FINAL REPORT

EFFECTS OF FISHING PILOT STUDY:

VISUAL SURVEYS ON CAIRNS SECTION CLOSED REEFS THAT WILL BE OPENED UNDER THE NEW ZONING PLAN

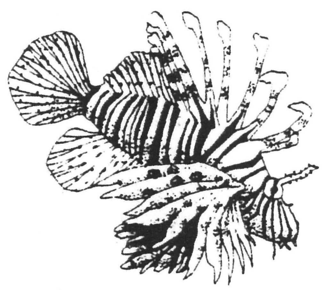
Prepared by

SEA RESEARCH

for

THE GREAT BARRIER REEF MARINE PARK AUTHORITY

July 1992



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CONTENTS

LIST OF TABLES

LIST OF FIGURES

EFFECTS OF FISHING PILOT STUDY: VISUAL SURVEYS ON CAIRNS SECTION CLOSED REEFS THAT WILL BE OPENED UNDER THE NEW ZONING PLAN

A Report to the Great Barrier Reef Marine Park Authority

From Sea Research: A.M. and A.L. Ayling

July 1992

SUMMARY

In January 1992 we made baseline surveys of large fishes and other organisms on the five protected MNP B reefs in the Cairns Section that are to be opened to fishing under the new zoning plan and on five open 'control' reefs. The opening reefs were Ribbon #4, Escape, Channel, Wardle and Northeaster, while the appropriate 'controls' were St. Crispins, Ruby, Pellowe, Nathan and Potter. Surveys were aimed primarily at the large fishes targeted by fishermen, including coral trout, all species of lethrinid and all species of lutjanid. In addition we made surveys of potential prey species (pomacentrids), other important reef organisms (chaetodontids, crown-of-thorns, giant clams) and encrusting communities (hard coral, soft coral). Underwater visual census techniques were used for the surveys, with 50 x 10 m transects for the large fishes, chaetodontids, crown-of-thorns and giant clams, and 20 x 2.5 m transects for the small prey fishes. The survey design incorporated three sites on the front of each reef and three on the back, with five replicate transects of each size counted in each site. The surveys on each reef took a day in the field using two observers.

Although the protection offered by the Marine Park zoning plan had been in place for eight years at the time of this survey there were no differences in the density of the common coral trout *Plectropomus leopardus* between protected and fished reefs (1.42 fish per transect versus 1.39). Previous studies have also detected no effect of fishing on total coral trout density, but have found significant increases in length of coral trout on protected reefs. These studies have also suggested that there is a compensatory increase in recruitment of coral trout on fished reefs. However, The present study found no difference in length of coral trout, or density of recruits, between fished and protected reefs. Although there were 30% fewer bluespot coral trout (*Plectropomus laevis*) on fished reefs compared with protected reefs this difference was not significant.

The red-throat sweetlip *Lethrinus miniatus*, a species that was confined to mid-shelf reefs south of Cairns and is a prime target for both commercial

and recreational fishermen, was recorded at significantly higher densities on protected reefs compared to fished reefs, with an order of magnitude more fish on the protected reefs at the time of this survey. Previous surveys have also suggested that the density of this species is significantly increased by protection from fishing pressure. The yellow-tailed emperor *Lethrinus atkinsoni* was also affected by fishing pressure and there were significantly higher densities of this species on protected mid-shelf reefs than on fished mid-shelf reefs.

There were no effects of protection on the density of the combined lutjanid species, or on any of the species separately, with the exception of the stripey *Lutjanus carponotatus* which was recorded at significantly higher densities on fished reefs, the opposite of what might be expected, although this did not appear to be a real effect.

As all previous studies of distribution on the Great Barrier Reef have found, the densities of most species counted in this survey were significantly different between mid-shelf and outer-shelf reefs. The common coral trout, for example was almost 4x more abundant on mid-shelf reefs compared with outer-shelf reefs. Within each of these major shelf position categories the survey reefs were generally similar, with the exception of Beaver Reef that had marked differences in the density of ten of the species counted.

We looked at the power of the counts of the various species surveyed. For the common coral trout a change in density of 20% of the grand mean (56% if site is the denominator for the F tests) could be detected with 90% power, an acceptable level, while for lethrinids and lutjanids the minimum detectable difference with 90% power ranged from 150 to over 200% of the grand mean. This study indicates that fishing pressure may be significantly affecting the density of a number of species of lethrinids and it is suggested that ways of increasing precision and power for underwater visual counts of these species be investigated.

INTRODUCTION

In their proposal for the design of a large scale experiment for measuring the effects of fishing on the Great Barrier Reef (GBR) Walters and Sainsbury suggest that the pilot study phase of the experiment be mainly aimed at testing and refining sampling methods. They also mention the possibilities of sampling on reefs that have been closed prior to the experiment and are opened at the start of the experiment but suggest that the effects of this are obvious and already fairly well understood. Although this is partly true the opening of five Cairns Section Marine National Park B (MNP B) Zoned reefs when the new zoning plan was implemented in February 1992 may provide an opportunity to test the ability of underwater visual counts of target species to detect changes in their populations.

As a result we suggested that surveys of target fish species, and a selection of other reef organisms that may be indirectly affected by fishing pressure, be made on the five protected MNP B reefs prior to the change in zoning and again five months after they were opened to fishing. In response to suggestions from the GBRMPA we did not use the effects of fishing clusters as controls as was originally proposed but rather selected five 'control' reefs that were open to fishing, one for each zoning change reef and as near as possible to the opening reefs in shelf position and shape. Where possible reefs from the proposed Cairns Section effects of fishing clusters were used as 'controls'. We also made surveys on the single protected reef in each of the two clusters to establish the start of a temporal baseline for these two reefs. Hence the modified design included a total of twelve reefs.

The major aim of this survey was to provide baseline data on the density of large target fishes (coral trout, lethrinids and lutjanids) from which to measure changes in fish populations on the MNP B reefs after they were opened to fishing. In addition baseline data were also collected on the density of a selection of potential prey of the target species (pomacentrids), other important reef species (butterflyfishes, crown-of-thorns and giant clams), the percentage cover of the major encrusting groups (hard corals, soft corals) and estimates of the damage caused to coral communities by *Drupella* grazing.

Although this survey was conducted primarily to establish such a baseline, we were also looking for answers to the following questions:

1. Were there any differences in target fish populations between the protected MNP B reefs and adjacent reefs that did not change zoning status and were open to fishing (hereafter referred to as fished 'controls'), after eight years of protection from fishing?

2. Were the underwater visual transects as used in this survey suitable for the powerful detection of change in reef fish populations?

3. Although a comparison of transect width was not an objective of the project (any comparison with the 50 x 5 m transects used on some of the survey reefs 12 months earlier is confounded with time) it was considered that such a comparison could yield some useful information.

METHODS

Study Sites

The study reefs can be grouped into five southern mid-shelf reefs offshore from Innisfail and seven outer-shelf reefs of the outer barrier between Cairns and Cooktown (figure 1, table 1). We have previously defined shelf position of a reef as the ratio of the distance offshore of the reef to the distance from the coast to the edge of the continental shelf at the latitude of the reef: 0 indicates a mainland fringing reef and 1.0 the outer face of a reef on the edge of the continental shelf. In previous studies we have considered reefs with a shelf position index between 0.2 and 0.8 to be mid-shelf reefs and those between 0.8 and 1.0 to be outer-shelf reefs (Ayling and Ayling 1983). Hence, although Wardle and Northeaster Reefs are the outermost reefs where they occur they are not near the edge of the shelf and are considered mid-shelf reefs.

Although shelf position was confounded with latitude in this study (all the mid-shelf reefs were in the south and the outer-shelf reefs in the north) the available evidence suggests that shelf position is more important than latitude in this area of the GBR, at least for coral trout (Ayling and Ayling 1986b). In the 1991 study there were similar differences between the outer barrier reefs between Cairns and Cooktown and the mid-shelf reefs in the same area, as there were between these northern outer barrier reefs and the southern group of mid-shelf reefs used in the present study (unpublished data held by the GBRMPA).

We have prior information from visual counts of target fish species and a range of other organisms on many of the study reefs in January-March 1991 (Mapstone et al. 1991), and from a few of the reefs in early 1983 (Ayling and Ayling 1986a) (table 1).

Figure 1. Map of the Cairns Section Showing the Position of the Study Reefs.

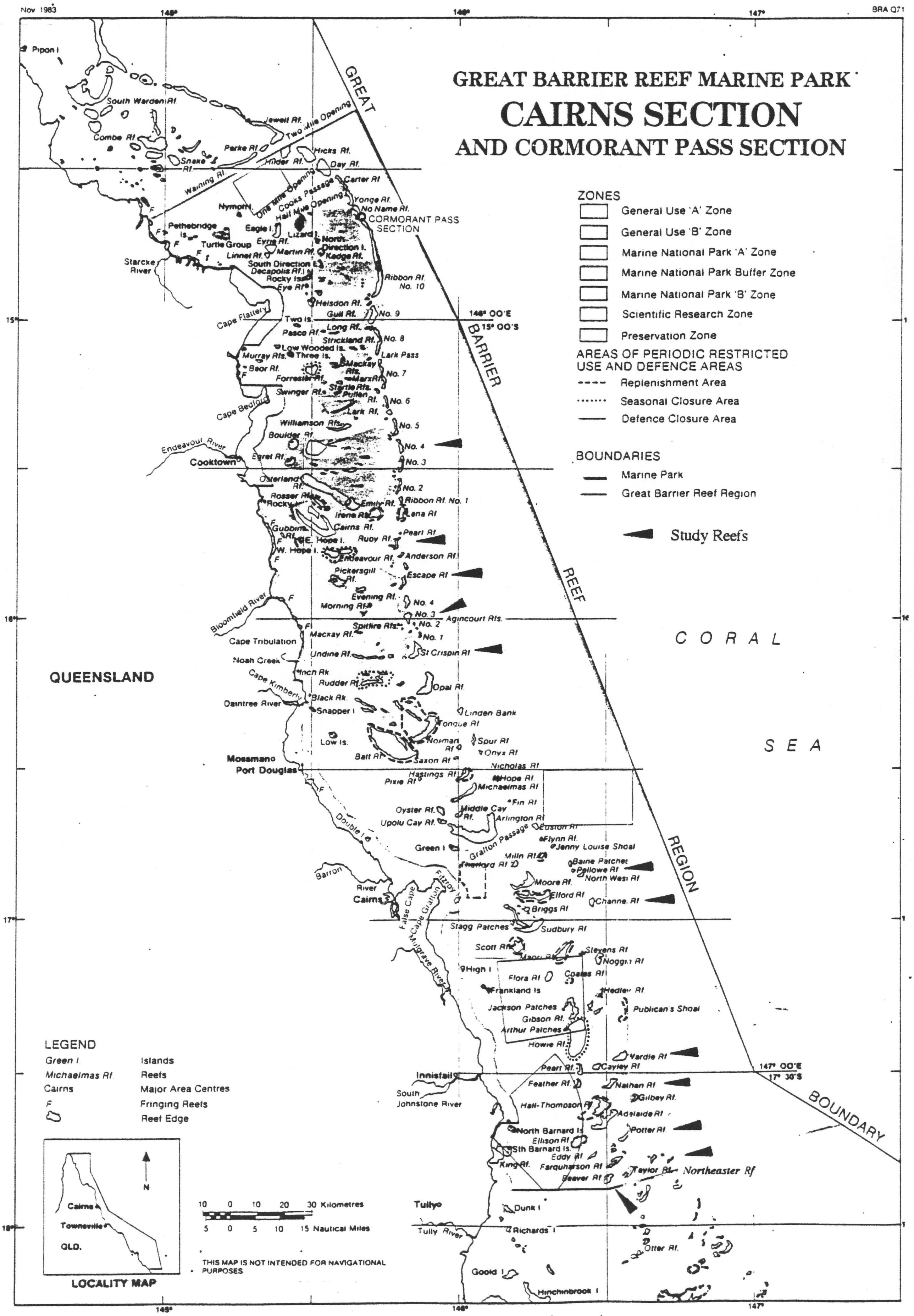


Table 1. Survey Reefs, with a Summary of Prior Information on Coral Trout Density.

Means from ten 50 x 20 m counts at a back reef site for 1983; grand means from four 50 x 5 m counts at six sites per reef for 1991 converted to density per 1000 sq m with standard errors in brackets.

Reef	Status	Shelf position	Density 1983	Density 1991
Opening MNP B reefs and 'controls' (north-south):				
Ribbon #4	protected	outer	2.0 (0.6)	3.00 (0.25)
St. Crispins	fished	outer	1.0 (0.3)	3.33 (1.11)
Escape	protected	outer		1.83 (0.49)
Ruby	fished	outer		
Channel	protected	outer	0.8 (0.5)	0.50 (0.13)
Pellowe	fished	outer		
Wardle	protected	mid	5.2 (0.8)	5.83 (0.87)
Nathan	fished	mid		
Northeaster	protected	mid		2.50 (0.74)
Potter	fished	mid		7.17 (2.61)
Effects of fishing cluster protected reefs:				
Agincourt 3	protected	outer		2.33 (0.41)
Beaver	protected	mid		7.17 (1.74)

Design

Six sites were surveyed on each reef: three evenly spaced sites in the front reef habitat and three in the back reef, with each site comprising approximately 500 m of reef edge. Five replicate 50 x 10 m transects were surveyed in each site with the transects run parallel to the reef edge and generally covering a depth range from 4-12 m. A gap of at least 50 m was left between transects, with minimum spacing of about 300m between sites.

We used 50 x 10 m transects for this survey for the following reasons:

1. They give equivalent estimates of the mean to those provided by 50 x 5 m transects (Ayling and Ayling 1991).

2. They give far fewer zero counts than the 50 x 5 m transects and provide a similarly powerful test of density change for a given effort (Ayling and Ayling 1991).

3. Fishing pressure affects population size structure as well as density (Ayling et al. in press). For the proposed survey reefs the overall mean density per 50 x 5 m transect was approximately 1 in early 1991; about 24 coral trout were recorded per reef with a design of three sites per habitat and four replicates per site. This number is too small to construct a meaningful length frequency distribution for each reef and increasing the

number of fish counted to about 60 by using five 50 x 10 m transects at each site was considered to be an important improvement.

Count Techniques

The methodology used was the same as that used in surveys by Mapstone et al. (1991) in the Cairns Section to estimate density of a similar suite of species. The following organisms were surveyed visually using either line or belt transects: *Plectropomus* spp., chaetodontids, all lutjanids and lethrinids, *Acanthaster planci, Tridacna derasa* and *T. gigas* (50 x 10 m belt transects); selected pomacentrids and *Thalassoma lunare* (20 x 2.5 m belt transects); total live hard coral and soft coral (20 m line transects); numbers of coral colonies suspected of being actively grazed by *Drupella* spp. (30 x 1 m belt transects). These methods have been found to be cost effective in previous work by Mapstone and Ayling.

Counts were made with a field team of 3 people including two divers and a boat person. One diver ran out a 50 m fibreglass tape along the reef slope at a depth of about 4-8 m. The principal observer (A.M. Ayling) followed slightly behind the tape layer, counting coral trout, the other large target fishes and crown-of-thorns within an estimated 10 m of the seaward side of the tape. When the principal observer completed the large fish count he returned along the tape counting *Drupella* damaged corals (and undamaged coral colonies) 0.5 m each side of the first 30 m of the tape and small fishes 1.25 m each side of the final 20 m of the tape (20 x 2.5 m). The tape layer followed, winding in the tape and summing live hard coral intercepts for the first 20 m of the return and soft coral intercepts for the next 20 m of the tape.

At the start of each transect a tape was run out at right angles to the proposed transect line to give the principal observer an indication of the width of the transect. At the end of the first pass along the transect the principal observer indicated his estimate of the width of the transect and this was measured with another tape by the tape layer and recorded.

The minimum total length of fish recorded in the counts was 6 cm for coral trout, 10 cm for lethrinids and lutjanids, 4 cm for chaetodontids and 2.5 cm for pomacentrids.

Previous work on the effect of protection on coral trout populations suggests that a major effect will be an increase in the mean length of the populations on closed reefs (Ayling and Ayling, 1986b). The total length of all coral trout recorded was estimated. It has been shown that with suitable training an adequate level of accuracy can be achieved using such estimations (Bell et al., 1985). Length estimation testing was undertaken by the trout counting observer (A.M. Ayling) at the beginning and end of the survey trip using wooden trout models supplied by the GBRMPA.

Timing of the Survey

The reefs were surveyed between the 20th January and the 7th February 1992, prior to the change of zoning in the Cairns Section in late February 1992. Each site took between 60 and 80 minutes underwater to survey, with the six sites on each reef taking approximately 9 hours including travel time between sites.

