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FINAL REPORT

BRAMBLE REEF REPLENISHMENT AREA: THIRD POST-OPENING SURVEY

Prepared by

SEA RESEARCH

for

THE GREAT BARRIER REEF MARINE PARK AUTHORITY

April 1998

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BRAMBLE REEF REPLENISHMENT AREA: THIRD POST-OPENING SURVEY

Final Report to the Great Barrier Reef Marine Park Authority

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

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SUMMARY

The replenishment area on Bramble Reef in the northern Central Section of the Great Barrier Reef Marine Park was closed to fishing by the GBRMPA on the 1st January 1992 to allow stocks of fish species targeted by fishermen to recover. We made a baseline survey of these target fish species and other important reef organisms on Bramble and three adjacent control reefs: John Brewer, Lodestone and Davies, in early September 1991, prior to the closure (Ayling and Ayling 1992a). Surveys of coral trout, crown-of-thorns starfish and butterflyfishes have been made on these control reefs on four occasions since 1983, providing a useful temporal comparison with the baseline results. Similar annual post-closure surveys have been made in the May/June period in 1992 (Ayling and Ayling 1993), 1993 and 1994 (Ayling and Ayling 1994b), and 1995 (Ayling and Ayling 1997). Concern that fishing pressure was being transferred from Bramble to three adjacent reefs following the replenishment closure resulted in the survey being extended to include these reefs, Britomart, Trunk and Little Trunk Reefs, as three new controls in all surveys since 1993. Bramble Reef was re-opened to fishing on 1st July 1995, and following reports of heavy fishing immediately following the opening we were contracted to conduct the first post-opening survey in August 1995, eight weeks after the opening (Ayling and Ayling 1997). Follow up surveys were made in May 1996 and July 1997 (this report), one and two years respectively after the re-opening.

The survey design incorporated two habitats per reef (front reef slope and back reef slope), with six random 500 m long sites in each habitat. We recorded large target fish in five 50 x 5 m strip transects within each site, a total of 60 transects per reef, covering a length of reef edge of 3 km (1.5 ha area of surveys). The estimated total length (TL) of all coral trout, lethrinids and lutjanids counted was recorded.

Mean density of adult common coral trout had increased markedly on all four original survey reefs over the first 2.5 years of the Bramble closure, with a grand mean of 30.5 per hectare (ha) in 1994, three times higher than the density of around 10 per ha during the 1991 baseline survey. The three new controls showed similar patterns and supported similar densities. At this stage the density of these large coral trout on Bramble was not significantly higher than any of the controls. It is surmised that several good years of coral trout recruitment, possibly combined with lower than average fishing pressure on the controls, was responsible for this general density increase. There were high levels of recruitment of this species on all reefs, especially in 1992, and the increase in overall density on each reef appeared to be largely related to the influx of new recruits over the period of the study. There was also a suggestion that the large increases in coral trout density on many of the reefs may have been influenced by the marked increase in the density of some pomacentrid prey species as coral communities recovered from crown-of-thorns devastation on these reefs.

Over the final 12 months of the Bramble closure adult common coral trout density continued to increase on Bramble reef, to over 4.5 times that recorded during the baseline, while density on all the controls decreased, possibly due to high commercial fishing pressure in the area. As a result adult densities on Bramble were over twice the grand mean from the six controls at the time of the re-opening.

Commercial and recreational fishing pressure was extremely high on Bramble in the first eight weeks following the opening and adult coral trout densities were reduced by almost 60% over that time, back to the level recorded on the controls. Density on all six controls also continued to decline and the grand mean of 15.9 per ha was about half that recorded during the peak density period 15 months earlier. This decline continued, both on Bramble and the controls, in the first year following the re-opening, with adult populations at this time being similar to those recorded during the baseline survey. At this stage densities on Bramble were only 20% of those present prior to the re-opening. Adult coral trout densities were similar in the current survey, both on Bramble and the controls, to those recorded in 1996.

