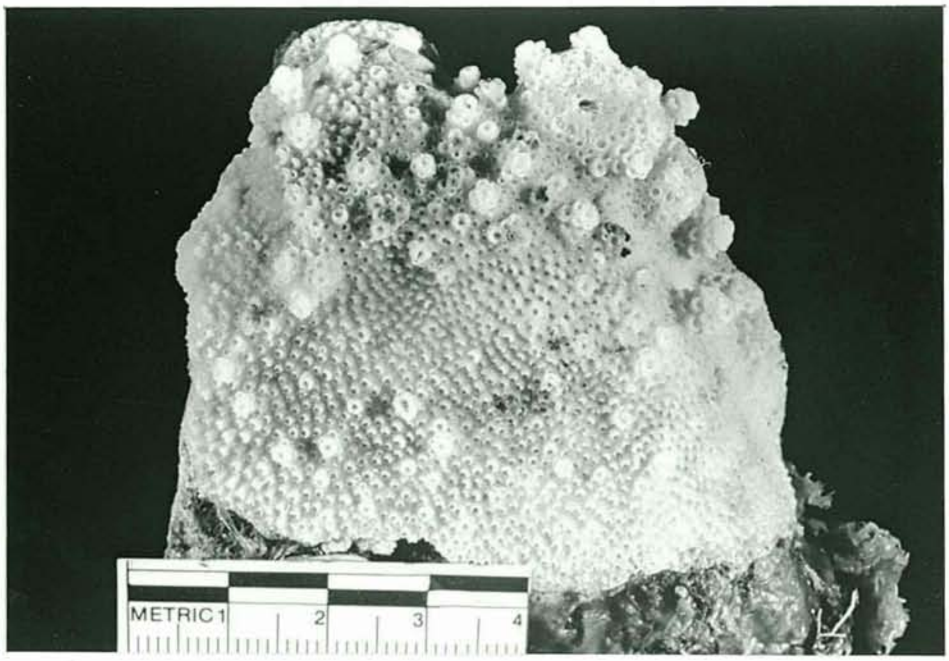


Figure 5.8a Encrusting *Acropora hyacinthus* found under *Sargassum spp.* North Repulse Island, Whitsunday islands.

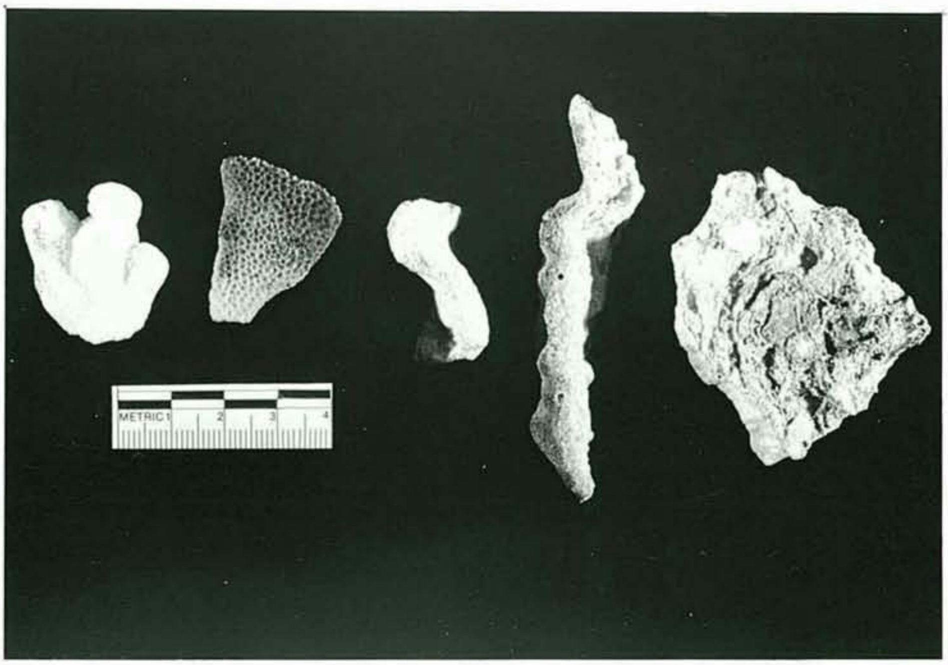


Figure 5.8b Five *Porites* species showing encrusting morphology, all colonies were found on reefs in the Northumberland islands.

CHAPTER 6. NATURAL DISTURBANCE: THE JANUARY 1991 FLOODS.

6.1 Introduction

Distribution and abundance patterns of corals are not always a long-term response to prevailing environmental conditions. Episodic disturbances also affect the structure of benthic assemblages and has been proposed by some authors as being essential for the maintenance of local diversity by preventing space monopolisation of fast-growing species (Connell 1978; Sousa 1979). This hypothesis is tested in this chapter, at two different locations, the Keppel and Whitsunday Islands, after some of the most intense rainfall and flooding the Queensland coast had experienced for 100 years because of the monsoonal depression associated with cyclone 'Joy'.

In mid December 1990 a low pressure system developed off the Queensland coast (15°S), which on the 19th of December was named tropical cyclone 'Joy'. With a barometric pressure of 995 Hpa it entered the Great Barrier Reef province. Its minimum central pressure dropped to 940 Hpa on the 23rd of December when it was located approximately 100km from Cairns (16°40'S). Destructive winds gusts at times exceeded 200km per hour. Considerable physical damage was evident on reefs in the Cairns region (T. Ayling, pers. comm.). For the next three days it moved steadily south and crossed the coast on the 26th of December at Townsville, 300km to the south of Cairns, where it formed into a tropical depression. Extensive rainfall associated with the depression, in late December 1990 and early January 1991, led to flooding of central Queensland. Rainfall was highest in the Mackay (21°S)/ Rockhampton (23°S) district where over 2000mm fell between the 23/12/90 and 7/1/91.

The Keppel Islands are located in the direct vicinity of the Fitzroy River mouth (the largest river in Queensland). In December the Fitzroy River normally discharges 480,857 megalitres per day (mean from 1965-1990). During the flood, discharge peaked at 1,250,000 megalitres per day, causing a 9m rise in river height (Baddiley 1992). In contrast, the Whitsunday Islands are located away from any major river influence, approximately 300km to the north. Although the Proserpine/O'Connell Rivers flow into the Whitsunday Islands, the recent construction of a dam precluded any intense river run-off.

This study assesses two extreme scenarios, one in the direct impact of flood waters and another away from flood-waters. The latter area was only subjected to direct rainfall, local run-off and overcast conditions (which was the case for most fringing reefs in the study area). More specifically, the study sought to examine:

1. whether the reefs were affected by regional conditions;
2. the scale of impact;
3. which species were most vulnerable.

6.2 Reef composition

Keppel Islands

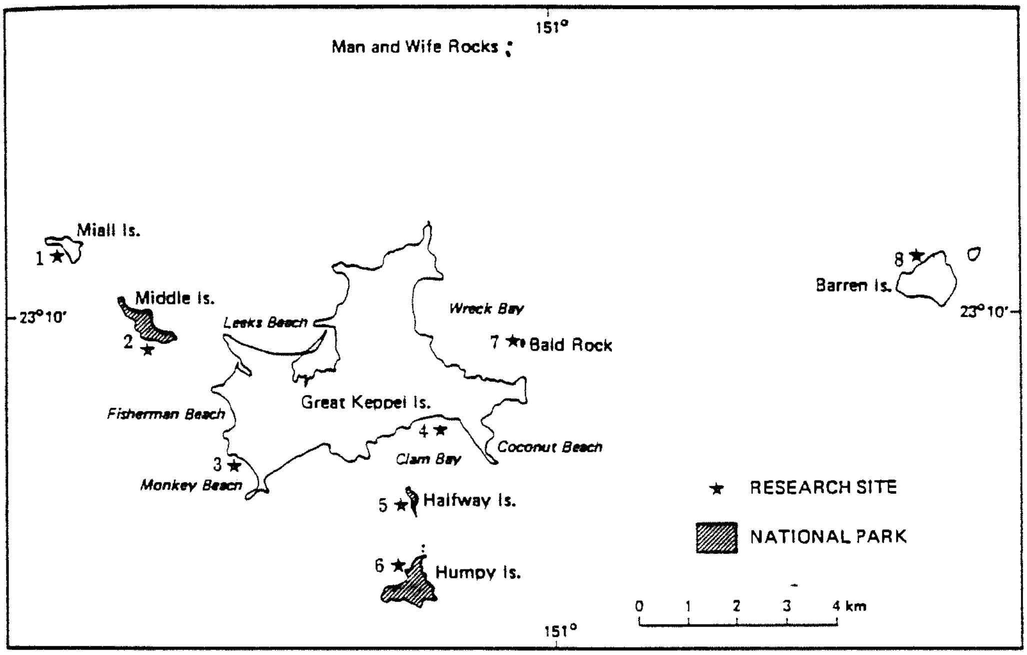
A preliminary survey was conducted in 1989 to examine the coral assemblages within Keppel Bay (Figure 6.1a). Leeward reefs were shallow with well defined reef flats. Windward reefs extended deeper. However, they did not support any reef flats. Benthic assemblages appeared very different than fringing reefs in the Northumberland, Cumberland and Whitsunday Islands. Reefs supported mainly fast growing arborescent *Acropora* species (primarily *A. formosa, A. microphthalma* and *A. millepora*) and some faviid and *Porites* spp. colonies (Figure 6.1b). Windward reefs were more diverse than leeward reefs.

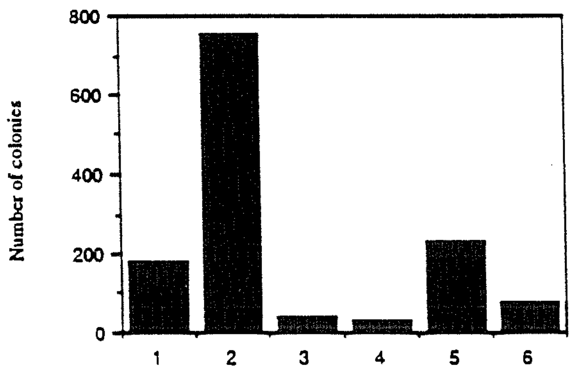
Whitsunday Islands

Well developed reefs in the eastern Whitsunday region (Figure 6.2a) supported diverse coral assemblages to 10-12m. A baseline survey was conducted in December 1990 when 165 species of scleractinian and alcyonarian corals were recorded using line transects (Appendix 7). Four distinct habitats were defined by a pilot study (Figure 6.2b):

1. The shallow flat area supported considerable macroalgae (most dominant were *Sargassum* spp., *Lobophora variegata, Hydroclathrus clathratus, Padina australis* and *Turbinaria ornata*). Coral cover was relatively low (ca 10%) dominated by encrusting *Montipora* spp., *Turbinaria* spp., *Pavona varians*, massive *Goniastrea* spp., *Porites* spp., *Acropora millepora* and *Acropora valida;*
2. The reef crest zone was occupied by a small number of species which form large monospecific stands, especially massive *Porites* spp., *Acropora* spp. and *Sinularia* spp. (soft coral). Coral cover was generally high (40%);
3. The upper slope generally supported the highest diversity of corals, classified as the *Acropora* spp./pocilloporid/mussid zone;
4 Below 6m-10m, slopes support mainly pectiniid and agariciid corals.

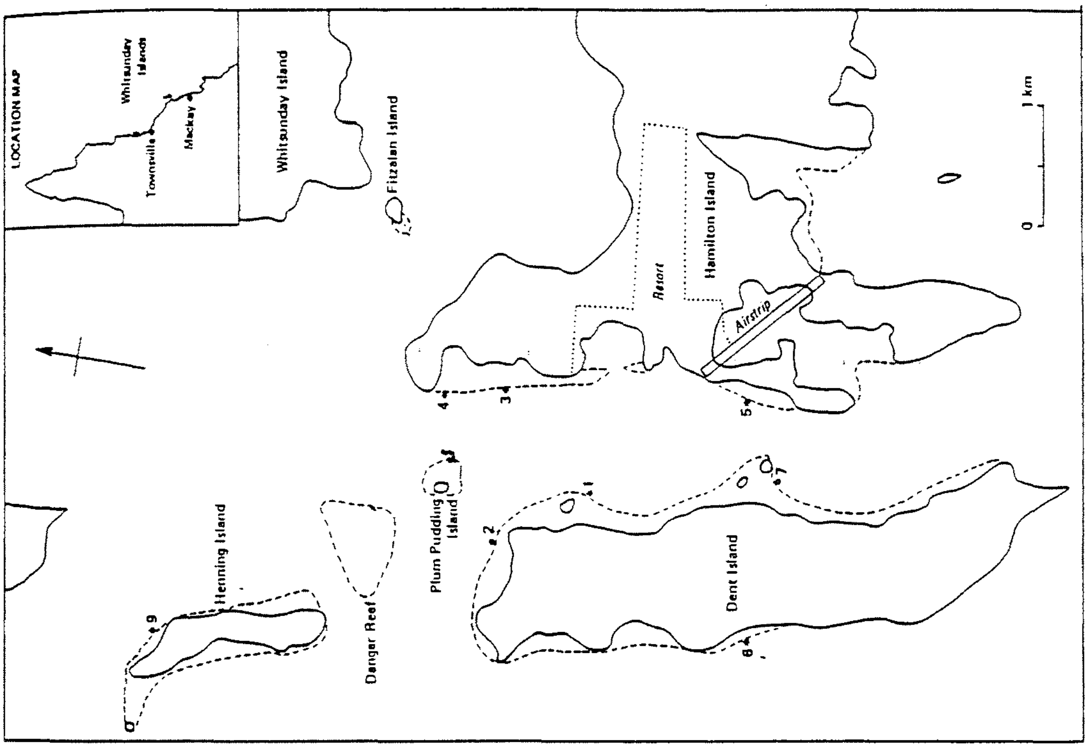
Figure 6.1a. Study sites in the Keppel Islands. **6.1b.** Relative abundance of faviids, *Acropora* spp., *Montipora* spp., poritids, pocilloporids, and other scleractinia, displayed as number of colonies for all sites combined.

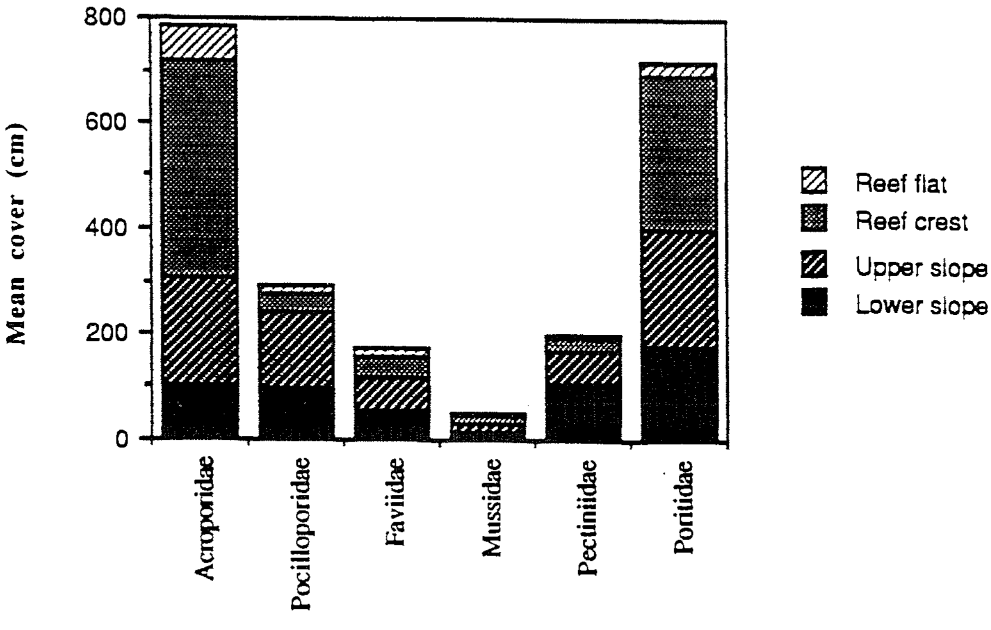




1 Faviids, 2 Acropora spp., 3 Montipora spp., 4 Poritids, 5 Pocilloporids, 6 Other Scleractinia

Figure 6.2a. Study sites in the eastern Whitsunday Islands. **6.2b.** Relative cover of six scleractinian families, in four habitats, before the January 1991 floods. Data were summed over 9 sites and four islands.





6.3 Conditions during the floods

Keppel Islands

The first freshwater plume spread over the reefs on the 2nd of January, 1991 (Figure 6.3). Salinities were low for 19 days. During the height of the flood salinities were in the order of 7 to 10 ppt at the surface, 15 to 28 ppt at 3m, 31 to 34 ppt at 6m and 33 to 34 ppt at 12m (O'Neill *et al* 1992). Tidal fluctuations were in excess of 4m during the peak flood period allowing semi-diurnal dilution (of hyposaline waters) on the high tides.

Whitsunday Islands

Unfortunately no direct salinity measurements were taken for the Whitsunday region. However, as mentioned above the Proserpine/O'Connell river, which flows into the southern Whitsunday Islands, did not flood. This was due to the construction of a large dam 57.7 km from the river mouth, and completed in December 1990. During the 20 day period of rainfall, the entire dam was nearly filled (catchment area 260km^2, holding 500,000 megalitres). The Whitsunday Islands therefore, were not under the influence of extensive river discharge (P. Harrison QDEH, pers. com.), but were subjected to reduced salinities in shallow waters due to heavy rainfall and local runoff.

6.4 Flood impact

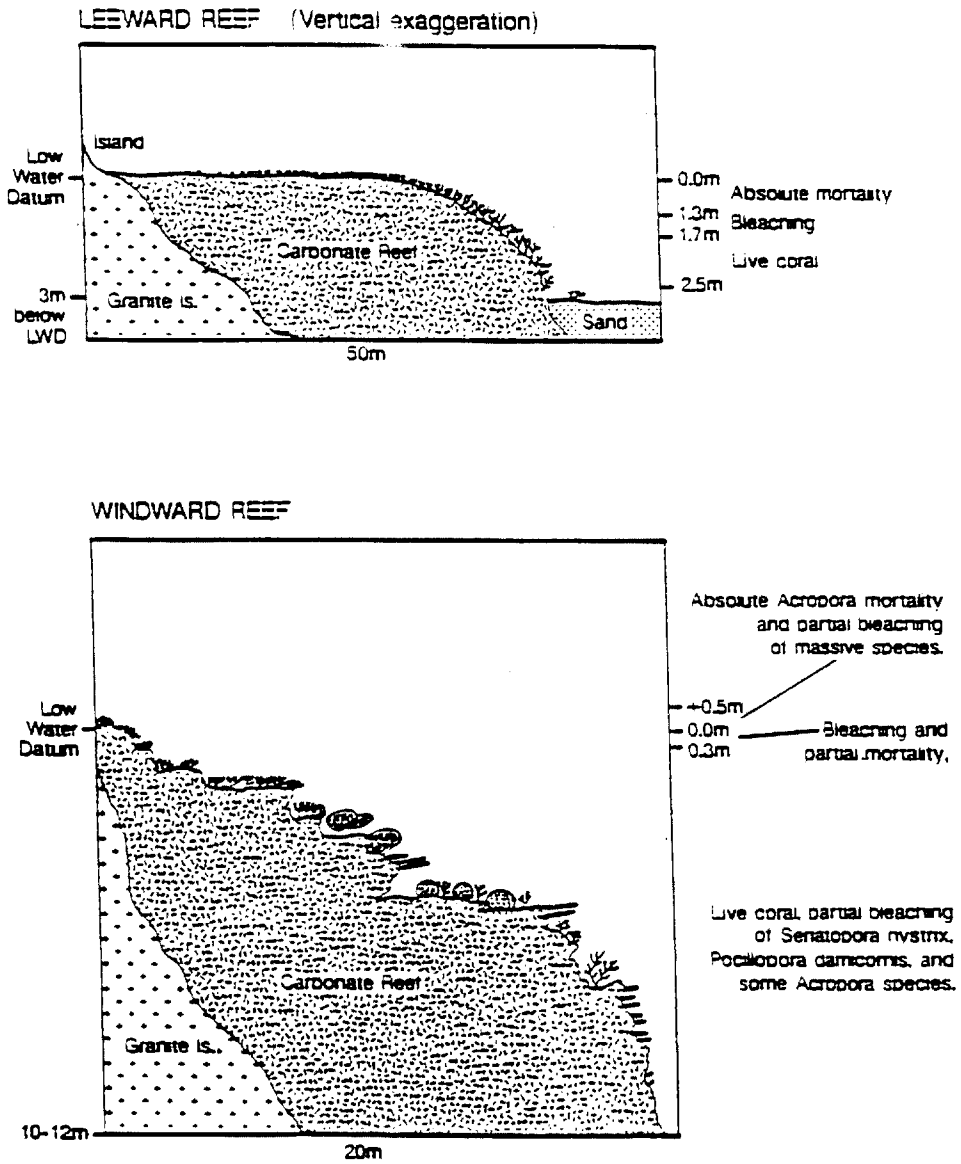
Keppel Islands

Damage was most apparent on leeward reefs on Great Keppel, Miall, Middle, Halfway and Humpy Islands (Figure 6.1a). Approximately 85% of the corals present before the floods were dead and overgrown by turf algae in February 1991, suggesting that mortality in shallow habitats had taken place shortly after inundation by flood waters. Mortality was most pronounced to 1.3m below LWD. A narrow band of bleached coral was evident at 1.3 - 1.7m (Figure 6.4 and 6.5). Below this zone most corals were alive, although the reef extended only a further 1.0m to 1.5m onto sand. In contrast, reefs to windward had only narrow reef flats, except Clam Bay, and approximately 5% of the established colonies were dead and overgrown with turf algae. Mortality at Clam Bay extended to 1.5m and damage was similar to leeward sites.

Figure 6.3 Fitzroy River discharge inundating the Keppel Islands, 2/1/91.

Figure 6.4 Bleached *Acropora formosa*, 1.5m, Clam Bay, Great Keppel Island, February 1991.

Figure 6.5. Vertical profile of leeward (a) and windward (b) reefs in the Keppel Islands. The extent of vertical damage is illustrated. Damage was less extensive on windward slopes because hyposaline conditions were only affected reef flats and shallow slopes, which are less developed to windward.



Mortality was most extensive for acroporids and pocilloporids. Some survival was apparent below LWD for the faviid genera *Leptastrea, Cyphastrea, Goniastrea, Favites, Favia,* and the species *Turbinaria* spp., some *Porites* spp., *Psammocora contigua* and *Coscinaraea columna* (Table 6.1). Ironically, the species most vulnerable to low salinities (*Acropora* spp.) dominate the Keppel Island reefs.

Table 6.1. Field observations of coral species varying in their susceptibility to acute salinity changes. Data compiled by $50m^2$ random swims at each site, measuring colony depth and condition.

Corals that appeared to consistently survive the hyposaline conditions in shallow waters (1.0m below LWD).
Scleractinia: *Goniastrea favulus, Goniastrea retiformis, Goniastrea australensis, Platygyra sinensis, Cyphastrea chalcidicum, Cyphastrea serailia, Leptastrea purpurea, Leptastrea inequalis, Favites russelli, Favites complanata, Favites pentagona, Favites flexuosa, Favites halicora, Favia pallida, Coscinaraea columna, Turbinaria mesenterina, Turbinaria bifrons, Turbinaria peltata, Turbinaria stellulata, Psammocora contigua.* Alcyonaria: *Capnella sp.*
Coral that were partially bleached and appeared to have recovery potential (1.0m below LWD).
Scleractinia: *Favia favus, Porites australiensis, Porites lutea/lobata, Goniopora spp., Montipora spp., Galaxea fasicularis, Hydnophora pilosa, Favia rotumana.* Alcyonaria: *Sarcophyton spp., Efflatournaria spp., Xenia sp., Alcyonium spp.*
Corals most susceptible to mortality (at 1.0m below LWD).
All *Acropora spp.* and all Pocilloporids.
Alcyonaria: *Dendronephthyea spp. Nephthea spp.*

Whitsunday Islands

There was no significant difference in the amount of (total) live coral cover between the observation periods, as suggested by the analysis of variance (Table 6.2a). There was a significant increase in the abundance of dead coral cover ($p < 0.001$, Table 6.2b), specially at sites 3, 4 and 6 (Figure 6.2). Sites 7, 2 and 5 were least affected. Although no specific families significantly declined over time, pocilloporids were considerably effected (Table 6.3). Other corals differed both between and within sites, however no significant temporal differences were detected (Table 6.2c - 6.2i).

The pocilloporid, *Seriatopora hystrix,* was most affected by the flood conditions, particularly at Hamilton Island where it was the dominant coral at 5m depth on the reef slopes (pers. obs.). Above the *S. hystrix* stands *Acropora* species (*A. formosa, A. elseyi, A. longicyathus, A. nobilis, A. microphthalma*) extended to the reef flat and covered at times over 70% of the substrate. These corals had no detectable change in cover or showed any signs of necrosis. Reef flat assemblages had only slight damage to the *Acropora* spp. and *Porites* spp. colonies. *Acropora latistella, Acropora valida, Acropora millepora* and *Acropora tenuis* were most affected.

Table 6.2. Summary of three factor Analyses of Variance (ANOVA) for coral cover of 9 key benthic components in the Whitsunday Islands, where time (fixed factor), site (random factor), and habitat (fixed factor) and time*habitat are the main effects of interest.

TAXA	df	SS	MS	F value	P	% variation
a. LIVE CORAL						
Time (A)	1	0.291	0.291	1.24	NS	1%
Site (B)	8	6.973	5.972	5.97	0.001	4%
Habitat (C)	3	55.530	18.510	42.12	0.001	88%
A*C	3	0.122	0.041	0.15	NS	2%
Error	272	31.549	0.146			5%
b. DEAD CORAL						
Time (A)	1	47.461	47.461	10.16	0.05	72%
Site (B)	8	44.540	5.567	9.37	0.001	8%
Habitat (C)	3	10.809	3.603	3.26	NS	5%
A*C	3	5.741	1.914	1.61	NS	3%
Error	272	128.400	0.594			12%
c. SOFT CORALS						
Time (A)	1	3.384	3.384	1.92	NS	15%
Site (B)	8	44.785	5.598	5.59	0.001	24%
Habitat (C)	3	25.522	8.507	3.54	NS	37%
A*C	3	1.144	0.381	1.01	NS	2%
Error	272	99.195	0.459			22%
d. ACROPORIDAE						
Time (A)	1	0.56	0.521	0.521	NS	1%
Site (B)	8	108.330	13.542	19.16	0.001	37%
Habitat (C)	3	48.444	16.147	4.44	0.05	44%
A*C	3	0.991	0.330	0.31	NS	1%
Error	272	152.693	0.707			17%
e. POCILLOPORIDAE						
Time (A)	1	0.829	0.829	0.54	NS	2%
Site (B)	8	140.990	17.624	17.41	0.001	38%
Habitat (C)	3	55.650	18.550	3.61	NS	39%
A*C	3	1.511	0.504	0.29	NS	1%
Error	272	218.680	1.012			20%
f. FAVIIDAE						
Time (A)	1	3.255	3.255	7.13	NS	13%
Site (B)	8	88.469	11.059	11.55	0.001	45%
Habitat (C)	3	13.159	4.386	1.53	NS	18%
A*C	3	0.997	0.332	0.26	NS	1%
Error	272	206.762	0.957			23%

continued...

Table 6.2 continued

TAXA	df	SS	MS	F value	P	% variation
g. PORITIDAE						
Time (A)	1	0.908	0.908	0.57	NS	2%
Site (B)	8	133.932	16.741	16.74	0.001	41%
Habitat (C)	3	46.223	15.406	3.56	NS	38%
A*C	3	0.792	0.264	0.35	NS	1%
Error	272	125.293	0.582			18%
h. PECTINIIDAE						
Time (A)	1	0.349	0.349	0.69	NS	0.5%
Site (B)	8	103.224	12.903	17.74	0.001	14%
Habitat (C)	3	215.701	71.902	21.92	0.001	79%
A*C	3	1.682	0.561	0.68	NS	0.5%
Error	272	157.121	0.727			6%
i. MUSSIDAE						
Time (A)	1	0.015	0.015	0.02	NS	1%
Site (B)	8	74.427	9.303	8.07	0.001	5%
Habitat (C)	3	9.564	3.188	2.23	NS	17%
A*C	3	3.953	1.318	1.42	NS	7%
Error	272	249.121	1.153			70%

Table 6.3 Changes in percent cover of Pocilloporidae at nine sites in the Whitsunday Islands.

SITE	1	2	3	4	5	6	7	8	9
TIME 1	8.81	12.88	204.90	415.12	51.25	118.2	11.94	16.88	32.94
TIME 2	16.81	12.75	90.44	154.93	9.06	93.30	12.50	28.75	17.38

6.5 Discussion

Direct flood impact

Extensive mortality was apparent on the leeward reefs of the Keppel Islands, although windward reefs were only marginally affected. *Acropora* spp. (A. *formosa, A. microphthalma, A. latistella, A. millepora, A. valida*) and pocilloporids (*Pocillopora damicornis, Seriatopora hystrix*) were most affected by the flood waters. Mortality of these corals did not extend beyond 1.7m (LWD). Slight differences in depth (sometimes only centimetres) appeared to influence bleaching probably caused by the strong stratification of the water column (O'Neill *et al* 1992). Massive colonies were more resilient to low salinity and were only partially bleached or had suffered partial mortality. Bleaching was usually restricted to the upper portion of the colonies. The consistent survival of most faviid colonies, in shallow waters, indicates that these species are most tolerant to reductions in salinity.

Bleaching

Bleaching does not always indicate coral death. Bleaching is a regular feature along inshore reefs between January and May (pers. obs.) and corals can survive without zooxanthellae for several months (Goreau 1964; Hayes and Bush 1990). Substantial research has focused on when and why bleaching occurs, it appears associated with coral stress and simply stated it is the expulsion of zooxanthellae. However, the thresholds and mechanisms involved are unclear and somewhat species specific. Some authors have described bleaching as a response associated with the release of excess mucus (excreted from the corals gastrovascular cavity disrupting the gastrodermis where the zooxanthellae are contained) (Hayes and Bush 1990). *In vitro* experiments indicate that zooxanthellae become motile (forming zoospores) when food reserves are depleted (Freudenthal 1962), this has interesting connotations within a symbiotic relationship specially when we consider that some zooxanthellae are classified in the (order Peridinieae) family Blastodiniaceae which is a parasitic family (Freudenthal 1962).

Sandermann (1988a,b) proposed a bleaching mechanism for corals which is best defined as oxygen toxicity. He suggested that under stress, photosynthesis increases which produces high oxygen concentration. Oxygen can be toxic when concentrations are excessive. Coles and Jokiel (1977) however reported on the lowering of the P:R ratio under thermal stress. Lowering of this ratio suggests a lowering in photosynthetic activity, a increase in respiration, or both. Either way, CO_2 is likely to increase, suggesting toxicity may stem from CO_2 poisoning rather than O_2 poisoning. This remains speculative however.

Damage to cells

Histopathological examination of the partially bleached *Seriatopora hystrix* and *Acropora formosa* colonies collected at Great Keppel Island during the floods showed degenerative changes. The most widespread and pronounced change was gross swelling and lysis of the epidermal cells; almost certainly due to the hypoosmotic effect of the very low salinities recorded in the region at the time. An acute toxic syndrome was diagnosed because of the absence of an infectious agent and/or inflammation. The production of large amounts of mucus and expulsion of zooxanthallae from the gastrodermis were less-specific indicators of stress which could have been due to the heavy sedimentary load and low light conditions in the water column (Rogers 1979). Bacteria emboli were also present in the sub-epidermis, however their presence was probably a consequence of secondary infection.

Moderate impacts

A regional increase in dead coral cover and active bleaching was evident during the monsoonal conditions in the Whitsunday Islands. Shallow *Acropora* spp. corals were not greatly affected. Deep pocilloporids were impacted probably because of low light (Stafford Smith unpubl. data); a consequence of overcast skies, high turbidity and plankton blooms during the monsoonal conditions (Brodie and Mitchell 1992).

Historical perspective

Hedley (1925) and Rainford (1925) described the effect of the 1918 floods on the coral assemblages of the Whitsunday Islands. These floods were more extensive than those in this study. The upper 2-3m of coral colonies were killed by the event. Below 3m only minimal damage occurred. It seems that the reefs had been extensively inundated by discharge from the Proserpine/O'Connell Rivers. Therefore, the disturbance was analogous to the impact that occurred on the Keppel Islands during early 1991.

Freshwater kills are also common at Kaneohe Bay, Hawaii (Banner 1968; Maragos 1974; Holthus *et al* 1989). These phenomena severely impacted the shallow *Porites compressa* assemblages. Goreau (1964) also reported on effects of hyposalinity on coral reefs. He similarly described mass expulsion of zooxanthellae due to coastal flooding (Jamaica) following Hurricane 'Flora' in 1963. Goreau convincingly argues that low salinity was the prime cause of bleaching. Differences in susceptibility (to bleaching) were consistently noted in different species. Bleaching did not extend below 3m however. Similarly, Collins (1978) reported on the effects of hyposaline conditions following cyclone 'Althea' (24/12/1971) and cyclone 'Bronwyn' (6/1/1972) on the coral assemblages of Magnetic Island, Queensland, Australia. Strong stratification of the water column killed shallow assemblages however deep corals were not subjected to hyposaline conditions. There was also differential mortality on the upper slopes where, he states *Montipora* spp., *Turbinaria* spp., *Porites* spp. and faviids were most tolerant, and *Acropora spp.* species were most vulnerable. Collins also followed the recovery of the reef, where he observed recruitment of scleractinian corals after 15 months. However, a different reef flat assemblage is now evident (1992) to that described by Collins. *Goniastrea* spp. now dominate the reef flat which was mainly occupied by *Acropora* spp. and *Porites spp.* (pers. obs.).

Significance of disturbance

The flood event was not unique to the Keppel Island region as inundation by freshwater, in the wake of the Fitzroy plume, occurs regularly, although intensity varies considerably (Bureau of Meteorology 1991; Figure 6.6). Hypothetically, intermittent disturbance events of this nature may allow the least susceptible species to dominate, such as *Porites* spp. and faviids. This is however not the case as colonies which survived the flood event in the short-term are not dominant within the region. Ironically, some of the species most susceptible to low salinities - *Acropora* spp. - dominate these reefs. Although some bleached corals recovered after three months (pers. obs.), recovery of the reef flats and upper slopes could take many years. Dominance may change, although, it seems probable that the reef will once again be dominated by fast growing (Oliver *et al* 1983; Simpson 1988) *Acropora* spp. a direct consequence of recruitment from a local (remnant survivors on the lower slopes) and regional source (Chapter 4 and 5; Table 6.11).

TABLE 6.11. Spatial variance of *Acropora* spp. dominance between four regions using data from appendix in volumes 10, 11, 12 and 13 Crown-of-thorns study, AIMS (1985). 31 outer reefs were surveyed. Total percent cover was summed for each site and converted to ratios.

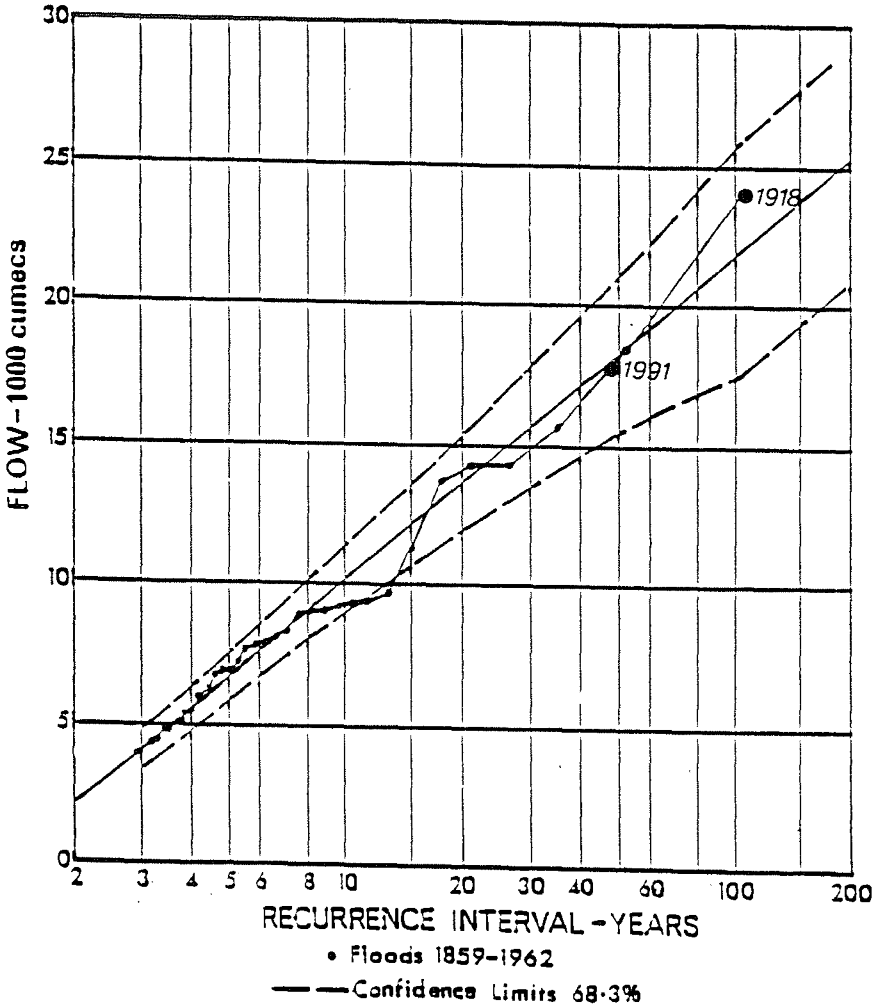
REGION (n = reefs surveyed)	*Acropora*	non-*Acropora*
Capricorn-Bunker (n=4) 3 metres	1:	0.31
6 metres	1:	0.55
12 metres	1:	1.17
Swain Complex (n = 10) 3 metres	1:	0.76
6 metres	1:	1.02
12 metres	1:	1.87
Pompey Complex (n=9) 3 metres	1:	0.83
6 metres	1:	0.86
12 metres	1:	2.25
Whitsunday complex (n= 9) 3 metres	1:	1.11
6 metres	1	1.33
12 metres	1	1.96

Disturbance theory

It is evident that cyclones can affect coral reefs in many ways, both directly by physical damage and indirectly by changing the ambient physico-chemical environment. Low surface salinity and low light levels, respectively, are probable causes for a regional decline in *Acropora* spp. on the Keppel Islands and pocilloporids in the Whitsunday Islands. Pocilloporid corals (*Seriatopora hystrix, Pocillopora damicornis* and *Stylophora pistillata*) and *Acropora* spp. were most vulnerable to low salinity and extreme changes in ambient light, and it appears that damage to these species is indicative of slight changes to the physico-chemical environment on a coral reef. It has been suggested that branching corals of this nature are more susceptible to physico-chemical stress because of their relatively high respiratory rate (Jokiel and Coles 1974) but their physical structure may also play a role. These types of corals are opportunistic by their nature - fast growing and highly fecund (Jackson & Hughes 1985), and have been described in chapter 4 as potentially transient assemblages (Assemblage J and K, Table 4.11).

Periodic exclusion of such opportunists may be essential in maintaining regional diversity over long time scales (Connell 1978). Episodic floods eliminate entire assemblages on the Keppel Islands and reduce coral diversity. Mild disturbance events, like those which occurred on the Whitsunday Islands select against corals which have the ability to grow fast and form large monospecific stands covering hundreds of metres. Mild disturbances suppress space monopolisation by such corals, temporally reducing local coral cover but making space for recolonization of other species, effectively enhancing diversity on a regional scale.

Figure 6.6. Frequency of flood events from the Fitzroy River for 103 years. Only twice in this period have flood waters been more severe, 1918 and 1954.



CHAPTER 7. ANTHROPOGENIC DISTURBANCE: EFFECTS OF SECONDARY SEWAGE.

7.1 Introduction

Fringing coral reefs are becoming increasingly subject to anthropogenic stresses. Elevated nutrient levels in particular have been shown to alter the fundamental nature of coral reefs (Smith *et al* 1981). River catchments and local sewage discharge have this potential (Yellowless 1990). Changes in water quality around coral reefs are known to influence algal productivity and the precipitation of calcium carbonate (Smith and Kinsey 1976; Kinsey and Davies 1979). Productivity is enhanced and calcification is reduced by elevated phosphorus levels (Kinsey 1979; Simkiss 1964). However, calcification may be enhanced, either directly through ammonium, ammonium hydroxide and urea (Campbell and Speeg 1969; Towe and Malone 1970; Crossland and Barnes 1974; Meyer and Schultz, 1985) or indirectly by assimilation of ammonium by endosymbionts (Muscatine and D'Elia 1978). Several studies have been conducted on stress response of coral reefs to elevated nutrients and sedimentation (Tomascik and Sander 1985, 1987; Dodge and Vaisnys 1977; Cortes and Risk 1985), these studies were all conducted on Caribbean reefs. No studies have been undertaken on nutrient tolerance levels of coral assemblages within the Great Barrier Reef (GBR), and it cannot be assumed that responses to stress are universal as there are no coral species which occur in both regions.

This study was conducted at Hayman Island, in the Whitsunday Island group (Figure 3.4). It assesses the change in coral assemblages along a eutrophication gradient in an area previously impacted by a number of activities including the dismantling of a jetty and dredging during a marina construction (prior to 1986). A localised study at increasing distance from a sewage outlet pipe sought to examine the spatial and temporal variation in coral composition, abundance, and coral growth documenting the nature and degree of change between 1986 and 1988. Such a study was thought to be appropriate for two reasons:

1. The study area is located in the Whitsunday Islands which supports 7 major resort islands, and from a management perspective the scale of impact of their discharge was unknown;
2. Understanding effects of elevated nutrients on a local scale may lead to predictions of effects on large spatial scales (riverine input).

Coral cores were taken from six *Porites* spp. colonies at increasing distance from the sewage outlet, and examined for growth rates and ultra-violet fluorescence. This genus was selected as it possesses skeletal banding (Buddemeier and Kinzie 1976) and has previously been used in palaeo-environmental studies (Isdale 1984; Boto and Isdale 1985).

7.2 Results

Spatial variability

Community composition and substrate availability varied considerably at all four locations; in the direct vicinity of discharge (location 1), 300m either side of the discharge (location 2 and 3) and at the control site, Blue Pearl Bay.

Location 1.

Sites near the outlet supported low coral cover (mean of 2%) although unconsolidated carbonate rubble was prolific (for coral settlement) (Figure 7.1). Faviids were the dominant coral at this location (Table 7.1 [*Favia* spp., *Favites* spp., *Goniastrea* spp., *Leptastrea* spp., *Cyphastrea* spp. Appendix 8]). Cover was slightly higher at site 2 and 3 (mean of 7-8%), than at site 1. Abundance of caespitose *Acropora* spp., massive *Porites* spp., and *Alcyonium* spp., increased at sites 2 and 3 (Appendix 8). Partial mortality on established *Porites* spp. frequently exceeded 50%.

Location 2.

Sites 4, 5 and 6 were very similar in composition (Table 7.1; Appendix 8) and diversity was relatively high. Coral colonies were generally large and dominated by massive *Porites* spp.. Coral cover was moderate (mean of 18-30%, Figure 7.1).

Location 3.

Coral cover varied from 8-25% at site 7, 8 and 9 (Figure 7.1). The assemblages consisted of small colonies supported on large relict *Porites* spp.. These assemblages suggest a previous disturbance to the *Porites* spp., now supporting newly established colonies. Coral species were mainly *Acropora* spp., *Alcyonium* spp. and *Sinularia* spp.. Sand constituted over 50% of site 9.

Location 4.

The control sites in Blue Pearl Bay supported high coral cover (50-60%, Figure 7.1) and diverse assemblages (Appendix 8). Large and abundant *Porites* spp. colonies (*P.rus, P.cylindrica, P.lutea, P. mayeri*) were most prolific, their abundance and size is indicative of relative stability (lack of recent disturbance).

Temporal change

Coral colonies increased in abundance at all sites over the period 1986 to 1988. The Multi-Dimensional Scaling analysis (MDS) shows the relative change in community structure at all sites from 1986 to 1988 (trajectories). A recovery was evident at most sites because most site positions, within the 2-D MDS diagram (Figure 7.3), had moved toward the control sites. With few exceptions increases in abundance were across all families during the two year period. Increases were greatest in the families Faviidae, Acroporidae and Poritidae (Table 7.1).

Each site was also assessed for change in relative composition. At each site coral taxa were allocated to one of five categories: 1 present in 1986 and increased in abundance; 2 present in 1986 and decreased in abundance; 3 abundance did not change; 4 became locally extinct; 5 local colonization. The results are shown graphically in Figure 7.4. The results for each location are now discussed.

Location 1.

Overall, site 1 had the lowest increase in colony abundance (Table 7.1). The outlet location was also notable for the following features: it exhibited the lowest number of colony increases; the greatest proportion of local extinction and colonization of new taxa was apparent between observations; coral colony turnover was higher than at other locations (Figure 7.4). Greatest increases in colony abundance were for small faviid colonies (*Favia* spp., *Favites* spp., *Goniastrea* spp., *Cyphastrea* spp. and *Leptastrea* spp.) and massive *Porites* spp. (Appendix 4). Large polyped fungiids and pectiniids were absent near the discharge outlet. Large increases were evident for the soft coral *Alcyonium* spp..Partial mortality of colonies was high at sites 2 and 3. The amount of partial mortality on *Porites* spp. did not change significantly between 1986 and 1988 at any site (Figure 7.5). However, at sites 2 and 3, a significant increase in colony damage on caespitose *Acropora* spp. was recorded between the two observation periods ($Z = 2.34$, $p < 0.02$) (Figure 7.6).

Location 2.

Large increases were evident for faviids (*Favia* spp., *Favites* spp. and *Goniastrea* spp.), acroporids, poritids, *Alcyonium* spp., and *Lobophytum* spp. (Table 7.1; Appendix 8). Large changes in *Alcyonium* spp. populations indicate that these corals tend to undergo mass mortality, suggesting a relatively ephemeral life-history strategy. Local extinction was minimal except for a few colonies of *Palauastrea ramosa, Pavona cactus, Sandalolitha robusta* and *Scolymia vitiensis*. Local colonization was high, especially *Lobophytum* spp. (Appendix 8).

Location 3.

Colony abundance increased considerably, especially at site 7. Faviids, acroporiids, poritids and pocilloporids increased most (Table 7.1). Caespitose *Acropora* spp., encrusting *Montipora* spp., massive *Porites* spp., *Stylophora pistillata, Alcyonium* spp., and *Sinularia* spp. increased considerably in this location (Appendix 8). Arborescent *Acropora* spp. declined in abundance Local extinction was minimal at all sites *(Figure 7.4)*. Assemblages at these sites were similar to the transient or early successional assemblages described in chapter 4 (assemblage J and K), composed of *Acropora* spp., pocilloporids, *Sinularia* spp., and in this case *Alcyonium* spp.. Partial mortality of *Acropora* spp., at site 7, was significantly higher in 1988 than 1986 ($Z = 3.42$, $p < 0.01$) (Figure 7.6).

Location 4.

The control sites were surveyed only in 1988.

Table 7.1. Summary table displaying the variation in abundance of total coral colonies in the two year sampling period (1986 and 1988) at nine sites (S1 to S9) on Hayman Island. Scleractinian families and Alcyonaria genera are summarised (where + indicates the total number of colonies that increased and - indicates the total number that decreased.

Overall scleractinian change between 1986 and 1988.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
FAVIIDAE	+38	+91	+202	+292	+261	+266	+182	+17	+47
ACROPORIDAE	+3	+19	+52	+45	+68	+52	+109	+26	+32
PORITIDAE	+17	+50	+43	+60	+72	+61	+70	+6	+7
FUNGIIDAE	-	-	-	+5	-1	-	+3	1	-
POCILLOPORIDAE	+5	+2	+12	+14	+10	-	+62	+24	+6
OCULINIDAE	-	+1	+4	+6	+6	+6	+2	-	-
AGARICIIDAE	-1	+6	-2	+21	+4	+6	+5	4	-
MUSSIDAE	-1	+8	+1	+23	+10	+38	+4	16	+3
CARYOPHYLLIIDAE	-	-	-	+1	-	+5	-	-	-
MERULINIDAE	-5	-	-1	+1	-	+1	-	-	-
PECTINIIDAE	-	+7	-1	+14	+7	+17	+2	4	-
DENDROPHYLLIIDAE	-	+2	+3	-1	+2	+2	+6	-	+4
SIDERASTREIDAE	+1	+1	-	-	-15	-	-	+2	
ASTROCOENIIDAE	-	-	+2	-	-	-	-	-	-
TOTAL	**+57**	**+187**	**+315**	**+481**	**+424**	**+454**	**+445**	**+316**	+101

Overall Alcyonaria change between 1986 and 1988.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Alcyonium	+13	+372	+142	+259	-271	+250	+227	+355	-16
Sinularia	-2	-39	+7	+81	+61	-4	+124	+61	-22
Lobophytum	+2	-3	-	+19	+782	+6	-14	+3	+2
Sarcophyton	-3	-	-	-2	-3	-19	-33	+28	-1
Stereonephthea	-	-	-	-	-	-	-	+1	+2
Nephthea	-	-	-	-1	-	-	-	-	+27
Dendronephthea	-	-	-	-	-	-	-	-	-
Xenia	-	-	-	-	-	-	-	-	+2
Cladiella	-	-	-	+47	+4	+20	-	+21	+2
Pachyclavularia	-	-	-	-	-	-	+5	-	+32
TOTAL	**+10**	**+330**	**+149**	**+357**	**+569**	**+237**	**+304**	**+474**	**+28**

Change in abundance

If sewage was affecting the abundance and composition of the adjacent corals, one would expect location 1 to be different from the other locations in an analysis of variance. This was not the case, location 2 was different (Table 7.2). It is however obvious that sewage has had some influence on the benthic assemblages (Figure 7.2). There appears to be two reasons why an effect was not detected via the analysis of variance design:

1. The experimental design was set-up to detect an effect (should it occur) over 100's of metres. The effect was only very localised (10's metres). ie. impact was evident at site 1 and part of site 2 and 3;
2. The corals at location 3 were supported on relict *Porites* spp., these assemblages appear to be in an early successional stage, thereby consistently grouping with depauperate sites in location 1.

Table 7.2. Summary of two factor analysis of variance (ANOVA) comparing the absolute abundance of coral colonies, partitioned mainly at family level, between 2 times and 3 locations. Location 1 sewage outlet, Location 2 east of sewage, Location 3 west of sewage. Significance of the F-value and variance component for each factor (parentheses) are expressed, where * $0.05 > p > 0.01$, ** $p < 0.01$, ns $p > 0.05$. Results of *a posteriori* Tukey test are expressed for both factors.