Analysis

A number of different analyses were undertaken on the survey data. The difference between the 50 x 5 m transects surveyed in 1991 by the same principle observer and the 50 x 10 m transects surveyed in 1992 was tested for the 8 reefs that were common to both surveys (table 2A). Reefs are considered random in this analysis as we are interested in the general effect of transect type/time rather than the effect on the specific eight reefs, whereas in the following two analyses reefs are fixed; we are interested in the patterns for those particular reefs not in extrapolating to other reefs. To look at the effects of eight years of protection on the MNP B reefs an analysis of the balanced group of five protected reefs and five similar fished 'controls' was undertaken (table 2B). In addition, an analysis of the patterns attributable to habitat, zoning status, shelf position, reef, and site was made for the eight reefs that were balanced with regard to shelf position and zoning status (table 2C). To balance the design this analysis excluded the two small outer-shelf reefs Channel and Pellowe that were not part of the outer barrier line of reefs, as well as the two extra protected reefs, Agincourt 3 and Beaver.

Table 2. Survey Analysis.

A. Comparison of Transect Types/Time.

Factor	Source of variation	Fixed/Random	df	Denominator
A	Transect type/Time	F	1	A*D(C)
B	Habitat	F	1	B*D(C)
C	Shelf position	F	1	D(C)
D	Reef (C)	R	6	E(ABCD)
E	Site (ABCD)	R	64	Residual
	A*B		1	A*B*D(C)
	A*C		1	A*D(C)
	A*D(C)		6	E(ABCD)
	B*C		1	B*D(C)
	B*D(C)		6	E(ABCD)
	A*B*C		1	A*B*D(C)
	A*B*D(C)		6	E(ABCD)

B. Comparison of Protected and Fished Reefs.

Factor	Source of variation	Fixed/Random	df	Denominator
A	Habitat	F	1	D(ABC)
B	Zoning status	F	1	D(ABC)
C	Reef (B)	F	8	D(ABC)
D	Site (ABC)	R	40	Residual
	A*B		1	D(ABC)
	A*C(B)		8	D(ABC)

C. Balanced Survey Analysis.

Factor	Source of variation	Fixed/Random	df	Denominator
A	Habitat	F	1	E(ABCD)
B	Shelf position	F	1	E(ABCD)
C	Zoning status	F	1	E(ABCD)
D	Reef (BC)	F	4	E(ABCD)
E	Site (ABCD)	R	32	Residual
	A*B		1	E(ABCD)
	A*C		1	E(ABCD)
	A*D(BC)		4	E(ABCD)
	A*B*C		1	E(ABCD)
	B*C		1	E(ABCD)

RESULTS

Summaries.

The data for all the organisms counted are summarised in tables i-vi in appendix 1. Anova tables for the analyses are in appendix 4.

Estimation of Transect Width.

The mean estimate of transect width for the entire 360 transects was 9.93 m with a standard deviation of only 0.65 m, and a range from 8.4 to 11.8 m (appendix 2). Reef means, for the 30 transects on each reef, ranged from 9.8 to 10.1 m. Given that there was no consistent over or under-estimation, and that the grand mean was very close to the required 10 m, no adjustment of the individual count totals was made.

Comparison of Transect Performance

The 50 x 10 m counts employed on this survey took only slightly longer than the 50 x 5 m transects. The average time taken to survey a 50 x 10 m transect was 6.1 mins compared with 4.2 mins for counting the same fish species along a 50 x 5 m transect, an increase in time for each reef of about an hour. Considering that it takes around 3 mins to swim 50 m in a straight line at a fish counting pace of 0.5 knots the extra search time involved in the wider transects is substantial. However, by starting slightly earlier in the morning and having a shorter mid-day break it was still possible to survey 6 sites in a day, as was possible for the 50 x 5 m transect surveys.

For the common coral trout the wider transects recorded fewer zero counts than the 5 m wide counts, with 33% zero compared with 50% on the same reefs in 1991 for the nine reefs for which comparisons were possible. Densities of coral trout were nominally 20% lower than on the same reefs in 1991: 2.99 per 1000 sq m compared with 3.74 (table 3A), although this difference was not significant (table 3B). The change between 1991 and 1992 was not consistent (table 3A), with two reefs showing an increase in density, two approximately the same in both surveys and the rest showing reductions of from 20-50%.

Similar differences were shown for the other species or species groups for which comparisons were possible (table 3B), with a mean density reduction of 26%, but the differences were only significant for total lutjanids and total chaetodontids. Previous limited comparisons (only six sites) suggested that there was no difference in the density estimations from the different width transects, but it is possible that this is at least partly responsible for the observed differences, especially as there were at least nominal reductions for all five of the species/species groups. However, it should be remembered that transect width is confounded with time in the analysis, and that the significant interactions involving transect width/time (see appendix 4) make simple interpretation difficult.

Table 3. Comparison of Large Fish Density at Different Transect Widths/Times.

A. Coral Trout.

Grand means from four 50 x 5 m counts at six sites per reef for 1991; grand means from five 50 x 10 m counts at six sites per reef for 1992 converted to density per 1000 sq m with standard errors in brackets.

Reef	1991 (50 x 5)	1992 (50 x 10)
Ribbon #4	3.00 (0.25)	1.53 (0.38)
Escape	1.83 (0.49)	0.87 (0.14)
Agincourt 3	2.33 (0.41)	1.34 (0.34)
St. Crispins	3.33 (1.11)	3.00 (0.56)
Channel	0.50 (0.13)	0.87 (0.28)
Wardle	5.83 (0.87)	5.40 (0.56)
Potter	7.17 (2.61)	4.00 (0.42)
NE	2.50 (0.74)	4.07 (0.44)
Beaver	7.17 (1.74)	5.80 (0.54)
Grand mean	3.74	2.99

B. Other Species.

Species/Group	1991 50 x 5	1992 50 x 10	Reduction	F	df	Significance (p)
Plectropomus leopardus	3.74	2.99	21%	2.99	1/6	NS (0.13)
Lethrinids	2.88	2.11	27%	2.41	1/6	NS (0.17)
Monotaxis grandoculis	6.62	5.54	16%	0.97	1/6	NS (0.36)
Lutjanids	13.56	8.24	39%	5.22	1/6	NS (0.06)
Chaetodontids	36.42	25.68	29%	37.06	1/6	*** (0.001)

Large Fishes

Coral Trout

The common coral trout *Plectropomus leopardus* was recorded at a grand mean density of 1.41 fish per 500 sq m transect during this survey, equivalent to 28.2 per ha (appendix 1). There were significant differences between the front and back reef habitat (table 4) with an overall 70% more fish recorded in the back reef surveys (1.77 vs. 1.04 fish per transect). The habitat x shelf position interaction was significant (table 4). On mid-shelf

Figure 2. Within Reef and Cross Shelf Distribution of Large Fishes.

A. Coral Trout and Lethrinids: Graphs show grand mean density per 50 x 10 m transect for all sites in each habitat within each shelf position for all 12 reefs. Error bars are standard errors.

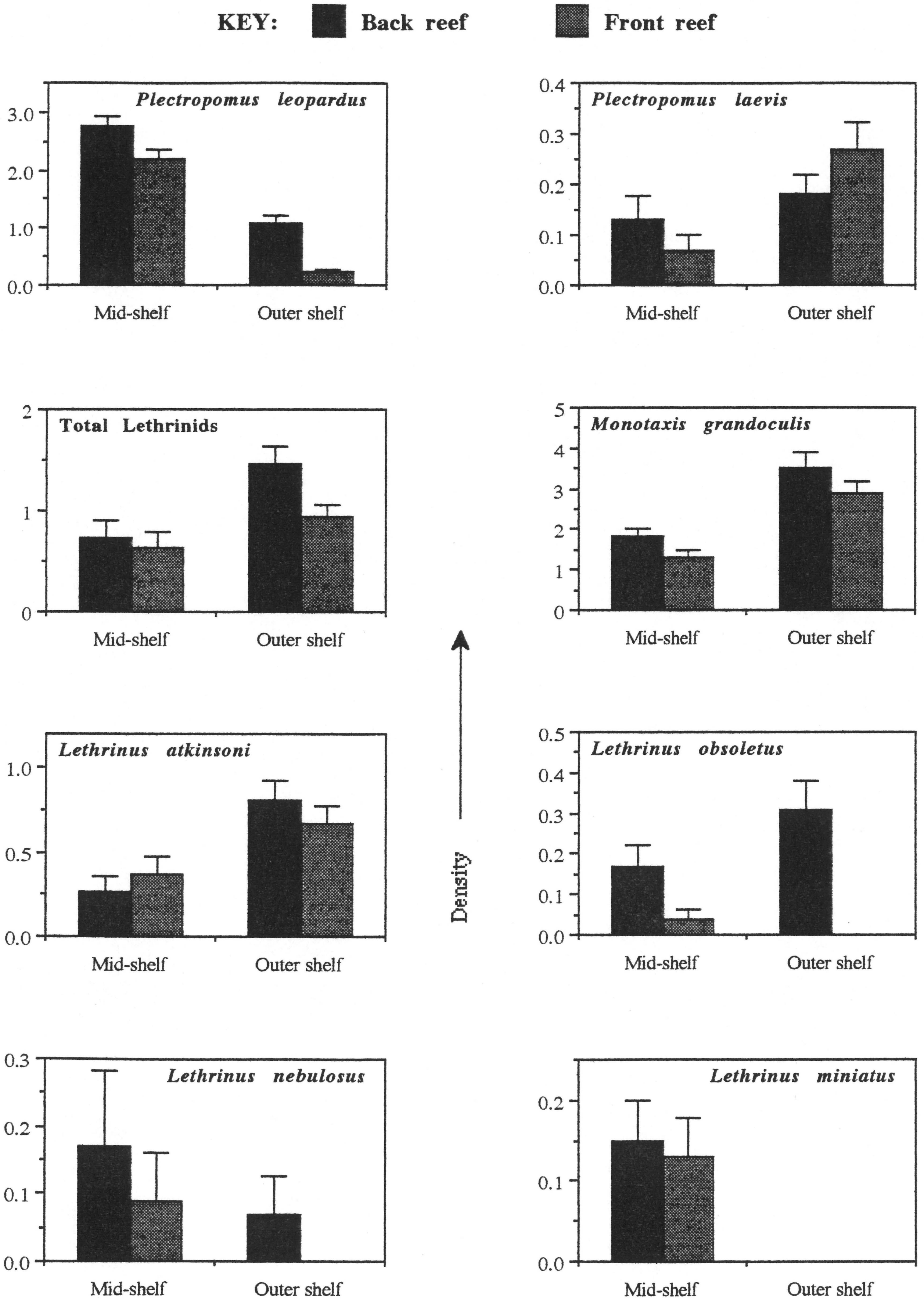


Figure 2. Within Reef and Cross Shelf Distribution of Large Fishes.

B. Lutjanids and Chaetodontids: Graphs show grand mean density per 50 x 10 m transect for all sites in each habitat within each shelf position for all 12 reefs. Error bars are standard errors.

KEY: ■ **Back reef** ▒ **Front reef**

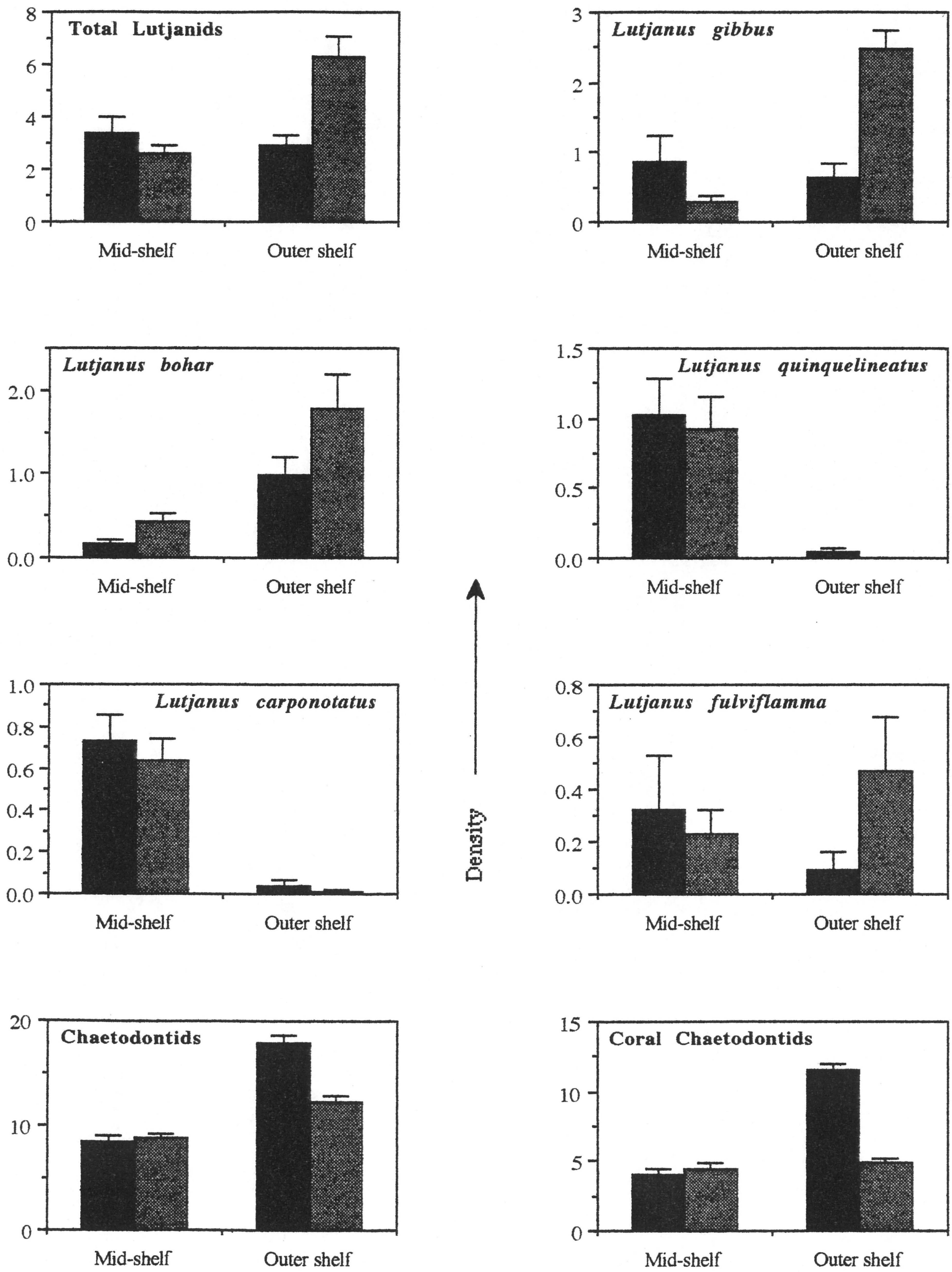


Figure 3. Effects of Fishing on the Density of a Selection of Target Fishes.

A. Coral Trout and Lethrinids: Graphs show grand mean density per 50 x 10 m transect for all sites in each zone within each shelf position for the 5 pairs of reefs only. Error bars are standard errors. Probability values for tests of significance of zone differences are shown.

