GREAT BARRIER REEF
MARINE PARK AUTHORITY

RESEARCH PUBLICATION No. 46

Norman Reef Great Adventures Pontoon: 1997 biological survey and summary of damage from cyclone Justin

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Reef

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Sea Research

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SUMMARY

Cyclone Justin crossed the coast in the vicinity of Cairns in March 1997. The 50 knot northerly winds that followed the passage of the cyclone led to the break-off of the Great Adventures Norman Reef pontoon, and its subsequent grounding on the reef flat. Sea Research was asked to resurvey the permanent transects that were set up near this pontoon for past monitoring programs as a prelude to repositioning the pontoon. The aim was to establish what damage had occurred in the benthic community due to the pontoon break-off, and to compare this with the effects of the cyclonic waves themselves on the benthic community. A quantitative survey was also made of the pontoon drag scar on the reef flat, and of surrounding reef benthic communities to determine the effects of the pontoon grounding. The survey was carried out in April 1997, almost a month after the cyclonic episode.

The same techniques used in the previous monitoring programs were employed. Quantitative measurements of the cover of corals and other encrusting organisms, of coral colony height, and coral colony damage, were made along permanent 20 m transects. A total of 40 transects were used, split between control and pontoon sites, and deep and shallow depth strata.

The percentage of damaged coral colonies in the benthic community was between 15-20% during this survey, an order of magnitude higher than during the 1992-93 monitoring program. In spite of the pontoon break-off, damage levels were higher in the control site than in the pontoon site. Coral colony height had decreased, at least nominally, along most transects since 1993, although the changes were not significant. It is suggested that expected gains due to coral growth between 1993 and the time of the cyclone were lost to cyclone induced coral breakage.

Although there had been an average 6% reduction in hard coral cover at the pontoon site this was not significantly greater than the almost 2% reduction in the control site. The reduction at the pontoon site was due to cyclonic breakage of fragile acroporids in the shallow community and to the shading death of poritid coral beneath the pontoon. Breakage of acroporids in the shallow control site was countered to some extent by rapid growth of staghorn acroporids in the deep site.

Overall benthic community damage was no higher in the vicinity of the pontoon than in the control site, despite the obvious structural damage caused by dragging chains and blocks, and by the pontoon itself. There had been some natural structural damage in the control site caused by cyclonic wave action.

In the reef flat community there was a gradient of decreasing coral cover, from 40% to around 10% cover, with increasing distance from the edge of the reef flat. The dragging pontoon had destroyed about half of this coral near the reef flat edge, but about two thirds of cover was dead further up on the reef flat. Almost all remaining corals were damaged but most had repaired themselves by the time of this survey.

Ball park estimates suggest that the pontoon break-off destroyed about 320 sq m of living hard coral on Norman Reef, whereas cyclonic wave action led to a natural loss of around 15 000 sq m of coral from the back face of the reef, a figure several orders of magnitude higher.

INTRODUCTION

Great Adventures (then Hayles) installed a pontoon and began running daily tourist trips to Norman Reef in 1987. This small reef, which is located about 60 km north of Cairns (figure 1), was attractive to the tourist industry due to its rich coral communities, clear water, and proximity to Cairns. We previously set up a monitoring program, based on permanent 20 m line intersect transects, to look at the effect on the reef community of the first 12 months of operation of that facility (Ayling and Ayling 1989).

During the first year of operation of the original pontoon (April 1987-June 1988) almost 10% of the coral cover beneath the pontoon was destroyed either by shading or mooring chain abrasion (a 4.3% reduction against the 4.6% increase in both control sites). Coral height was also significantly reduced beneath the pontoon from a mean of 26.4 cm to 20 cm per colony. There were no detectable effects of diver activity damage, either on coral cover or colony height over the first 12 months. Similarly, semi-sub operation had not caused any significant decrease in coral cover or colony height.

In June 1992 Great Adventures installed a new, larger pontoon in the same location as the original operation. As part of the Great Barrier Reef Marine Park Authority's permit assessment process, we set up a new monitoring program, based on the original permanent transects where possible, to look at the effects of the pontoon change over and the first 12 months of operation of the new pontoon.

Neither tourist snorkelling activities nor inexperienced resort divers, had any effect on coral cover, coral heights or rates of colony damage (Ayling and Ayling 1994a). Coral cover and coral colony height continued to decrease under the pontoon, due to shading and chain abrasion. Overall coral cover had reduced from 61% in 1987 to 49% in 1993, while average coral colony height fell from 26.3 to 14 cm over the same period.

The major influence on coral communities in this area was not the tourist operations but the large waves generated by cyclones Ivor and Joy in 1990. They caused a reduction in coral height in all groups of transects between 1988 and 1992, and gave rise to a marked reduction in coral cover along exposed transects. The five transects set up in 1987 to monitor semi-sub activity were most exposed to these cyclone waves and suffered a 50% reduction in coral cover between 1988 and 1992 (Ayling and Ayling 1994a).

In late March 1997 the passage of cyclone Justin along a path about 20 km east of Norman Reef gave rise to a northerly wind of around 50 knots that broke the Great Adventures pontoon from its moorings. The pontoon was then driven onto the reef flat for a distance of 240 m before it came to rest. This created a damage scar an average of 13 m wide that affected an area of reef flat of 2200 sq m (personal communications from Marine Parks). The break-off also caused some damage at the pontoon site as chains and blocks were dragged over coral communities, and the pontoon broke off the top of the bommie immediately in front of the viewing chamber.

It was agreed during discussions between Sea Research, Great Adventures, Marine Parks and the Great Barrier Reef Marine Park Authority that a resurvey of all permanent transects from the 1992-93 monitoring program should be carried out as a prelude to repositioning the pontoon. This would establish the extent of damage that had occurred, both due to the pontoon break-off, and to the effects of the cyclonic waves themselves. It was also decided that a quantitative survey should be made of the drag scar on the reef flat, and of surrounding reef benthic communities to determine the extent of damage that had occurred due to the pontoon grounding. This survey was carried out between the 18-22 April, almost a month after the passage of the cyclone.