Source of Variation	Time	Location	Error	Tukey - Time	Tukey - Location
Degrees of freedom	1	2	14		
Faviidae	** (68)	* (ns)	(6)	2 > 1	2 > 1=3
Acropora spp.	ns (11)	** (80)	(9)	2 > 1	3 > 2=1
Montipora spp.	** (73)	ns (20)	(7)	2 > 1	2 > 3=1
Poritidae	** (67)	* (28)	(5)	2 > 1	2 > 1=3
Pocilloporidae	* (45)	* (45)	(10)	2 > 1	3 > 2=1
Other Scleractinian	* (50)	** (43)	(7)	2 > 1	2 > 1=3
Soft corals	** (66)	ns (27)	(7)	2 > 1	2=3=1

Coral growth

Annual growth rates of the six massive *Porites* spp. (4 *P. lutea*, 2 *P. mayeri*) ranged from 7.5 to 11.8 mm y^{-1}, which is within the range reported for the central Great Barrier Reef (Isdale 1981). Colony 5, *Porites lutea*, derived from the outlet location, had a considerably faster growth rate than other colonies examined (Fig. 7.7).

A fluorescent signal was present in all cores although its periodicity varied considerably (Fig.7.8). High fluorescence in the cores from Blue Pearl Bay (cores 1, and 2, Figure 7.8a and b) correlated with dense summer bands, whereas at other locations fluorescence correlated with winter bands. No added fluorescence was apparent in the sewage core. There was a particularly strong signal in 1974 in all except one core (core 1, Blue Pearl Bay). Using this 1974 band as a datum, the dead *Porites* spp. at site 7 was shown to have died in 1985 (Figure 7.8c), which coincides incidentally with the period of marina development (approximately 250m to the east). An anomalous dense fluorescent band was evident just prior to death. High magnification revealed large extra-skeletal aggregations of crystals in this band (on the coenosteum) that were absent from an adjacent living colony at the same period (Figure 7.8d). Similar crystal aggregations were also observed throughout the core at site 3 (sewage outlet) (Fig. 7.9a), but were not observed elsewhere (Fig 7.9b).

In order to assess density differences, mercury intrusion volumes were measured for three cores. The core taken in the vicinity of discharge measured 0.330 cm^{-3} gm^{-1}, or at least 24% greater than measurements made for other cores (ie. less porous). Intrusion volumes from other cores were : core 1 had a 0.261 cm^{-3} gm^{-1} for the light band and a 0.266 cm^{-3} gm^{-1} for the dense band; the core from site 7 (west) was 0.257 cm^{-3} $gm^{-1.}$

7.3 Discussion

Community effects

Discernible effects of secondary sewage discharge was evident only in the direct vicinity of sewage discharge. Effects were evident 20-40m from the outlet pipe (for a maximum discharge of 500 m^3/day). The sites closest to the discharge had the lowest coral cover and lowest number of taxa. Colonization appeared restricted in comparison to other sites. A high turnover in established colonies near the outlet was apparent, although taxa which colonised the sewage area exhibited a wide range of life history characteristics and were not solely fast growing, ephemeral species. Paradoxically, the coral core taken near the sewage discharge had the highest growth rate and density. This result must be regarded as tenuous because only one core was taken near the discharge outlet.

At the outlet sites, although there was abundant carbonate available for colonization *Acropora* spp. abundance was low. A significant increase in tissue damage on *Acropora* spp. was recorded near the discharge outlet. These types of corals are renowned for high metabolism and growth and may be more susceptible to nutrient stress. Stress on corals may enhance mortality in the sewage area because a disproportionate amount of resources are allocated to maintenance, effectively reducing survival because of metabolic exertion.

Processes causing partial mortality may extend to mortality of whole colonies or populations. Large-polyped colonies, except for some faviids were relatively rare in the direct vicinity of the discharge. Low coral abundance appears indicative of localised stress for large-polyped corals (mussids, pectiniids, fungiids, dendrophylliids). Alternatively, propagules of these species may not have been available (eg. *Turbinaria* spp. are relatively uncommon on outer Whitsunday Islands). However, a similar phenomenon was reported by Tomascik and Sander (1987) who described predominantly small polyped species in polluted and high sediment environments. Recently, Edmunds and Spencer-Davies (1989) showed that the small polyped *Porites* spp. growing under stress became completely autotrophic. Large polyped corals may lack the nutritional flexibility observed in small polyped species and may be selected against under stress.

Coral growth

Fluorescence of *Porites* spp. varied within and between locations, and inter and intra-specifically. Although major episodic events such as the 1974 flood is exhibited in five of the six cores sampled, fluorescence is not consistent between all cores. This finding is a probable consequence of different run-off patterns and flora composition in the two bays (P. Isdale, pers. comm.).

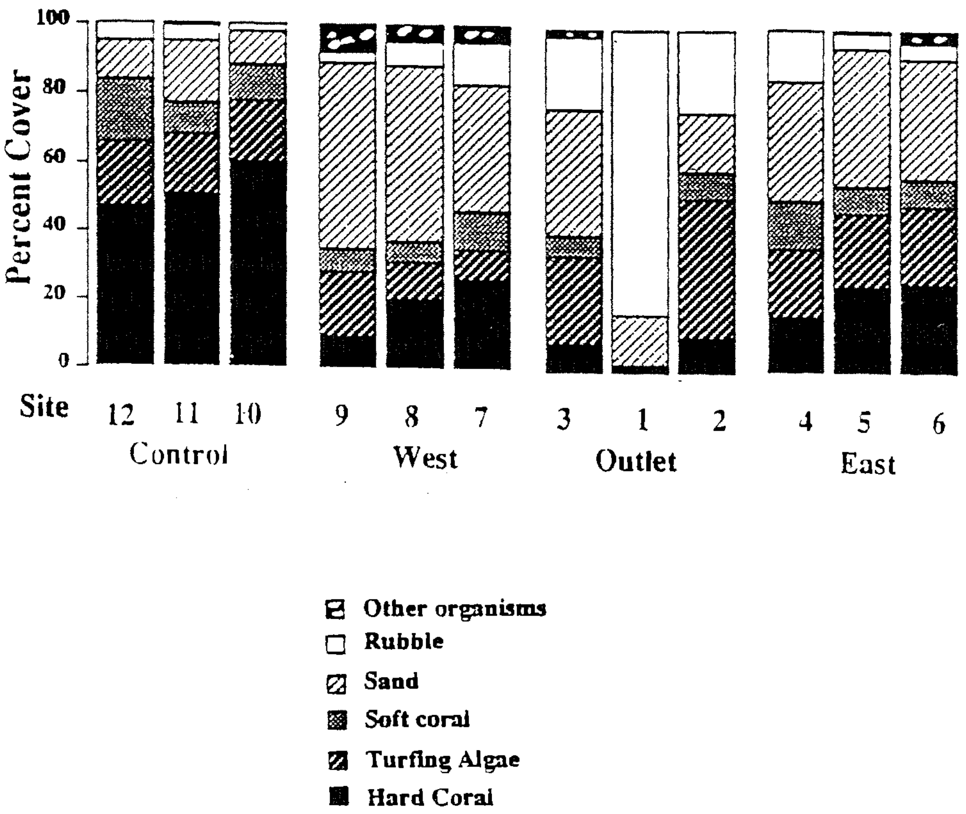
The core taken closest to the outlet, *Porites lutea*, grew considerably faster and was less porous than other colonies measured. Large extra-skeletal aggregations of crystals were evident on the coral coenosteum in two situations: 1 throughout the core near the sewage discharge; 2 prior to death of a colony well away from the discharge outlet. These crystal aggregations are a possible indicator of elevated nutrients. Similar results have recently been obtained by adding elevated nitrogenous nutrients to *Tridacna* spp. (giant clam) (Yellowless pers. comm.). However, accepting these corals as simple recorders of environmental stimuli is questionable as the elevation in concentration of another nutrient species, eg. phosphorous, has been shown to be toxic and suppress calcification and growth (Simkiss 1964; Rasmussen 1988).

Possible processes

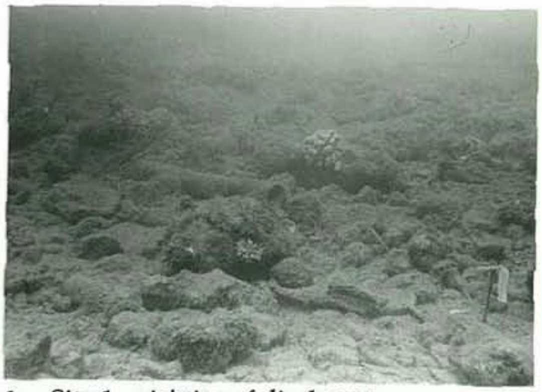
Sewage input has led to the co-incidence of restricted colonization, an instability within the community and enhanced growth of an established colony. Effects on colonization success may be a consequence of processes acting directly on the larvae before settlement, or via chemical cues making the substrate unsuitable for settlement. High post-settlement mortality may also restrict colonization.

It has been shown that increased nutrient levels enhance the production of algal biomass, and high algal biomass may reduce both opportunities for settlement, and survival of settled spat through competition. However, the outer Whitsunday Islands do not generally support macrophytes such as *Sargassum* spp. even in summer months (pers. obs.), and the abundance of turf algae did not seem particularly high about the sewage outlet. Therefore colonization suppression does not appear to be a consequence of algal competition. Direct effects of sewage discharge on colonization are possible, however underlying processes remain unclear. An improvement in water quality may reverse the effect, alleviating restraints on colonization which may progressively lead to an increase in coral abundance and diversity.

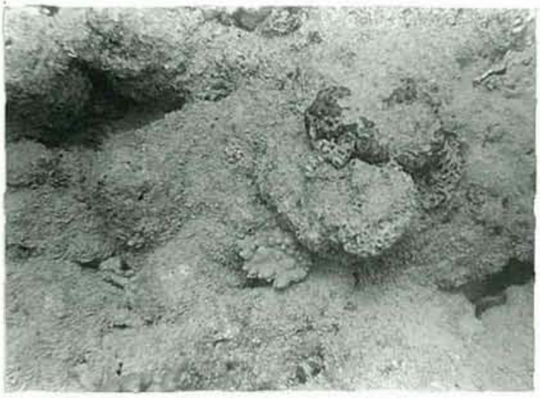
Figure 7.1 Percent cover of major benthic components derived from three 20m line transects at each site.



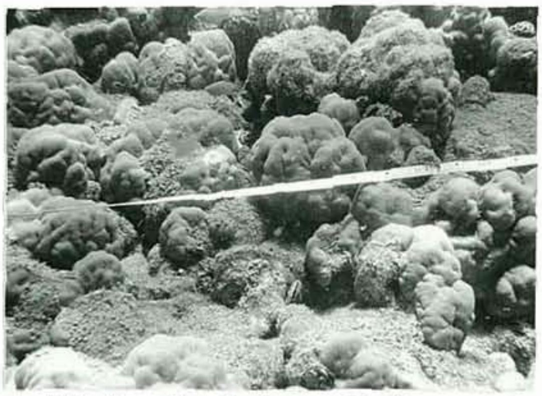
a. Sewage being discharged.



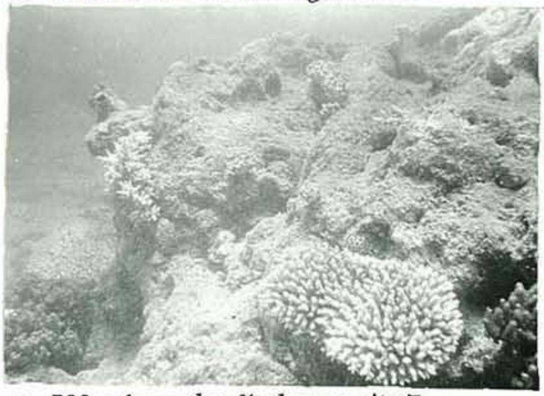
b. Site 1, vicinity of discharge.



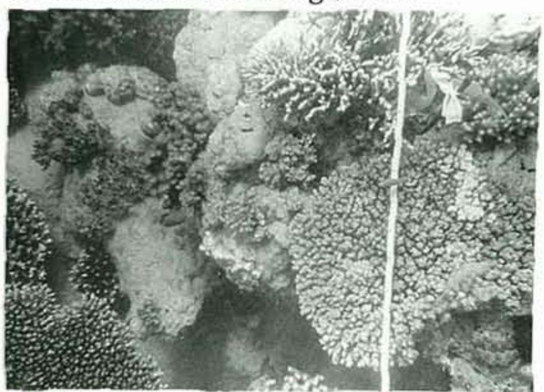
c. 20m from the discharge, site 2 .



d. 20m from the discharge, site 2.



e. 500m from the discharge, site 7.



f. 500m from the discharge, site 8.

g. Control area, site 10.

h. Control area, site 11.

Figure 7.2 Coral assemblages at varying distance from the sewage discharge, Hayman Island.

Figure 7.3 Schematic illustration of a Multi-Dimensional Scaling (MDS) analysis undertaken on spatial (sites 1-9 and control sites) and temporal data (1986 and 1998) simultaneously (Stress 0.19).

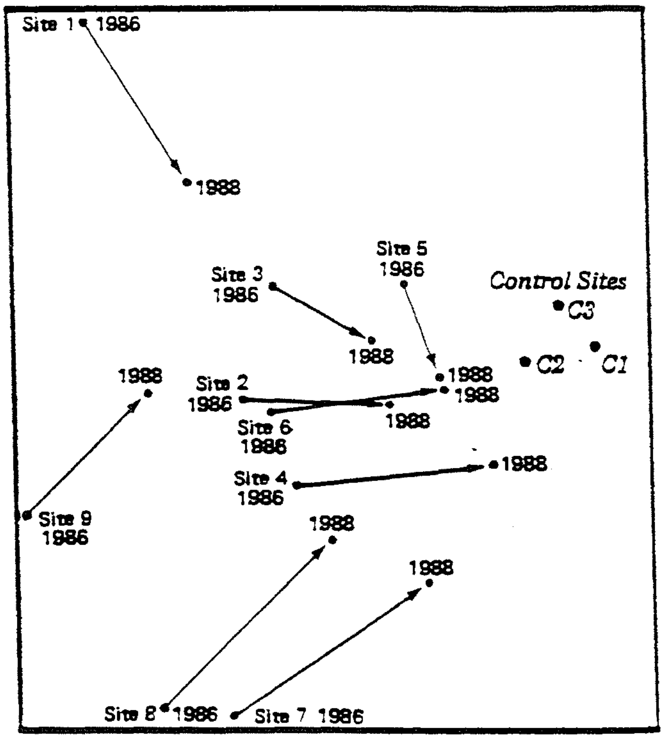


Figure 7.4 Relative change in abundance of hard and soft coral colonies between 1986 and 1988.

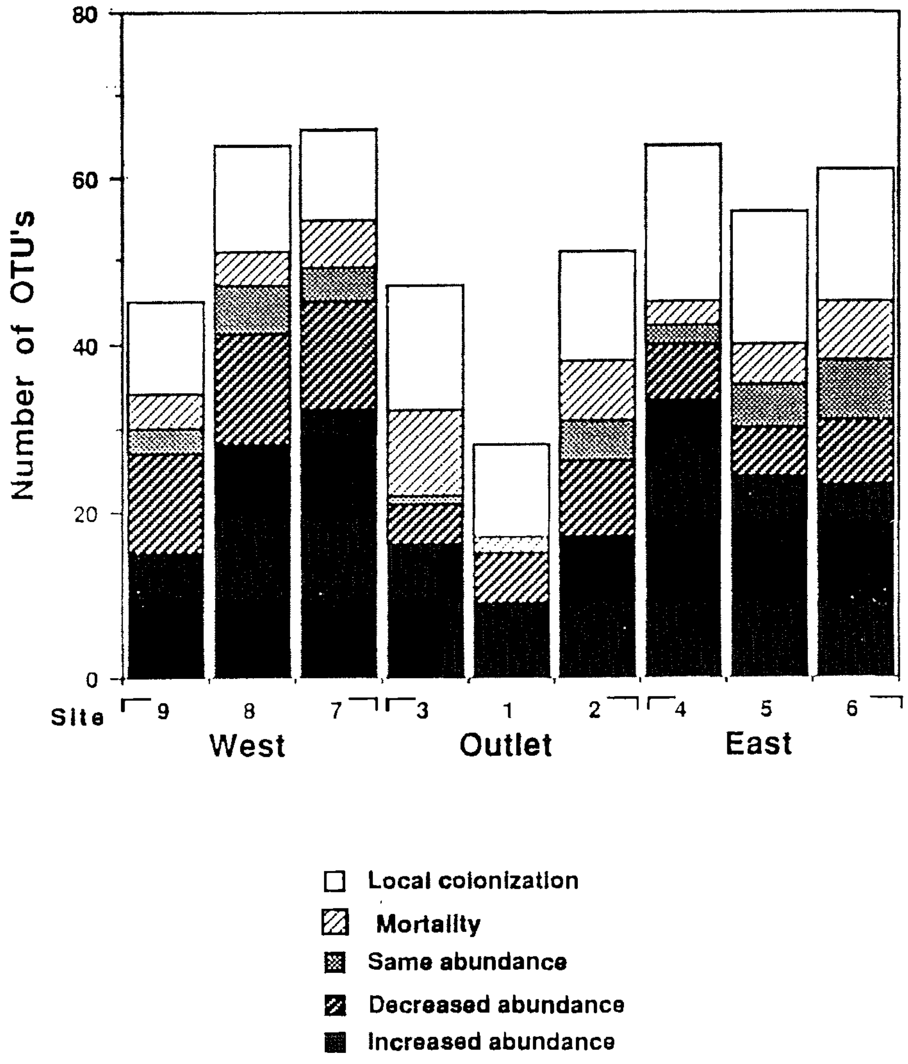


Figure 7.5 Temporal comparison of damage estimates for massive *Porites* spp.

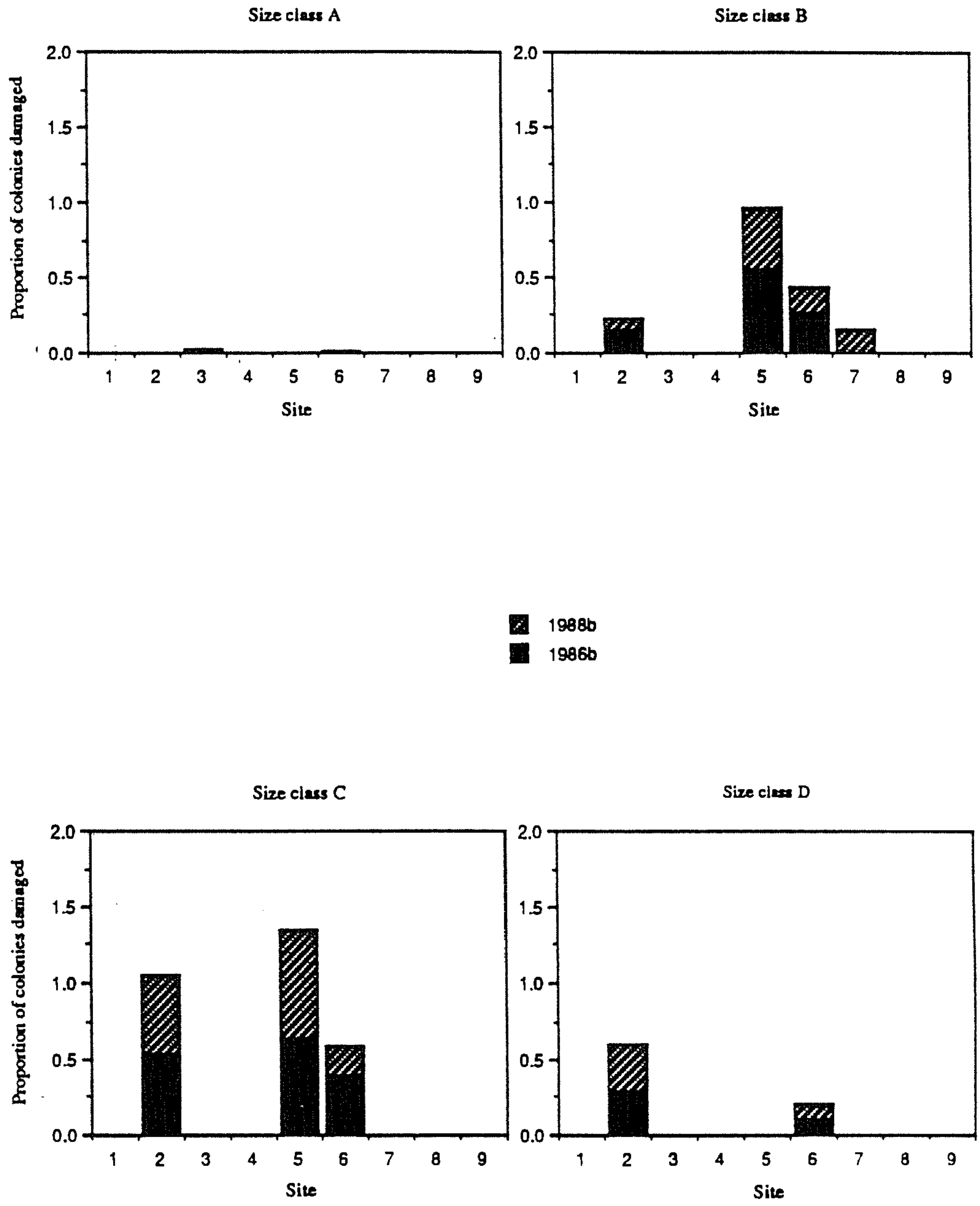
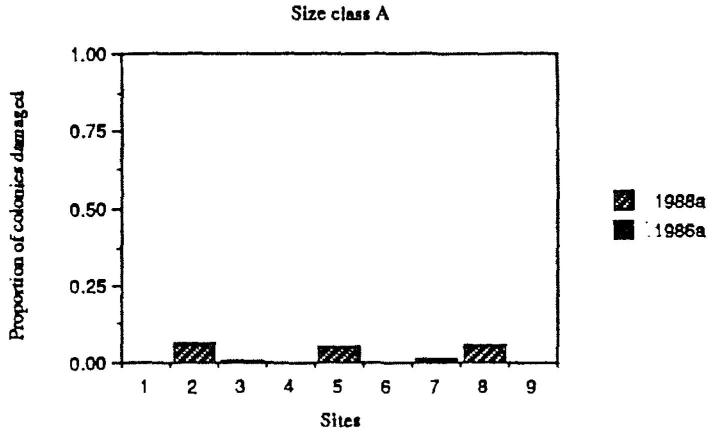


Figure 7.6 Temporal comparison of damage estimates for caespitose *Acropora* spp.



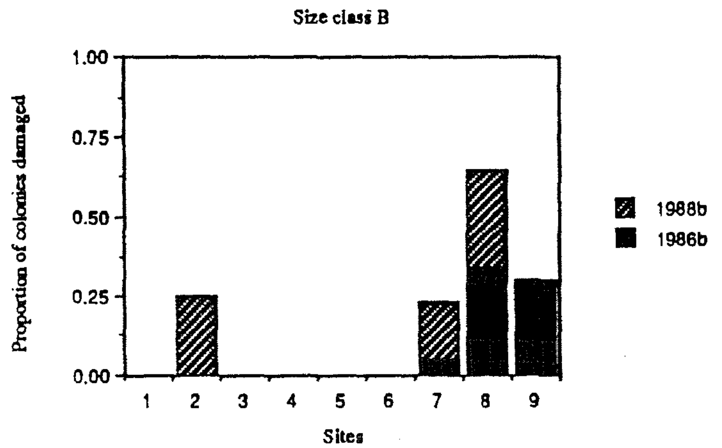


Figure 7.8. Six fluorescent images and x-radiographs from six *Porites* sp. cores, Hayman Island.

a. Longitudinal section of a core taken from a *Porites mayeri* colony in the control site, Blue Pearl Bay, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 7.4 mm/year, standard error 0.25.

b. Longitudinal section of a core taken from a *Porites lutea* colony in the control site, Blue Pearl Bay, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 7.7 mm/year, standard error 0.30.

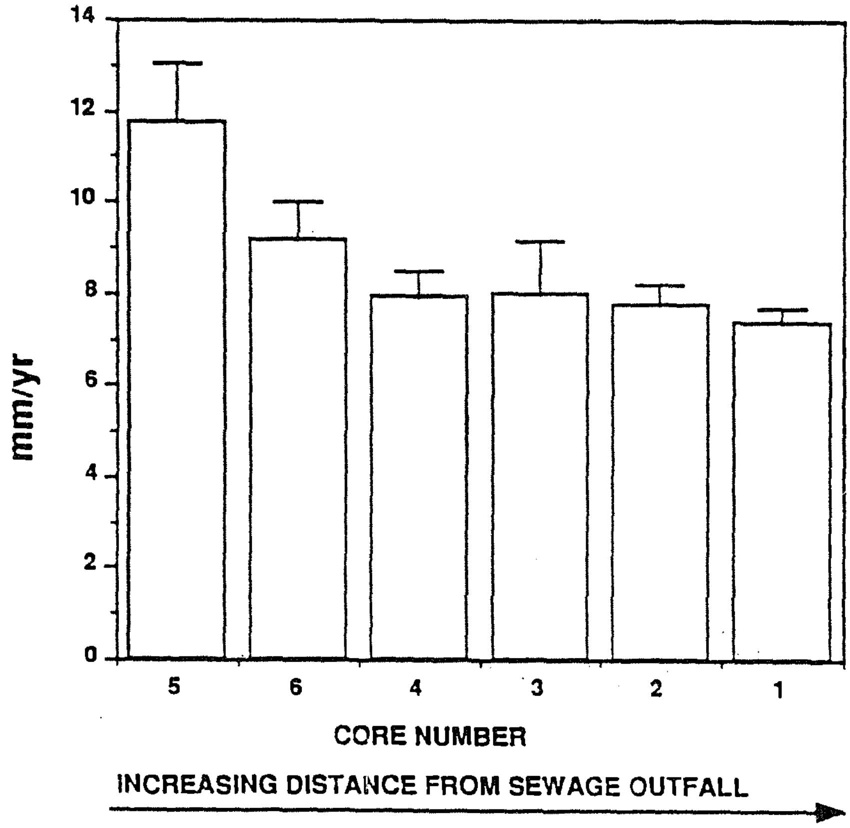
c. Longitudinal section of a core taken from a dead *Porites* spp. colony at site 7, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 8.0 mm/year, standard error 0.50.

d. Longitudinal section of a core taken from a *Porites mayeri* colony at site 7, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 7.7 mm/year, standard error 0.35.

e. Longitudinal section of a core taken from a *Porites lutea* colony at site 3, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 12.5 mm/year, standard error 0.69.

f. Longitudinal section of a core taken from a *Porites lutea* colony at site 4, Hayman Island.
Left: Positive print taken under ultra-violet light illustrating fluorescent banding.
Right: X-radiograph. Mean annual growth 8.1 mm/year, standard error 0.52.

Figure 7.7 Growth rates of six *Porites* spp., at increasing distance from the sewage outlet.



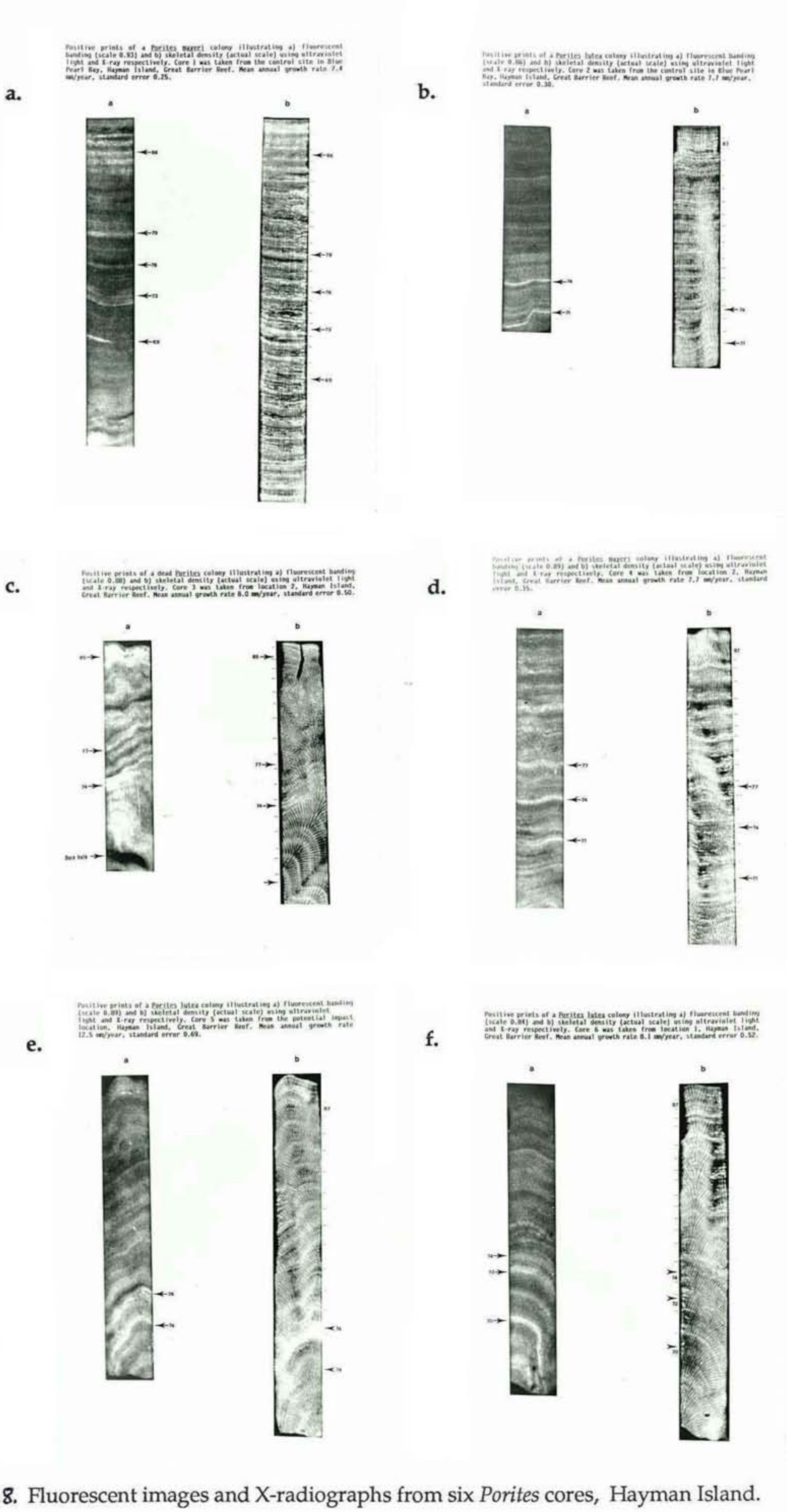


Figure 7.8. Fluorescent images and X-radiographs from six *Porites* cores, Hayman Island.

a.

b.

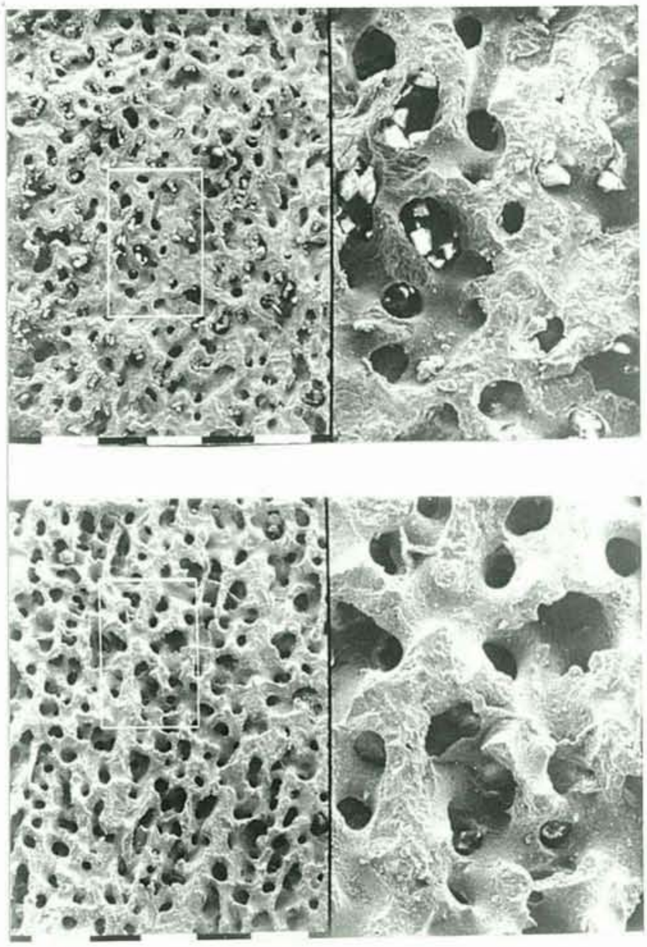


Figure 7.9 Scanned electronmicrographs of the cross-section of two *Porites* cores. **a.** Core 5, taken in the direct vicinity of sewage discharge showing extra-skeletal aragonite aggregations. **b.** Core 2, taken in the control site with no extra-skeletal aggregations.

CHAPTER 8. DISCUSSION AND CONCLUSION

Regional overview

This project set to assess why fringing reef development was poor at 21°S. Coral composition and dominance varied considerably between regions. Reefs in the Whitsunday Islands were large and diverse, both inshore and offshore. *Porites* spp. and faviids were the dominant corals. Inshore reefs in the Cumberland Islands were narrow, with low coral diversity and abundant macrophytes. Offshore islands supported large reefs with complex coral assemblages. Acroporidae and Pocilloporidae were most prolific on these islands. In the Northumberland Islands, reefs were small and restricted to windward slopes. *Montipora* spp./*Turbinaria* spp. and macrophyte (Phaeophyta) assemblages were most common. Further south, around the Keppel Islands, extensive reef flats were evident, and *Acropora* spp. dominated.

Environmental correlates

Depth and distance from the mainland were significantly correlated with species composition and abundance. Aerial exposure, upper and lower light limits and turbidity may best explain these reflected gradients. Descriptions on vertical stratification or zonation are prevalent in the literature (Wells 1954; Geister 1977; Chappell 1980). Done (1983), described zonation as "not due to environmental variability *per se* but to its stratification on the reef's surface (ie. environmental zonation)". Similarly, Chappell (1980) defined zonation as a response to numerous stress gradients attenuating down the reef slope (wave action, subaerial exposure, and illumination).

Corals can tolerate aerial exposure for some time, although prolonged and frequent exposure is harmful. Faviids appear most resilient to such conditions. In shallow depths coral settlement and growth may also be restricted by harmful ultra-violet light (Jokiel 1980). Light decreases most rapidly in the first 3m of water (Dustan 1982), however an input of suspended sediments along shallow inshore environments exacerbates this limiting effect and appears to compress the euphotic zone (Chapter 4). Lower limits may be simply a consequence of light attenuation with depth and the inability of corals to compensate their photosynthetic rates (McCloskey *et al* 1978). Low light conditions can induce morphological adaptations (Chapter 5) and cause stress (Chapter 6).

Vertical distribution patterns may stem from responses very early in a corals life-history and may not be merely a consequence of post-settlement selection. Indeed coral species appear phototactic at the pre-settlement stage (R. Babcock pers. comm.), and settle on environmental cues (Morse *et al* 1988). These adaptations ensure that optimal conditions are met very early in the life of a coral colony.

Recurring species were observed in four general zones: 1 the shallow macroalgae zone on inshore islands and the faviid, *Acropora* spp. zone on outer islands; 2 the reef crest zone which is composed of large monospecific colonies; 3 the upper diverse slope; 4 the pectiniid/agariciid zone on the lower slopes. However, reef crests were absent on Northumberland Island reefs (Curlew and Digby Islands).

Clearly, the reduced growth zones (above 3m and below 7m) described from geological data (Davies *et al* 1985) coincide with the upper macroalgal habitat < 3m and low light conditions > 7m. Reduced growth rates were thought to be a consequence of turbid water conditions and periodic reductions in salinity. However, consistently high macroalgal biomass is more likely to limit growth rather than episodic reductions in salinity. These conditions appear exacerbated in the Northumberland Islands, and a reduced euphotic zone limits coral growth between 3 and 7 metres.

Exposure was also highly significant in this study. The amount of water movement has often been described as a major determinant structuring coral assemblages (Bradbury and Young 1981; Done 1982, Sheppard 1982). In previous work, exposure has been described as a wave-attenuating factor, and corals were distributed in accordance (Roberts *et al* 1974; Rosen 1975; Geister 1977; Dana 1979). However, in this study the protective influence of bayheads were significantly correlated with the distribution of coral assemblages, indicating that a binary exposure scale is most appropriate for fringing reefs on continental islands - ie. sheltered or exposed.

No significant difference in temperature was detected between reefs in the Northumberland Islands, the Keppel Islands and Capricorn Bunker group further south (NOAA AVHRR satellite imagery, Kleypas 1991). Nutrient concentrations (NO_3, NH_4, $Si(OH)_4$) declined in a uniform manner from the Proserpine/O'Connell Rivers in the wet season and PO_4, $Si(OH)_4$ and suspended sediments were significantly correlated with tidal amplitude. However, quantitative gradients did not significantly correlate with benthic assemblages.

Coral morphology and size

Environmental gradients described above were significantly correlated with species composition. Similar sites were grouped independent of location, except in extreme habitats. However, once size was considered there was a strong location effect (ie. neighbouring sites and sites on adjacent islands grouped). This finding indicates that regional conditions have a strong influence on scleractinian colony growth.

A comparison of coral abundance, morphology and size on reefs in the Whitsunday and Northumberland Islands showed that although overall abundance did not significantly vary, significant morphological differences were evident. Major framework builders, massive and branching corals, dominated reefs between 20°S and 21°S. They significantly declined at 21°S (especially massive *Porites* spp., *Acropora formosa, Acropora nobilis, Porites cylindrica* and *Millepora tenella*). Their decline is not constrained by latitude as these corals were observed on the Keppel Islands and the Capricorn Bunker reefs (further offshore 23°S). Fast growing, encrusting and plate-like corals were dominant in the Northumberland Islands. Even the normally massive *Porites* spp. were encrusting. Many other caespitose colonies had tightly packed branches in the Northumberland Islands. Regional changes in morphology are likely to be a response towards maximising available light.

The two regions supported coral colonies of considerably different size structure. Colonies were generally between 11-50cm in the Northumberland Islands, however size was more variable in the Whitsunday Islands. These results suggest that the Northumberland Islands are subject to low recruitment rates, high post-settlement mortality and/or restricted growth. This phenomena appears to be a consequence of environmental conditioning where the Northumberland reefs are under more stress.

Tidal amplitude became a highly significant gradient when composition and size were analysed, indicating tidal fluctuations, indirectly, have a strong negative influence on colony growth. These results were apparent only for scleractinian species, not alcyonarian species. Large tidal fluctuations (10m) cause considerable water movement across shallow shoals which induces high turbidity (Kleypas 1991). Low light conditions, a consequence of high turbidity, can cause coral stress and selective coral mortality (Rogers 1979).

Reef growth

Fast growing corals were significantly more abundant in the Northumberland Islands. Coral assemblages were mainly *Montipora* spp., *Turbinaria* spp., pocilloporids, *Sinularia* spp., *Briareum* spp., *Lobophytum* spp. and caespitose *Acropora* spp. Transient assemblages and high colony turnover may extend to transient reefs, as suggested by the dead Holocene reef on Marble Island. Geological evidence further indicates that a 4,000 year delay in reef initiation was evident at Middle Percy Island (Kleypas 1992). In total the Northumberland region appears to be stressful environment for coral growth. In terms of whole reef growth high turbidity may have consistently reduced light levels and restricted Holocene reef growth by inducing:

1. A reduced euphotic zone;
2. A delay in reef initiation;
3. Lack of major framework builders and mainly encrusting, platelike and columnar coral morphologies;
4. Transient coral assemblages;
5. Suppressed larval recruitment or high post-settlement mortality.

Natural disturbance

The prolonged reduction in salinity, associated with the 1991 Queensland floods (cyclone'Joy'), caused a considerable decline in live coral biomass in the Keppel Islands. The dominant coral genus *Acropora* was most affected. On reefs in the Whitsunday region, there was minimal mortality amongst shallow corals, except *Acropora* spp., however many deep water pocilloporids (eg. *Seriatopora hystrix*) were killed. Low light levels associated with the cyclone may have been responsible for this mortality.

The coral species most affected by the disturbance were opportunists, a definition given to species that have the following traits; fast-growing, less dense, settle quickly and locally (Jackson and Hughes 1985) and metabolise faster (Jokiel and Coles 1974). These traits suggest an ephemeral nature which allows species to maintain a high reproductive output and undergo rapid growth on settlement. These type of species appear most vulnerable to physio-chemical stress.

Although large scale disturbances tend to eliminate entire assemblages and reduce local diversity (Keppel Islands), mild disturbances remove vulnerable opportunists and prevent space monopolisation (Whitsunday Islands). Space is made available for recruitment, effectively enhancing local diversity. Therefore, intermittent exclusion events such as monsoonal depressions and associated rainfall may be essential in maintaining regional diversity on long time scales.

Anthropogenic disturbance

Temporal change in species composition varied in accordance with distance from the sewage outlet at Hayman Island. Discernible effects were evident for 20-40 metres either side of the outlet with a maximum discharge of 500 m^3/day. Sites closest to discharge had the lowest coral cover and lowest number of taxa, colonization was restricted, the greatest proportion of local extinction and colonization of new taxa was apparent between the two observations (community instability). Partial mortality of *Acropora* spp. significantly increased in the direct vicinity of the outlet as opposed to no change in *Porites* spp.. Faviids were most prevalent and large polyped pectiniids and fungiids were absent in the direct impact area. Paradoxically, *Porites* spp. corals that were established in the direct vicinity of the discharge appeared to grow faster than elsewhere.

The study on the effect of sewage discharge into Kaneohe Bay is highly regarded (Maragos *et al* 1985). It is often assumed that there was a total lack of calcifying organisms in the direct vicinity of discharge, prior to the diversion experiment in 1977-78 (Smith *et al* 1981), however Maragos *et al* (1985) reported *Porites* and *Montipora* species in the south bay (ie. in the direct vicinity of discharge) but in much less abundance than elsewhere in the bay. These species appear most tolerant to adverse conditions. Similarly, the Northumberland region supported mainly *Montipora* spp., *Turbinaria* spp. and faviids species and large macrophytes. Change toward such an assemblage is indicative of change towards extreme conditions. Beyond these extremes corals can not function normally and reefs undergo degradation.

If changes in water quality were to take place on a regional scale through mild, although chronic, eutrophication, changes detrimental to community structure may be minimal and localised. Impact of elevated nutrient concentrations may be indistinguishable as biological systems have an inherent capacity to mask the nutritional status of the reef through hydrolysis of dissolved organics by enzyme activity (Dunlap 1985) and benthic assimilation.

Once a threshold is reached coral response may result in suppressed colonization, high turnover rates and reduced taxa. If the two case studies are considered in unison, natural disturbance events would be expected to continue. However, recovery processes may be slowed through anthropogenic input.

Conclusions

Coral distribution and abundance patterns were reflected along several environmental gradients; tidal fluctuations, depth, exposure, and distance from the mainland. These correlations suggest that the local and regional conditions may have a continual influence on species composition and growth form. A corollary of this is that coral/coral interactions may have minimal influence on macroscale distribution and abundance patterns, defining only small scale patterns and local variability.

Regional distribution patterns varied considerably. As most corals broadcast their gametes, potentially they allow their distribution range to be extended. Favourable connectivity has been reported in the inshore region in the southern Great Barrier Reef and distribution patterns may not be a prime consequence of inefficient dispersal, rather a result of differential post-settlement survival in environments varying in regional conditions.

The magnitude and frequency of disturbance appears to influence local and regional diversity patterns. Periodic exclusion of opportunistic corals by mild disturbance events may be essential in maintaining diversity on long time scales. On the other hand, large disturbance events reduce local diversity. Locally elevated nutrient concentrations appears to suppress colonization and cause community instability.

This project examined why fringing reef development was poor around 21°S. Extreme tidal fluctuations appeared to influence coral morphology and exclude major framework builders. Encrusting and platey corals are more adapted to the Northumberland conditions however their encrusting growth does not contribute overly to reef development. Consistently high turbidity leads to reduced light transmission, which appears to have restricted coral growth and reef initiation to such a degree that only limited reef accretion has occurred in the Northumberland Islands through the Holocene period.

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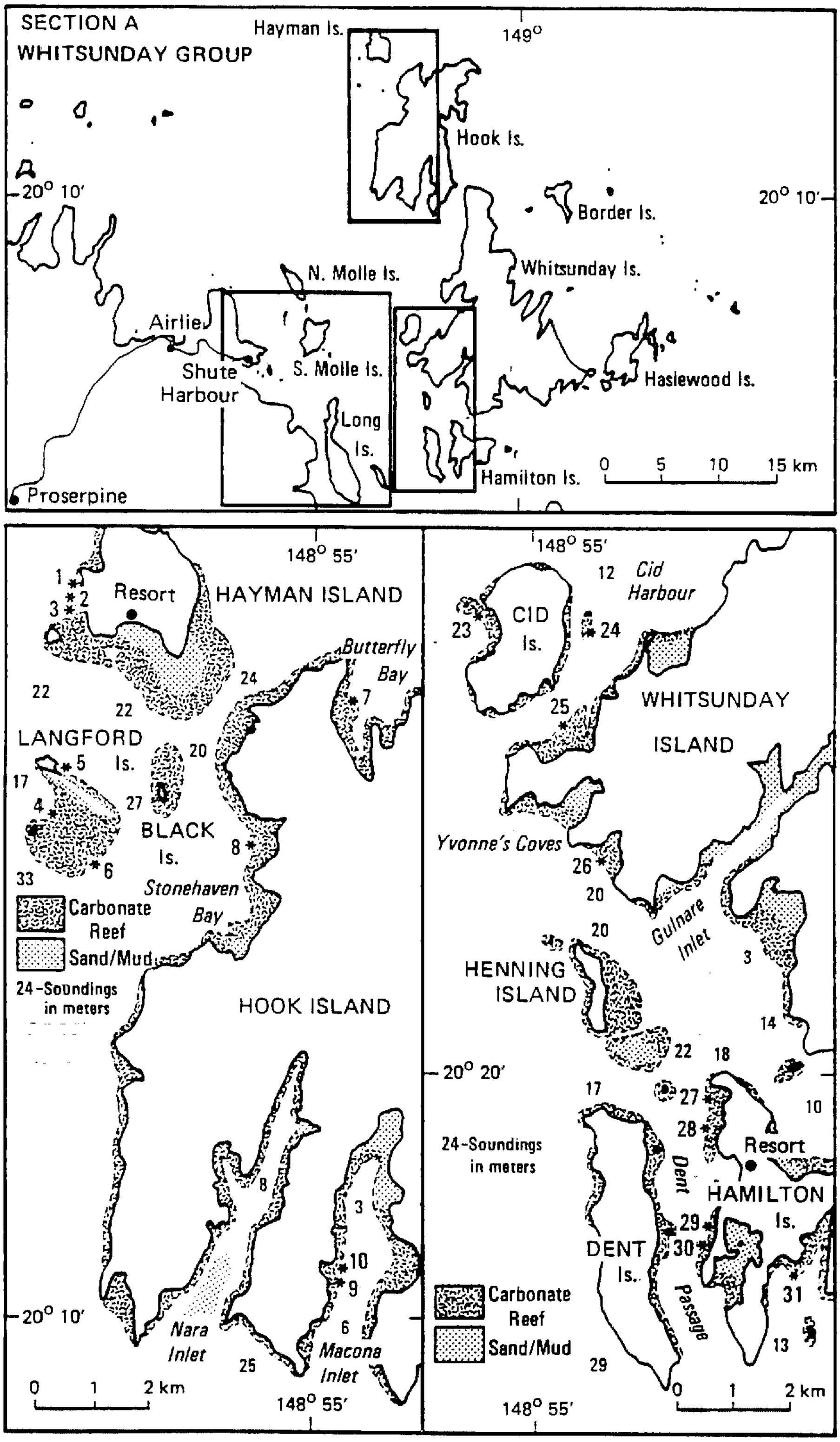
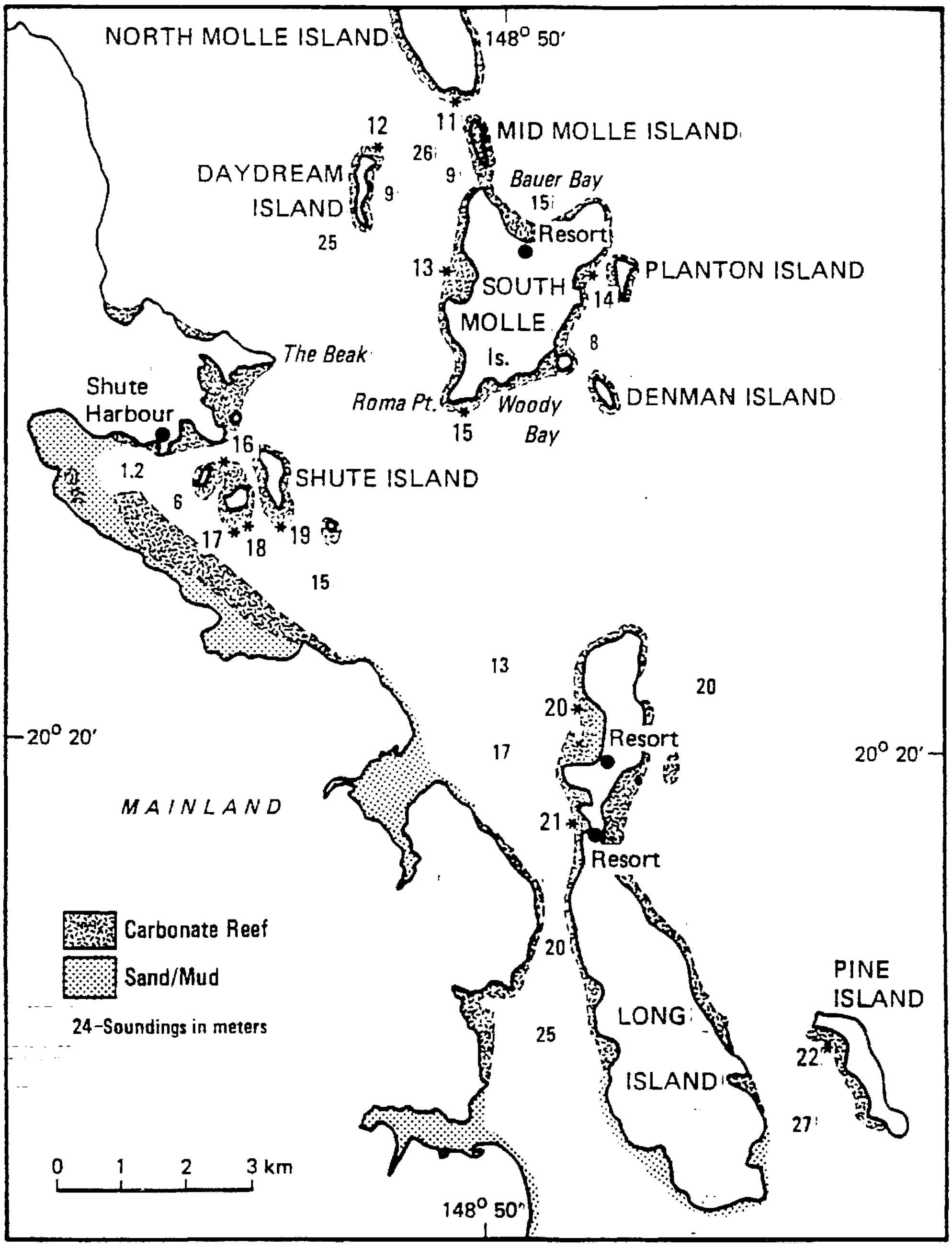
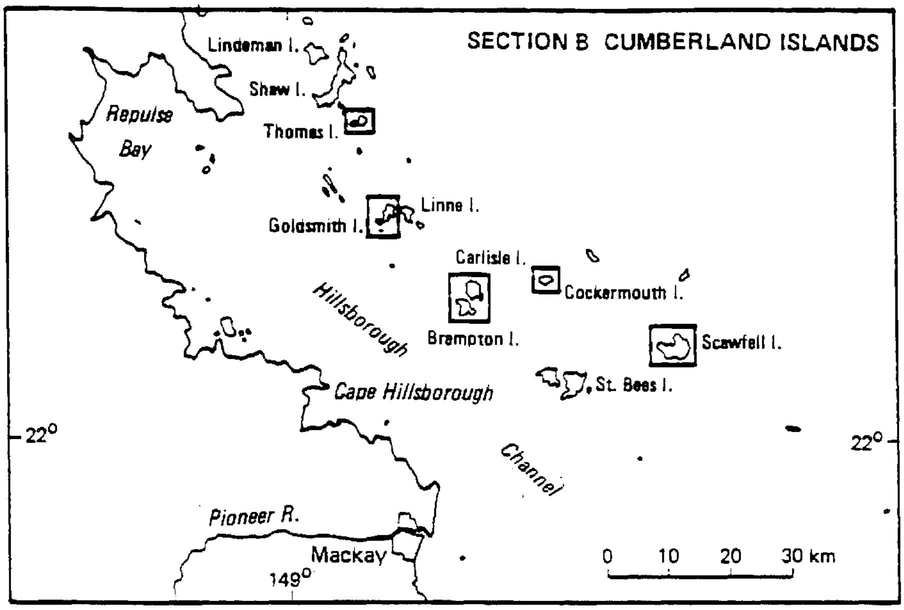
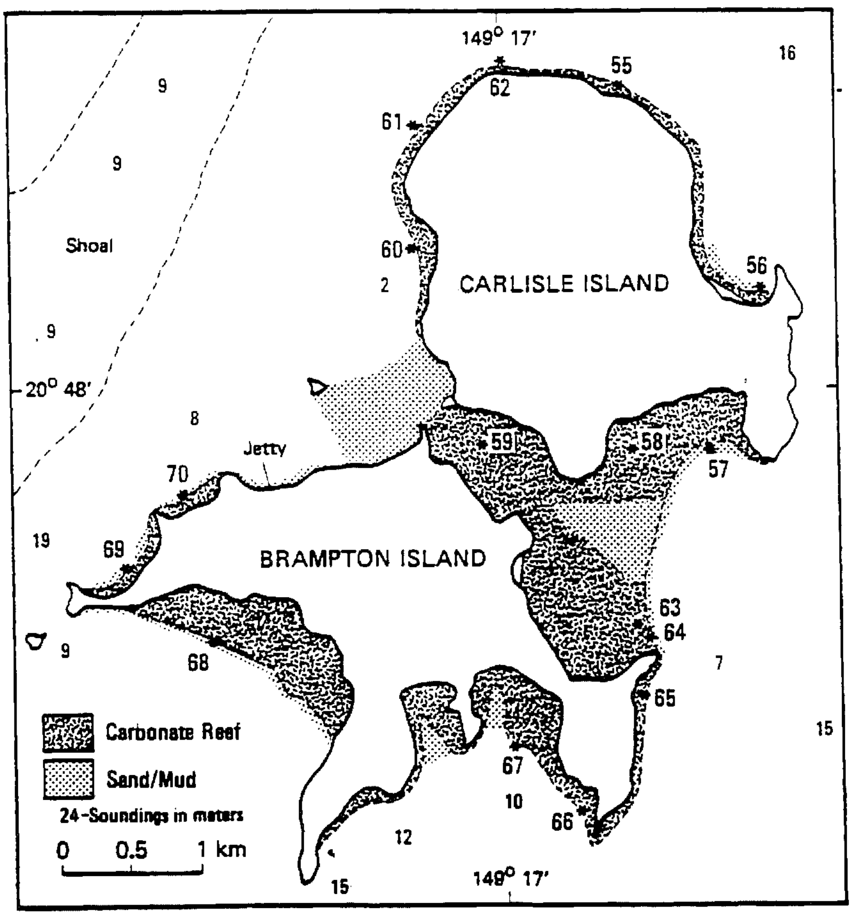
APPENDICES

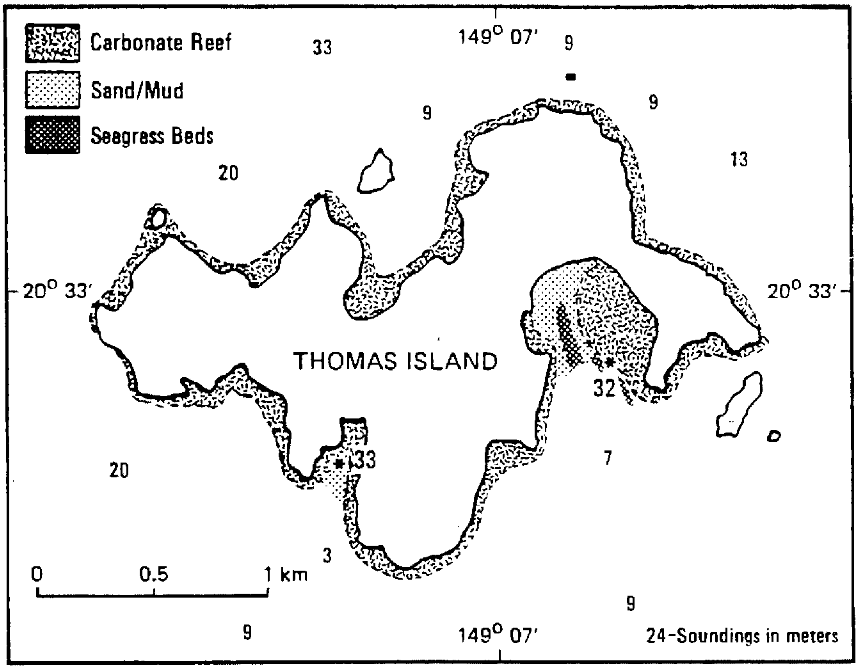
APPENDIX 1. Location of study sites.