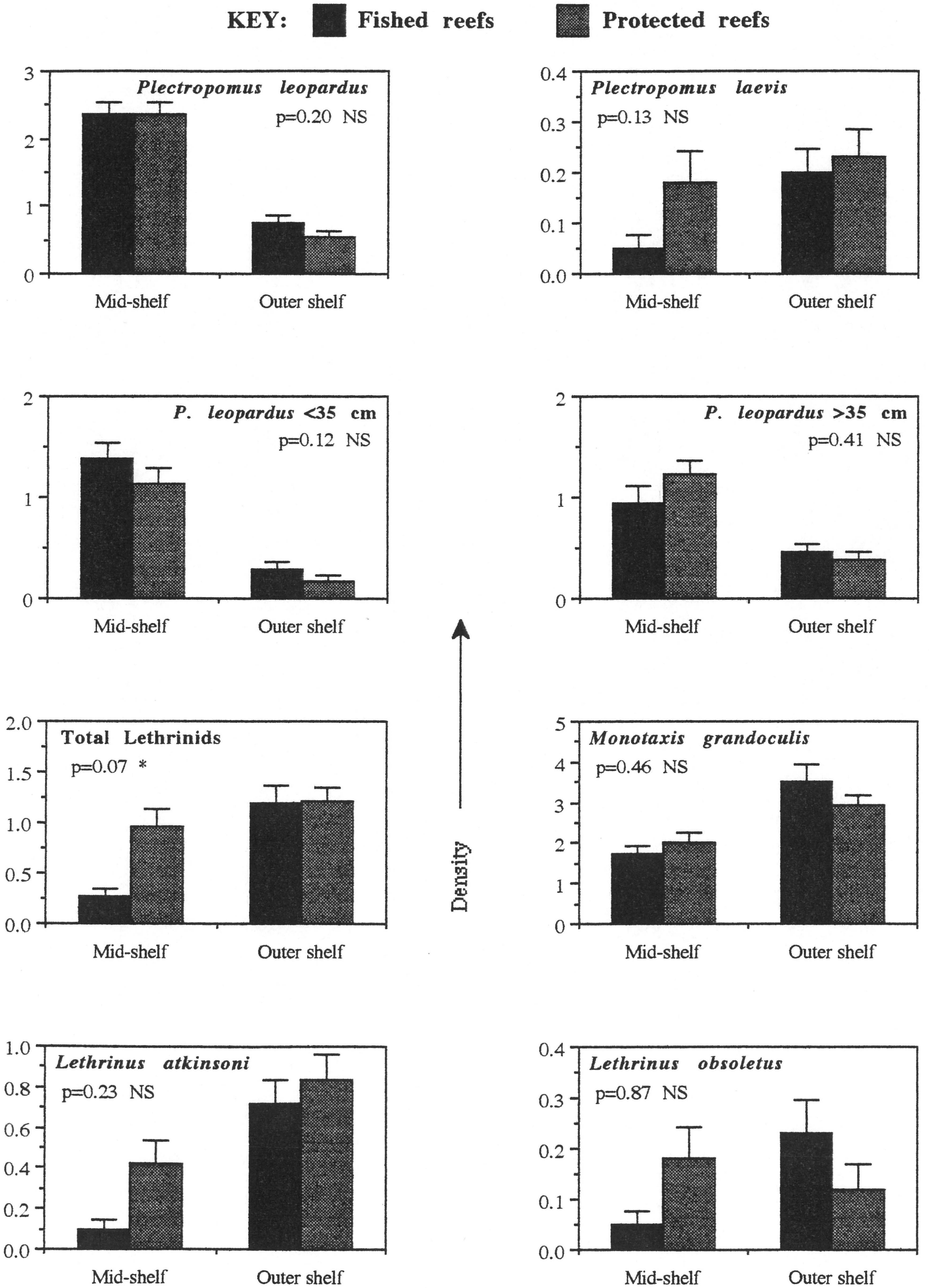


Figure 3. Effects of Fishing on the Density of a Selection of Target Fishes.

B. Lethrinids, Lutjanids and Chaetodontids: Graphs show grand mean density per 50 x 10 m transect for all sites in each zone within each shelf position for the 5 pairs of reefs only. Error bars are standard errors. Probability values for tests of significance of zone differences are shown.

KEY: Fished reefs Protected reefs

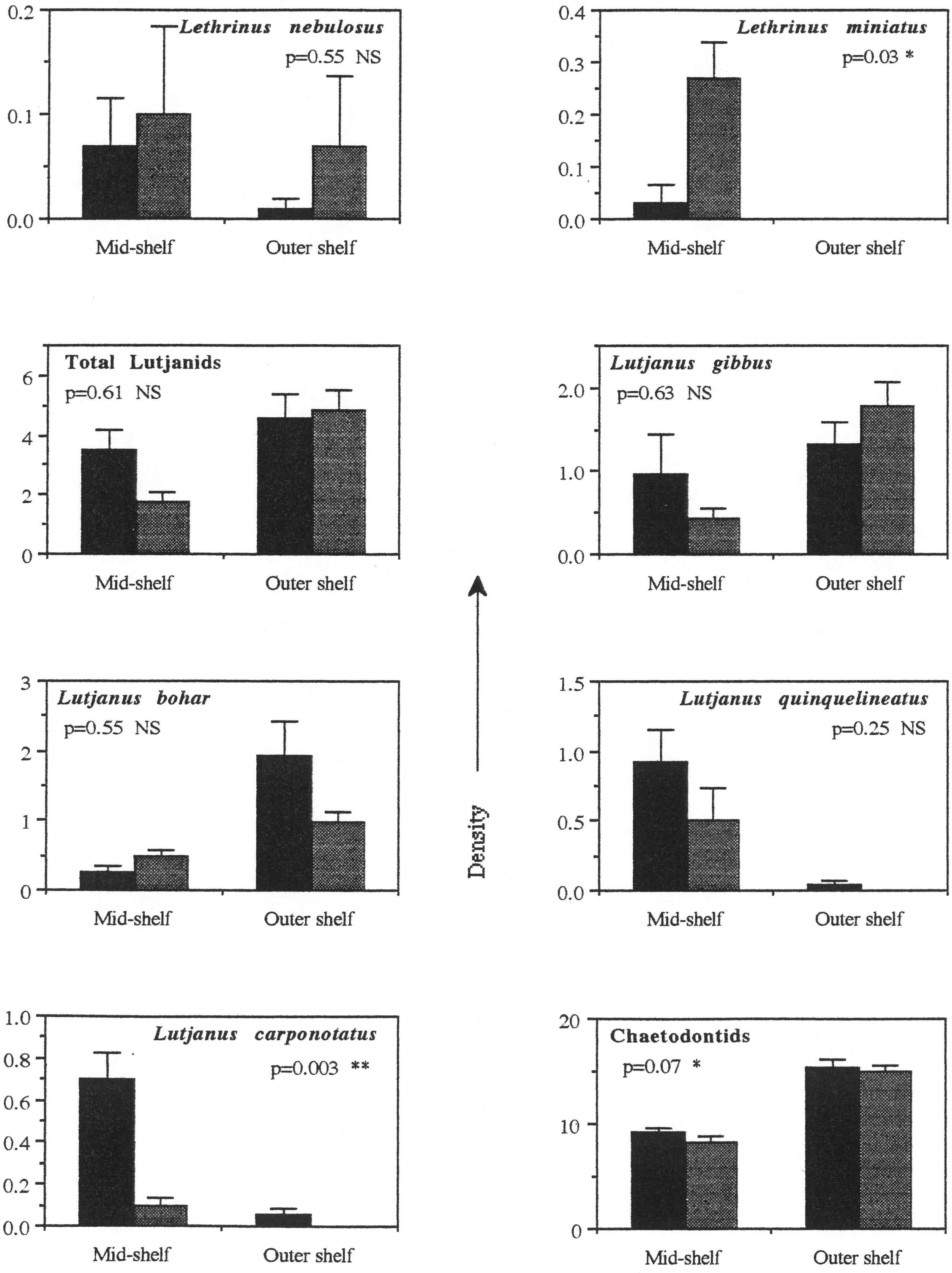


Table 4. Summary of the Anova Results Showing the Significance of the Factors Tested.

Zone (10 reefs) is from the analysis of the 5 pairs of protected/fished reefs, other factors from the 8 reef balanced design analysis. NS = not significant; * = 0.01<p<0.1; ** = 0.001<p<0.01; *** = p<0.001; na = not analysed. Note: using the pooled residual as the denominator for the F tests where site is not significant does not change the significance levels.

Factor:	Habitat	Shelf position	Zone	Zone (10 reefs)	Reef	Site	Significant interaction terms
Large Fishes							
Plectropomus leopardus	***	***	NS	NS	***	NS	H*P; H*R(P)
P. leopardus recruits	NS	***	NS	NS	NS	**	nil
P. leopardus <35 cm TL	**	***	NS	NS	*	*	H*P*Z
P. leopardus >35 cm TL	***	***	NS	NS	***	NS	H*P; P*Z
P. laevis	NS	**	NS	NS	*	NS	H*P
Lethrinids - total	NS	**	*	*	NS	***	nil
Lethrinus atkinsoni	NS	**	NS	NS	NS	***	nil
Lethrinus obsoletus	**	NS	NS	NS	NS	***	H*P*Z; P*Z
Lethrinus nebulosus	NS	NS	NS	NS	NS	NS	nil
Lethrinus miniatus	NS	***	na	*	*	***	nil
Monotaxis grandoculis	*	***	NS	NS	NS	*	H*P*Z
Lutjanids - total	*	**	NS	NS	NS	***	H*P; H*Z; H*R(P);P*Z
Lutjanus gibbus	*	**	NS	NS	NS	***	H*P; H*Z
Lutjanus bohar	**	*	NS	NS	NS	***	H*R(P)
Lutjanus quinquelineatus	NS	*	NS	NS	*	***	nil
Lutjanus carponotatus	NS	***	**	**	NS	***	P*Z
Lutjanus fulviflamma	NS	NS	NS	NS	NS	***	nil
Chaetodontids	NS	***	NS	*	NS	***	nil
Coral feeding chaetodontids	NS	***	NS	NS	NS	***	H*P
Small Fishes							
Pomacentrus molluccensis	***	*	*	NS	NS	***	H*P
Amblyglyphidodon curacao	***	***	NS	NS	NS	***	nil
Chrysiptera rollandi	***	*	***	**	NS	***	H*Z; H*R(P); P*Z
Plectroglyphidodon lacrymatus	*	NS	NS	*	**	***	nil
Encrusting Organisms							
Hard coral cover	*	***	NS	NS	NS	***	nil
Soft coral cover	***	***	*	**	*	***	nil
Giant Clams							
Tridacna gigas	*	NS	*	*	NS	**	nil
Tridacna derasa	***	*	*	*	NS	*	H*Z

reefs there were only 25% more coral trout on the back reef compared with the front reef (2.75 vs. 2.20 fish per transect), a non-significant difference, while on outer-shelf reefs there were 5x as many common coral trout on the back reef as on the front (1.08 vs. 0.22). The site factor was not significant (table 4).

As can be seen from the above figures there was also an overall significant density difference between outer and mid-shelf reefs (table 4). There were almost 4x as many common coral trout on mid-shelf reefs compared with outer-shelf reefs (2.47 vs. 0.65 fish per transect).

There were no significant differences in common coral trout density between protected and fished reefs, either for outer or mid-shelf reefs, or within the front and back reef habitats (table 4). Overall densities were 1.42 per transect on protected reefs compared with 1.39 on fished reefs (figure 2).

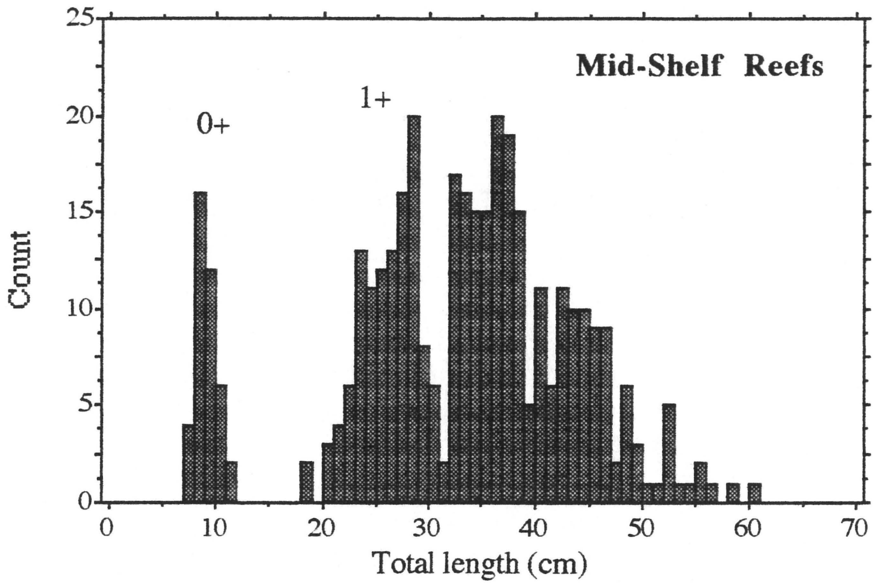
The trials showed that our length estimations of coral trout were relatively accurate (appendix 3), with a mean absolute error of 3.7-4.3% of the actual length. If coral trout are split into two populations, those young fish <35 cm in total length (TL) and those fish >35 cm TL that are available to fishermen the patterns were similar for both groups to those described above for the total population (table 4).

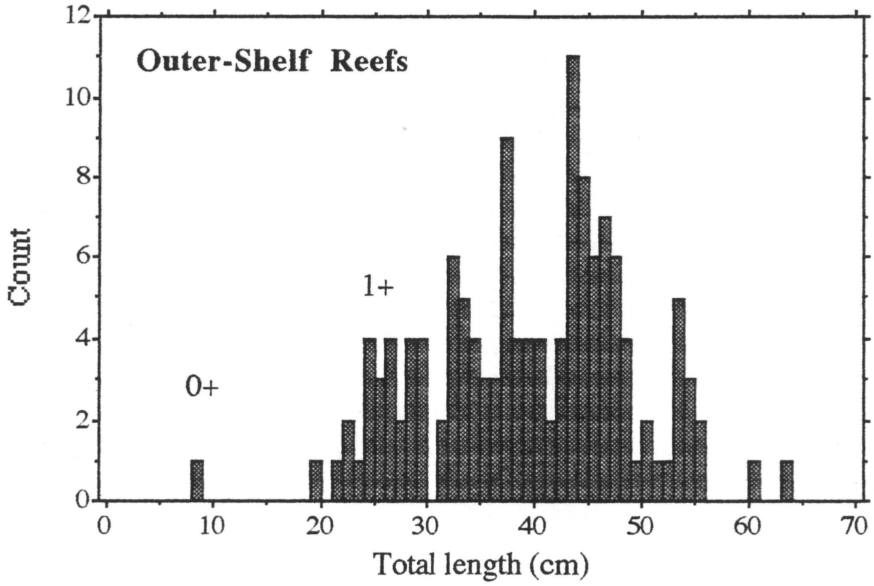
We were able to separate 0+ recruits from the rest of the coral trout population and look at the patterns of their distribution. Juveniles settle during December and are secretive until they reach a length of about 7 cm, at which time they begin to swim up off the bottom and can be recorded in the counts (Fowler et al. 1991; A.M. Ayling personal observations). Some recruits were between 7 and 11 cm TL at the time of this survey (figure 4), but the number recorded was probably lower than if the counts had been made a few months later as in 1991. The majority of recruits were recorded on the mid-shelf reefs, with only a single individual counted on the seven outer-shelf reefs (figure 4). On mid-shelf reefs densities were approximately the same in the front and back reef habitats (table 4). There were also no significant differences between fished and protected reefs or between reefs in each shelf position, but there were significant differences between sites suggesting that recruits were patchily distributed at this scale (table 4).

As has been shown in previous surveys (Ayling and Ayling 1986a) the mean length of the common coral trout was markedly higher on outer-shelf reefs (38.9 cm TL) than on mid-shelf reefs (31.9 cm). However, there was no difference in length between fished reefs (33.0 cm) and protected reefs (34.3 cm).

Figure 4. Length frequencies of the common coral trout.

The 0+ and 1+ peaks are indicated.





The footballer/bluespot coral trout *Plectropomus laevis* was almost an order of magnitude less abundant than the common coral trout, with a grand mean of 0.17 fish per transect. Habitat differences were not significant (table 4), although the interaction between habitat and shelf position was: there were higher densities of this species on the front of outer-shelf reefs compared with the back but the opposite on mid-shelf reefs. There were over twice as many *P. laevis* on outer-shelf reefs compared to mid-shelf reefs, a significant difference (table 4). As with the common coral trout there were no significant site effects for this species.

Although there were 30% fewer *P. laevis* on fished reefs compared with protected reefs (figure 3) this difference was not significant at the 0.1 probability level (p=0.13).

Lethrinids.

Lethrinids were recorded at a grand mean density of 0.99 fish per transect during this survey. There were significantly more lethrinids on outer-shelf reefs than on mid-shelf reefs (1.20 fish per transect vs. 0.69), and significantly more on protected reefs than fished reefs (figure 3). Although there were 29% fewer lethrinids in the front reef habitat than in the back reef these differences were not significant.(table 4; figure 2). This group of fishes is characterised by very patchy distributions, reflected in the very significant site effect in the analyses (table 4).

Nine species of lethrinids were recorded during this survey, but only two of these, the yellow-tailed emperor *Lethrinus atkinsoni* and the orange-striped emperor *L. obsoletus*, were at all common. Separate analyses were carried out for these two species plus the commercially important red-throat sweetlip *L. miniatus* and the spangled emperor or yellow sweetlip *L. nebulosus*, although these latter species were relatively uncommon in the counts with grand means around 0.1 individuals per transect. *L. atkinsoni* was significantly more abundant on outer-shelf reefs than mid-shelf reefs (figure 2), but did not show any significant habitat preference within reefs. *L. obsoletus* was more abundant in the back reef habitat, without a significant cross-shelf effect. For the commercially important species, *L. miniatus* was found only on the mid-shelf reefs and there were no significant effects in the distribution of *L. nebulosus*.