This report presents a brief summary of the results of the Norman Reef re-survey, and reef flat damage survey, and a comparison with results from the previous two monitoring programs.

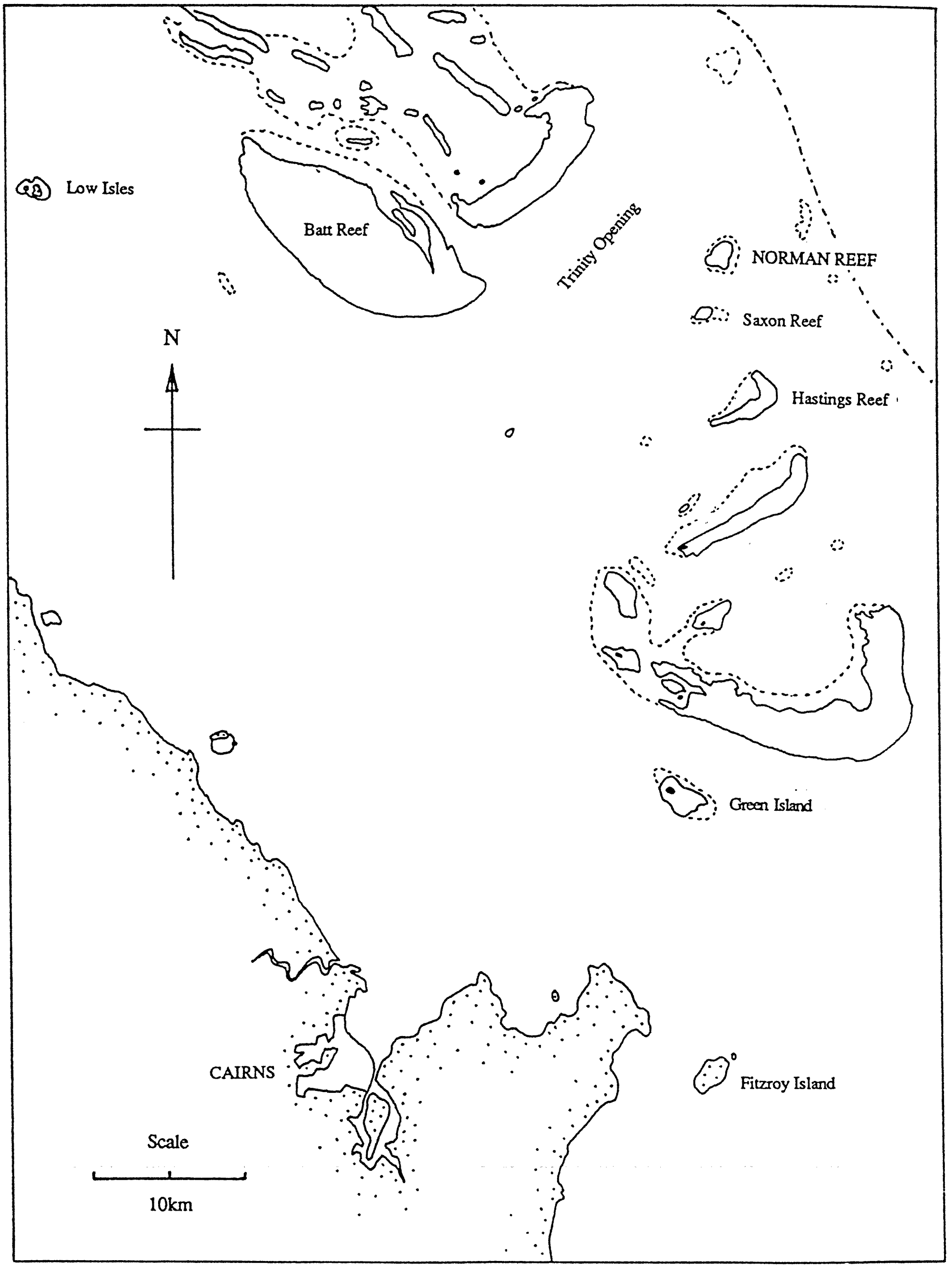

Figure 1. Map of the Cairns local area showing the location of Norman Reef

METHODS

Coral Transects

Coral cover was surveyed along the same permanently marked 20 m long intersect line transects used for the 1987 and 1992 monitoring programs. These transects were positioned haphazardly and were marked by using 100 mm masonry nails driven into the coral substratum at approximately 2 m intervals along the transect line. Our experience has shown that masonry nails are inconspicuous but provide reliable marks that can be relocated over a period of at least five years.

The following organisms or groups of organisms were surveyed along the line intersect transects: all hard corals down to species level where possible but to structural groupings where reliable field identification is not possible, e.g. *Porites* spp. massive; total cover of fire corals (*Millepora* spp.); all soft corals to generic level where possible; total sponges; total area of substratum covered by turfing algae; total area covered by macroalgae. The intersect lengths in centimetres of all the above organisms with the transect line were recorded and converted to percentage cover measurements.

As we were interested in the possible effects of tourist activities, pontoon operations and cyclonic waves on fragile and branching type corals, measures of coral height were made along all the transects. Breakage of branching coral tips may not affect measurements of percentage cover significantly but can reduce coral height (Ayling and Ayling 1989). To quantify coral height the maximum height of living sections of branching and plate type corals was measured in a square metre centred on each metre of the transect line, giving 20 height measurements for each transect. For corymbose plate and tabulate type corals the 'height' was measured from the central stalk of the colony out to the widest part of the plate. If there was no erect hard coral within this square metre the colony nearest to the line outside this area was measured. The coral height for each transect was expressed as the mean of these 20 heights.

