RESEARCH PUBLICATION No.26

The Effect of Sediment Run-off on the Coral Populations of Fringing Reefs at Cape Tribulation

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Great Barrier Reef Marine Park Authority

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December 1991

A REPORT TO THE GREAT BARRIER REEF MARINE PARK AUTHORITY

ISSN 1037-1508
ISBN
Published by GBRMPA

The opinions expressed in this document are not necessarily those of the Great Barrier Reef Marine Park Authority.

Ayling, Tony, 1947-
The effect of sediment run-off on the coral populations of fringing reefs at Cape Tribulation

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ISBN 0 642 17402 4.

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593.6099436

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SUMMARY

The aims of this study were to investigate the effects of sediment run-off caused by the construction in late 1984 of a coastal road through rainforest catchments on the coral communities of the Cape Tribulation fringing reefs. In the absence of any pre-construction baseline we relied on surveys of two similar control locations north and south of the potential impact location adjacent to the new road catchment to determine the significance of any changes that occurred. The southern control was adjacent to the long-established portion of the road south of Cape Tribulation and the northern control adjacent to a small undisturbed catchment.

Depth stratification in the coral communities was measured at several sites and it was decided to confine the surveys to the explanate *Montipora*/clumping *Acropora* assemblage that was dominant between 2-4 m below MSL. In deeper water a suite of more massive corals such as *Galaxea* and *Hydnophora* was present but this depth strata was not represented at many of the sites and was excluded from the annual surveys.

Four sites were established in each location and five permanent 20 m intersect line transects set up to survey coral communities at each site in 1985. These transects were resurveyed prior to the wet season each year from 1985 to 1988. Post wet season surveys proved to be impossible due to SE weather conditions and very poor water visibility.

At the time of the initial survey there was no evidence of coral death caused by sediment run-off during the 1984/85 wet season in spite of evidence from Bonham (1985) of extensive sediment run-off into the coastal environment from the new road site. Coral cover was high in all three locations with a grand mean cover of just over 50%. A small cyclonic episode in April 1986 caused an overall 23% reduction in coral cover to a grand mean of 39% in 1986 and there was a further slight reduction to 37.5% caused by a widespread coral bleaching episode in February 1987. Both these disturbances caused consistent reductions across all three locations. No disturbances occurred in 1988 and coral cover increased by 33% back to the initial levels of about 50% in all locations.

Five haphazard transects surveyed concurrently at each site showed a less distinct pattern but were basically similar. Haphazard transects were also surveyed annually at five shallow reef sites in the new road location where silt laden water had been observed running directly across the fringing reef during a flight over the area in February 1985. No significant temporal changes were recorded at these sites between 1985 and 1988.

Monitoring of ten large coral colonies at each site suggested that these larger colonies, that may not have been adequately sampled using the line transects, were not adversely affected during the three years of this survey.

Fish communities on these fringing reefs are considerable different from those on offshore reefs. There is a relatively low diversity of reef fishes in this region with low numbers of herbivores and low numbers of the larger piscivores such as coral trout. There is a suite of species that appear to be confined to the fringing reef environment, and a further group of species that are only found on offshore reefs to the south of the

Whitsunday Region. There were no changes detected in the fish communities of the new road location during this study that were not also evident in the control locations

This study suggests that there has been no effect on the coral communities of the Cape Tribulation fringing reefs that can be attributed to the run-off of sediments from the new road location. It is our contention that these fringing reefs are healthy, supporting a rich growth of a wide variety of coral species, and able to cope with acute disturbances such a cyclones and coral bleaching episodes with minimal disruption.

We suggest that permanent monitoring sites be established on a variety of fringing reefs to look at long term changes in coral communities that may be due to man-induced changes to the coastal environment in an attempt to test the widely held perception that many fringing reefs are either degraded or suffering chronic siltation stress.

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INTRODUCTION

Public perception of the Cape Tribulation region is focused on the twin features of rainforest and fringing reefs. This area is the major accessible locality in the Great Barrier Reef (GBR) Marine Park where coral reefs occur adjacent to rainforest. These reefs are among the most extensive on the east coast (Craik and Dutton, 1987); fringing reefs of varying degrees of development front over 80% of the coastline between Noah Head and the Bloomfield River. Preliminary surveys in late 1984 and 1985 suggested that the coral communities of these reefs were rich and diverse: Veron (1987) reported 141 species in 50 genera. This study recorded 3 species not previously reported from the GBR.

The Cape Tribulation fringing reefs have grown throughout their history in an environment of heavy terrigenous sediments input (Johnson and Carter, 1987). Average annual rainfall in the Cape Tribulation area is about 3,750 mm and normally carries large amounts of sediment into the inshore zone. Sediments from the reef and inner shelf contained from 50-80% terrigenous material. Cores showed that the terrigenous content of the inner shelf muds was generally constant suggesting that there has been little change in terrigenous sediment input during accumulation.

There was considerable controversy during 1984 over the decision to construct a coast road through rainforest from Cape Tribulation to the Bloomfield River in Far-North Queensland. This unsealed road was completed in late 1984 and subsequent observations during the 1985 wet season showed that there was heavy local run-off of silt into coastal waters from the road (Bonham, 1985). There was concern that this silt run-off could cause permanent damage to the fringing reef communities in the area. Sea Research was contracted by the Marine Park Authority at the end of 1985 to make a three year study on the fringing reefs in the Cape Tribulation area to determine if the observed silt run-off was affecting the coral communities. This was part of a multidisciplinary study in the area that included sections on reef structure and development (Partain and Hopley, 1989), the sedimentary framework of the reefs (Johnson and Carter, 1987), sedimentation rates (Hopley et al., 1990), hydrology (Parnell, 1989) and coral settlement and recruitment (Fisk and Harriott, 1989).

The Cape Tribulation coast is characterised by steep rainforest covered hills falling directly to the sea from over 1000 m. Rainfall is high, averaging almost 4,000 mm per year, with annual totals of more than 6,000 mm not unusual. Most rainfall occurs between January and April and during this period 24 hr falls sometimes exceed 500 mm.

Between April and October SE trade winds blow onshore, resuspending the shelf sediments and holding a wide band of turbid water against the coast. Water visibility in these prevailing conditions ranges from less than 50 cm to about 2 m. During the remainder of the year extended calm periods occur regularly and during these calm spells water visibility usually ranges between 2 and 6 m, although it may occasionally reach 10 m.

The main problem faced was how to resolve the question of whether any damage detected was resulting from the run-off of silt in view of the absence of any comprehensive pre-road biological data from the area. As the road was constructed in late 1984 there had been a full wet season of run-off before this study started. It was decided that the Cape Tribulation coast could be divided into three locations, two of which could be used as controls for the third in relation to this problem.

Location 1. Coastline from Noah Creek north past Cape Tribulation, adjacent to the long-established section of the road that runs from the Daintree River to 2 km north of Cape Tribulation (control 1).

Location 2. Coastline from 2 km north of Cape Tribulation to Cowie Point where the newly constructed road runs adjacent to the coast and where silt laden run-off from the road was observed during the 1985 wet season.

Location 3. Coastline from Cowie Point to just south of the Bloomfield River where the new road is diverted inland and direct run-off is unaffected by any road construction (control 2).

There are further problems with this approach; it could be argued that silt run-off may also be affecting the adjacent control areas, but these are unavoidable as fringing reefs from further afield are not strictly comparable and may suffer natural changes not suffered by the Cape Tribulation area reefs.

The main question we sought to answer was whether there were any changes to coral communities in the Cape Tribulation region that could be attributed to sediment run-off from the new road. We needed to describe the existing coral communities, look for any evidence of reef damage from the 1985 wet season and monitor any future changes in both the impact and control locations.

METHODS

Selection of Study Sites

Fringing reefs in the area occur in two main situations: along steep rocky shores and on coastal sediment bodies such as river mouth bars and beach shoals. The reefs along rocky shore sections of coast total about 8.3 km in the Cape Tribulation region. These reefs are narrow and generally fall abruptly to the inner shelf sediments at a depth of only 1-3 m below Australian Height Datum (AHD). Reefs developed on sediment banks are wider (from 100-600 m wide) and more extensive, ranging from 300 m to 3 km long, with a total of 13.4 km in the Cape Tribulation region. Most of these reefs have an inner sandy beach and a subfossil outer reef flat with living corals largely confined to the reef slope. These sediment bank reefs generally fall more gently to the shelf sediments, reaching depths of a maximum of about 6 m below AHD. The reef flat on all these fringing reefs is approximately 0.8 m higher than modern coral growth. This was formed during the late post-glacial around 6000 years BP when sea levels were about 1 m higher than they are at present (Johnson and Carter, 1987).

A preliminary assessment of all reefs on the 25 km of coast between Noah Head and the Bloomfield River was made during September 1985 (Ayling and Ayling, 1985) using spot check techniques at 20 sites, including 5 where conspicuous sediment run-off had been observed during a flight over the area in February 1985. It was decided to confine the major study to the deeper sediment bank based reefs where hard corals were abundant as it was the fate of the coral communities of the region we were primarily interested in. Four similar sites where the reef reached a depth of at least 4 m below AHD were chosen in each location (figure 1). Each site was restricted to a short length of reef about fifty metres long having broadly homogeneous coral communities. Four sites were used to give some indication of the range of conditions within each location.

Depth Stratification

As a preliminary to the major survey the depth stratification of the coral communities was measured at one site by surveying five haphazard 10 m intersect line transects to measure the abundance of corals and other encrusting organisms at four depths. These surveys indicated that there was a marked depth stratification in the reef community (results, table 2). It was decided to restrict the main survey at each site to the *Montipora*/*Acropora* depth strata between about 2 and 4 m depth; this strata had a high coral cover and moderately high diversity and was present at all sites, whereas the deeper strata was not well developed at all sites.

Permanent Transects

At each of the major sites (sites 1-12, figure 1) five haphazardly positioned permanent 20 m line transects were marked with reinforcing rod stakes every 5 m and recorded for coral cover. A fibreglass tape was stretched tightly between the stakes and the intersection of this tape with each coral colony beneath it was recorded in cm. Such intersect transects have been widely used to estimate the cover of benthic organisms (Loya, 1976; Mapstone et al., 1989).

The permanent transects were set up and surveyed initially in October/November 1985 and resurveyed in September 1986, November 1987 and November 1988.

At the time of the initial 1985 survey a series of stereo photo pairs were taken along a 10 m segment of one of the permanent transects at each site using Terry Done's stereo-photographic apparatus. The results of this were not acceptable as the distance from the camera to the coral was too great for flash photos to be successful in the turbid water we normally experienced. In subsequent years the same 10 m segment was photographed when the water was suitably clear using natural light using a single camera with a wide angle lens. Conditions were only suitable for photography on a small proportion of the days spent in the region.

Haphazard Transects

Within these same 12 sites another five haphazard un-marked transects were surveyed each year from 1985 to 1987. Separate haphazard transects were surveyed each year and the re-surveys were thus independent of each other. Survey dates were October/November 1985, January 1987 and November 1987.

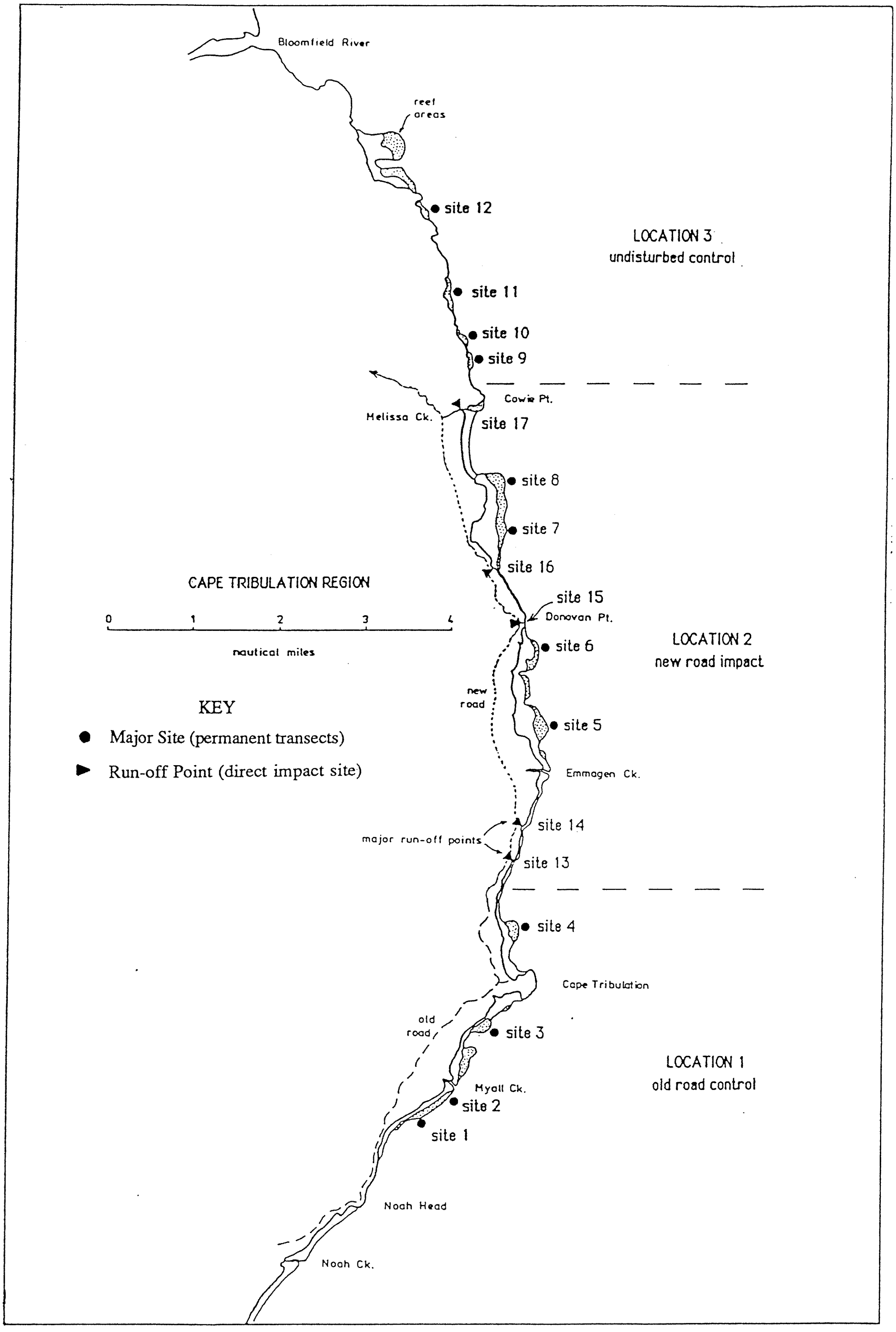
Marked Corals

During October/November 1985 the position of 10 large coral colonies of a range of species was noted within each of the 12 sites. The condition of these colonies was noted at the time of each re-survey.