Although most of these species were recorded at lower densities on fished reefs than protected reefs (figure 3) only *L. miniatus* showed a significant zone effect in this survey. There was a suggestion that the fishing effect was greater on mid-shelf reefs than on the outer-shelf, probably due to the easier access of fishermen to mid-shelf reefs. Separate analyses of the two protected/fished pairs of mid-shelf reefs confirmed the zone effect on *L. miniatus* distribution (p<0.001), and showed a similar effect for *L. atkinsoni*(p=0.05). *L. miniatus* was an order of magnitude more abundant on the protected reefs while *L. atkinsoni* was over 4x more abundant. The zone effect was almost significant for *L. obsoletus* (p=0.11) with 3.6x greater numbers recorded on protected reefs compared to fished reefs for this species.

Although the other lethrinid species were not recorded in sufficient numbers to make analysis possible, some comments on there distribution might be useful. The yellowlip emperor *L. xanthochilus* and the yellow-spotted emperor *L. erythracanthus* were only seen on outer-shelf reefs; the former was 4x as abundant in the front reef habitat compared to the back on these reefs, while the latter was 4x more abundant on the back reef. The long-nosed emperor *L. olivaceus* was also only recorded on outer-shelf reefs during this survey but was equally abundant in front and back reef habitats. The other two lethrinids, the sand emperor *L. semicinctus* and the pink-eared emperor *L. lentjan*, were associated with areas of sandy substratum and were occasionally encountered where transects crossed sand patches.

The commonest species in the family Lethrinidae was the big-eye bream *Monotaxis grandoculis*, recorded at a grand mean density of 2.52 per transect. This species is not caught by fishermen as it does not take a hook and little is known of its habits and ecology. It was found in significantly higher densities in the back reef habitat compared to the front reef (2.79 fish per transect vs. 2.24), and on outer-shelf reefs compared to mid-shelf reefs (3.20 vs. 1.56). There were no differences in density between fished and protected reefs (table 4).

Lutjanids.

Lutjanids were more abundant than lethrinids, with a combined grand mean density of 3.91 fish per transect. There were significantly higher densities on the front reef compared to the back and on the outer-shelf reefs compared to the mid-shelf reefs. On mid-shelf reefs habitat differences were not significant, whereas on outer-shelf reefs there were far more lutjanids on the front than the back, giving a significant habitat x position interaction (table 4). As for lethrinids the distribution of these fishes was very patchy at the scale of transect size used for this survey and there were significant site effects for all species (table 4).

Fourteen species of lutjanids were recorded during this survey but only five of these were common enough to enable separate analyses of distribution patterns to be made. The paddletail *Lutjanus gibbus* was the most abundant species and showed similar patterns to those described above for lutjanids as a whole, being over 4x as abundant on the front of outer-shelf reefs than in any other location (figure 2). The red bass *L. bohar* was also most abundant on the front of outer-shelf reefs, and more abundant on outer-shelf reefs than mid-shelf reefs (figure 2). The five-lined seaperch *L. quinquelineatus*, on the other hand, showed no habitat preferences, and was virtually absent from outer-shelf reefs, a very similar pattern to that shown by the stripey *L. carponotatus*. Although the black-spot snapper *L.*

fulviflamma was nominally most abundant on the front of outer-shelf reefs it showed no significant abundance patterns.(table 4).

Of the other nine species of lutjanid, five were restricted to outer-shelf reefs, two were only recorded on mid-shelf reefs and two were found on both types of reef. The maori seaperch *L. rivulatus* and the black-banded seaperch *L. semicinctus* were both only seen on the front of outer-shelf reefs, while the bluestripe seaperch *L. kasmira*, the yellow-margined seaperch *L. fulvus* and the one-spot seaperch *L. monostigma* were all found on both the front and back of these reefs. The moses perch *L. russelli* was seen only in the back reef habitat of both mid- and outer-shelf reefs. The other three species, the red emperor *L. sebae*, the bigeye seaperch *L. lutjanus* and the dark-tailed seaperch *L. lemniscatus*, were only recorded from a few individuals.

All lutjanids are taken by fishermen but of the species that were common on this survey two are not eaten due to an official ban on sale for fish poisoning reasons (*L. gibbus* and *L. bohar*), while the others are generally too small except for use as bait. Overall there were nominally slightly more lutjanids on fished reefs than on protected reefs (figure 3) but this difference was not significant. Of the five species analysed separately only *L. carponotatus* showed a significant zone effect, being more abundant on fished than on protected reefs (table 4, figure 3). However, as can be seen from appendix 1, table iii, this species was 3x as abundant on Beaver Reef (a protected reef not included in any of the analyses) than on any other reef, and this is probably not a real effect.

Chaetodontids.

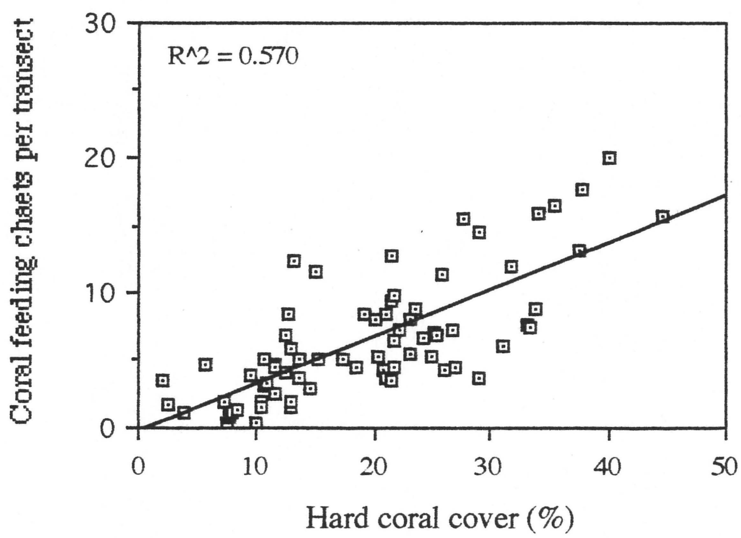
Chaetodontids (butterflyfishes) were common at this scale of sampling, with a grand mean density from this survey of 12.43 per transect. Overall there were almost twice as many chaetodontids on outer-shelf reefs as on mid-shelf reefs (figure 2). Slightly more than half of the chaetodontids recorded were obligate hard coral feeders (6.54 per transect). As would be expected there was a significant positive correlation between the density of these coral feeding species of chaetodontids at each site and the cover of living hard coral at that site (figure 5). As a result there was a significant site effect in the distribution of chaetodontids (table 4). Although these fishes are not directly subject to fishing pressure the effect of protection was tested to look for any indirect effects. There was a significant difference in the 10 reef analysis but not in the balanced 8 reef design (excluding Channel and Pellowe) (table 4).

Small Fishes.

Analyses were only carried out for the four most abundant pomacentrids (table 4). Most species were significantly more abundant in the back reef habitat than in the front reef habitat, and on mid-shelf reefs than outer-shelf reefs, with the exception of *Plectroglyphidodon lacrymatus*, which was more abundant on front reefs and showed no significant cross-shelf trends. Two species, *Chrysiptera rollandi* and *Plectroglyphidodon lacrymatus*, showed significant zoning differences, the former being more abundant on fished reefs than protected reefs, and the latter more abundant on protected reefs.

Figure 5. Relationship of Chaetodontid Density to Hard Coral Cover.

Density of hard coral feeding chaetodontids per 500 sq m transect is shown for each site.



Other Organisms.

The grand mean hard coral cover from all the survey reefs was 19.4%, with reef means ranging from a low of 10.2% on Nathan Reef to a high of 30.6% on Agincourt 3 Reef. Living coral percentage cover was significantly higher on outer-shelf reefs compared with mid-shelf reefs. On outer-shelf reefs there was higher coral cover on the back reef than the front reef but this pattern was reversed on mid-shelf reefs. Overall there was significantly higher cover in the front reef habitat than in the back. There were no significant differences in hard coral cover between fished and protected reefs (table 4).

Soft corals were also important with a grand mean cover of 12.1%, with reef means ranging from 5.0% on Agincourt 3 Reef to 21.2% on Wardle Reef. Percentage covers were significantly higher on mid-shelf reefs compared with outer-shelf reefs and significantly higher in the front reef habitat compared with the back on both mid- and outer-shelf reefs. There was a significantly higher cover of soft corals on fished reefs compared to protected reefs (table 4).

Giant clams were counted along the same 50 x 10 m transects as the large fishes. The larger *T. gigas* was recorded at a grand mean density of 0.16 per transect with *T. derasa* almost twice as abundant at 0.3 individuals per transect. Both species showed the same distribution patterns on the survey reefs. There were 4x more clams on the back reef than on the front, and 2x as many on mid-shelf compared to outer-shelf reefs, although the latter differences were not significant. There were also significantly higher densities of both species on protected reefs compared to fished reefs (table 4).

Only four crown-of-thorns were recorded during this survey: one 25 cm in diameter on the front of Potter Reef, one 40 cm diameter on the back of Pellowe Reef, and two 45 and 50 cm diameter on the back of St. Crispins Reef.

Characteristics of the Survey Reefs.

It is worth considering here how comparable the survey reefs are. Are all the twelve reefs similar? It is clear that mid-shelf reefs as a group differ markedly from outer-shelf reefs, with all except four of the species analysed showing significant cross-shelf differences (table 4). The reefs surveyed within each shelf position and within each zone type were generally similar, with the reef factor not significant for most organisms (table 4).

However, there were a few exceptions to these overall similarities of reefs within each shelf position. Beaver Reef was apparently very different, not only from the other mid-shelf reefs, but from all the survey reefs (see tables i-vi in appendix 1). This reef had high coral cover compared to other mid-shelf reefs; 22.8% cover compared with 12.5% mean cover for the other four reefs. This was also reflected in a higher density of coral feeding chaetodontids on Beaver reef. The other eleven reefs had a mean density of *Monotaxis grandoculis* of 2.71 fish per transect, 8x that recorded on Beaver of 0.33 per transect. Similarly, the two lutjanids *Lutjanus gibbus and L. bohar* were an order of magnitude less abundant on Beaver than on the other survey reefs. On the other hand *Lutjanus carponotatus* and *L. quinquelineatus* were 3x and 2x as abundant respectively on Beaver Reef compared with the other reefs. The density of three of the small fish species was anomalous on Beaver Reef. *Pomacentrus molluccensis* was 8x more abundant, and *Chrysiptera rollandi* 4x more abundant, on Beaver compared to the other eleven reefs, while *Plectroglyphidodon lacrymatus* was absent on Beaver but occurred commonly on all other survey reefs with a mean density of 3.9 fish per transect. Beaver reef also had *T. gigas* density 4x that recorded on the other reefs.

Channel and Pellowe Reefs were generally similar to the other outer-shelf reefs but coral communities on the front reef had been badly damaged by tropical cyclone Joy in December 1990. The smaller of the giant clam species, *T. derasa*, was not recorded on these two reefs although it had a mean density of 3.6 per transect on the other ten reefs.

DISCUSSION.

Effects of Fishing.

Coral trout are the most sought after of the reef fish species, both by commercial and recreational fishermen. Previous studies we have made have suggested that fishing pressure has no significant effect on the density of the common coral trout *Plectropomus leopardus* (Ayling et al in press), a finding that is further supported by the results of the present survey. Grand mean density of coral trout on the five fished reefs was 1.39 fish per transect, almost exactly comparable to the 1.42 recorded from the seven reefs that had been protected from fishing for eight years.

In the previous studies mentioned there was an effect of protection on the length of common coral trout; the mean length of fish was significantly higher on protected reefs than on fished reefs (Ayling et al. in press). Although mean length of this species was slightly higher on the protected reefs in the present survey the difference was not significant (table 5). Similarly, the results from the present survey did not show a significant increase in the number of recruits and juvenile coral trout <35 cm TL on fished reefs compared to protected reefs that had been demonstrated in previous studies and is thought to be partly responsible for the lack of a detectable fishing effect on the density of this species (table 5).

It could be argued that as most of the reefs surveyed in this study were toward the outer edge of the shelf then fishing pressure on the open reefs would not be as great as on reefs closer to the shore and hence a fishing effect might not be expected. However, a fishing effect was not found on mid-shelf reefs off Cairns in the 1991 survey, where reefs are closer to the shore and more assessable to small boat fishermen than in any other area of the GBR. It has also been shown that commercial fishermen take more than half of the coral trout caught in the GBR region (Blamey and Hundloe 1992; Trainor 1991) and their activities are not restricted by distance offshore. It should also be pointed out that the abundance of some lethrinids was apparently affected by fishing on this set of reefs, indicating that fishing pressure was present.

Table 5. Effect of Protection on the Density and Length of Coral Trout.

Results from mid-shelf reefs only. Density of the various categories is in number per hectare, length is total length in cm. Cairns 91 data from Ayling et al. in press; Capricorn 86 data from Ayling and Ayling 1986b.

	Density		Recruits		<35 cm		>35 cm		Length	
Area	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.
This survey	47.4	50.8	5.0	5.6	27.6	26.4	19.0	24.4	31.1	32.4
Cairns 91	45.7	44.7	13.6	7.3	25.9	18.3	19.9	26.4	30.0	35.6
Capricorn 86	49.0	57.0	na	na	26.0	12.0	23.0	45.0	35.7	44.6

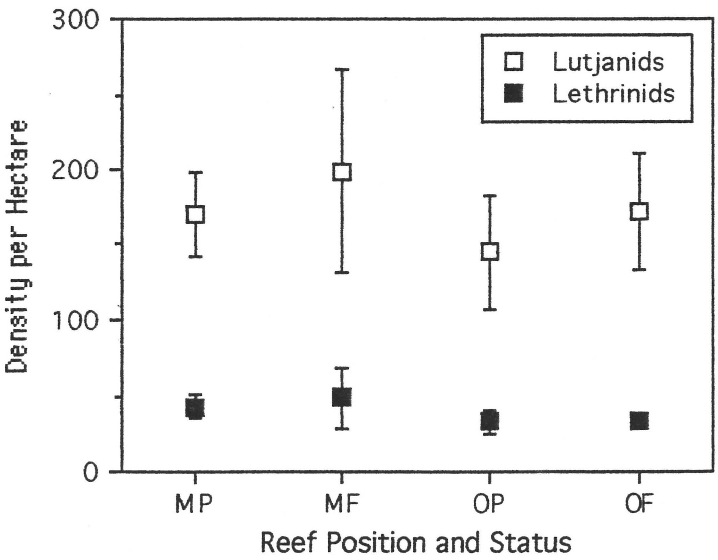
The previous studies mentioned have also looked at the effect of protection on the density of lethrinids and lutjanids. The most important species in these families from the reef fishermen's point of view is the red-throat sweetlip *L. miniatus*. The 1986 survey of ten reefs in the Capricorn-Bunker Group, five of which had been protected from fishing for from 2.5-6 years looked at the density of *Lethrinus miniatus* as well as coral trout (Ayling and Ayling 1986b). Density on the protected reefs was almost 3x higher than on the fished reefs (6.5 vs. 2.3 per ha), a difference that was significant (F=16.77, df=1/8, p=0.004). At the same time the density of this species on the back of nine reefs in the Swain Group was 17.3 per ha (Ayling and Ayling 1986b). During a survey in 1991 of Bramble Reef off Lucinda that had reputedly been subject to heavy fishing pressure the density of *L. miniatus* was an order of magnitude lower than on three control reefs (Ayling and Ayling 1992). Similarly, the present survey found that this species was almost an order of magnitude lower in abundance on the fished mid-shelf reefs compared with the protected reefs. It is apparent that the density of the red-throat sweetlip *L. miniatus* is markedly affected by fishing pressure and should be a prime target for any future surveys.

The surveys on 47 reefs in the Cairns Section in 1991 (Mapstone et al. 1991) did not show any effect of fishing on the total density of Lethrinids, either on mid-shelf or outer-shelf reefs (figure 6). The present survey showed similar overall results but there were significantly lower densities of the most abundant species *L. atkinsoni* on fished mid-shelf reefs compared to protected reefs, in addition to the results presented above for *L. miniatus.*

In the surveys made to date, including the present survey, protection from fishing has not been shown to have any effect on the density of lutjanids (figures 3, 5). Although all lutjanids are caught by fishermen none of the reef dwelling species are targeted in the way that coral trout and *L. miniatus* are. In addition the two most abundant species, *Lutjanus gibbus* and *L. bohar* are not eaten or sold because of the threat of ciguatera poisoning. One of the lutjanids, the stripey *L. carponotatus*, was significantly more abundant on fished reefs compared with protected reefs (but see comments in results section).