As an additional measure of coral damage, apart from the measures of colony height mentioned above, the number of damaged colonies in a 20 x 1 m strip centred on each line transect were counted along with the number of undamaged coral colonies in the same area so that the percentage of colonies damaged could be calculated. A colony was classed as damaged if any tips or edges were broken or if gouges and scrapes were present on the surface. Colonies less than 5 cm in diameter were excluded from these counts. Colonies over 50 cm in diameter were split into a number of nominal 'colonies' approximately 50 cm square and damage within each section recorded. This technique takes less than five minutes for each transect.

Sampling Design

The original 1987 design used four groups of five transects. In the vicinity of the pontoon there were five shallow transects to look at the effects of tourist snorkelling activities in front of the pontoon, and five transects in deeper water beneath the pontoon to look at the effect of shading and mooring chain abrasion. There were also five shallow control transects and five deep control transects set up about 100-200 m south of the pontoon.

In 1992 an additional four groups of five transects were set up. These included five new shallow snorkeller impact transects to cover more comprehensively the area used by pontoon visitors, five deep transects along the resort diver trail immediately in front of the pontoon, as well as five new shallow controls and five new deep controls about 100 m north of the pontoon site (figure 2).

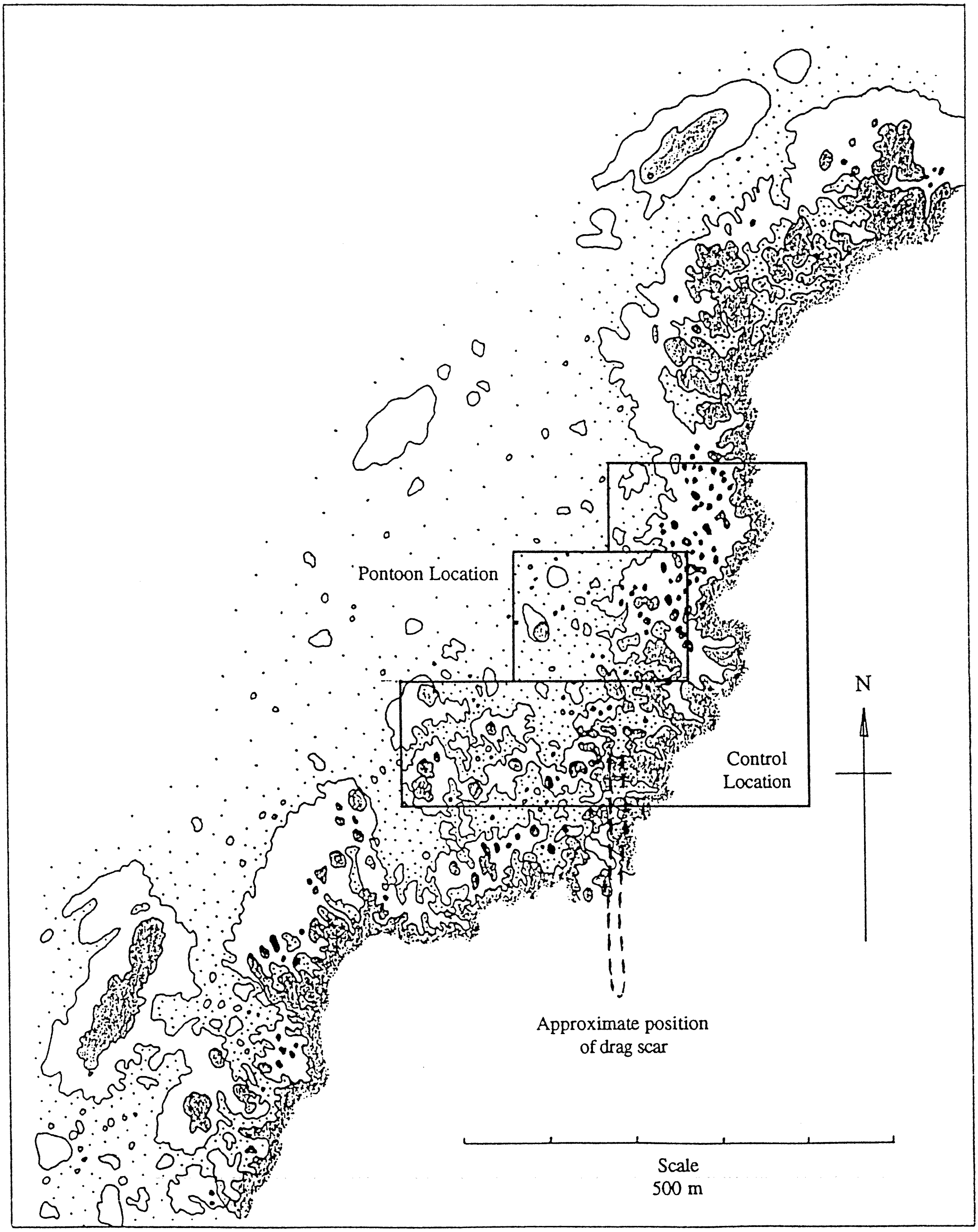

Figure 2. Norman Reef study area showing the position of the study locations

Table 1. Design of the coral survey component. Figures indicate number of transects.

Status	Impact			Control	
Potential impact	**shading**	**fin damage**		**nil**	**nil**
Year established	**1987**	**1987**	**1992**	**1987**	**1992**
Shallow		5x	5x	5x	5x
Deep	5x		5x	5x	5x

Drag Scar Damage

Because the benthic community on the reef flat changes with increasing distance from the reef edge, the scar survey was divided into three sections. Each section comprised about an 80 m length of scar and parts of the surrounding undamaged community on each side of the scar. Six haphazard 20 m line intersect transects were surveyed in each section, with three control transects surveyed on each side of the scar. The percentage of damaged coral colonies was measured along a 20 x 1 m strip in the same way as for the permanent transects, but coral height measurements were not made for these transects.