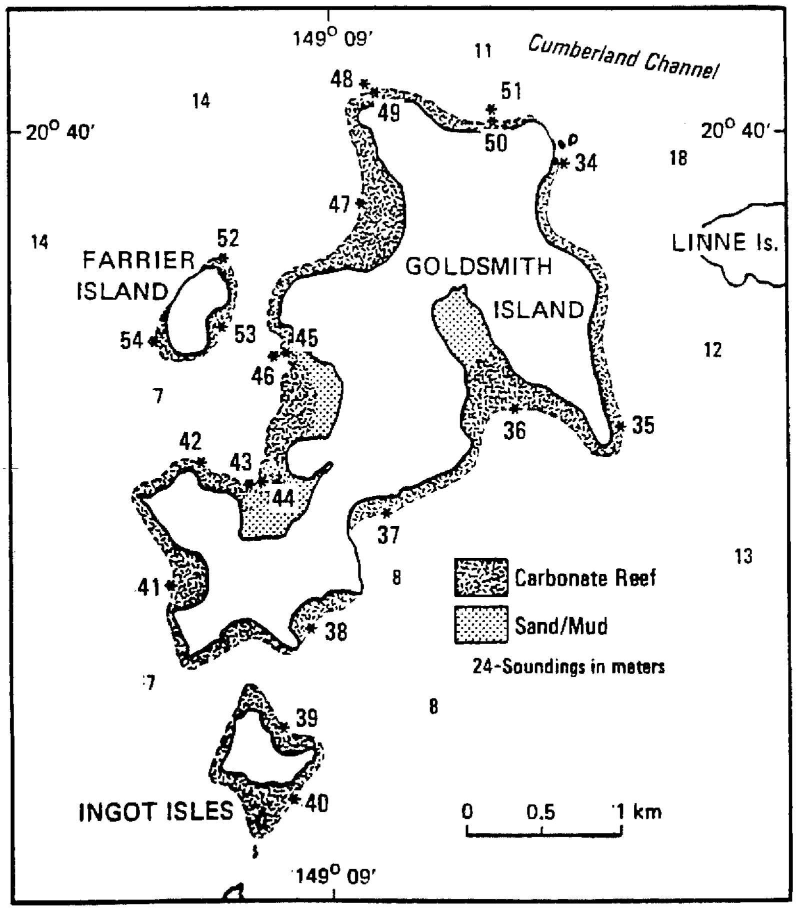


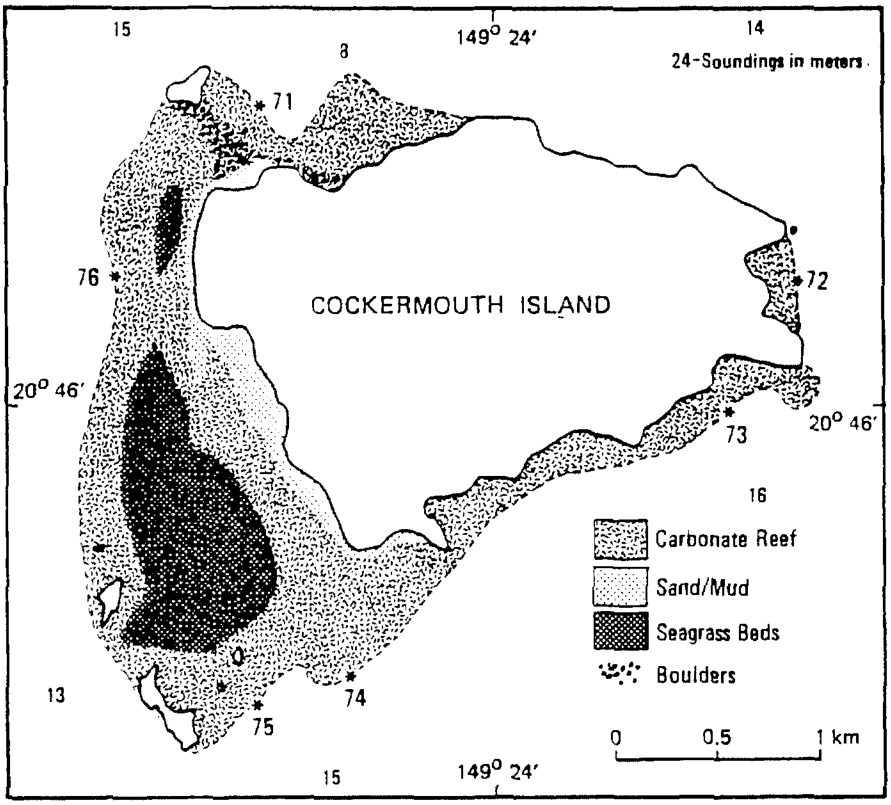

NORTH MOLLE ISLAND
148° 50′
MID MOLLE ISLAND
DAYDREAM ISLAND
Bauer Bay
Resort
SOUTH MOLLE Is.
PLANTON ISLAND
The Beak
Shute Harbour
Roma Pt.
Woody Bay
DENMAN ISLAND
SHUTE ISLAND
20° 20′
MAINLAND
Resort
Resort
LONG ISLAND
PINE ISLAND
Carbonate Reef
Sand/Mud
24-Soundings in meters
0 1 2 3 km
148° 50′

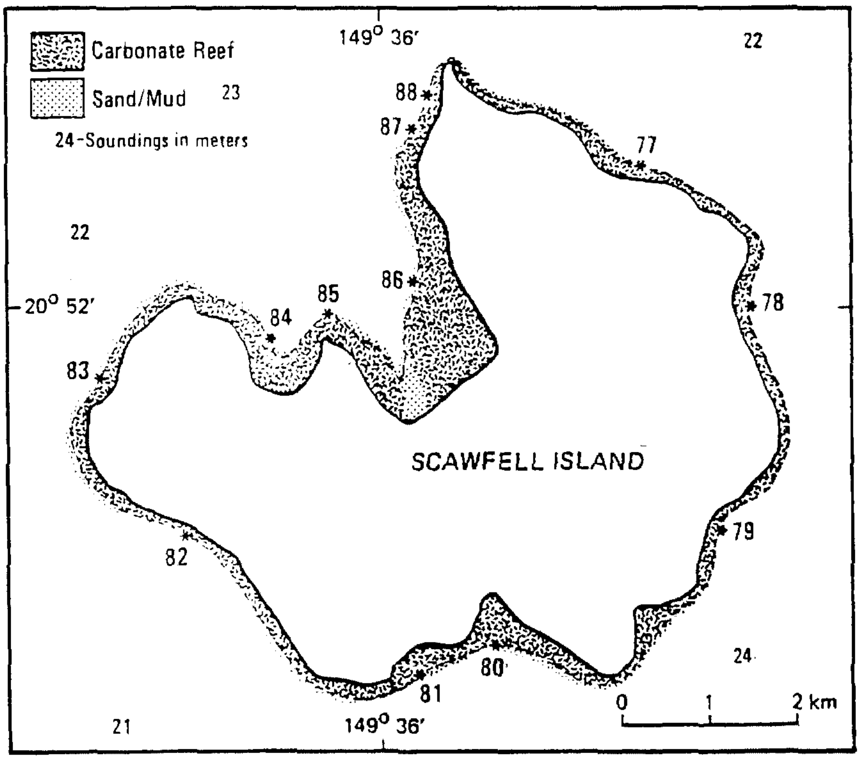

SECTION B CUMBERLAND ISLANDS
Lindeman I.
Shaw I.
Repulse Bay
Thomas I.
Linne I.
Goldsmith I.
Carlisle I.
Cockermouth I.
Hillsborough
Brampton I.
Scawfell I.
St. Bees I.
Cape Hillsborough
22°
22°
Channel
Pioneer R.
Mackay
149°
0 10 20 30 km

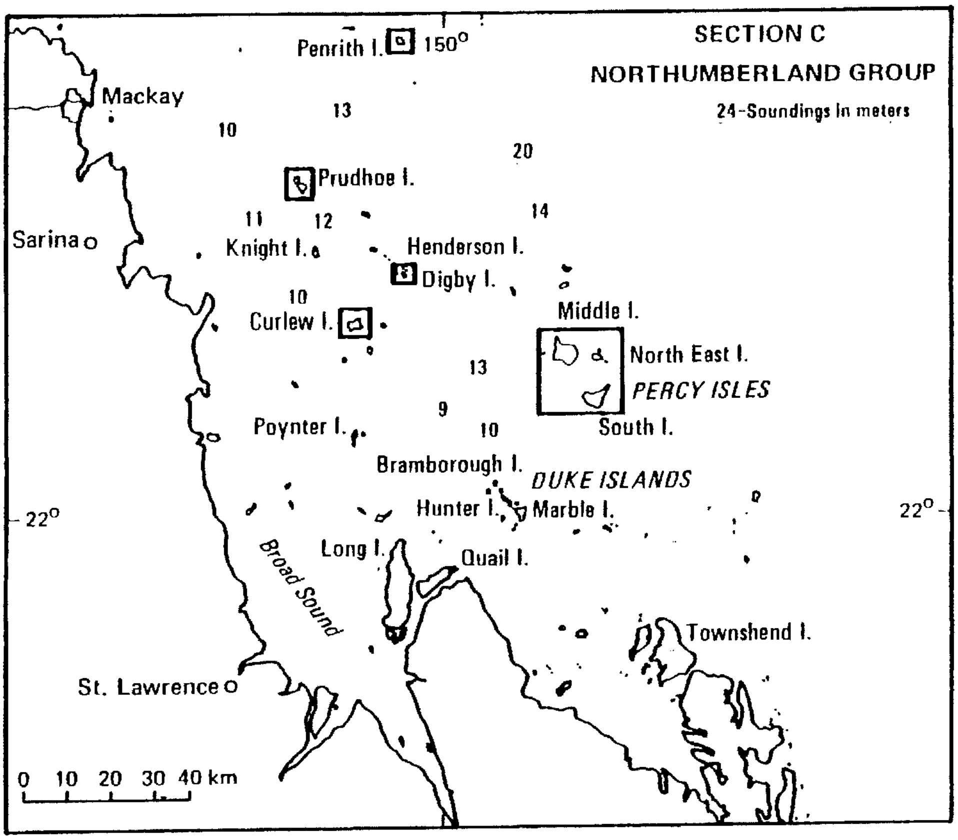

149° 17'
16
55
62
9
61
9
Shoal
60
56
CARLISLE ISLAND
2
9
20° 48'
8
59
58
57
Jetty
70
19
69
BRAMPTON ISLAND
63
64
9
68
7
65
Carbonate Reef
Sand/Mud
24-Soundings in meters
15
67
10
66
12
0 0.5 1 km
15
149° 17'

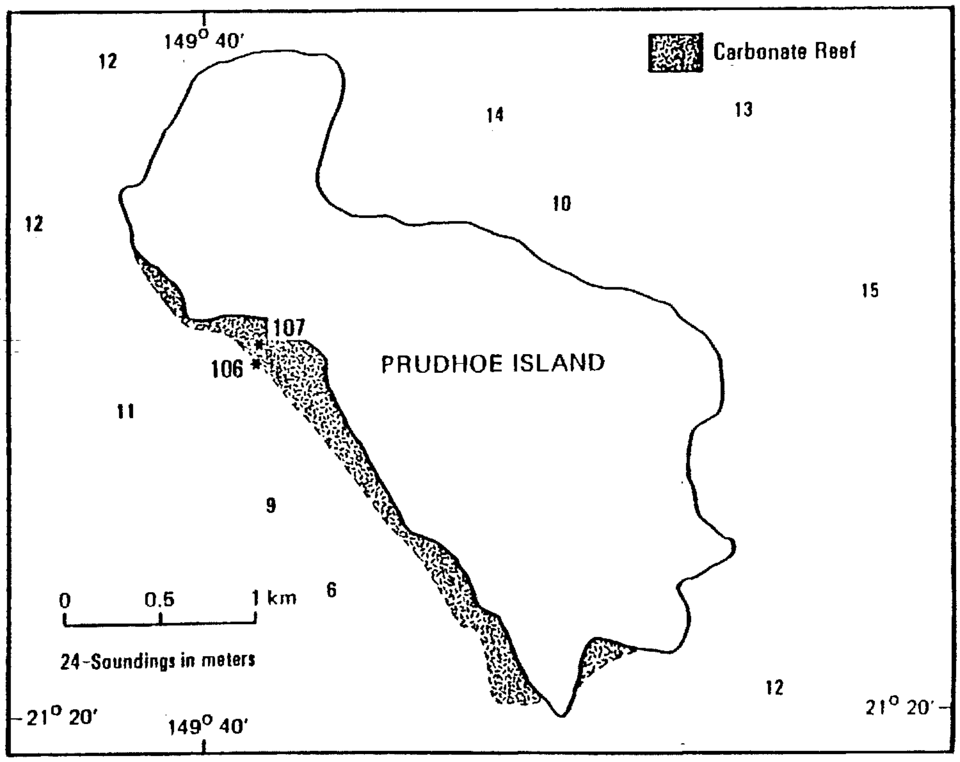

Carbonate Reef
Sand/Mud
Seagrass Beds
149° 07'
20° 33'
THOMAS ISLAND
32
33
0 0.5 1 km
24-Soundings in meters
33
9
9
9
13
20
20
7
3
9
9

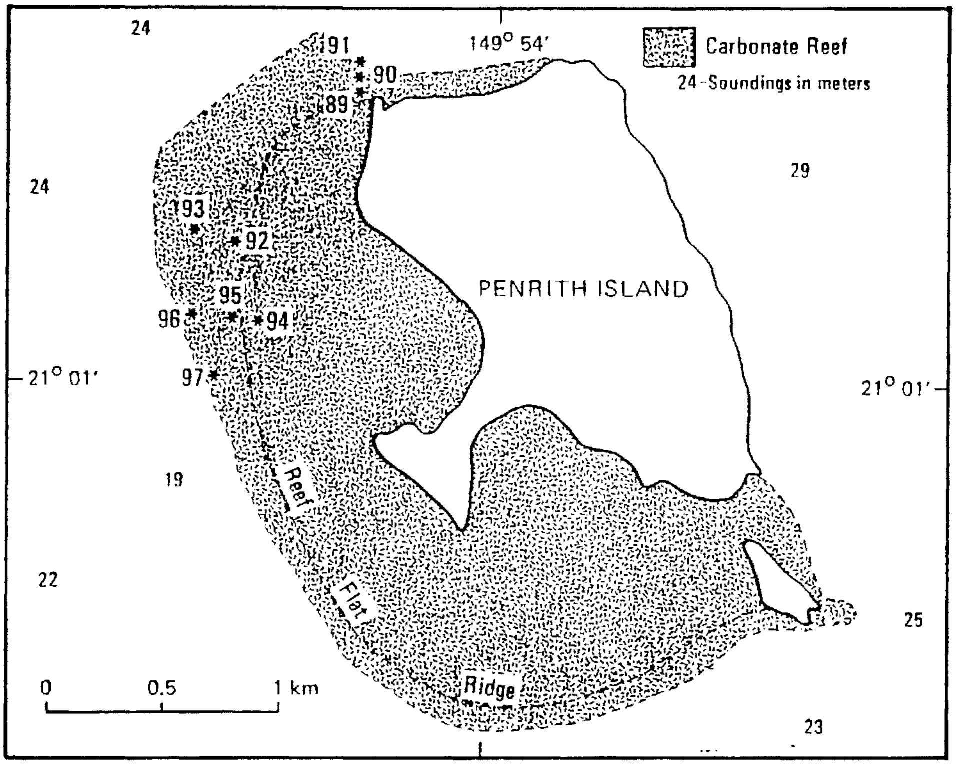

149° 09'
Cumberland Channel
20° 40'
FARRIER ISLAND
GOLDSMITH ISLAND
LINNE Is.
INGOT ISLES
Carbonate Reef
Sand/Mud
24-Soundings in meters
0 0.5 1 km
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
11
14
14
18
12
7
13
8
8
7

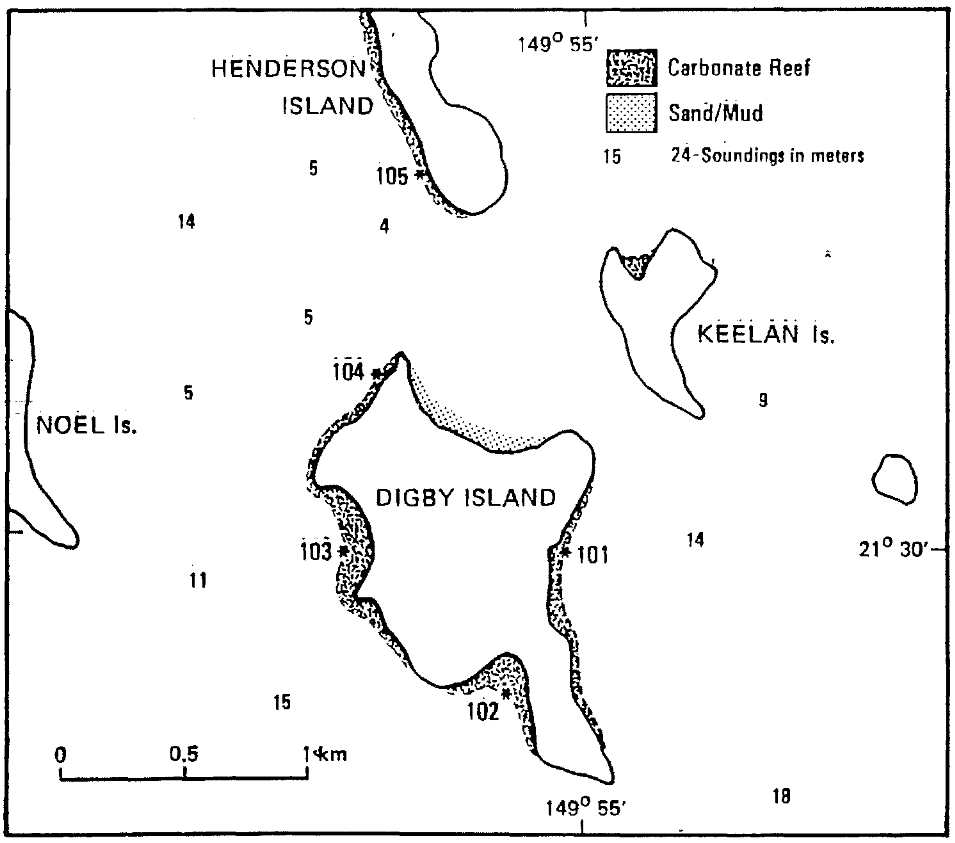

15
8
149° 24'
14
24-Soundings in meters
71
72
76
COCKERMOUTH ISLAND
20° 46'
73
20° 46'
16
Carbonate Reef
Sand/Mud
Seagrass Beds
Boulders
13
74
75
0
0.5
1 km
15
149° 24'

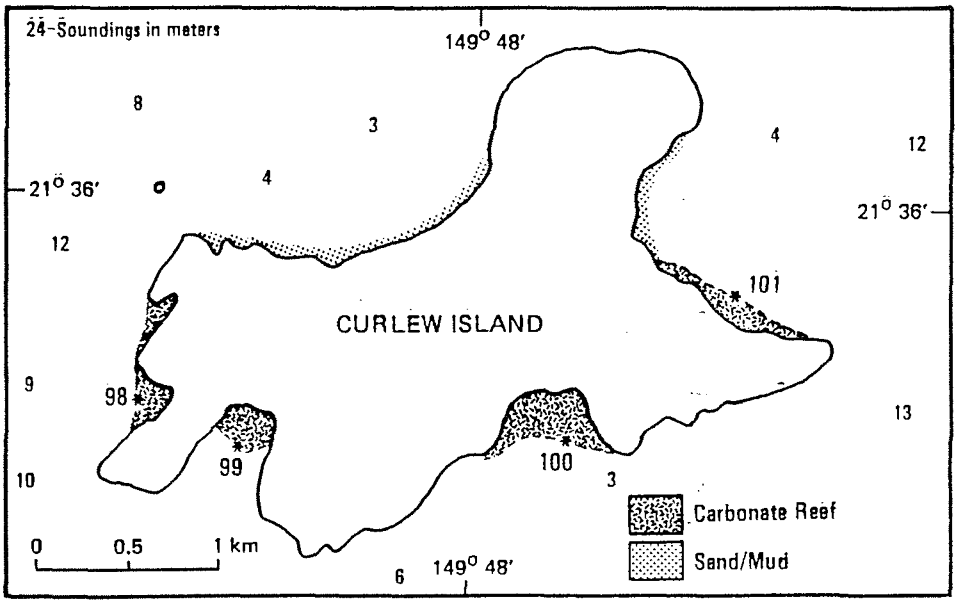

Carbonate Reef
Sand/Mud
23
24-Soundings in meters
149° 36'
22
88
87
77
22
86
85
84
20° 52'
78
83
SCAWFELL ISLAND
79
82
80
81
24
0
1
2 km
21
149° 36'

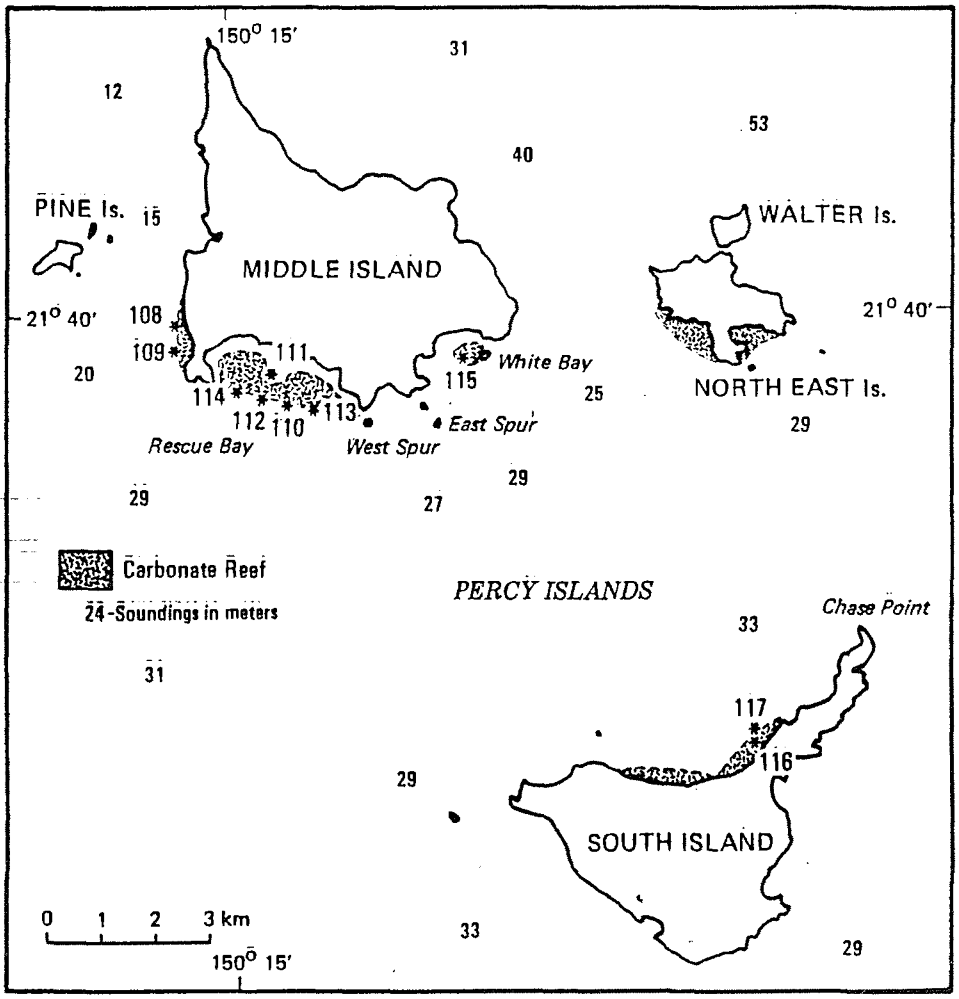

SECTION C
NORTHUMBERLAND GROUP
24-Soundings in meters
Penrith I.
150°
Mackay
Prudhoe I.
Sarina
Knight I.
Henderson I.
Digby I.
Middle I.
Curlew I.
North East I.
PERCY ISLES
South I.
Poynter I.
Bramborough I.
DUKE ISLANDS
Hunter I.
Marble I.
22°
22°
Broad Sound
Long I.
Quail I.
Townshend I.
St. Lawrence
0 10 20 30 40 km

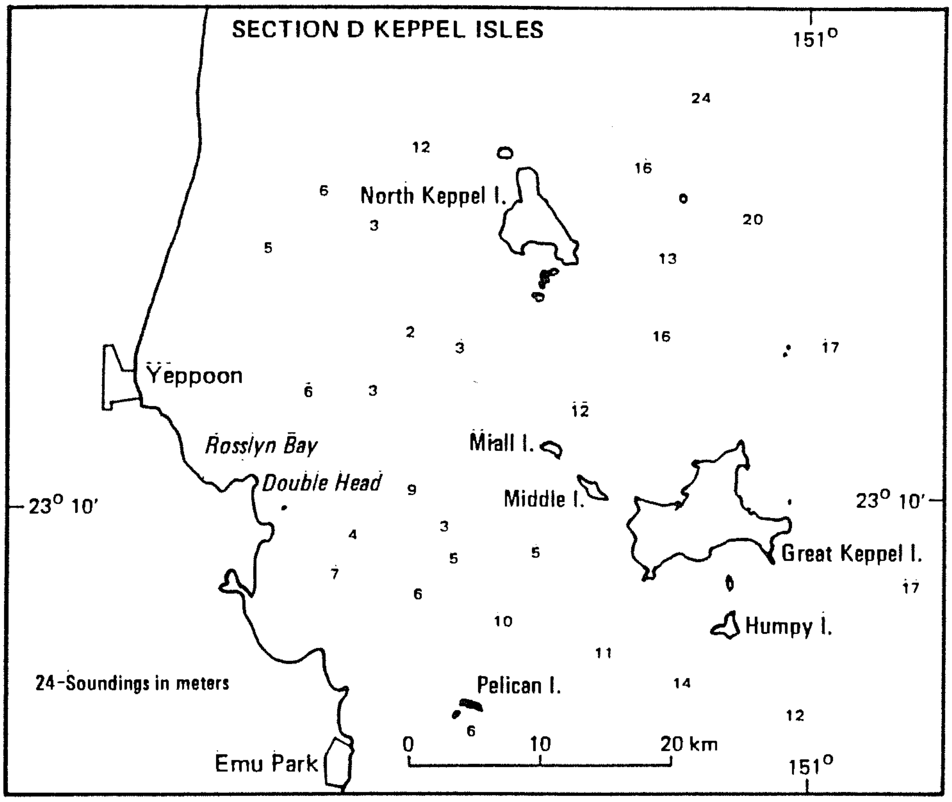

149° 40′
Carbonate Reef
PRUDHOE ISLAND
107
106
0 0.5 1 km
24-Soundings in meters
21° 20′
149° 40′
21° 20′

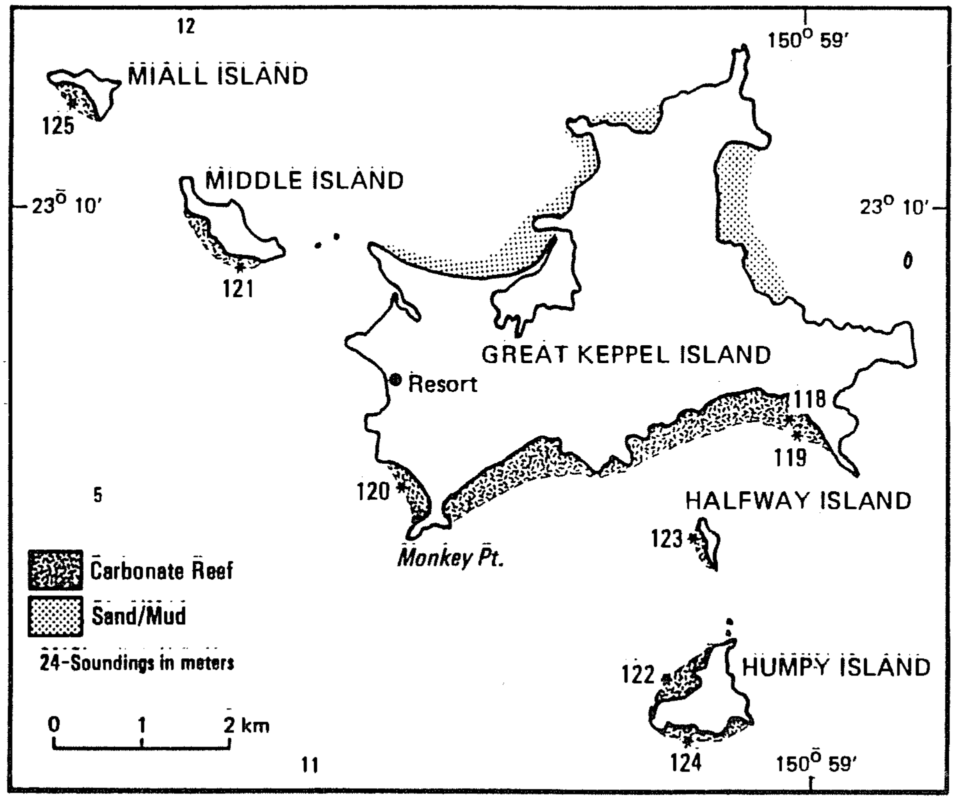

24
91
149° 54′
Carbonate Reef
24-Soundings in meters
90
89
24
29
193
92
PENRITH ISLAND
95
96
94
21° 01′
97
21° 01′
19
Reef
Flat
22
25
0
0.5
1 km
Ridge
23


HENDERSON
ISLAND
149° 55′
Carbonate Reef
Sand/Mud
15
24-Soundings in meters
5
105
14
4
KEELAN Is.
5
104
5
NOEL Is.
9
DIGBY ISLAND
103
101
14
21° 30′
11
15
102
0
0.5
1 km
149° 55′
18


24-Soundings in meters
149° 48'
8
3
4
12
21° 36'
4
12
21° 36'
101
CURLEW ISLAND
9
98
13
99
100
10
3
Carbonate Reef
0
0.5
1 km
Sand/Mud
6
149° 48'


150° 15'
31
12
53
40
PINE Is.
15
WALTER Is.
MIDDLE ISLAND
21° 40'
108
21° 40'
109
111
White Bay
20
115
25
NORTH EAST Is.
114
112
110
113
East Spur
29
Rescue Bay
West Spur
29
29
27
Carbonate Reef
24-Soundings in meters
PERCY ISLANDS
Chase Point
33
31
117
116
29
SOUTH ISLAND
0
1
2
3 km
33
29
150° 15'


SECTION D KEPPEL ISLES
151°
North Keppel I.
Yeppoon
Rosslyn Bay
Double Head
Miall I.
Middle I.
Great Keppel I.
Humpy I.
Pelican I.
Emu Park
23° 10′
24-Soundings in meters
0 10 20 km


150° 59′
MIALL ISLAND
125
MIDDLE ISLAND
121
23° 10′
GREAT KEPPEL ISLAND
Resort
118
119
120
Monkey Pt.
HALFWAY ISLAND
123
HUMPY ISLAND
122
124
Carbonate Reef
Sand/Mud
24-Soundings in meters
0 1 2 km

APPENDIX 2. Regional benthic data. Absolute abundance of coral colonies expressed in size classes. Size classes 1-10cm, 11-50cm, 51-100cm, 101-300cm, > 300cm.

Northern Whitsunday Islands.

Operational Taxonomic Units	SITE									
	1	2	3	4	5	6	7	8	9	10
Caulastrea sp.	-	-	-	1	-	-	-	-	-	-
Favia spp.	75,51,1	29,23,2	61,23	0,4	2,48	16,6	4,11	30,34	0,6,2	25,44,3
Favites spp.	55,52	32,52,1	71,29	0,3	5,26	14,16	0,6	7,25	10,27	30,63
Goniastrea spp.	41,18	21,13,1	88,15,1	0,1	6,18	30,14	5,9	92,16,3	8,26	12,38
Platygyra spp.	3,7	3,5,1	4,3	1,6,1	0,4	0,8	4,1	0,10	1,6	0,2
Leptoria phrygia	4,5	0,5	7,2	-	-	-	0,1	2	0,1	-
Oulophyllia crispa	-	0,1	-	0,1	0,4	2,0	0,4	-	0,3	0,1
Montastrea spp.	-	-	-	-	0,3	-	-	1,8	2,6	1,1
Plesiastrea versipora	0,1	-	-	-	-	-	-	-	-	-
Diploastrea heliopora	0,0,1	0,2,2	1,1,1	0,1,2,1	-	-	0,1,1	-	-	3,10
Leptastrea spp.	3,3	1,1	3,2	-	0,3	2,6	-	4,4	3,12,2	16,42,1
Cyphastrea spp.	7,6,1	0,8	2,2	0,1	4,11,1	0,2	0,10,1	10,4	2,10	2,12,1
Echinopora spp.	0,3,5,1	4,3,1	0,4,4	0,2,0,1	0,6,4	0,2	-	0,14	1,2	0,2
Acropora "fine branching"	-	0,3	-	-	-	0,3	1,1	-	0,10	1,5
Acropora "thick branching"	2,1	-	-	-	-	-	-	12,24	1,6	1,1
Acropora "caespitosa"	7,8,1	19,19	9,3	0,3,1	0,6	4,22	3,3	0,8,2	3,16	6,12,7
Acropora humilis	-	0,2	1,1	-	-	0,6	-	0,2	-	-
Acropora "stout"	0,1	-	-	-	0,2	-	-	-	-	0,1,1
Acropora "tabulate"	0,2,1	0,2,1	1	0,2	0,4	0,2	1,4	-	-	-
Acropora palifera	-	-	-	-	-	0,2	0,1	-	0,1	-
Astreopora spp.	3,6	0,2	-	0,3	0,10,2	-	0,3	0,6	1,2	3,11
Montipora sp. "foliose"	0,2,2	0,1	-	-	-	-	-	-	-	-
Montipora sp. "encrusting free-lip"	4,16,1	7,7	1,4	0,1	8	2	-	6,16	6,17,3	-
Montipora sp. "encrusting no free-lip	-	-	-	-	0,7	10,8	-	-	-	9,11,5
Montipora sp. "submassive"	-	-	-	-	-	-	0,1	0,4	-	-
Porites sp. "massive"	15,10,6,7	5,47,10,3	15,29,3,3	0,4	8,14,2	2,4	1,21,8	66,54,9	18,23,3	29,41,2
Porites sp. "encrusting"	-	-	-	-	0,2	-	-	-	8,12	4,5
Porites cylindrica	3,46,13,1	4,8,19,4	0,46,34,6	0,0,0,1	-	-	0,3,1	-	-	-
Porites annae	1,28,24,1	2,11,16,1	6,22,0,15	-	-	-	-	-	-	-
Goniopora spp.	2,7,1	2,7,1	2,1,1	1	8,4,2	0,2	0,19,3	0,4	3,13	5,25
Pocillopora damicornis	4,2	6,3	0,2,2	0,1	4,8	0,4	0,5	6,4	0,2,1	1,2
Seriatopora hystrix	4,5,1	0,2	0,2	0,1	2,18	0,2	0,5	-	-	-
Stylophora pistillata	0,3	3,5	2,1	-	0,2	0,4	1,3	0,8	1,4,1	1,2
Palauastrea ramosa	-	-	-	-	0,1	-	-	-	-	-
Pavona cactus	-	0,4	-	-	2,2,1	-	0,1	-	0,2	-
Pavona "massive"	0,1	-	-	-	0,10	-	-	0,3	-	1,7
Pachyseris rugosa	0,2,0,1	4,5	0,2	-	-	-	-	-	-	-
Pachyseris speciosa	-	-	-	-	0,2	-	0,1	-	-	0,1
Galaxea spp.	0,3	5,1	0,2	-	0,2	-	0,4	-	0,3	3,15
Merulina ampliata	2,2	0,1	0,1	0,1	2,4	-	0,5	-	0,2	2,7
Hydnophora spp.	-	0,1	1	-	0,4	-	-	0,2	0,2	0,4
Scolymia sp.	-	-	-	-	-	-	-	0,4	-	-
Acanthastrea sp.	1,0	2,4	-	-	-	0,3	-	-	-	1,6
Lobophyllia spp.	13,23	6,15	8,9	0,3	2,20	2,8	1,12,1	4,9	2,8	3,9
Symphyllia spp.	0,2	1,3	1,1	-	-	0,5	0,3,0,1	-	-	1,3
Echinophyllia sp.	0,2	-	-	-	-	-	-	-	0,1	0,4
Oxypora sp.	-	-	-	0,1	-	0,2	0,2,1	-	-	-
Mycedium elephantotus	-	-	-	-	0,3	-	-	-	0,1	0,2
Pectinia spp.	0,5	0,1	-	0,1	0,6	-	0,8,1	7,8	2,8	3,26
Leptoseris sp.	-	0,1	-	-	-	-	-	-	-	-
Euphyllia sp.	-	-	-	-	-	-	0,1	-	-	-
Cataphyllia jardinei	-	1	-	-	-	-	-	-	-	-
Plerogyra sp.	-	-	-	-	-	0,1	0,2	-	-	-
Physogyra lichtensteini	-	-	-	-	-	-	-	0,0,2	-	-
Turbinaria spp.	5,7	11,5	0,2	0,1	-	-	0,4	-	3,8	1,5
Heliofungia actiniformis	-	-	-	-	-	-	-	-	-	-
Cycloseris spp.	0,3	0,3	2	-	0,8	-	0,1	-	-	-
Fungia spp.	-	-	-	-	0,4	-	10,15	-	1,4	3,13,6
Herpolitha sp.	0,1	-	-	-	0,2	-	0,2	-	0,2	-
Podabacia crustacea	-	0,1	-	-	-	0,2	0,2	-	-	-
Polyphyllia talpina	0,1	0,1	-	-	-	-	-	-	-	-
Soft Corals										
Tubipora musica	0,1	1,2	0,1	-	-	-	-	-	-	-
Lobophytum spp.	22,14,1	6,3	-	-	2,7,1	0,16	30,4,1	2,4	11,24,5,4	18,135,18
Alcyonium sp.	435,65,1	453,4	674, 107	30	2,6,1	42,8	-	320,42	4,13,2	8,30
Cladiella sp.	-	-	-	-	17,5	0,4	-	-	2,4	28,22
Sarcophyton spp.	11,11	14,12	-	-	0,27,1	0,12	60,13,4	0,2	-	5,16
Sinularia spp.	29,61,1	64,21	-	40,3	0,23	6,12,1	0,3,3	2,6	5,29,31	0,1
Briareum sp.	1,1,1	-	-	-	0,3	-	-	-	-	-
Paralemnalia sp.	-	-	-	-	7	-	-	42,23	-	-
Nephthea spp.	16,2	36	0,0,11	-	7,8	-	20,2	-	-	-
Dendronephthya sp.	-	-	-	-	2	-	-	-	-	-
Xenia sp.	-	-	-	18	230,52	-	-	65,0	-	2
OTHERS										
Millepora tenella	0,36,16	2,10,8,1	2,20,13,1	-	8,14	4,2,2	0,12,4	3,16,2	7,36,9	15
Millepora "encrusting"	-	-	-	-	-	-	-	-	1,2	-
Zoanthids	0,3,1	3,3	-	-	-	-	-	0,4	1	12,26,1
Porifera spp.	-	-	-	-	-	-	-	-	0,4	8,33
Porifera "cliona-type"	-	-	-	0,1	2,6	0,0,1	-	-	0,3	-

OPERATIONAL TAXONOMIC UNITS	SITE											
	11	12	13	14	15	16	17	18	19	20	21	22
Caulastrea sp.	3	0,1	-	-	-	-	-	-	-	-	-	-
Favia spp.	8,10	3,10	0,2	0,8	0,16	0,3	-	0,2	3,28	27,16	2,2	-
Favites spp.	6,15	0,8	0,3,1	5,22,1	0,26	-	-	0,2	0,2	0,12	6,10	-
Goniastrea spp	6,21	0,14	0,1	1,13	0,8	0,1	0,1	0,2	1,24,1	8	-	1,8
Platygyra spp.	0,2	0,1	-	1,1	-	-	-	1	0,2	-	2	4,1
Leptoria phrygia	-	-	-	-	0,1	-	0,0,1	0,0,1	-	-	-	-
Oulophyllia crispa	-	-	-	0,1	-	-	-	-	-	3	-	-
Montastrea sp.	-	-	-	0,1	-	-	-	-	-	-	-	-
Plesiastrea versipora	0,1	-	-	-	-	-	-	-	-	-	-	-
Leptastrea sp.	2,19	0,1	2	0,2	0,3	-	-	0,1	4,10,6	0,4	-	-
Cyphastrea spp.	1,8	-	-	2,2	0,2	-	-	-	2	23,4	-	10,5
Echinopora spp.	-	0,1	-	0,10	0,3,0,0,1	-	-	-	-	-	-	0,10
Acropora "fine branching"	1,2	0,10,11,3	2,1	-	-	0,3,2,0,1	0,2,5,4,5	-	4,4	-	-	-
Acropora "thick branching"	-	0,14,27,7	-	-	-	0,3,3,8	0,0,0,0,5	0,4	1	-	-	-
Acropora "caespitose"	7,15,1	7,44,17,2	1,2	0,7	0,1	5,6,6	-	0,14,3	1,0,1	3,12	6	14,5
Acropora "tabulate"	-	0,4,3	-	-	-	-	-	-	-	-	-	-
Acropora "stout"	0,3,1	0,4	-	-	-	0,1,1	-	-	-	-	-	-
Acropora palifera	-	0,1,1	-	-	-	0,9,14	0,2,1,1	0,14,2	-	-	2,8	3,9
Acropora "encrusting"	1	-	-	-	-	-	-	-	-	-	-	-
Astreopora spp.	-	0,1	-	-	0,10	0,1	0,1	0,1	4,3	-	-	-
Montipora sp. "foliose"	2,3	0,6,1	-	0,3	-	-	-	0,8,5	-	2	-	5,8
Montipora "encrusting free-lip"	8,5,3,4	1,14	1,3,1,2	0,4	-	0,8	0,5,1	104,53,20	1,5	2,2	-	76,73,1
Montipora "encrusting no free-lip"	8,40,2	0,2,1	-	1,1	-	5,8	-	0,2,2	5,2,1	6,12	2,4	-
Montipora "submassive"	5,12,1	0,6,1	-	0,2	0,0,1	-	0,0,1	0,1,2	2,7,1	4	2,2	-
Porites "massive"	0,10	0,5,1	0,34	0,8,2	0,17,11,2	0,3,2	-	0,5	4,7	84,6,12	10	16,13,3
Porites sp. "encrusting"	1,5	-	2,3	37, 120	1,24,1		-	-	-	-	-	60,44
Porites branching	-	0,1	-	-	-	0,8,6,14	-	-	-	10,68,12,9	8,2	-
Goniopora spp	4,15	0,3	5,3	50,66	0,32,2	0,5,2	-	0,7	1,2	4,4	2,6	6,8
Pocillopora damicornis	2,28	0,15,2	-	0,14	0,1	0,10	2,7	0,9,1	0,11	8	-	10,15
Seriatopora hystrix.	2,11	2,28,3	-	-	0,1	0,8,4	0,5,2	0,33	2,6	-	-	-
Stylophora pistillata	10,38	0,31,2	0,1	-	-	-	0,0,1	-	-	0,7	-	0,3
Pavona cactus	0,6,1	-	-	-	0,3	-	-	-	-	-	-	-
Pavona "massive"	-	-	-	4,5	-	-	-	-	1,4	-	-	-
Pavona decussata	-	-	-	-	-	0,0,1	-	-	-	-	-	3,2
Leptoseris sp.	-	-	-	3,3	-	-	-	-	-	-	-	-
Pachyseris rugosa	-	-	0,3	6,41,3	-	-	-	-	-	0,2	-	-
Pachyseris speciosa	-	0,1	-	0,3	0,2	-	-	-	0,4	-	-	0,3
Pseudosiderastrea tayamai	-	0,1	-	-	-	-	-	-	-	-	-	-
Galaxea spp.	0,3	0,4	0,1	0,5	0,9,0,1	-	0,3	-	0,12	-	2,6	5,10
Merulina ampliata	0,1	0,4	-	0,12	0,9,1	0,4	-	-	0,2	2,4	-	-
Coscinaraea sp.	-	-	-	-	-	-	-	-	-	0,3	0,6	-
Claverina triangularis	-	-	-	-	-	-	-	-	1	-	-	-
Hydnophora spp.	3,6	0,2	-	0,1	0,5	0,2	0,0,1	-	1,7,1	-	0,2	-
Scolymia sp.	-	-	-	0,2	-	-	-	-	-	-	-	-
Lobophyllia spp	0,11	0,17	0,4	-	1,21,2	0,4	-	0,1	2,21,1	8,12	10,10	0,6
Symphyllia spp.	-	0,1	0,1	-	0,2	-	-	-	-	4	-	-
Echinophyllia spp.	-	-	-	0,3	0,3	-	-	-	1,7	-	0,4	-
Oxypora sp.	-	0,1	-	-	-	-	-	-	1	-	0,2	-
Mycedium elephantotus	-	0,2	-	-	-	-	-	-	0,6	-	-	-
Pectinia spp.	0,1	0,1	-	0,2	0,1,1	-	-	-	1,5,1	-	0,6	-
Euphyllia spp.	-	0,2	-	1,6	0,8,1	-	-	-	0,8	-	0,2	0,7
Cataphyllia jardinei	-	-	-	-	-	-	-	0,1	0,2	-	0,5,1	-
Plerogyra sp.	-	0,2	-	0,1	0,1	-	-	-	0,1	0,4	0,2	-
Turbinaria "foliose"	1,9	0,9	-	2,12,2	1,10	0,25	-	0,25	4,13	-	5,8	-
Turbinaria "encrusting"	-	-	-	1,8	0,1	-	-	-	1	18,2	-	-
Cycloseris spp.	-	0,1	0,2	0,6	-	-	-	-	3,19	-	-	4
Heliofungia actiniformis	-	-	-	0,2	0,11	-	0,1	-	-	-	4	-
Fungia spp	-	0,1	0,3	0,5	0,1	-	-	-	1,2	-	0,4	4,4
Herpolitha sp.	-	0,1	0,1	0,2	-	-	-	-	0,9	11	-	-
Polyphyllia talpina	-	-	0,2	-	0,4	-	-	0,2	0,2	-	-	-
Podabacia crustacea	0,2	0,1	0,6	0,2	0,1	-	0,1	-	0,10	-	12,20	-
SOFT CORALS												
Tubipora musica	-	-	-	2,7	-	-	-	0,1	4,4	-	-	-
Pachyclavularia sp.	-	-	18	-	-	-	-	-	-	-	-	-
Lobophytum spp.	-	-	-	0,0,1	0,1	0,7	0,1,1	0,4	0,2	0,3	2,4	-
Alcyonium sp.	2,8	-	1,3	0,2	2,38,8	0,4	0,0,1	0,3	67,18,2	-	4,2	-
Cladiella spp.	-	-	-	0,6,1	1,5	0,5,1,1	-	-	-	8	4,2	-
Sarcophyton spp.	3,3	-	7,7	11,1	3,7,1	0,14,4	7,3,3	0,5	52,47,16	5	40,8	-
Sinularia spp.	-	-	0,1	-	-	0,2,3,3	-	-	-	-	4,8,2	-
Briareum sp.	0,2	-	-	27,34,9,2	-	10,4,3	-	-	-	-	-	0,48
Nephthea spp.	-	-	-	-	-	-	0,1	-	-	-	40,6	-
Lemnalia sp.	-	-	-	-	-	0,4	-	-	-	-	-	-
Xenia sp.	-	-	0,3	-	1	0,1	-	80,4	600,60,32	25,0	8,6	-
OTHERS												
Gorgonian spp.	-	-	-	-	-	-	-	-	0,7	-	-	-
Millepora tenella	-	-	-	-	0,3,1	0,1	-	-	0,0,2,1	10,20	4,4,1	-
Millepora "encrusting"	-	-	-	-	-	-	-	-	-	-	0,1	-
Palythoa sp.	-	-	-	-	2	-	-	-	-	-	-	-
Zoanthus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Porifera spp.	7	-	1,3	2	0,3	-	-	-	3,16	-	2,3	0,3
Porifera "cliona-type"	3	-	-	-	0,0,5,1	-	-	0,0,2	-	-	-	-