Figure 6. Comparison of Lutjanid and Lethrinid Density on Protected and Fished Reefs in the Cairns Section - Jan-Mar 1991.

Data from survey proposed by Mapstone et al. (1991). Figures shown are grand means per hectare from the combined reefs in each category. MP = mid-shelf protected reefs (n=10); MF = mid-shelf fished reefs (n=16); OP = outer-shelf protected reefs (n=8); OF = outer-shelf fished reefs (n=13). Error bars are standard errors.



Discussion of Techniques for the Resurvey of the Study Reefs.

As mentioned previously, although most recent surveys of large fish species have used 50 x 5 m transects it was decided to use wider 50 x 10 m transects for this survey for the following reasons:

1. The information available suggested that they give equivalent estimates of the mean to those provided by 50 x 5 m transects (Ayling and Ayling 1991).

2. They give far fewer zero counts than the 50 x 5 m transects and provide a similarly powerful test of density change for a given effort (Ayling and Ayling 1991).

3. The wider transects increase the number of fish counted per reef and give better estimates of length frequency for the populations of coral trout.

Previous comparisons suggested that 10 m wide transects gave similar estimates of the mean for coral trout to those from 5 m wide transects. Any comparisons of the 50 x 10 m transects from the present survey with the 50 x 5 m transects surveyed on some of the reefs 12 months earlier will be confounded with time. However, all five groups for which comparisons were possible showed nominal reductions, two of which (chaetodontids and lutjanids) were significant at the 0.1 level, indicating that the 50 x 10 m transects may have been underestimating density.

In the present survey 37% of the 50 x 10 m transects recorded zero common coral trout (44% of front reef transects and 22% of back reef transects). On the nine reefs that could be compared with the 1991 surveys using 50 x 5 m transects, 33% of counts recorded zero counts compared with 50% of the transects in 1991. There was also an improvement in precision using the wider transects: overall grand mean precision from the present survey was 0.42 compared with 0.56 for the 5 m wide transects in 1991.

We calculated the minimum change that could be detected with 90% power with a type I error of 0.1 for a range of species and species groups using the results from the analyses (Table 6). These power estimations are based on Cohen (1988) and use the effect size index (f) where $f = s_m/s$, where s_m is the standard deviation of the population means and s is the standard deviation within the populations. In this case an estimation of s is provided by the square root of the denominator mean square from the appropriate F test. When site was the denominator f_{zone}=0.464 (u=1, n'=21).

There was a linear relationship between precision and power (hence minimum detectable change) (figure 7). Power was improved if the pooled residual df was used as the basis of n' (Table 6). In this case, for one group of fished reefs and one of protected reefs, f_{zone}=0.179 (u=1, n'=141).

The power of the common coral trout surveys to detect change with 90% power (20% of the grand mean assuming pooled residual) was better than predicted in the survey proposal (38%). It is also worth noting that if surveys were confined to the back reef habitat and the same effort expended (6 sites), then the power was improved to enable an 18% change to be detected with 90% power. This is because many more zero counts were recorded on front reefs than on back reefs (44% vs. 22%). Similarly, if surveys had been confined to mid-shelf reefs, where density was higher and precision improved, with the same effort a change of only 14% of the mean could be detected with 90% power (Table 6). The survey technique and design used for this survey was adequate for the common coral trout, providing good precision and power.

Table 6. Minimum Detectable Change with 90% Power.

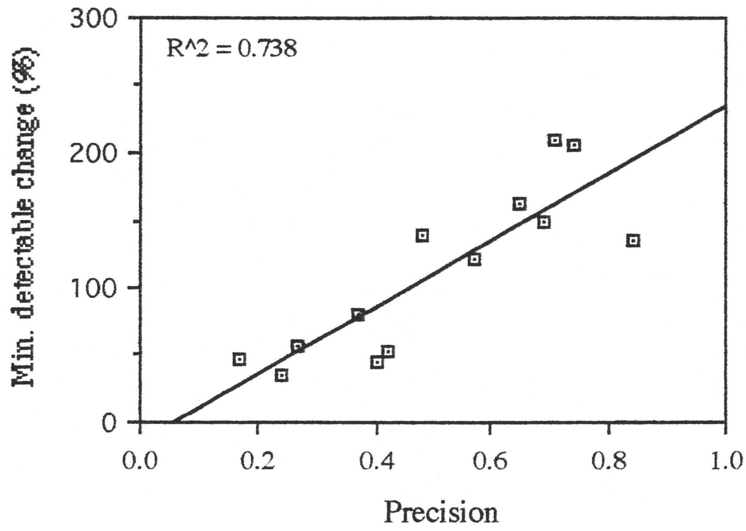
Minimum detectable difference is expressed as a percentage of the grand mean.
* Where site was not significant and tests were made over pooled residual. ** Detectable differences assume equal effort to design used. na = not applicable.

Species/Group	Grand mean	Precision	Minimum detectable difference	* Minimum detectable difference (pooled ms)
Plectropomus leopardus	1.41	0.42	52%	20%
P. leopardus (mid-shelf) **	2.47	0.24	36%	14%
P. leopardus (back reef) **	1.77	0.40	46%	18%
P. laevis	0.17	0.84	136%	60%
Total Lethrinids	0.99	0.57	122%	na
Lethrinus atkinsoni	0.56	0.69	149%	na
Lethrinus miniatus	0.06	0.74	205%	na
Monotaxis grandoculis	2.52	0.37	80%	na
Total Lutjanids	3.91	0.48	140%	na
Lutjanus gibbus	1.15	0.65	162%	na
Lutjanus bohar	0.94	0.71	210%	na
Total Chaetodontids	12.43	0.17	47%	na
Hard Coral Feeding Chaets	6.54	0.27	57%	na

The same technique also provides a reasonably powerful estimate of the mean of chaetodontid populations, but is far less powerful for lethrinids or lutjanids, either as a group or as individual species, or for the bluespot coral trout *P. laevis*. In view of the apparent effect of fishing pressure on the density of at least some of the lethrinids it would be useful in the context of the effects of fishing experiment if the count technique and design could be modified to get more powerful estimates of the density of these species.

Several alternatives are possible to increase power. 1. We could increase replication within each site. This would add over an hour to the reef survey time for each additional replicate (6 x 10-12 minutes), and the addition of even one replicate per site would mean that a reef would take more than a day to survey. In our experience there is no way we could cut down the time taken for each count and increase replication by modifying the technique; even leaving out all the return surveys (small fish, *Drupella* etc.) would only save a minute or so per transect and would not leave time for an extra replicate per site. Laying out transect lines and picking them up from the boat is far more time consuming than doing it underwater and is only possible at some sites.

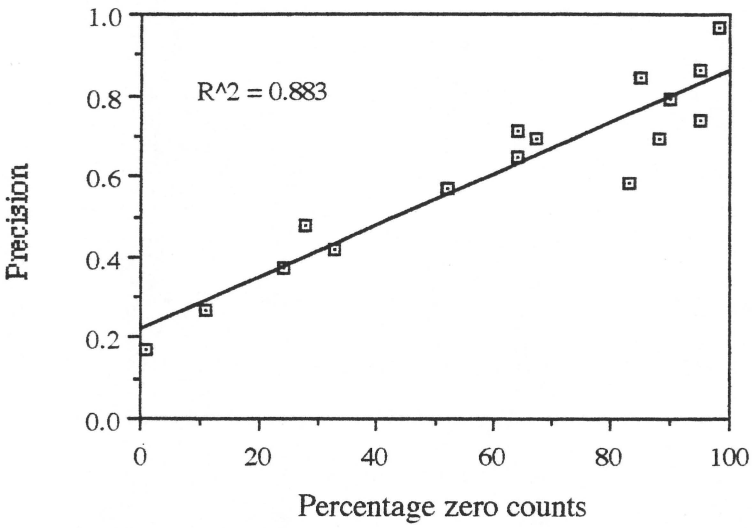
Figure 7. Relationship of Minimum Detectable Difference to Precision.



2. We could increase the number of sites. This could be done either by increasing the number of sites per habitat, adding 3 hours to the reef survey time for each additional pair of sites, or by restricting surveys to a single habitat.

3. In view of the relationship between precision and power (figure 7), and between precision and the number of zero counts (figure 8), we could also increase power by increasing the area of each transect and reducing the number of zero counts. As an extreme example, a ten times increase in area to 500 x 10 m or 0.5 ha would give grand means of 1.7 fish per transect for *P. laevis*, and ranging from 0.6 fish per transect for *Lethrinus miniatus* to 5.6 for *Lethrinus atkinsoni* for the lethrinids, and from 3.0 for *Lutjanus carponotatus* to 11.5 for *Lutjanus gibbus* for the lutjanids with corresponding decreases in the likelihood of zero counts. Each transect would take about 60 mins to survey and would take the place of a site in the present design. Six transects could be surveyed in a day, either three in each habitat or six on the back reef habitat. This technique would need to be tested to confirm an improvement in power for a corresponding effort.

Figure 8. Relationship of Precision to Zero Counts.



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APPENDIX 1. DENSITY SUMMARIES FROM THE SURVEYS.

Table i. Summary of Density of Fishing Target Species: Coral Trout.

Figures show means from 50 x 10 m transects from all reefs grouped in various categories with standard deviations in italics.

	P. leopardus		Trout recruits		Trout <35 cm		Trout >35 cm		*P. laevis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	1.39	*1.46*	0.10	*0.34*	0.73	*1.04*	0.65	*1.02*	0.14	*0.38*
Protected Reefs	1.42	*1.52*	0.12	*0.40*	0.66	*1.05*	0.77	*0.96*	0.20	*0.46*
Fished Front	1.12	*1.24*	0.15	*0.43*	0.64	*0.94*	0.45	*0.78*	0.20	*0.46*
Protected Front	0.99	*1.38*	0.14	*0.45*	0.47	*0.96*	0.53	*0.84*	0.17	*0.45*
Fished Back	1.67	*1.61*	0.05	*0.23*	0.81	*1.14*	0.85	*1.18*	0.08	*0.27*
Protected Back	1.85	*1.54*	0.10	*0.34*	0.85	*1.11*	1.00	*1.02*	0.22	*0.48*
Fished Outer Shelf	0.74	*1.15*	-	-	0.29	*0.66*	0.46	*0.77*	0.20	*0.45*
Protected Outer	0.58	*0.89*	0.01	*0.09*	0.16	*0.43*	0.43	*0.72*	0.24	*0.50*
Fished Mid-Shelf	2.37	*1.34*	0.25	*0.51*	1.38	*1.17*	0.95	*1.25*	0.05	*0.22*
Protected Mid	2.54	*1.45*	0.28	*0.56*	1.32	*1.25*	1.22	*1.06*	0.13	*0.40*
Habitat										
Front Reef	1.04	*1.32*	0.14	*0.44*	0.54	*0.95*	0.50	*0.82*	0.18	*0.45*
Back Reef	1.77	*1.57*	0.08	*0.30*	0.83	*1.12*	0.94	*1.09*	0.16	*0.41*
Shelf Position										
Outer Shelf Reefs	0.65	*1.01*	0.00	*0.07*	0.21	*0.54*	0.44	*0.74*	0.22	*0.48*
Mid-Shelf Reefs	2.47	*1.41*	0.27	*0.54*	1.35	*1.22*	1.11	*1.14*	0.10	*0.34*
Outer Shelf Front	0.22	*0.46*	-	-	0.07	*0.25*	0.16	*0.40*	0.27	*0.54*
Outer Shelf Back	1.08	*1.21*	0.01	*0.10*	0.36	*0.70*	0.71	*0.88*	0.18	*0.41*
Mid-Shelf Front	2.20	*1.26*	0.35	*0.63*	1.20	*1.16*	0.97	*1.00*	0.07	*0.25*
Mid-Shelf Back	2.75	*1.50*	0.19	*0.43*	1.49	*1.26*	1.25	*1.26*	0.13	*0.41*
Reef Means										
Wardle	2.70	*1.53*	0.10	*0.31*	1.13	*1.17*	1.57	*1.22*	0.20	*0.48*
Nathan	2.73	*1.44*	0.30	*0.53*	1.67	*1.15*	1.07	*1.44*	0.10	*0.31*
Potter	2.00	*1.14*	0.20	*0.48*	1.10	*1.12*	0.83	*1.05*	-	-
Northeaster	2.03	*1.22*	0.27	*0.52*	1.13	*1.17*	0.90	*0.88*	0.17	*0.46*
Beaver	2.90	*1.49*	0.47	*0.73*	1.70	*1.37*	1.20	*0.96*	0.03	*0.18*
Channel	0.43	*0.77*	-	-	0.13	*0.43*	0.30	*0.65*	0.17	*0.46*
Pellowe	0.43	*0.57*	-	-	0.13	*0.35*	0.3	*0.53*	0.03	*0.18*
St. Crispins	1.50	*1.55*	-	-	0.63	*0.96*	0.87	*1.01*	0.13	*0.35*
Agincourt 3	0.67	*0.92*	0.03	*0.18*	0.10	*0.31*	0.57	*0.77*	0.27	*0.52*
Escape	0.43	*0.77*	-	-	0.07	*0.25*	0.37	*0.76*	0.20	*0.48*
Ruby	0.30	*0.65*	-	-	0.10	*0.31*	0.20	*0.48*	0.43	*0.63*
Ribbon #4	0.77	*1.04*	-	-	0.33	*0.61*	0.47	*0.68*	0.33	*0.55*
Grand Mean	1.41	*1.49*	0.11	*0.37*	0.69	*1.05*	0.72	*0.99*	0.17	*0.43*

Table ii. Summary of Density of Fishing Target Species: Lethrinids.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lethrinidae		*Lethrinus atkinsoni*		*Lethrinus obsoletus*		*Lethrinus miniatus*		*Monotaxis grandoculis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	0.83	*1.35*	0.47	*0.90*	0.16	*0.51*	0.01	*0.16*	2.79	*3.60*
Protected Reefs	1.10	*1.52*	0.63	*1.03*	0.12	*0.42*	0.09	*0.33*	2.32	*2.29*
Fished Front	0.68	*0.97*	0.41	*0.76*	0.03	*0.16*	0.03	*0.23*	2.23	*2.35*
Protected Front	0.91	*1.37*	0.64	*1.07*	0.01	*0.10*	0.08	*0.30*	2.25	*2.52*
Fished Back	0.97	*1.64*	0.53	*1.03*	0.29	*0.67*	-	-	3.36	*4.46*
Protected Back	1.30	*1.64*	0.62	*0.99*	0.23	*0.56*	0.10	*0.36*	2.39	*2.05*
Fished Outer Shelf	1.20	*1.57*	0.72	*1.06*	0.23	*0.62*	-	-	3.50	*4.31*
Protected Outer	1.21	*1.41*	0.75	*1.06*	0.10	*0.42*	-	-	2.98	*2.37*
Fished Mid-Shelf	0.27	*0.58*	0.10	*0.35*	0.05	*0.22*	0.03	*0.26*	1.73	*1.67*
Protected Mid	0.97	*1.65*	0.47	*0.96*	0.14	*0.41*	0.21	*0.49*	1.44	*1.86*
Habitat										
Front Reef	0.82	*1.22*	0.54	*0.95*	0.02	*0.13*	0.06	*0.27*	2.24	*2.44*
Back Reef	1.16	*1.64*	0.58	*1.01*	0.26	*0.61*	0.06	*0.28*	2.79	*3.30*
Shelf Position										
Outer Shelf Reefs	1.20	*1.48*	0.74	*1.06*	0.16	*0.52*	-	-	3.20	*3.34*
Mid-Shelf Reefs	0.69	*1.37*	0.32	*0.80*	0.11	*0.35*	0.14	*0.42*	1.56	*1.79*
Outer Shelf Front	0.94	*1.18*	0.67	*1.01*	-	-	-	-	2.90	*2.75*
Outer Shelf Back	1.47	*1.69*	0.81	*1.11*	0.31	*0.70*	-	-	3.50	*3.83*
Mid-Shelf Front	0.64	*1.27*	0.37	*0.85*	0.04	*0.20*	0.13	*0.41*	1.31	*1.51*
Mid-Shelf Back	0.73	*1.47*	0.27	*0.74*	0.17	*0.45*	0.15	*0.43*	1.81	*2.00*
Reef Means										
Wardle	0.73	*1.01*	0.33	*0.76*	0.20	*0.55*	0.20	*0.48*	1.83	*1.80*
Nathan	0.27	*0.58*	0.07	*0.25*	0.07	*0.25*	0.07	*0.37*	1.50	*1.11*
Potter	0.27	*0.58*	0.13	*0.43*	0.03	*0.18*	-	-	1.97	*2.08*
Northeaster	1.30	*1.84*	0.50	*1.04*	0.17	*0.38*	0.33	*0.55*	2.17	*2.26*
Beaver	0.87	*1.94*	0.57	*1.07*	0.07	*0.25*	0.10	*0.40*	0.33	*0.55*
Channel	1.23	*1.52*	0.77	*1.10*	0.27	*0.69*	-	-	0.93	*1.11*
Pellowe	0.90	*1.16*	0.50	*0.78*	0.20	*0.61*	-	-	2.63	*3.00*
St. Crispins	1.67	*2.06*	1.00	*1.23*	0.43	*0.82*	-	-	4.90	*6.48*
Agincourt 3	0.77	*0.94*	0.47	*0.78*	0.03	*0.18*	-	-	3.17	*1.93*
Escape	1.03	*1.07*	0.73	*1.01*	-	-	-	-	3.57	*1.81*
Ruby	1.03	*1.30*	0.67	*1.09*	0.07	*0.25*	-	-	2.97	*1.67*
Ribbon #4	1.80	*1.79*	1.03	*1.27*	0.10	*0.40*	-	-	4.23	*2.90*
Grand Mean	0.99	*1.45*	0.56	*0.98*	0.14	*0.46*	0.06	*0.28*	2.52	*2.91*