Timing of the Surveys

All 40 monitoring transects were re-located and re-surveyed between 18-22 April 1997. Although it was almost five years since the transects had been marked they were all located successfully using the detailed maps of distance and direction to each nail, and the type of coral or substratum that each nail was driven into. Although some nails had either fallen out, rusted away, or been overgrown by living corals, a minimum of four nails were re-located per transect, ensuring that the transects were located close to their original positions. All nails were replaced as near as possible to their former position. The drag scar surveys were carried out during the same period.

Analysis

Patterns in the cover of encrusting organisms for the line transects were tested using a repeated measures analysis of variance, suggested as appropriate for a design such as this by Kaly et al. (1993) (table 2). Separate analyses were made for the five time design that included the data from the previous two programs and the 1997 re-survey with five transects per location, and the three time design with 10 transects per location from the 1992-93 program and the 1997 survey, as well as for each depth strata. The term of most interest in these analyses was the time x location interaction. A significant interaction would result if coral cover was reduced at the impact location compared with the control by the activities associated with the pontoon, or by the pontoon breakaway.

Table 2. Coral cover survey analysis. Summarises the design for the four different repeated measures analyses of variance:
df 1 = 2 locations (impact, control); 5 times (87, 88, 92, 93, 97); 5 transects per location
df 2 = 2 locations; 2 times (92, 93); 10 transects per location

Source of variation	df 1	df 2	Denominator
Between Transects:			
Location	1	1	error (l)
error (l)	8	18	
Within Transects:			
Time	4	2	error (T)
T x L	4	2	error (T)
error (T)	32	36	

RESULTS

Shallow Transects

Overall coral cover decreased slightly in both the control site and the impact site between the 1992 survey and this survey, and as a result the time x location interaction was not significant. This was due to a decrease in cover of the more fragile acroporid species. The cover of the more massive growth form poritid and faviid corals did not change significantly over this time (figure 3, table 3). The time x location interaction was significant for faviids: cover decreased slightly at the impact site, probably due to shading by over-growing acroporids, and increased at the control site.

Table 3. Analysis results for the 1992-1997 coral cover data. Separate analyses were made for each depth strata as they were looking at different potential impacts. See table 2 for analysis details. Note: NS = not significant; * = 0.1>p>0.01; ** = 0.01>p>0.001; *** = p<0.001.

	Shallow transects			Deep transects		
	Location	Time	TxL	Location	Time	TxL
Total hard corals	**	*	NS	*	NS	***
Pocilloporidae	NS	NS	NS	*	*	NS
Acroporidae	NS	*	NS	**	**	**
Poritidae	**	NS	NS	**	*	NS
Faviidae	NS	NS	*	*	NS	NS
Total soft corals	NS	NS	NS	NS	NS	NS
Coral height	NS	*	NS	*	NS	*
Colony damage	NS	***	NS	NS	***	*

Five of these transects had been part of the 1987-88 monitoring program and had been surveyed five times over the past 10 years (figure 3). Over this time period hard coral cover had remained relatively stable on the control transects, but had increased by a mean of about 30% on the impact transects, giving a significant time x location interaction in this case (table 4). This change was primarily due to a 40% increase in the cover of fast growing acroporid corals, as well as an increase in faviid corals up till 1992. Poritid coral cover remained stable on both the control and impact transects.

Table 4. Analysis results for the 1987-1997 coral cover data. Separate analyses were made for each depth strata as they were looking at different potential impacts. See table 2 for analysis details. Note: NS = not significant; * = 0.1>p>0.01; ** = 0.01>p>0.001; *** = p<0.001.

	Shallow transects			Deep transects		
	Location	Time	TxL	Location	Time	TxL
Total hard corals	*	NS	*	NS	NS	**
Pocilloporidae	NS	NS	*	**	NS	NS
Acroporidae	NS	NS	NS	*	*	**
Poritidae	NS	NS	NS	*	*	NS
Faviidae	**	*	NS	NS	NS	NS
Total soft corals	NS	NS	NS	NS	NS	NS
Coral height	NS	NS	NS	NS	***	***