Direct Impact Sites

During a flight over the Cape Tribulation area in the 1985 wet season observations were made of the points where most sediment run-off from the road actually entered the marine system, either through creeks or down gullies. These points are marked on the map in figure 1. None of these run-off points impinged on the major fringing reef areas but rather occurred along the rocky shore sections of the coast where the reefs are narrow and generally fall abruptly to the inner shelf sediments at a depth of only a few metres. The depth stratum that was surveyed at the other 12 sites was not present at these shallow sites but it was decided that surveys should be made of the benthic communities on the deepest parts of the reef nearest to the run-off point to see if silt impinging directly on the reefs had any affect. At each of these five additional sites (labelled 13-17) five haphazard 20 m line transects were surveyed at the time of the permanent transect surveys in the years 1985-1988. No separate controls were possible for these direct impact sites as this shallow rock fringing habitat was confined to the impact location (2).

Figure 1. Map of the Cape Tribulation Region Showing the Study Locations and Sites and the Major Points of Sediment Run-Off.



Re-surveys

Initially it was planned to make two surveys per year at all sites, one prior to the wet season in the period September-December, and one post wet season during the months April-July. However, the wet season did not finish until May in this region on the years of the survey and by that time strong SE winds had set in and made conditions unsuitable for surveys until September-October. Regular trips to the area were made during lulls in the SE winds but conditions were almost always so bad that sites and transects could not be reliably detected or the corals identified.

Analysis

The haphazard transects at the major sites were analysed using three factor analysis of variance, while the haphazard transects at the five run-off sites were analysed using a two factor analysis of variance (table 1). The permanent transects for each years survey were analysed separately with a two factor analysis of variance to see if patterns were the same at the beginning and end of the program, while changes through time were checked with an analysis of variance of the proportional changes in abundance between successive surveys (table 1). In the majority of cases the data were square root transformed prior to analysis.

Fish Counts

The consistently poor visibility encountered on the reefs during this study made reliable estimates of fish density difficult to obtain. It was also found that at many of the sites there was not enough reef area to allow five replicate fish counts to be surveyed. After a number of attempts it was decided to limit fish counts to a single site in each location, and to use five replicate 50 x 10 m transects counted in separate 5 m wide swathes. A 50 m fibreglass tape was run out by one observer while the fish counter (AMA) recorded all non-secretive reef fish within 5 m of one side of the tape. At the end of the tape the fish counter crossed over and recorded fish in a 5 m strip back along the other side of the tape, while the tape layer wound in the tape. Fish counts were made at sites 1 (location 1), 6 (location 2) and 9 (location 3), and were only made when the underwater visibility was more than 5 m.

Table 1. Analysis of Variance Models Used for Data Analysis.

A. Permanent Transects for Each Annual Survey.

Factor	Source of Variation	Fixed/Random	df	Denominator
A	Location	F	2	Site (A)
B	Site (A)	R	9	Residual

B. Proportional Change in Abundance Between Successive Surveys of Permanent Transects.

Factor	Source of Variation	Fixed/Random	df	Denominator
A	Location	F	2	B(A)*C
B	Site (A)	R	9	B(A)*C
C	Time Interval	F	2	B(A)*C
	A*C		4	B(A)*C
	B(A)*C		18	Residual

C. Haphazard Transects at Major Study Sites.

Factor	Source of Variation	Fixed/Random	df	Denominator
A	Location	F	2	B(A)*C
B	Site (A)	R	9	B(A)*C
C	Time	R	2	B(A)*C
	A*C		4	B(A)*C
	B(A)*C		18	Residual

D. Haphazard Transects at Run-Off Sites.

Factor	Source of Variation	Fixed/Random	df	Denominator
A	Site	F	4	A*B
B	Time	R	3	Residual
	A*B		12	Residual

RESULTS

Depth Stratification

These surveys indicated that there was a marked depth stratification in the reef community (table 2). The intertidal reef flat supported a low algal turf but was largely devoid of hard corals. The large brown alga *Sargassum* occurs in a dense band from about mean low tide level down to a depth of about 1 m and then decreases in density down to about 3 m depth. Hard corals increase in abundance with increasing depth, approaching 70% cover below 5 m. In addition the species composition of the hard coral community changes with depth.

On the reef flat the only common species was the faviid *Goniastrea aspera.* At the lower limit of the *Sargassum* distribution several species of explanate and whorl-forming *Montipora* peaked in abundance, along with a suite of small clumping *Acropora* species, including *A. brueggemanni, A. tenuis, A. palifera, A. willisae, A. valida, A. divaricata* and *A.* sp. nov. (a new species discovered by Terry Done and referred to by Veron as 'terry'). In deeper water both *Montipora* and *Acropora* spp. decreased rapidly in abundance while a number of massive and large explanate corals became more common (list in table 2). Soft corals were most abundant in shallow water, while sponges became more common in deeper water.

As has been mentioned the survey transects were largely confined to the *Montipora/Acropora* depth stratum, although occasional transects passed through parts of the deeper water coral community. The deeper water coral community was only well developed at about four of the sites; the reef did not extend deep enough at the other sites, and surveys were not made in this habitat.

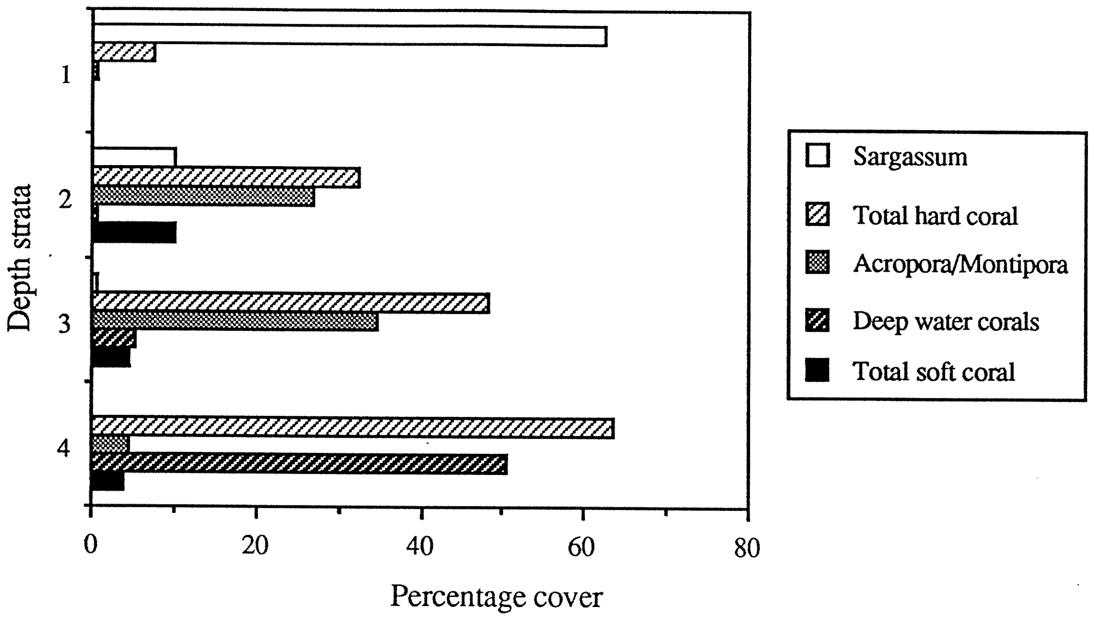
Table 2. Depth Stratification in the Cape Tribulation Fringing Reef Community.

Figures show mean percentage cover from each group of 5 transects with standard deviation in brackets. Deep water corals includes the following species and genera: *Pachyseris speciosa, Podabacia crustacea, Goniopora, Alveopora, Platygyra, Hydnophora excesa, Galaxea, Merulina ampliata, Lobophyllia, Symphyllia, Echinopora, Echinophyllia, Oxypora, Mycedium elephantotus ,Pectinia lactuca*

	Depth 1 (0 m)		Depth 2 (0-2 m)		Depth 3 (2-4 m)		Depth 4 (4-6 m)	
Sargassum spp.	62.4	(19.8)	10.1	(3.6)	0.5	(0.7)	-	
Total Hard Coral	7.3	(6.6)	32.5	(11.5)	48.4	(12.6)	63.6	(15.7)
Pocilloporidae	-		0.6	(0.7)	4.7	(2.5)	1.3	(1.7)
Acropora spp.	-		0.9	(1.1)	6.2	(3.4)	1.7	(2.0)
Montipora spp.	0.7	(1.2)	26.0	(10.6)	28.5	(8.3)	3.0	(4.1)
Porites spp.	0.6	(0.8)	3.8	(4.1)	1.0	(1.2)	3.2	(3.4)
Favidae	6.0	(6.1)	0.5	(0.5)	1.1	(1.5)	3.3	(3.6)
Turbinaria spp.	-		-		0.2	(0.5)	0.3	(0.7)
Deep Water Corals	-		0.6	(1.0)	5.1	(3.0)	50.7	(17.7)
Total Soft Coral	-		10.1	(9.2)	4.4	(4.8)	3.9	(2.3)
Total Sponges	-		-		0.2	(0.4)	0.7	(1.6)

Figure 2. Depth Stratification on Cape Tribulation Fringing Reefs

Bars show mean percentage cover from five 10 m line transects at each depth.



Permanent Transects

At the time of the initial survey in October-November 1985 live hard coral cover was high (table 3), with site means ranging from 33.2 to 62.6% cover. There were significant differences between sites in locations 1 and 2 but no significant differences between locations (table 4). There was no evidence of any extensive coral death during the previous 12-24 months. The level of dead standing coral was low at all sites indicating that the run-off of silt during the first wet season after road construction (1985) had not caused any marked reduction in coral cover at any of our survey sites.

Table 3. Mean Coral Cover for Major Survey Locations: 1985-1988

Recorded as grand mean % cover with standard deviation in brackets from five permanent 20 m intersect line transects at 4 sites in each location.

	Nov. 1985		Sept. 1986		Nov. 1987		Nov. 1988	
Location 1	53.1	(9.4)	40.4	(10.3)	39.5	(7.5)	50.0	(10.0)
Location 2	46.1	(9.6)	38.7	(8.1)	36.5	(12.0)	49.3	(10.6)
Location 3	53.1	(10.5)	38.0	(9.1)	36.6	(11.3)	50.2	(9.4)
Grand Means								
	50.8	**(9.9)**	**39.0**	**(9.2)**	**37.5**	**(10.4)**	**49.8**	**(10.0)**

Species composition was similar at most sites (table 5) with explanate and whorl forming *Montipora* spp. dominating with a grand mean cover of almost 25% (table 6). A number of species of corymbose plate forming *Acropora* spp. were also important with a grand mean cover of 12.5%. Other groups each accounted for less than 2% cover with the exception of the deep water corals, a grouping of over 20 species that covered a mean of 7.4%. The only exception to this general pattern of species composition was site 5 in location 2 just north of the Emmagen Creek outfall, the site with the lowest total coral cover (33.2%) (table 5). At this site *Montipora* and *Acropora* spp. accounted for less than 2% cover while *Turbinaria* spp. were dominant with a combined cover of over 11%. The deep water corals were also important (>11%), as were soft corals with a cover twice that of any other site (30%). This site was particularly silty and it is possible that the different composition of the coral community reflects the proximity of Emmagen Creek.