Table iii. Summary of Density of Fishing Target Species: Lutjanids.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lutjanidae		*Lutjanus gibbus*		*Lutjanus bohar*		*Lutjanus quinquelineatus*		*Lutjanus carponotatus*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect										
Fished Reefs	4.16	*6.73*	1.18	*3.01*	1.26	*3.75*	0.39	*1.21*	0.31	*0.73*
Protected Reefs	3.74	*4.98*	1.12	*2.17*	0.70	*1.19*	0.44	*1.60*	0.29	*0.73*
Fished Front	4.55	*7.25*	1.09	*1.85*	1.84	*4.74*	0.28	*1.05*	0.27	*0.70*
Protected Front	4.90	*5.93*	1.90	*2.74*	0.79	*1.01*	0.47	*1.56*	0.27	*0.65*
Fished Back	3.77	*6.19*	1.27	*3.85*	0.68	*2.28*	0.51	*1.36*	0.36	*0.76*
Protected Back	2.58	*3.47*	0.34	*0.85*	0.62	*1.34*	0.41	*1.64*	0.30	*0.81*
Fished Outer Shelf	4.61	*7.53*	1.32	*2.57*	1.92	*4.71*	0.04	*0.33*	0.06	*0.27*
Protected Outer	4.56	*5.78*	1.73	*2.62*	0.99	*1.39*	-	-	-	-
Fished Mid-Shelf	3.48	*5.28*	0.97	*3.59*	0.27	*0.61*	0.92	*1.76*	0.70	*1.00*
Protected Mid	2.64	*3.40*	0.32	*0.88*	0.32	*0.68*	1.02	*2.32*	0.67	*1.01*
Habitat										
Front Reef	4.75	*6.49*	1.57	*2.44*	1.23	*3.18*	0.39	*1.37*	0.27	*0.67*
Back Reef	3.08	*4.81*	0.73	*2.60*	0.64	*1.79*	0.45	*1.53*	0.33	*0.79*
Shelf Position										
Outer Shelf Reefs	4.58	*6.57*	1.55	*2.60*	1.39	*3.28*	0.02	*0.22*	0.02	*0.18*
Mid-Shelf Reefs	2.98	*4.25*	0.58	*2.38*	0.30	*0.65*	0.98	*2.11*	0.68	*1.00*
Outer Shelf Front	6.28	*7.84*	2.48	*2.79*	1.79	*4.04*	-	-	0.01	*0.10*
Outer Shelf Back	2.89	*4.42*	0.63	*2.01*	0.99	*2.24*	0.04	*0.31*	0.04	*0.24*
Mid-Shelf Front	2.61	*2.77*	0.29	*0.77*	0.44	*0.76*	0.93	*2.00*	0.63	*0.93*
Mid-Shelf Back	3.35	*5.34*	0.87	*3.26*	0.16	*0.49*	1.03	*2.22*	0.73	*1.07*
Reef Means										
Wardle	1.87	*2.06*	0.47	*1.01*	0.57	*0.82*	0.27	*1.14*	0.20	*0.41*
Nathan	1.47	*1.63*	0.20	*0.48*	0.13	*0.43*	0.10	*0.40*	0.77	*0.90*
Potter	5.50	*6.76*	1.73	*4.98*	0.40	*0.72*	1.73	*2.18*	0.63	*1.10*
Northeaster	1.60	*3.04*	0.40	*1.07*	0.40	*0.77*	0.73	*2.32*	-	-
Beaver	4.47	*4.09*	0.10	*0.40*	-	-	2.07	*2.84*	1.80	*0.96*
Channel	2.23	*3.39*	0.77	*2.13*	0.77	*1.48*	-	-	-	-
Pellowe	3.40	*4.57*	1.07	*2.07*	1.10	*1.71*	0.03	*0.18*	0.07	*0.25*
St. Crispins	3.53	*6.63*	1.40	*3.55*	1.33	*3.24*	0.10	*0.55*	-	-
Agincourt 3	3.63	*3.49*	1.60	*1.94*	1.03	*1.25*	-	-	-	-
Escape	4.63	*5.10*	2.10	*2.55*	1.03	*1.10*	-	-	-	-
Ruby	6.90	*10.1*	1.50	*1.80*	3.33	*7.18*	-	-	0.10	*0.40*
Ribbon #4	7.73	*8.40*	2.43	*3.41*	1.13	*1.70*	-	-	-	-
Grand Mean	3.91	*5.77*	1.15	*2.55*	0.94	*2.60*	0.42	*1.45*	0.30	*0.73*

Table iv. Summary of Density of Chaetodontids and Giant Clams (*Tridacna* spp.).

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics. Note: Coral Chaets = hard coral feeding chaetodontids.

	Chaetodontids		Coral Chaets		*T. gigas*		*T. derasa*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect								
Fished Reefs	12.86	*7.05*	6.45	*5.24*	0.07	*0.31*	0.21	*0.47*
Protected Reefs	12.11	*7.22*	6.60	*5.30*	0.21	*0.51*	0.37	*0.77*
Fished Front	10.84	*4.70*	4.56	*3.17*	0.04	*0.20*	0.12	*0.40*
Protected Front	10.87	*6.67*	4.84	*3.67*	0.14	*0.40*	0.15	*0.41*
Fished Back	14.88	*8.34*	8.33	*6.17*	0.11	*0.39*	0.29	*0.51*
Protected Back	13.36	*7.56*	8.36	*6.05*	0.29	*0.60*	0.58	*0.96*
Fished Outer Shelf	15.30	*7.63*	8.53	*5.63*	0.04	*0.21*	0.14	*0.41*
Protected Outer	15.00	*7.36*	7.93	*5.63*	0.11	*0.38*	0.20	*0.56*
Fished Mid-Shelf	9.20	*3.85*	3.32	*2.23*	0.12	*0.42*	0.30	*0.53*
Protected Mid	8.27	*4.90*	4.83	*4.25*	0.36	*0.62*	0.59	*0.93*
Habitat								
Front Reef	10.86	*5.92*	4.72	*3.47*	0.10	*0.34*	0.14	*0.41*
Back Reef	13.99	*7.91*	8.35	*6.09*	0.21	*0.53*	0.46	*0.81*
Shelf Position								
Outer Shelf Reefs	15.13	*7.46*	8.19	*5.63*	0.08	*0.32*	0.18	*0.50*
Mid-Shelf Reefs	8.64	*4.52*	4.23	*3.65*	0.26	*0.56*	0.47	*0.81*
Outer Shelf Front	12.31	*6.43*	4.90	*3.60*	-	-	0.01	*0.10*
Outer Shelf Back	17.94	*7.38*	11.47	*5.37*	0.16	*0.44*	0.34	*0.66*
Mid-Shelf Front	8.81	*4.41*	4.47	*3.27*	0.24	*0.49*	0.32	*0.57*
Mid-Shelf Back	8.47	*4.65*	3.99	*3.99*	0.28	*0.63*	0.63	*0.97*
Reef Means								
Wardle	8.23	*3.68*	3.87	*2.85*	0.27	*0.74*	0.43	*0.77*
Nathan	7.97	*3.72*	3.67	*2.47*	0.07	*0.25*	0.37	*0.61*
Potter	10.43	*3.64*	2.97	*1.94*	0.17	*0.53*	0.23	*0.43*
Northeaster	5.77	*3.18*	2.67	*2.50*	0.27	*0.45*	0.90	*1.27*
Beaver	10.8	*6.07*	7.97	*5.01*	0.53	*0.63*	0.43	*0.57*
Channel	9.03	*5.22*	4.17	*3.88*	0.10	*0.31*	-	-
Pellowe	14.90	*8.86*	8.47	*7.01*	0.03	*0.18*	-	-
St. Crispins	16.50	*7.99*	8.17	*5.06*	0.03	*0.18*	0.20	*0.48*
Agincourt 3	19.13	*7.83*	11.47	*7.15*	0.03	*0.18*	0.07	*0.25*
Escape	15.40	*6.38*	8.23	*4.59*	0.23	*0.63*	0.33	*0.71*
Ruby	14.50	*5.84*	8.97	*4.72*	0.07	*0.25*	0.23	*0.50*
Ribbon #4	16.43	*6.02*	7.83	*3.89*	0.07	*0.25*	0.40	*0.77*
Grand Mean	12.43	*7.15*	6.54	*5.27*	0.16	*0.45*	0.30	*0.66*

Table v. Summary of Density of Prey Species: Pomacentrids.

Figures show means from 20 x 2.5 m transects grouped in various categories with standard deviations in italics. *Pom. molluc.* = *Pomacentrus molluccensis*, *Ambly.* = *Amblyglyphidodon curacao*, *Chrysiptera* = *C. rollandi*, *Pl. lacry.* = *Plectroglyphidodon lacrymatus*, *Pl. dicki* = *Plectroglyphidodon dicki.*

	Pom. molluc.		*Ambly.*		*Chrysiptera*		*Pl. lacry.*		*Pl. dicki*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	8.6	*11.7*	1.42	*2.51*	2.79	*5.00*	2.79	*4.48*	0.75	*2.05*
Protected Reefs	12.6	*25.6*	1.55	*2.54*	2.08	*4.52*	4.03	*5.58*	0.54	*1.56*
Fished Front	3.1	*7.5*	0.87	*2.81*	0.41	*1.50*	4.08	*5.60*	1.44	*2.71*
Protected Front	5.8	*13.8*	0.99	*2.27*	0.43	*1.71*	3.92	*6.00*	1.05	*2.06*
Fished Back	14.0	*12.7*	1.97	*2.05*	5.17	*6.05*	1.87	*2.56*	0.05	*0.32*
Protected Back	19.4	*32.2*	2.11	*2.68*	3.73	*5.71*	4.13	*5.15*	0.04	*0.31*
Fished Outer Shelf	6.6	*11.9*	0.74	*1.30*	1.50	*3.91*	2.36	*3.96*	1.23	*2.53*
Protected Outer	5.1	*8.6*	0.69	*1.54*	1.06	*2.20*	4.48	*5.50*	0.88	*1.94*
Fished Mid-Shelf	11.4	*10.9*	2.43	*3.41*	4.73	*5.81*	3.90	*5.05*	0.02	*0.13*
Protected Mid	22.7	*35.5*	2.70	*3.10*	3.44	*6.18*	3.43	*5.65*	0.10	*0.54*
Habitat										
Front Reef	4.7	*11.7*	0.94	*2.50*	0.42	*1.62*	3.99	*5.82*	1.21	*2.36*
Back Reef	17.2	*26.0*	2.06	*2.43*	4.33	*5.89*	3.19	*4.40*	0.04	*0.31*
Shelf Position										
Outer Shelf Reefs	5.7	*10.2*	0.71	*1.44*	1.25	*3.05*	3.57	*5.01*	1.03	*2.22*
Mid-Shelf Reefs	18.2	*28.8*	2.59	*3.22*	3.96	*6.05*	3.62	*5.40*	0.07	*0.43*
Outer Shelf Front	-	-	-	-	-	-	3.22	*5.41*	1.98	*2.80*
Outer Shelf Back	11.5	*11.9*	1.43	*1.78*	2.50	*3.95*	3.91	*4.57*	0.08	*0.41*
Mid-Shelf Front	11.2	*15.9*	2.25	*3.48*	1.01	*2.40*	5.07	*6.23*	0.13	*0.60*
Mid-Shelf Back	25.1	*36.4*	2.93	*2.91*	6.91	*7.10*	2.17	*3.97*	-	-
Reef Means										
Wardle	6.1	*7.0*	2.17	*3.06*	0.93	*1.70*	9.17	*6.47*	0.03	*0.18*
Nathan	10.7	*9.7*	2.63	*4.33*	3.80	*4.15*	4.77	*5.42*	-	-
Potter	12.1	*12.2*	2.23	*2.19*	5.67	*7.04*	3.03	*4.57*	0.03	*0.18*
Northeaster	6.5	*6.6*	3.03	*3.13*	1.30	*2.60*	1.13	*2.10*	0.27	*0.91*
Beaver	55.4	*46.0*	2.90	*3.13*	8.10	*8.60*	-	-	-	-
Channel	3.3	*5.2*	0.60	*1.07*	0.67	*1.52*	3.13	*4.24*	0.37	*1.22*
Pellowe	2.5	*3.4*	0.63	*0.89*	0.30	*0.92*	1.77	*2.28*	0.67	*1.67*
St. Crispins	13.5	*17.5*	0.87	*1.53*	3.63	*6.10*	2.63	*4.06*	0.83	*1.93*
Agincourt 3	7.2	*10.3*	0.7	*0.99*	1.30	*2.53*	4.77	*5.56*	1.50	*2.66*
Escape	6.5	*11.5*	1.00	*2.51*	1.17	*2.45*	5.73	*6.78*	0.87	*1.61*
Ruby	3.9	*6.5*	0.73	*1.44*	0.57	*1.36*	2.67	*5.10*	2.20	*3.42*
Ribbon #4	3.3	*5.2*	0.47	*1.11*	1.10	*2.22*	4.27	*5.08*	0.77	*1.91*
Grand Mean	10.9	*21.0*	1.50	*2.52*	2.38	*4.73*	3.59	*5.17*	0.63	*1.78*

Table vi. Summary of Cover of Encrusting Organisms and *Drupella* Damage.

Figures show means from 20 m line intersect transects for the cover of encrusting organisms, from 30 x 1 m transects for coral colony density, and the percentage of coral colonies damaged by *Drupella* grazing in 30 x 1 m transects, grouped in various categories with standard deviations in italics.