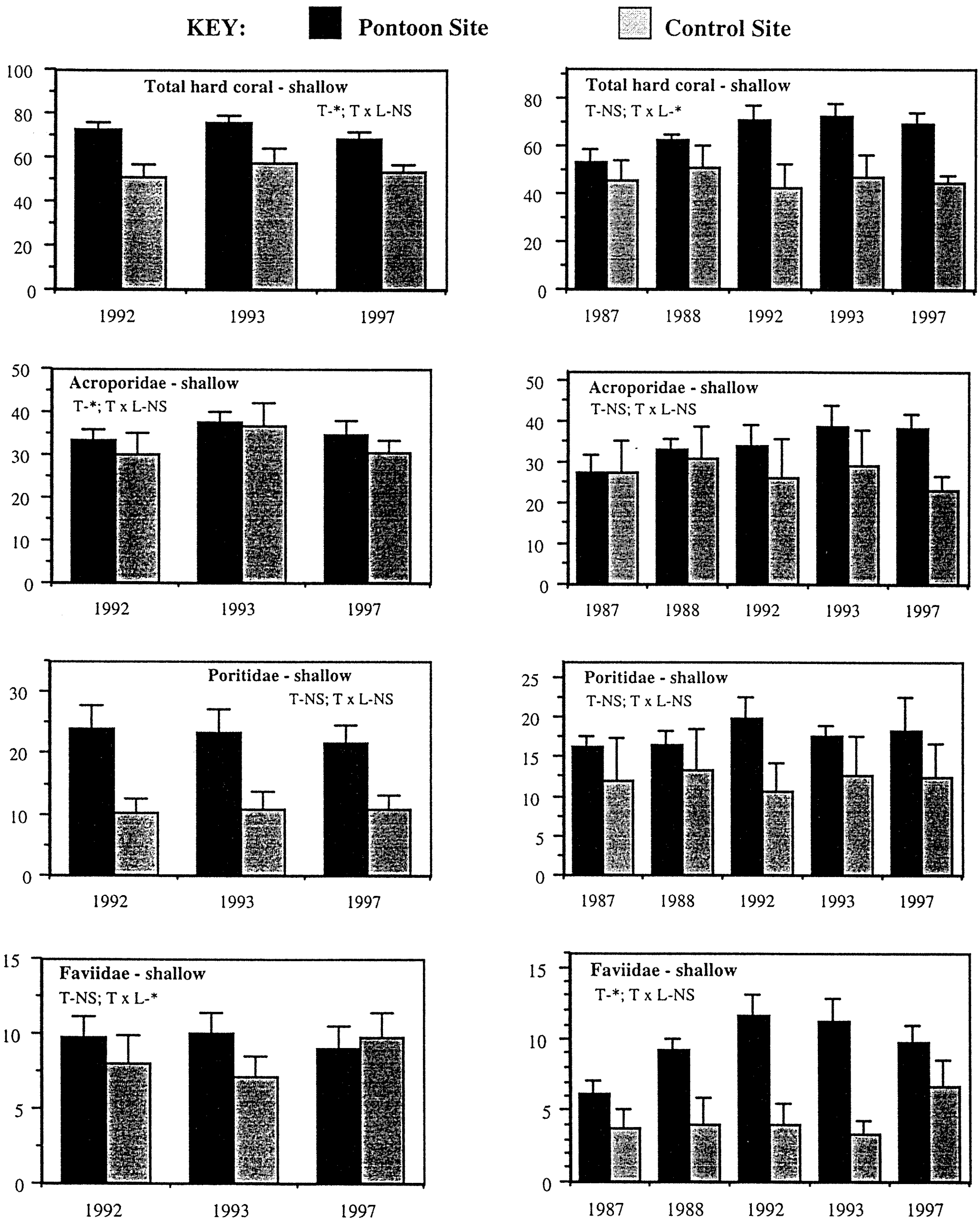

Figure 3. Cover changes of encrusting organisms in shallow monitoring sites. Left graphs show results from 10 transects per site over five years; right graphs from five transects per site for 10 years. Error bars are standard errors. Significance of tests for time and time x location are shown. NS = not significant; * = 0.05>p>0.01; ** = 0.01>p>0.001; *** = 0.001>p

Although mean colony height increased slightly at the pontoon site between 1993 and 1997, and decreased significantly on the shallow control site, the time x location interaction was not significant (figure 5). The percentage of coral colonies that showed evidence of recent damage was almost an order of magnitude greater in 1997 compared with levels recorded in the 1992-93 monitoring program (figure 6). There were nominally more damaged colonies in the control site than in the impact site during the 1997 survey but the time x location interaction was not significant (table 3).

Deep Transects

In the four years between the 1993 survey and this survey there had been a slight decrease in the total cover of hard corals on the deep impact transects (figure 4). Over the same period there had been an increase in coral cover on the controls, and as a result the time x location interaction was significant (table 3). Acroporid cover had increased significantly on the controls and remained stable on the impact transects, whereas poritid cover recorded a decrease on the impact transects and remained stable on the controls. There were no significant changes in faviid abundance.

The five long-term deep control transects showed a 50% increase in hard coral cover over the 10 years since they were first surveyed (figure 4). This compares with an overall 30% decrease in cover on the impact transects that were beneath the pontoon over the same period, and the time x location interaction was highly significant. The change on the controls was due to a five times increase in acroporid cover, there was a 15% decrease in poritid, and a 25% decrease in faviid cover. The coral decrease on the impact transects was primarily due to a drop in poritid cover.

There was a slight decrease in mean coral colony height between 1993 and 1997, both in the deep control and impact sites (figure 5). As in the shallow transects, there was an almost order of magnitude difference in the level of damaged coral colonies measured in 1997 compared with 1993. There were more damaged corals in the control site than in the impact site (figure 6) and the time x location interaction was significant.

Drag Scar Damage

The pontoon created a drag scar for a distance of approximately 240 m across the reef flat and an average of 13 m wide. Coral cover was greatest near the outer edge of the reef flat, where the pontoon first hit, with overall mean cover of around 40% in the undamaged community (figure 7). Acroporids made up over 80% of this cover, and half of this was staghorn growth form species. Although almost all the coral colonies in this section of the drag scar were badly damaged, living corals still covered over 20% of the scraped substratum and the surviving corals looked healthy at the time of this survey. Staghorn acroporids had been reduced to fragments but many were alive and starting to regrow.

Corals were less abundant in the second section of the scar (reef flat 1 in figure 7), where there was more sand lying on the substratum, and corals in the undisturbed control covered about 25% of the surface. Coral cover in this section was also dominated by acroporids which accounted for about 90% of the total cover. Damage along the drag scar was similar to that in the outer section, with all coral colonies broken up but about half of the coral cover still alive (figure 7).

The section of the drag scar furthest up on the reef flat (reef flat 2 in the figure 7) had damaged a benthic community that lived on a predominantly sand substratum. Coral cover in the undamaged control was less than 15%, about 75% of which was acroporids. Coral damage was proportionally greatest in this section of the scar, with 100% of coral colonies damaged, and coral cover reduced to less than a third of that in the controls (figure 7).