There were no significant differences between locations for any of the species groups indicating that the controls were comparable to the potential impact location. Within the locations, site 1 was anomalous at Location 1 with low cover of *Acropora* spp. and high cover of faviids and soft corals, while site 5 was very different from all other sites as has already been mentioned. As a result of these few anomalous sites there were significant site differences in all species groups (table 4).

Table 4. Analysis of the Permanent Transect Data.

A. Significance of Patterns from the Beginning and End of the Survey

NS = not significant; * 0.05>p>0.01; ** = 0.01>p>0.001; *** = p<0.001

	1985		1988	
Family/Group	Location	Site (L)	Location	Site (L)
Total Coral	NS	***	NS	***
Pocilloporidae	NS	NS	***	NS
Acropora spp.	NS	***	NS	***
Montipora spp.	NS	***	NS	***
Porites spp.	NS	***	NS	NS
Faviidae	NS	***	NS	***
Turbinaria spp.	NS	***	NS	***
Deep Water Corals	NS	***	NS	***
Soft Corals	NS	***	NS	***

B. Analysis of Variance Results for Proportional Change in Permanent Transect Data.

NS = not significant; * 0.05>p>0.01; ** = 0.01>p>0.001; *** = p<0.001

Family/Group	Location	Site (L)	Time	L * T	S * T
Total Coral	NS	NS	***	NS	NS
Pocilloporidae	NS	NS	***	NS	NS
Acropora spp.	NS	NS	***	NS	NS
Montipora spp.	NS	NS	***	NS	NS
Porites spp.	NS	NS	NS	NS	NS
Faviidae	NS	NS	NS	NS	NS
Turbinaria spp.	NS	NS	NS	NS	NS
Deep Water Corals	NS	NS	***	NS	NS
Soft Corals	NS	NS	NS	NS	NS

There were marked and significant changes in hard coral cover from year to year (table 3 and 4, figure 3). An overall 23% reduction in coral cover from 1985 to 1986 was caused by strong wind episodes. This was followed by a further reduction of 4% from 1986 to 1987 that was caused by a widespread bleaching episode on fringing reefs between at least Cairns and Cooktown. From 1987 to 1988 the normal rapid growth of these fringing reef corals in the absence of disturbances led to a 33% increase in hard coral cover with the 1988 level very similar to the initial 1985 cover at all sites.

Table 5. Species Composition of the Coral Community at Each Site at the Beginning and End of the Survey.

Coral cover shown as mean percentage cover from five 20 m permanent transects.

Sample date	1985	1988	1985	1988	1985	1988	1985	1988	**1985**	**1988**
LOCATION 1	**Site 1**		**Site 2**		**Site 3**		**Site 4**		**Grand Mean**	
Total Hard Coral	40.4	37.2	53.4	54.2	62.6	54.0	56.0	54.7	**53.1**	**50.0**
Pocilloporidae	2.8	3.3	1.2	1.7	3.2	3.3	4.2	2.4	**2.9**	**2.7**
Acropora spp.	3.8	2.9	21.1	26.3	13.2	9.0	25.4	28.0	**15.9**	**16.6**
Montipora spp.	25.4	24.6	19.3	16.3	37.4	30.2	24.0	21.9	**26.5**	**23.2**
Porites spp.	0.8	0.1	2.3	1.2	0.1	0.4	0.1	0.6	**0.8**	**0.6**
Faviidae	4.4	3.2	0.9	0.9	0.5	1.0	0.5	0.1	**1.6**	**1.3**
Turbinaria spp.	0.1	-	0.4	0.4	0.1	-	-	0.1	**0.1**	**0.1**
Deep Water Corals	2.0	2.1	6.7	6.6	7.7	9.7	1.6	1.2	**4.5**	**4.9**
Total Soft Corals	14.9	18.8	6.1	5.5	4.4	5.0	1.9	3.1	**6.8**	**8.1**
Total Sponges	-	0.8	-	-	0.1	0.1	0.4	1.1	**0.1**	**0.5**
LOCATION 2	**Site 5**		**Site 6**		**Site 7**		**Site 8**		**Grand Mean**	
Total Hard Coral	33.2	31.4	53.2	54.9	58.6	50.2	39.4	60.6	**46.1**	**49.3**
Pocilloporidae	2.0	0.8	0.4	0.6	1.8	0.6	2.5	1.0	**1.7**	**0.7**
Acropora spp.	2.0	1.3	9.5	10.7	19.3	14.9	11.2	17.0	**10.5**	**10.9**
Montipora spp.	1.5	2.3	19.2	14.2	30.8	27.2	21.8	34.0	**18.3**	**19.4**
Porites spp.	1.3	1.0	2.3	2.7	0.1	0.1	0.3	0.9	**1.0**	**1.2**
Faviidae	1.9	3.0	2.7	3.8	0.6	0.6	0.2	0.3	**1.4**	**1.9**
Turbinaria spp.	11.3	9.3	-	0.3	4.0	3.1	0.2	0.2	**3.9**	**3.2**
Deep Water Corals	11.4	12.0	18.6	21.5	1.8	3.4	2.7	5.3	**8.6**	**10.5**
Total Soft Corals	29.8	20.6	3.5	4.1	3.1	2.6	0.1	1.5	**9.1**	**7.2**
Total Sponges	3.7	5.4	-	0.7	1.1	1.5	1.6	0.7	**1.6**	**2.1**
LOCATION 3	**Site 9**		**Site 10**		**Site 11**		**Site 12**		**Grand Mean**	
Total Hard Coral	54.2	49.6	51.9	45.4	47.3	46.0	59.1	59.6	**53.1**	**50.1**
Pocilloporidae	2.0	0.7	1.4	0.3	1.8	0.7	1.0	0.5	**1.5**	**0.5**
Acropora spp.	14.3	10.1	9.9	6.8	12.7	14.0	7.5	6.5	**11.1**	**9.3**
Montipora spp.	27.7	26.2	23.8	20.1	17.1	13.9	45.0	44.0	**28.4**	**26.1**
Porites spp.	0.6	0.9	1.4	1.0	1.1	1.0	0.2	0.9	**0.8**	**0.9**
Faviidae	0.5	1.3	0.6	0.8	3.3	2.4	0.1	0.1	**1.1**	**1.2**
Turbinaria spp.	0.9	1.2	1.3	1.2	0.2	0.3	0.2	0.1	**0.7**	**0.7**
Deep Water Corals	8.2	9.2	12.7	14.1	10.6	12.6	4.6	7.0	**9.0**	**10.7**
Total Soft Corals	11.7	13.8	8.9	9.2	7.5	5.7	11.6	8.7	**9.9**	**9.3**
Total Sponges	-	2.3	-	0.1	0.2	0.2	0.1	-	**0.1**	**0.6**

These changes were consistent across all sites at all three locations and there were no significant differences between locations at the time of any of the surveys (table 3 and 4).

Cyclone Damage (1986)

In the 1986 wet season two cyclones affected the Cape Tribulation coast. In late January Cyclone Winifred moved south about 100 km offshore from the Cape Tribulation region before crossing the coast between Cairns and Cardwell. Winds of 40-50 knots were recorded at Low Isles but were not as high in the study area. Cyclone Namu formed in the northern Coral Sea in late April 1986 and moved SW before breaking up off Cooktown on 27-28 April. Winds in the Cape Tribulation region were estimated at 40-50 knots for several days.

Figure 3. Changes in Coral Cover in the Three Locations: 1985-1988

Grand mean percentage cover from the permanent transects at the four sites in each location are shown. Location 1 is adjacent to the old road, location 2 is adjacent to the new road, location 3 in the northern undisturbed control.

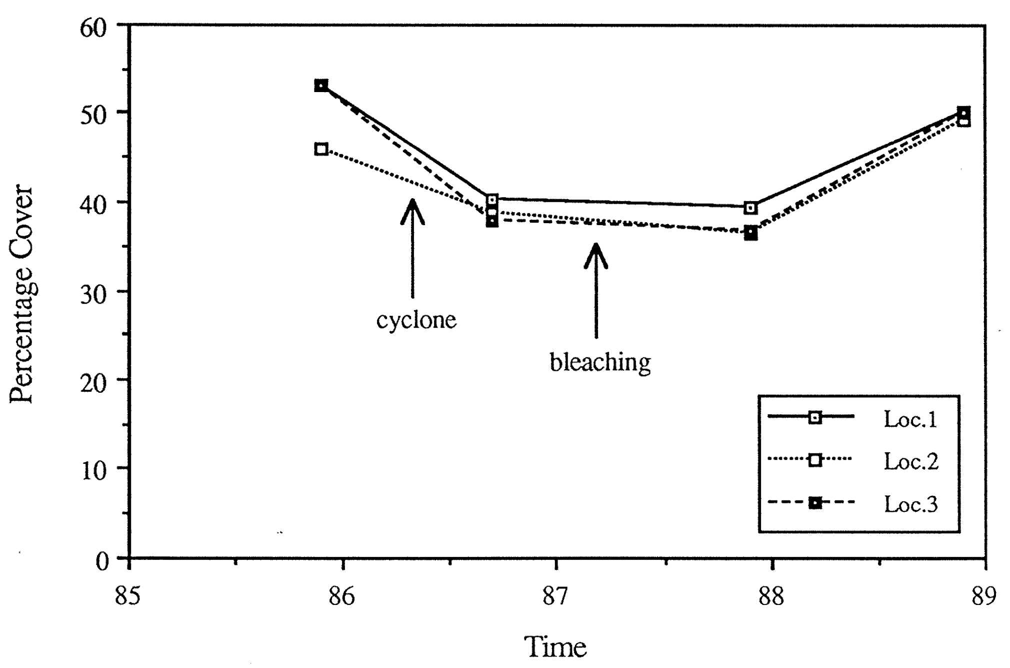


Table 6. Temporal Patterns in the Composition of the Fringing Reef Communities: Permanent Transects

Recorded as grand mean % cover with standard deviation in brackets from the permanent 20 m intersect line transects over all sites.

	1985		1986		1987		1988	
Total Hard Coral	50.8	(9.9)	39.0	(9.2)	37.5	(10.4)	49.8	(10.0)
Pocilloporidae	2.0	(1.8)	1.5	(1.5)	0.9	(1.1)	1.3	(1.3)
Acropora spp.	12.5	(6.4)	9.6	(5.7)	9.0	(5.1)	12.3	(6.1)
Montipora spp.	24.4	(7.5)	17.0	(7.2)	16.8	(6.8)	22.9	(7.7)
Porites spp.	0.9	(0.9)	1.1	(1.1)	0.8	(0.9)	0.9	(1.2)
Favidae	1.4	(1.4)	1.2	(1.5)	1.2	(1.3)	1.5	(1.6)
Turbinaria spp.	1.6	(2.7)	1.1	(2.4)	1.3	(2.8)	1.3	(2.8)
Deep Water Corals	7.4	(5.3)	6.8	(5.4)	6.9	(5.4)	8.7	(6.4)
								(
Total Soft Coral	8.6	(6.5)	7.5	(6.9)	6.8	(7.4)	8.2	(6.4)
Total Sponges	0.6	(0.9)	0.4	(0.7)	0.8	(1.1)	1.1	(1.1)

A selection of the survey sites were visited in May 1986 to check on the condition of the benthic communities after this strong wind episode. There was extensive damage, including over-turning and fragmentation of coral colonies, especially in the northern control location that was closest to the cyclone. The permanent transect survey was carried out in September, five months after the cyclone and at this stage the extent of damage was no longer obvious at most sites as all the broken edges had repaired themselves and algal turf had grown over all freshly exposed non-living surfaces. However, the surveys showed that there had been a significant reduction in coral cover in all locations. The mean reduction in coral cover in location 2 was 16%, less than in location 1 (24%) or location 3 (28%).

Not all corals were affected by this cyclonic episode (table 6, figure 4). The dominant groups *Montipora* and *Acropora* spp. showed marked reductions, as did the Pocilloporidae and some of the deep water corals, while the more massive and robust corals were not affected. All these reductions were consistent over sites and locations (table 4).

Bleaching Episode

Our last pre-wet survey visit to the Cape Tribulation area in 1986/87 was on the 15th January 1987. All live hard coral appeared normal at this time. The area was subsequently visited on the 26th February 1987 and it was noticed that many of the corals were bleached, having completely lost their zooxanthellae. At this time close examination showed that all the bleached corals were still alive. Some soft corals were also bleached. Such bleaching episodes have been reported previously (Fisk and Done 1985, Harriott 1985, Oliver 1985), and are thought to result in the death of many of the coral colonies affected.

Subsequent checks on the 8th March 1987 revealed that all 12 major Cape Tribulation sites were affected. Five haphazard 20 m line transects were surveyed at one site in each of the three monitoring locations and showed that 33.8%, 42.2% and 23.3% of the total hard corals at each site had been bleached (table 7).

Surveys on previous days found that the bleaching episode was not confined to Cape Tribulation reefs but was also affecting fringing and inshore reefs between Cairns and Cape Tribulation. Five line transects of 10 m were surveyed on Alexandra Reef (16-039) south of Port Douglas and on Yule Reef (16-081) off Yule Point: 55.2% and 52.9% respectively of the hard corals at these two sites had been bleached (table 7).