	% Hard coral		% Soft coral		Coral colonies		*Drupella* damage	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect								
Fished Reefs	17.7	*12.2*	15.7	*13.5*	80.8	*57.7*	0.21	*0.47*
Protected Reefs	20.6	*13.0*	9.60	*11.4*	95.6	*61.6*	0.37	*0.77*
Fished Front	15.7	*8.72*	15.2	*12.4*	101.4	*72.2*	0.12	*0.40*
Protected Front	20.0	*12.2*	12.1	*13.2*	119.0	*74.0*	0.15	*0.41*
Fished Back	19.7	*14.6*	16.1	*14.5*	60.2	*24.7*	0.29	*0.51*
Protected Back	21.1	*13.9*	7.1	*8.7*	72.2	*32.4*	0.58	*0.96*
Fished Outer Shelf	22.4	*12.9*	13.4	*14.6*	88.2	*66.3*	0.14	*0.41*
Protected Outer	23.1	*13.2*	6.6	*9.4*	107.7	*68.7*	0.20	*0.56*
Fished Mid-Shelf	10.6	*6.2*	19.1	*10.7*	69.6	*39.4*	0.30	*0.53*
Protected Mid	17.2	*12.1*	13.6	*12.7*	79.5	*46.3*	0.59	*0.93*
Habitat								
Front Reef	18.2	*11.1*	13.4	*13.0*	111.7	*73.6*	0.14	*0.41*
Back Reef	20.5	*14.1*	10.8	*12.3*	67.2	*30.0*	0.46	*0.81*
Shelf Position								
Outer Shelf Reefs	22.8	*13.0*	9.5	*12.3*	99.4	*68.2*	0.18	*0.50*
Mid-Shelf Reefs	14.6	*10.7*	15.8	*12.2*	75.5	*43.8*	0.47	*0.81*
Outer Shelf Front	19.4	*10.5*	10.3	*11.8*	125.3	*85.6*	0.01	*0.10*
Outer Shelf Back	26.2	*14.3*	8.7	*12.9*	73.5	*26.0*	0.34	*0.66*
Mid-Shelf Front	16.5	*11.6*	17.8	*13.3*	92.6	*46.7*	0.32	*0.57*
Mid-Shelf Back	12.6	*9.2*	13.9	*10.7*	58.4	*33.0*	0.63	*0.97*
Reef Means								
Wardle	13.8	*7.7*	21.2	*15.3*	97.8	*36.1*	0.77	*0.93*
Nathan	10.2	*5.2*	17.7	*9.4*	61.6	*23.2*	1.72	*2.51*
Potter	11.0	*7.1*	20.5	*11.9*	77.6	*49.8*	1.12	*2.17*
Northeaster	15.0	*12.2*	9.5	*9.3*	46.1	*31.9*	2.04	*4.28*
Beaver	22.8	*14.0*	10.3	*9.2*	94.6	*50.2*	2.0	*2.73*
Channel	14.6	*12.1*	6.4	*9.5*	54.8	*31.3*	3.11	*3.51*
Pellowe	21.6	*16.4*	18.2	*18.6*	49.6	*25.8*	2.57	*2.63*
St. Crispins	22.4	*13.6*	14.8	*12.9*	71.6	*30.5*	4.17	*3.48*
Agincourt 3	30.6	*12.9*	5.0	*9.9*	105.4	*43.6*	3.50	*3.32*
Escape	24.9	*13.0*	6.0	*7.1*	117.8	*68.8*	3.36	*3.63*
Ruby	23.2	*7.1*	7.1	*8.9*	143.6	*83.1*	4.04	*3.90*
Ribbon #4	22.2	*9.4*	8.9	*10.6*	153.0	*81.3*	1.94	*2.27*
Grand Mean	19.4	*12.7*	12.1	*12.7*	89.4	*60.4*	2.53	*3.21*

Reef/Site	#1	#2	#3	#4	#5	Mean	Reef mean	
Wardle							9.80	
Site 1	9.9	10.6	9.8	9.7	10	10		**Grand Mean**
Site 2	11	9.8	10.5	9.2	10.2	10.14		**9.93**
Site 3	10.3	8.8	11.2	9.5	9.3	9.82		**Std. Dev.**
Site 4	10.1	9.3	8.8	9.5	9.6	9.46		**0.65**
Site 5	10.7	8.9	9.4	8.9	10.3	9.64		**Max. Est.**
Site 6	8.6	10.8	8.5	11.4	9.3	9.72		**11.80**
Nathan							9.97	**Min. Est.**
Site 1	10.6	10.1	9.6	10.4	11	10.34		**8.40**
Site 2	11	10.1	8.9	9.8	11.2	10.2		
Site 3	10	9.7	9.6	9.6	10.3	9.84		
Site 4	9.4	9.4	11.2	8.4	9.5	9.58		
Site 5	9.1	11.1	9.5	10	10	9.94		
Site 6	10.1	8.5	11.4	9.7	9.9	9.92		
Potter							9.98	
Site 1	10.2	11	9.4	10.5	10	10.22		
Site 2	10.1	9.7	9.9	10	9	9.74		
Site 3	9.8	9.8	9.7	10.7	10	10		
Site 4	9.2	9.7	10.4	9.9	8.8	9.6		
Site 5	10.2	9.8	9.8	8.9	11.1	9.96		
Site 6	10.4	10.8	10.3	10	10.2	10.34		
North Easter							10.06	
Site 1	9.8	10.3	11.1	9.7	10.4	10.26		
Site 2	10.3	10.5	10.2	10.9	10	10.38		
Site 3	9.3	10.5	9.5	11.1	9.8	10.04		
Site 4	9.4	10.3	9.2	10.1	10.4	9.88		
Site 5	9.3	9.7	11.2	10	10	10.04		
Site 6	9.6	9.9	9.9	9.3	10	9.74		
Beaver							9.83	
Site 1	10.2	9.5	9.7	10	8.9	9.66		
Site 2	11.2	10.3	8.4	9.3	10	9.84		
Site 3	9.8	9.7	9.7	10.3	10	9.9		
Site 4	10	8.9	10.9	11.2	9.7	10.14		
Site 5	9.3	8.9	9.4	11.2	9.7	9.7		
Site 6	9.7	9.6	10.6	9.2	9.5	9.72		
Channel							9.99	
Site 1	10.6	10.4	10.7	9.4	9.4	10.1		
Site 2	9.6	11.3	10.4	9.1	9	9.88		
Site 3	9.8	10.8	9.3	10.4	10.4	10.14		
Site 4	9.7	9.8	9.2	11.6	8.7	9.8		
Site 5	9.7	9	11.5	9.8	9.9	9.98		
Site 6	10	10.1	11.5	8.7	10	10.06		
Pellowe							9.80	
Site 1	10.7	9.7	9.8	10.9	8.9	10		
Site 2	10.2	9.5	10.7	9.6	9.5	9.9		
Site 3	10	10	10.6	8.9	10.6	10.02		
Site 4	9.6	10.3	9.9	9.4	8.9	9.62		
Site 5	9.8	9.4	10	9	9.9	9.62		
Site 6	9.4	9.8	10	9.6	9.5	9.66		

Reef/Site	#1	#2	#3	#4	#5	Mean	Reef mean
St. Crispins							9.97
Site 1	9.6	9.1	9.6	10.7	9.6	9.72	
Site 2	10.6	11.5	9.8	8.6	9.5	10	
Site 3	10.4	10.7	10.5	10	10.3	10.38	
Site 4	10.5	10.5	9.4	9.3	9.7	9.88	
Site 5	10.1	10.1	10.1	10	9.9	10.04	
Site 6	9.6	9	10.5	9.8	10	9.78	
Agincourt 3							9.97
Site 1	8.8	10	10	10.8	10	9.92	
Site 2	8.9	10	10.7	10.4	10.4	10.08	
Site 3	10.7	9.4	10	10.3	9.3	9.94	
Site 4	9.8	9.8	9.7	9.6	11.4	10.06	
Site 5	9.5	11.8	9.1	9	10.3	9.94	
Site 6	8.8	9.5	11.4	10.5	9.3	9.9	
Escape							10.06
Site 1	11.1	10.2	9.7	9.9	10.3	10.24	
Site 2	9.9	9.7	10.6	9.9	10.4	10.1	
Site 3	9.4	10	10.8	9.3	11	10.1	
Site 4	9.7	10.1	9.3	9.4	9.7	9.64	
Site 5	10.6	9.5	10.8	9.9	10.4	10.24	
Site 6	9.5	10	9.2	9.8	11.8	10.06	
Ruby							9.89
Site 1	10.3	10	9	10.1	10.3	9.94	
Site 2	9.8	9.9	10.1	9.8	10.1	9.94	
Site 3	10.1	10.8	8.9	11.1	9.2	10.02	
Site 4	9.8	10.5	10	9.4	9.6	9.86	
Site 5	9.8	9.7	10.2	10.4	9.3	9.88	
Site 6	9.7	10.1	9.6	9.8	9.4	9.72	
Ribbon #4							9.87
Site 1	10.5	9.6	10.3	9.6	9.6	9.92	
Site 2	9.4	9.6	9.9	9.8	10.2	9.78	
Site 3	9.8	9.5	10.1	10	10.2	9.92	
Site 4	10.3	9.1	9.3	9	10	9.54	
Site 5	10.4	9.5	10	9.7	10	9.92	
Site 6	11.3	10.4	10.2	9.5	9.3	10.14	

Fish #	Actual TL (cm)	Est. TL: 1 (cm)	Error (cm)	Error/TL (%)	Est. TL: 2 (cm)	Error (cm)	Error/TL (%)
1	48	45	-3	6.25	50	2	4.17
2	38	36	-2	5.26	39	1	2.63
3	26	26	0	0.00	26	0	0.00
4	44	38	-6	13.64	46	2	4.55
5	36	36	0	0.00	40	4	11.11
6	57	55	-2	3.51	52	-5	8.77
7	88	88	0	0.00	88	0	0.00
8	70	68	-2	2.86	68	-2	2.86
9	47	43	-4	8.51	47	0	0.00
10	6	6	0	0.00	6	0	0.00
11	18	18	0	0.00	18	0	0.00
12	43	42	-1	2.33	44	1	2.33
13	77	72	-5	6.49	80	3	3.90
14	64	57	-7	10.94	65	1	1.56
15	66	65	-1	1.52	65	-1	1.52
16	12	12	0	0.00	12	0	0.00
17	60	50	-10	16.67	62	2	3.33
18	40	40	0	0.00	42	2	5.00
19	41	38	-3	7.32	43	2	4.88
20	78	73	-5	6.41	74	-4	5.13
21	24	24	0	0.00	28	4	16.67
22	68	65	-3	4.41	67	-1	1.47
23	50	47	-3	6.00	46	-4	8.00
24	28	28	0	0.00	29	1	3.57
25	75	76	1	1.33	67	-8	10.67
26	40	40	0	0.00	40	0	0.00
27	58	58	0	0.00	55	-3	5.17
28	58	58	0	0.00	57	-1	1.72
29	53	52	-1	1.89	60	7	13.21
30	52	54	2	3.85	48	-4	7.69
31	61	58	-3	4.92	60	-1	1.64
32	49	46	-3	6.12	48	-1	2.04
33	30	32	2	6.67	32	2	6.67
34	76	76	0	0.00	75	-1	1.32
35	32	35	3	9.38	32	0	0.00
36	62	62	0	0.00	60	-2	3.23
37	45	46	1	2.22	44	-1	2.22
38	53	52	-1	1.89	53	0	0.00
39	46	44	-2	4.35	50	4	8.70
40	22	25	3	13.64	24	2	9.09
41	82	85	3	3.66	68	-14	17.07
42	55	53	-2	3.64	52	-3	5.45
43	36	37	1	2.78	35	-1	2.78
44	75	72	-3	4.00	68	-7	9.33
45	42	42	0	0.00	42	0	0.00
46	62	60	-2	3.23	60	-2	3.23
47	34	34	0	0.00	34	0	0.00
Mean	49.51	48.28	-1.23	3.74	48.96	-0.55	4.31

APPENDIX 4. ANALYSIS OF VARIANCE TABLES

Note that for all analyses except those for total chaetodontids the raw data has been square-root transformed after the addition of 0.5 to each datum. See table 2 in the main body of the report for analysis details.

A. Comparison of Transect Type/Time.

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus			Lethrinids		
Transect type/Time	1	5.153	2.987	0.135	3.919	2.412	0.171
Habitat	1	25.242	19.875	0.004	1.751	0.794	0.407
Position on shelf	1	64.239	15.469	0.008	2.297	0.765	0.415
Reef (P)	6	4.153	5.330	<0.001	3.002	1.213	0.311
Site (THPR)	64	0.779	1.106	0.284	2.475	1.826	<0.001
T x H	1	0.797	1.520	0.264	0.634	0.371	0.565
T x P	1	0.026	0.015	0.906	1.838	1.131	0.329
T x R(P)	6	1.725	2.214	0.055	1.625	0.656	0.685
H x P	1	11.195	8.814	0.025	4.181	1.896	0.218
H x R(P)	6	1.270	1.630	0.153	2.205	0.891	0.507
T x H x P	1	2.926	5.577	0.056	1.157	0.678	0.442
T x H x R(P)	6	0.525	0.673	0.672	1.706	0.689	0.659
Residual	336	0.705			1.355		
		Monotaxis grandoculis			Lutjanids		
Transect type/Time	1	7.824	0.965	0.364	188.742	5.220	0.062
Habitat	1	5.704	0.555	0.484	102.570	2.299	0.180
Position on shelf	1	268.817	25.143	0.002	84.005	0.700	0.435
Reef (P)	6	10.691	4.320	0.001	120.001	3.983	0.002
Site (THPR)	64	2.475	0.905	0.680	30.129	2.926	<0.001
T x H	1	1.204	0.223	0.653	22.920	0.721	0.428
T x P	1	16.363	2.019	0.205	1.926	0.053	0.825
T x R(P)	6	8.105	3.275	0.007	36.160	1.200	0.318
H x P	1	0.338	0.033	0.862	77.945	1.747	0.234
H x R(P)	6	10.269	4.149	0.001	44.614	1.481	0.199
T x H x P	1	0.337	0.063	0.811	3.228	0.102	0.761
T x H x R(P)	6	5.395	2.180	0.056	31.776	1.055	0.399
Residual	336	2.735			10.297		
		Chaetodontids					
Transect type/Time	1	769.223	37.064	<0.001			
Habitat	1	196.204	0.951	0.367			
Position on shelf	1	3845.34	56.368	<0.001			
Reef (P)	6	68.218	2.122	0.063			
Site (THPR)	64	32.151	3.247	<0.001			
T x H	1	13.223	0.182	0.684			
T x P	1	416.067	20.048	0.004			
T x R(P)	6	20.754	0.648	0.693			
H x P	1	133.007	0.645	0.453			
H x R(P)	6	206.226	6.414	<0.001			
T x H x P	1	2.535	0.035	0.858			
T x H x R(P)	6	72.493	2.255	0.049			
Residual	336	9.901					

B. Comparison of Protected and Fished Reefs (5+5 reefs).

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus - total			*P.leopardus* - recruits		
Habitat	1	14.349	49.340	<0.001	0.012	0.332	0.568
Zoning status	1	0.502	1.727	0.196	0.012	0.332	0.568
Reef (Z)	8	9.774	33.609	<0.001	0.125	3.408	0.005
Site (HZR)	40	0.291	1.204	0.200	0.037	2.016	<0.001
H x Z	1	2.435	8.373	0.006	0.073	2.005	0.165
H x R(Z)	8	1.018	3.502	0.004	0.021	0.583	0.786
Residual	240	0.241			0.018		
		P. leopardus - <35 cm TL			*P. leopardus* - >35 cm TL		
Habitat	1	1.323	9.810	0.003	2.642	33.992	<0.001
Zoning status	1	0.338	2.505	0.121	0.070	0.896	0.350
Reef (Z)	8	1.945	14.425	<0.001	1.078	13.870	<0.001
Site (HZR)	40	0.135	1.356	0.087	0.078	0.603	0.972
H x Z	1	0.405	3.003	0.091	0.042	0.542	0.466
H x R(Z)	8	0.225	1.672	0.136	0.205	2.637	0.020
Residual	240	0.099			0.129		
		Plectropomus laevis			Total Lethrinids		
Habitat	1	0.006	0.170	0.682	1.085	2.167	0.149
Zoning status	1	0.090	2.385	0.130	1.788	3.572	0.066
Reef (Z)	8	0.127	3.335	0.005	0.952	1.901	0.087
Site (HZR)	40	0.038	0.907	0.634	0.501	2.848	<0.001
H x Z	1	0.177	4.657	0.037	0.151	0.301	0.586
H x R(Z)	8	0.080	2.116	0.057	0.546	1.091	0.389
Residual	240	0.042			0.176		
		Lethrinus atkinsoni			*Lethrinus obsoletus*		
Habitat	1	0.028	0.083	0.775	1.260	16.054	<0.001
Zoning status	1	0.503	1.498	0.228	0.002	0.028	0.869
Reef (Z)	8	0.579	1.724	0.123	0.113	1.434	0.213
Site (HZR)	40	0.336	3.014	<0.001	0.079	2.498	<0.001
H x Z	1	0.018	0.052	0.820	0.005	0.068	0.796
H x R(Z)	8	0.218	0.650	0.732	0.147	1.879	0.091
Residual	240	0.111			0.031		
		Lethrinus nebulosus			*Lethrinus miniatus*		
Habitat	1	0.005	0.189	0.666	0.003	0.083	0.775
Zoning status	1	0.010	0.369	0.547	0.167	5.451	0.025
Reef (Z)	8	0.023	0.862	0.556	0.091	2.954	0.011
Site (HZR)	40	0.027	1.000	0.477	0.031	2.578	<0.001
H x Z	1	0.0001	0.005	0.943	0.003	0.083	0.775
H x R(Z)	8	0.026	0.965	0.476	0.033	1.072	0.401
Residual	240	0.027			0.012		
		Monotaxis grandoculis			Total Lutjanids		
Habitat	1	2.951	4.709	0.036	10.935	4.532	0.040
Zoning status	1	0.072	0.116	0.736	0.536	0.222	0.640
Reef (Z)	8	3.755	5.992	<0.001	7.013	2.906	0.012
Site (HZR)	40	0.627	1.792	0.004	2.413	3.690	<0.001
H x Z	1	0.405	0.646	0.426	3.590	1.488	0.230
H x R(Z)	8	1.028	1.641	0.144	6.903	2.861	0.013
Residual	240	0.350			0.654		
		Lutjanus gibbus			*Lutjanus bohar*		
Habitat	1	6.087	8.046	0.007	3.580	5.898	0.020
Zoning status	1	0.178	0.236	0.630	0.225	0.371	0.546
Reef (Z)	8	1.866	2.467	0.028	1.490	2.454	0.029
Site (HZR)	40	0.757	2.779	<0.001	0.607	2.429	<0.001
H x Z	1	4.093	5.411	0.025	0.910	1.499	0.228
H x R(Z)	8	2.620	3.463	0.004	1.922	3.166	0.007
Residual	240	0.272			0.250		