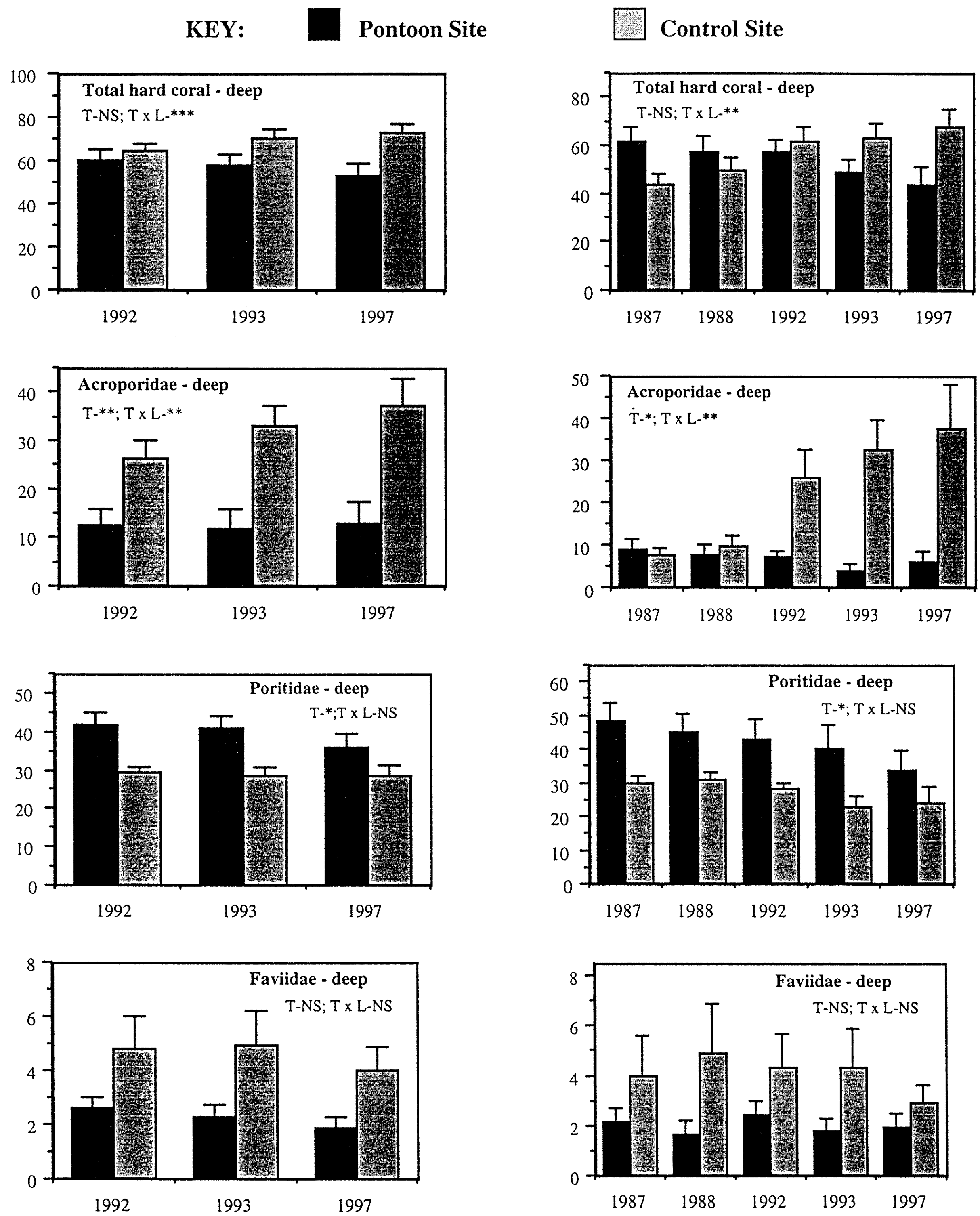

Figure 4. Cover changes of encrusting organisms in deep monitoring sites. Left graphs show results from 10 transects per site over five years; right graphs fromfive5 transects per site for 10 years. Error bars are standard errors. Significance of tests for time and time x location are shown. NS = not significant; * = 0.05>p>0.01; ** = 0.01>p>0.001; *** = 0.001>p

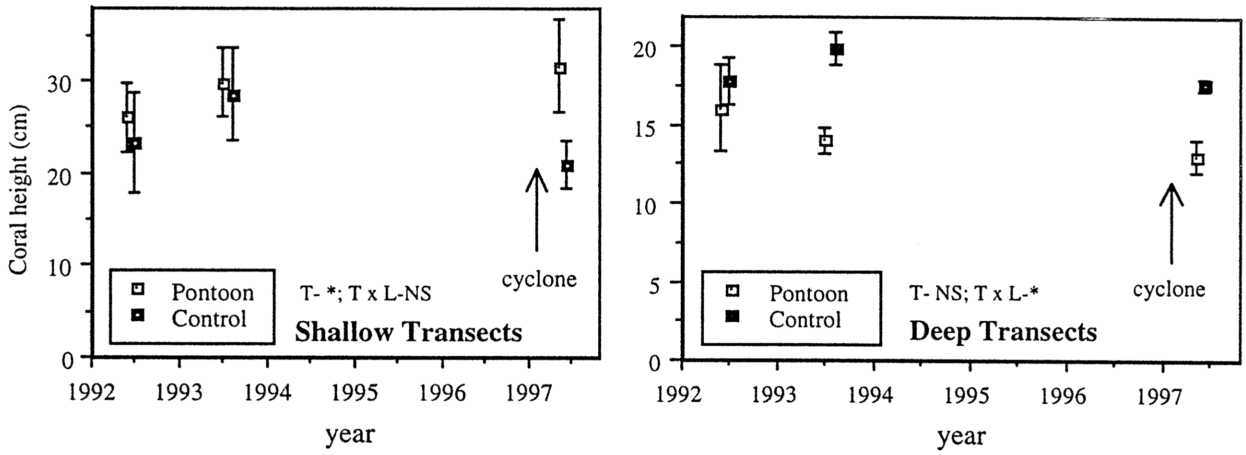

Figure 5. Patterns of coral height change at the pontoon and control locations. Graphs show mean coral colony height per location from twenty measurements along each of the ten 20 x 1 m transects at each location. The approximate time of the impact from cyclone Justin is indicated. Error bars are standard errors. Significance of tests for time and the time x location interaction are shown. NS = not significant; * = 0.05>p>0.01; ** = 0.01>p>0.001; *** = 0.001>p