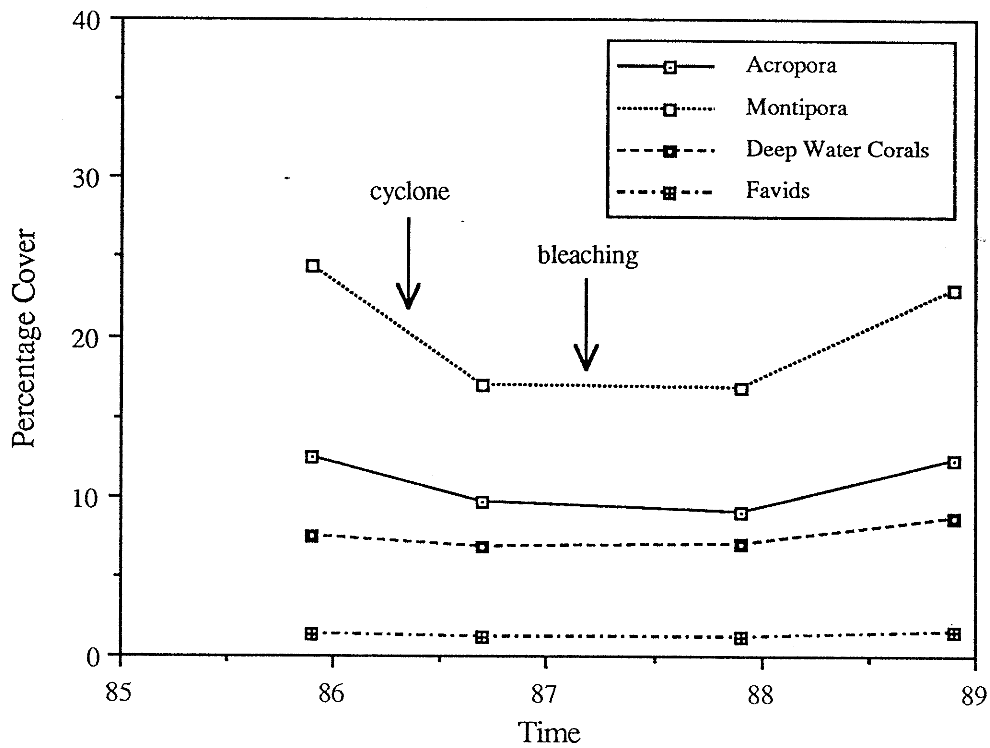
Other sites looked at but not surveyed quantitatively were (from north to south): Black Rocks Reef (16-005) with ≈30% bleaching; Snapper Island (16-006) with ≈20% bleaching; Low Isles (16-028) with <1% bleaching; Island Point Reef (16-010) with ≈20% bleaching of very low coral cover; Wentworth Reef (16-037) with ≈25% bleaching; Garrioch Reef (16-082) with ≈50% bleaching.

Not all coral species were equally affected (table 7). Some species were totally bleached, notably the pocilloporids *Pocillopora, Stylophora* and *Seriatopora,* while others such as *Podabacia, Turbinaria* and *Galaxea* were not affected. Other species ranged between these two extremes.

One cause of such coral bleaching is thought to be high water temperatures but light seems to play some role; on many of the bleached corals examined at Cape Tribulation the shaded parts of a colony were unaffected. The weather was unusually calm in this region between September 1986 and March 1987, with only a few short periods of rough weather and as a result the inshore water mass remained relatively clear and warm, with temperatures in the upper few metres of water ranging from 30-34°C.

Figure 4. Changes in Cover of the Major Groups of Corals: 1985-1988.

Grand mean percentage cover from the permanent transects at all sites is shown.



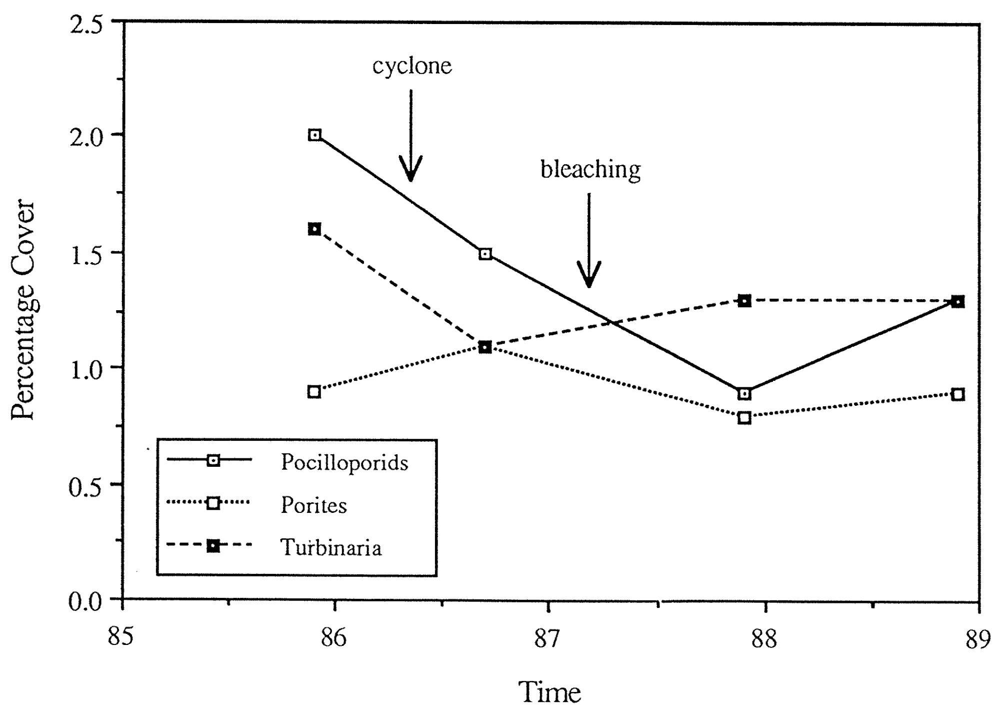


Table 7. Bleaching of Hard Corals on the Cape Tribulation Reefs.

Data from 5 intersect line transects (20 m transects on Cape Tribulation sites, 10 m on other two). Figures show percentage of total intersects that were bleached for each species (- indicates species not recorded at that site).

Species	Reef					
	Alexandra	Yule	Cape Tribulation			Grand
			Site 4	Site 6	Site 9	Mean
Percentage Coral Cover	**59.1**	**54.3**	**44.1**	**56.4**	**42.1**	**51.2**
POCILLOPORIDAE						
Pocillopora hystrix	100	100	100	100	100	**100**
Stylophora pistillata	100	-	99	100	100	**100**
ACROPORIDAE						
Acropora sp. terry	-	86	6	0	12	**18**
A. willisae	0	19	0	0	0	**6**
A. divaricata	0	80	0	22	0	**12**
A. formosa	48	33	0	0	19	**16**
A. brueggemanni	100	100	0	0	-	**23**
A. spp. plate	51	-	0	0	8	**6**
Montipora spp. explanate	41	49	37	45	28	**39**
Montipora hispida	-	100	100	100	100	**100**
AGARICIIDAE						
Pavona spp.	-	-	-	46	0	**43**
Pachyseris speciosa	0	-	-	0	-	**0**
FUNGIIDAE						
Fungia spp.	35	21	20	100	0	**24**
Podabacia crustacea	0	0	-	0	0	**0**
PORITIDAE						
Goniopora spp.	-	0	-	0	-	**0**
Porites spp. massive	-	93	0	30	100	**40**
Porites lichen	100	-				
FAVIIDAE						
Favia spp.	62	64	-	79	65	**67**
Favites spp.	79	-	-	0	-	**67**
Goniastrea spp.	0	0	0	0	0	**0**
Cyphastrea	19	8	-	0	0	**9**
Platygyra	100	100	100	100	100	**100**
Hydnophora excesa	100	47	-	49	0	**48**
OCULINIDAE						
Galaxea spp.	16	17	0	0	0	**4**
MERULINIDAE						
Merulina ampliata	97	87	-	100	100	**94**
MUSSIDAE						
Lobophyllia spp.	100	100	-	0	0	**50**
Symphyllia spp.	0	0	-	0	-	**0**
PECTINIIDAE						
Echinopora spp. explanate	100	-	-	97	100	**97**
Echinophyllia spp.	100	0	-	-	-	**92**
Oxypora lacera	-	100	-	-	-	**100**
Mycedium elephantotus	91	71	-	13	0	**64**
Pectinia lactuca	97	100	26	72	0	**74**
CARYOPHYLLIDAE						
Euphyllia glabrescens	-	23	-	-	-	**23**
DENDROPHYLLIIDAE						
Turbinaria mesenterina	0	0	0	-	0	**0**
Total % Corals Bleached	55.2	52.9	33.8	42.2	23.3	41.5

Given the high growth rate observed for some of the common species (many of the explanate colonies had grown 5-10 cm around the strings marking some transects in 12 months) it was expected that there would be an increase in coral cover after the cyclone damage by the time of the November 1987 survey, 18 months after the cyclone. It seems likely that coral death caused by this bleaching episode negated the expected increase (table 8). Almost without exception Pocilloporid corals were completely bleached in this episode. In Nov. 1987 most colonies in this group were partially or largely dead, although parts of most colonies had regained their zooxanthellae. Many patches within explanate *Montipora* colonies were also freshly dead; another probable result of the bleaching episode.

Table 8. Effect of the 1987 Bleaching Episode on the Cover of Selected Coral Species

Recorded as the grand mean % cover, with standard deviation in brackets, from the permanent 20 m intersect line transects from all four sites within each location.

	Pocilloporidae				*Montipora*			
	1986		1987		1986		1987	
Location 1	2.3	(2.2)	2.1	(1.9)	19.4	(8.0)	19.5	(6.3)
Location 2	1.4	(0.8)	0.4	(0.5)	14.6	(4.0)	12.2	(6.4)
Location 3	1.0	(0.9)	0.2	(0.3)	17.1	(8.7)	18.8	(7.6)
Grand Mean	**1.6**	**(1.5)**	**0.9**	**(1.1)**	**17.0**	**(7.2)**	**16.8**	**(6.8)**

Siltation Effects.

Although there were significant differences in coral cover between sites in locations 1 and 2 that were consistent through time, there were no differences between locations for any year during the survey (table 3, 4, figure 3). This suggests that there has been no influence in the impact location (2) over and above that of the various natural disturbances, that may have been caused by siltation.

Haphazard Transects

Although overall patterns in total coral cover measured using five haphazard transects at each site were less consistent than in the permanent transects (tables 9 and 10, figure 5) they also showed no significant differences among locations at any time during the survey (table 11). In location 3 the general trend was the same as for the permanent transects, with an 18% reduction in coral cover caused by cyclone Namu between 1985 and 1986, and very little difference between 1986 and 1987. However, in location 1 there was an equivalent increase in coral cover over the second year to the cyclone caused fall in the first year. The location 2 sites on the other hand remained virtually unchanged over the two years of the survey.

As for the permanent transects, there were no changes through time in the cover of some of the coral groups as recorded with these haphazard transects. These included favids, *Turbinaria* spp., soft corals and, strangely, *Acropora* spp (table 10, 11). Although there were no location effects in total hard coral cover there were significant location and site effects for most families or groups (table 11), driven by the few anomalous sites mentioned previously.

Table 9. Comparison of Coral Cover in the Three Survey Locations 1985-1987: Haphazard Transects.

The grand mean % cover is shown, with standard deviation in brackets, from five haphazard 20 m intersect line transects at four combined sites within each location.

	Nov 1985		Jan 1987		Nov 1987	
Location 1	49.1	(7.8)	41.4	(10.8)	50.5	(14.4)
Location 2	48.9	(13.8)	48.5	(10.4)	45.1	(17.8)
Location 3	60.5	(9.8)	49.5	(11.8)	49.3	(11.3)
Grand Means	**52.8**	**(10.8)**	**46.5**	**(11.0)**	**48.3**	**(14.7)**

Figure 5. Changes in Coral Cover in the Three Locations: 1985-1988

Grand mean percentage cover from the haphazard transects at the four sites combined in each location are shown.

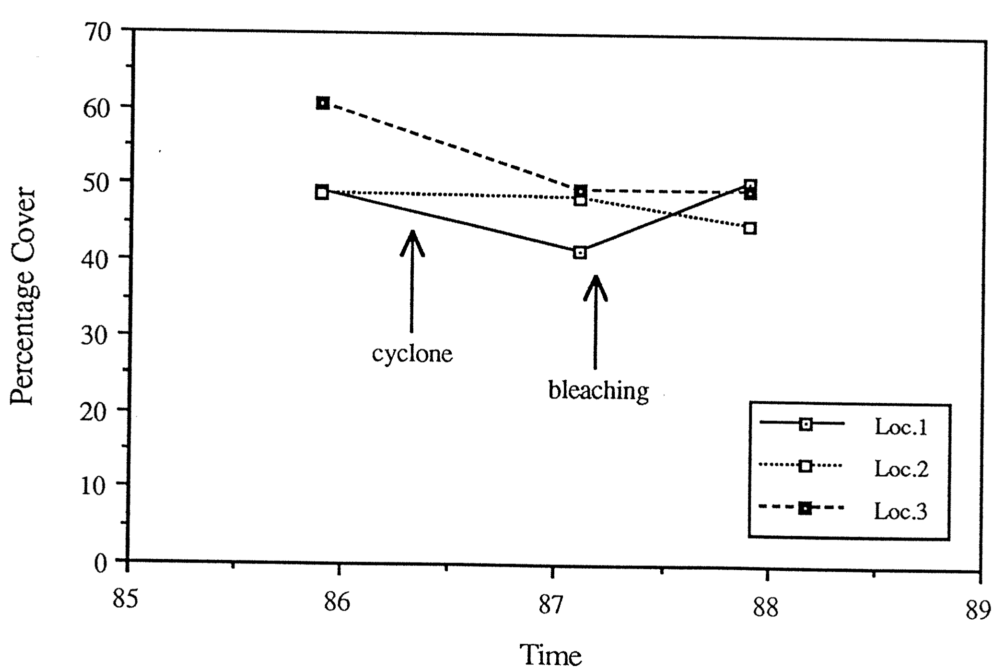


Table 10. Temporal Patterns in the Composition of the Fringing Reef Communities: Haphazard Transects

Recorded as the grand mean % cover with standard deviation in brackets from the haphazard 20 m intersect line transects over all sites.