B. Comparison of Protected and Fished Reefs (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Lutjanus quinquelineatus			*Lutjanus carponotatus*		
Habitat	1	0.003	0.007	0.932	0.017	0.166	0.686
Zoning status	1	0.500	1.347	0.253	1.048	10.189	0.003
Reef (Z)	8	1.173	3.158	0.007	0.404	3.928	0.002
Site (HZR)	40	0.371	5.687	<0.001	0.103	3.033	<0.001
H x Z	1	0.474	1.276	0.265	0.063	0.609	0.440
H x R(Z)	8	0.206	0.555	0.808	0.077	0.748	0.649
Residual	240	0.065			0.034		
		Lutjanus fulviflamma			Total Chaetodontids		
Habitat	1	0.384	0.813	0.373	568.563	7.635	0.009
Zoning status	1	0.436	0.922	0.343	266.963	3.585	0.066
Reef (Z)	8	0.418	0.885	0.537	516.457	6.935	<0.001
Site (HZR)	40	0.472	3.941	<0.001	74.467	4.189	<0.001
H x Z	1	0.707	1.496	0.229	124.163	1.667	0.204
H x R(Z)	8	0.335	0.709	0.682	208.513	2.800	0.015
Residual	240	0.120			17.778		
		Coral Feeding Chaetodontids			*Pomacentrus molluccensis*		
Habitat	1	21.323	19.670	<0.001	260.186	55.436	<0.001
Zoning status	1	2.970	2.740	0.106	16.758	3.570	0.066
Reef (Z)	8	9.215	8.500	<0.001	10.812	2.304	0.039
Site (HZR)	40	1.084	2.989	<0.001	4.693	5.626	<0.001
H x Z	1	0.638	0.589	0.448	3.575	0.762	0.388
H x R(Z)	8	6.925	6.388	<0.001	7.455	1.588	0.159
Residual	240	0.363			0.834		
		Amblyglyphidodon curacao			*Chrysiptera rollandi*		
Habitat	1	18.881	26.829	<0.001	67.517	64.846	<0.001
Zoning status	1	0.001	0.002	0.964	11.187	10.744	0.002
Reef (Z)	8	2.896	4.115	0.001	4.567	4.387	<0.001
Site (HZR)	40	0.704	2.390	<0.001	1.041	3.772	<0.001
H x Z	1	0.152	0.215	0.645	5.221	5.014	0.031
H x R(Z)	8	0.332	0.472	0.869	2.953	2.836	0.014
Residual	240	0.294			0.276		
		Plectroglyphidodon lacrymatus			Hard Coral Cover		
Habitat	1	2.237	0.837	0.366	31.665	0.491	0.487
Zoning status	1	9.134	3.418	0.072	5.186	0.080	0.778
Reef (Z)	8	7.366	2.756	0.016	314.556	4.882	<0.001
Site (HZR)	40	2.672	3.683	<0.001	64.435	3.612	<0.001
H x Z	1	6.015	2.251	0.141	70.874	1.100	0.301
H x R(Z)	8	5.254	1.966	0.076	354.549	5.502	<0.001
Residual	240	0.725			17.841		
		Soft Coral Cover			*Drupella* Damage		
Habitat	1	211.407	1.720	0.197	10.686	13.548	<0.001
Zoning status	1	949.346	7.724	0.008	1.262	1.600	0.213
Reef (Z)	8	471.498	3.836	0.002	3.470	4.400	<0.001
Site (HZR)	40	122.903	7.130	<0.001	0.789	1.902	0.002
H x Z	1	441.439	3.592	0.065	0.086	0.108	0.744
H x R(Z)	8	661.614	5.386	<0.001	4.28	5.426	<0.001
Residual	240	17.238			0.415		
		Tridacna gigas			*Tridacna derasa*		
Habitat	1	0.442	7.846	0.008	2.185	20.654	<0.001
Zoning status	1	0.214	3.806	0.058	0.492	4.647	0.037
Reef (Z)	8	0.038	0.667	0.717	0.344	3.254	0.006
Site (HZR)	40	0.056	1.798	0.004	0.106	1.699	0.009
H x Z	1	0.163	2.887	0.097	0.492	4.647	0.037
H x R(Z)	8	0.049	0.869	0.550	0.127	1.200	0.324
Residual	240	0.031			0.062		

C. Balanced Eight Reef Analysis.

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus - total			*P. leopardus* - recruits		
Habitat	1	5.220	32.792	<0.001	0.015	0.332	0.569
Position on shelf	1	22.387	141.0	<0.001	0.701	15.326	<0.001
Zoning status	1	0.189	1.189	0.284	0.015	0.332	0.569
Reef (PZ)	4	1.209	7.594	<0.001	0.035	0.756	0.562
Site (HPZR)	32	0.159	1.236	0.193	0.046	2.016	0.002
H x P	1	1.635	10.272	0.003	0.015	0.332	0.569
H x Z	1	0.448	2.811	0.103	0.092	2.005	0.167
H x R(Z)	4	0.402	2.525	0.060	0.011	0.231	0.919
H x P x Z	1	0.116	0.727	0.400	0.092	2.005	0.167
P x Z	1	0.158	0.992	0.327	0.015	0.332	0.569
Residual	192	0.129			0.023		
		P. leopardus - <35 cm TL			*P. leopardus* - >35 cm TL		
Habitat	1	1.352	8.321	0.007	2.108	22.597	<0.001
Position on shelf	1	10.136	62.399	<0.001	3.780	40.524	<0.001
Zoning status	1	0.409	2.516	0.123	0.096	1.029	0.318
Reef (PZ)	4	0.452	2.782	0.043	0.583	6.249	<0.001
Site (HPZR)	32	0.162	1.413	0.082	0.093	0.654	0.923
H x P	1	0.047	0.287	0.596	1.127	12.083	0.002
H x Z	1	0.346	2.130	0.154	0.002	0.021	0.887
H x R(Z)	4	0.289	1.779	0.157	0.093	0.995	0.425
H x P x Z	1	0.509	3.133	0.086	0.043	0.465	0.500
P x Z	1	0.013	0.079	0.781	0.527	5.651	0.024
Residual	192	0.115			0.143		
		Plectropomus laevis			Total Lethrinids		
Habitat	1	0.045	1.141	0.293	0.493	0.909	0.348
Position on shelf	1	0.377	9.478	0.004	4.721	8.700	0.006
Zoning status	1	0.045	1.141	0.293	1.644	3.030	0.091
Reef (PZ)	4	0.107	2.699	0.048	0.476	0.878	0.488
Site (HPZR)	32	0.040	0.862	0.683	0.543	3.202	<0.001
H x P	1	0.193	4.839	0.035	0.900	1.658	0.207
H x Z	1	0.078	1.969	0.170	0.012	0.022	0.884
H x R(Z)	4	0.074	1.871	0.140	0.538	0.991	0.427
H x P x Z	1	0.006	0.159	0.693	0.017	0.031	0.862
P x Z	1	0.078	1.969	0.170	0.901	1.661	0.207
Residual	192	0.046			0.169		
		Lethrinus atkinsoni			*Lethrinus obsoletus*		
Habitat	1	0.010	0.028	0.869	0.719	10.872	0.002
Position on shelf	1	3.803	10.753	0.003	0.008	0.116	0.735
Zoning status	1	0.364	1.030	0.318	0.012	0.178	0.676
Reef (PZ)	4	0.138	0.390	0.815	0.106	1.605	0.197
Site (HPZR)	32	0.354	3.278	<0.001	0.066	2.625	<0.001
H x P	1	0.446	1.262	0.270	0.049	0.741	0.396
H x Z	1	0.242	0.685	0.414	0.001	0.010	0.923
H x R(Z)	4	0.059	0.168	0.953	0.115	1.741	0.165
H x P x Z	1	0.054	0.154	0.698	0.540	8.171	0.007
P x Z	1	0.186	0.525	0.474	0.362	5.470	0.026
Residual	192	0.108			0.025		
		Lethrinus nebulosus			*Monotaxis grandoculis*		
Habitat	1	0.006	0.189	0.667	1.929	3.764	0.061
Position on shelf	1	0.010	0.293	0.592	18.724	36.543	<0.001
Zoning status	1	0.013	0.369	0.548	0.399	0.778	0.384
Reef (PZ)	4	0.035	1.021	0.412	0.397	0.774	0.550
Site (HPZR)	32	0.034	1.000	0.474	0.512	1.393	0.091
H x P	1	0.050	1.488	0.232	0.054	0.106	0.747
H x Z	1	0.0002	0.005	0.943	1.187	2.316	0.138
H x R(Z)	4	0.033	0.979	0.433	1.041	2.032	0.113
H x P x Z	1	0.025	0.734	0.398	2.542	4.960	0.033
P x Z	1	0.004	0.103	0.750	0.033	0.065	0.801
Residual	192	0.034			0.368		

C. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Total Lutjanids			*Lutjanus gibbus*		
Habitat	1	14.812	5.375	0.027	4.558	5.296	0.028
Position on shelf	1	22.632	8.214	0.007	10.664	12.391	0.001
Zoning status	1	0.070	0.025	0.875	0.466	0.541	0.467
Reef (PZ)	4	5.247	1.904	0.134	0.437	0.508	0.730
Site (HPZR)	32	2.755	4.601	<0.001	0.861	3.393	<0.001
H x P	1	14.482	5.256	0.029	8.808	10.234	0.003
H x Z	1	8.465	3.072	0.089	7.407	8.607	0.006
H x R(Z)	4	7.223	2.621	0.053	1.847	2.146	0.098
H x P x Z	1	0.502	0.182	0.672	0.579	0.672	0.418
P x Z	1	8.327	3.022	0.092	1.503	1.746	0.196
Residual	192	0.599			0.254		
		Lutjanus bohar			*Lutjanus quinquelineatus*		
Habitat	1	5.900	8.463	0.007	0.001	0.001	0.971
Position on shelf	1	4.221	6.055	0.019	3.219	6.950	0.013
Zoning status	1	0.0001	0.0001	0.991	0.574	1.238	0.274
Reef (PZ)	4	0.567	0.813	0.549	1.266	2.733	0.046
Site (HPZR)	32	0.697	2.950	<0.001	0.463	5.752	<0.001
H x P	1	1.514	2.171	0.150	0.016	0.034	0.855
H x Z	1	0.561	0.805	0.376	0.542	1.170	0.288
H x R(Z)	4	2.772	3.976	0.010	0.304	0.656	0.627
H x P x Z	1	0.259	0.372	0.546	0.343	0.741	0.396
P x Z	1	0.403	0.578	0.453	0.369	0.796	0.379
Residual	192	0.236			0.081		
		Lutjanus carponotatus			*Lutjanus fulviflamma*		
Habitat	1	0.021	0.169	0.684	0.679	1.184	0.285
Position on shelf	1	1.687	13.356	<0.001	0.004	0.007	0.935
Zoning status	1	1.162	9.193	0.005	0.368	0.642	0.429
Reef (PZ)	4	0.078	0.620	0.651	0.480	0.837	0.512
Site (HPZR)	32	0.126	3.146	<0.001	0.573	4.322	<0.001
H x P	1	0.001	0.009	0.926	0.565	0.986	0.328
H x Z	1	0.078	0.620	0.437	1.147	2.000	0.167
H x R(Z)	4	0.146	1.157	0.348	0.276	0.482	0.749
H x P x Z	1	0.010	0.080	0.780	0.138	0.240	0.627
P x Z	1	0.807	6.384	0.017	1.125	1.963	0.171
Residual	192	0.040			0.133		
		Total Chaetodontids			Coral Feeding Chaetodontids		
Habitat	1	44.204	0.527	0.473	2.055	1.965	0.171
Position on shelf	1	3473.20	41.413	<0.001	65.309	62.441	<0.001
Zoning status	1	47.704	0.569	0.456	0.205	0.196	0.661
Reef (PZ)	4	64.638	0.771	0.552	0.611	0.584	0.676
Site (HPZR)	32	83.867	4.850	<0.001	1.046	2.702	<0.001
H x P	1	165.004	1.967	0.170	15.576	14.892	<0.001
H x Z	1	24.704	0.295	0.591	0.139	0.133	0.718
H x R(Z)	4	31.471	0.375	0.825	0.605	0.578	0.681
H x P x Z	1	175.104	2.088	0.158	0.458	0.438	0.513
P x Z	1	102.704	1.225	0.277	0.003	0.003	0.956
Residual	192	17.292			0.387		
		Pomacentrus molluccensis			*Amblyglyphidodon curacao*		
Habitat	1	223.883	39.799	<0.001	14.376	17.354	<0.001
Position on shelf	1	23.901	4.249	0.048	17.432	21.044	<0.001
Zoning status	1	22.197	3.946	0.056	<0.001	<0.001	0.995
Reef (PZ)	4	6.158	1.095	0.376	0.449	0.543	0.706
Site (HPZR)	32	5.625	6.107	<0.001	0.828	2.346	<0.001
H x P	1	25.129	4.467	0.042	0.428	0.517	0.477
H x Z	1	5.056	0.899	0.350	0.234	0.283	0.599
H x R(Z)	4	7.268	1.292	0.294	0.344	0.415	0.796
H x P x Z	1	2.457	0.437	0.514	0.714	0.861	0.360
P x Z	1	0.802	0.143	0.708	0.135	0.162	0.690
Residual	192	0.921			0.353		

C. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Chrysiptera rollandi			*Plectroglyphidodon lacrymatus*		
Habitat	1	71.866	61.198	<0.001	13.705	4.337	0.045
Position on shelf	1	6.922	5.895	0.210	1.503	0.476	0.495
Zoning status	1	15.985	13.613	<0.001	8.370	2.649	0.113
Reef (PZ)	4	2.085	1.776	0.158	12.565	3.976	0.010
Site (HPZR)	32	1.174	3.671	<0.001	3.160	4.041	<0.001
H x P	1	1.490	1.269	0.268	5.297	1.676	0.205
H x Z	1	7.915	6.740	0.014	3.813	1.207	0.280
H x R(Z)	4	2.768	2.357	0.075	1.998	0.632	0.643
H x P x Z	1	1.738	1.480	0.233	0.500	0.158	0.694
P x Z	1	6.266	5.336	0.028	1.313	0.415	0.524
Residual	192	0.320			0.782		
		Hard Coral Cover			Soft Coral Cover		
Habitat	1	290.234	5.007	0.032	1821.01	14.357	<0.001
Position on shelf	1	2130.64	36.754	<0.001	2097.90	16.540	<0.001
Zoning status	1	87.910	1.516	0.227	409.198	3.226	0.082
Reef (PZ)	4	7.029	0.121	0.974	309.314	2.439	0.067
Site (HPZR)	32	57.970	3.299	<0.001	126.835	7.337	<0.001
H x P	1	33.422	0.577	0.453	94.879	0.748	0.394
H x Z	1	14.285	0.246	0.623	293.087	2.311	0.138
H x R(Z)	4	69.761	1.203	0.329	167.454	1.320	0.284
H x P x Z	1	18.321	0.316	0.578	113.155	0.892	0.352
P x Z	1	55.603	0.959	0.335	5.093	0.040	0.843
Residual	192	17.571			17.286		
		Tridacna gigas			*Tridacna derasa*		
Habitat	1	0.372	5.364	0.027	2.731	20.654	<0.001
Position on shelf	1	0.106	1.532	0.225	0.423	3.196	0.083
Zoning status	1	0.203	2.933	0.096	0.614	4.647	0.039
Reef (PZ)	4	0.030	0.428	0.787	0.143	1.080	0.383
Site (HPZR)	32	0.069	1.997	0.002	0.132	1.699	0.016
H x P	1	0.020	0.290	0.594	0.113	0.853	0.363
H x Z	1	0.148	2.128	0.154	0.614	4.647	0.039
H x R(Z)	4	0.092	1.322	0.283	0.050	0.379	0.822
H x P x Z	1	0.001	0.016	0.900	0.033	0.251	0.620
P x Z	1	0.010	0.145	0.706	0.100	0.755	0.391
Residual	192	0.035			0.078		