The other major target species, the red-throat sweetlip *Lethrinus miniatus*, showed basically the same density patterns as coral trout except that density on Bramble was consistently lower than on most of the controls over the first three surveys. Density of this species also reached a peak on most reefs in 1994 and decreased by over 75% in the following 2 years up to the 1996 survey. This also suggested that fishing pressure had been high on these reefs since May 1994. However, densities of this species had increased by an order of magnitude by the time of the 1997 survey, both on Bramble and on all the controls. Prior to 1997 almost all individuals of this species counted were full-size adults over 50 cm TL, but during 1997 most individuals recorded were between 40 and 45 cm TL, suggesting that the increase had been caused by an influx of young adults onto the reef.

The combined density of other lethrinids fluctuated slightly, with a sharp dip on Davies in 1993, but numbers did not change significantly over this study, and did not increase at all on Bramble relative to the controls. Although lutjanid density was higher on Bramble during the baseline survey than in all subsequent surveys, there were no significant overall density changes. Reef differences in lutjanid numbers were consistent, with very low numbers on Davies and very high numbers on Little Trunk, compared to the other five reefs. Densities of the stripey *Lutjanus carponotatus* did not change significantly during this study.

In summary, the closure of Bramble Reef resulted in an increase in adult coral trout density relative to the controls only over the final year of the 3.5 year closure, but this may have been due to higher levels of recruitment on Bramble compared to the controls rather than to any protection resulting from the replenishment closure. Densities of all other target species did not change on Bramble Reef during the replenishment closure. Two months following the re-opening adult coral trout densities on bramble had been reduced by almost 60% and were not significantly higher than any of the controls. The value of such closures for reef management is a question that will need to be addressed by management.

The surveys of other reef organisms suggested that the major change in the communities on these reefs over the past 6 years has been the strong recovery of hard coral cover after these reefs were devastated by crown-of-thorns in 1983-84 (1985-90 for Davies). As a result there were significant increases in hard coral cover, in the numbers of chaetodontids and in the density small pomacentrids, including *Pomacentrus moluccensis* and *Chrysiptera rollandi,* on these three reefs. Hard coral cover increased from less than 10% grand mean to around 35% over this time, and there were similar or higher increases in the other groups mentioned.

It appeared that Cyclone Justin reduced coral cover and pomacentrid density on the back reef habitat of these reefs in March 1997, with a 20-30% decrease in these groups being recorded between May 1996 and July 1997.

1. INTRODUCTION

The GBRMPA closed the replenishment area on Bramble Reef in the northern Central Section of the Great Barrier Reef Marine Park (18°25'S, 146°43'E) (figure 1) on the 1st January 1992. In order to get some indication of the effect of this fishing closure on the reef communities Sea Research was asked to implement a monitoring program on the reef. This program was designed primarily to look at the abundance of the common coral trout, the most important of the recreationally and commercially targeted fish species. The design included an initial comprehensive baseline survey in September 1991 on Bramble and on three similar control reefs: John Brewer, Lodestone and Davies. To check on recovery rates of target populations annual post-closure surveys using the same techniques were made starting in June 1992 (reported by Ayling and Ayling 1993) and repeated in May-June 1993 and May-June 1994 (Ayling and Ayling 1994). The final survey during the time of reef closure was made in May-June 1995 (Ayling and Ayling 1977), immediately prior to the re-opening of the replenishment area on 1st July 1995 after a closure of 3.5 years. Due to high levels of fishing on Bramble after the opening the GBRMPA required the first post-opening survey to be carried out in mid-August 1995 (Ayling and Ayling 1977). Further surveys were made on all reefs in May 96 and July 97 to follow trends in reef populations in the two years following the Bramble re-opening.

Concern was expressed by local fishermen that fishing pressure formerly targeted at Bramble was being transferred to the three neighbouring reefs: Britomart, Trunk and Little Trunk, and at the request of the GBRMPA the survey was expanded to include these reefs in 1993, and for all subsequent surveys. The same survey techniques were used on all seven reefs.

The primary aim of this survey was to detect changes in the density of the reef dwelling fish species targeted by recreational and commercial fishermen. Of these the two species of most concern were the common coral trout *Plectropomus leopardus* and the red-throat sweetlip *Lethrinus miniatus*. In a study of commercial line fishing in Queensland, Trainor (1991) reported that in 1989, coral trout were the largest single component of the catch, accounting for 31% of the total catch, followed by spanish mackerel (23%), with the red-throat sweetlip third with 14% of the catch. Of secondary importance in our study were all other lethrinids and lutjanids. We were also interested in any changes that may have occurred in the length frequency patterns of the major target species. The other fishes, invertebrates and encrusting organisms recorded were important in a reef monitoring context, and to look at any secondary effects that may result from density changes in the target fish populations. These data can be collected without any additional time involvement and provide extra information on the condition and composition of the reef communities that may be relevant to the questions addressed by this survey.