	1985		1986		1987	
Total Hard Coral	52.8	(10.8)	46.4	(11.0)	48.2	(14.7)
Pocilloporidae	2.4	(1.4)	1.9	(1.5)	1.1	(1.2)
Acropora spp.	10.5	(6.0)	9.7	(5.7)	12.7	(6.5)
Montipora spp.	24.2	(9.2)	18.7	(9.0)	23.1	(9.8)
Porites spp.	2.1	(3.9)	1.5	(2.9)	1.0	(1.2)
Favidae	1.4	(1.2)	1.8	(1.7)	1.3	(1.3)
Turbinaria spp.	1.3	(1.8)	2.6	(3.3)	1.6	(2.7)
Deep Water Corals	9.8	(5.7)	9.4	(4.5)	6.5	(4.5)
Total Soft Coral	7.1	(5.7)	5.4	(4.5)	7.2	(5.0)
Total Sponges	0.4	(0.8)	0.9	(1.4)	0.6	(1.2)

Table 11. Analysis of Variance Results for Haphazard Transect Data.

NS = not significant; * 0.05>p>0.01; ** = 0.01>p>0.001; *** = p<0.001

Family/Group	Location	Site (L)	Time	L * T	S (L) * T
Total Coral	NS	*	**	*	NS
Pocilloporidae	***	NS	***	NS	*
Acropora spp.	NS	*	NS	NS	**
Montipora spp.	***	***	**	NS	NS
Porites spp.	***	***	**	NS	NS
Faviidae	NS	***	NS	NS	NS
Turbinaria spp.	***	**	NS	*	***
Deep Water Corals	***	***	*	**	*
Soft Corals	***	***	NS	NS	*

Run-Off Sites

Coral cover was extremely patchy in all these sites which may have accounted for some of the variability among years as these surveys used haphazard transects. Mean percentage cover of hard corals at these sites ranged from 3.3 to 48.1 at the time of the initial survey to 1.6 to 39.3 three years later (table 12). There were no significant changes in total coral cover over this time (table 13), although the grand means showed approximately the same pattern as the permanent transects with a reduction in cover over 1986 and 1987 (table 12, figure 6). All these run-off sites had a relatively high cover of the brown coral-killing encrusting sponge *Turpios* sp. (table 14), a species that was rare at the 12 major sites, but the abundance of this species was constant over the three years of the survey. Although the results show that sponge cover in 1985 was significantly lower than the other three years (table 13) this was an artifact caused by our failure to recognise some areas of brown-stained coral as the sponge *Turpios* sp. during the first survey.

Site 17, on the south side of Cowie Point was directly off the mouth of Melissa Creek and was completely inundated with sediment laden water when observed from the air in February 1985. This site had a rich coral community with similar cover to the 12 main sites, but was unusual (as was site 5) in that there was a relatively high cover of *Turbinaria* spp. (8.5%) and massive *Porites* (5.3%). As in the case of site 5 it is possible that normal high silt levels at this site due to the proximity of Melissa Creek are responsible for the unusual species composition of the coral community. Cover of *Montipora* spp. was comparable with the major sites (18.1%), but cover of *Acropora* spp. was very low (0.9%). There were no significant changes in the cover of any species groups at this site, or at any of the other direct run-off sites, during the course of the survey (table 13, figure 7).

Table 12. Comparison of Hard Coral Cover at the Five Points of Major Silt Run-Off Between 1985 and 1988

Recorded as mean % cover with standard deviation in brackets from five haphazard 20 m intersect line transects at each site

	Nov. 1985		Sept. 1986		Nov. 1987		Nov. 1988	
Site 13	3.3	(2.0)	3.4	(2.9)	1.2	(0.9)	1.6	(1.2)
Site 14	26.8	(7.8)	20.5	(9.6)	15.2	(10.5)	30.9	(15.3)
Site 15	28.2	(4.9)	24.4	(11.5)	26.5	(13.5)	31.3	(8.2)
Site 16	29.4	(6.8)	30.0	(12.6)	36.4	(10.9)	25.1	(4.5)
Site 17	48.1	(12.7)	40.8	(14.8)	35.9	(9.4)	39.3	(14.0)
Grand Means	**27.2**	**(7.7)**	**23.8**	**(11.0)**	**23.0**	**(10.0)**	**25.6**	**(10.2)**

Figure 6. Changes in Coral Cover in the Run-Off Sites: 1985-1988

Grand mean percentage cover from the haphazard transects at the combined five sites is shown.

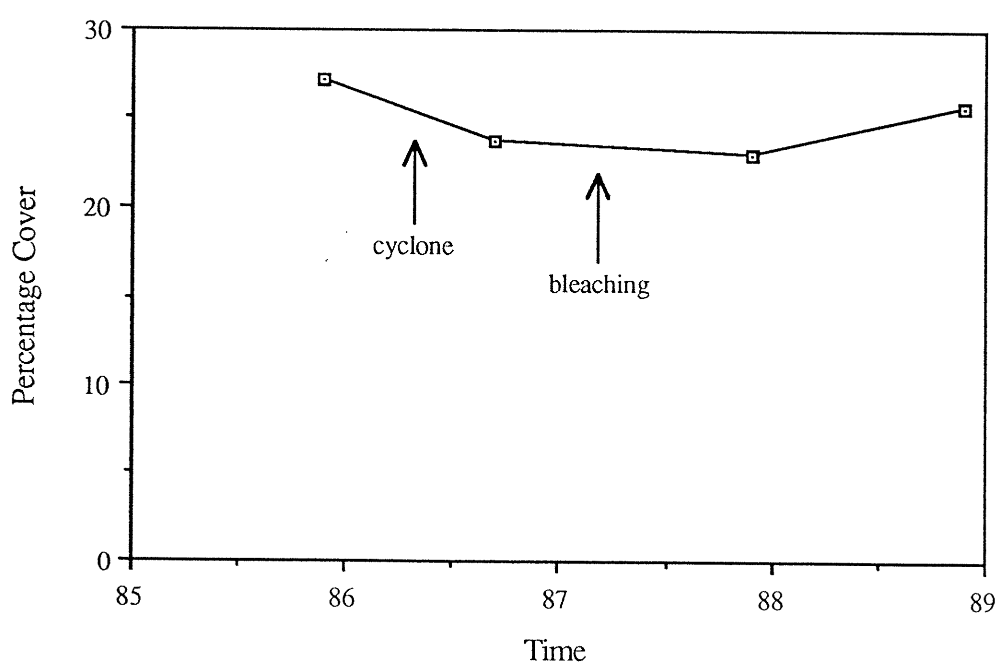
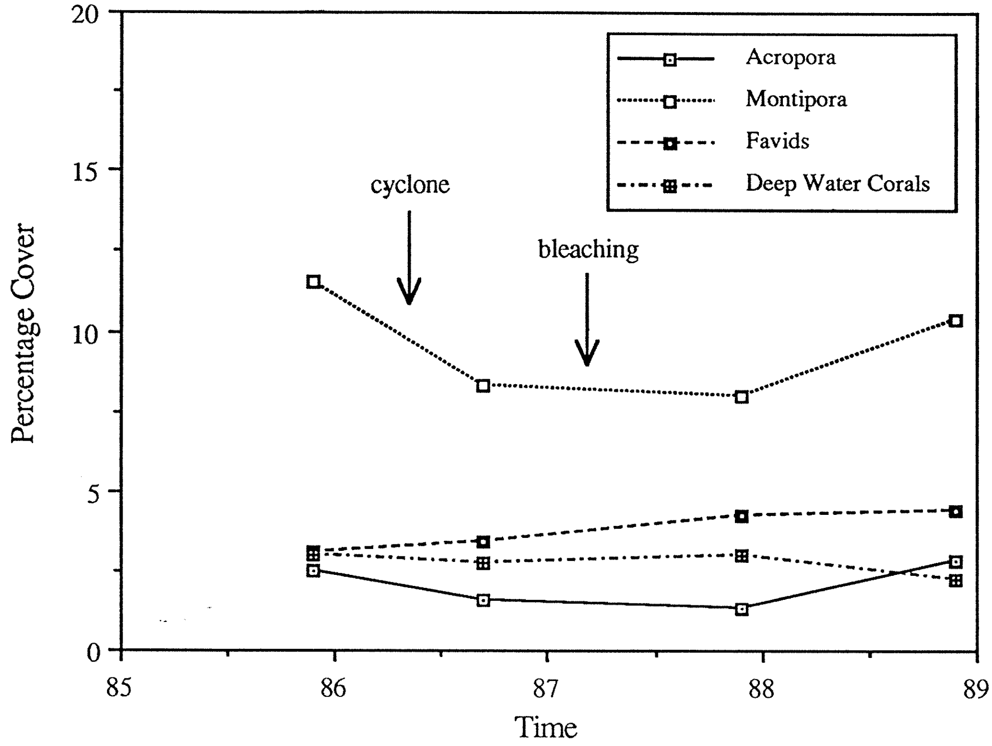


Figure 7. Changes in Cover of the Major Groups of Corals: 1985-1988.

Grand mean percentage cover from the haphazard transects at all five run-off sites is shown.



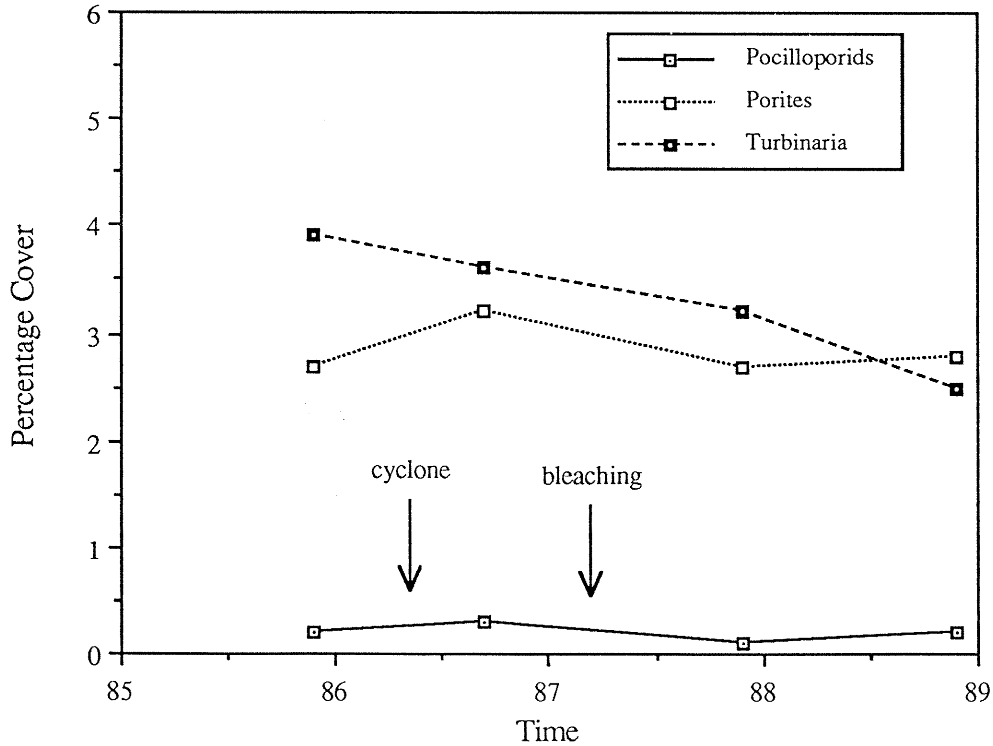


Table 13. Analysis of Variance Results for Run-Off Site Data.

NS = not significant; * 0.05>p>0.01; ** = 0.01>p>0.001; *** = p<0.001

Family/Group	Site	Time	S * T
Total Coral	***	NS	NS
Pocilloporidae	***	NS	NS
Acropora spp.	***	NS	NS
Montipora spp.	***	NS	NS
Porites spp.	***	NS	NS
Faviidae	***	NS	NS
Turbinaria spp.	***	NS	NS
Deep Water Corals	***	NS	NS
Soft Corals	***	NS	NS
Sponges	***	*	NS

Table 14. Temporal Patterns in the Composition of the Fringing Reef Communities at the Major Run-Off Sites

Recorded as the grand mean % cover with standard deviation in brackets from the haphazard 20 m intersect line transects over all sites.