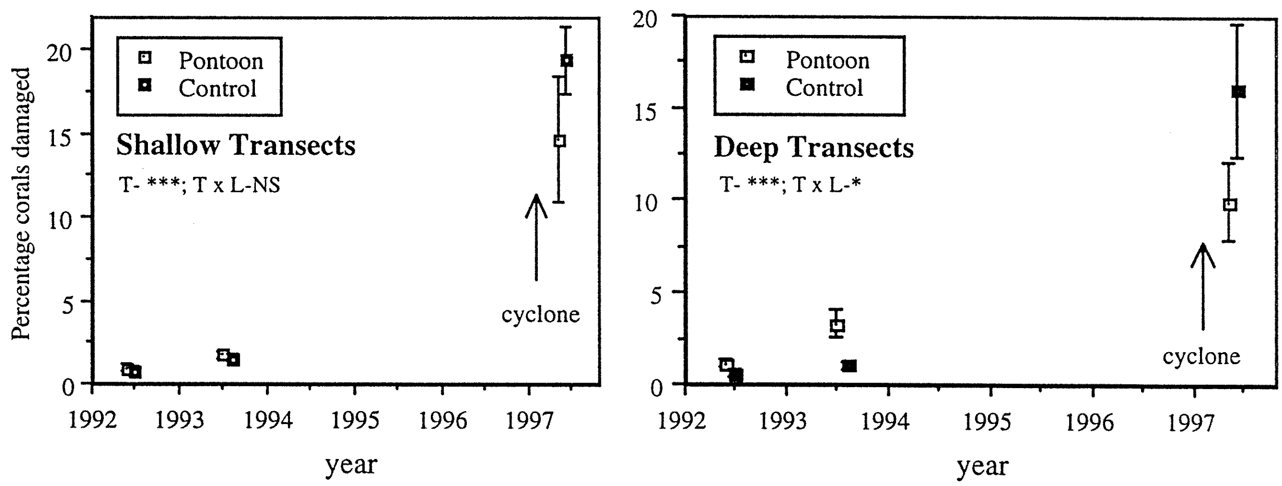

Figure 6. Patterns of coral damage at the pontoon and control locations. Graphs show mean percentage of coral colonies damaged in ten 20 x 1 m transects at each location. The approximate time of the impact from cyclone Justin is indicated. Error bars are standard errors. Significance of tests for time and the time x location interaction are shown. NS = not significant; * = 0.05>p>0.01; ** = 0.01>p>0.001; *** = 0.001>p

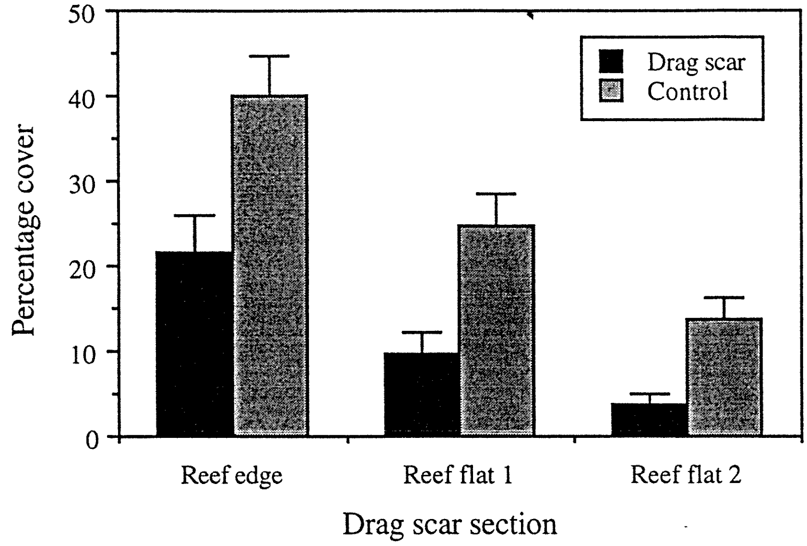

Figure 7. Comparison of coral cover in the drag scar and adjacent reef flat benthic community. Graph shows mean percentage cover of hard coral from six 20 m line intersect transects within three sections of the drag scar, and six transects in the nearby undisturbed community (control). Error bars are standard errors.

Millepora fire corals and *Heliopora* blue corals were relatively common near the reef edge in the undisturbed community, with about 8% cover, most of which was destroyed by the dragging pontoon. Only 0.4% cover of these two groups remained alive in the reef edge drag scar section. Soft corals were also most abundant near the reef flat edge where they covered about 13% of the undamaged substratum. This was reduced by about 75% in the drag scar. Sponges were relatively common in the sandy reef flat community where the pontoon came to rest (reef flat 2), covering about 6% of the substratum, or about half that of hard corals in this section. Sponge cover was reduced to about 1.4% in this section of the drag scar, a 75% reduction. A mean of around 20% of all three drag scar sections was covered with a fine brown algal turf growing on the newly damaged coral substratum. Scarid and acanthurid fishes were grazing intensively on this turf, which was not present in the undisturbed community.

DISCUSSION

There was no evidence from the first two Norman Reef monitoring programs that the operation of the Great Adventures pontoon facility was causing any damage to coral communities. There had been some coral death beneath the pontoon due to shading and chain abrasion but tourist activities had had no discernible effect. The greatest effect recorded in these programs was the damage to corals in the control site and the semi-sub site caused by the wave action associated with cyclones Ivor and Joy in 1990 (Ayling and Ayling 1994a).

Going on previous experience (Ayling and Ayling 1994a, 1994b, 1994c, 1995), and assuming no other disturbance occurred, coral cover and coral height should have increased due to normal growth in the four years since the last survey in 1993. However, the northerly wind associated with cyclone Justin, that led to the break-off of the pontoon, caused significant natural damage to the coral community. In the control site, between 15-20% of coral colonies showed evidence of damage, compared with only 1-2% during the 1992-93 monitoring program. Coral height decreased slightly between 1993 and 1997, and overall coral cover decreased slightly in shallow water, and increased slightly in deep water, over the same period. These changes were due in both cases to changes in cover of the fast-growing, but fragile, acroporid corals. In shallow water the cyclonic waves had broken off part or all of many acroporid colonies, leading to a decrease in cover of around 20%, while poritids and faviids either increased slightly or remained stable. In deep water the rapid increase in acroporid cover evident between 1987 and 1993 had continued, in spite of the evidence of substantial damage to many of the colonies. This was primarily caused by the rapid spreading of the staghorn acroporids *Acropora microphthalma* and *A. youngei*. These spreading staghorn colonies had smothered some of the faviids and reduced cover of this group.