The baseline survey showed that the density of the common coral trout was not significantly different on Bramble, Lodestone and John Brewer reefs but was significantly higher on Davies Reef (Ayling and Ayling 1992a). In the first 9 months after the closure of Bramble Reef coral trout density increased significantly on all four survey reefs (Ayling and Ayling 1993). This increase was mainly caused by high levels of recruitment of 0+ coral trout and was similar on Bramble to that recorded on the controls; the reef x time interaction was not significant. Both total coral trout density and adult density (coral trout >38 cm TL), continued to increase on all four reefs through 1993 and 1994. By May 1994 adult density on Bramble was 3.1x that recorded during the baseline survey. However, density on the three controls was also 2.3-3.0x that from the baseline and the reef x year interaction from the analyses was not significant. At the time of the re-opening of Bramble Reef in July 1995 the densities of adult coral trout on the reef were over 4.5x those recorded during the baseline, while that on the controls was about half this level, giving a significant reef x year interaction at this time.

Adult coral trout density on the additional three control reefs first surveyed in 1993 was not significantly different to that recorded on the other four reefs during both the 1993 and 1994 surveys, suggesting that these reefs were not subjected to a significant increase in fishing pressure following the closure of Bramble to fishing.

After the re-opening a high pulse of fishing pressure on Bramble (Campbell Davies unpublished data) reduced adult coral trout densities dramatically. Mean densities on Bramble had been reduced by 60% within two months, and by 80% after twelve months, back to those recorded during the baseline survey. Adult coral trout densities also decreased substantially on the controls over this period, and 12 months after the Bramble re-opening grand mean densities on the controls were also similar to those recorded during the baseline.

As has been mentioned the red-throat sweetlip *Lethrinus miniatus* is another fish much sought after by fishermen and recent work has suggested that this species may be a better indicator of fishing pressure than the common coral trout (Ayling and Ayling 1992b, 1994). During the baseline survey red-throat sweetlip were recorded at densities an order of magnitude higher on the three control reefs compared with Bramble. Although this pattern may have been caused by other factors, the recorded differences may indicate that Bramble had been subjected to higher fishing levels than the three controls. The density of this species on Bramble remained basically unchanged during the following four years; there was no evidence that red-throated sweetlip had increased in density on Bramble after more than three years of protection from fishing. Red-throat sweetlip showed a decrease in density on all controls following a peak of 7.2 per ha in May 1994. By May 1996 densities were down by 75% to 1.9 per ha, and were not significantly different from the consistently low densities recorded on Bramble.

Coastwatch sighting records of possible fishing vessels for all survey reefs except Little Trunk from the 18 month period prior to the replenishment closure and the 18 months following replenishment closure suggested that the closure had little effect on fishing pressure on Bramble during this period. This disturbing level of non-compliance by fishermen, combined with generally low fishing pressure on the controls, may have been largely responsible for the lack of any closure effect on fished populations on Bramble (Ayling and Ayling 1994b). However, sightings of potential fishing vessels on Bramble were also higher than before the closure during the second half of the supposed closure (Ayling and Ayling 1997). It is possible that the higher coral trout densities recorded on Bramble compared with the controls during the final year of the closure may have been due to the consistently higher recruitment levels on Bramble rather that to any fishing protection.

This report presents the results of the third post-opening survey carried out in July 1997, about 2 years after the replenishment area was re-opened to fishing. These results are compared to those from the previous surveys and the significance of the spatial and temporal patterns observed is discussed. The major objective of the present phase of this project was to provide data on the longer term effect of the reopening on fish populations on Bramble Reef and to compare any changes to those from the three original control reefs and the three additional controls added in 1993.