	1985		1986		1987		1988	
Total Hard Coral	27.2	(7.7)	23.8	(11.0)	23.0	(10.0)	25.6	(10.2)
Pocilloporidae	0.2	(0.4)	0.3	(0.6)	0.1	(0.2)	0.2	(0.4)
Acropora spp.	2.5	(3.1)	1.6	(2.1)	1.3	(1.8)	2.8	(3.6)
Montipora spp.	11.5	(8.6)	8.3	(5.4)	8.0	(5.6)	10.4	(6.7)
Porites spp.	2.7	(2.2)	3.2	(2.8)	2.7	(2.1)	2.8	(2.3)
Favidae	3.1	(2.6)	3.4	(3.0)	4.2	(3.5)	4.4	(2.8)
Turbinaria spp.	3.9	(3.0)	3.6	(4.1)	3.2	(3.0)	2.5	(1.9)
Deep Water Corals	3.0	(2.5)	2.7	(3.2)	3.0	(1.9)	2.2	(1.9)
Total Soft Coral	0.2	(0.3)	0.3	(0.8)	0.3	(0.6)	0.8	(1.3)
Total Sponges	1.7	(2.3)	3.4	(2.1)	3.4	(3.5)	3.3	(2.0)

Fish Abundance

Both the number of species and the density of some of the common species increased between the 1985 and the 1986 surveys (table 15). Fish numbers were very similar in both the 1986 and 1987 surveys (table 15).

Fish populations in the three Cape Tribulation survey locations were very similar, characterised by low diversity and low densities compared with mid-shelf and outer-shelf reefs. A total of 104 species have been recorded from these reefs to date (appendix 2) and only about 15 of these occur at densities of more than 10 per hectare (ha). Coral trout densities range from 0-8 per ha compared to 13-52 per ha on mid-shelf reefs in this region. Total butterflyfish densities range from 8-52 per ha compared with 378-462 per ha on mid-shelf reefs with high hard coral cover.

A number of the fish species are only found on these turbid coastal or inshore reefs, including *Parma oligolepis, Pomacentrus tripunctatus*, *Pomacentrus* sp. nov., *Neopomacentrus bankieri*, *Halichoeres dussumieri*, *H. miniatus*, *Leptoscarus vaigiensis* and *Acanthurus grammoptilus*. Another group of species occurs on the off-shore reefs south of Mackay but is only found on coastal reefs further north, notably *Choerodon graphicus*, *C. vitta*, and *Pseudolabrus guentheri*.

Table 15. Abundance of Non-Secretive Fish Species on the Cape Tribulation Fringing Reefs:1985-1987

Recorded as the mean from five 50 x 10m transect counts.

FAMILY	Location 1			Location 2			Location 3		
Species	1985	1986	1987	1985	1986	1987	1985	1986	1987
SERRANIDAE									
Plectropomus leopardus	0.2	0.2	-	-	-	-	-	-	-
Plectropomus maculatus	-	-	-	-	0.2	-	-	0.2	-
Cephalopholis boenack	1.0	1.2	1.6	0.8	0.2	2.2	0.4	0.8	1.2
Epinephalus quoyanus	0.4	0.8	0.2	0.2	0.2	0.2	-	0.6	-
LUTJANIDAE									
Lutjanus carponotatus	2.0	2.8	2.0	0.8	1.0	2.2	1.4	2.8	2.6
Lutjanus spp.	0.2	0.8	-	1.4	0.2	3.6	0.4	-	0.8
LETHRINIDAE									
Lethrinus spp.	-	1.0	-	-	0.2	0.4	-	-	-
MULLIDAE									
Parupeneus indicus	-	1.2	0.6	-	0.4	1.4	0.6	0.6	1.2
Parupeneus spp.	-	1.2	-	-	0.2	0.4	-	-	0.2
CHAETODONTIDAE									
Chaetodon aureofasciatus	-	0.2	0.4	0.4	0.2	0.2	0.6	0.8	0.2
Chaetodon rainfordi	-	-	0.2	-	0.2	-	0.4	1.0	-
Chaetodon vagabundus	0.4	1.2	0.4	0.4	-	0.6	-	0.6	-
Chaetodon spp.	-	0.8	0.2	-	0.2	0.8	0.2	-	-
POMACANTHIDAE									
Pomacanthus sexstriatus	0.6	0.2	0.4	-	0.2	1.0	0.2	-	0.4
POMACENTRIDAE									
Pomacentrus wardi	78.0	77.8	79.2	34.6	80.4	88.4	81.8	136.2	131.0
Pomacentrus sp.	8.0	3.8	6.0	1.6	2.2	6.4	1.0	0.4	1.0
Stegastes apicalis	3.2	3.2	3.4	6.4	5.2	5.4	17.8	9.2	9.6
Abudefduf bengalensis	1.2	0.6	2.0	1.4	1.6	7.0	7.2	6.2	14.0
Neopomacentrus bankieri.	24.6	76.0	36.4	19.8	106.2	95.4	21.2	26.0	56.0
other pomacentrids	0.4	0.2	0.2	-	0.6	1.0	-	0.4	2.0
LABRIDAE									
Cheilinus chlorurus	1.0	0.6	0.2	-	-	0.6	0.2	0.8	0.4
Choerodon schoenleini	0.8	-	-	-	0.4	0.8	-	0.8	-
Halichoeres dussumieri	16.2	25.8	24.8	15.0	26.0	26.2	10.8	21.4	32.4
Halichoeres miniatus	2.2	17.8	5.6	0.4	1.0	0.4	2.0	0.8	3.6
Hemigymnus melapturus	0.4	1.4	0.4	0.2	-	1.0	0.4	0.8	0.6
Labroides dimidiatus	0.4	1.8	1.0	0.6	0.6	0.8	0.6	1.2	0.6
Thalassoma lunare	5.0	6.2	3.8	2.0	4.6	4.4	1.4	3.2	1.4
other labrids	1.2	4.6	2.4	1.2	0.2	1.8	0.2	1.8	2.8
SCARIDAE									
Scarus ghobban	0.2	0.4	0.2	-	0.2	0.8	-	-	0.2
Scarus rivulatus	-	3.4	0.8	-	-	-	-	1.6	2.0
ACANTHURIDAE									
Acanthurus grammoptilus	1.0	0.8	-	0.8	0.4	1.0	0.2	0.2	0.4
Naso unicornis	-	1.4	2.0	-	-	0.2	-	0.4	-
NUMBER OF SPECIES	26	38	31	23	27	45	21	31	38

It has been noted that juveniles of many fish species occurred in moderate numbers during the Nov-Jan period (eg *Pomacentrus moluccensis, Siganus* spp., *Scarus* spp.). However, these were not recorded as adults in the following year and either do not survive through the turbid and turbulent waters of the trade wind season or move elsewhere as they grow larger.

Monitoring of Large Coral Colonies

The majority of the large corals were not in the depth strata in which the transects were positioned as the only suitable corals in those areas were large *Montipora* explanate patches, large patches of *Acropora* and the occasional massive *Porites* colony. In order to include a variety of species, a number of the more massive species from the deeper strata were included where possible (table 16). The largest corals recorded were massive *Porites* colonies, with the three largest being 8.8, 5.9 and 4.8 m in diameter. There were no losses in the large coral colonies monitored at each site, although some of the explanate and staghorn species were damaged during the cyclonic episode. Some individuals were completely bleached in early 1987, but all had recovered completely by the November 1987 survey.

Table 16. List of the Large Coral Colonies Monitored at Each Site.

Numbers beneath each coral name record the largest dimension of the colony. Abbreviations: Acrop.= *Acropora* spp.; Astreo.= *Astreopora* spp.; Caul.= *Caulastrea furcata*; Echin.= *Echinopora* explanate; Galax.= *Galaxea* spp.; Gonio.= *Goniopora* spp.; Hydno.= *Hydnophora* spp.; Lobo.= *Lobophyllia hemprichii*; Merul. = *Merulina ampliata*; Monti.= *Montipora* explanate; Myced.= *Mycedium elephantotus*; Pachy.= *Pachyseris speciosa*; Pectin.= *Pectinia lactuca*; Platy.= *Platygyra* spp.; Podab.= *Podabacia crustacea*; Turbin.= *Turbinaria* spp.

Site #	1	2	3	4	5	6	7	8	9	10
Site 1	Porites 4.8	Pavona 4.25	Platy. 0.9	Monti. 2.1	Caul. 4.8	Monti. 1.75	Monti. 2.6	Hydno. 1.35	Monti. 2.7	Monti. 2.35
Site 2	Porites 5.9	Platy. 1.2	Merul. 1.15	Platy. 1.7	Pachy. 3.55	Porites 1.65	Platy. 3.9	Gonio. 1.15	Pachy. 2.1	Favia 0.9
Site 3	Pectin. 1.3	Pectin. 1.3	Favia 0.95	Astreo. 2.1	Hydno. 2.0	Pectin. 1.05	Porites 2.25	Myced. 1.15	Pectin. 1.85	Lobo. 1.05
Site 4	Pectin. 1.05	Podab. 1.0	Pectin. 1.15	Porites 3.6	Hydno. 1.1	Porites 8.8	Monti. 2.55	Acrop 2.3	Acrop 1.85	Monti. 2.2
Site 5	Galax. 0.75	Hydno. 0.75	Turbin 1.45	Turbin 1.2	Turbin 1.15	Merul. 0.95	Podab. 0.9	Podab. 1.05	Porites 0.85	Porites 0.8
Site 6	Porites 1.55	Galax. 1.05	Pectin. 1.25	Pectin. 1.4	Porites 1.15	Galax. 1.65	Monti. 2.6	Podab. 1.15	Echin. 2.25	Galax 2.1
Site 7	Pectin. 0.85	Pectin. 1.05	Turbin 0.8	Turbin 1.2	Echin. 1.6	Monti. 1.6	Acrop. 0.65	Acrop. 1.15	Porites 3.2	Porites 2.1
Site 8	Favia 0.85	Pectin. 1.1	Pectin. 1.0	Hydno. 1.55	Porites 1.4	Porites 1.1	Myced. 2.15	Echin. 2.2	Monti. 1.95	Monti. 2.3
Site 9	Porites 1.9	Monti. 4.1	Acrop. 0.95	Monti. 2.05	Platy. 1.1	Acrop. 1.25	Porites 1.55	Monti. 1.3	Hydno. 1.75	Echin. 1.85
Site 10	Podab. 0.95	Merul. 1.1	Myced. 0.9	Pectin. 1.25	Pectin. 0.95	Monti. 1.8	Merul. 0.85	Myced. 1.45	Pectin. 1.1	Acrop. 0.75
Site 11	Pectin. 1.3	Acrop. 0.85	Pectin. 1.6	Porites 0.65	Turbin 1.25	Pavona 1.0	Acrop. 1.4	Acrop. 1.85	Hydno. 1.6	Echin. 1.0
Site 12	Porites 2.5	Echin. 1.35	Echin. 0.95	Hydno. 1.05	Myced. 0.8	Monti. 3.6	Monti. 2.55	Monti. 4.2	Monti. 2.0	Monti. 2.45

DISCUSSION

One of the major problems with achieving our aim of detecting changes in the coral community of the Cape Tribulation fringing reefs caused by increased silt run-off was the lack of any baseline data. However, a number of factors suggest that there had not been extensive coral death on these reefs during the 12 months preceding our initial survey in October 1985. During this initial survey dead standing hard corals were present at low levels at all sites, including those immediately adjacent to the major sediment run-off points. This suggested that there had not been abnormal levels of coral death during the previous wet season when sediment run-off from the new road was very high (Bonham, 1985). Coral cover was similar in all three locations at the time of the initial survey, again suggesting that there had not been any unusual coral mortality in the new road location during the previous 12 months.

During the three years of this survey we detected no evidence of hard coral death due to siltation at any of the sites, either from the permanent and haphazard line transect measurements at the 12 major sites, or from the haphazard transects at the shallow direct run-off sites, or from general observations in the area. There was also no evidence that chronic siltation stress had reduced the ability of corals in the new road location to cope with acute disturbance; cyclone and bleaching damage was similar in all locations.

The study was carried out during a period of normal rainfall; the lack of observed impact was not caused by a period of below average rainfall. Rainfall in the region during March 1985, immediately after construction of the road and 6 months before the start of our survey, was very high. There were also several periods of very high rainfall in early 1986 with Cyclones Winifred and Namu, with 24 hr falls of over 600 mm recorded. Overall rainfall figures for the years 1985-1988 were about average for the region.

Fisk and Harriott (1989), in a concurrent study of coral spat settlement and juvenile coral recruitment over a two year period, found no correlation between settlement or recruitment rates and the reported increased sediment input into location 2. Their study looked at two components of recruitment of corals; settlement of larvae onto plates and recruitment from spat (assumed to be larval derived) and small coral fragments into permanently marked quadrats.