As well as the coral colony damage evident from our surveys there was substantial structural damage throughout the control site and in other areas of the reef. Many large colonies had been torn from the reef by the force of the waves, damaging part of the reef substratum and breaking other corals as they were rolled over the reef. Some large *Porites* heads had been turned over, and a few large bommies up to three metres in diameter had fallen on their side.

The break-off of the pontoon also caused the shifting and dragging of blocks and chains at the pontoon site. This should have increased damage in the vicinity of the pontoon compared to the control site. Despite the fact that a lot of obvious damage was observed at the pontoon site that was due to the pontoon break-off, the overall level of damage was equal or greater in the control site. In the shallow coral community, levels of coral colony damage were about 25% lower at the pontoon site than in the control site, colony height stayed approximately the same, rather than reducing as in the control site, and coral cover reduced by about the same level in both sites. The pattern was similar in the deep coral community, with significantly fewer damaged coral colonies at the pontoon site compared with the control site and a similar drop in coral height in both sites. There was, however, significantly higher coral cover in the deep control site compared with the pontoon site in 1997. This was due to continuing shading death of corals beneath the pontoon, especially of poritid corals, rather than to any pontoon break-off effects.

This supports the observation made previously (Ayling and Ayling 1994a) that many of the control site transects are more exposed to northerly wave action than those at the pontoon site, and hence more likely to suffer damage during a cyclonic episode.

While it is difficult to separate the low level of pontoon operation and tourist use damage from the substantial cyclone induced damage, there is no evidence that there was any noticeable damage at the pontoon site that may have been due to operations in the four years between May 1993 and the time of the cyclone. An exception to this is the already mentioned shading death of some poritid corals beneath the pontoon.

Although the dragging of the pontoon caused obvious structural damage to a small section of the reef flat community, it was surprising how much coral remained alive within the 2200 sq m drag scar. Although badly damaged, between a third and a half of corals were still alive at the time of this survey, almost four weeks after the cyclone. Most coral fragments had begun to repair themselves and it is expected that recovery of these acroporid dominated communities will be relatively rapid. The drag scar runs across the edge of the large patch of bright blue *Acropora nobilis* staghorn coral that we noted in 1987 (Ayling and Ayling 1989), and has badly damaged a section of this colony. However, most of the broken staghorn fingers were still alive and were showing evidence of repair and regrowth.

Management Implications

Two previous monitoring programs suggested that the Great Adventures Norman Reef pontoon was having very little detrimental effect on reef communities in the vicinity. Although almost a million people visited this site between 1987 and 1993 the only detectable effects were a slight but significant reduction in coral cover and coral height beneath the pontoon attributable to shading induced coral death and mooring chain abrasion. Tourist use of the area did not have a detrimental effect on coral communities in the vicinity of the pontoon; coral cover had actually increased markedly in the snorkelling area since the installation of the original pontoon due to natural coral growth. As far as it is possible to tell given the high level of cyclone damage, the results from the present 1997 survey suggest a similar story. Although pontoon shading had continued to reduce coral cover immediately beneath the pontoon, giving a 29% overall reduction over 10 years, there was no other evidence of damage due to pontoon operations.

The major effect on reef benthic communities in the area has been the northerly winds associated with two cyclones, Ivor in March 1990 and Justin in March 1997. Waves associated with Justin damaged 15-20% of coral colonies throughout the monitoring area and caused a reduction in coral height. There was also an overall nominal reduction in coral cover of 5.4% since 1993, and some reef structural damage.

Although the pontoon break-off caused some damage to reef communities in the vicinity of the pontoon site, this did not lead to an increase in damage at the pontoon site compared to the control site. The pontoon created a 240 m long drag scar across the reef flat of Norman Reef. To put this in perspective the scar affected an area that made up less than 0.1% of the reef flat of Norman Reef. The dragging pontoon only destroyed an area of approximately 320 sq m of living hard coral on the reef flat. This area is insignificant when it is considered that the cyclone probably destroyed a ball park estimate of 15 000 sq m of living coral along the back face of Norman Reef (this figure derives from aerial photos, which suggest there is about 30 ha of reef slope on this face, and assumes a conservative 5% coral cover reduction as measured between 1993 and 1997 in this study). The reef damage caused by the pontoon break-off episode was insignificant compared to that caused naturally by the cyclone.

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REFERENCES

Ayling, A.M. and A.L. Ayling 1989. Norman Reef environmental monitoring project. Research Publication No. 19. Great Barrier Reef Marine Park Authority, Townsville.

Ayling, A.M. and A.L. Ayling 1994a. Norman Reef environmental monitoring project - 1992-93 survey. Unpublished report to the Great Barrier Reef Marine Park Authority.

Ayling, A.M. and A.L. Ayling 1994b. Hardy Reef - monitoring of the impact of the new Fantasea Cruises pontoon. Unpublished report to the Great Barrier Reef Marine Park Authority.

Ayling, A.M. and A.L. Ayling 1994c. Moore Reef - monitoring of the effects of the new Great Adventures pontoon. Unpublished report to the Great Barrier Reef Marine Park Authority.

Ayling, A.M. and A.L. Ayling 1995. Moore Reef - monitoring of the effects of the Sunlover Cruises pontoon. Unpublished report to the Great Barrier Reef Marine Park Authority.

Kaly, U.L., B.D. Mapstone, A.M. Ayling and J.H. Choat 1993. Assessment of Environmental Impacts on Coral Communities of the Dredging of Platypus Channel, Cleveland Bay, Townsville, 1993. Unpublished report to the Townsville Port Authority. 48 pages.

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