Eastern Whitsunday Islands

OPERATIONAL TAXONOMIC UNITS	SITE								
	23	24	25	26	27	28	29	30	31
Caulastrea sp.	-	-	1,2	-	-	0,1	-	-	-
Favia spp.	1,2	0,10	15,16	0,1	0,1	-	0,7	2,8,1	0,6
Favites spp.	1,7	1,6	2,1	0,1	-	0,1	2,4	3,5,1	2,5
Goniastrea spp.	0,4	0,10	12,22	0,3	-	-	1,5	0,8	3,6
Platygyra spp.	-	0,1	-	-	-	-	-	-	2,3,1
Montastrea spp.	-	-	0,3	-	0,1	-	0,1	-	-
Diploastrea heliopora	-	-	-	-	-	-	-	0,1	-
Plesiastrea versipora	-	-	-	-	-	-	-	-	0,1
Leptastrea spp.	1,0	0,2	1,3	-	-	-	-	-	0,4
Cyphastrea spp.	-	1,3	7,3	1	-	-	-	0,4	-
Echinopora sp.	-	-	-	-	-	-	0,1	-	-
Acropora "fine branching"	-	-	0,2	-	0,6,1,4,1	0,0,1,1	1,7	-	-
Acropora "thick branching"	-	0,3	-	-	0,4,9,3,3	0,9,8,1,5	-	-	-
Acropora "caespitose"	3,7	-	16,24	5,8	0,16,0,1	0,7,3	7,14	0,10,1	2,12,1
Acropora humilis	-	0,3	-	-	-	0,1	-	-	-
Acropora "tabulate"	-	-	-	-	-	0,1	0,1	0,1	-
Acropora "stout"	-	-	-	-	-	-	-	0,1	0,1
Acropora palifera	-	-	-	0,1	0,1	0,1	-	-	-
Astreopora spp.	0,7	0,1	1,4,1	0,1	-	-	2,4	0,2	0,3
Montipora sp. "foliose"	0,2	0 -	-	-	0,1	0,1	-	-	-
Montipora sp. "encrusting free-lip"	-	0,3	2,1	5,4	-	-	0,2,2	2,8	0,43,20
Montipora sp. "encrusting no free-lip	0,3	0,1	8,8	2,2	-	-	0,1,1	0,3	0,10,1
Montipora sp. "submassive"	0,4	1,1	0,2	0,2	-	-	43,48,4	0,45,11	0,9
Porites sp. "massive"	1,16,64	1,3	20,5	0,2,1	-	-	1,3	0,2	2,6,1
Porites sp. "encrusting"	3,25	2,2,2	1	-	-	-	-	-	-
Porites "branching"	0,3,1	-	-	-	-	0,1	0,2,1	0,1	-
Goniopora spp.	1,16,2	0,4	1,3,0,0,1	0,5	-	-	1,13,4	0,14	0,5
Pocillopora damicornis	0,4	1,7	-	0,4	0,1	-	2,5	-	0,5
Seriatopora spp.	0,10	1,2	-	2,2	0,95,18,3,3	10,21,13,4,1	3,22	5,20	0,1
Stylophora pistillata	0,6	61,105,9	6,22	0,8	-	-	0,1	0,2	-
Palauastrea ramosa	-	0,1,2	-	-	-	-	-	0,1	0,7
Pavona sp. "massive"	0,2	0,1	0,1	-	-	-	-	0,2	0,5
Leptoseris sp.	-	-	-	-	-	-	-	0,2	-
Pachyseris rugosa	8,21	-	-	-	-	-	-	0,5	-
Pachyseris speciosa	0,2	-	-	-	-	0,1	0,3	0,3,5	0,2,1
Pseudosiderastrea tayamei	-	-	-	-	-	-	-	0,1	-
Galaxea spp.	-	-	3,4	-	-	-	1,4,3	0,2,4	0,6,6
Merulina ampliata	1	0,2	0,1	1,0	0,1,1	-	2,2,1	0,6,3	-
Hydnophora spp.	0,1	0,2	2,0	0,4	-	-	0,1	0,3	-
Cynaria lacrymalis	1	0,2	-	-	-	-	-	-	-
Scolymia sp.	0,1	-	0,1	-	-	-	-	0,3	1
Acanthastrea sp.	-	-	-	-	-	-	-	-	0,1
Lobophyllia spp.	1,2	1,4	0,3	-	0,4	-	2,7,12	0,16,4	1
Symphyllia sp.	-	-	-	-	-	-	0,1	0,2	-
Echinophyllia spp.	-	0,1	-	-	-	-	0,4	0,3	-
Oxypora sp.	0,1	-	-	0,3	-	-	1,2	0,3,3	-
Mycedium elephantotus	-	-	1,0	-	0,1	-	0,4	0,2	-
Pectinia sp.	-	-	0,1	0,1	0,1	-	0,17,8,1	0,2,5,2	-
Euphyllia sp.	-	0,1	-	-	-	-	-	0,5	-
Catephyllia jardinei	-	-	-	-	-	0,1	-	-	0,1
Plerogyra sp.	-	-	-	-	0,2	-	-	0,1	-
Physogyra sp.	-	-	-	-	-	-	-	0,1	-
Turbinaria "foliose"	0,0,1	0,3	0,1	-	-	-	-	0,3	0,3
Turbinaria "encrusting"	1,2	-	1,3	-	-	-	-	-	0,12
Heliofungia actiniformis	0,2	-	-	-	0,5	0,1	0,8	-	-
Fungia spp.	1	-	1,6	0,1	0,5	-	12,16	8,19	1
Herpolitha sp.	-	-	-	-	0,1	-	0,6	0,4	-
Polyphyllia talpina	0,2	-	-	-	-	-	-	-	-
Podabacia crustacea	0,3	0,2	-	-	-	-	2,12	1,10	-
Soft Corals									
Tubipora musica	-	1,1	-	3,7	-	-	-	-	-
Lobophytum spp.	1,8,1	0,1	-	1,2	-	-	-	0,2	-
Alcyonium sp.	10,10	134, 459	48,8,1	8,12	0,9,1	0,3	0,13,3	1,6	0,8
Cladiella spp.	3,11	0,2	22,9	0.2	-	-	-	-	-
Sarcophyton spp.	17,10	17,18	185,25	0,8	2,8	0,6	23,26	12,7	-
Sinularia spp.	2.1	-	0.1	-	0,11,1	2,5	27,44	0,3	0,2
Briareum sp.	0,4	-	0,2	1,22,5,9	-	-	0,11	1,6	0,2
Nephthea spp.	-	0,10	-	-	-	2	0,20	-	-
Anthelia sp.	-	-	1,2	-	-	-	-	-	-
Xenia sp.	0,3	20,19,2	21,2	8,6,2	30,54,1	0,3,1	220,1	-	5
OTHERS									
Millepora tenella	0,4	-	0,6	1,4	1	0,4,3	0,13,4,1	0,1	1
Zoanthus	-	0,1	-	-	-	-	-	-	-
Porifera sp.	0,1	38,17	7,1	-	3,5	0,2	2	1,3	-
Porifera "cliona-type"	0,3,1	-	2,1	-	-	-	-	-	-

Appendix III.
Goldsmith & Thomas Islands

OPERATIONAL TAXONOMIC UNITS	SITE																						
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Caulastrea sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Favia spp.	1	2	9	-	7	6	4,1	-	2	11	8	2	1	6	3	4	6	12,3	1	-	2	1	2
Favites spp.	-	5	3	-	6	1	4	-	2	2	4	2	4	-	1	2	1	12	6	-	1	3,1	-
Goniastrea spp.	1	1	1	-	8	-	3	-	-	3,3	-	-	-	2	-	3	1	2,2	5	-	1	-	1
Platygyra spp.	-	-	5,1	-	6,3	4	3	-	-	1	0,1	-	-	2	-	5	3	2	2	-	-	-	-
Leptoria phrygia	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Culophyllia crispa	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Montastrea spp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptastrea spp.	-	-	1	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-	-	-
Cyphastrea spp.	1	2	-	-	5	-	4	-	-	-	5	2	-	3	-	2	4	1	-	2,0,3	1	1	-
Echinopora spp.	-	-	-	-	1	-	-	-	-	-	1,1	-	-	-	-	1	-	-	1	3,0,2	-	-	-
Acropora "fine branching"	1	-	-	-	-	-	-	5	-	-	-	-	3	-	4	-	-	-	-	-	-	-	-
Acropora "thick branching"	1	-	-	-	1	-	-	-	-	-	-	-	-	-	8	-	10	6	-	-	-	10	0,5,15
Acropora "caespitose"	2	-	9	-	6	8	2	-	-	5	-	1	1	3	-	-	-	-	20,8	-	-	-	-
Acropora "tabulate"	2,2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Acropora "stout"	-	6	7	-	4	20	-	1	2	3	-	-	-	-	-	3	-	1	2	-	-	-	3
Acropora "encrusting"	-	-	-	-	3	3	2	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Astreopora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Montipora "foliose"	1	1	-	-	6	2	-	2	5	6	-	2	2	1	-	3	-	-	-	-	-	-	-
Montipora "encrusting free lip"	7,3,4	15,1	-	-	10,4	4,2	3,1	7	2,2	14,2	3	8	6	-	-	13,3	-	3	6	-	-	-	4
Montipora "encrusting no free lip"	3,1,1	25,4,1	3	20	18	27,3	0,4	15	8,4	0,3	-	-	-	-	-	6,3	-	-	2	-	-	2	-
Porites "massive"	0,0,1,2	3,2,1	3,2	-	2,4	4,2	-	-	6	3	3	0,0,3,2	0,6,1,1	0,1	2	4	5	1,1	-	-	2,1,1,1	0,2	0,3
Porites "encrusting"	8	-	-	-	21	2	28	12	1	-	-	1	-	0,2	-	-	-	-	-	-	-	-	-
Porites "branching"	-	-	-	-	-	-	-	-	-	-	-	6,1	-	-	-	-	-	-	-	-	-	-	-
Goniopora spp.	2	3	4	-	9	-	18	1	3	8	2,1	42,6,2	28,1,3	8,3	5	8	2	1,1	6,0,1	1	15	3	3
Alveopora spp.	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	3	2	-
Pocillopora damicornis	10	2	2	4	12	-	2	-	1	4	3	3	4	2	-	-	-	-	12	-	-	-	-
Seriatopora hystrix	16,3,1	2	-	-	2	-	-	-	-	-	18	-	-	1	-	17	-	-	-	-	-	-	-
Stylophora pistillata	-	-	-	-	2	-	-	-	-	1	1	1	2	3	-	12	-	-	2	-	1	-	-
Pavona cactus	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Pavona "massive"	-	30	-	-	-	-	-	-	5	-	-	-	-	1	-	2	-	-	-	-	-	2	-
Leptoseris spp.	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	1	-	1	-	-	-	5	-
Pachyseris rugosa	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-
Pachyseris speciosa	0,0,1	7,0,1	-	-	1,5	-	2	-	6,1	9,4	3	-	-	1	-	3	1,1	7,10	-	6,1	-	1	1
Coscinaraea columna	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-
Galaxea spp.	-	-	1	-	8	-	3	2	-	-	2	2	1	5	2	1	1	2,2	-	1	1	-	-
Hydnophora spp.	-	-	2	-	-	2,1	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Merulina ampliata	-	1	-	-	0,2	-	-	-	1	1,1	4,1	-	-	0,1	-	-	-	4,13	-	3	-	1	-
Scolymia sp.	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Acanthastrea spp.	-	-	6	-	-	-	-	-	-	-	1	-	-	-	-	3	1	-	-	-	1	-	-
Lobophyllia spp.	2	1	-	-	0,1	-	-	1	-	-	21	3,0,1	1	7,8	1	6	2	15,2	2	3,4	1	0,0,1	-
Symphyllia spp.	0,0,0,1	-	-	-	-	0,6	-	-	-	-	0,2	-	-	-	1	-	-	-	-	-	-	-	1
Echinophyllia spp.	-	0,0,0,1	-	1	-	-	-	-	1,1	1	1	-	-	-	1	-	1	-	-	-	-	1	-
Oxypora lacera	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	5,11	-	2	-	-	-
Mycedium elephantotus	-	1	-	-	2	-	1	-	3	3	1	-	-	-	-	-	2	3,3	-	1	-	4	-
Pectinia spp.	2,1	-	1	-	-	-	-	-	1	-	5,3	-	-	-	2	-	-	2	-	-	-	2	-
Euphyllia spp.	2	-	-	-	-	-	-	-	-	-	-	1	-	-	6	-	-	-	-	2	6	4	-
Catalaphyllia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-
Pterogyra sinuosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Turbinaria "foliose"	-	-	1	-	1,4	2	4,1	-	5	1	-	-	-	-	1	-	5	-	-	-	2	1	-
Turbinaria "encrusting free-lip"	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fungia spp.	18,3	0	-	-	-	-	3	8	-	4	1	-	6	1	2	3	-	-	-	-	3	1	-
Heliofungia actiniformis	-	-	-	-	-	-	-	-	-	-	2	-	1	-	1	-	-	-	-	-	-	2	-
Herpetoglossa simplex	1	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Herpetolitha weberi	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	1	-
Polyphyllia talpina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Podabacia crustacea	-	3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-

Cumberland Islands: Goldsmith and Thomas Island. Size classes 1-50cm, 51-100cm, 101-300cm, > 300cm.

Goldsmith & Thomas cont...

OPERATIONAL TAXONOMIC UNITS	SITE																						
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
SOFT CORALS																							
Tubipora musica	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lobophytum spp.	-	-	2	-	5	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-
Alcyonium sp.	-	2	2	-	4	1	-	-	-	1	-	4	1	3	2	8,3	1	5,3	-	-	-	-	-
Sarcophyton sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	5	2	3
Sinularia spp.	-	1	-	-	-	2	-	-	-	-	3	3	-	3	2	5,2	-	2	2	0,1	1	-	-
Briareum sp.	10,4,5,1	-	-	-	22	2	-	0,2	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-
Nephthea spp.	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Cespitularia sp.	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	-	-
Anthelia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Xenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
OTHERS																							
Zoanthidae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Porifera sp.	3	-	-	-	3	-	-	3	-	1	11	5	4	20	2	2	1	-	-	4	8	6	23
Porifera "cliona-type"	-	-	-	-	-	-	-	-	5	3	-	-	-	-	-	-	-	-	-	-	3,3	-	15,8
Millepora "branching"	1	-	-	-	-	-	-	-	-	-	3	1	1	-	-	-	-	-	-	-	-	1	16,12,8
Millepora "massive"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Goldsmith & Thomas cont...

OPERATIONAL TAXONOMIC UNITS	SITE																						
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
SOFT CORALS																							
Tubipora musica	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lobophytum spp.	-	-	2	-	5	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-
Alcyonium sp.	-	2	2	-	4	1	-	-	-	1	-	4	1	3	2	8,3	1	5,3	-	-	-	-	-
Sarcophyton sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	5	2	3
Sinularia spp.	-	1	-	-	-	2	-	-	-	-	3	3	-	3	2	5,2	-	2	2	0,1	1	-	-
Briareum sp.	10,4,5,1	-	-	-	22	2	-	0,2	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-
Nephthea spp.	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Caespitularia sp.	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	-	-
Anthelia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Xenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
OTHERS																							
Zoanthidae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Porifera sp.	3	-	-	-	3	-	-	3	-	1	11	5	4	20	2	2	1	-	-	4	8	6	23
Porifera "cliona-type"	-	-	-	-	-	-	-	-	-5	3	-	-	-	-	-	-	-	-	-	-	3,3	-	15,8
Millepora "branching"	1	-	-	-	-	-	-	-	-	-	3	1	1	-	-	-	-	-	-	-	-	1	16,12,6
Millepora "massive"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Carlisle & Brampton Is.

OPERATIONAL TAXONOMIC UNITS	SITE															
	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Favia spp.	4	3	4	-	-	5	7	2	1	2,1	1	5	3	5	6	8
Favites spp.	4	5	-	-	-	1	8	14	-	0,2	1,1	-	3	-	5	3
Goniastrea spp.	5	2	2	17	-	-	3,2	-	-	2	4	3	-	2	1	2
Platygyra spp.	2	-	3	-	-	1	3	4	-	0,1	-	-	2	-	2,1	2
Montastrea spp.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Leptastrea spp.	1	-	-	-	-	-	2	-	-	-	-	1	-	2	2	-
Cyphastrea spp.	1,0,1,1	-	1,0,0,1	-	-	-	3	-	-	-	-	-	7,1	3,1	-	3
Echinopora spp.	0,1,1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1
Moseleya latistellata	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Acropora "fine branching"	-	-	-	-	5,1	-	-	-	-	-	-	-	-	-	-	-
Acropora "thick branching"	1	-	2	-	-	-	0,1	2	-	-	-	5,0,1,7	-	0,1	-	-
Acropora "caespitose"	3	-	10,3,4	4,1	29,0,5	2	8	15,2,6	16,0,0,1	3	3	8,4	19	5	3	3
Acropora "tabulate"	2	1	2,11,7	-	5,0,5	7	1	3,0,1	10	-	3,1	2,2,2	-	-	1	-
Acropora "stout"	-	-	-	-	-	-	-	1	-	-	1	4	-	-	-	-
Acropora palifera	-	1	-	12	-	3	-	-	5	3	-	-	-	-	-	-
Astreopora spp.	-	-	-	-	-	-	2,0,1	-	-	-	-	5	-	1	5,1	2
Montipora "foliose"	33,4,2	-	0,1,1	-	2	-	2	14,9,1	4	5,2	1	1,0,1	23,4	9,4	5,1	
Montipora "encrusting"	27,3,4	1,1	2	-	-	0,24,1	13,12	22,2	-	16,2	0,1	11,4	14,0,1	47,5,1	15,0,1	12,1
Montipora "submassive"	3	-	3	-	-	-	-	-	-	2	-	-	4	3	-	-
Porites "massive"	0,1	0,2	1,1	-	-	5,3	6,3,1	4	-	-	2,1	2,1	3	-	3,1	4,6,1
Porites "encrusting"	3	1	-	-	-	2	2	6	-	- 2	1	1	-	-	7	1
Goniopora spp.	6	5	1	-	-	8,1	2	5	-	1,1	-	2,3	1	2	7	17,2
Alveopora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pocillopora damicornis	2	-	8	-	0,10	8	-	9	10	4	4	7	5	6	4	-
Seriatopora hystrix	1	-	-	-	1	4	7	5	-	-	-	1	1	-	-	-
Stylophora pistillata	-	-	2,1	-	5	2	3	-	-	-	-	2	2	-	1	
Pavona cactus	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
Pavona venosa	3	-	-	-	-	-	7	24,3	-	3	-	-	-	4	11	1,3
Pachyseris rugosa	-	-	-	-	-	-	-	-	-	-	-	-	3,2	-	1	5,5,4
Pachyseris speciosa	4,6,2	-	-	-	-	-	11,2,5	1,2	-	-	-	-	12,9	-	3,1	3
Galaxea spp.	-	-	-	-	-	-	3	3	-	-	-	-	-	0,1	4	1,4,2
Merulina ampliata	4,5	1	-	-	-	-	9,3	4	-	1,1	-	-	-	-	4	0,3
Hydnophora spp.	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1,1	1
Lobophyllia spp.	-	-	-	-	-	-	3,1	3	-	-	1	2	1	-	2	4,3
Acanthastrea sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Symphyllia sp.	2	-	-	-	-	-	1	-	-	-	-	1	2	1	-	2
Echinophyllia sp.	1	-	-	-	-	-	-	1	-	-	-	-	-	2	-	3,2
Oxypora lacera	0,1,3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	0,0,1
Mycedium elephantotus	0,6	-	-	-	-	-	-	1	-	0,2	-	2	2	-	9,2	6
Pectinia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Euphyllia sp.	-	-	-	-	-	2	2	-	-	-	-	1	-	-	-	-
Plerogyra sinuosa	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Turbinaria "encrusting"	-	21	-	-	-	-	-	-	-	5,2	-	7,1	2,1	-	-	-
Turbinaria "foliose"	2	-	1	-	-	8	1	18	-	-	0,3	5,1	2	-	4,1	4,1
Fungia spp.	-	-	-	-	1	6	-	-	-	2	-	1	1,8	-	1	-
Herpolitha weberi	-	-	-	-	-	-	-	-	-	-	-	-	6	3	-	-
Herpolitha limax	1	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Herpetoglussa simplex	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Podabacia crustacea	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-
Catalphyllia jardinei	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubipora musica	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-

OPERATIONAL TAXONOMIC UNITS	SITE															
	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
SOFT CORALS																
Pachyclavularia sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Lobophytum spp.	1	1	7,11	-	1	-	1,1	0,1	0,1	-	-	-	1	-	-	-
Alcyonium sp.	1	-	2	-	12,3	-	11	1	-	-	-	1,2	2	4	4	7,2
Cladiella sp.	-	-	-	-	-	-	-	-	-	1	-	-	1,2	-	-	-
Sarcophyton sp.	-	-	2	3	7	2	2	2	2	2	8,5	3,1	-	1	2	-
Sinularia spp.	11,1	1	-	-	0,1	2,3	5,1	2,1	-	-	4,1	0,1	1,1	5	8	2
Briareum sp.	3	-	5	-	-	-	2	1	-	9,2	-	1,2	-	5,1	4	-
Nephthea sp.	-	-	1	-	-	2	-	1	-	-	-	-	-	1	-	-
Xenia sp.	-	-	2	-	-	-	-	-	-	-	3	5	-	1	-	-
OTHERS																
Porifera spp.	13	1	5	-	9	14	17	9	3	4	-	2	8	3	6	10
Porifera "cliona-type"	-	-	2,3	-	9	-	-	-	-	1	3	-	-	2	8	4

Cockermouth & Seawfell

OPERATIONAL TAXONOMIC UNITS	SITE																	
	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
Calaustrea sp.	-	-	-	-	-	-	-	-	-	3	-	-	-	-	5	-	-	-
Favia spp.	16	-	-	1	2,1	7	-	8	4	5	7,2	1	3,2	10,4	10,2	6,0,1	9,2	0,1
Favites spp.	23,5	3	3,1	2,1	4,1	6,1,2	-	9,1	8,1	9	13,3	8	3	1	6,3	4,3	6	10,2
Goniastrea spp.	18,1	-	1,1	4	4,1	9	-	5,1	2	7	12,1	1	2,2	8	5	8,1	6	10,2
Platygyra spp.	4	4,3	3	1,3	2,0,1	3	1	15,8	8,2	1,2	9,5	1	3	5	2,1	1	4,1	-
Leptoria phrygia	-	-	-	-	1,1	-	-	-	1	-	-	-	0,1	4	1,1	-	2,2	-
Oulophyllia crispa	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-
Montastrea spp.	-	1	-	-	1	-	-	-	-	-	1	1	-	-	-	2	-	-
Plesiastrea versipora	3,1	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-
Diploastrea heliopora	-	-	-	-	-	-	-	-	-	-	-	-	0,1	-	0,4	2	-	0,2
Cyphastrea spp.	7,3,1	-	0,1	-	-	3,6	15,1	4,4	5,2	57,1	2,6	2,3	5,1,1	0,1	-	1,0,1	2	1
Echinopora spp.	-	-	-	-	-	-	3	3,3	-	0,1	-	-	-	2,1	0,1	0,1	-	-
Acropora "thick branching"	1	1,2	3	-	0,0,1	3,4	0,1	-	-	0,0,1	0,1	0,6,2	0,9,2	1,3	1	1	0,14,5,2	0,11,7,2
Acropora "caespitose"	15,5	4,3	38,3	14,1	18,3	34,13,2	28,1	13	26,3	54,5	46,2	34,1,2	35,1,1	10,3,1	4	12,1	20,4	81,24,1
Acropora "tabulate"	1,2	5,9,5	5,6,1	0,2	8,4,1	3,2,1	1	4,1	6	3,7,1	3	0,1,4	2	-	1	2	1,7,1,3	2,3,2
Acropora "humilis"	0,1	0,1	15,1	1	4,1	0,5	-	-	-	-	22,2	0,1	-	-	-	-	-	-
Acropora "stout"	2	0,1	6,2	1	-	-	-	-	2,1	-	10,1	-	-	2	-	-	3	-
Acropora palifera	0,1	11,3	18,4,3	8	17,3	1,2	-	-	27,3	24,2	18	2	12	2	-	-	13,6	9,1
Acropora "encrusting"	-	2	7,5,4	-	2,1,1	-	-	-	-	-	-	-	-	-	-	-	-	-
Astreopora spp.	1	-	-	-	-	2	8	2	-	-	-	4	1	1	3	1	1	-
Montipora "foliose"	-	4	-	-	1	-	1,1	2,2	-	16,5	5	10	7,3	1,2	6	2	1,1	8,2
Montipora "encrusting free lip"	-	4	-	-	1	5	12,1	18,5,3	2,1	13,2	15,6	6	10,2	3	4,3,1	0,1	1,1	4,1
Montipora "encrusting no free lip"	6,5	7,6	1	2,1	2,1	12,2	1	7,1	2	2	6,1	-	-	3,3	5,1	3	2,1	3,2
Montipora "vertical projections"	-	1	-	-	-	-	11,1	1,2	-	22,3	2	13,7	16	3,3	1	-	2	4,2
Porites "massive"	9,1	2,1	-	1	2	7,4	-	-	1	-	-	0,2	-	9	10,5	3,4	5,1	8,1
Porites "encrusting"	-	3	5	0,1	3	-	3	-	-	-	-	-	-	5	-	-	-	1
Porites cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	3,6	1	1	-	1,2
Goniopora spp.	24,3,1	6	1	-	-	9	0,1	4	4,4	21,3	9,2	-	7	11,2	6,3	4,4	2	7
Alveopora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Pocillopora damicornis	8	14,4,1	10,1	6	22,7,1	2,4	10	12,3	22,3	22,1	16,2	11	18	1	5	6	8	9
Seriatopora hystrix	1,1	0,1	1	1	-	29,7	3	8	9	29	3	33	19	17	2	2	7	4
Stylophora pistillata	1,3	3,1	-	5	-	29,1	2	3	1,1	7,1	1,2	9	11,1	9,1	5	6,1	9	17,1
Pavona cactus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-
Pavona venosa	10	3,1	-	-	0,1	0,1	-	2	3	-	2	-	-	1	-	5	-	-
Pavona varians	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptoseris sp.	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coeloseris mayeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Pachyseris rugosa	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	-	2
Pachyseris speciosa	-	-	-	-	-	3,1	3	1,1	1	-	-	-	-	2,1	6,1	-	-	0,1
Coscinaria sp.	-	-	-	-	-	1	-	-	-	-	8	1	-	-	-	-	-	-
Galaxea spp.	10	0,1	-	-	-	8,1	10	4,1	1,1	38	32,1,2	0,1	7	3	-	2	1	-
Acrhelia horrescens	-	-	-	-	-	-	-	-	-	-	-	0,4	0,2	-	-	-	-	-
Psammocora explanulata	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Merulina ampliata	1	-	-	-	-	2	7	-	-	10,5	5	11,6	1	-	-	7,1	1	5,10
Hydnophora spp.	-	-	-	1	-	-	1	6	1	1,4,3	0,2	-	0,1	0,1	1,1	2	-	6,2
Acanthastrea spp.	-	-	5	-	-	1	-	1	-	1	-	-	-	-	2	-	-	-
Lobophyllia spp.	5	-	-	-	1,1	3,3	1	6,4	-	16,3	4,5	2,3	6,1	2,3	7,6,2	5,4,1	9,1	3,2
Symphyllia spp.	2	-	1	-	1,1	-	1	1,1	0,1	1,1	0,4	2	2,1	2	2,3	2	-	1
Echinophyllia spp.	1,2	-	-	-	-	2	1	-	-	-	1	1	-	-	3	-	1	1
Oxypora lacera	1	-	-	-	-	-	-	1	-	-	1	-	-	-	2	-	1	1
Mycedium elephantotus	1	-	-	-	-	-	1	0,1	-	1,1	1	-	-	-	2	-	-	-
Pectinia spp.	2,1	-	-	-	-	1	2,1	0,1	-	-	-	0,1	0,0,1	2,1	8,1,0,1	4,0,1	0,1	2
Euphyllia spp.	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
Plerogyra sinuosa	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Physogyra lichtensteini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Turbinaria "foliose"	-	-	-	-	-	3,1	-	3,1	-	-	-	6	2	2,1	1	-	-	-
Turbinaria "encrusting"	-	-	-	-	-	-	-	-	-	-	1	-	5	-	1	-	-	-
Fungia spp.	1	-	-	-	-	1	4,14	-	-	0,1	-	0,1	1,1	0,2	-	2,4	0,9	0,10
Herpetoglossa simplex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Podobacia crustacea	2	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	2
Herpolitha limax	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliofungia actiniformis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cockermouth & Scawfell cont..

OPERATIONAL TAXONOMIC UNITS	SITE 71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
SOFT CORALS																		
Tubipora musica	-	-	-	-	1	-	3	-	1	2	-	-	1	-	-	-	1	-
Lobophytum spp.	17,8,12	8,5,2	0,1	8,1	12,7,2	15,3	2,2	6,5	22,1	6,5,1	21,6	9,1,1	75,4,4	4,2	12,3,1	1,7,1	4	1,3
Alcyonium sp.	5	1	-	1,1	6	20	30	6	10	7,1	3	12,3	1,2	6,5	6,1	5,1	10	2,1
Cladiella sp.	-	-	-	-	19	2	3,1	1	-	7,1,1	-	20,2,1	9	-	29,2	6	-	1
Sarcophyton sp.	9,5	2	-	10	25,6	31,2	41,8,2	92,5	24,5	16,4,1	56	135,2,2	85,2	125	31,4	12	34	56,3
Sinularia spp.	-	5	-	-	-	1	-	4,5	-	-	-	-	-	15	1,2	-	1	-
Briareum sp.	7,13	2,3	-	4,5	-	0,2	4,2,1	1,5,1	1,9,4	14,5,2	4,4	6,5,1	66,6	6,3	3	4,2	-	1
Stereonephthea sp.	-	-	-	-	-	2	63,9	13,2	21	7,3	-	27,4	8	7,14	11,4	6,6	12	26,1
Nephthea sp.	10	-	-	-	-	14	24,1	-	11	24	2	104	24,3	1,3	4	2	5	31
Xenia sp.	-	1	-	-	3	-	55	41	-	228	-	26	60,3	-	-	-	-	0,1
OTHERS																		
Rumphella/Ellisella	-	-	-	-	-	-	1	5	-	-	-	1	1	2	2	1	2	-
Zoanthidae	10	-	6	-	1	1	-	1		14	8	-	-	10	4	-	-	-
Porifera spp.	4	1	-	-	1	6	2	3	5	5	2	2	2	2	8	3	3	1
Porifera "cliona-type"	4,1	3,3,1	5,3,1	-	2,1	1,1	0,1,1	3,6,1	2,0,1	0,3	3,1	-	-	-	-	2,3	-	-
Millepora "branching"	-	-	-	-	-	-	-	-	3,0,1	-	6,3	1	17,1	5,9,3	3,2	-	13	10
Millepora "encrusting"	0,1	-	-	-	1	-	-	1	2,2,2	1	2,2,3	-	1	1	-	3,9,3	2	0,1

Northumberland Islands. Size classes 1-10cm, 11-50cm, 51-100cm, 101-300cm, > 300cm.

SPECIES	SITE									
	98	99	100	101	102	103	104	105	106	107
Favia spp.	3,1	2	0,3	0,3		0,9	0,4	0,8	0,4	
Favites spp.		4.5	0,6	0,8	0,3	0,24	0,52	0,10,1	0,37	
Goniastrea spp.	2,8	1,10,1	0,9		0.4	0,28,1	0,19	0,11,	5,47,3	0,1
Platygyra spp.	0,3		0,8	0,1	0,1		0,2		2,14	
Leptoria phrygia					0,1		0,1,1			
Oulophyllia crispa			0,2			0,3	0,2	0,1	0.5	
Montastrea spp.			0,2							
Plesiastrea versipora	0,1,1								0.1	
Leptastrea spp.				0,5			0,8	0,3	0.2	0.1
Cyphastrea spp.	0,6	0,4	0,2	0,6	0,2	0,2	0,6	0.3		0.0,2,1
Echinopora spp.										0,1
Moseleya latistellata							0,1			
Acropora 'fine branching'		3,0			0,1					1,0,1,4,1
Acropora 'thick branching'					9	0,1,2		0,6,1	0,3,2,2	0,3,4,3,1
Acropora 'caespitose'	0,3	3.9	0.2,1	0,4	0,9,2	0.1,1	1,4,1	0,1,0,6	1,18,3,1	0,2,2,2
Acropora 'tabulate'		0.1	0,2,1	0,2,2	0,2,2	0,0,1	0,3		0,6,17,3	
Acropora palifera			0.2		0,1					0,2,1
Montipora 'foliose'		2.2	0,3						0,2,3	0,2
Montipora 'encrusting free-lip'	0.6	48,56,10	53,84,2	0.8	10,44,14	20,117,10	4,22,8	0,10,2	1,12,8,2	0,4,4
Montipora 'encrusting no free-li	0,3	5,1,1	0.1	0.5	0,5	0,10,3	0.6,1	0,7	1,5,7	
Montipora 'submassive'			0.17		0,1,1	0,2	0,0,1			0,1
Porites 'massive'		2,10,1	0,0,1		0,6,3	0,6,2	1,11,2,1	0,2,1	0.2	0.0.2
Porites 'encrusting'	0,3	10,10	0,2	0,7,1	5,13,3	0.3		0.2	0,8,0,1	
Porites 'branching'		0,2								
Goniopora spp.	0,1,1	0,5,1	0,8,1	0,3	0.6	0,13	0,15,1	0,24	1,10,2	0,1
Alveopora sp.								0:2		
Pocillopora damicornis			0,1	0,1,1	0,3	0,5	0,11	0,11	0,11,1	0,4
Seriatopora hystrix		1,0								
Stylophora pistillata	0,2	0,3						0,1	0,2	0,1
Pavona 'massive'		0,3	0,7		0,4	1,24,2	0,7,1	0,2	0,8	
Pavona 'submassive'			0,2							
Pachyseris rugosa										0,1
Pavona venosa										0,1
Pachyseris speciosa									0,1	
Galaxea spp.					0,1					0,1
Merulina ampliata						0,1		0,1		
Hydnophora spp.		0,3,1	0,2,3	0,4	0,1	0,1	2,8		0,1,1	0,1
Psammocora spp.			0,1			1,8	0,2			
Cynaria lacrymalis				0,1		0,1		0,3		
Scolymia spp.								0,1		
Acanthastrea spp.				0,1						
Lobophyllia spp.		0,1				0,11	0,10,1	0,4	0,9	0,1
Symphyllia spp.				0,5	0,1	0,3			0,2	
Echinophyllia spp.		0,2				0,7,2	1,2,1	0,1	0,3	
Oxypora sp.				0,2		0.3				
Mycedium elephantotus					0,1	0,2	1,3,1	0.2	0,3	
Pectinia spp.						0.1				
Euphyllia spp.		0,1				0.1	0,2	0,2	0,2	
Turbinaria spp.	7,27,1	6,23,6	0,52,6	0,39,4	0,14	1,38,2	5,38,1	0,13	5,54,27,6	0,1
Duccanopsammia axifuga	0,0,1									
Fungia spp.										0,5
Podabacia crustacea							0,1			
SOFT CORALS										
Lobophytum spp.	0,1	5,2,2	1,24,3	0,8	0,17,1	0,8,1	2,10,3	0,3	0.7.3	
Alcyonium sp.			0,2		0,5,2	2,8,1	4,6	0,4	0,3,2	
Cladiella sp.		1,6,1	0,2		0,2,1	5,15,1	3,5,1		0,2	
Sarcophyton sp.	2,1	0,3	0.2	0,6	2,4	0,9	4,5,3	0,4		
Sinularia spp.	0,1	0,2,1	0,2	0,2	0,5		0,1,1			0,1,3
Briareum sp.		5,15,4	0,14,4,1		0,5,2	0,6	0,3,1	-	0,1,1	0,0,4,7
Nephthea sp.					0,1	0,1			1	
Xenia sp.			0,2				0,1	3,5	0.1	
Capnella sp.		28,19	62,54,1		64,8,10			0,1	0,1	
Gorgonian spp.		0,2			0,1,1	0,4	1	0,2	0,2	
Zoanthus sp.		4,2	0,7		30,1,1					
Porifera spp.			0,1	0,12	0.2	0,7	0,14	1,8	0,7	
Porifera Cliona-type		0,1		0,15,1	0,1	0,3	0,8	0,3	0,4,1	
Anemone spp.			0,6							

Penrith Island.

SPECIES	SITE								
	89	90	91	92	93	94	95	96	97
Caulastrea sp.		1,0							
Favia spp.	8,27		5,39,2		8,7,1	-	1,1	0,2	1,1,1
Favites spp.	1,16				0,8,1		3,2,1	12,17	0,13
Goniastrea spp.	11,37		1,21	85,135,1	3,14	100,68,1	58,65,1	50,116,4	13,12
Platygyra spp.	2,8	0,1	0,6,1		0,10,1				4,1
Leptoria phrygia			0,3,3		0,3				
Oulophyllia crispa	0,1		0,2						
Montastrea spp.			0,1						
Plesiastrea versipora			0,0,1						
Leptastrea spp.	3,4								1
Echinopora spp.			0,2,1		0,8				
Acropora "fine branching"		4,1	0,1						
Acropora "thick branching"	0,10,2	8,3,1	0,11		2,9,4				
Acropora "caespitose"	0,10	30,16	3,33		6		7,7		1,8
Acropora humilis	0,1		0,4,2		3		0,1		
Acropora "tabulate"			0,9,2		2,0,2				
Acropora "stout"		0,1	1,4,2		10				
Acropora palifera		1,1	0,7,1		3,0,2				
Astreopora sp.	1,1								1,0,1
Montipora sp. "foliose"									1,0,1
Montipora sp. "encrusting free-lip"		0,1	0,3		5				
Montipora sp. "encrusting no free-lip"			0,1,1		3				
Montipora sp. "submassive"		1,1		0,1	0,0,1				
Porites sp. "massive"	5,3	3,1	10,27,4	79,34	4,10,3	69,16	1,1		
Porites sp. "encrusting"			0,2						
Porites annae					0,5,0,1				
Goniopora spp.	0,2	0,1	0,6		1,15				
Pocillopora damicornis	4,8	0,4	3,26,1		6,16,3			0,3	0,1
Seriatopora hystrix		0,3	0,7		0,5				
Stylophora pistillata	0,1	0,2	0,14,1		0,13				
Pavona sp. "massive"			0,1						
Pachyseris rugosa		0,1							
Galaxea spp.		0,1	0,1						
Merulina ampliata	-	0,2	0,2		0,1				
Hydnophora spp.		0,1	0,2		0,7				
Acanthastrea ssp.			0,2,3		0,1				
Lobophyllia spp.	0,2		0,2,1		0,1		0,1	0,3	
Symphyllia spp.	0,3	0,1	1,7,5		0,5				0,1
Turbinaria spp.		0,0,1	1				0,2		
Cycloseris spp.	0,1								
Heliofungia actiniformis				0,1					
Fungia spp.		1,7	0,5						
Tubiopora musica					0,1	2,1			
SOFT CORALS									
Pachyclavularia sp.				2,9					
Lobophytum spp.	0,21,3	1,13	2,17,7		12,0,20			0,17	6,15,2
Alcyonium sp.								18,15,	
Cladiella sp.	1				0,2				0,5
Sarcophyton sp.	55,15,1,1	5,10,1	0,21,1		20,4,50			8,11	33,15
Sinularia spp.	0,33,1,1	0,1,1	1,2,4,2		1,84,4		19,27	0,5,2	1,2
Capnella sp.	10				3		0,5	2,4	1
Briareum sp.	2	0,3	3,0,1						
Nephthea sp.	733	33	207		161			97	0,1
Xenia sp.	191,3	990	147		124			691	5
Gorgonian spp.					21				
Millepora tenella					0,5,5				
Millepora sp. "encrusting"					0,1				
Palythoa sp.	14								
Zoanthid sp.			3					8,0	
Porifera spp.							27,31	41,43	47,35

Percy Islands.

SPECIES	SITE									
	108	109	110	111	112	113	114	115	116	117
Caulastrea sp.	-	-	1	-	-	-	-	-	-	1
Favia spp.	3	1,1	2	1,3	1	0,1	-	-	5,1	-
Favites spp.	9	2,7	3,5	12	1	1,2	0,1	0,2	-	-
Goniastrea spp.	3,6	2,4	20,31	3,2	-	-	0,2	-	77,79,1	1,1
Platygyra spp.	1,2	-	3,2	1	-	0,1	-	-	-	0,0,1
Leptoria phrygia	-	-	-	-	1	-	-	-	-	-
Oulophyllia crispa	-	0,1	-	-	-	-	-	-	-	-
Montastrea sp.	0,1	-	-	-	-	-	-	-	-	-
Leptastrea spp.	-	-	5,1	-	-	-	2,2	-	-	-
Cyphastrea spp.	1,1	-	-	3,1	-	-	-	-	2,0	2
Echinopora sp.	-	-	-	-	-	-	-	-	-	0,6,2
Acropora "fine branching"	1,1	-	-	-	-	-	-	-	-	-
Acropora "thick branching"	0,1	-	-	-	1	-	-	-	-	-
Acropora "caespitose"	3,8,1	2,6,2,1	-	3,0,1	1,5,2	6	1,0	0,1	0,1	1,3
Acropora humilis	-	-	-	-	-	3	-	-	-	-
Acropora "tabulate"	0,0,3	0,2,1	1	4,1	0,2,11,15	0,0,0,1.	0,3	-	-	-
Acropora "stout"	-	0,3	3,3,1	-	-	-	0,1	-	-	-
Acropora palifera	-	-	-	0,0,1	-	1,6	-	-	-	-
Montipora sp. "foliose"	0,0,0,3	84,130,14	39,2	61,33	0,1,3,1	1	9,18	-	-	7,26,7
Montipora sp. "encrusting free-lip	0,0,1	0,5,1	1,1	1,2	1,0,2	24,30,1	0,3,1,5	33,13,1	1,8,4	8,7
Montipora sp. "submassive"	-	-	-	-	-	-	-	-	0,3	-
Porites sp. "massive"	0,0,0,0,1	2,1,1	3	1	0,0,2,1,2	-	4,8,2	-	25,1	1,0,1,1
Porites sp. "encrusting"	1	-	1,1	63,25	-	68,19,1	-	48,12	-	51,52,3
Porites annae	-	-	1	-	-	0,0,3	0,1	0,0,2	-	5,10
Goniopora spp.	1	0,5	7,17	2	1,2	-	1,1	0,1	-	2,0
Pocillopora damicornis	2,3	5,18,1	1,7	1,2	1,1	2,4	1,1	-	1,0	1,2
Seriatopora hystrix	0,2	3,2	-	-	-	-	-	-	-	-
Stylophora pistillata	1,1	0,4	1,	1,2	-	0,1	0,1	0,1	-	2,2
Psammocora contigua	-	-	1,1	-	-	0,1	-	-	-	-
Pavona venosa	1	1	-	33,98	-	-	-	-	-	-
Coscinarea sp.	-	-	-	-	-	6,6	-	10,9	-	-
Pachyseris rugosa	-	-	-	-	-	-	-	-	-	0,6
Pachyseris speciosa	-	-	-	-	-	-	-	3,1	-	-
Galaxea sp.	-	0,2	-	1	0,0,1	-	-	-	-	1
Merulina ampliata	-	-	-	1	-	-	-	-	-	-
Hydnophora sp.	1	1	-	-	0,1,1	1,1	-	-	-	0,1
Scolymia sp.	-	-	-	-	-	-	3,0	-	-	1,1
Acanthastrea sp.	-	-	-	-	0,1,1	-	-	-	-	-
Lobophyllia spp.	0,0,1	3	1,3,1	1,1	0,0,2	-	-	-	-	1,2
Echinophyllia sp.	0,0,1	-	-	-	0,0,2	-	-	-	-	-
Oxypora sp.	0,0,1	-	-	-	-	-	-	-	-	0,0,1
Mycedium elephantotus	1	-	-	-	0,0,1	-	-	-	-	1,1
Pectinia sp.	-	-	-	-	0,0,0,0,1	-	-	-	-	-
Euphyllia sp.	2	1	-	1	-	-	-	-	-	-
Turbinaria spp.	-	1,0,1	23,8	7,7	-	38,12	4,6	0,1	-	0,2,2
Fungia spp.	1	-	2,3	-	-	-	-	-	-	-
Podabacia crustacea	0,0,1	-	-	-	-	-	-	-	-	0,1,1
Soft Corals										
Tubipora musica	-	-	-	-	-	-	-	2,0	-	-
Lobophytum spp.	-	0,0,1	1,0,2	-	-	1,1	0,3	-	1,2	0,2
Alcyonium sp.	-	-	-	-	0,1	-	-	-	-	-
Sacrophyton sp.	1	3	1,1	1	0,4	0,2	-	-	7,0	6,10
Sinularia spp.	1	8	-	5	0,0,0,1	2,10	8,10,1,1	0,5	1	5,20,7
Briareum sp.	3,3	3	1,1	2	-	2,3	-	10,1	-	25,31,3
Xenia sp.	-	-	-	-	5,5	-	-	-	10	-
Efflatournaria sp.	-	-	5,8	-	-	0,1	-	-	-	-
Capnella sp.	-	-	12,2,1	-	-	4	-	5	-	0,0,1
Porifera spp.	-	-	-	-	-	-	16,10	5	-	-
Porifera "cliona-type"	-	-	-	0,0,1	0,0,1	-	3,1,1	2,1	1	-

Keppel Islands

Species	SITE							
	118	119	120	121	122	123	124	125
Favia spp.	-	-	0,2	-	3	0,1	2,0	1,3
Favites spp.	4,	13,1	-	-	5,3	3	12,3	-
Goniastrea spp.	1	2	0,2	-	9,2	3,4	10,5	2,4
Platygyra spp.	-	-	-	-	1	-	1	-
Leptoria phrygia	1	1,1	-	-	0,1	1	-	-
Oulophyllia crispa	-	-	-	-	-	0,1	-	-
Montastrea sp.	-	-	-	-	-	0,1	-	-
Leptastrea spp.	0,1,1	3	-	-	7,5	5	2	6,18,1
Cyphastrea spp.	0,1	-	-	-	10,5	3	0,1	-
Acropora "fine branching"	-	-	-	-	-	0,6,1,4	0,3,1	2,7,1
Acropora "thick branching"	0,1,5,3,4	0,2,5,6,1	0,3,1,1,4	0,6,2,2,4	3,18	0,9,19,6,3	0,18,15,6,3	4,65,9,2
Acropora "caespitose"	3,6,5	3,1,12,2	0,1	0,1	41,74,7,3	2,21,5	2,8,1	5,4,1
Acropora humilis	-	-	-	-	1	0,1	-	-
Acropora "tabulate"	1,1,2,1	1,2,3,2	-	0,3	2,2,0,2	0,9,7	5,15,1	0,13,17,3
Acropora "stout"	0,3,2	0,0,2,2	-	-	11,11,5,2	4,16,10,1	0,2	5,16,1,1
Astreopora sp.	-	0,1	-	-	-	-	-	-
Montipora "encrusting"	1,1	3,1,1,2	0,4	-	1,11,1	0,6	5,3	2,1
Porites "massive"	0,0,0,1	-	-	-	-	16,1,1	1,2	1,1
Porites "encrusting"	-	-	1,2	-	-	-	-	-
Goniopora spp.	0,0,0,1	-	-	-	0,1	-	0,2	-
Pocillopora damicornis	6,2	1	0,2	0,2	38,35	10,44,2	5,4	18,41,1
Seriatopora hystrix	-	-	-	-	-	-	1	-
Stylophora pistillata	-	0,1	-	-	10,3	0,1	2	-
Palaustrea ramosa	-	-	-	-	0,1	-	-	-
Pavona venosa	-	4	-	-	1,1	-	2,2	1
Acanthastrea sp.	-	-	-	-	0,1	0,1	-	-
Lobophyllia sp.	-	-	-	-	-	-	1	-
Turbinaria spp.	2	1,1,1	-	-	1,3	0,1	20,12	1,2
Fungia sp.	-	-	0,3	0,2	-	-	-	-
Hydnophora sp.	0,1	-	-	-	1,2	0,1	-	2,2,1
SOFT CORALS								
Lobophytum sp.	-	-	-	-	-	1	-	0,1
Alcyonium sp.	-	-	-	-	1,3	-	8,1	3
Sarcophyton sp.	3,1	1,2	-	-	7,9	1	4,2	0,5
Sinularia spp.	4,3	-	-	-	4,4,1	5,2	-	0,3
Xenia sp.	-	-	-	-	196,3	12	6,1	1,3
Briareum sp.	-	-	-	-	-	-	1	-
SPONGES								
Porifera "cliona-type"	-	-	-	-	-	-	1	0,3
Porifera spp.	-	0,2	-	-	-	12,5	0,1,0,1	1,1

APPENDIX 3. Percent cover of major benthic components derived from 20m line transects for 125 sites.2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
HC	23	48	37	46	27	14	34	33	9	17	4	66	1	18	9	30	78	29	11	36	23	12	2	6	4
MA	-	-	-	-	-	-	-	-	-	2	22	-	58	47	35	7	1	47	3	11	27	75	81	-	14
SC	12	4	25	16	33	14	18	2	24	2	2	4	1	8	3	13	8	2	42	1	11	2	-	22	7
TA	24	7	25	28	27	41	14	6	32	59	9	-	11	10	7	20	9	5	40	18	13	10	4	-	4
OT	24	7	7	3	4	1	29	11	-	9	-	5	1	3	10	-	-	-	2	6	-	-	-	-	1
AB	17	34	6	7	9	30	5	48	35	11	63	25	28	14	36	30	4	17	2	28	26	1	13	72	70

	26	27	28	29	30	31	32	33	34		36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
HC	7	78	85	22	16	6	19	29	10	-	21	8	3	1	12	28	13	12	23	7	13	1	14	24	51
MA	42	1	-	13	12	53	34	47	53	-	25	58	47	78	46	25	41	44	43	38	53	79	51	53	24
SC	4	3	2	16	9	-	6	-	-	-	3	-	1	1	1	3	4	2	1	4	7	-	1	1	-
TA	10	5	6	29	40	21	29	7	30	-	30	5	17	2	6	4	16	2	5	25	5	-	2	10	7
OT	-	-	2	8	10	-	8	-	1	-	1	2	-	-	-	1	1	-	-	-	-	-	-	-	-
AB	37	13	5	12	13	20	4	17	6	-	20	27	32	18	35	39	25	40	28	26	22	20	32	12	18

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
HC	2	18	4	4	35	3	17	6	55	2	32	24	20	15	9	20	23	19	24	6	24	38	22	34	29
MA	83	50	78	46	26	83	27	16	-	15	14	24	24	20	49	30	58	61	33	46	42	30	39	19	19
SC	1	-	1	1	2	2	2	1	20	4	1	-	-	7	-	-	1	4	-	1	16	1	-	4	15
TA	-	5	6	11	22	8	39	63	-	-	20	12	31	37	22	5	18	5	13	8	7	22	25	21	19
OT	-	-	1	1	-	-	-	-	-	-	1	-	-	-	2	-	-	2	-	-	4	5	2	-	3
AB	14	27	10	37	15	4	15	14	25	79	32	40	25	21	18	45	-	9	30	39	7	4	12	22	15

	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
HC	25	11	33	33	46	41	21	36	36	35	28	54	61	14	12	17	4	31	-	2	11	9	1	13	19
MA	35	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	1	-	5	78	52	46
SC	6	26	11	24	38	10	40	44	11	31	29	14	17	13	22	27	1	40	-	1	1	5	-	7	5
TA	32	55	32	9	16	10	13	6	20	22	12	14	18	23	19	20	-	20	39	5	3	75	10	8	16
OT	2	-	3	11	-	23	2	-	21	-	1	1	1	-	-	20	1	9	-	1	3	10	-	-	1
AB	-	8	13	23	-	16	24	14	12	12	30	17	3	50	47	16	94	-	39	90	82	36	11	20	13

	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
HC	15	4	25	14	8	53	29	18	-	8	2	-	3	5	2	1	14	53	94	64	83	19	66	19	36
MA	41	61	46	29	26	20	-	70	-	49	90	-	75	49	87	23	53	-	-	29	7	5	-	5	-
SC	-	1	1	9	-	3	34	2	-	3	-	-	1	5	-	-	1	-	-	-	-	-	1	-	1
TA	32	8	16	13	2	15	18	2	-	23	-	-	8	5	3	8	3	-	-	-	3	-	5	-	2
OT	1	2	-	3	2	-	6	-	-	8	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-
AB	11	24	12	32	61	9	13	8	-	9	8	-	12	36	7	68	29	47	6	6	7	76	28	76	61

APPENDIX 4. Environmental gradients for each site. Where Dep is the depth (LWD), Is. where each island is allocated a number, Reg. region, Ti is the tidal amplitude, Dm. distance from mainland, Dr. distance from nearest river, Sd. shelf depth, Ex. exposure.