Settlement densities of spat on plates were an order of magnitude higher than had been previously reported from off-shore reefs. Densities varied from year to year but these differences were not consistent over all sites or locations. Due to the extreme variability in settlement onto the plates and problems with the loss of plates in bad weather, patterns in the data were not clear. For instance, settlement densities among locations in 1987 were not significantly different in spite of a 37x difference between locations 1 and 3.(27 vrs 1023). Over the same period a 53x difference between the 2 highest density sites and the two lowest density sites was recorded as significant. However, there appeared to be a trend for lower settlement onto the plates in the southern location 1. Fisk and Harriott suggested this was due to a northerly longshore drift of larvae within the study area. This appears to imply that the system is closed, when in fact there are extensive fringing reefs with rich coral communities between 6 and 20 km south of location 1 that could act as a source of larvae in the event of northerly drift over the critical planktonic period.

Although settlement rates on plates were very high larval recruitment rates were low on these reefs possibly due to inadequate levels of suitable settlement substrata. The researchers found no significant differences in recruitment from spat or from fragments among sites or locations. The most abundant groups in the depth strata sampled, *Acropora* and *Montipora* spp., recruited most commonly by fragmentation (24x spat recruitment rate), whereas poritids and favids recruited equally from larvae and fragmentation. Although there were trends toward differences from year to year in settlement rates there were no significant differences in spat recruitment patterns from year to year. Fisk and Harriott used their permanent quadrats to look at mortality rates of juvenile corals. Over a two year period these rates were very high (40-90%) but they did not differ significantly between sites. They also found no impact of increased run-off in location 2 on the size structure of the coral communities in that location.

Their study parallels our own in finding no effects of the silt run-off from the new road on the coral community, either on settlement densities of larvae (highest in location 2 and 3), recruitment rates of spat or fragments, mortality rates of juveniles or size frequency distributions of the coral colonies.

The picture of these reefs that emerges to date can be summarised in the following general points:

Hard corals are more abundant on these fringing reefs than on most off-shore reefs: the grand mean cover of hard corals on these sites was initially 50.8 ± 9.0%, compared with 23.0 ± 10.9% on a selection of 42 reefs in the Central Section of the GBR Marine Park, and 22.6 ± 12.8% on 38 reefs in the Capricorn Section.

These fringing reefs are self contained within the coastal environment with minimal input from off-shore reefs (Fisk and Herriott 1989).

The corals that grow in the area are silt tolerant and must normally cope with a high silt content and severely reduced light penetration for long periods when the SE trade winds are blowing. Most of the corals are dark brown in colour, presumably to maximise light absorption.

These fringing reefs are able to cope with regular, often severe disturbance. Tropical cyclone Manu, although it caused an overall reduction in coral cover of 23%, was a minor episode and such events probably occur with a return time of about five years - similar episodes occurred in March 1990 (cyclone Ivor) and December 1990 (cyclone Joy. Severe episodes have occurred in the Cape Tribulation area at least twice this century: in 1911 and 1934.

Preliminary observations suggest that many of the corals grow very rapidly and can regenerate from small broken fragments after episodes of damage; note the 33% increase in cover over 12 months in 1987/88.. Others, such as *Porites* colonies and many of the deep water strata corals, are massive enough to survive high wind episodes and *Porites* heads up to 8 m in diameter have been found in this area.

This combination of factors: high cover; high diversity; high growth rates; good resistance to disturbance, suggests that the Cape Tribulation reefs are in a healthy state and not suffering from chronic siltation stress as has been suggested by Hopley et al (1990).

Although Hopley et al. (1990) found that siltation rates in the new road location were 6x higher than in the northern control location this was not reflected in any changes in the coral communities of this location. In view of this it is worth looking at their sediment results in some detail. The mud component was similar at all sites in all three locations; it was the sand component that was significantly higher in the new road location. Correlations of siltation rates with weather factors suggested that sand siltation rates were related to maximum wind speed; extensive resuspension of sand only occurred at wind speeds over 20 knots. They considered that silt run-off from the new road had increased the amount of sand lying on the reef flat and reef slope of the new road location and it was resuspension of this that resulted in the 6x difference in siltation rates. Proximity to the source of sand certainly seemed to be important as the sediment traps 20 cm above the substratum had mean siltation rates twice that of the traps 60 cm above the substratum.

An examination of the sand sedimentation levels at the different sites within each location shows that there were very high rates at four of the six sites in location 2. These four sites are all located in areas where the reef is very narrow and falls abruptly to the sand in only 1-2 m depth below AHD. It may be that the close proximity of the sediment wedge to the trap positions at these sites resulted in the higher sediment rates.

Hopley et al (1990) claim that sediment does not normally remain on coral reef communities and that there was more sediment lying on the new road communities that could be resuspended by wave action. While sediment does not normally remain on living corals, sediment accumulates in all available depressions, especially on the deeper parts of the reef. Our observations did not indicate that there were larger amounts of sediment resting on the reef in the new road location than in the two control locations. Unfortunately it was not possible to distinguish between sediment deposited from the road, sediments sourced from the reef and resuspended sediment (Hopley et al., 1990) so this claim can not be substantiated. However, Parnell (1989) reported that normal ambient sediment levels in the near-shore water mass were about 100 mg/litre. It would require settlement from only 3 litres per day to achieve the maximum levels recorded by Hopley et al. (1990).

The sedimentation study, as with our own coral community work, suffered from not having any pre-road construction baseline data for comparison. It is possible that sedimentation levels at these narrow, shallow reef sites were previously higher than the other sites. Note that in the Magnetic Island baseline study, reported by Mapstone et al. (1989), sedimentation rates were naturally higher in the potential impact sites from a marina development prior to any disturbance occurring.

It is also worth noting that the mean sedimentation rates shown by Hopley et al. (1990) in their figure 4 are not directly comparable between the three locations. Traps in locations 1 and 2 were emptied on 6 occasions but those in location 3 were only emptied on 2 of these occasions, both of which showed a low sedimentation rate at all locations. If the means from these two time periods are compared, sedimentation rates in the new road location were only 1.8x those in the old road location and 3x those in the northern control location, compared to the 3x and 6x respectively claimed by Hopley et al.

The overall grand mean sedimentation rate of 110.3 mg/sqcm/day is similar to that measured at other fringing reefs in the northern GBR region (table 17).

Table 17. Sedimentation Rates from Fringing Reefs in the GBR Region.

Rates shown are mg sediment per square cm per day.

Area	Reference	Time	mean	range
Cape Tribulation	Hopley et al. (1990)	1986	110.3	3.1 - 303.5
Magnetic Island	Mapstone et al. (1989)	1989	46.2	2.6 - 356.6
Low Isles	Marshall and Orr (1931)	1929	69.7	0.6 - 899.9

While the Cape Tribulation values are high they are comparable with the other areas and cannot be considered unnatural in this context, especially as most measurements were taken during the wet season when levels may be expected to be higher than during the rest of the year.

All the sediments associated with these fringing reefs have a terrigenous content of over 50% (Johnson and Carter, 1987) indicating that they have always grown under heavy terrigenous input with high turbidity and high suspended sediment concentrations. However, Partain and Hopley (1989) report that the reefs ceased prograding about 5,000 years ago and claim that this is because sedimentation levels have passed beyond the threshold that allows for active reef growth. Our data do not support this contention (e.g. the 33% increase in coral cover over 12 months; high coral cover) and we suggest that there may be an alternative explanation for the apparent lack of progradation of these reefs. It is hard to imagine that these reefs have been just managing to maintain themselves at such a high level of coral cover for 5,000 years in spite of many acute disturbances from cyclones and other sources over this time. There has been a similar lack of progradation on the outer face of the ribbon reefs (Kinsey, personal communication), in an area where sedimentation rates are extremely low.

In conclusion we would reiterate that our studies, although conducted over a relatively limited time period, indicate that the Cape Tribulation fringing reefs are apparently healthy, with a high cover of a wide variety of corals, high growth rates and the ability to recover rapidly from major disturbances.

IMPLICATIONS FOR MANAGEMENT AND SUGGESTIONS FOR FURTHER WORK

There seems to be a widely held belief that fringing reefs on the north Queensland coast are either degraded or in a state of chronic stress and poised on the brink of degradation. Our experience over the past seven years suggests that this is probably not the case and that the majority of fringing reefs are at least as healthy and robust as offshore reefs. Extensive surveys on Magnetic Island (reported by Mapstone et al., 1989), Low Isles (unpublished data), reefs between Cairns and Port Douglas (table 7) and around Dent and Hamilton Islands in the Whitsunday Group (Ayling and Ayling, 1991a), as well as on the Cape Tribulation reefs (this study), have shown that all these reefs have very rich coral communities with live coral cover usually ranging from 50 to 75%. These means are comparable to the maximum coral cover recorded on the upper windward slope of the richest, undisturbed offshore reefs measured using the same technique (Ayling and Ayling, 1991b; Mapstone and Ayling, unpublished data).

The present study also indicates that corals in these fringing reef communities are fast growing and able to recover quickly from disturbance. They are present in environments where the normal levels of sedimentation are up to several orders of magnitude higher than those regarded as normal for offshore reefs and it is this factor that appears to have been responsible for the degradation belief. Rich coral reefs are associated with clear blue waters.

It is extremely important for GBR managers to know which of these views is correct if decisions on coastal development are to be made. We suggest that it is vital that a number of permanent monitoring sites be set up on a range of fringing reefs at varying distances from potential human influences to establish if degradation is in fact occurring in these communities. The sites should be monitored in the long term; the three year term of this study was not felt to be sufficient to look at this problem.

In addition a comparative study of the growth rates of a range of coral species on fringing and offshore reefs would provide useful information to help resolve this question.

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ACKNOWLEDGMENTS

Charlie Veron provided invaluable assistance with the identification of the Cape Tribulation coral species that is gratefully acknowledged. Warren Nott provided field assistance during the 1985 survey. Wendy Craik, Claudia Baldwin, Ian Dutton and other past and present staff of the GBRMPA have provided assistance that has made this project much easier.

APPENDIX 1. ANALYSIS OF VARIANCE TABLES

A. Permanent Transects for Each Annual Survey.

Source of Variation	df	MS	F	p	MS	F	p
		Total Coral Cover 85			Total Coral Cover 86		
Location	2	1.950	0.861	~0.4	0.151	0.071	~0.9
Site (L)	9	2.266	4.472	<0.001	2.127	3.786	<0.001
Residual	48	0.507			0.562		
		Total Coral Cover 87			Total Coral Cover 88		
Location	2	0.552	0.338	~0.1	0.069	0.026	~0.9
Site (L)	9	1.633	2.125	0.045	2.648	5.162	<0.001
Residual	48	0.768			0.513		
		Pocilloporids 85			Pocilloporids 86		
Location	2	1.627	2.926	~0.1	1.140	1.572	~0.25
Site (L)	9	0.556	1.088	0.389	0.725	1.960	0.065
Residual	48	0.511			0.370		
		Pocilloporids 87			Pocilloporids 88		
Location	2	6.726	29.371	<0.001	4.793	21.786	<0.001
Site (L)	9	0.229	0.878	0.552	0.222	0.587	0.801
Residual	48	0.260			0.378		
		Acropora 85			*Acropora* 86		
Location	2	3.094	0.479	~0.65	2.228	0.321	~0.7
Site (L)	9	6.456	7.927	<0.001	6.937	7.780	<0.001
Residual	48	0.815			0.892		
		Acropora 87			*Acropora* 88		
Location	2	2.176	0.352	~0.7	3.059	0.342	~0.7
Site (L)	9	6.179	9.073	<0.001	8.938	12.705	<0.001
Residual	48	0.681			0.703		
		Montipora 85			*Montipora* 86		
Location	2	10.450	1.070	~0.3	3.637	0.498	~0.6
Site (L)	9	9.766	15.391	<0.001	7.297	9.893	<0.001
Residual	48	0.635			0.738		
		Montipora 87			*Montipora* 88		
Location	2	8.480	1.375	~0.3	4.658	0.474	~0.6
Site (L)	9	6.166	8.491	<0.001	9.837	14.358	<0.001
Residual	48	0.726			0.685		
		Porites 85			*Porites* 86		
Location	2	0.079	0.058	~0.9	2.099	1.662	~0.25
Site (L)	9	1.352	5.573	<0.001	1.263	4.047	<0.001
Residual	48	0.243			0.312		
		Porites 87			*Porites* 88		
Location	2	1.492	1.624	~0.25	0.233	0.333	~0.7
Site (L)	9	0.919	3.962	<0.001	0.699	1.893	0.076
Residual	48	0.232			0.369		
		Turbinaria 85			*Turbinaria* 86		
Location	2	6.963	1.965	~0.2	4.906	1.822	~0.2
Site (L)	9	3.543	7.452	<0.001	2.693	7.538	<0.001
Residual	48	0.475			0.357		
		Turbinaria 87			*Turbinaria* 88		
Location	2	6.228	2.741	~0.15	6.662	2.487	~0.15
Site (L)	9	2.272	4.717	<0.001	2.679	6.409	<0.001
Residual	48	0.482			0.418		