2. METHODS

Davies, Lodestone and John Brewer Reefs were used as the original control reefs (figure 1). All three are in the same inner mid-shelf position as Bramble and are open to fishing. These reefs have also had several series of counts of coral trout, butterflyfishes and crown of thorns made on both front and back reef sites since early 1983 and hence some indication of temporal patterns has been established (Ayling and Ayling, 1989). Three additional fished control reefs, all within a few miles of Bramble Reef, were added to the design for all post-1993 surveys at the request of the GBRMPA. The survey design used two habitats (front reef, back reef), with 6 sites in each habitat and 5 replicate 50 x 5 m counts at each site. The sites in each habitat were selected haphazardly but were spaced so as to cover the entire length of each habitat, as long as there was at least 300 m between sites.

Data from the 1996 and 1997 surveys were compared with a 4 factor analysis of variance (table 1). Homogeneity of variances was checked using Cochran's C and plots of means against variances, and the data transformed if necessary using either square root or log 10 (raw data +1) transformations (table 3). Post-hoc comparisons of reef means were made using Fisher's Protected Least Significant Difference Test. The significance of density differences between Bramble and the controls were tested using a planned contrast analysis.

Table 1. Survey Analysis - Between Years.

Factor	Source of variation	Fixed/ Random	df	Denominator
R	Reef	F	6	none appropriate
H	Habitat	F	1	none appropriate
S	Site (RH)	R	70	S (RH) x Y
Y	Year	R	1	S (RH) x Y
	R x H		6	none appropriate
	R x Y		6	S (RH) x Y
	H x Y		1	S (RH) x Y
	S (RH) x Y		70	Residual
	R x H x Y		6	S (RH) x Y

There were no appropriate F ratios for the terms habitat, reef and reef x habitat in these analyses and separate analyses were made for the data from the July 1997 survey only using a 3 factor analysis of variance (table 2).

Table 2. Survey Analysis - Within Year.

Factor	Source of variation	Fixed/Random	df	Denominator
R	Reef	F	6	S(RH)
H	Habitat	F	1	S(RH)
S	Site (RH)	R	70	Residual
	R x H		6	S(RH)

The count methodology was the same as that used in the baseline survey (Ayling and Ayling 1992a), and all subsequent surveys. The following organisms were surveyed visually using either line or belt transects: *Plectropomus* spp., all chaetodontids, and all lutjanids and lethrinids (50 x 5 m belt transects); total pomacentrids along with

Pomacentrus moluccensis, *Amblyglyphidodon curacao* and *Chrysiptera rollandi* (50 x 1 m belt transects); total live hard coral and soft coral (20 m line intersect transects).