SITE	Dep	Is	Reg	Ti	Dm	Dr	Sd	EX
Site 1	3	8	1	1	3	8	6	0
Site 2	3	8	1	1	3	8	6	0
Site 3	3	8	1	1	3	8	6	0
Site 4	3	22	1	2	3	4	5	0
Site 5	2	22	1	2	3	4	6	0
Site 6	2	22	1	2	3	4	9	0
Site 7	2	21	1	2	2	7	7	1
Site 8	2	21	1	2	2	7	6	0
Site 9	2	21	1	1	2	7	2	1
Site 10	2	21	1	1	2	7	2	1
Site 11	2	9	2	2	1	6	7	0
Site 12	3	10	2	2	1	6	7	0
Site 13	2	9	2	2	1	6	3	1
Site 14	2	9	2	2	1	6	3	0
Site 15	3	9	2	2	1	6	4	0
Site 16	2	12	2	2	1	6	2	1
Site 17	2	12	2	2	1	6	4	1
Site 18	2	12	2	2	1	6	4	1
Site 19	2	12	2	2	1	6	4	1
Site 20	1	19	2	4	1	5	4	0
Site 21	3	19	2	4	1	5	5	1
Site 22	2	20	2	4	1	5	7	1
Site 23	2	11	3	2	2	6	4	1
Site 24	2	11	3	2	2	6	4	0
Site 25	2	11	3	2	2	6	4	1
Site 26	2	11	3	2	2	6	6	0
Site 27	2	7	3	2	2	5	6	0
Site 28	2	7	3	2	2	5	6	0
Site 29	2	7	3	2	2	5	6	0
Site 30	2	7	3	2	2	5	6	0
Site 31	2	7	3	2	2	5	4	1

Site 32	3	2	4	3	2	4	2	1
Site 33	3	2	4	3	2	4	5	1
Site 34	2	1	4	3	4	5	5	1
Site 36	2	1	4	3	4	5	4	1
Site 37	2	1	4	3	4	5	3	1
Site 38	2	1	4	3	4	5	3	1
Site 39	3	1	4	3	4	5	3	1
Site 40	3	1	4	3	4	5	4	0
Site 41	1	1	4	3	4	5	2	1
Site 42	2	1	4	3	4	5	2	1
Site 43	2	1	4	3	4	5	2	1
Site 44	2	1	4	3	4	5	2	1
Site 45	2	1	4	3	4	5	2	1
Site 46	3	1	4	3	4	5	2	1
Site 47	2	1	4	3	4	5	3	0
Site 48	3	1	4	3	4	5	3	0
Site 49	2	1	4	3	4	5	3	0
Site 50	2	1	4	3	4	5	3	0
Site 51	3	1	4	3	4	5	3	0
Site 52	2	1	4	3	4	5	4	0
Site 53	3	1	4	3	4	5	3	1
Site 54	3	1	4	3	4	5	3	0
Site 55	3	4	4	3	3	4	5	0
Site 56	3	4	4	3	3	4	5	1
Site 57	2	4	4	3	3	4	2	1
Site 58	1	4	4	3	3	4	1	0
Site 59	2	4	4	3	3	4	1	0
Site 60	2	4	4	3	3	4	1	0
Site 61	3	4	4	3	3	4	2	0
Site 62	3	4	4	3	3	4	3	0
Site 63	1	5	4	3	3	4	2	0
Site 64	3	5	4	3	3	4	2	0
Site 65	2	5	4	3	3	4	2	0
Site 66	2	5	4	3	3	4	3	1
Site 67	3	5	4	3	3	4	3	0
Site 68	2	5	4	3	3	4	4	0
Site 69	2	5	4	3	3	4	3	1
Site 70	3	5	4	3	3	4	3	1

Site 71	2	3	4	3	4	5	3	1
Site 72	2	3	4	3	4	4	5	0
Site 73	2	3	4	3	4	5	5	0
Site 74	2	3	4	3	4	5	4	0
Site 75	2	3	4	3	4	5	4	0
Site 76	2	3	4	3	4	5	4	0
Site 77	2	6	4	3	5	6	6	0
Site 78	3	6	4	3	5	6	6	0
Site 79	3	6	4	3	5	6	7	0
Site 80	3	6	4	3	5	6	6	1
Site 81	3	6	4	3	5	6	6	0
Site 82	3	6	4	3	5	6	6	0
Site 83	3	6	4	3	5	6	6	1
Site 84	3	6	4	3	5	6	6	1
Site 85	3	6	4	3	5	6	6	1
Site 86	3	6	4	3	5	6	6	1
Site 87	3	6	4	3	5	6	6	1
Site 88	3	6	4	3	5	6	6	1
Site 89	1	23	5	3	8	8	1	1
Site 90	2	23	5	3	8	8	1	1
Site 91	2	23	5	3	8	8	6	1
Site 92	1	23	5	3	8	8	1	0
Site 93	2	23	5	3	8	8	1	0
Site 94	1	23	5	3	8	8	1	0
Site 95	1	23	5	3	8	8	1	0
Site 96	1	23	5	3	8	8	1	0
Site 97	1	23	5	3	8	8	1	0
Site 98	2	13	6	5	4	8	3	1
Site 99	2	13	6	5	4	8	3	1
Site 100	2	13	6	5	4	8	1	1
Site 101	3	14	6	5	5	9	4	0
Site 102	2	14	6	5	5	9	4	1
Site 103	2	14	6	5	5	9	3	1
Site 104	2	14	6	5	5	9	2	0
Site 105	2	14	6	5	5	9	2	0
Site 106	3	15	6	4	5	6	3	0
Site 107	2	15	6	4	5	6	3	0
Site 108	2	16	6	4	7	9	6	1

Site 109	2	16	6	4	7	9	6	1
Site 110	2	16	6	4	7	9	7	0
Site 111	1	16	6	4	7	9	7	0
Site 112	3	16	6	4	7	9	7	0
Site 113	2	16	6	4	7	9	7	0
Site 114	2	16	6	4	7	9	7	0
Site 115	2	16	6	4	7	9	8	1
Site 116	1	17	6	4	7	9	1	1
Site 117	2	17	6	4	7	9	9	1
Site 118	2	18	7	2	2	2	1	1
Site 119	3	18	7	2	2	2	4	1
Site 120	2	18	7	2	2	2	3	1
Site 121	2	18	7	2	2	2	2	0
Site 122	2	18	7	2	2	2	4	1
Site 123	2	18	7	2	2	2	4	1
Site 124	3	18	7	2	2	2	4	1
Site 125	2	18	7	2	2	2	3	1

APPENDIX 5. Summary table of major taxa. Where Freq. is the percent frequency of occurrence for all sites, Mean is the mean colony number for all sites, Whit. is the mean colony number for the Whitsunday Islands, Cum., Nor and Kep. is the mean colony number for the Cumberland, Northumberland and Keppel Islands respectively. Some taxa abbreviations include enc. encrusting, efl. encrusting with free growing outer edge, enfl. encrusting with no free growing outer edge, sub. submassive.

TAXA	Freq	Mean	Whit	Cum	Nor	Kep
FAVIIDAE						
Favia spp.	83.5	8.96	22.90	4.52	2.80	1.37
Favites spp.	80.9	10.22	22.06	4.46	9.75	5.87
Goniastrea spp.	78.3	11.17	21.32	3.39	19.50	5.50
Platygyra spp.	60.0	2.50	2.97	2.71	2.10	0.25
Cyphastrea spp.	60.9	3.71	5.48	3.44	2.20	2.50
Leptastrea spp.	18.3	0.40	4.60	0.30	1.45	6.00
Echinopora spp.	24.3	1.03	2.58	0.53	0.45	-
Oulophyllia spp.	19.1	0.37	0.71	0.11	0.70	0.13
Leptoria sp.	36.5	2.06	0.77	0.23	0.20	0.63
Montastrea spp.	15.7	0.37	0.90	0.18	0.15	0.13
Caulastrea spp.	9.6	0.19	0.32	0.16	0.15	-
Diploastrea sp.	9.6	0.32	0.90	0.16	-	-
Plesiastrea sp.	7.0	0.11	0.09	0.13	0.15	-
Moseleya sp.	1.7	0.02	-	0.02	0.05	-
ACROPORIDAE						
A. 'fine caespitose'	64.4	8.04	7.87	10.46	2.50	5.63
A. 'stout caespitose'	63.5	5.73	7.77	3.64	3.75	17.37
A. 'tabulate'	54.8	3.39	0.87	3.28	4.50	11.13
A. 'fine arborsecent'	33.9	2.16	3.55	1.66	0.60	4.12
A. 'thick arborescent'	37.4	4.52	5.26	1.61	1.55	29.50
A. 'stout'	34.8	1.90	0.55	1.59	0.90	11.87
A. palifera	30.4	2.55	2.32	3.82	0.35	-
A. humilis	15.6	0.67	0.52	1.00	0.15	0.25
A. 'encrusting'	8.7	0.29	0.03	0.59	-	-
Astreopora	33.9	1.29	3.19	0.80	0.20	0.13
Montipora 'efl'	78.3	15.87	19.42	8.52	35.50	4.62
Montipora 'enfl'	50.4	4.33	6.55	4.11	3.25	-
Montipora 'folise'	51.3	6.40	1.61	4.28	22.30	-
Montipora 'sub.'	33.9	2.95	7.03	1.61	1.40	0.38
PORITIDAE						
Porites 'massive'	77.4	9.94	26.03	3.61	5.50	3.00

Porites 'enc.'	43.5	6.34	6.81	2.27	19.40	0.38
Porites 'branching'	16.5	3.03	10.58	0.34	0.10	-
Porites annae	10.4	2.96	9.42	-	2.40	-
Goniopora/Alveopora	83.5	8.12	13.03	7.01	6.65	0.50
POCILLOPORIDAE						
P. damicornis	80.9	7.78	7.03	6.48	5.15	26.38
S. pistillata	61.7	5.00	11.42	3.17	1.30	2.13
Seriatopora spp.	48.7	5.61	12.22	4.59	0.40	0.13
Palauastrea sp.	4.4	0.11	0.39	-	-	0.13
AGARICIIDAE						
Pavona 'massive'	40.0	2.19	1.65	2.30	3.05	1.37
Pavona cactus	6.1	0.28	0.39	0.38	-	-
Pavona 'sub.'	2.6	0.03	0.06	-	0.10	-
Pavona 'enc.'	2.6	1.22	0.32	-	6.55	-
Pachyseris rugosa	17.4	1.15	2.97	0.52	0.55	-
Pachyseris speciosa	37.4	1.72	1.48	2.69	0.05	-
SIDERASTREIDAE						
Coscinaraea/Psammocora	6.9	0.20	0.29	0.09	3.05	-
Pseudosiderastrea sp.	1.7	0.02	0.06	-	-	-
OCULINIDAE						
Galaxea spp.	50.4	2.72	4.26	3.11	0.35	-
Archelia sp.	1.7	0.05	-	0.11	-	-
MERULINIDAE						
Hydnophora spp.	48.7	1.28	1.87	0.80	1.75	1.13
Clavularia sp.	0.9	0.01	0.03	-	-	-
Merulina spp.	44.4	2.02	2.87	2.50	0.15	-
MUSSIDAE						
Lobophyllia spp.	67.8	5.36	11.16	3.86	2.65	0.13
Symphyllia spp.	36.5	0.83	1.03	0.93	0.55	0.13
Acanthastrea spp.	16.5	0.39	0.58	0.39	0.15	0.25
Scolymia spp.	9.6	0.19	0.38	0.07	0.30	-
Cynarina sp.	4.4	0.07	0.09	-	0.25	-
PECTINIIDAE						
Mycedium sp.	34.8	0.89	0.71	1.12	0.85	-
Pectinia spp.	33.9	1.61	4.19	0.93	0.15	-
Echinophyllia spp.	31.3	0.76	1.06	0.54	1.20	-
Oxypora spp.	23.5	0.55	0.74	0.59	0.35	-
FUNGIIDAE						

Fungia spp.	42.6	2.38	5.06	1.80	0.55	0.63
Podabacia sp.	20.9	0.96	3.09	0.19	0.20	-
Herpolitha sp.	17.4	0.49	1.29	0.30	-	-
Heliofungia sp.	13.9	0.59	1.97	0.12	-	-
Cycloseris sp.	13.0	0.25	0.51	0.23	-	-
Herpetoglossa sp.	7.8	0.14	0.19	0.18	-	-
Polyphyllia sp.	6.1	0.12	0.42	0.02	-	-
Sandolitha sp.	2.6	0.03	-	0.07	-	-
Diaseris spp.	1.7	0.02	-	0.04	-	-
CARYOPHYLLIIDAE						
Euphyllia spp.	27.8	0.76	1.42	0.55	0.60	-
Plerogyra sp.	11.3	0.17	0.48	0.09	-	-
Catalaphyllia sp.	6.1	0.12	0.35	0.05	-	-
Physogyra sp.	2.6	0.05	0.09	0.05	-	-
DENDROPHYLLIIDAE						
Turbinaria 'foliose'	59.1	6.23	5.00	1.77	20.95	5.50
Turbinaria 'efl'	21.7	1.05	1.32	0.48	2.65	-
Turbinaria 'enfl'	2.6	0.31	0.39	0.43	-	-
Duccanopsammia sp.	0.9	0.01	-	-	0.05	-
ALCYONARIA						
Sarcophyton sp.	72.2	15.7	25.74	15.9	4.05	4.25
Alcyonium spp.	66.1	29.96	101.68	4.25	2.00	2.00
Sinularia spp.	59.1	6.09	14.81	2.00	5.20	3.25
Lobophytum spp.	58.3	7.23	12.26	6.00	5.75	0.13
Briareum sp.	49.6	5.67	6.74	5.03	8.05	0.13
Xenia sp.	36.5	19.82	50.48	7.67	1.60	31.63
Nephthea spp.	26.9	4.11	6.48	4.80	0.15	-
Cladiella spp.	26.9	2.78	5.32	1.95	2.30	-
Capnella spp.	7.80	2.37	-	-	13.65	-
Anthelia sp.	2.6	0.05	0.16	0.02	-	-
Stereonephthea spp.	0.8	0.01	0.06	4.39	-	-
Dendronephthea spp.	1.7	0.03	0.06	0.02	-	-
Efflatournaria spp.	1.7	0.12	-	-	0.70	-
Cespitularia spp.	1.7	0.04	-	0.09	-	-
HYDROCORALS						
Millepora 'branching'	30.4	4.32	12.22	2.11	-	-
Millepora 'enc.'	6.1	0.26	0.12	0.46	-	-
Millepora 'massive'	6.9	0.14	0.16	0.19	-	-

PORIFERA						
Cliona type	39.1	1.80	1.06	2.18	2.45	0.38
Submassive	63.5	4.49	5.29	4.39	4.15	3.00
GORGONIANS	13.9	0.34	0.23	0.27	0.65	0.50

APPENDIX 6. Summary statistics of line transect data (nb. The before flood data was based on two 20m line transects [40m], the after flood data, due to poor visibility was based on the average of three 15m transects [45m]). Where E is the total cover, and n, SD and mean are the number of recordings, standard deviation and mean of each particular category.

SITE 1 (Miall Island) before the flood at 0.5m below LWD

	n	E	SD	mean	%
Hard coral	41	1451	36.6	35.4	36.5%
Sand/rubble	27	2362	101.1	87.5	59%
Turf algae	2	85	10.6	42.5	2%
Dead coral	4	59	6.9	14.8	1.5%
Soft coral	2	43	3.5	21.5	1%

AFTER THE FLOOD at -1.5m.

	n	E	SD	mean	%
Hard coral	3	112	32.8	37.4	8%
Sand/rubble	5	455	78.9	91	30%
Turf algae	4	144	15.2	36.0	10%
Dead coral	13	472	13.5	36.3	31%
Bleached coral	8	317	34.4	39.5	21%

SITE 2 (Middle Island) before the flood at 1.0m below LWD

	n	E	SD	mean	%
Hard coral	35	3311	85.1	94.6	83%
Macroalgae	18	293	12.7	16.3	7%
Dead coral	2	16	2.8	8.0	1%
Sand/rubble	5	257	12.6	51.4	6%
Turf algae	4	123	21.2	31.0	3%

AFTER THE FLOODS
At 1.5m below LWD.

	n	E	SD	mean	%
Live hard coral	5	327	84.8	65.4	22%
Bleached coral	20	699	65.1	34.9	46%
Dead coral	3	324	281.9	108	22%
Sand/rubble	4	150	14.2	37.5	10%

At 2.0m below LWD

	n	E	SD	mean	%
Live hard coral	22	1170	60.1	53.2	78
Bleached coral	2	52	8.6	26.0	4%
Dead coral	3	45	7.9	15.0	3%
Sand/rubble	5	233	13.2	46.6	15%

SITE 3 (Monkey Bay) before the floods at 1.0m below LWD

	n	E	SD	mean	%
Hard coral	80	2574	62.4	32.1	64%
Macroalgae	61	1164	16.6	19.1	29%
Turf algae/rubble	16	246	23.7	15.4	6%
Coralline algae	3	16	7.2	5.3	1%

AFTER THE FLOOD

	n	E	SD	mean	%
Hard coral	5	152	28.8	30.4	10
Bleached coral	1	8	0	8	1
Dead coral	14	1182	108.9	84.4	78
Turf algae	6	148	11.8	24.7	10
Coralline algae	2	10	1.4	5.0	1

SITE 4 (Clam Bay) before the floods at 1.0m below LWD

	n	E	SD	mean	%
Hard coral	12	3740	347.6	311.6	93.5%
Rubble	3	260	116.8	86.6	6.5%

At 8.5m below LWD

	n	E	SD	mean	%
Hard coral	15	2129	162.9	141.9	53%
Sand/rubble	12	1871	143.8	155.9	47%

AFTER THE FLOODS
At 1.0m below LWD

	n	E	Sd	mean	%
Live hard coral	0	0	0	0	0
Dead coral	1	1500	-	1500	100%

At 2.0m below LWD

	n	E	SD	mean	%
Live hard coral	5	134	22	26.8	9
Dead coral	9	1309	182.4	145.4	87
Bleached coral	3	57	18.5	19	4

At 2.5m below LWD

	n	E	SD	mean	%
Live hard coral	12	493	35.4	41.5	33
Dead coral	20	762	20.9	38.1	51
Bleached coral	10	245	14.9	24.3	16

At 4.0m below LWD

	n	E	SD	mean	%
Live hard coral	13	1190	112	91.5	79
Dead coral	4	153	14	38.3	10
Bleached coral	2	67	0.7	33.5	5
Rubble	1	90	0	90	6

At 6.0m below LWD

	n	E	SD	mean	%
Live hard coral	7	1328	192	189.7	89
Bleached coral	4	113	3.4	28.3	8
Sand/rubble	1	59	0	59	3

At 7.0m below LWD

	n	E	SD	mean	%
Live hard coral	10	1187	136	118.7	79
Bleached coral	1	7	0	7	1
Soft coral	2	43	0.7	21.5	3
Sand/rubble	3	263	78.2	87.7	17

SITE 5 (Halfway Island) at 0.5m above LWD

	n	E	SD	mean	%
Hard coral	48	2640	43.2	55.0	66%
Soft coral	2	35	3.5	17.5	1%
Turf algae	7	196	10.8	28.0	5%
Sand/rubble	23	1129	39.6	49.1	28%

AFTER THE FLOODS
At 0.3m below LWD

	n	E	Sd	mean	%
Dead coral	12	1037	81.1	86.4	69%
Sand/rubble	6	463	44.3	77.2	31%

At 0.8m below LWD

	n	E	SD	mean	%
Bleached coral	7	156	13.8	22.3	10%
Dead Coral	9	510	46.6	56.6	34%
Sand/rubble	10	834	64.3	83.4	56%

At 1.5m below LWD

	n	E	SD	mean	%
Live hard coral	1	9	0	9	1%
Bleached coral	2	53	7.8	26.5	3%
Dead coral	1	45	0	45	3%
Sand/rubble	12	1090	60.1	90.8	73%
Macroalgae	7	303	86.4	43.3	20%

SITE 6 (Humpy Island) at LWD.

Before the flood	n	E	SD	mean	%
Hard coral	26	752	25.1	28.9	19%
Macroalgae	13	186	5.3	14.3	5%
Soft coral	1	20	-	20	-
Sand/rubble	36	3042	77.8	84.5	76%

AFTER THE FLOOD
Problems obtaining line transect information on this dive.

SITE 7 (Bald Rock) after the flood 0.5m above LWD

	n	E	SD	mean	%
Live hard coral	11	218	10.4	19.7	14%
Bleached coral	10	232	14.5	23.2	16%
Dead coral	10	187	8.7	18.5	12%
Turf algae	19	860	24.0	45.2	57%
Soft coral	1	3	0	3	1%

At LWD

	n	E	SD	mean	%
Live hard coral	15	340	15.1	24.4	23%
Bleached coral	4	156	0	46.3	10%
Dead coral	10	370	18.5	40.6	25%
Turf algae	15	576	23.8	37.3	38%
Soft coral	2	58	2.8	29.0	4%

At 0.2m below LWD

	n	E	SD	mean	%
Live hard coral	15	427	18.2	28.5	28%
Bleached coral	3	102	17.6	34.0	7%
Dead coral	15	552	23.0	36.8	37%
Turf algae	9	321	11.5	35.6	21%
Soft coral	5	98	10.1	19.6	7%

SITE 8 (Barron Island) after the floods, new permanent sites.
At 0.2m above LWD

	n	E	SD	mean	%
Live hard coral	25	675	24.5	27.0	34%
Dead coral	14	724	52.9	51.8	36%
Turf algae	10	313	29.8	31.3	16%
Bleached coral	3	47	8.9	15.6	2%
Sand/rubble	4	241	40.5	60.3	12%

At LWD

	n	E	SD	mean	%
Live hard coral	24	683	28.8	28.5	34%
Dead coral	22	824	29.8	37.5	41%
Bleached coral	4	61	11.5	15.3	3%
Turf algae	8	358	38.2	44.8	18%
Sand/rubble	1	26	-	26	1%
Others	3	48	8.6	16	3%

At 0.3m below LWD

	n	E	SD	mean	%
Live hard coral	19	775	37.4	40.8	39%
Dead coral	21	964	35.9	45.9	48%
Bleached coral	2	88	41.0	44.0	5%
Turf algae	6	145	10.0	24.2	7%
Others	4	28	2.3	7	1%

At 2.5m below LWD

	n	E	SD	mean	%
Live hard coral	26	1157	40.6	44.5	58%
Dead coral	10	524	31.6	52.4	26%
Turf algae	6	92	11.6	15.3	5%
Soft coral	2	171	82.7	85.5	8%
Sand/rubble	2	56	8.5	28.0	3%

At 3.0m below LWD

	n	E	SD	mean	%
Live hard coral	36	1383	44.8	38.4	69%
Turf algae	11	251	18.0	22.8	13%
Soft coral	12	111	5.3	9.3	5%
Rubble	7	255	30.8	36.4	13%

Species List for the Keppel Islands, 1989.

Pocilloporidae

Pocillopora damicornis
Stylophora pistillata
Seriatopora hystrix
Palauastrea ramosa

Acroporidae

A. tenuis
A. loripes
A. cytherea
A. glauca
A. hyacinthus
A. nasuta
A. nana
A. nobilis
A. sarmentosa
A. millepora
A. solitaryensis
A. pulchra
A. aspera
A. microphthalma
A. formosa
A. cerealis
A. dendrum
A. microclados
A. selago
A. aculeus
A. valida
A. clathrata
A. divaricata
A. subulata
A. latistella
A. humilis
A. secale
A. samoensis

Montipora aequituberculata
Montipora venosa
Montipora efflorescens
Montipora tuberculosa
Montipora crassituberculata
Montipora angulata
Montipora hispida

Poritidae

P. australiensis
P. lutea/lobata
Goniopora spp.
P. annae
P. densa

Faviidae

Favia rotumana
Favia lizardensis
Favia speciosa
Favites halicora
Favites flexuosa
Favites complanata
Goniastrea australiensis
Goniastrea favulus
Platygyra daedalea
Oulophyllia crispa
Cyphastrea chalcidicum
Cyphastrea serailia
Leptastrea transversa
Favia favus
Favia pallida
Favites russelli
Favites chinensis
Favites pentagona
Goniastrea palauensis
Goniastrea retiformis
Leptoria phrygia
Platygyra sinensis
Montastrea curta
Cyphastrea microphthalma
Leptastrea purpurea
Leptastrea inequalis

Dendrophylliidae

Turbinaria bifrons
Turbinaria stellulata
Turbinaria mesenterina
Turbinaria peltata
Turbinaria frondens
Turbinaria reniformis

Other families

Galaxea fascicularis
Hydnophora excesa
Coscinaraea columna
Pavona venosa
Hydnophora pilosa
Psammocora contigua
Acanthastrea echinata
Fungia spp.

APPENDIX 7: EASTERN WHITSUNDAY ISLANDS - TIME 1.
Frequency and total cover were calculated for four 20m line transects.

TIME	SITE	HABITAT	SPECIES	FREQUENCY	TOTAL COVER
SITE 1.					
Reef flat					
1	1	1	Acropora spp.	1	5
1	1	1	Alcyonium spp.	1	6
1	1	1	Briareum sp.	1	14
1	1	1	Cyphastrea spp.	1	11
1	1	1	Favites spp.	3	36
1	1	1	Galaxea spp.	1	3
1	1	1	Goniopora spp.	3	15
1	1	1	Lobophyllia spp.	2	27
1	1	1	Lobophytum spp.	2	42
1	1	1	Macroalgae	18	2792
1	1	1	Montipora spp.	4	63
1	1	1	Porites spp.	1	14
1	1	1	Seagrass	15	2043
1	1	1	Sponge	11	111
1	1	1	Symphyllia spp.	2	10
Reef crest					
1	1	2	Acropora divaricata	2	35
1	1	2	Acropora formosa	5	76
1	1	2	Acropora latistella	2	83
1	1	2	Acropora microphthalma	1	31
1	1	2	Acropora palifera	1	63
1	1	2	Acropora tenuis	2	78
1	1	2	Acropora valida	1	72
1	1	2	Alcyonium spp.	4	97
1	1	2	Astreopora spp.	1	14
1	1	2	Briareum sp.	8	112
1	1	2	Dead coral	2	58
1	1	2	Favia favus	1	8
1	1	2	Favia matthaii	1	3
1	1	2	Favia maxima	1	13
1	1	2	Favia pallida	1	16
1	1	2	Favites flexuosa	1	7
1	1	2	Fungia spp.	5	88
1	1	2	Galaxea spp.	4	59
1	1	2	Goniastrea aspera	3	21
1	1	2	Goniastrea australensis	1	20
1	1	2	Goniastrea pectinata	1	10
1	1	2	Goniopora spp.	4	37
1	1	2	Heliofungia actiniformis	3	29
1	1	2	Herpolitha spp.	3	31
1	1	2	Hydnophora rigida	2	35
1	1	2	Leptastrea purpurea	1	6
1	1	2	Lobophyllia pachysepta	1	3
1	1	2	Lobophyllia spp.	7	156
1	1	2	Lobophytum spp.	2	32
1	1	2	Macroalgae	15	350
1	1	2	Merulina ampliata	5	69
1	1	2	Millepora spp.	12	231
1	1	2	Montastrea spp.	3	22
1	1	2	Montipora spp.	3	51
1	1	2	Mycedium elephantotus	1	18
1	1	2	Nephthea spp.	4	65
1	1	2	Padina sp.	5	82
1	1	2	Pectinia alcicornis	8	219
1	1	2	Pectinia paeonia	1	17
1	1	2	Pectinia sp.	5	107
1	1	2	Podabacia crustacea	7	97
1	1	2	Porites massive	2	39
1	1	2	Porites annae	32	1450
1	1	2	Porites cylindrica	18	687
1	1	2	Rubble	6	179
1	1	2	Sarcophyton sp.	11	245
1	1	2	Sinularia spp.	3	49
1	1	2	Sponge	10	182
1	1	2	Turbinaria mesenterina	2	63
1	1	2	Turbinaria reniformis	2	29
1	1	2	Turbinaria spp.	1	18
1	1	2	Xenia sp.	5	27
Upper slope					
1	1	3	Acropora cerealis	2	27
1	1	3	Acropora divaricata	3	60
1	1	3	Acropora formosa	2	72
1	1	3	Acropora humilis	1	9
1	1	3	Acropora latistella	2	37

1	1	3	Acropora nasuta	1	28
1	1	3	Acropora selago	1	9
1	1	3	Acropora valida	3	40
1	1	3	Alcyonium spp.	4	80
1	1	3	Astreopora spp.	1	12
1	1	3	Briareum sp.	4	34
1	1	3	Cyphastrea serailia	1	4
1	1	3	Cyphastrea spp.	4	47
1	1	3	Dead coral	1	60
1	1	3	Echinophyllia spp.	4	135
1	1	3	Echinopora horrida	1	23
1	1	3	Echinopora lamellosa	1	74
1	1	3	Echinopora spp.	2	145
1	1	3	Favia rotundata	1	22
1	1	3	Favia speciosa	1	17
1	1	3	Favites flexuosa	1	3
1	1	3	Favites halicora	2	25
1	1	3	Fungia spp.	2	15
1	1	3	Galaxea spp.	6	153
1	1	3	Goniastrea edwardsi	1	6
1	1	3	Goniopora spp.	8	304
1	1	3	Herpolitha spp.	3	47
1	1	3	Hydnophora exesa	2	53
1	1	3	Leptastrea purpurea	1	2
1	1	3	Lobophyllia spp.	3	44
1	1	3	Lobophytum spp.	2	12
1	1	3	Merulina ampliata	3	89
1	1	3	Millepora spp.	4	140
1	1	3	Montastrea spp.	1	13
1	1	3	Montipora spp.	1	10
1	1	3	Mycedium elephantotus	4	80
1	1	3	Nephthea spp.	18	486
1	1	3	Oxypora spp.	2	27
1	1	3	Pachyseris speciosa	2	69
1	1	3	Palauastrea ramosa	1	33
1	1	3	Pavona decussata	1	25
1	1	3	Pectinia alcicornis	1	39
1	1	3	Pectinia sp.	4	165
1	1	3	Podabacia crustacea	2	30
1	1	3	Porites massive	1	16
1	1	3	Porites annae	20	546
1	1	3	Porites cylindrica	18	594
1	1	3	Rubble	9	535
1	1	3	Sarcophyton sp.	14	215
1	1	3	Seriatopora hystrix	1	28
1	1	3	Sinularia spp.	6	133
1	1	3	Sponge	6	65
1	1	3	Stylophora pistillata	3	61
1	1	3	Symphyllia spp.	1	13
1	1	3	Turbinaria mesenterina	6	241
1	1	3	Turbinaria reniformis	1	13
Lower slope					
1	1	4	Acropora divaricata	2	110
1	1	4	Acropora formosa	2	82
1	1	4	Acropora latistella	1	32
1	1	4	Acropora spat	1	3
1	1	4	Acropora valida	4	95
1	1	4	Astreopora spp.	2	84
1	1	4	Briareum sp.	3	19
1	1	4	Coscinaraea spp.	2	31
1	1	4	Cyphastrea spp.	3	21
1	1	4	Echinophyllia aspera	2	25
1	1	4	Echinophyllia orpheensis	1	7
1	1	4	Echinophyllia spp.	14	446
1	1	4	Euphyllia cristata	1	13
1	1	4	Favites halicora	1	13
1	1	4	Fungia spp.	2	33
1	1	4	Galaxea spp.	3	289
1	1	4	Goniastrea pectinata	2	8
1	1	4	Goniopora spp.	16	314
1	1	4	Herpolitha spp.	1	4
1	1	4	Hydnophora rigida	1	9
1	1	4	Lobophyllia hemprichii	1	11
1	1	4	Lobophyllia pachysepta	1	7
1	1	4	Lobophyllia spp.	2	21
1	1	4	Macroalgae	5	60
1	1	4	Merulina ampliata	7	167
1	1	4	Montastrea spp.	2	26
1	1	4	Montipora spp.	7	117
1	1	4	Mycedium elephantotus	5	81
1	1	4	Nephthea spp.	7	116
1	1	4	Oxypora spp.	1	49
1	1	4	Pachyseris speciosa	8	337

1	1	4	Pectinia alcicornis	6	157
1	1	4	Pectinia paeonia	3	56
1	1	4	Pectinia sp.	2	53
1	1	4	Platygyra sinensis	1	11
1	1	4	Platygyra spp.	2	28
1	1	4	Podabacia crustacea	2	58
1	1	4	Porites encrusting	2	16
1	1	4	Porites annae	2	38
1	1	4	Porites cylindrica	4	70
1	1	4	Porites lichen	6	103
1	1	4	Rubble	10	666
1	1	4	Sarcophyton sp.	13	242
1	1	4	Seriatopora hystrix	2	19
1	1	4	Sinularia spp.	4	72
1	1	4	Sponge	10	215
1	1	4	Turbinaria reniformis	2	50

SITE 2.
Reef flat

1	2	1	Acanthastrea spp.	1	8
1	2	1	Acropora millepora	1	26
1	2	1	Catalaphyllia jardinei	1	16
1	2	1	Cespitularia sp.	2	24
1	2	1	Cyphastrea spp.	1	8
1	2	1	Favites complanata	1	3
1	2	1	Fungia spp.	1	9
1	2	1	Goniopora spp.	1	36
1	2	1	Heliofungia actiniformis	1	13
1	2	1	Lobophyllia hemprichii	2	9
1	2	1	Lobophytum spp.	3	47
1	2	1	Macroalgae	54	3542
1	2	1	Plesiastrea versipora	1	9
1	2	1	Pocillopora damicornis	1	7
1	2	1	Porites massive	2	34
1	2	1	Porites cylindrica	1	10
1	2	1	Sarcophyton sp.	6	65
1	2	1	Seagrass	16	2090
1	2	1	Sinularia spp.	5	65
1	2	1	Sponge	7	125
1	2	1	Turbinaria mesenterina	1	19

Reef crest

1	2	2	Acropora divaricata	2	57
1	2	2	Acropora formosa	3	38
1	2	2	Acropora latistella	4	168
1	2	2	Acropora microphthalma	2	37
1	2	2	Acropora millepora	1	17
1	2	2	Acropora nasuta	2	37
1	2	2	Acropora tenuis	3	69
1	2	2	Acropora valida	1	28
1	2	2	Alcyonium spp.	2	20
1	2	2	Briareum sp.	2	22
1	2	2	Cespitularia sp.	1	16
1	2	2	Cyphastrea chalcidicum	2	11
1	2	2	Echinopora gemmacea	2	51
1	2	2	Echinopora mammiformis	3	37
1	2	2	Euphyllia divisa	1	37
1	2	2	Favia lizardensis	1	14
1	2	2	Favia pallida	2	14
1	2	2	Favia rotundata	1	26
1	2	2	Favia spp.	3	29
1	2	2	Favites abdita	1	27
1	2	2	Favites flexuosa	1	3
1	2	2	Favites halicora	1	44
1	2	2	Goniastrea spp.	2	15
1	2	2	Goniopora spp.	2	20
1	2	2	Hydnophora rigida	1	13
1	2	2	Leptastrea spp.	1	3
1	2	2	Lobophyllia spp.	2	34
1	2	2	Millepora spp.	14	796
1	2	2	Montipora spp.	4	108
1	2	2	Padina sp.	2	37
1	2	2	Parerythropodium sp.	3	35
1	2	2	Pavona cactus	10	259
1	2	2	Platygra lamellina	3	41
1	2	2	Plesiastrea versipora	1	10
1	2	2	Pocillopora damicornis	1	19
1	2	2	Porites massive	3	33
1	2	2	Porites annae	14	320
1	2	2	Porites cylindrica	45	2393
1	2	2	Sarcophyton sp.	18	485
1	2	2	Seriatopora hystrix	2	39
1	2	2	Sinularia spp.	13	467
1	2	2	Stylophora pistillata	1	33

1	2	2	Xenia sp.	2	9
Upper slope					
1	2	3	Acropora cerealis	3	70
1	2	3	Acropora latistella	5	117
1	2	3	Acropora microphthalma	2	19
1	2	3	Acropora selago	1	16
1	2	3	Acropora valida	4	163
1	2	3	Alcyonium spp.	9	91
1	2	3	Astreopora spp.	3	52
1	2	3	Caulastrea spp.	1	21
1	2	3	Echinopora gemmacea	6	305
1	2	3	Echinopora horrida	1	34
1	2	3	Euphyllia divisa	1	48
1	2	3	Favia speciosa	1	14
1	2	3	Goniastrea pectinata	1	37
1	2	3	Goniopora spp.	8	186
1	2	3	Lobophyllia hemprichii	2	20
1	2	3	Lobophyllia spp.	2	116
1	2	3	Lobophytum spp.	3	50
1	2	3	Macroalgae	3	23
1	2	3	Merulina ampliata	2	16
1	2	3	Millepora spp.	3	178
1	2	3	Montastrea spp.	2	17
1	2	3	Montipora spp.	6	158
1	2	3	Padina sp.	12	270
1	2	3	Pavona cactus	2	20
1	2	3	Pavona explanulata	1	26
1	2	3	Pectinia sp.	1	10
1	2	3	Platygyra spp.	3	24
1	2	3	Pocillopora damicornis	1	25
1	2	3	Podabacia crustacea	1	18
1	2	3	Porites massive	8	663
1	2	3	Porites annae	6	65
1	2	3	Porites cylindrica	9	207
1	2	3	Sarcophyton sp.	10	226
1	2	3	Seriatopora hystrix	2	28
1	2	3	Sinularia spp.	7	140
1	2	3	Sponge	2	35
1	2	3	Stylophora pistillata	2	32
1	2	3	Turbinaria peltata	1	22
Lower slope					
1	2	4	Acropora formosa	1	6
1	2	4	Alcyonium spp.	2	16
1	2	4	Alveopora spp.	1	27
1	2	4	Astreopora spp.	1	5
1	2	4	Briareum sp.	1	9
1	2	4	Cynarina lacrymalis	1	12
1	2	4	Cyphastrea spp.	1	14
1	2	4	Echinophyllia spp.	4	114
1	2	4	Echinopora gemmacea	1	22
1	2	4	Favia favus	1	11
1	2	4	Favia rotundata	1	11
1	2	4	Favites abdita	1	12
1	2	4	Favites russelli	3	42
1	2	4	Fungia spp.	1	14
1	2	4	Galaxea spp.	2	79
1	2	4	Goniopora spp.	4	70
1	2	4	Heliofungia actiniformis	1	23
1	2	4	Herpolitha spp.	1	8
1	2	4	Hydnophora exesa	1	7
1	2	4	Lobophyllia spp.	1	6
1	2	4	Lobophytum spp.	2	36
1	2	4	Montipora spp.	7	119
1	2	4	Moseleya latistellata	1	4
1	2	4	Nephthea spp.	1	28
1	2	4	Pavona cactus	1	14
1	2	4	Pavona explanulata	1	63
1	2	4	Pectinia sp.	2	39
1	2	4	Platygyra spp.	2	21
1	2	4	Pocillopora damicornis	1	23
1	2	4	Porites massive	11	789
1	2	4	Sarcophyton sp.	9	149
1	2	4	Seagrass	11	2307
1	2	4	Sinularia spp.	4	36
1	2	4	Sponge	12	204
1	2	4	Turbinaria mesenterina	2	25
1	2	4	Turbinaria spp.	1	4
SITE 3.					
Reef flat					
1	3	1	Acropora cerealis	1	13
1	3	1	Acropora formosa	3	27

1	3	1	Acropora millepora	2	16
1	3	1	Acropora nobilis	1	19
1	3	1	Briareum sp.	9	231
1	3	1	Cespitularia sp.	8	153
1	3	1	Cyphastrea serailia	2	13
1	3	1	Euphyllia ancora	1	6
1	3	1	Euphyllia divisa	2	14
1	3	1	Favia favus	1	7
1	3	1	Favites halicora	2	19
1	3	1	Goniastrea spp.	1	28
1	3	1	Goniopora spp.	4	67
1	3	1	Lobophyllia spp.	1	8
1	3	1	Lobophytum spp.	8	92
1	3	1	Macroalgae	42	2828
1	3	1	Montipora spp.	3	26
1	3	1	Nephthea spp.	4	22
1	3	1	Pavona decussata	1	4
1	3	1	Plerogyra sinuosa	1	21
1	3	1	Porites massive	1	11
1	3	1	Porites annae	1	3
1	3	1	Porites lichen	4	26
1	3	1	Sarcophyton sp.	8	142
1	3	1	Seagrass	10	570
1	3	1	Sinularia spp.	20	535
1	3	1	Soft coral (species)	1	13
1	3	1	Sponge	6	62
1	3	1	Xenia sp.	11	151
Reef crest					
1	3	2	Acropora elseyi	9	181
1	3	2	Acropora formosa	52	3362
1	3	2	Acropora latistella	1	38
1	3	2	Acropora longicyathus	7	101
1	3	2	Acropora microphthalma	4	31
1	3	2	Acropora nobilis	13	425
1	3	2	Briareum sp.	1	9
1	3	2	Lobophytum spp.	8	301
1	3	2	Macroalgae	28	1255
1	3	2	Padina sp.	2	43
1	3	2	Porites annae	1	8
1	3	2	Sarcophyton sp.	1	8
1	3	2	Sinularia spp.	4	36
1	3	2	Stylophora pistillata	1	12
Upper slope					
1	3	3	Acropora elseyi	23	1574
1	3	3	Acropora formosa	24	2331
1	3	3	Acropora latistella	1	28
1	3	3	Acropora longicyathus	2	22
1	3	3	Acropora microphthalma	9	193
1	3	3	Acropora nobilis	7	275
1	3	3	Alcyonium spp.	2	19
1	3	3	Briareum sp.	1	15
1	3	3	Dead coral	1	396
1	3	3	Goniopora spp.	1	7
1	3	3	Leptastrea purpurea	1	4
1	3	3	Lobophyllia hemprichii	1	31
1	3	3	Lobophytum spp.	1	12
1	3	3	Macroalgae	6	53
1	3	3	Millepora spp.	1	52
1	3	3	Montipora spp.	4	76
1	3	3	Pectinia paeonia	1	16
1	3	3	Sarcophyton sp.	1	16
1	3	3	Seriatopora hystrix	23	825
1	3	3	Sinularia spp.	1	7
1	3	3	Soft coral (species)	1	4
1	3	3	Stylophora pistillata	2	7
Lower slope					
1	3	4	Acropora elseyi	7	59
1	3	4	Acropora latistella	1	18
1	3	4	Acropora valida	1	16
1	3	4	Alcyonium spp.	1	6
1	3	4	Alveopora spp.	1	75
1	3	4	Astreopora spp.	1	32
1	3	4	Echinophyllia spp.	4	177
1	3	4	Fungia spp.	2	28
1	3	4	Galaxea spp.	2	15
1	3	4	Goniopora spp.	12	267
1	3	4	Herpolitha spp.	1	8
1	3	4	Merulina ampliata	4	98
1	3	4	Montipora spp.	9	339
1	3	4	Mycedium elephantotus	1	14
1	3	4	Padina sp.	2	14

1	3	4	Pectinia paeonia	2	17
1	3	4	Pectinia sp.	2	35
1	3	4	Pocillopora damicornis	1	33
1	3	4	Podabacia crustacea	1	25
1	3	4	Porites massive	1	28
1	3	4	Sarcophyton sp.	2	15
1	3	4	Seriatopora hystrix	40	2401
1	3	4	Sinularia spp.	1	7
1	3	4	Sponge	10	147
1	3	4	Turbinaria mesenterina	1	34

SITE 4.