Source of Variation	df	MS	F	p	MS	F	p
			Faviids 85			Faviids 86	
Location	2	0.365	0.172	~0.9	0.173	0.086	~0.9
Site (L)	9	2.122	6.340	<0.001	2.016	5.862	<0.001
Residual	48	0.335			0.344		
			Faviids 87			Faviids 88	
Location	2	0.191	0.081	~0.9	0.375	0.155	~0.9
Site (L)	9	2.348	7.615	<0.001	2.415	5.799	<0.001
Residual	48	0.308			0.417		
			Deep Water Corals 85			Deep Water Corals 86	
Location	2	5.047	1.008	~0.4	6.053	1.242	~0.3
Site (L)	9	5.005	6.503	<0.001	4.874	5.027	<0.001
Residual	48	0.770			0.970		
			Deep Water Corals 87			Deep Water Corals 88	
Location	2	6.572	1.338	~0.3	7.972	1.714	~0.25
Site (L)	9	4.912	5.202	<0.001	4.650	4.610	<0.001
Residual	48	0.944			1.009		
			Soft Corals 85			Soft Corals 86	
Location	2	3.096	0.279	~0.75	1.267	0.146	~0.9
Site (L)	9	11.090	8.531	<0.001	8.687	5.056	<0.001
Residual	48	1.300			1.718		
			Soft Corals 87			Soft Corals 88	
Location	2	1.077	0.124	~0.9	1.386	0.213	~0.9
Site (L)	9	8.708	5.544	<0.001	6.503	5.673	<0.001
Residual	48	1.571			1.146		
			Sponges 85			Sponges 86	
Location	2	4.242	4.032	~0.06	0.434	0.775	~0.5
Site (L)	9	1.052	5.141	<0.001	0.560	2.660	0.014
Residual	48	0.205			0.210		
			Sponges 87			Sponges 88	
Location	2	2.992	3.916	~0.07	2.904	1.421	~0.3
Site (L)	9	0.764	2.320	0.029	2.044	6.472	<0.001
Residual	48	0.329			0.316		

B. Proportional Change in Abundance Between Successive Surveys of Permanent Transects.

Source of Variation	df	MS	F	p	MS	F	p
		Total Coral Cover			Pocilloporids		
Time	2	3491541	80.452	<0.001	9084.04	7.871	<0.001
Location	2	34493.5	0.795	~0.45	546.04	0.850	~0.4
Site (L)	9	42058.8	0.969	~0.5	406.31	0.633	~0.75
Time x Location	4	58240.8	1.342	~0.25	697.87	1.087	~0.5
Time x Site (L)	18	43399.3	1.038	0.422	642.11	0.556	0.925
Residual	144	41815.9			1145.1		
		Acropora			*Montipora*		
Time	2	234049	16.202	<0.001	1095335	27.170	<0.001
Location	2	4971.5	0.344	~0.7	14171.6	0.352	~0.7
Site (L)	9	9114.4	0.631	~0.7	15557.2	0.386	~0.9
Time x Location	4	11023.8	0.763	~0.5	83897.3	2.081	~0.15
Time x Site (L)	18	14446.0	1.096	0.362	40314.2	1.538	0.085
Residual	144	13175.9			26207.1		
		Porites			*Turbinaria*		
Time	2	1057.9	2.336	~0.1	2374.5	2.234	~0.1
Location	2	154.87	0.342	~0.7	282.95	0.266	~0.75
Site (L)	9	204.89	0.452	~0.8	259.30	0.244	~0.75
Time x Location	4	965.22	2.132	~0.12	1895.2	1.783	~0.2
Time x Site (L)	18	452.83	0.852	0.637	1063.0	0.342	0.994
Residual	144	531.76			3080.0		
		Faviids			Deep Water Corals		
Time	2	1189.7	1.821	~0.2	34503.9	15.990	<0.001
Location	2	456.72	0.700	~0.5	1886.5	0.874	~0.5
Site (L)	9	312.90	0.480	~0.9	581.64	0.270	~0.9
Time x Location	4	322.96	0.495	~0.75	3314.0	1.536	~0.25
Time x Site (L)	18	652.34	0.643	0.860	2157.8	0.149	1.00
Residual	144	1013.9			14508.4		
		Soft Corals			Sponges		
Time	2	42972.1	3.038	~0.07	2939.3	3.071	~0.07
Location	2	6731.5	0.476	~0.6	26.406	0.028	~0.9
Site (L)	9	7311.1	0.517	~0.8	582.18	0.608	~0.75
Time x Location	4	16270.8	1.150	~0.3	3911.0	4.087	~0.04
Time x Site (L)	18	14146.5	0.622	0.878	956.99	1.788	0.032
Residual	144	22755.2			535.27		

C. Haphazard Transects at Major Study Sites.

Source of Variation	df	MS	F	p	MS	F	p
		Total Coral Cover			Pocilloporids		
Time	2	3.557	7.94	~0.004	6.530	10.398	<0.001
Location	2	1.311	1.57	~0.25	4.695	15.048	<0.001
Site (L)	9	1.915	4.275	~0.004	0.932	1.484	~0.25
Time x Location	4	2.006	4.48	~0.01	1.361	2.167	~0.1
Time x Site (L)	18	0.448	0.537	0.936	0.628	2.014	0.012
Residual	144	0.833			0.312		
		Acropora			*Montipora*		
Time	2	3.367	1.969	~0.2	8.385	8.196	~0.003
Location	2	2.233	1.306	~0.25	8.786	7.653	<0.001
Site (L)	9	8.995	5.260	~0.002	12.504	12.222	<0.001
Time x Location	4	2.984	1.745	~0.2	1.322	1.292	~0.3
Time x Site (L)	18	1.710	2.166	0.006	1.023	0.891	0.590
Residual	144	0.789			1.148		
		Porites			*Turbinaria*		
Time	2	1.898	7.622	~0.005	31.285	1.697	~0.2
Location	2	3.430	4.942	~0.02	40.643	5.740	~0.015
Site (L)	9	1.783	7.161	<0.001	90.970	4.935	~0.003
Time x Location	4	0.346	1.390	~0.25	67.893	3.68	~0.025
Time x Site (L)	18	0.249	0.359	0.993	18.432	2.603	<0.001
Residual	144	0.694			7.081		
		Faviids			Deep Water Corals		
Time	2	1.048	2.460	~0.1	5.840	4.771	~0.025
Location	2	0.346	0.812	~0.4	6.38	8.728	<0.001
Site (L)	9	2.557	6.002	<0.001	10.222	8.351	<0.001
Time x Location	4	0.831	1.951	~0.15	7.891	6.447	~0.003
Time x Site (L)	18	0.426	1.081	0.377	1.224	1.676	0.050
Residual	144	0.394			0.731		
		Soft Corals			Sponges		
Time	2	3.394	1.895	~0.15	3.569	3.520	~0.05
Location	2	8.570	4.785	<0.001	16.931	16.697	<0.001
Site (L)	9	13.610	7.599	<0.001	3.468	3.420	~0.015
Time x Location	4	1.815	1.013	~0.3	4.509	4.447	~0.015
Time x Site (L)	18	1.791	1.674	0.050	1.014	0.760	0.744
Residual	144	1.069			1.335		

D. Haphazard Transects at Run-Off Sites.

Source of Variation	df	MS	F	p	MS	F	p
		Total Coral Cover			*Acropora*		
Time	3	1.525	1.592	0.198	1.257	1.742	0.165
Site	4	71.912	68.28	<0.001	7.272	24.904	<0.001
Time x Site	12	1.054	1.101	0.3711	0.292	0.405	0.958
Residual	80	0.957			0.722		
		Montipora			*Porites*		
Time	3	2.182	2.450	0.070	0.351	0.569	0.637
Site	4	28.607	29.46	<0.001	9.549	19.65	<0.001
Time x Site	12	0.971	1.090	0.380	0.486	0.786	0.663
Residual	80	0.890			0.618		
		Turbinaria			Faviids		
Time	3	0.513	0.661	0.578	0.635	1.089	0.359
Site	4	17.273	48.66	<0.001	10.073	13.31	<0.001
Time x Site	12	0.355	0.458	0.933	0.757	1.298	0.236
Residual	80	0.776			0.583		
		Deep Water Corals			Sponges		
Time	3	0.426	0.830	0.481	2.560	4.310	0.007
Site	4	10.462	44.52	<0.001	15.434	22.34	<0.001
Time x Site	12	0.235	0.457	0.934	0.691	1.164	0.323
Residual	80	0.514			0.594		

APPENDIX 2. LIST OF FISHES OBSERVED ON THE FRINGING REEFS OF THE CAPE TRIBULATION REGION

Abundance scale codes: A = abundant (commonly seen on all dives); C = common (seen on most dives); O = occasional (10-20 seen in 3 years) R = rare (only 1-2 seen in 3 years).

Hemiscyllidae - long-tailed carpet sharks		
	Hemiscyllium ocellatum	R
Dasyatidae - stingrays		
	Himantura granulatum	O
Muraenidae - moray eels		
	Gymnothorax sp.	R
Chanidae - milkfishes		
	Chanos chanos	O
Latidae - barramundis		
	Lates calcarifer	R
Holocentridae - squirrelfishes		
	Myripristis sp.	R
Centropomidae - sand basses		
	Psammoperca waigiensis	O
Platycephalidae - flatheads		
	Platycephalus arenarius	R
Serranidae - groupers		
	Plectropomus maculatus	O
	P. leopardus	O
	Cephalopholis boenak	C
	C. cyanostigma	R
	C. microprion	R
	Epinephalus malabaricus	R
	E. quoyanus	R
Carangidae - jacks and trevallys		
	Cananx sp.	O
	C. melampygus	O
Lutjanidae - snappers		
	Lutjanus fulvus	R
	L. fulviflamma	O
	L. russelli	O
	L. carponotatus	C
	L. argentimaculatus	O
	L. rivulatus	O
	L. vitta	O
	L. lemniscatus	F
Haemulidae - sweetlips		
	Plectorhynchus gibbosus	O
	P. flavomaculatus	R
	Diagramma pictum	O

Nemipteridae - threadfin breams		
	Pentapodus paradiseus ?	R
	Scolopsis lineatus	
Lethrinidae - emperor fishes		
	Lethrinus laticaudis	O
	L. atkinsoni	R
	L. obsoletus	R
	L. harak	O
	L. miniatus	R
Mullidae - goatfishes		
	Parupeneus indicus	O
	P. multifasciatus	O
	P. ciliatus	R
	P. barberinus	R
	Upeneus tragula	R
	Mulloides flavolineatus	R
Kyphosidae - rudderfishes		
	Kyphosus sp.	O
Ephippidae - batfishes		
	Platax pinnatus	R
	P. batavianus	R
	P. teira	R
Chaetodontidae - butterflyfishes		
	Chelmon rostratus	O
	Chaetodon aureofasciatus	C
	C. auriga	O
	C. rainfordi	C
	C. trifascialis	O
	C. vagabundus	C
	C. plebeius	R
	C. melannotus	R
	C. lineolatus	R
Pomacanthidae - angelfishes		
	Pomacanthus sexstriatus	C
	P. semicirculatus	R
Pomacentridae - damselfishes		
	Abudefduf bengalensis	A
	A. sexfasciatus	O
	A. vaigiensis	R
	A. whitleyi	R
	Pomacentrus wardi	A
	P. nagasakiensis	R
	P. chrysurus	R
	P. moluccensis	R
	P. tripunctatus	C
	P. coelestis	R
	P. sp.	C
	Stegastes apicalis	A
	Parma oligolepis	R

Neopomacentrus bankieri.	A
N. azysron	C
Neoglyphidodon nigroris	O
N. melas	O
Labridae - wrasses	
Anampses geographicus	O
Choerodon fasciatus	R
C. graphicus	O
C. schoenleinii	R
C. anchorago	R
C. cyanodus	R
C. vitta	R
Cheilinus chlorurus	O
Epibulus insidiator	R
Gomphosus varius	O
Halichoeres marginatus	R
H. miniatus	A
H. dussumieri	A
H. melanurus	O
Hemigymnus melapturus	C
H. fasciatus	O
Cheilio inermis	O
Labrichthys unilineatus	O
Labroides dimidiatus	C
L. bicolor	R
Pseudolabrus guentheri	O
Pterogogus amboinensis.	O
Stethojulis strigiventer	O
S. interrupta	R
Thalassoma lunare	C
T. hardwicke	R
T. jansenii	R
Scaridae - parrotfishes	
Scarus altipinnis	R
S. ghobban	C
S. microrhinos	R
S. rivulatus	C
S. sordidus	R
Leptoscarus vaigiensis	R
Acanthuridae - surgeonfishes	
Ctenochaetus striatus	R
Acanthurus grammoptilus	O
A. dussumieri	R
A. triostegus (juvenile)	R
Naso annulatus (juvenile)	R
Naso unicornis	C
Siganidae - rabbitfishes	
Siganus lineatus	O
S. fuscescens	R

S. doliatus	R
Scombridae - mackerels and tunas	
Scomberomorus queenslandicus	R
Balistidae - triggerfishes	
Balistoides viridescens	R
Monacanthidae - leatherjackets	
Aleuterus scriptus	R
Pervagor sp.	R
Ostraciidae - boxfishes	
Ostracion meleagris?	O
Tetradontidae - pufferfishes	
Arothron stellatus	O
A. meleagris	R