Reef flat

1	4	1	Acropora digitifera	1	16
1	4	1	Acropora formosa	6	85
1	4	1	Acropora millepora	3	114
1	4	1	Cyphastrea spp.	2	33
1	4	1	Favia spp.	6	55
1	4	1	Fungia spp.	1	15
1	4	1	Goniopora spp.	8	229
1	4	1	Halimeda spp.	3	30
1	4	1	Lobophytum spp.	1	72
1	4	1	Macroalgae	19	1824
1	4	1	Merulina ampliata	2	38
1	4	1	Millepora spp.	3	41
1	4	1	Montipora spp.	5	107
1	4	1	Padina sp.	12	353
1	4	1	Pocillopora damicornis	3	41
1	4	1	Porites spp.	3	21
1	4	1	Sand	3	272
1	4	1	Sarcophyton sp.	10	224
1	4	1	Seagrass	10	422
1	4	1	Seriatopora hystrix	5	40
1	4	1	Sinularia spp.	4	54
1	4	1	Sponge	13	178
1	4	1	Stylophora pistillata	6	142
1	4	1	Symphyllia spp.	2	25
1	4	1	Turbinaria reniformis	1	30

Reef crest

1	4	2	Acropora divaricata	1	16
1	4	2	Acropora elseyi	15	463
1	4	2	Acropora formosa	22	949
1	4	2	Acropora latistella	2	20
1	4	2	Acropora longicyathus	19	612
1	4	2	Acropora microphthalma	7	249
1	4	2	Acropora millepora	2	29
1	4	2	Acropora nasuta	2	34
1	4	2	Acropora nobilis	7	254
1	4	2	Acropora palifera	6	257
1	4	2	Acropora selago	1	16
1	4	2	Acropora tenuis	3	109
1	4	2	Acropora valida	3	47
1	4	2	Alcyonium spp.	5	67
1	4	2	Echinopora horrida	1	10
1	4	2	Echinopora lamellosa	1	8
1	4	2	Echinopora mammiformis	1	16
1	4	2	Echinopora spp.	1	22
1	4	2	Euphyllia ancora	1	5
1	4	2	Favia matthaii	1	8
1	4	2	Fungia spp.	2	26
1	4	2	Goniastrea aspera	1	6
1	4	2	Goniopora spp.	6	174
1	4	2	Heliofungia actiniformis	1	23
1	4	2	Hydnophora rigida	1	48
1	4	2	Leptastrea purpurea	1	9
1	4	2	Leptastrea transversa	1	6
1	4	2	Lobophyllia corymbosa	1	14
1	4	2	Lobophyllia hemprichii	2	14
1	4	2	Lobophytum spp.	2	31
1	4	2	Macroalgae	7	162
1	4	2	Millepora spp.	3	271
1	4	2	Montipora spp.	5	70
1	4	2	Nephthea spp.	2	31
1	4	2	Pectinia alcicornis	3	29
1	4	2	Pectinia sp.	3	73
1	4	2	Platygyra sinensis	1	15
1	4	2	Plesiastrea versipora	4	41
1	4	2	Porites massive	2	10
1	4	2	Rubble	8	370
1	4	2	Sarcophyton sp.	5	58
1	4	2	Seriatopora hystrix	18	439
1	4	2	Sinularia spp.	9	193
1	4	2	Sponge	2	29

1	4	2	Stylophora pistillata	6	57
Upper slope					
1	4	3	Acropora austera	1	46
1	4	3	Acropora cerealis	2	24
1	4	3	Acropora divaricata	1	16
1	4	3	Acropora elseyi	13	405
1	4	3	Acropora formosa	17	508
1	4	3	Acropora latistella	7	78
1	4	3	Acropora longicyathus	1	16
1	4	3	Acropora microphthalma	2	27
1	4	3	Acropora palifera	1	10
1	4	3	Acropora valida	3	54
1	4	3	Alcyonium spp.	1	4
1	4	3	Caulastrea spp.	3	100
1	4	3	Echinophyllia spp.	1	16
1	4	3	Echinopora lamellosa	2	6
1	4	3	Fungia spp.	1	8
1	4	3	Galaxea spp.	2	26
1	4	3	Goniopora spp.	3	55
1	4	3	Heliofungia actiniformis	1	13
1	4	3	Lobophyllia spp.	1	3
1	4	3	Merulina ampliata	2	70
1	4	3	Millepora spp.	1	72
1	4	3	Montipora encrusting	6	67
1	4	3	Moseleya latistellata	2	17
1	4	3	Pectinia alcicornis	2	10
1	4	3	Pectinia sp.	1	23
1	4	3	Rubble	11	510
1	4	3	Sarcophyton sp.	5	58
1	4	3	Seriatopora hystrix	53	3819
1	4	3	Sinularia spp.	5	56
1	4	3	Soft coral (species)	2	20
1	4	3	Sponge	1	11
1	4	3	Stylophora pistillata	2	36
Lower slope					
1	4	4	Acropora longicyathus	4	55
1	4	4	Acropora valida	2	20
1	4	4	Alcyonium spp.	1	13
1	4	4	Caulastrea spp.	1	8
1	4	4	Echinophyllia spp.	8	224
1	4	4	Favia favus	1	23
1	4	4	Favia spp.	1	18
1	4	4	Favites spp.	2	53
1	4	4	Fungia spp.	4	76
1	4	4	Galaxea spp.	2	20
1	4	4	Goniastrea spp.	1	24
1	4	4	Goniopora spp.	5	75
1	4	4	Leptastrea spp.	1	14
1	4	4	Leptoria phrygia	1	26
1	4	4	Lobophyllia hemprichii	3	40
1	4	4	Lobophyllia spp.	2	21
1	4	4	Macroalgae	2	21
1	4	4	Montipora spp.	8	171
1	4	4	Mycedium elephantotus	1	14
1	4	4	Nephthea spp.	1	13
1	4	4	Pachyseris speciosa	4	190
1	4	4	Padina sp.	3	32
1	4	4	Pectinia sp.	3	48
1	4	4	Podabacia crustacea	1	26
1	4	4	Porites encrusting	2	20
1	4	4	Porites massive	4	88
1	4	4	Rubble	23	1402
1	4	4	Sarcophyton sp.	5	42
1	4	4	Seriatopora hystrix	45	2067
1	4	4	Sponge	8	89
1	4	4	Turbinaria spp.	2	33
SITE 5.					
Reef flat					
1	5	1	Briareum sp.	1	13
1	5	1	Cyphastrea spp.	2	25
1	5	1	Euphyllia divisa	1	9
1	5	1	Favia favus	1	12
1	5	1	Favia pallida	2	8
1	5	1	Favia speciosa	1	7
1	5	1	Favia spp.	1	13
1	5	1	Favites chinensis	1	6
1	5	1	Galaxea spp.	2	19
1	5	1	Goniastrea spp.	2	32
1	5	1	Goniopora spp.	4	55
1	5	1	Herpolitha spp.	2	26
1	5	1	Leptastrea spp.	1	13

1	5	1	Lobophyllia hemprichii	3	29
1	5	1	Lobophyllia spp.	2	75
1	5	1	Lobophytum spp.	1	20
1	5	1	Macroalgae	61	6194
1	5	1	Merulina ampliata	2	30
1	5	1	Montipora spp.	3	70
1	5	1	Mycedium elephantotus	1	6
1	5	1	Padina sp.	4	63
1	5	1	Porites annae	2	28
1	5	1	Sand	3	115
1	5	1	Sarcophyton sp.	6	78
1	5	1	Seagrass	3	75
1	5	1	Sinularia spp.	1	8
1	5	1	Stylophora pistillata	1	25
Reef crest					
1	5	2	Acropora elseyi	1	19
1	5	2	Acropora latistella	4	78
1	5	2	Acropora nasuta	1	22
1	5	2	Acropora tenuis	1	36
1	5	2	Alcyonium spp.	2	18
1	5	2	Briareum sp.	7	132
1	5	2	Caulastrea spp.	5	504
1	5	2	Echinopora gemmacea	2	43
1	5	2	Echinopora lamellosa	1	8
1	5	2	Favia pallida	1	8
1	5	2	Favia rotundata	2	26
1	5	2	Fungia spp.	4	41
1	5	2	Galaxea spp.	1	9
1	5	2	Goniopora spp.	8	155
1	5	2	Heliofungia actiniformis	2	17
1	5	2	Lobophyllia corymbosa	1	42
1	5	2	Lobophyllia hemprichii	3	21
1	5	2	Lobophyllia spp.	2	87
1	5	2	Lobophytum spp.	2	40
1	5	2	Macroalgae	26	1182
1	5	2	Merulina ampliata	2	21
1	5	2	Millepora encrusting	4	50
1	5	2	Millepora spp.	10	507
1	5	2	Montipora spp.	3	105
1	5	2	Nephthea spp.	5	99
1	5	2	Oxypora spp.	1	9
1	5	2	Pachyseris rugosa	1	94
1	5	2	Padina sp.	5	92
1	5	2	Pectinia alcicornis	6	101
1	5	2	Pectinia sp.	4	177
1	5	2	Physogyra lichtensteini	2	18
1	5	2	Pocillopora damicornis	3	65
1	5	2	Podabacia crustacea	3	114
1	5	2	Porites annae	21	546
1	5	2	Porites cylindrica	2	120
1	5	2	Porites lichen	1	7
1	5	2	Rubble	4	281
1	5	2	Sarcophyton sp.	12	254
1	5	2	Seriatopora hystrix	5	87
1	5	2	Sinularia spp.	2	57
1	5	2	Xenia sp.	5	42
Upper slope					
1	5	3	Acropora divaricata	4	100
1	5	3	Acropora latistella	6	125
1	5	3	Acropora longicyathus	2	17
1	5	3	Acropora sarmentosa	1	56
1	5	3	Acropora valida	3	87
1	5	3	Alcyonium spp.	4	142
1	5	3	Alveopora spp.	1	54
1	5	3	Astreopora spp.	1	22
1	5	3	Briareum sp.	2	41
1	5	3	Caulastrea spp.	9	285
1	5	3	Cyphastrea spp.	1	12
1	5	3	Echinophyllia spp.	4	110
1	5	3	Echinopora lamellosa	1	6
1	5	3	Favia rotundata	2	40
1	5	3	Favia spp.	1	23
1	5	3	Favites pentagona	1	12
1	5	3	Fungia spp.	1	24
1	5	3	Galaxea spp.	2	16
1	5	3	Goniastrea pectinata	2	31
1	5	3	Goniopora spp.	5	108
1	5	3	Heliofungia actiniformis	2	39
1	5	3	Hydnophora rigida	1	12
1	5	3	Lobophyllia hemprichii	2	28
1	5	3	Lobophyllia spp.	4	78
1	5	3	Macroalgae	3	26

1	5	3	Merulina ampliata	18	490
1	5	3	Millepora spp.	4	91
1	5	3	Montipora spp.	5	131
1	5	3	Mycedium elephantotus	1	16
1	5	3	Nephthea spp.	2	26
1	5	3	Oxypora spp.	5	94
1	5	3	Pachyseris speciosa	1	8
1	5	3	Padina sp.	2	19
1	5	3	Pectinia alcicornis	3	55
1	5	3	Pectinia sp.	12	462
1	5	3	Podabacia crustacea	3	109
1	5	3	Porites massive	1	8
1	5	3	Porites annae	7	87
1	5	3	Rubble	2	156
1	5	3	Sarcophyton sp.	16	439
1	5	3	Seriatopora hystrix	19	438
1	5	3	Sinularia spp.	4	95
1	5	3	Soft coral (species)	1	8
1	5	3	Sponge	7	65
1	5	3	Stylophora pistillata	2	17
Lower slope					
1	5	4	Acropora cerealis	1	11
1	5	4	Acropora divaricata	1	20
1	5	4	Acropora latistella	2	83
1	5	4	Acropora valida	2	70
1	5	4	Alcyonium spp.	2	15
1	5	4	Alveopora spp.	1	18
1	5	4	Caulastrea spp.	3	23
1	5	4	Coscinaraea spp.	3	72
1	5	4	Echinophyllia aspera	3	72
1	5	4	Echinophyllia echinoporoide	1	4
1	5	4	Echinophyllia orpheensis	2	20
1	5	4	Echinophyllia spp.	13	341
1	5	4	Echinopora gemmacea	2	175
1	5	4	Favia pallida	1	11
1	5	4	Favia spp.	1	13
1	5	4	Favites halicora	2	30
1	5	4	Favites spp.	1	7
1	5	4	Fungia spp.	5	63
1	5	4	Galaxea spp.	4	55
1	5	4	Goniastrea spp.	3	26
1	5	4	Goniopora spp.	2	27
1	5	4	Hydnophora exesa	1	22
1	5	4	Leptastrea purpurea	1	6
1	5	4	Lobophyllia hemprichii	4	81
1	5	4	Lobophyllia spp.	2	86
1	5	4	Macroalgae	6	51
1	5	4	Merulina ampliata	5	326
1	5	4	Montastrea spp.	1	33
1	5	4	Montipora spp.	23	682
1	5	4	Moseleya latistellata	2	13
1	5	4	Mycedium elephantotus	3	62
1	5	4	Nephthea spp.	2	33
1	5	4	Oxypora spp.	1	65
1	5	4	Pachyseris speciosa	3	76
1	5	4	Pavona explanulata	3	145
1	5	4	Pectinia paeonia	3	35
1	5	4	Pectinia sp.	11	198
1	5	4	Pocillopora damicornis	3	45
1	5	4	Porites massive	1	3
1	5	4	Rubble	6	394
1	5	4	Sarcophyton sp.	8	102
1	5	4	Seriatopora hystrix	10	143
1	5	4	Sponge	14	227
1	5	4	Turbinaria spp.	1	27
SITE 6.					
Reef flat					
1	6	1	Acropora latistella	1	90
1	6	1	Briareum sp.	1	20
1	6	1	Cyphastrea spp.	2	36
1	6	1	Echinopora spp.	1	12
1	6	1	Favia spp.	3	21
1	6	1	Goniopora spp.	1	14
1	6	1	Millepora spp.	4	79
1	6	1	Montipora spp.	15	469
1	6	1	Pocillopora damicornis	1	4
1	6	1	Sand	3	280
1	6	1	Seagrass	2	70
1	6	1	Sinularia spp.	2	14
1	6	1	Sponge	2	8
1	6	1	Symphyllia spp.	1	16
1	6	1	Turbinaria peltata	2	27

1	6	1	Turbinaria reniformis	4	80
Reef crest					
1	6	2	Acropora cerealis	8	79
1	6	2	Acropora cytherea	1	43
1	6	2	Acropora divaricata	8	410
1	6	2	Acropora elseyi	9	574
1	6	2	Acropora formosa	9	390
1	6	2	Acropora latistella	12	447
1	6	2	Acropora longicyathus	14	434
1	6	2	Acropora microphthalma	7	111
1	6	2	Acropora millepora	2	46
1	6	2	Acropora nobilis	14	806
1	6	2	Acropora sarmentosa	3	53
1	6	2	Acropora tenuis	3	32
1	6	2	Acropora valida	8	310
1	6	2	Acropora yongei	1	28
1	6	2	Alcyonium spp.	3	55
1	6	2	Briareum sp.	2	45
1	6	2	Cyphastrea spp.	1	14
1	6	2	Euphyllia ancora	1	7
1	6	2	Favites chinensis	1	18
1	6	2	Fungia spp.	1	12
1	6	2	Galaxea spp.	2	17
1	6	2	Goniastrea palauensis	1	6
1	6	2	Goniopora spp.	1	13
1	6	2	Heliofungia actiniformis	5	94
1	6	2	Hydnophora exesa	1	17
1	6	2	Lobophytum spp.	1	42
1	6	2	Macroalgae	2	64
1	6	2	Millepora encrusting	3	54
1	6	2	Millepora spp.	3	69
1	6	2	Montipora spp.	3	25
1	6	2	Pachyseris speciosa	2	49
1	6	2	Padina sp.	1	12
1	6	2	Pectinia paeonia	1	17
1	6	2	Pectinia sp.	1	43
1	6	2	Platygyra spp.	2	16
1	6	2	Pocillopora damicornis	1	11
1	6	2	Podabacia crustacea	1	14
1	6	2	Porites encrusting	2	16
1	6	2	Porites annae	4	56
1	6	2	Sarcophyton sp.	4	96
1	6	2	Seriatopora hystrix	9	115
1	6	2	Sinularia spp.	9	192
1	6	2	Sponge	1	18
1	6	2	Stylophora pistillata	13	290
1	6	2	Turbinaria mesenterina	1	9
Upper slope					
1	6	3	Acropora cerealis	9	357
1	6	3	Acropora cytherea	1	31
1	6	3	Acropora digitifera	3	98
1	6	3	Acropora divaricata	6	111
1	6	3	Acropora elseyi	4	137
1	6	3	Acropora formosa	9	267
1	6	3	Acropora latistella	22	910
1	6	3	Acropora longicyathus	3	119
1	6	3	Acropora microphthalma	5	80
1	6	3	Acropora nobilis	1	33
1	6	3	Acropora sarmentosa	1	19
1	6	3	Acropora selago	2	40
1	6	3	Acropora tenuis	1	20
1	6	3	Acropora tortuosa	2	102
1	6	3	Acropora valida	16	524
1	6	3	Alcyonium spp.	3	31
1	6	3	Barabattola amicorum	1	37
1	6	3	Caulastrea spp.	1	45
1	6	3	Echinophyllia aspera	1	7
1	6	3	Echinophyllia orpheensis	1	12
1	6	3	Echinophyllia spp.	3	68
1	6	3	Euphyllia spp.	1	24
1	6	3	Galaxea spp.	1	8
1	6	3	Goniopora spp.	1	25
1	6	3	Heliofungia actiniformis	1	12
1	6	3	Herpolitha spp.	1	22
1	6	3	Hydnophora exesa	1	25
1	6	3	Hydnophora rigida	3	81
1	6	3	Lobophyllia hemprichii	1	8
1	6	3	Macroalgae	3	41
1	6	3	Merulina ampliata	5	69
1	6	3	Montipora spp.	9	195
1	6	3	Pachyseris speciosa	1	16
1	6	3	Padina sp.	2	41

1	6	3	Pectinia alcicornis	1	10
1	6	3	Pectinia paeonia	3	41
1	6	3	Pectinia sp.	1	76
1	6	3	Plesiastrea versipora	1	24
1	6	3	Pocillopora damicornis	1	17
1	6	3	Porites encrusting	2	19
1	6	3	Porites massive	1	17
1	6	3	Porites annae	4	60
1	6	3	Porites cylindrica	1	26
1	6	3	Sarcophyton sp.	6	143
1	6	3	Seagrass	1	55
1	6	3	Seriatopora hystrix	21	553
1	6	3	Sinularia spp.	7	146
1	6	3	Soft coral (species)	1	32
1	6	3	Sponge	4	65
1	6	3	Stylophora pistillata	7	102
1	6	3	Turbinaria bifrons	1	9
1	6	3	Turbinaria mesenterina	1	12
1	6	3	Turbinaria peltata	1	5
1	6	3	Zooanthid	1	11
Lower slope					
1	6	4	Acropora cerealis	4	87
1	6	4	Acropora valida	4	53
1	6	4	Alcyonium spp.	1	8
1	6	4	Briareum sp.	1	23
1	6	4	Capnella sp.	1	16
1	6	4	Caulastrea spp.	3	46
1	6	4	Coscinaraea spp.	1	8
1	6	4	Cyphastrea japonica	1	3
1	6	4	Diploastrea heliopora	1	64
1	6	4	Echinophyllia aspera	4	95
1	6	4	Echinophyllia echinoporoide	3	33
1	6	4	Echinophyllia orpheensis	1	8
1	6	4	Echinophyllia spp.	4	252
1	6	4	Favia rotundata	3	84
1	6	4	Favites spp.	1	14
1	6	4	Galaxea spp.	1	9
1	6	4	Goniastrea palauensis	4	41
1	6	4	Goniopora spp.	7	139
1	6	4	Heliofungia actiniformis	1	18
1	6	4	Juncella	4	16
1	6	4	Lobophyllia hemprichii	3	46
1	6	4	Lobophytum spp.	1	6
1	6	4	Macroalgae	1	16
1	6	4	Montipora spp.	14	387
1	6	4	Mycedium elephantotus	1	18
1	6	4	Pachyseris speciosa	2	36
1	6	4	Pectinia lactuca	3	27
1	6	4	Pectinia paeonia	1	4
1	6	4	Pectinia sp.	1	46
1	6	4	Physogyra lichtensteini	2	28
1	6	4	Platygra lamellina	1	26
1	6	4	Platygyra spp.	3	96
1	6	4	Pocillopora damicornis	1	4
1	6	4	Porites encrusting	7	93
1	6	4	Porites massive	3	61
1	6	4	Porites annae	2	37
1	6	4	Rubble	3	246
1	6	4	Sarcophyton sp.	1	11
1	6	4	Seriatopora hystrix	28	796
1	6	4	Sinularia spp.	5	91
1	6	4	Sponge	12	286
1	6	4	Turbinaria mesenterina	4	92
SITE 7.					
Reef flat					
1	7	1	Acropora tenuis	1	9
1	7	1	Briareum sp.	8	173
1	7	1	Coscinaraea spp.	1	16
1	7	1	Cyphastrea chalcidicum	2	15
1	7	1	Favia favus	1	8
1	7	1	Favites abdita	1	8
1	7	1	Favites flexuosa	2	13
1	7	1	Galaxea spp.	5	62
1	7	1	Goniastrea spp.	1	5
1	7	1	Goniopora spp.	4	60
1	7	1	Leptastrea purpurea	2	24
1	7	1	Leptastrea spp.	1	19
1	7	1	Lobophytum spp.	11	199
1	7	1	Macroalgae	51	3734
1	7	1	Montipora encrusting	5	74
1	7	1	Montipora spp.	2	34
1	7	1	Platygyra daedalea	1	17

1	7	1	Pocillopora damicornis	2	33
1	7	1	Porites massive	6	73
1	7	1	Porites annae	5	67
1	7	1	Porites lichen	1	8
1	7	1	Sand	11	832
1	7	1	Seagrass	6	645
1	7	1	Sinularia spp.	1	9
1	7	1	Soft coral (species)	1	11
1	7	1	Sponge	2	42
1	7	1	Turbinaria mesenterina	6	99
1	7	1	Turbinaria peltata	1	17
1	7	1	Xenia sp.	1	9
Reef crest					
1	7	2	Briareum sp.	20	680
1	7	2	Coscinaraea spp.	1	12
1	7	2	Cyphastrea spp.	1	13
1	7	2	Echinopora lamellosa	1	7
1	7	2	Echinopora mammiformis	1	17
1	7	2	Euphyllia spp.	1	62
1	7	2	Favites abdita	1	38
1	7	2	Favites flexuosa	2	22
1	7	2	Fungia spp.	1	8
1	7	2	Goniastrea pectinata	1	13
1	7	2	Goniopora spp.	8	177
1	7	2	Heliofungia actiniformis	1	9
1	7	2	Lobophyllia hemprichii	2	54
1	7	2	Lobophyllia spp.	2	127
1	7	2	Lobophytum spp.	6	87
1	7	2	Macroalgae	32	1392
1	7	2	Millepora spp.	2	90
1	7	2	Pachyseris rugosa	15	1777
1	7	2	Padina sp.	1	16
1	7	2	Pectinia sp.	1	13
1	7	2	Podabacia crustacea	1	43
1	7	2	Porites massive	15	640
1	7	2	Porites annae	5	85
1	7	2	Porites cylindrica	7	289
1	7	2	Sand	1	110
1	7	2	Sarcophyton sp.	1	23
1	7	2	Turbinaria mesenterina	22	605
1	7	2	Turbinaria reniformis	5	62
Upper slope					
1	7	3	Acropora valida	1	26
1	7	3	Alcyonium spp.	1	20
1	7	3	Astreopora spp.	1	35
1	7	3	Briareum sp.	26	1039
1	7	3	Echinopora mammiformis	1	41
1	7	3	Favia matthaii	1	24
1	7	3	Favites abdita	1	14
1	7	3	Favites flexuosa	2	17
1	7	3	Galaxea spp.	1	24
1	7	3	Goniopora spp.	13	1528
1	7	3	Lobophyllia hemprichii	3	61
1	7	3	Lobophyllia spp.	2	33
1	7	3	Lobophytum spp.	1	16
1	7	3	Macroalgae	27	1027
1	7	3	Millepora spp.	5	76
1	7	3	Pachyseris rugosa	3	171
1	7	3	Pavona cactus	4	96
1	7	3	Pectinia alcicornis	1	8
1	7	3	Podabacia crustacea	1	20
1	7	3	Porites massive	5	150
1	7	3	Porites annae	3	60
1	7	3	Porites cylindrica	14	830
1	7	3	Psammocora spp.	1	9
1	7	3	Rubble	9	595
1	7	3	Sand	1	105
1	7	3	Sinularia spp.	7	168
1	7	3	Sponge	1	8
1	7	3	Turbinaria mesenterina	9	605
1	7	3	Turbinaria reniformis	1	23
Lower slope					
1	7	4	Acropora valida	1	72
1	7	4	Alcyonium spp.	2	32
1	7	4	Briareum sp.	4	50
1	7	4	Echinophyllia orpheensis	1	22
1	7	4	Echinopora gemmacea	1	12
1	7	4	Euphyllia spp.	1	6
1	7	4	Favites flexuosa	2	29
1	7	4	Galaxea spp.	1	6
1	7	4	Goniastrea spp.	1	23

1	7	4	Goniopora spp.	25	2124
1	7	4	Hydnophora exesa	2	33
1	7	4	Hydnophora rigida	2	29
1	7	4	Leptastrea spp.	3	40
1	7	4	Lobophyllia hemprichii	1	7
1	7	4	Lobophyllia spp.	1	8
1	7	4	Macroalgae	19	671
1	7	4	Montipora spp.	2	30
1	7	4	Mycedium elephantotus	1	51
1	7	4	Oxypora spp.	1	47
1	7	4	Padina sp.	2	26
1	7	4	Palauastrea ramosa	4	127
1	7	4	Pavona cactus	16	971
1	7	4	Pavona decussata	6	256
1	7	4	Pectinia alcicornis	1	28
1	7	4	Pectinia paeonia	2	45
1	7	4	Pectinia sp.	4	51
1	7	4	Platygyra sinensis	1	8
1	7	4	Plesiastrea versipora	1	17
1	7	4	Pocillopora damicornis	1	23
1	7	4	Podabacia crustacea	3	101
1	7	4	Porites annae	1	8
1	7	4	Porites cylindrica	3	40
1	7	4	Porites lichen	1	13
1	7	4	Sand	18	756
1	7	4	Sarcophyton sp.	5	84
1	7	4	Seriatopora hystrix	1	8
1	7	4	Sinularia spp.	7	107
1	7	4	Sponge	2	13
1	7	4	Turbinaria mesenterina	2	162
1	7	4	Turbinaria spp.	1	13

SITE 8.

Reef flat

1	8	1	Acropora spp.	2	39
1	8	1	Alcyonium spp.	3	19
1	8	1	Cyphastrea spp.	1	9
1	8	1	Favia spp.	1	9
1	8	1	Fungia spp.	1	20
1	8	1	Goniopora spp.	3	32
1	8	1	Lobophyllia spp.	1	14
1	8	1	Lobophytum spp.	2	16
1	8	1	Macroalgae	1	20
1	8	1	Montipora spp.	4	125
1	8	1	Porites massive	3	24
1	8	1	Sand	2	70
1	8	1	Sarcophyton sp.	3	16
1	8	1	Seagrass	19	2789
1	8	1	Soft coral (species)	2	71
1	8	1	Sponge	11	122
1	8	1	Stylophora pistillata	11	194
1	8	1	Turbinaria peltata	1	10
1	8	1	Xenia sp.	4	34

Reef crest

1	8	2	Acropora divaricata	7	155
1	8	2	Acropora elseyi	2	44
1	8	2	Acropora formosa	8	365
1	8	2	Acropora humilis	2	41
1	8	2	Acropora latistella	2	114
1	8	2	Acropora microphthalma	4	105
1	8	2	Acropora millepora	2	80
1	8	2	Acropora nobilis	11	534
1	8	2	Acropora selago	1	22
1	8	2	Acropora tenuis	3	97
1	8	2	Acropora valida	2	55
1	8	2	Alcyonium spp.	5	93
1	8	2	Cyphastrea chalcidicum	1	8
1	8	2	Cyphastrea spp.	1	14
1	8	2	Euphyllia divisa	1	8
1	8	2	Favia favus	3	20
1	8	2	Favia speciosa	1	3
1	8	2	Favites abdita	1	12
1	8	2	Favites halicora	1	11
1	8	2	Fungia spp.	2	22
1	8	2	Goniastrea pectinata	1	8
1	8	2	Goniopora spp.	2	45
1	8	2	Heliofungia actiniformis	1	8
1	8	2	Hydnophora exesa	2	15
1	8	2	Lobophyllia hemprichii	1	12
1	8	2	Macroalgae	6	101
1	8	2	Merulina ampliata	1	13
1	8	2	Millepora spp.	7	202
1	8	2	Montipora spp.	9	178

1	8	2	Padina sp.	2	37
1	8	2	Parerythropodium sp.	2	19
1	8	2	Pectinia alcicornis	1	6
1	8	2	Pectinia sp.	1	16
1	8	2	Porites massive	10	216
1	8	2	Porites annae	17	425
1	8	2	Porites cylindrica	27	2327
1	8	2	Rubble	5	293
1	8	2	Sarcophyton sp.	1	4
1	8	2	Sinularia spp.	16	515
1	8	2	Stylophora pistillata	4	43

Upper slope

1	8	3	Acropora cerealis	7	94
1	8	3	Acropora dendrum	1	87
1	8	3	Acropora divaricata	5	152
1	8	3	Acropora formosa	3	97
1	8	3	Acropora latistella	1	16
1	8	3	Acropora microclados	1	29
1	8	3	Acropora selago	1	42
1	8	3	Acropora spat	3	12
1	8	3	Acropora valida	2	34
1	8	3	Alcyonium spp.	3	28
1	8	3	Alveopora spp.	1	18
1	8	3	Astreopora spp.	6	64
1	8	3	Barabattoia amicorum	2	114
1	8	3	Caulastrea spp.	1	13
1	8	3	Cyphastrea japonica	1	15
1	8	3	Cyphastrea spp.	3	49
1	8	3	Diploastrea heliopora	1	98
1	8	3	Echinophyllia aspera	1	31
1	8	3	Echinophyllia spp.	2	19
1	8	3	Euphyllia divisa	2	31
1	8	3	Favia favus	2	20
1	8	3	Favia lizardensis	1	19
1	8	3	Favia matthaii	2	11
1	8	3	Favia spp.	1	8
1	8	3	Favites halicora	1	11
1	8	3	Fungia spp.	1	8
1	8	3	Goniastrea spp.	2	12
1	8	3	Goniopora spp.	4	82
1	8	3	Hydnophora rigida	1	85
1	8	3	Leptastrea spp.	2	22
1	8	3	Leptoseris spp.	1	74
1	8	3	Lobophyllia corymbosa	1	7
1	8	3	Lobophyllia hemprichii	4	71
1	8	3	Lobophyllia spp.	1	16
1	8	3	Lobophytum spp.	2	37
1	8	3	Macroalgae	3	50
1	8	3	Millepora spp.	1	28
1	8	3	Montipora spp.	12	360
1	8	3	Moseleya latistellata	1	7
1	8	3	Mycedium elephantotus	1	32
1	8	3	Oulophyllia crispa	1	42
1	8	3	Pachyseris speciosa	3	83
1	8	3	Padina sp.	2	32
1	8	3	Pavona cactus	2	75
1	8	3	Pavona explanulata	3	48
1	8	3	Pectinia alcicornis	1	19
1	8	3	Pectinia paeonia	3	66
1	8	3	Pectinia sp.	5	220
1	8	3	Podabacia crustacea	2	35
1	8	3	Porites massive	9	120
1	8	3	Porites annae	8	138
1	8	3	Porites cylindrica	1	8
1	8	3	Porites vaughani	2	14
1	8	3	Rubble	13	1176
1	8	3	Sarcophyton sp.	3	39
1	8	3	Sinularia spp.	5	93
1	8	3	Sponge	3	25
1	8	3	Stylophora pistillata	2	33
1	8	3	Turbinaria mesenterina	1	13
1	8	3	Turbinaria peltata	2	55

Lower slope

1	8	4	Acropora cerealis	1	31
1	8	4	Acropora divaricata	1	8
1	8	4	Acropora valida	2	14
1	8	4	Alcyonium spp.	1	8
1	8	4	Alveopora spp.	2	28
1	8	4	Astreopora spp.	2	23
1	8	4	Barabattoia amicorum	2	80
1	8	4	Coscinaraea spp.	2	28

1	8	4	Cyphastrea chalcidicum	1	11
1	8	4	Cyphastrea serailia	1	6
1	8	4	Cyphastrea spp.	1	24
1	8	4	Echinophyllia aspera	3	103
1	8	4	Echinophyllia echinoporoide	2	26
1	8	4	Echinophyllia orpheensis	6	173
1	8	4	Echinophyllia spp.	7	178
1	8	4	Favia spp.	1	9
1	8	4	Favites complanata	2	9
1	8	4	Favites flexuosa	1	5
1	8	4	Favites halicora	1	14
1	8	4	Fungia spp.	1	12
1	8	4	Goniastrea spp.	4	42
1	8	4	Goniopora spp.	8	254
1	8	4	Hydnophora exesa	3	53
1	8	4	Leptastrea purpurea	1	7
1	8	4	Leptastrea spp.	1	22
1	8	4	Leptoseris spp.	5	75
1	8	4	Lobophytum spp.	1	8
1	8	4	Montipora spp.	11	268
1	8	4	Mycedium elephantotus	3	22
1	8	4	Oulophyllia crispa	2	58
1	8	4	Pachyseris speciosa	12	605
1	8	4	Pectinia alcicornis	2	20
1	8	4	Pectinia paeonia	5	67
1	8	4	Pectinia sp.	2	26
1	8	4	Physogyra lichtensteini	1	34
1	8	4	Platygyra sinensis	1	21
1	8	4	Platygyra spp.	3	82
1	8	4	Podabacia crustacea	2	22
1	8	4	Porites encrusting	1	12
1	8	4	Porites massive	14	438
1	8	4	Rubble	6	583
1	8	4	Sarcophyton sp.	4	24
1	8	4	Sinularia spp.	2	54
1	8	4	Sponge	14	237
1	8	4	Turbinaria mesenterina	3	50
1	8	4	Turbinaria spp.	1	6
SITE 9.					
Reef flat					
1	9	1	Acropora spat	2	8
1	9	1	Acropora valida	1	32
1	9	1	Alveopora spp.	1	4
1	9	1	Cyphastrea spp.	1	16
1	9	1	Favites spp.	2	16
1	9	1	Goniopora spp.	3	24
1	9	1	Lobophyllia spp.	1	17
1	9	1	Lobophytum spp.	5	55
1	9	1	Macroalgae	37	1473
1	9	1	Millepora spp.	1	51
1	9	1	Montipora spp.	1	31
1	9	1	Padina sp.	6	152
1	9	1	Porites massive	2	76
1	9	1	Sarcophyton sp.	1	8
1	9	1	Seagrass	13	3515
1	9	1	Sinularia spp.	3	39
1	9	1	Xenia sp.	1	8
Reef crest					
1	9	2	Acropora cerealis	1	26
1	9	2	Acropora dendrum	1	37
1	9	2	Acropora divaricata	7	117
1	9	2	Acropora formosa	2	54
1	9	2	Acropora latistella	2	62
1	9	2	Acropora microphthalma	3	95
1	9	2	Acropora millepora	1	41
1	9	2	Acropora nasuta	6	141
1	9	2	Acropora nobilis	1	76
1	9	2	Acropora palifera	2	40
1	9	2	Acropora sarmentosa	1	19
1	9	2	Acropora selago	3	26
1	9	2	Acropora tenuis	1	20
1	9	2	Acropora valida	8	313
1	9	2	Alcyonium spp.	6	103
1	9	2	Barabattoia amicorum	1	18
1	9	2	Cyphastrea chalcidicum	3	37
1	9	2	Cyphastrea spp.	1	28
1	9	2	Diploastrea heliopora	1	43
1	9	2	Echinophyllia spp.	1	12
1	9	2	Echinopora gemmacea	1	33
1	9	2	Favia favus	1	8
1	9	2	Favia spp.	1	6

1	9	2	Favites complanata	1	10
1	9	2	Favites halicora	1	12
1	9	2	Favites spp.	2	22
1	9	2	Goniastrea spp.	1	5
1	9	2	Goniopora spp.	4	117
1	9	2	Herpolitha spp.	1	3
1	9	2	Hydnophora exesa	1	5
1	9	2	Hydnophora rigida	2	65
1	9	2	Leptastrea purpurea	1	6
1	9	2	Lobophyllia pachysepta	1	3
1	9	2	Lobophyllia spp.	2	35
1	9	2	Macroalgae	20	551
1	9	2	Merulina ampliata	2	23
1	9	2	Millepora encrusting	4	88
1	9	2	Millepora spp.	4	55
1	9	2	Montipora spp.	13	284
1	9	2	Moseleya latistellata	1	6
1	9	2	Nephthea spp.	1	8
1	9	2	Pachyseris speciosa	1	16
1	9	2	Padina sp.	4	85
1	9	2	Palauastrea ramosa	1	52
1	9	2	Pavona decussata	2	23
1	9	2	Pectinia paeonia	1	3
1	9	2	Pectinia sp.	1	34
1	9	2	Porites massive	4	95
1	9	2	Porites annae	14	375
1	9	2	Sarcophyton sp.	10	188
1	9	2	Seagrass	9	216
1	9	2	Seriatopora hystrix	1	17
1	9	2	Sinularia spp.	25	710
1	9	2	Sponge	1	17
1	9	2	Stylophora pistillata	10	212
1	9	2	Zooanthid	1	32
Upper slope					
1	9	3	Acanthastrea spp.	1	5
1	9	3	Acropora cerealis	2	54
1	9	3	Acropora digitifera	1	11
1	9	3	Acropora divaricata	3	63
1	9	3	Acropora formosa	1	8
1	9	3	Acropora latistella	4	94
1	9	3	Acropora microphthalma	1	25
1	9	3	Acropora palifera	1	33
1	9	3	Acropora selago	1	6
1	9	3	Acropora valida	7	187
1	9	3	Alcyonium spp.	6	73
1	9	3	Alveopora spp.	4	86
1	9	3	Astreopora spp.	1	74
1	9	3	Barabattoia amicorum	1	32
1	9	3	Briareum sp.	1	13
1	9	3	Caulastrea spp.	5	114
1	9	3	Cyphastrea chalcidicum	1	11
1	9	3	Cyphastrea spp.	1	7
1	9	3	Diploastrea heliopora	1	8
1	9	3	Echinophyllia aspera	3	28
1	9	3	Echinophyllia orpheensis	1	21
1	9	3	Favia favus	4	38
1	9	3	Favites flexuosa	1	3
1	9	3	Galaxea spp.	2	15
1	9	3	Goniastrea pectinata	1	21
1	9	3	Goniastrea spp.	2	25
1	9	3	Goniopora spp.	9	264
1	9	3	Hydnophora exesa	2	18
1	9	3	Lobophyllia spp.	2	12
1	9	3	Macroalgae	5	87
1	9	3	Merulina ampliata	1	22
1	9	3	Millepora encrusting	1	6
1	9	3	Millepora spp.	3	46
1	9	3	Montipora spp.	6	138
1	9	3	Oxypora spp.	1	52
1	9	3	Padina sp.	6	129
1	9	3	Palauastrea ramosa	3	93
1	9	3	Parerythropodium sp.	1	6
1	9	3	Pavona cactus	3	28
1	9	3	Pectinia paeonia	3	31
1	9	3	Pectinia sp.	4	92
1	9	3	Platygra lamellina	1	4
1	9	3	Platygyra spp.	1	32
1	9	3	Podabacia crustacea	1	3
1	9	3	Porites encrusting	1	7
1	9	3	Porites massive	13	459
1	9	3	Porites annae	8	95
1	9	3	Porites cylindrica	1	10
1	9	3	Rubble	1	60

1	9	3	Sarcophyton sp.	22	613
1	9	3	Seagrass	2	38
1	9	3	Seriatopora hystrix	1	33
1	9	3	Sinularia spp.	9	158
1	9	3	Sponge	5	86
1	9	3	Stylophora pistillata	6	84
1	9	3	Turbinaria mesenterina	3	69
1	9	3	Turbinaria peltata	1	32
1	9	3	Turbinaria spp.	1	6
Lower slope					
1	9	4	Acanthastrea spp.	1	4
1	9	4	Acropora divaricata	1	18
1	9	4	Acropora valida	2	43
1	9	4	Alcyonium spp.	1	15
1	9	4	Alveopora spp.	4	47
1	9	4	Astreopora spp.	2	24
1	9	4	Barabattoia amicorum	2	79
1	9	4	Caulastrea spp.	1	22
1	9	4	Cyphastrea spp.	3	26
1	9	4	Echinophyllia spp.	4	96
1	9	4	Echinopora mammiformis	2	19
1	9	4	Favia lizardensis	1	29
1	9	4	Favia spp.	1	15
1	9	4	Favites halicora	1	12
1	9	4	Galaxea spp.	1	19
1	9	4	Goniastrea spp.	3	16
1	9	4	Goniopora spp.	14	254
1	9	4	Hydnophora exesa	1	38
1	9	4	Leptastrea spp.	1	43
1	9	4	Lobophytum spp.	1	6
1	9	4	Macroalgae	9	148
1	9	4	Montipora spp.	16	526
1	9	4	Moseleya latistellata	3	17
1	9	4	Pachyseris speciosa	4	39
1	9	4	Pavona spp.	2	54
1	9	4	Pectinia sp.	3	56
1	9	4	Podabacia crustacea	3	70
1	9	4	Porites encrusting	4	40
1	9	4	Porites massive	5	84
1	9	4	Porites annae	4	50
1	9	4	Rubble	12	1072
1	9	4	Sarcophyton sp.	15	276
1	9	4	Sinularia spp.	3	31
1	9	4	Sponge	9	102
1	9	4	Stylophora pistillata	3	35
1	9	4	Turbinaria mesenterina	1	25
1	9	4	Turbinaria peltata	1	8

APPENDIX 7: EASTERN WHITSUNDAY ISLANDS - TIME 2 (AFTER MONSOONAL PASSAGE).

Frequency and total cover were calculated for four 20m line transects.

TIME	SITE	HABITAT	SPECIES	FREQUENCY	TOTAL COVER
SITE 1.					
Reef flat					
2	1	1	Acropora spat	1	3
2	1	1	Capnella sp.	1	7
2	1	1	Coscinaraea spp.	1	7
2	1	1	Cyphastrea chalcidicum	1	4
2	1	1	Cyphastrea serailia	1	6
2	1	1	Favia rotundata	1	10
2	1	1	Favites abdita	2	16
2	1	1	Favites flexuosa	1	13
2	1	1	Favites matthaii	1	8
2	1	1	Goniopora spp.	2	17
2	1	1	Leptastrea transversa	2	7
2	1	1	Lobophyllia hemprichii	3	34
2	1	1	Lobophytum spp.	1	11
2	1	1	Macroalgae	31	1868
2	1	1	Porites encrusting	1	12
2	1	1	Porites massive	1	8
2	1	1	Sarcophyton sp.	1	11
2	1	1	Seagrasses	17	1925
2	1	1	Sinularia spp.	2	18
2	1	1	Sponge	8	109
2	1	1	Turbinaria spp.	1	8
Reef crest					
2	1	2	Acropora divaricata	1	32
2	1	2	Acropora formosa	9	171
2	1	2	Acropora latistella	4	224
2	1	2	Acropora palifera	1	54
2	1	2	Acropora tenuis	1	51
2	1	2	Acropora valida	3	55
2	1	2	Alcyonium spp.	4	53
2	1	2	Barabattoia amicorum	2	39
2	1	2	Briareum sp.	7	128
2	1	2	Caulastrea furcata	2	32
2	1	2	Echinophyllia aspera	1	22
2	1	2	Echinophyllia orpheensis	1	16
2	1	2	Echinopora spp.	3	158
2	1	2	Favia pallida	1	15
2	1	2	Favia rotundata	1	7
2	1	2	Favites halicora	1	6
2	1	2	Favites spp.	1	13
2	1	2	Fungia spp.	4	74
2	1	2	Galaxea spp.	6	123
2	1	2	Goniastrea spp.	1	22
2	1	2	Goniopora spp.	3	70
2	1	2	Heliopora coerulea	2	19
2	1	2	Herpolitha spp.	1	12
2	1	2	Hydnophora rigida	1	27
2	1	2	Lobophyllia hemprichii	4	70
2	1	2	Millepora massive	2	45
2	1	2	Millepora spp.	12	455
2	1	2	Montipora spp.	2	19
2	1	2	Nephthea spp.	4	82
2	1	2	Oxypora spp.	1	8
2	1	2	Pectinia lactuca	3	200
2	1	2	Pectinia paeonia	4	32
2	1	2	Pectinia spp.	4	113
2	1	2	Platygyra spp.	2	11
2	1	2	Plerogyra sinuosa	1	32
2	1	2	Podabacia crustacea	8	191
2	1	2	Porites massive	2	72
2	1	2	Porites annae	20	614
2	1	2	Porites cylindrica	6	258
2	1	2	Porites lichen	4	128
2	1	2	Sarcophyton sp.	16	393
2	1	2	Sinularia spp.	11	389
2	1	2	Sponge	1	12
2	1	2	Stylophora pistillata	1	18
2	1	2	Turbinaria bifrons	1	26
2	1	2	Turbinaria mesenterina	2	62
2	1	2	Turbinaria reniformis	3	36
2	1	2	Turbinaria spp.	1	6
2	1	2	Xenia sp.	2	40
Upper slope					
2	1	3	Acropora cerealis	1	23
2	1	3	Acropora divaricata	3	66

2	1	3	Barabattoia amicorum	3	30
2	1	3	Briareum sp.	2	26
2	1	3	Cynarina lacrymalis	1	8
2	1	3	Dead coral	1	35
2	1	3	Echinophyllia aspera	3	60
2	1	3	Favia favus	1	9
2	1	3	Favites flexuosa	1	6
2	1	3	Favites matthaii	1	8
2	1	3	Favites spp.	2	21
2	1	3	Fungia spp.	2	23
2	1	3	Galaxea spp.	5	124
2	1	3	Goniastrea spp.	1	6
2	1	3	Goniopora spp.	8	178
2	1	3	Heliopora coerulea	4	67
2	1	3	Hydnophora exesa	2	23
2	1	3	Hydnophora pilosa	1	35
2	1	3	Lobophyllia hemprichii	7	145
2	1	3	Merulina ampliata	1	18
2	1	3	Millepora spp.	2	19
2	1	3	Montipora spp.	3	69
2	1	3	Mycedium elephantotus	3	72
2	1	3	Nephthea spp.	8	187
2	1	3	Oxypora spp.	1	83
2	1	3	Pachyseris speciosa	3	79
2	1	3	Pectinia lactuca	2	79
2	1	3	Pectinia paeonia	3	44
2	1	3	Pectinia spp.	9	328
2	1	3	Platygyra spp.	1	9
2	1	3	Plerogyra sinuosa	2	15
2	1	3	Podabacia crustacea	5	143
2	1	3	Porites annae	15	381
2	1	3	Porites cylindrica	11	528
2	1	3	Porites lichen	6	152
2	1	3	Sarcophyton sp.	14	251
2	1	3	Seriatopora hystrix	8	152
2	1	3	Sinularia spp.	12	274
2	1	3	Sponge	2	45
2	1	3	Stylophora pistillata	1	36
2	1	3	Turbinaria reniformis	3	97
Lower slope					
2	1	4	Acropora divaricata	1	46
2	1	4	Acropora sarmentosa	1	41
2	1	4	Acropora valida	7	217
2	1	4	Alcyonium spp.	3	15
2	1	4	Alveopora spp.	3	73
2	1	4	Barabattoia amicorum	1	29
2	1	4	Coscinaraea spp.	1	6
2	1	4	Dead coral	4	163
2	1	4	Diploastrea heliopora	1	6
2	1	4	Echinophyllia aspera	6	221
2	1	4	Echinophyllia spp.	1	45
2	1	4	Euphyllia ancora	1	9
2	1	4	Euphyllia spp.	1	7
2	1	4	Favia favus	1	19
2	1	4	Favia maritima	1	6
2	1	4	Favia speciosa	1	8
2	1	4	Favia spp.	3	66
2	1	4	Favites abdita	3	57
2	1	4	Favites chinensis	1	16
2	1	4	Favites halicora	1	9
2	1	4	Fungia spp.	1	32
2	1	4	Galaxea spp.	4	88
2	1	4	Goniopora spp.	13	286
2	1	4	Halimeda spp.	1	16
2	1	4	Lobophyllia hemprichii	8	184
2	1	4	Montipora spp.	6	120
2	1	4	Mycedium elephantotus	6	139
2	1	4	Oxypora spp.	5	89
2	1	4	Pachyseris speciosa	13	420
2	1	4	Palauastrea ramosa	1	9
2	1	4	Pavona explanulata	1	12
2	1	4	Pectinia lactuca	3	100
2	1	4	Pectinia paeonia	3	68
2	1	4	Pectinia spp.	3	119
2	1	4	Platygyra lamellina	1	10
2	1	4	Plerogyra sinuosa	3	69
2	1	4	Porites annae	11	174
2	1	4	Porites cylindrica	1	32
2	1	4	Porites lichen	5	131
2	1	4	Sarcophyton sp.	8	156
2	1	4	Seriatopora hystrix	4	54
2	1	4	Sinularia spp.	1	8
2	1	4	Sponge	13	245

SITE 2.

Reef flat

2	2	1	Acropora formosa	1	6
2	2	1	Astreopora spp.	1	6
2	2	1	Barabattoia amicorum	1	14
2	2	1	Cespitularia sp.	1	3
2	2	1	Euphyllia ancora	1	16
2	2	1	Favites complanata	1	11
2	2	1	Goniopora spp.	7	173
2	2	1	Halimeda spp.	1	7
2	2	1	Leptastrea transversa	1	14
2	2	1	Lobophyllia corymbosa	4	80
2	2	1	Lobophyllia hemprichii	1	3
2	2	1	Lobophytum spp.	2	31
2	2	1	Macroalgae	37	2805
2	2	1	Montipora encrusting	1	8
2	2	1	Montipora spp.	1	16
2	2	1	Pavona decussata	1	17
2	2	1	Platygyra spp.	1	18
2	2	1	Porites massive	2	23
2	2	1	Sarcophyton sp.	6	53
2	2	1	Seagrasses	13	1420
2	2	1	Sinularia spp.	3	23
2	2	1	Sponge	4	65
2	2	1	Turbinaria peltata	1	18

Reef crest

2	2	2	Acropora aculeus	1	18
2	2	2	Acropora divaricata	2	17
2	2	2	Acropora formosa	1	7
2	2	2	Acropora valida	2	54
2	2	2	Alcyonium spp.	5	69
2	2	2	Cyphastrea japonica	1	14
2	2	2	Dead coral	1	31
2	2	2	Echinopora gemmacea	4	151
2	2	2	Favia lizardensis	1	80
2	2	2	Favia pallida	1	3
2	2	2	Favites abdita	1	26
2	2	2	Goniastrea aspera	1	8
2	2	2	Goniastrea spp.	2	17
2	2	2	Hydnophora microconos	1	12
2	2	2	Lobophyllia hemprichii	1	22
2	2	2	Millepora encrusting	2	57
2	2	2	Millepora spp.	10	597
2	2	2	Montipora spp.	1	16
2	2	2	Nephthea spp.	2	38
2	2	2	Palythoa	1	33
2	2	2	Pavona cactus	6	199
2	2	2	Porites massive	3	281
2	2	2	Porites annae	14	275
2	2	2	Porites cylindrica	38	2933
2	2	2	Porites spp.	3	32
2	2	2	Sarcophyton sp.	15	326
2	2	2	Seriatopora hystrix	1	23
2	2	2	Sinularia spp.	6	226
2	2	2	Sponge	1	12
2	2	2	Stylophora pistillata	2	55

Upper slope

2	2	3	Acropora cerealis	1	43
2	2	3	Acropora latistella	2	107
2	2	3	Acropora microphthalma	1	48
2	2	3	Acropora selago	1	21
2	2	3	Acropora valida	2	72
2	2	3	Alcyonium spp.	17	259
2	2	3	Astreopora spp.	2	33
2	2	3	Barabattoia amicorum	4	50
2	2	3	Cynarina lacrymalis	1	4
2	2	3	Cyphastrea chalcidicum	1	8
2	2	3	Echinophyllia aspera	1	9
2	2	3	Echinopora gemmacea	3	48
2	2	3	Echinopora horrida	1	28
2	2	3	Echinopora mammiformis	3	21
2	2	3	Favia spp.	1	6
2	2	3	Favites pentagona	1	14
2	2	3	Favites spp.	2	25
2	2	3	Galaxea spp.	1	8
2	2	3	Goniopora spp.	3	126
2	2	3	Heliopora coerulea	1	24
2	2	3	Lobophyllia hemprichii	2	38
2	2	3	Millepora spp.	4	71
2	2	3	Montipora encrusting	2	9
2	2	3	Montipora spp.	2	66

2	2	3	Nephthea spp.	6	249
2	2	3	Palauastrea ramosa	1	82
2	2	3	Pavona cactus	13	960
2	2	3	Pavona explanulata	2	16
2	2	3	Pectinia paeonia	1	8
2	2	3	Pectinia spp.	[illegible]	18
2	2	3	Platygyra sinensis	[illegible]	13
2	2	3	Pocillopora damicornis	1	26
2	2	3	Porites massive	3	90
2	2	3	Porites annae	6	44
2	2	3	Porites cylindrica	7	178
2	2	3	Porites spp.	7	442
2	2	3	Sarcophyton sp.	19	474
2	2	3	Sinularia spp.	9	206
2	2	3	Xenia sp.	1	12
Lower slope					
2	2	4	Acropora latistella	1	56
2	2	4	Acropora sarmentosa	1	11
2	2	4	Acropora valida	1	7
2	2	4	Alcyonium spp.	1	9
2	2	4	Barabattoia amicorum	2	23
2	2	4	Echinophyllia aspera	1	12
2	2	4	Favia rotundata	3	22
2	2	4	Favia spp.	1	10
2	2	4	Favites russelli	1	7
2	2	4	Favites spp.	2	81
2	2	4	Galaxea spp.	1	43
2	2	4	Goniopora spp.	3	73
2	2	4	Herpolitha spp.	1	2
2	2	4	Merulina ampliata	1	18
2	2	4	Montastrea curta	1	3
2	2	4	Montipora spp.	5	73
2	2	4	Mycedium elephantotus	1	22
2	2	4	Pavona cactus	7	132
2	2	4	Pavona explanulata	3	69
2	2	4	Platygyra lamellina	1	6
2	2	4	Plerogyra sinuosa	1	16
2	2	4	Podabacia crustacea	1	18
2	2	4	Porites massive	2	132
2	2	4	Porites lichen	1	10
2	2	4	Porites spp.	5	309
2	2	4	Sarcophyton sp.	13	278
2	2	4	Sinularia spp.	3	77
2	2	4	Sponge	1	10
2	2	4	Stylophora pistillata	1	18
2	2	4	Turbinaria mesenterina	1	11
2	2	4	Turbinaria peltata	5	99
2	2	4	Turbinaria reniformis	1	4
SITE 3.					
Reef flat					
2	3	1	Acropora divaricata	3	26
2	3	1	Acropora formosa	7	89
2	3	1	Acropora humilis	1	12
2	3	1	Acropora longicyathus	3	12
2	3	1	Acropora microphthalma	1	9
2	3	1	Acropora nobilis	2	7
2	3	1	Acropora palifera	4	30
2	3	1	Acropora spat	1	2
2	3	1	Acropora tenuis	9	129
2	3	1	Alcyonium spp.	7	83
2	3	1	Astreopora spp.	1	18
2	3	1	Cyphastrea chalcidicum	2	15
2	3	1	Dead coral	2	240
2	3	1	Echinophyllia orpheensis	1	4
2	3	1	Favia favus	1	12
2	3	1	Favites spp.	1	22
2	3	1	Goniopora spp.	6	65
2	3	1	Lobophyllia spp.	1	7
2	3	1	Lobophytum spp.	3	54
2	3	1	Macroalgae	25	1238
2	3	1	Millepora spp.	1	22
2	3	1	Montipora spp.	5	66
2	3	1	Palythoa	1	13
2	3	1	Paraclavarina triangularis	22	823
2	3	1	Pectinia alcicornis	5	132
2	3	1	Pectinia paeonia	1	7
2	3	1	Podabacia crustacea	1	7
2	3	1	Porites encrusting	2	14
2	3	1	Porites massive	4	63
2	3	1	Porites annae	2	20
2	3	1	Seagrasses	15	1577

2	3	1	Sinularia spp.	6	60
2	3	1	Soft coral species	5	139
2	3	1	Sponge	2	32
2	3	1	Xenia sp.	7	252
2	3	1	Zooanthid	1	7
Reef crest					
2	3	2	Acropora elseyi	8	937
2	3	2	Acropora formosa	43	4188
2	3	2	Acropora longicyathus	1	64
2	3	2	Acropora microphthalma	4	70
2	3	2	Acropora nobilis	8	678
2	3	2	Dead coral (Acropora)	6	237
2	3	2	Dead coral (Seriatopora)	3	62
2	3	2	Lobophytum spp.	2	19
2	3	2	Millepora spp.	1	51
2	3	2	Seriatopora hystrix	13	384
Upper slope					
2	3	3	Acropora elseyi	17	1035
2	3	3	Acropora formosa	12	299
2	3	3	Acropora longicyathus	8	105
2	3	3	Acropora microphthalma	27	1431
2	3	3	Bryzoan	1	7
2	3	3	Dead coral	14	288
2	3	3	Dead coral (Acropora)	6	169
2	3	3	Dead coral (Seriatopora)	21	763
2	3	3	Fungia spp.	1	21
2	3	3	Seriatopora hystrix	25	855
2	3	3	Sponge	8	162
Lower slope					
2	3	4	Acropora elseyi	10	156
2	3	4	Acropora microphthalma	4	90
2	3	4	Acropora nobilis	3	27
2	3	4	Briareum sp.	1	8
2	3	4	Dead coral	27	1014
2	3	4	Dead coral (Seriatopora)	21	972
2	3	4	Echinophyllia orpheensis	1	12
2	3	4	Favia favus	1	6
2	3	4	Favia rotundata	1	12
2	3	4	Fungia spp.	1	18
2	3	4	Goniopora spp.	1	15
2	3	4	Halimeda spp.	1	4
2	3	4	Montipora spp.	1	31
2	3	4	Mycedium elephantotus	2	45
2	3	4	Seriatopora hystrix	16	494
2	3	4	Sponge	9	109
SITE 4.					
Reef flat					
2	4	1	Acropora brueggemanni	1	46
2	4	1	Acropora elseyi	1	7
2	4	1	Acropora formosa	7	55
2	4	1	Acropora verweyi	1	7
2	4	1	Briareum sp.	3	41
2	4	1	Cyphastrea spp.	5	87
2	4	1	Euphyllia spp.	1	36
2	4	1	Favites spp.	1	33
2	4	1	Goniopora spp.	6	97
2	4	1	Leptastrea spp.	1	28
2	4	1	Macroalgae	46	2603
2	4	1	Montipora encrusting	1	18
2	4	1	Montipora spp.	2	31
2	4	1	Pocillopora damicornis	3	45
2	4	1	Porites massive	2	40
2	4	1	Sarcophyton sp.	5	65
2	4	1	Seagrasses	8	755
2	4	1	Sinularia spp.	5	87
2	4	1	Sponge	4	62
2	4	1	Stylophora pistillata	1	6
2	4	1	Turbinaria mesenterina	1	13
Reef crest					
2	4	2	Acropora brueggemanni	3	44
2	4	2	Acropora divaricata	2	25
2	4	2	Acropora elseyi	3	130
2	4	2	Acropora formosa	7	302
2	4	2	Acropora humilis	1	12
2	4	2	Acropora latistella	4	147
2	4	2	Acropora longicyathus	6	416
2	4	2	Acropora nobilis	3	43
2	4	2	Acropora sp.	2	99
2	4	2	Acropora subulata	3	120

2	4	2	Acropora valida	4	99
2	4	2	Alcyonium spp.	1	8
2	4	2	Briareum sp.	4	33
2	4	2	Dead coral (Acropora)	5	117
2	4	2	Dead coral (Seriatopora)	2	36
2	4	2	Echinophyllia aspera	1	33
2	4	2	Fungia spp.	3	49
2	4	2	Galaxea spp.	1	6
2	4	2	Goniopora spp.	2	20
2	4	2	Lobophyllia spp.	1	11
2	4	2	Macroalgae	35	1668
2	4	2	Millepora spp.	6	189
2	4	2	Montipora encrusting	1	4
2	4	2	Montipora spp.	4	57
2	4	2	Pachyseris speciosa	1	12
2	4	2	Pectinia paeonia	5	172
2	4	2	Pectinia spp.	2	38
2	4	2	Porites encrusting	2	7
2	4	2	Porites massive	1	12
2	4	2	Sarcophyton sp.	11	258
2	4	2	Seriatopora hystrix	19	411
2	4	2	Sinularia spp.	9	203
Upper slope					
2	4	3	Acropora dendrum	1	22
2	4	3	Acropora elseyi	5	59
2	4	3	Acropora formosa	3	64
2	4	3	Acropora latistella	4	35
2	4	3	Acropora microphthalma	1	21
2	4	3	Acropora nobilis	4	76
2	4	3	Acropora valida	8	161
2	4	3	Barabattoia amicorum	1	68
2	4	3	Caulastrea furcata	5	95
2	4	3	Coralline algae	1	24
2	4	3	Dead coral	1	5
2	4	3	Dead coral (Acropora)	1	21
2	4	3	Dead coral (Seriatopora)	10	273
2	4	3	Euphyllia ancora	1	12
2	4	3	Favites chinensis	1	9
2	4	3	Fungia spp.	3	30
2	4	3	Galaxea spp.	2	11
2	4	3	Goniastrea palauensis	1	5
2	4	3	Goniastrea spp.	2	37
2	4	3	Goniopora spp.	1	13
2	4	3	Halimeda spp.	1	8
2	4	3	Herpolitha spp.	1	16
2	4	3	Hydnophora spp.	1	21
2	4	3	Lobophyllia corymbosa	1	11
2	4	3	Lobophyllia hemprichii	5	73
2	4	3	Macroalgae	5	78
2	4	3	Merulina ampliata	3	45
2	4	3	Millepora spp.	1	4
2	4	3	Montipora encrusting	7	90
2	4	3	Montipora spp.	10	245
2	4	3	Mycedium elephantotus	2	24
2	4	3	Pectinia lactuca	1	16
2	4	3	Pectinia paeonia	1	11
2	4	3	Pectinia spp.	3	107
2	4	3	Platygyra spp.	1	17
2	4	3	Porites massive	1	7
2	4	3	Porites annae	1	9
2	4	3	Sarcophyton sp.	11	199
2	4	3	Seriatopora hystrix	29	1445
2	4	3	Sinularia spp.	14	198
2	4	3	Stylophora pistillata	2	11
Lower slope					
2	4	4	Acropora latistella	1	9
2	4	4	Acropora valida	5	78
2	4	4	Alcyonium spp.	2	13
2	4	4	Alveopora spp.	3	33
2	4	4	Antipatharia	1	12
2	4	4	Briareum sp.	4	65
2	4	4	Dead coral (Seriatopora)	12	338
2	4	4	Echinophyllia aspera	8	252
2	4	4	Echinophyllia orpheensis	5	106
2	4	4	Echinopora spp.	2	14
2	4	4	Euphyllia ancora	1	13
2	4	4	Favia speciosa	1	84
2	4	4	Favites complanata	1	11
2	4	4	Galaxea spp.	2	97
2	4	4	Goniopora spp.	2	65
2	4	4	Hydnophora spp.	1	52
2	4	4	Lobophyllia hemprichii	3	47

2	4	4	Macroalgae	1	4
2	4	4	Merulina ampliata	1	17
2	4	4	Montipora encrusting	9	133
2	4	4	Montipora spp.	13	203
2	4	4	Mycedium elephantotus	5	160
2	4	4	Oxypora spp.	7	104
2	4	4	Pachyseris speciosa	5	83
2	4	4	Pavona varians	4	69
2	4	4	Pectinia paeonia	2	31
2	4	4	Platygyra lamellina	1	37
2	4	4	Platygyra spp.	2	30
2	4	4	Porites encrusting	7	91
2	4	4	Porites lichen	2	54
2	4	4	Sarcophyton sp.	12	224
2	4	4	Seriatopora hystrix	18	560
2	4	4	Sinularia spp.	7	116
2	4	4	Sponge	3	44

SITE 5.

Reef flat

2	5	1	Acropora formosa	1	12
2	5	1	Alcyonium spp.	1	8
2	5	1	Briareum sp.	1	17
2	5	1	Favia favus	1	7
2	5	1	Favia speciosa	2	46
2	5	1	Favites halicora	1	8
2	5	1	Galaxea spp.	2	23
2	5	1	Goniopora spp.	7	83
2	5	1	Lobophyllia hemprichii	3	40
2	5	1	Macroalgae	52	4027
2	5	1	Montipora encrusting	2	50
2	5	1	Montipora spp.	4	60
2	5	1	Pavona decussata	1	62
2	5	1	Pocillopora damicornis	1	14
2	5	1	Sarcophyton sp.	2	19
2	5	1	Seagrasses	2	37
2	5	1	Sinularia spp.	1	8
2	5	1	Turbinaria bifrons	1	5
2	5	1	Xenia sp.	1	26

Reef crest

2	5	2	Acropora divaricata	1	27
2	5	2	Acropora formosa	1	7
2	5	2	Acropora longicyathus	1	17
2	5	2	Acropora valida	2	37
2	5	2	Alcyonium spp.	5	72
2	5	2	Alveopora spp.	1	58
2	5	2	Briareum sp.	6	127
2	5	2	Caulastrea furcata	6	183
2	5	2	Dead coral (Acropora)	1	23
2	5	2	Echinopora gemmacea	2	24
2	5	2	Favia rotundata	1	42
2	5	2	Favia speciosa	2	36
2	5	2	Favia spp.	1	3
2	5	2	Favites halicora	1	27
2	5	2	Fungia spp.	2	30
2	5	2	Goniopora spp.	6	268
2	5	2	Heliopora coerulea	1	32
2	5	2	Hydnophora exesa	1	12
2	5	2	Lobophyllia hemprichii	9	260
2	5	2	Macroalgae	15	689
2	5	2	Merulina ampliata	1	17
2	5	2	Millepora spp.	15	615
2	5	2	Montipora encrusting	2	23
2	5	2	Montipora spp.	1	17
2	5	2	Nephthea spp.	3	59
2	5	2	Pachyseris rugosa	1	43
2	5	2	Pachyseris speciosa	1	7
2	5	2	Pectinia lactuca	2	122
2	5	2	Pectinia spp.	3	59
2	5	2	Physogyra lichtensteini	1	26
2	5	2	Pocillopora damicornis	1	11
2	5	2	Podabacia crustacea	3	117
2	5	2	Porites massive	2	33
2	5	2	Porites annae	17	548
2	5	2	Porites cylindrica	1	153
2	5	2	Sarcophyton sp.	12	291
2	5	2	Seriatopora hystrix	1	43
2	5	2	Sinularia spp.	9	271
2	5	2	Soft coral species	3	73
2	5	2	Sponge	2	11
2	5	2	Stylophora pistillata	1	17
2	5	2	Turbinaria peltata	1	11
2	5	2	Xenia sp.	5	51

Upper slope					
2	5	3	Acropora formosa	1	36
2	5	3	Acropora palifera	2	23
2	5	3	Acropora valida	8	207
2	5	3	Alcyonium spp.	4	57
2	5	3	Alveopora spp.	2	58
2	5	3	Barabattoia amicorum	1	14
2	5	3	Briareum sp.	2	18
2	5	3	Caulastrea furcata	1	68
2	5	3	Dead coral (Seriatopora)	3	51
2	5	3	Echinopora lamellosa	2	41
2	5	3	Favia favus	1	5
2	5	3	Favites chinensis	1	23
2	5	3	Favites flexuosa	1	6
2	5	3	Favites pentagona	1	9
2	5	3	Fungia spp.	1	12
2	5	3	Galaxea spp.	4	52
2	5	3	Goniopora spp.	9	967
2	5	3	Heliopora coerulea	2	41
2	5	3	Hydnophora spp.	1	27
2	5	3	Lobophyllia hemprichii	8	144
2	5	3	Macroalgae	4	75
2	5	3	Merulina ampliata	1	38
2	5	3	Millepora massive	3	48
2	5	3	Millepora spp.	7	161
2	5	3	Montipora encrusting	1	19
2	5	3	Montipora spp.	3	77
2	5	3	Mycedium elephantotus	1	17
2	5	3	Oxypora spp.	3	37
2	5	3	Pachyseris rugosa	1	28
2	5	3	Pachyseris speciosa	2	24
2	5	3	Pectinia lactuca	4	66
2	5	3	Pectinia spp.	7	251
2	5	3	Physogyra lichtensteini	2	163
2	5	3	Plerogyra sinuosa	1	12
2	5	3	Pocillopora damicornis	1	17
2	5	3	Podabacia crustacea	3	97
2	5	3	Polyphyllia talpina	1	12
2	5	3	Porites annae	9	251
2	5	3	Porites cylindrica	2	108
2	5	3	Sarcophyton sp.	16	361
2	5	3	Sinularia spp.	4	267
2	5	3	Sponge	4	49
2	5	3	Turbinaria mesenterina	1	53
Lower slope					
2	5	4	Acropora latistella	1	48
2	5	4	Alcyonium spp.	6	68
2	5	4	Alveopora spp.	1	14
2	5	4	Briareum sp.	1	9
2	5	4	Cynarina lacrymalis	1	5
2	5	4	Dead coral	1	6
2	5	4	Echinophyllia aspera	8	267
2	5	4	Echinophyllia spp.	4	32
2	5	4	Favites spp.	1	18
2	5	4	Fungia spp.	1	13
2	5	4	Galaxea spp.	3	23
2	5	4	Goniastrea palauensis	1	5
2	5	4	Goniopora spp.	23	1015
2	5	4	Herpolitha spp.	1	6
2	5	4	Hydnophora spp.	1	17
2	5	4	Lobophyllia hemprichii	9	183
2	5	4	Merulina ampliata	6	218
2	5	4	Millepora spp.	3	35
2	5	4	Montipora spp.	13	191
2	5	4	Mycedium elephantotus	4	132
2	5	4	Oxypora spp.	6	67
2	5	4	Pachyseris speciosa	1	5
2	5	4	Palauastrea ramosa	1	7
2	5	4	Pectinia lactuca	1	75
2	5	4	Pectinia paeonia	2	21
2	5	4	Pectinia spp.	1	17
2	5	4	Plerogyra sinuosa	1	8
2	5	4	Porites encrusting	1	7
2	5	4	Porites massive	1	22
2	5	4	Porites lichen	1	14
2	5	4	Psammocora spp.	2	27
2	5	4	Sarcophyton sp.	9	161
2	5	4	Seriatopora hystrix	2	24
2	5	4	Sinularia spp.	2	38
2	5	4	Sponge	9	148
2	5	4	Stylophora pistillata	1	12

SITE 6.

Reef flat

2	6	1	Acropora divaricata	1	13
2	6	1	Acropora formosa	3	92
2	6	1	Acropora humilis	1	7
2	6	1	Acropora latistella	8	188
2	6	1	Acropora nobilis	1	320
2	6	1	Acropora valida	1	35
2	6	1	Alcyonium spp.	3	34
2	6	1	Goniopora spp.	1	5
2	6	1	Hydnophora rigida	1	6
2	6	1	Juncella	1	1
2	6	1	Macroalgae	29	2791
2	6	1	Montipora spp.	5	174
2	6	1	Nephthea spp.	1	23
2	6	1	Pocillopora damicornis	1	24
2	6	1	Porites massive	1	5
2	6	1	Sarcophyton sp.	4	31
2	6	1	Seriatopora caliendrum	1	16
2	6	1	Seriatopora hystrix	2	10
2	6	1	Sponge	1	22
2	6	1	Stylophora pistillata	3	41
2	6	1	Turbinaria peltata	1	28

Reef crest

2	6	2	Acropora formosa	4	144
2	6	2	Acropora latistella	9	434
2	6	2	Acropora longicyathus	1	97
2	6	2	Acropora nobilis	1	33
2	6	2	Acropora sarmentosa	2	66
2	6	2	Acropora selago	1	4
2	6	2	Acropora subulata	4	151
2	6	2	Acropora tenuis	1	6
2	6	2	Acropora valida	5	97
2	6	2	Alcyonium spp.	3	55
2	6	2	Briareum sp.	1	12
2	6	2	Cyphastrea spp.	1	9
2	6	2	Dead coral (Acropora)	1	11
2	6	2	Dead coral (Seriatopora)	2	26
2	6	2	Echinophyllia orpheensis	2	32
2	6	2	Favia spp.	1	14
2	6	2	Favites complanata	1	46
2	6	2	Favites spp.	3	41
2	6	2	Galaxea spp.	1	8
2	6	2	Goniopora spp.	3	36
2	6	2	Hydnophora exesa	1	24
2	6	2	Juncella	3	39
2	6	2	Leptastrea spp.	1	24
2	6	2	Lobophytum spp.	1	37
2	6	2	Macroalgae	25	916
2	6	2	Montipora spp.	6	247
2	6	2	Moseleya latistellata	1	12
2	6	2	Mycedium elephantotus	1	12
2	6	2	Parerythropodium sp.	1	17
2	6	2	Platygyra spp.	1	8
2	6	2	Porites lichen	1	12
2	6	2	Sarcophyton sp.	6	69
2	6	2	Seriatopora hystrix	8	187
2	6	2	Sinularia spp.	9	179
2	6	2	Sponge	5	67
2	6	2	Stylophora pistillata	3	52
2	6	2	Turbinaria mesenterina	2	74
2	6	2	Turbinaria peltata	1	14
2	6	2	Turbinaria spp.	2	9
2	6	2	Xenia sp.	5	46

Upper slope

2	6	3	Acropora clathrata	1	22
2	6	3	Acropora dendrum	2	46
2	6	3	Acropora elseyi	2	96
2	6	3	Acropora formosa	6	124
2	6	3	Acropora latistella	21	1144
2	6	3	Acropora subulata	2	17
2	6	3	Acropora valida	17	489
2	6	3	Alcyonium spp.	3	40
2	6	3	Astreopora spp.	1	37
2	6	3	Briareum sp.	6	130
2	6	3	Cyphastrea spp.	1	16
2	6	3	Dead coral	4	73
2	6	3	Dead coral (Acropora)	4	128
2	6	3	Dead coral (Seriatopora)	7	130
2	6	3	Echinophyllia aspera	2	32
2	6	3	Goniopora spp.	5	104
2	6	3	Halimeda spp.	1	4

2	6	3	Heliopora coerulea	3	69
2	6	3	Hydnophora spp.	2	15
2	6	3	Leptastrea spp.	2	11
2	6	3	Lobophyllia hemprichii	3	24
2	6	3	Macroalgae	5	84
2	6	3	Millepora spp.	1	11
2	6	3	Montipora encrusting	8	84
2	6	3	Montipora spp.	12	435
2	6	3	Pachyseris rugosa	1	43
2	6	3	Pachyseris speciosa	3	45
2	6	3	Pectinia paeonia	1	18
2	6	3	Pectinia spp.	3	47
2	6	3	Platygyra spp.	1	38
2	6	3	Plerogyra sinuosa	1	12
2	6	3	Podabacia crustacea	2	56
2	6	3	Porites encrusting	2	14
2	6	3	Porites massive	1	12
2	6	3	Porites annae	1	4
2	6	3	Sarcophyton sp.	4	50
2	6	3	Seriatopora hystrix	22	804
2	6	3	Sinularia spp.	14	272
2	6	3	Sponge	4	70
2	6	3	Stylophora pistillata	1	38

Lower slope

2	6	4	Acropora latistella	1	19
2	6	4	Acropora valida	4	92
2	6	4	Alcyonium spp.	3	41
2	6	4	Astreopora spp.	1	22
2	6	4	Briareum sp.	3	49
2	6	4	Coralline algae	1	13
2	6	4	Coscinaraea spp.	1	6
2	6	4	Dead coral (Acropora)	1	26
2	6	4	Dead coral (Seriatopora)	8	101
2	6	4	Echinophyllia aspera	11	457
2	6	4	Echinopora lamellosa	2	20
2	6	4	Echinopora spp.	2	67
2	6	4	Euphyllia spp.	1	24
2	6	4	Favia speciosa	1	37
2	6	4	Favia spp.	1	13
2	6	4	Fungia spp.	1	22
2	6	4	Galaxea spp.	6	270
2	6	4	Goniastrea spp.	1	28
2	6	4	Goniopora spp.	10	178
2	6	4	Heliopora coerulea	2	40
2	6	4	Lobophyllia hemprichii	6	87
2	6	4	Montipora encrusting	10	195
2	6	4	Montipora spp.	6	229
2	6	4	Mycedium elephantotus	11	277
2	6	4	Oxypora spp.	10	314
2	6	4	Pachyseris speciosa	14	716
2	6	4	Pectinia paeonia	1	13
2	6	4	Podabacia crustacea	1	88
2	6	4	Porites massive	2	36
2	6	4	Porites annae	2	16
2	6	4	Psammocora spp.	1	11
2	6	4	Seriatopora hystrix	18	320
2	6	4	Sinularia spp.	5	97
2	6	4	Sponge	9	166
2	6	4	Turbinaria mesenterina	1	8

SITE 7.
Reef flat

2	7	1	Acropora latistella	1	28
2	7	1	Acropora spat	1	2
2	7	1	Acropora tenuis	1	12
2	7	1	Alveopora spp.	1	162
2	7	1	Briareum sp.	2	19
2	7	1	Capnella sp.	2	18
2	7	1	Cyphastrea spp.	3	52
2	7	1	Echinophyllia spp.	1	18
2	7	1	Favites abdita	1	11
2	7	1	Galaxea spp.	3	39
2	7	1	Goniastrea aspera	1	8
2	7	1	Goniastrea spp.	3	36
2	7	1	Goniopora spp.	6	134
2	7	1	Heliopora coerulea	1	8
2	7	1	Hydnophora exesa	1	16
2	7	1	Lobophyllia corymbosa	1	15
2	7	1	Lobophytum spp.	2	29
2	7	1	Macroalgae	43	3444
2	7	1	Montipora spp.	12	288
2	7	1	Pavona decussata	2	35

2	7	1	Plesiastrea versipora	2	26
2	7	1	Pocillopora damicornis	4	60
2	7	1	Porites massive	6	88
2	7	1	Sarcophyton sp.	1	10
2	7	1	Seagrasses	1	20
2	7	1	Sinularia spp.	2	38
2	7	1	Sponge	1	24
2	7	1	Turbinaria bifrons	1	18
2	7	1	Turbinaria mesenterina	8	124
Reef crest					
2	7	2	Acropora valida	1	25
2	7	2	Alcyonium spp.	4	41
2	7	2	Barabattoia amicorum	2	23
2	7	2	Briareum sp.	23	974
2	7	2	Coscinaraea spp.	1	83
2	7	2	Cyphastrea chalcidicum	1	4
2	7	2	Favia rotundata	1	14
2	7	2	Fungia spp.	1	11
2	7	2	Goniastrea aspera	1	7
2	7	2	Goniopora spp.	8	663
2	7	2	Hydnophora exesa	1	17
2	7	2	Lobophyllia hemprichii	2	48
2	7	2	Macroalgae	29	1058
2	7	2	Merulina ampliata	1	25
2	7	2	Millepora spp.	4	98
2	7	2	Pachyseris rugosa	3	423
2	7	2	Pachyseris speciosa	1	36
2	7	2	Pectinia spp.	1	10
2	7	2	Pocillopora damicornis	1	27
2	7	2	Podabacia crustacea	4	77
2	7	2	Porites encrusting	1	26
2	7	2	Porites massive	14	611
2	7	2	Porites annae	5	66
2	7	2	Porites cylindrica	21	617
2	7	2	Porites lichen	6	131
2	7	2	Sarcophyton sp.	3	122
2	7	2	Seriatopora hystrix	1	12
2	7	2	Sinularia spp.	6	93
2	7	2	Turbinaria mesenterina	19	427
2	7	2	Turbinaria reniformis	3	267
Upper slope					
2	7	3	Alcyonium spp.	1	11
2	7	3	Briareum sp.	26	933
2	7	3	Cyphastrea japonica	1	9
2	7	3	Echinophyllia aspera	1	52
2	7	3	Euphyllia spp.	1	30
2	7	3	Favia pallida	1	14
2	7	3	Fungia spp.	2	18
2	7	3	Goniopora spp.	3	1392
2	7	3	Heliopora coerulea	1	16
2	7	3	Lobophyllia hemprichii	1	16
2	7	3	Macroalgae	7	109
2	7	3	Merulina ampliata	2	26
2	7	3	Millepora spp.	8	280
2	7	3	Montipora spp.	1	28
2	7	3	Pachyseris rugosa	2	90
2	7	3	Pachyseris speciosa	1	16
2	7	3	Palauastrea ramosa	3	101
2	7	3	Pavona cactus	3	94
2	7	3	Pavona decussata	8	171
2	7	3	Pectinia lactuca	1	6
2	7	3	Pectinia spp.	1	42
2	7	3	Podabacia crustacea	1	31
2	7	3	Porites encrusting	2	14
2	7	3	Porites massive	4	275
2	7	3	Porites annae	1	108
2	7	3	Porites cylindrica	16	814
2	7	3	Sarcophyton sp.	1	11
2	7	3	Sinularia spp.	4	74
2	7	3	Sponge	1	14
2	7	3	Turbinaria mesenterina	12	489
Lower slope					
2	7	4	Acropora valida	2	45
2	7	4	Alveopora spp.	1	45
2	7	4	Briareum sp.	6	163
2	7	4	Cyphastrea japonica	2	290
2	7	4	Echinophyllia aspera	1	9
2	7	4	Echinopora gemmacea	8	249
2	7	4	Favites matthaii	1	18
2	7	4	Favites russelli	1	14
2	7	4	Fungia spp.	1	8

2	7	4	Galaxea spp.	3	33
2	7	4	Goniopora spp.	22	1978
2	7	4	Lobophyllia hemprichii	6	185
2	7	4	Macroalgae	11	187
2	7	4	Merulina ampliata	1	24
2	7	4	Montipora spp.	1	39
2	7	4	Oxypora spp.	2	37
2	7	4	Pachyseris rugosa	9	241
2	7	4	Pavona cactus	10	528
2	7	4	Pavona decussata	1	122
2	7	4	Pectinia spp.	3	74
2	7	4	Porites massive	2	59
2	7	4	Porites annae	2	41
2	7	4	Porites cylindrica	12	471
2	7	4	Sarcophyton sp.	2	58
2	7	4	Sinularia spp.	1	24
2	7	4	Sponge	2	20
2	7	4	Turbinaria mesenterina	11	341
2	7	4	Turbinaria peltata	2	41
SITE 8.					
Reef flat					
2	8	1	Acropora divaricata	2	31
2	8	1	Acropora formosa	11	347
2	8	1	Acropora millepora	4	58
2	8	1	Acropora palifera	4	82
2	8	1	Acropora tenuis	1	6
2	8	1	Acropora valida	3	46
2	8	1	Alcyonium spp.	1	10
2	8	1	Cyphastrea chalcidicum	1	8
2	8	1	Cyphastrea spp.	1	13
2	8	1	Dead coral	8	180
2	8	1	Dead coral (Acropora)	1	12
2	8	1	Euphyllia ancora	1	11
2	8	1	Favites abdita	1	9
2	8	1	Favites flexuosa	1	22
2	8	1	Favites halicora	1	5
2	8	1	Favites spp.	3	36
2	8	1	Goniastrea aspera	1	8
2	8	1	Goniopora spp.	2	24
2	8	1	Lobophyllia hemprichii	3	23
2	8	1	Macroalgae	24	1746
2	8	1	Millepora encrusting	1	6
2	8	1	Montipora encrusting	7	138
2	8	1	Montipora spp.	8	233
2	8	1	Oulophyllia crispa	1	4
2	8	1	Pachyseris speciosa	1	7
2	8	1	Porites massive	1	12
2	8	1	Sarcophyton sp.	2	16
2	8	1	Seagrasses	5	108
2	8	1	Seriatopora hystrix	1	7
2	8	1	Sinularia spp.	4	61
2	8	1	Stylophora pistillata	11	139
2	8	1	Trachyphyllia geoffroyi	1	6
2	8	1	Turbinaria mesenterina	1	22
2	8	1	Turbinaria reniformis	1	8
Reef crest					
2	8	2	Acropora cerealis	3	61
2	8	2	Acropora divaricata	6	133
2	8	2	Acropora elseyi	3	34
2	8	2	Acropora formosa	28	2130
2	8	2	Acropora longicyathus	2	59
2	8	2	Acropora loripes	1	39
2	8	2	Acropora microphthalma	3	215
2	8	2	Acropora millepora	2	43
2	8	2	Acropora nobilis	2	90
2	8	2	Acropora palifera	2	50
2	8	2	Acropora selago	1	22
2	8	2	Acropora subulata	3	57
2	8	2	Acropora valida	11	352
2	8	2	Alcyonium spp.	3	102
2	8	2	Astreopora spp.	1	9
2	8	2	Dead coral	1	5
2	8	2	Dead coral (Acropora)	2	45
2	8	2	Euphyllia spp.	2	56
2	8	2	Favites chinensis	1	44
2	8	2	Favites halicora	1	19
2	8	2	Fungia spp.	1	13
2	8	2	Galaxea spp.	1	18
2	8	2	Goniopora spp.	3	46
2	8	2	Hydnophora exesa	1	17

2	8	2	Hydnophora rigida	1	27
2	8	2	Lobophyllia hemprichii	1	18
2	8	2	Millepora spp.	6	288
2	8	2	Montipora encrusting	1	24
2	8	2	Montipora spp.	10	243
2	8	2	Pachyseris speciosa	2	46
2	8	2	Pavona cactus	3	51
2	8	2	Pavona decussata	1	38
2	8	2	Pectinia spp.	1	20
2	8	2	Porites massive	5	177
2	8	2	Porites annae	10	138
2	8	2	Porites cylindrica	5	193
2	8	2	Sarcophyton sp.	5	110
2	8	2	Seriatopora caliendrum	1	13
2	8	2	Seriatopora hystrix	4	67
2	8	2	Sinularia spp.	26	1108
2	8	2	Soft coral species	3	14
2	8	2	Stylophora pistillata	3	72
Upper slope					
2	8	3	Acropora brueggemanni	4	139
2	8	3	Acropora divaricata	1	53
2	8	3	Acropora formosa	3	109
2	8	3	Acropora subulata	1	72
2	8	3	Acropora valida	9	371
2	8	3	Alcyonium spp.	1	12
2	8	3	Astreopora spp.	1	18
2	8	3	Barabattoia amicorum	2	45
2	8	3	Briareum sp.	5	75
2	8	3	Caulastrea furcata	1	16
2	8	3	Cyphastrea japonica	1	27
2	8	3	Dead coral (Acropora)	2	27
2	8	3	Dead coral (Seriatopora)	1	42
2	8	3	Echinophyllia aspera	3	98
2	8	3	Echinopora lamellosa	2	85
2	8	3	Echinopora spp.	2	53
2	8	3	Favia speciosa	2	75
2	8	3	Favites flexuosa	2	10
2	8	3	Favites halicora	2	50
2	8	3	Galaxea spp.	2	15
2	8	3	Goniopora spp.	4	150
2	8	3	Leptastrea spp.	2	61
2	8	3	Leptoria phrygia	1	88
2	8	3	Lobophyllia hemprichii	4	89
2	8	3	Merulina ampliata	1	16
2	8	3	Millepora massive	3	134
2	8	3	Millepora spp.	3	65
2	8	3	Montipora encrusting	8	102
2	8	3	Montipora spp.	9	285
2	8	3	Mycedium elephantotus	2	58
2	8	3	Oulophyllia crispa	1	36
2	8	3	Pachyseris speciosa	3	53
2	8	3	Pavona decussata	2	37
2	8	3	Pectinia alcicornis	1	7
2	8	3	Pectinia lactuca	6	154
2	8	3	Pectinia spp.	8	405
2	8	3	Platygyra spp.	1	28
2	8	3	Plerogyra sinuosa	2	65
2	8	3	Pocillopora damicornis	1	9
2	8	3	Porites annae	12	198
2	8	3	Porites cylindrica	14	476
2	8	3	Porites vaughani	4	47
2	8	3	Sarcophyton sp.	6	75
2	8	3	Seriatopora hystrix	3	42
2	8	3	Sinularia spp.	2	124
2	8	3	Soft coral species	1	23
2	8	3	Stylophora pistillata	5	111
Lower slope					
2	8	4	Acropora valida	4	91
2	8	4	Alcyonium spp.	1	11
2	8	4	Alveopora spp.	1	24
2	8	4	Astreopora spp.	3	44
2	8	4	Cyphastrea spp.	1	13
2	8	4	Echinophyllia aspera	6	152
2	8	4	Echinopora spp.	5	50
2	8	4	Favia speciosa	1	51
2	8	4	Fungia spp.	1	22
2	8	4	Galaxea spp.	1	15
2	8	4	Goniopora spp.	2	57
2	8	4	Leptastrea spp.	6	423
2	8	4	Lobophyllia hemprichii	3	27
2	8	4	Montipora encrusting	1	102
2	8	4	Montipora spp.	18	668

2	8	4	Mycedium elephantotus	11	351
2	8	4	Oxypora spp.	3	88
2	8	4	Pachyseris rugosa	1	19
2	8	4	Pachyseris speciosa	2	61
2	8	4	Pavona explanulata	1	153
2	8	4	Pavona varians	1	22
2	8	4	Pectinia alcicornis	1	22
2	8	4	Pectinia paeonia	1	16
2	8	4	Pectinia spp.	3	79
2	8	4	Platygyra pini	1	26
2	8	4	Platygyra spp.	2	24
2	8	4	Plerogyra sinuosa	1	42
2	8	4	Podabacia crustacea	2	30
2	8	4	Porites massive	3	147
2	8	4	Porites annae	5	61
2	8	4	Porites cylindrica	1	29
2	8	4	Sarcophyton sp.	1	18
2	8	4	Soft coral species	3	44
2	8	4	Sponge	6	96
2	8	4	Turbinaria peltata	1	23

SITE 9.
Reef flat

2	9	1	Acropora formosa	1	11
2	9	1	Briareum sp.	1	16
2	9	1	Favia favus	1	17
2	9	1	Favites flexuosa	1	12
2	9	1	Galaxea spp.	1	23
2	9	1	Goniopora spp.	2	11
2	9	1	Lobophytum spp.	3	51
2	9	1	Macroalgae	26	1800
2	9	1	Nephthea spp.	1	21
2	9	1	Pocillopora damicornis	1	16
2	9	1	Seagrasses	6	1810
2	9	1	Sinularia spp.	1	12
2	9	1	Turbinaria bifrons	1	8
2	9	1	Turbinaria mesenterina	1	12
2	9	1	Turbinaria reniformis	1	19

Reef crest

2	9	2	Acropora divaricata	1	18
2	9	2	Acropora formosa	12	446
2	9	2	Acropora selago	1	33
2	9	2	Acropora spat	1	2
2	9	2	Acropora valida	5	123
2	9	2	Alcyonium spp.	2	48
2	9	2	Astreopora spp.	1	14
2	9	2	Dead coral (Acropora)	1	36
2	9	2	Diploastrea heliopora	1	12
2	9	2	Favia favus	4	35
2	9	2	Favia maxima	1	17
2	9	2	Favia rotundata	1	6
2	9	2	Favia stelligera	1	3
2	9	2	Fungia spp.	1	6
2	9	2	Galaxea spp.	1	8
2	9	2	Goniopora spp.	5	203
2	9	2	Hydnophora rigida	1	15
2	9	2	Lobophyllia hemprichii	4	37
2	9	2	Lobophytum spp.	2	89
2	9	2	Macroalgae	2	90
2	9	2	Merulina ampliata	2	62
2	9	2	Millepora encrusting	1	8
2	9	2	Millepora massive	3	84
2	9	2	Millepora spp.	9	332
2	9	2	Montipora spp.	4	98
2	9	2	Palauastrea ramosa	1	39
2	9	2	Pavona decussata	2	13
2	9	2	Pectinia spp.	1	33
2	9	2	Porites massive	10	364
2	9	2	Porites annae	12	319
2	9	2	Porites cylindrica	15	982
2	9	2	Sarcophyton sp.	12	322
2	9	2	Sinularia spp.	10	253
2	9	2	Sponge	1	42
2	9	2	Stylophora pistillata	1	27
2	9	2	Turbinaria mesenterina	1	28
2	9	2	Zooanthid	2	28

Upper slope

2	9	3	Acropora formosa	2	55
2	9	3	Acropora valida	6	146
2	9	3	Alcyonium spp.	2	35
2	9	3	Alveopora spp.	1	26
2	9	3	Astreopora spp.	3	87

2	9	3	Barabattoia amicorum	3	48
2	9	3	Caulastrea curvata	2	16
2	9	3	Caulastrea sp.	1	19
2	9	3	Dead coral (Acropora)	2	38
2	9	3	Dead coral (Seriatopora)	1	27
2	9	3	Echinopora gemmacea	4	97
2	9	3	Echinopora lamellosa	2	55
2	9	3	Favia stelligera	5	183
2	9	3	Favites halicora	3	49
2	9	3	Galaxea spp.	1	43
2	9	3	Goniopora spp.	4	123
2	9	3	Lobophyllia hemprichii	2	26
2	9	3	Millepora spp.	7	131
2	9	3	Montipora spp.	6	99
2	9	3	Oulophyllia crispa	1	24
2	9	3	Pachyseris speciosa	1	8
2	9	3	Palauastrea ramosa	4	207
2	9	3	Pavona decussata	2	30
2	9	3	Pectinia spp.	3	68
2	9	3	Platygyra spp.	3	163
2	9	3	Porites massive	13	499
2	9	3	Porites annae	10	264
2	9	3	Porites cylindrica	12	899
2	9	3	Sarcophyton sp.	24	761
2	9	3	Sinularia spp.	9	167
2	9	3	Sponge	2	33
2	9	3	Stylophora pistillata	3	20
2	9	3	Turbinaria peltata	1	4
Lower slope					
2	9	4	Acropora formosa	1	32
2	9	4	Acropora valida	2	29
2	9	4	Alcyonium spp.	2	11
2	9	4	Alveopora spp.	2	114
2	9	4	Astreopora spp.	3	28
2	9	4	Coscinaraea spp.	1	6
2	9	4	Cyphastrea japonica	2	71
2	9	4	Cyphastrea spp.	3	35
2	9	4	Echinopora gemmacea	2	13
2	9	4	Echinopora mammiformis	1	8
2	9	4	Favites flexuosa	1	7
2	9	4	Favites matthaii	1	13
2	9	4	Galaxea spp.	1	38
2	9	4	Goniopora spp.	8	300
2	9	4	Hydnophora rigida	2	9
2	9	4	Lobophyllia hemprichii	1	25
2	9	4	Merulina ampliata	1	9
2	9	4	Montipora spp.	8	159
2	9	4	Mycedium elephantotus	1	4
2	9	4	Pachyseris speciosa	2	22
2	9	4	Palauastrea ramosa	1	8
2	9	4	Pavona decussata	6	88
2	9	4	Pectinia paeonia	2	22
2	9	4	Pectinia spp.	1	32
2	9	4	Platygyra spp.	4	133
2	9	4	Plerogyra sinuosa	1	22
2	9	4	Plesiastrea versipora	1	52
2	9	4	Podabacia crustacea	4	60
2	9	4	Porites encrusting	2	14
2	9	4	Porites massive	12	899
2	9	4	Porites cylindrica	2	6
2	9	4	Sarcophyton sp.	19	532
2	9	4	Sinularia spp.	3	39
2	9	4	Sponge	6	82
2	9	4	Turbinaria mesenterina	2	17
2	9	4	Turbinaria peltata	1	11
2	9	4	Turbinaria stellulata	2	25

Benthic assemblages recorded at Impact Location on Hayman Island in 1986 and 1988. Shallow indicates abundance of Operational Taxonomic Units (OTU) 0-2 m below Low Water Datum (LWD); Deep indicates abundance of OTUs 2-4 m below LWD; Total indicates the total abundance of each OTU at each site; Change indicates the difference between 1986 and 1988 data, where I - increased, D - decreased, S - similar, M - mortality, R - recruitment. Size class A (1 - 50 cm) is assumed unless otherwise stated [B 51-100 cm, C 101-300 cm, D > 300 cm].

OPERATIONAL TAXONOMIC UNITS	SITE 1							SITE 2							SITE 3						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
HARD CORALS																					
Favia spp.	3	10	13	14	22	36	I + 23	34	58	92	39	75	114	I + 22	46	55	101	54	84	138	I + 37
Favia spp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	0	0	0	D - 2
Favites spp.	6	6	12	7	9	16	I + 4	22	47	69	45	39	84	I + 15	25	43	68	60	55	115	I + 47
Goniastrea spp.	2	4	6	7	5	12	I + 6	10	12	22	33	21	54	I + 32	17	11	28	27	40	67	I + 39
Oulophyllia crispa	-	-	-	-	-	-	-	0	1	1	2	0	2	I + 1	0	1	1	0	2	2	I + 1
Diploastrea heliopora	1	0	1	0	0	0	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptastrea spp.	2	7	9	3	9	12	I + 3	2	1	3	11	6	17	I + 14	10	13	23	12	33	45	I + 22
Cyphastrea spp.	10	7	17	5	10	15	D - 2	3	6	9	1	7	8	D - 1	5	16	21	16	11	27	I + 6
Acropora fine branching	2	0	2	- 5	0	5	I + 3	5	0	5	2	1	3	I + 2	-	-	-	-	-	-	-
Acropora tabulate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	0	1	1	D - 1
Acropora shrub-like	-	-	-	-	-	-	-	43	11	54	30	7	37	D - 17	16	33	49	36	47	83	I + 34
Acropora shrub-like B	-	-	-	-	-	-	-	2	2	4	1	1	2	D - 2	-	-	-	-	-	-	-
Acropora humilis	-	-	-	-	-	-	-	2	1	3	1	0	1	D - 2	-	-	-	-	-	-	-
Acropora humilis B	-	-	-	-	-	-	-	1	0	1	0	0	0	D - 1	-	-	-	-	-	-	-
Acropora stout	-	-	-	-	-	-	-	0	1	1	1	1	2	I + 1	1	0	1	1	2	3	I + 2
Astreopora spp.	0	3	3	1	0	1	D - 2	0	1	1	6	4	10	I + 9	0	5	5	3	5	8	I + 3
Montipora encrusting	1	5	6	5	2	7	I + 1	3	7	10	29	10	39	I + 29	4	8	12	0	32	32	I + 20
Porites massive	1	0	1	7	10	17	I + 16	9	12	21	36	27	63	I + 42	9	11	20	31	39	70	I + 50
Porites massive B	0	0	0	1	0	1	I + 1	2	0	2	3	3	6	I + 4	-	-	-	-	-	-	-
Porites massive C	-	-	-	-	-	-	-	2	1	3	2	4	6	I + 3	-	-	-	-	-	-	-
Porites massive D	-	-	-	-	-	-	-	3	2	5	3	0	3	D - 2	-	-	-	-	-	-	-
Goniopora spp.	-	-	-	-	-	-	-	1	0	1	5	1	6	I + 5	4	8	12	1	0	1	D - 11
Pocillopora damicornis	-	-	-	-	-	-	-	3	4	7	8	2	10	I + 3	-	-	-	-	-	-	-
Stylophora pistillata	-	-	-	-	-	-	-	3	1	4	3	1	4	S	-	-	-	-	-	-	-
Stylophora pistillata B	-	-	-	-	-	-	-	1	0	1	0	0	0	D - 1	-	-	-	-	-	-	-
Hydnophora spp.	2	4	6	1	0	1	D - 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pachyseris rugosa	-	-	-	-	-	-	-	1	0	1	0	1	1	S	-	-	-	-	-	-	-
Pachyseris speciosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0	2	2	I + 1
Galaxea spp.	2	0	2	0	1	1	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scolymia vitiensis	-	-	-	-	-	-	-	0	2	2	1	1	2	S	-	-	-	-	-	-	-
Acanthastrea spp.	-	-	-	-	-	-	-	1	0	1	1	0	1	S	-	-	-	-	-	-	-
Lobophyllia spp.	1	3	4	1	1	2	D - 2	8	9	17	11	12	23	I + 6	10	8	18	11	7	18	S
Echinophyllia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	3	0	1	1	D - 2
Pectinia paeonia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	5	2	4	6	I + 1
SOFT CORALS																					
Alcyonuim spp.	7	6	13	1	25	26	I + 13	144	71	215	377	220	587	I + 372	22	52	74	118	98	216	I + 142
Sinularia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4	0	11	11	I + 7

Continued ...

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OPERATIONAL TAXONOMIC UNITS	SITE 1							SITE 2							SITE 3						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
HYDROZOA																					
Millepora branching	-	-	-	-	-	-	-	4	7	11	15	21	36	I + 25	10	2	12	10	4	14	I + 2
Millepora branching B	-	-	-	-	-	-	-	4	4	8	3	2	5	D - 3	2	0	2	0	1	1	D - 1
Millepora massive	-	-	-	-	-	-	-	1	0	1	1	0	1	S	-	-	-	-	-	-	-
Millepora massive C	-	-	-	-	-	-	-	0	1	1	0	0	0	D - 1	-	-	-	-	-	-	-
ONLY PRESENT IN 1986																					
HARD CORALS																					
Platygyra spp.	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-
Acropora fine branching	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	-	-	-	M
Acropora fine branching B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Acropora humilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	3	-	-	-	M
Hydnophora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Porites cylindrica	-	-	-	-	-	-	-	1	0	1	-	-	-	M	-	-	-	-	-	-	-
Porites cylindrica B	-	-	-	-	-	-	-	1	0	1	-	-	-	M	-	-	-	-	-	-	-
Pavona venosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Leptoseris spp.	1	0	1	-	-	-	M	0	1	1	-	-	-	M	1	1	2	-	-	-	M
Coscinaraea spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Heliofungia actiniformis	-	-	-	-	-	-	-	1	0	1	-	-	-	M	-	-	-	-	-	-	-
Cycloseris spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Turbinaria stellulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	-	-	-	M
SOFT CORALS																					
Lobophytum spp.	-	-	-	-	-	-	-	0	3	3	-	-	-	M	-	-	-	-	-	-	-
Sinularia spp.	1	0	1	-	-	-	M	31	8	39	-	-	-	M	-	-	-	-	-	-	-
Sarcophyton spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	-	-	-	M
NEW RECRUIT TYPES																					
HARD CORALS																					
Caulastrea spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Platygyra spp.	-	-	-	0	1	1	R	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Leptoria phrygia	-	-	-	2	0	2	R	-	-	-	2	0	2	R	-	-	-	12	33	45	R
Diploastrea heliopora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Montastrea spp.	-	-	-	-	-	-	-	-	-	-	2	3	5	R	-	-	-	4	0	4	R
Plesiastrea versipora	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Echinopora spp.	-	-	-	2	0	2	R	-	-	-	1	0	1	R	-	-	-	-	-	-	-
Stylocoeniella armata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Porites cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	4	R
Pocillopora damicornis	-	-	-	5	0	5	R	-	-	-	-	-	-	-	-	-	-	0	7	7	R
Seriatopora hystrix	-	-	-	-	-	-	-	-	-	-	2	0	2	R	-	-	-	0	1	1	R
Stylophora pistillata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Pseudosiderastr[illegible]ayami	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	0	1	1	R
Galaxea spp.	-	-	-	-	-	-	-	-	-	-	1	0	1	R	-	-	-	0	4	4	R

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OPERATIONAL TAXONOMIC UNITS	SITE 1							SITE 2							SITE 3						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
Acanthastrea spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Podabacia crustacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Psammocora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Pavona venosa	-	-	-	0	1	1	R	-	-	-	2	0	2	R	-	-	-	-	-	-	-
Symphyllia spp.	-	-	-	0	1	1	R	-	-	-	2	0	2	R	-	-	-	-	-	-	-
Echinophyllia spp.	-	-	-	-	-	-	-	-	-	-	3	1	4	R	-	-	-	-	-	-	-
Pectinia spp.	-	-	-	-	-	-	-	-	-	-	2	1	3	R	-	-	-	-	-	-	-
Psammocora spp.	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pachyseris speciosa	-	-	-	-	-	-	-	-	-	-	0	2	2	R	-	-	-	-	-	-	-
Turbinaria stellulata	-	-	-	2	0	2	R	-	-	-	2	1	3	R	-	-	-	-	-	-	-
Acropora stout	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SOFT CORALS																					
Lobophytum spp.	-	-	-	1	1	2	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HYDROZOA																					
Millepora branching	-	-	-	5	0	5	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Benthic assemblages recorded at Location One on Hayman Island in 1986 and 1988. Shallow indicates abundance of Operational Taxonomic Units (OTU) 0-2 m below Low Water Datum (LWD); Deep indicates abundance of OTUs 2-4 m below LWD; Total indicates the total abundance of each OTU at each site; Change indicates the difference between 1986 and 1988 data, where I - increased, D - decreased; S - similar, M - mortality, R - recruitment. Size class A (1-50 cm) is assumed unless otherwise stated [B 51-100 cm, C 101-300 cm, D > 300 cm].

OPERATIONAL TAXONOMIC UNITS	SITE 4							SITE 5							SITE 6						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
HARD CORALS																					
Favia spp.	35	33	68	98	89	187	I + 119	32	40	72	89	84	173	I + 101	16	24	40	68	80	148	I + 108
Favia spp. B	0	1	1	0	0	0	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Favites spp.	28	12	40	84	58	142	I + 102	24	20	44	53	38	91	I + 47	30	21	51	67	74	141	I + 90
Favites spp. B	0	0	0	1	0	1	I + 1	1	0	1	0	0	0	D - 1	-	-	-	-	-	-	-
Goniastrea spp.	12	11	23	27	23	50	I + 27	11	17	28	25	44	69	I + 41	17	15	32	19	43	62	I + 30
Goniastrea spp. B	-	-	-	-	-	-	-	0	3	3	0	1	1	D - 2	-	-	-	-	-	-	-
Platygyra spp.	2	0	2	3	0	3	I + 1	-	-	-	-	-	-	-	3	3	6	2	3	5	D - 1
Platygyra spp. B	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	0	1	1	0	0	0	D - 1
Leptastrea spp.	10	9	19	8	7	15	D - 4	0	2	2	6	23	29	I + 27	0	4	4	2	7	9	I + 5
Leptastrea ssp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	0	0	0	D - 2
Cyphastrea spp.	-	-	-	-	-	-	-	2	8	10	22	11	33	I + 33	6	6	12	20	16	36	I + 24
Montastrea spp.	-	-	-	-	-	-	-	0	1	1	0	1	1	S	-	-	-	-	-	-	-
Echinopora spp.	-	-	-	-	-	-	-	0	1	1	2	1	3	I + 2	1	2	3	3	3	6	I + 3
Echinopora spp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0	0	0	D - 1
Diploastrea heliopora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	1	1	2	I + 1
Acropora shrub-like	27	13	40	49	17	66	I + 26	20	8	28	37	11	48	I + 20	0	22	22	21	33	54	I + 32
Acropora shrub-like B	1	0	1	3	0	3	I + 2	1	0	1	0	1	1	S	0	1	1	1	0	1	S
Acropora thick branching	3	1	4	1	1	2	D - 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora thick branching B	0	0	0	2	0	2	I + 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora fine branching	1	0	1	1	1	2	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora fine branching B	0	0	0	3	0	3	I + 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora humilis	0	3	3	3	0	3	S	2	0	2	1	1	2	S	-	-	-	-	-	-	-
Acropora tabulate	2	0	2	1	0	1	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora tabulate B	0	0	0	2	0	2	I + 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astreopora spp.	-	-	-	-	-	-	-	1	3	4	4	5	9	I + 5	-	-	-	-	-	-	-
Montipora encrusting	38	3	41	38	6	44	I + 3	10	6	16	25	22	47	I + 31	10	17	27	24	27	51	I + 24
Montipora encrusting B	3	0	3	2	0	2	D - 1	-	-	-	-	-	-	-	1	1	2	2	0	2	S
Porites massive	11	8	19	34	25	59	I + 40	14	14	28	39	46	85	I + 57	5	13	18	21	36	57	I + 39
Porites massive B	0	0	0	0	1	1	I + 1	2	2	4	3	7	10	I + 6	3	5	8	4	4	8	S
Porites massive C	-	-	-	-	-	-	-	2	3	5	0	2	2	D - 4	2	3	5	3	5	8	I + 3
Porites massive D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	3	8	1	0	1	D - 7
Porites cylindrica	10	4	14	9	12	21	I + 7	8	9	17	15	15	30	I + 13	2	3	5	5	13	18	I + 13
Porites cylindrica B	-	-	-	-	-	-	-	2	0	2	0	1	1	D - 1	2	5	7	1	8	9	I + 2
Goniopora spp.	1	1	2	10	3	13	I + 11	1	2	3	2	3	5	I + 2	-	-	-	-	-	-	-
Goniopora spp. B	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pocillopora damicornis	4	1	5	13	6	19	I + 14	2	2	4	6	2	8	I + 4	-	-	-	-	-	-	-
Stylophora pistillata	5	1	6	8	12	20	I + 14	2	1	3	6	0	6	I + 3	2	3	5	2	3	5	S

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OPERATIONAL TAXONOMIC UNITS	SITE 4							SITE 5							SITE 6						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
Stylophora pistillata B	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seriatopora hystrix	-	-	-	-	-	-	-	0	1	1	4	0	4	I + 3	0	1	1	1	0	1	S
Pavona cactus	5	10	15	8	17	25	I + 10	1	1	2	4	1	5	I + 3	-	-	-	-	-	-	-
Leptoseris spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0	2	2	I + 1
Leptoseris spp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	1	1	I + 1
Pachyseris speciosa	2	0	2	5	1	6	I + 4	1	1	2	2	1	3	I + 1	-	-	-	-	-	-	-
Pachyseris speciosa B	0	0	0	1	6	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pachyseris rugosa	-	-	-	-	-	-	-	1	3	4	1	4	5	I + 1	-	-	-	-	-	-	-
Acanthastrea spp.	0	1	1	2	4	6	I + 5	-	-	-	-	-	-	-	1	2	3	2	5	7	I + 4
Lobophyllia spp.	8	8	16	28	12	40	I + 24	3	9	12	9	8	17	I + 5	3	5	8	14	24	38	I + 30
Symphyllia spp.	1	0	1	3	1	4	I + 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectinia spp.	0	2	2	5	6	11	I + 9	0	2	2	5	3	8	I + 6	0	1	1	3	9	12	I + 11
Echinophyllia spp.	3	0	3	2	6	8	I + 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphyllia spp.	-	-	-	-	-	-	-	0	1	1	0	1	1	S	1	0	1	0	1	1	I + 5
Plerogyra spp.	1	0	1	1	0	1	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fungia spp.	2	7	9	1	7	8	D - 1	-	-	-	-	-	-	-	0	1	1	0	2	2	I + 1
Scolymia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	1	0	1	S
Turbinaria foliose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	2	2	0	2	S
SOFT CORALS																					
Lobophytum spp.	19	2	21	28	12	40	I + 19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alcyonium spp.	200	186	3	295	350	645	I + 259	220	135	355	0	84	84	D - 271	120	127	247	134	363	497	I + 4
Sarcophyton spp.	-	-	-	-	-	-	-	28	6	34	8	7	15	D - 19	-	-	-	-	-	-	-
Sinularia spp.	22	75	97	109	69	178	I + 81	0	8	8	12	57	69	I + 61	10	30	40	34	4	38	D - 2
Sinularia spp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0	0	0	D - 1
HYDROZOA																					
Millepora branching	-	-	-	-	-	-	-	12	13	25	21	21	42	I + 17	4	4	8	7	5	12	I + 250
Millepora branching B	-	-	-	-	-	-	-	3	4	7	11	8	19	I + 12	4	4	8	2	4	6	D - 2
Millepora branching C	-	-	-	-	-	-	-	0	1	1	0	1	1	S	-	-	-	-	-	-	-
Millepora encrusting	8	6	14	14	10	24	I + 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Millepora encrusting B	4	1	5	1	2	3	D - 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zoanthids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	2	3	0	3	I + 1
ONLY PRESENT IN 1986																					
HARD CORALS																					
Palaustrea ramosa	5	10	15	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montastrea spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	5	-	-	-	M
Acropora thick branching	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Acropora palifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Acropora stout	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-
Pavona cactus	-	-	-	-	-	-	-	3	0	3	-	-	-	M	-	-	-	-	-	-	-
Sandalolitha robusta	-	-	-	-	-	-	-	0	1	1	-	-	-	M	1	0	1	-	-	-	M
Scolymia vitiensis	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-

Continued ...

Benthic assemblages recorded at location two on Hayman Island in 1986 and 1988. Shallow indicates abundance of Operational Taxonomic Units (OTU) 0-2 m below Low Water Datum (LWD); Deep indicates abundance of OTUs 2-4 m below LWD; Total indicates the total abundance of each OTU at each site; Change indicates the difference between 1986 and 1988 data, where I - increased, D - decreased, S - similar, M - mortality, R - recruitment. Size class A (1-50 cm) is assumed unless otherwise stated [B 51-100 cm, C 101-300 cm, D > 300 cm].

OPERATIONAL TAXONOMIC UNITS	SITE 7							SITE 8							SITE 9						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
HARD CORALS																					
Favia spp.	7	9	16	48	33	81	I + 65	1	1	2	25	21	46	I + 44	5	2	7	17	6	23	I + 16
Favia spp. B	0	3	3	0	2	2	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Favites spp.	16	13	29	62	45	107	I + 78	8	8	16	29	28	57	I + 41	3	0	3	14	7	21	I + 18
Favites spp. B	2	0	2	0	0	0	D - 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goniastrea spp.	5	12	17	25	19	44	I + 27	6	14	20	11	16	27	I + 7	4	1	5	7	7	14	I + 9
Platygyra spp.	1	2	3	2	0	2	D - 1	2	1	3	0	1	1	D - 2	-	-	-	-	-	-	-
Leptastrea spp.	1	2	3	6	6	12	S	0	2	2	5	9	14	I + 12	1	3	4	4	0	4	S
Leptastrea spp. B	0	0	0	0	1	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diploastrea heliopora	-	-	-	-	-	-	-	0	2	2	0	2	2	D	-	-	-	-	-	-	-
Diploastrea heliopora B	1	0	1	1	0	1	S	0	1	1	0	0	0	D - 1	-	-	-	-	-	-	-
Cyphastrea spp.	0	3	3	7	2	9	I + 6	-	-	-	-	-	-	-	3	3	6	7	4	11	I + 5
Cyphastrea spp. B	0	0	0	2	1	3	I + 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinopora spp. B	-	-	-	-	-	-	-	0	3	3	0	1	1	D - 2	-	-	-	-	-	-	-
Acropora fine branching	2	3	5	0	1	1	D - 4	32	39	71	13	34	47	D - 24	10	12	22	9	8	17	D - 5
Acropora fine branching B	-	-	-	-	-	-	-	6	7	13	7	5	12	D - 1	4	4	8	0	2	2	D - 6
Astreopora spp.	2	3	5	8	7	15	I + 10	0	2	2	4	3	7	I + 5	1	1	2	1	3	4	I + 2
Astreopora spp. B	1	2	3	1	0	1	D - 2	0	2	2	4	3	7	I + 5	-	-	-	-	-	-	-
Acropora tabulate	-	-	-	-	-	-	-	4	0	4	8	3	11	I + 7	-	-	-	-	-	-	-
Acropora tabulate B	-	-	-	-	-	-	-	2	2	4	1	1	2	D - 2	-	-	-	-	-	-	-
Acropora tabulate C	-	-	-	-	-	-	-	1	2	3	0	1	1	D - 2	-	-	-	-	-	-	-
Acropora thick branching	2	2	4	3	2	5	I + 1	1	0	1	0	4	4	I + 3	-	-	-	-	-	-	-
Acropora thick branching B	4	3	7	6	2	8	I + 1	1	4	5	1	1	2	D - 3	-	-	-	-	-	-	-
Acropora thick branching C	0	0	0	1	0	1	I + 1	1	2	3	0	1	1	D - 2	-	-	-	-	-	-	-
Acropora humilis	3	1	4	6	1	7	I + 3	0	1	1	4	4	8	I + 7	2	2	4	2	5	7	I + 3
Acropora humilis B	3	1	4	6	1	7	I + 3	7	10	17	0	1	1	D - 16	1	6	7	1	0	1	D - 6
Acropora palifera	-	-	-	-	-	-	-	1	0	1	1	0	1	S	-	-	-	-	-	-	-
Acropora stout shrub	34	51	85	93	50	143	I + 58	8	0	8	41	35	76	I + 68	0	0	0	12	20	32	I + 32
Acropora stout shrub B	38	35	73	21	32	53	D - 20	16	11	27	17	16	33	I + 6	2	6	8	1	5	6	D - 2
Acropora stout shrub C	2	0	2	2	0	2	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora stout	0	2	2	4	0	4	I + 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montipora encrusting	7	16	23	44	36	80	I + 57	6	0	6	44	36	80	I + 74	1	0	1	13	4	17	I + 16
Montipora encrusting B	-	-	-	-	-	-	-	5	1	6	2	2	4	D - 2	2	4	6	0	0	0	D - 6
Porites massive	9	8	17	35	44	79	I + 62	6	8	14	24	13	37	I + 23	0	5	5	5	7	12	I + 7
Porites massive B	1	5	6	1	5	6	S	-	-	-	-	-	-	-	0	2	2	0	3	3	I + 1
Porites massive C	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	0	1	1	0	1	1	S
Porites massive D	1	0	1	0	0	0	D - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seriatopora hystrix	4	4	8	4	3	7	D - 1	0	1	1	0	3	3	I + 2	-	-	-	-	-	-	-

Continued ...

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OPERATIONAL TAXONOMIC UNITS	SITE 4							SITE 5							SITE 6						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
SOFT CORALS																					
Sarcophyton spp.	0	3	3	-	-	-	M	-	-	-	-	-	-	-	26	4	30	-	-	-	M
Sarcophyton spp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3	-	-	-	M
HYDROZOA																					
Millepora encrusting	-	-	-	-	-	-	-	3	5	8	-	-	-	M	0	3	3	-	-	-	M
Millepora branching B	0	1	1	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEW RECRUIT TYPES																					
HARD CORALS																					
Leptoria phrygia	-	-	-	3	0	3	R	-	-	-	4	7	11	R	-	-	-	0	8	8	R
Oulophyllia spp.	-	-	-	1	0	1	R	-	-	-	0	1	1	R	-	-	-	1	0	1	R
Plesiastrea versipora	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	1	0	1	R
Diploastrea heliopora	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Cyphastrea spp.	-	-	-	17	24	41	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora fine branching	-	-	-	-	-	-	-	-	-	-	5	4	9	R	-	-	-	-	-	-	-
Acropora stout	-	-	-	4	0	4	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acropora thick branching	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	3	R
Montipora encrusting	-	-	-	-	-	-	-	-	-	-	2	1	3	R	-	-	-	-	-	-	-
Astreopora spp.	-	-	-	4	2	6	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psammocora spp.	-	-	-	-	-	-	-	-	-	-	1	1	2	R	-	-	-	2	8	10	R
Goniopora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	7	11	R
Pavona venosa	-	-	-	1	0	1	R	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Pavona decussata	-	-	-	4	0	4	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptoseris spp.	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Pachyseris rugosa	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Pachyseris speciosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	3	R
Galaxea spp.	-	-	-	2	1	3	R	-	-	-	1	1	2	R	-	-	-	2	2	4	R
Acanthastrea spp.	-	-	-	-	-	-	-	-	-	-	3	1	4	R	-	-	-	-	-	-	-
Merulina spp.	-	-	-	0	1	1	R	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Symphyllia sp.	-	-	-	-	-	-	-	-	-	-	1	1	2	R	-	-	-	2	2	4	R
Echinophyllia spp.	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	1	4	5	R
Oxypora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Scolymia australis	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphyllia spp.	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbinarea foliose	-	-	-	0	2	2	R	-	-	-	1	0	1	R	-	-	-	-	-	-	-
Turbinarea encrusting	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	1	5	6	R
Herpolitha limax	-	-	-	0	1	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Podabacia crustacea	-	-	-	1	1	2	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SOFT CORALS																					
Pachyclavularia spp.	-	-	-	2	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lobophytum spp.	-	-	-	-	-	-	-	-	-	-	584	198	782	R	-	-	-	6	0	6	R
Cladiella spp.	-	-	-	1	46	47	R	-	-	-	4	0	4	R	-	-	-	20	0	20	R
Nephthea spp.	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zoanthids	-	-	-	2	0	2	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Continued

OPERATIONAL TAXONOMIC UNITS	SITE 7							SITE 8							SITE 9						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
Stylophora pistillata	3	2	5	17	27	44	I + 39	3	7	10	9	17	26	I + 16	4	2	6	5	10	15	I + 9
Stylophora pistillata B	-	-	-	-	-	-	-	2	0	2	1	2	3	I + 1	0	7	7	0	0	0	D - 7
Pocillopora damicornis	4	4	8	10	22	32	I + 24	3	4	7	5	7	12	I + 5	0	4	4	4	4	8	I + 4
Pavona venosa	0	2	2	2	2	4	I + 2	0	1	1	1	3	4	I + 3	-	-	-	-	-	-	-
Pachyseris speciosa	0	1	1	3	3	6	I + 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pachyseris speciosa B	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scolymia vitiensis	-	-	-	-	-	-	-	0	1	1	1	1	2	I + 1	-	-	-	-	-	-	-
Galaxea spp.	0	1	1	1	2	3	I + 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthastrea spp.	-	-	-	-	-	-	-	0	1	1	0	1	1	S	-	-	-	-	-	-	-
Lobophyllia spp.	3	4	7	1	10	11	I + 4	2	3	5	9	12	21	I + 16	-	-	-	-	-	-	-
Fungia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	2	0	2	S
Turbinaria foliose	0	1	1	0	4	4	I + 3	-	-	-	-	-	-	-	1	0	1	0	0	0	D - 1
SOFT CORALS																					
Lobophytum spp.	-	-	-	-	-	-	-	0	2	2	0	5	5	I + 3	-	-	-	-	-	-	-
Lobophytum spp. B	-	-	-	-	-	-	-	1	0	1	1	0	1	S	-	-	-	-	-	-	-
Alcyonium spp.	120	109	229	261	195	456	I + 227	58	125	183	259	277	536	I + 353	83	70	153	71	66	137	D - 16
Sarcophyton spp.	1	68	69	11	94	105	I + 36	8	2	10	3	6	9	D - 1	1	6	7	2	4	6	D - 1
Sarcophyton spp. B	4	8	12	0	4	4	D - 8	-	-	-	-	-	-	-	1	2	3	0	1	1	D - 2
Sinularia spp.	85	57	142	85	182	267	I + 125	49	59	108	66	105	171	I + 63	31	15	46	6	18	24	D - 22
Sinularia spp. B	0	9	9	7	1	8	D - 1	2	0	2	0	1	1	D - 2	-	-	-	-	-	-	-
Nephthea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	0	29	29	I + 27
Stereonephthya sp.	-	-	-	-	-	-	-	0	1	1	0	2	2	I + 1	-	-	-	-	-	-	-
Zoanthids	0	2	2	20	215	235	I + 233	2	4	6	4	3	7	I + 1	2	0	2	13	6	19	I + 17
HYDROZOA																					
Millepora branching	0	2	2	6	10	16	I + 14	3	4	7	0	12	12	I + 5	1	0	1	5	0	5	I + 4
Millepora branching B	4	2	6	4	1	5	D - 1	1	0	1	1	1	2	I + 1	2	2	4	0	1	1	D - 3
Millepora branching C	0	0	0	1	0	1	I + 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Millepora encrusting	0	7	7	2	6	8	I + 1	0	2	2	7	4	11	I + 9	-	-	-	-	-	-	-
Millepora encrusting B	2	3	5	0	4	4	D -1	0	2	2	1	1	2	S	-	-	-	-	-	-	-
Millepora encrusting C	0	1	1	0	0	0	D - 1	0	1	1	0	1	1	S	-	-	-	-	-	-	-
ONLY PRESENT IN 1986																					
HARD CORALS																					
Oulophyllia spp. B	0	2	2	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montastrea spp. B	1	0	1	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Platygyra spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	M
Goniopora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	-	-	-	M
Galaxea spp.	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-
Herpolitha spp.	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-
Sandalolitha robusta	-	-	-	-	-	-	-	0	1	1	-	-	-	M	-	-	-	-	-	-	-
Symphyllia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	5	-	-	-	M

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OPERATIONAL TAXONOMIC UNITS	SITE 7							SITE 8							SITE 9						
	1986			1988			Change	1986			1988			Change	1986			1988			Change
	Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total		Shallow	Deep	Total	Shallow	Deep	Total	
Acropora stout B	1	0	1	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthastrea spp.	3	0	3	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SOFT CORALS																					
Lobophytum spp.	7	7	14	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dendronephthya spp.	1	0	1	-	-	-	M	0	1	1	-	-	-	M	-	-	-	-	-	-	-
HYDROZOA																					
Millepora encrusting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	-	-	-	M
NEW RECRUIT TYPES																					
Leptoria phrygia	-	-	-	3	1	4	R	-	-	-	0	2	2	R	-	-	-	-	-	-	-
Olophyllia spp.	-	-	-	1	3	4	R	-	-	-	2	0	2	R	-	-	-	0	1	1	R
Diploastrea heliopora	-	-	-	0	1	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyphastrea spp.	-	-	-	-	-	-	-	-	-	-	6	7	13	R	-	-	-	-	-	-	-
Echinopora spp.	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Acropora stout	-	-	-	-	-	-	-	-	-	-	2	1	3	R	-	-	-	-	-	-	-
Acropora tabulate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	3	R
Acropora palifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Goniopora spp.	-	-	-	1	7	8	R	-	-	-	1	1	2	R	-	-	-	-	-	-	-
Acanthastrea spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	R
Lobophyllia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	7	R
Echinophyllia spp.	-	-	-	-	-	-	-	-	-	-	0	3	3	R	-	-	-	-	-	-	-
Pectinia spp.	-	-	-	1	1	2	R	-	-	-	0	1	1	R	-	-	-	-	-	-	-
Scolymia vitiensis	-	-	-	2	1	3	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliofungia actiniformis	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fungia spp.	-	-	-	1	0	1	R	-	-	-	1	0	1	R	-	-	-	-	-	-	-
Podabacia crustacea	-	-	-	1	0	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psammocora spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Turbinaria foliose	-	-	-	-	-	-	-	-	-	-	0	4	4	R	-	-	-	-	-	-	-
Pachyseris speciosa	-	-	-	-	-	-	-	-	-	-	1	0	1	R	-	-	-	-	-	-	-
Porites annae	-	-	-	-	-	-	-	-	-	-	0	1	1	R	-	-	-	-	-	-	-
SOFT CORALS																					
Lobophytum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	R
Cladiella spp.	-	-	-	-	-	-	-	-	-	-	20	1	21	R	-	-	-	0	2	2	R
Stereonephthya sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Xenia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	2	R
Pachyclavularia sp.	-	-	-	1	1	2	R	-	-	-	-	-	-	-	-	-	-	19	13	32	R
Pachyclavularia sp. B	-	-	-	1	2	3	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Benthic assemblages recorded at Control Location on Hayman Island in 1988. Shallow indicates abundance of Operational Taxonomic Units (OTU) 0-2 m below Low Water Datum (LWD); Deep indicates abundance of OTUs 2-4 m below LWD; Total indicates the total abundance of each OTU at each site; Change indicates the difference between 1986 and 1988 data, where I - increased, D - decreased, S - similar, M - mortality, R - recruitment. Size class A (1-50 cm) is assumed unless otherwise stated (b 51-100 cm, C 101-300 cm, D > 300 cm).

OPERATIONAL TAXONOMIC UNITS	CONTROL 1			CONTROL 2			CONTROL 3		
	1988			1988			1988		
	Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total
HARD CORAL									
Favia spp.	37	90	127	23	29	52	49	35	84
Favia spp. B	-	-	-	2	0	2	-	-	-
Favites spp.	31	76	107	56	33	84	62	38	100
Favites spp. B	-	-	-	0	1	1	-	-	-
Goniastrea spp.	29	30	59	22	12	34	57	46	103
Goniastrea spp. B	-	-	-	1	0	1	0	1	1
Platygyra spp.	5	5	10	7	1	8	2	5	7
Platygyra spp. B	-	-	-	1	0	1	-	-	-
Montastrea spp.	0	1	1	-	-	-	-	-	-
Leptoria phrygia	7	2	9	2	3	5	5	4	9
Plesiastrea versipora	0	1	1	-	-	-	-	-	-
Oulophyllia spp.	-	-	-	0	1	1	-	-	-
Diploastrea heliopora	0	1	1	2	0	2	1	1	2
Diploastrea heliopora B	-	-	-	2	0	2	0	1	1
Leptastrea spp.	3	3	6	1	1	2	2	3	5
Cyphastrea spp.	4	9	13	3	3	6	3	1	4
Cyphastrea spp. B	0	1	1	-	-	-	-	-	-
Echinopora spp.	-	-	-	4	3	7	3	1	4
Echinopora spp. B	5	0	5	0	1	1	0	4	4
Echinopora spp. C	1	0	1	-	-	-	-	-	-
Acropora stout shrub	11	4	15	32	6	38	11	1	12
Acropora stout shrub B	0	1	1	-	-	-	-	-	-
Acropora stout	1	0	1	-	-	-	-	-	-
Acropora fine branching	-	-	-	0	3	3	-	-	-
Acropora humilis	-	-	-	2	0	2	0	2	2
Acropora tabulate	1	1	2	2	0	2	1	0	1
Acropora tabulate B	1	0	1	1	0	1	-	-	-
Astreopora spp.	5	4	9	2	0	2	-	-	-
Hydnophora spp.	-	-	-	1	0	1	1	0	1
Montipora foliose	0	2	2	0	1	1	-	-	-
Montipora foliose B	0	2	2	-	-	-	-	-	-
Montipora encrusting	11	9	20	8	6	14	1	4	5
Montipora encrusting B	0	1	1	-	-	-	-	-	-
Porites massive	23	2	25	21	31	52	29	15	44
Porites massive B	4	2	6	8	2	10	2	1	3
Porites massive C	4	3	7	1	2	3	3	0	3
Porites cylindrica	25	24	49	11	1	12	-	-	-

Continued ...

Continued

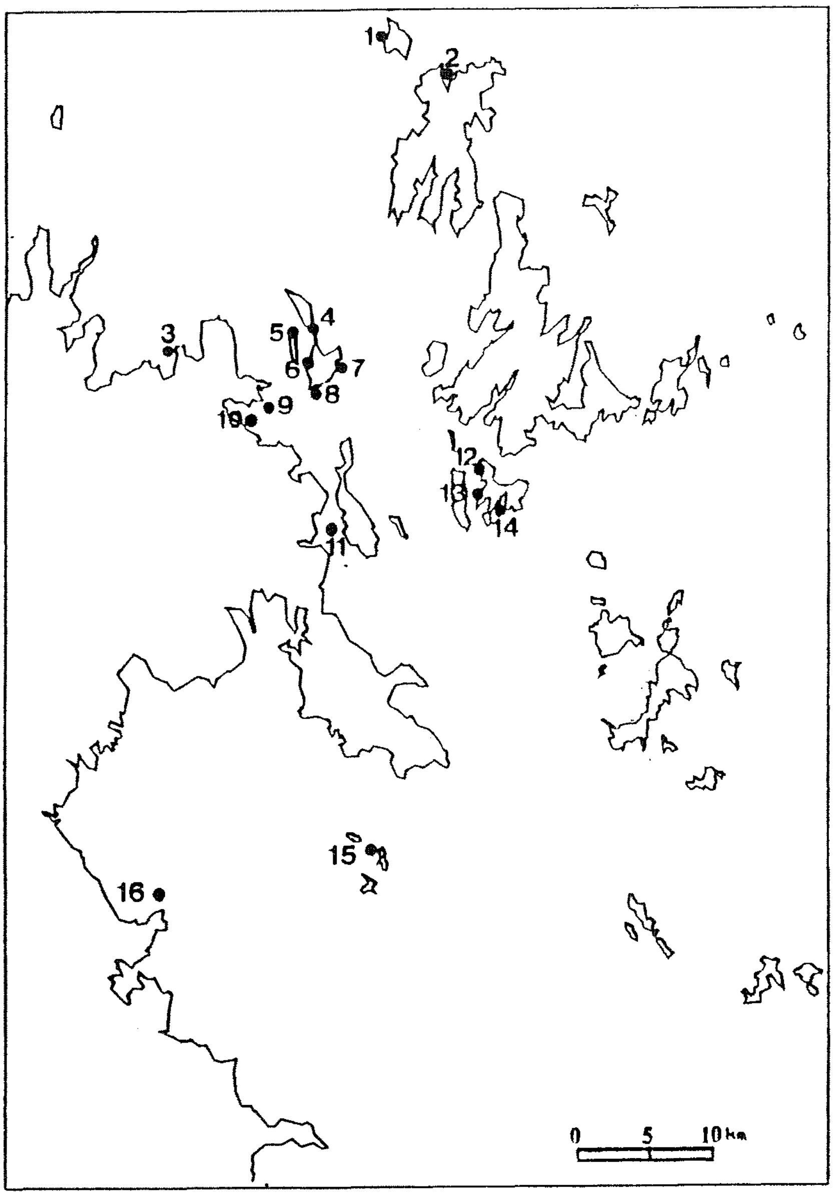
OPERATIONAL TAXONOMIC UNITS	CONTROL 1 1988 Shallow	CONTROL 1 1988 Deep	CONTROL 1 1988 Total	CONTROL 2 1988 Shallow	CONTROL 2 1988 Deep	CONTROL 2 1988 Total	CONTROL 3 1988 Shallow	CONTROL 3 1988 Deep	CONTROL 3 1988 Total
Porites cylindrica B	11	12	23	6	13	19	-	-	-
Porites cylindrica C	0	1	1	1	3	4	-	-	-
Porites annae	9	20	29	8	5	13	11	17	28
Porites annae B	13	11	24	8	8	16	-	-	-
Porites annae C	0	1	1	0	1	1	6	9	15
Goniopora spp.	4	5	9	3	6	9	2	0	2
Goniopora spp. B	0	1	1	0	1	1	1	0	1
Goniopora spp. C	-	-	-	-	-	-	0	1	1
Pocillopora damicornis	2	4	6	8	1	9	0	2	2
Pocillopora damicornis B	-	-	-	-	-	-	2	0	2
Seriatopora hystrix	1	8	9	0	2	2	0	2	2
Seriatopora hystrix B	0	1	1	-	-	-	-	-	-
Stylophora pistillata	1	2	3	6	2	8	3	0	3
Pavona cactus	-	-	-	2	2	4	-	-	-
Pavona venosa	1	0	1	-	-	-	-	-	-
Pachyseris speciosa	1	1	2	5	4	9	0	2	2
Pachyseris speciosa C	0	1	1	-	-	-	-	-	-
Galaxea spp.	2	1	3	4	2	6	1	1	2
Leptoseris spp.	-	-	-	0	1	1	-	-	-
Merulina ampliata	0	4	4	1	0	1	1	0	1
Acanthastrea spp.	1	0	1	4	2	6	-	-	-
Symphyllia spp.	0	2	2	-	-	-	-	-	-
Pectinia spp.	2	3	5	1	0	1	-	-	-
Echinophyllia spp.	1	1	2	-	-	-	-	-	-
Lobophyllia spp.	18	18	36	-	-	-	10	7	17
Symphyllia spp.	0	2	2	2	2	4	2	0	2
Euphyllia spp.	-	-	-	1	0	1	-	-	-
Fungia spp.	2	1	3	0	3	3	1	1	2
Podabacia crustacea	-	-	-	1	0	1	-	-	-
Herpolitha spp.	0	1	1	-	-	-	-	-	-
Polyphyllia talpina	1	0	1	1	0	1	-	-	-
Turbinaria foliose	1	9	10	0	8	8	1	1	2
Turbinaria encrusting	2	0	2	2	6	8	-	-	-
Tubipora spp.	0	1	1	2	1	3	1	0	1
SOFT CORALS									
Lobophytum spp.	11	25	36	8	1	9	-	-	-
Lobophytum spp. B	1	0	1	-	-	-	-	-	-
Alcyonium spp.	160	340	500	104	353	457	494	203	781
Alcyonium spp. B	0	1	1	-	-	-	-	-	-
Nephthea spp.	3	15	18	16	20	36	11	0	11
Sarcophyton spp.	2	20	22	14	2	16	-	-	-
Sinularia spp.	32	58	90	37	48	85	-	-	-

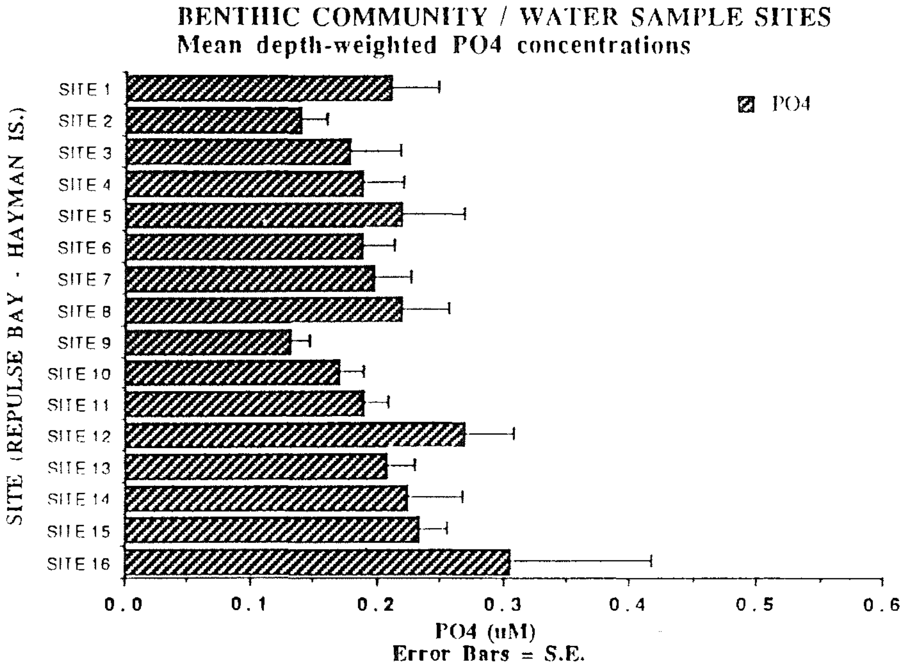
Continued ...

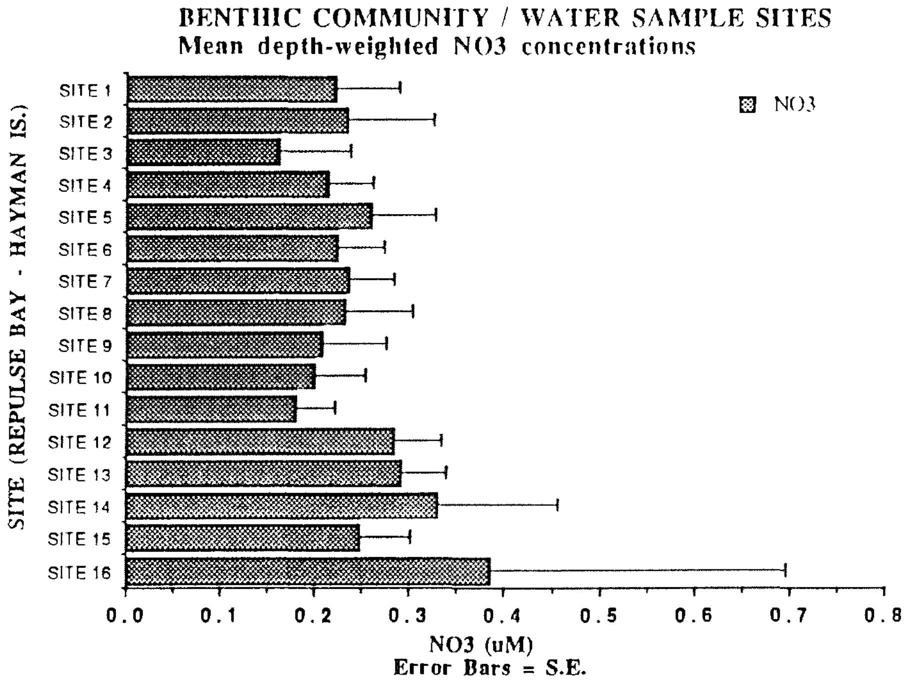
Continued

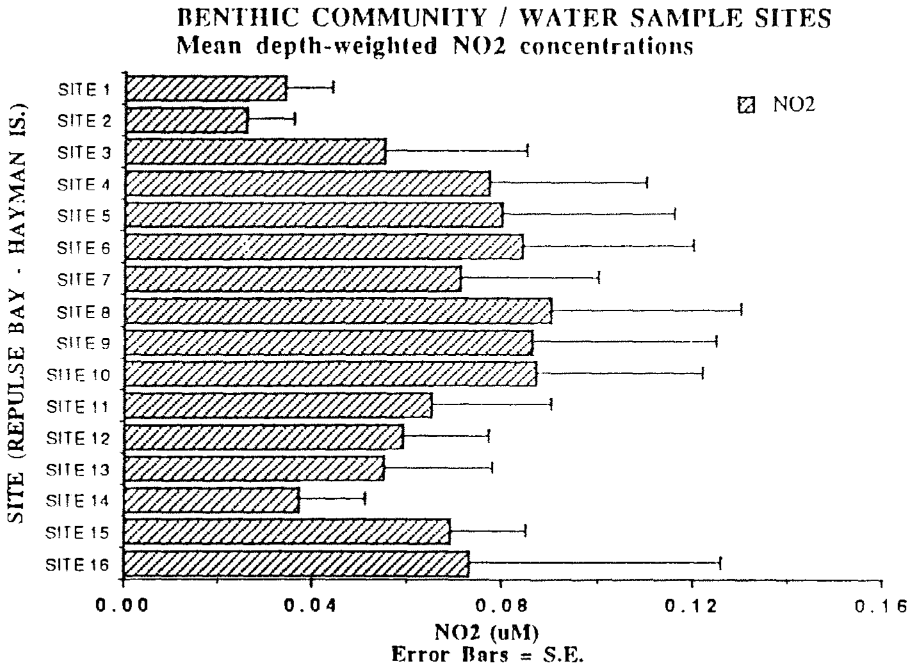
OPERATIONAL TAXONOMIC UNITS	CONTROL 1 1988			CONTROL 2 1988			CONTROL 3 1988		
	Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total
Sinularia spp. B	0	1	1	-	-	-	-	-	-
Briareum sp.	2	0	2	-	-	-	-	-	-
Briareum sp. B	0	1	1	-	-	-	-	-	-
HYDROZOA									
Millepora branching	18	8	36	4	8	12	14	8	22
Millepora branching B	8	8	16	1	7	8	9	4	13
Millepora branching C	-	-	-	0	1	1	0	1	1
Zoanthids	3	0	3	6	0	6	-	-	-
Zoanthids B	1	0	1	-	-	-	-	-	-

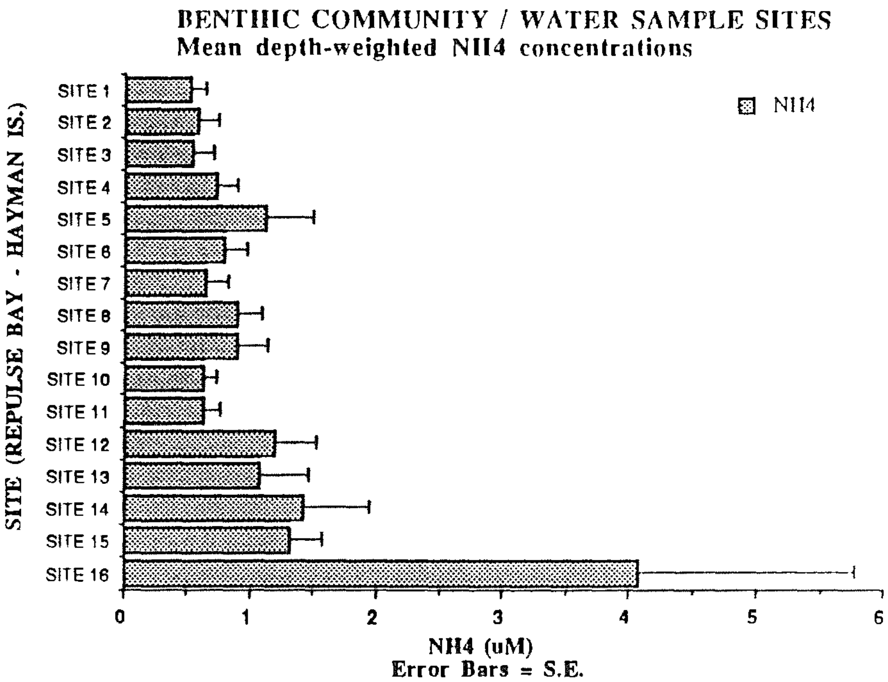
APPENDIX 9. Study sites for collaborative research on nutrient concentrations and benthic assemblages in the Whitsunday Islands

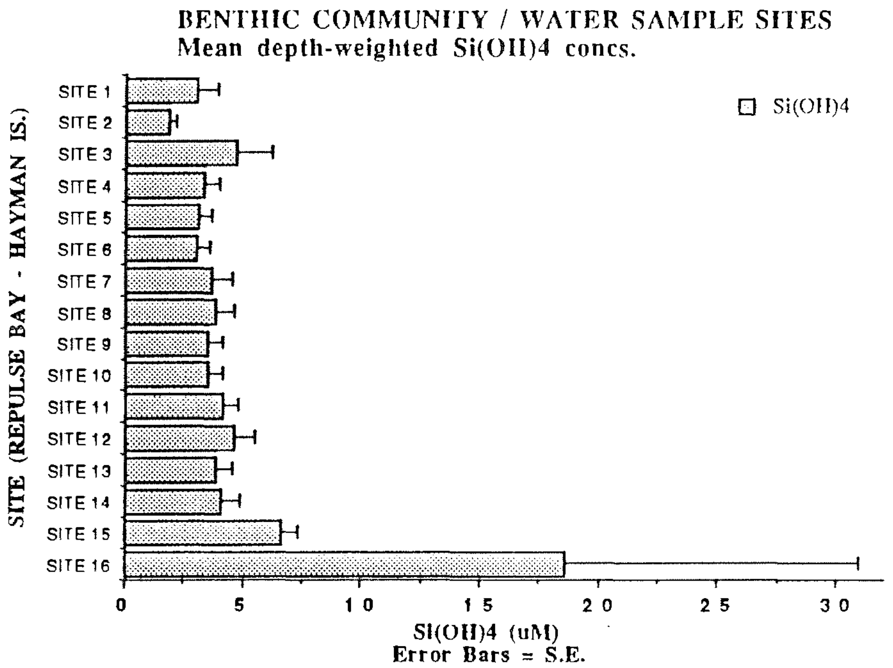


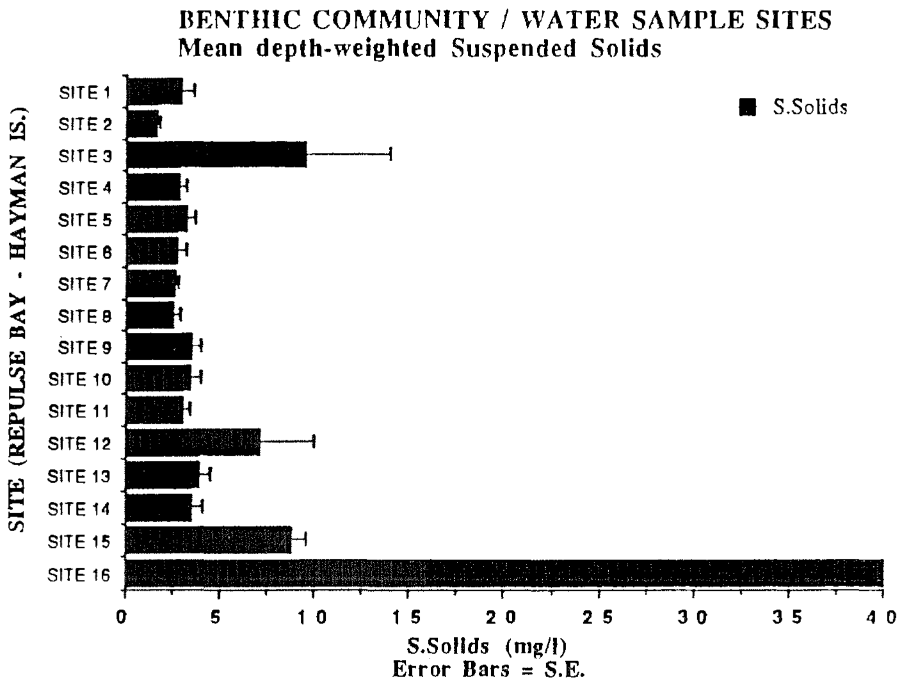

BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted PO4 concentrations
PO4
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
0.0
0.1
0.2
0.3
0.4
0.5
0.6
PO4 (uM)
Error Bars = S.E.


BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted NO3 concentrations
NO3
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
NO3 (uM)
Error Bars = S.E.


BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted NO2 concentrations
NO2
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
0.00
0.04
0.08
0.12
0.16
NO2 (uM)
Error Bars = S.E.


BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted NH4 concentrations
NH4
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
0
1
2
3
4
5
6
NH4 (uM)
Error Bars = S.E.


BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted Si(OH)4 concs.
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
Si(OH)4
0
5
10
15
20
25
30
Si(OH)4 (uM)
Error Bars = S.E.


BENTHIC COMMUNITY / WATER SAMPLE SITES
Mean depth-weighted Suspended Solids
SITE (REPULSE BAY - HAYMAN IS.)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITE 10
SITE 11
SITE 12
SITE 13
SITE 14
SITE 15
SITE 16
S.Solids
0
5
10
15
20
25
30
35
40
S.Solids (mg/l)
Error Bars = S.E.

Appended benthic data for nutrient/benthic study, for 3 sites not reported in Appendix 1, Muddy Bay (site 3), Repulse Island (site 15), Repulse Bay (site 16).

Species/Genera	S3	S15	S16
Caulastrea spp.	-	-	-
Favia spp.	-	3	-
Favites spp.	-	8	-
Goniastrea spp.	-	12,1	-
Platygyra spp.	-	-	-
Leptoria phygria	-	-	-
Oulophyllia spp.	-	-	-
Montastea spp.	-	1	-
Plesiastrea versipora	-	-	-
Diploastrea heliopora	-	-	-
Leptastrea spp.	-	1	1
Cyphastrea spp.	-	3	-
Echinopora spp.	-	-	-
Moseleya latistellata	-	1	-
Acropora "fine branching"	-	-	-
Acropora "thick branching"	-	-	-
Acropora "stout caespitose"	-	-	-
Acropora "fine caespitose"	-	-	-
Acropora "tabulate"	-	-	-
Acropora "stout"	-	-	-
Acropora "palifera-type"	-	-	-
Acropora "encrusting"	-	2	-
Astreopora spp.	-	-	-
Montipora "foliose"	-	-	-
Montipora "efl"	-	29,16,2	-
Montipora "enfl"	-	-	-
Montipora "vp"	-	-	-
Porites "massive"	-	-	-
Porites "encrusting"	-	2	-
Porites cylindrica	-	-	-
Goniopora spp.	-	8	-
Alveopora spp.	-	1	-
Pocillopora damicornis	-	8	-
Seriatopora spp.	-	-	-
Stylophora pistillata	-	-	-
Palauastrea ramosa	-	-	-
Pavona cactus	-	-	-

Pavona varians	-	-	-
Pavona "other"	-	1	-
Leptoseris spp.	-	-	-
Pachyseris rugosa	-	-	-
Pachyseris speciosa	-	-	-
Pseudosiderastrea tayamai	-	-	-
Coscinaraea spp.	-	4	-
Galaxea spp.	-	-	-
Merulina ampliata	-	-	-
Scolymia spp.	-	-	-
Acanthastrea spp.	-	-	-
Lobophyllia spp.	-	12,5	-
Symphyllia spp.	-	-	-
Echinophyllia spp.	-	-	-
Oxypora spp.	-	-	-
Mycedium spp.	-	-	-
Pectinia spp.	-	-	-
Euphyllia spp.	-	-	-
Catalaphyllia jardinei	-	-	-
Plerogyra sinuosa	-	-	-
Physogyra lichtensteini	-	-	-
Turbinaria "foliose"	-	-	-
Turbinaria "efl"	-	17,1,4	-
Turbinaria "enfl"	-	-	-
Cycloseris spp.	-	-	-
Heliofungia actiniformis	-	-	-
Fungia spp.	-	-	-
Herpolitha spp.	-	-	-
Herpetoglossa simplex	-	-	-
Polyphyllia talpina	-	-	-
Podabacia crustacea	-	-	-
Hydnophora spp.	-	-	-
Sarcophyton sp.	-	42,3	-
Sinularia spp.	-	24,1	-
Lobophytum spp.	-	-	-

Briareum sp.	-	3	-
Alcyonium spp.	-	-	-
Xenia elongata	-	-	-
Cladiella sp.	-	-	-
Millepora tenella	-	-	-
Porifera spp.	-	-	-
Zoanthidae	-	-	-
Porifera (cliona)	-	6,2	-
Nephthea sp.	-	-	-
Tubiopora musica	-	-	-
Anthelia sp.		-	
Pachyclavularia	-	-	-
Lemnalia sp.	-	-	-
Psammocora spp.	-	1	-
Millepora "encrusting"	-	1	-