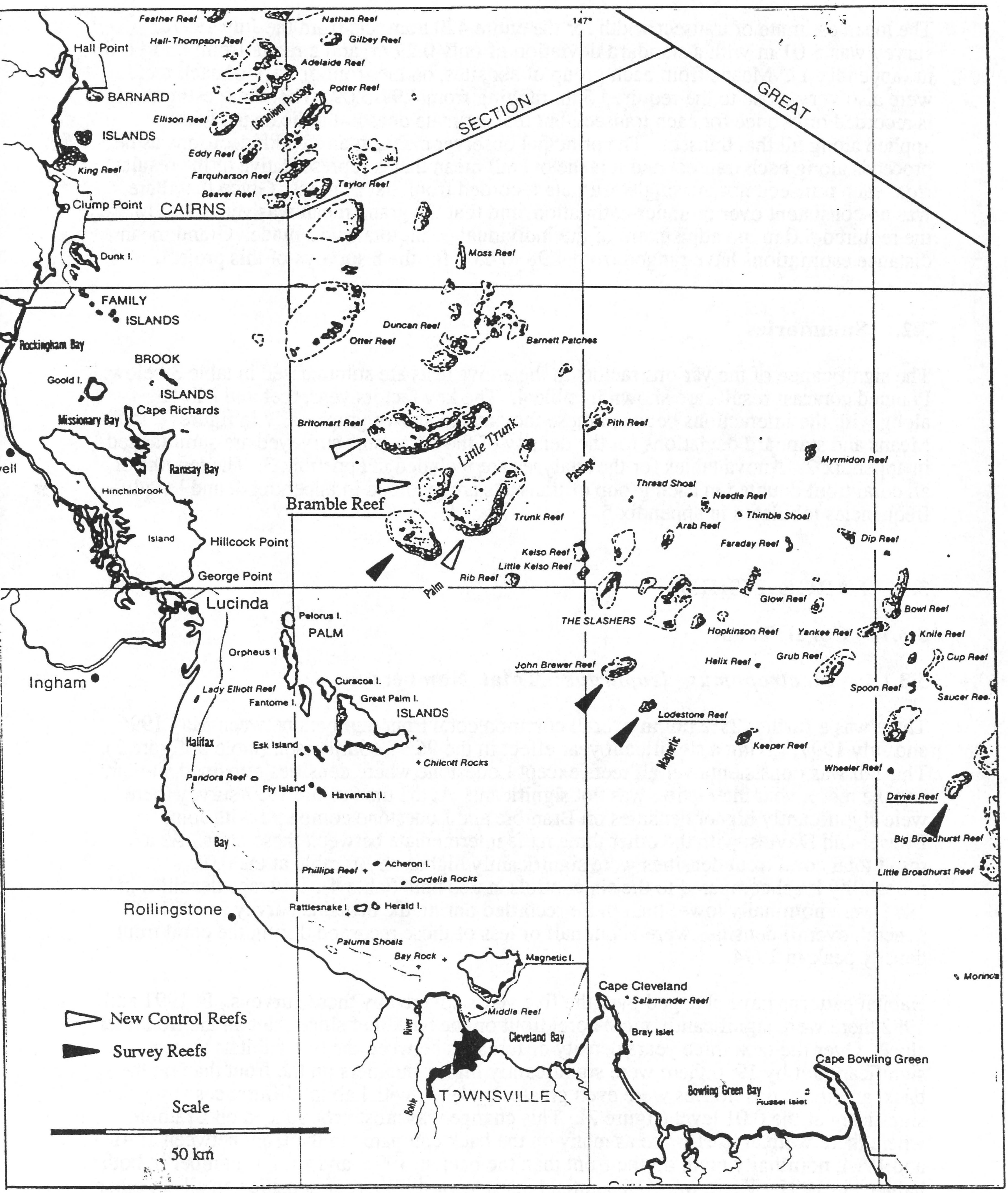
Counts were made with a field team of 2 divers plus a boat person. One observer ran out a 50 m fibreglass tape along the reef slope, parallel to the reef edge, at a depth of about 6-8 m. The principal observer (AMA) swam slightly in front of the tape layer, counting coral trout, other large target fishes and crown-of-thorns starfish within an estimated 5 m wide strip. When the principal observer had completed the large fish count he returned along the tape counting small fishes 0.5 m each side of tape (50 x 1 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.

At the end of the first pass along the transect the estimated 5 m width was checked by the tape layer by running out a tape to a bottom feature selected by the principal observer as representing the outer edge of the estimated strip.

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 the closed reef (Bramble) (Ayling et al. 1991). Hence, the total length of all coral trout recorded was estimated, as was the length of all lethrinids and lutjanids counted.

The field work for the July 1997 survey was carried out between the 24th July and 6th August. The timing of the trip was designed so as to be able to separate the coral trout 0+ size class from the rest of the population and so get an indication of recruitment levels of this species for each reef. Each site took between 60-70 mins to survey and we were able to survey each reef in 2 working days.

Figure 1. Map of the Northern Central Section Showing the Position of the Study Reefs.



3. RESULTS

3.1. Estimation of Transect Width.

The mean estimate of transect width for the entire 420 transects from the July 1997 survey was 5.01 m with a standard deviation of only 0.29 m, and a range from 4.3 to 6.0 m (appendix 1). Means from each group of six sites, on the front or back of each reef, were also very close to the required 5 m, ranging from 4.97-5.09. The width estimation is recorded only once for each transect, but that estimate does not indicate the width applied along all that transect. The principal observer makes many width decisions as he proceeds along each transect and it is the overall mean that is representative of the results from each transect, not the single estimate recorded from that transect. Given that there was no consistent over or under-estimation, and that the grand mean was very close to the required 5.0 m, no adjustment of the individual count totals was made. Grand mean distance estimations have ranged from 4.98 to 5.03 for the 8 surveys of this project.

3.2. Summaries

The significance of the various factors in the anova tests are summarised in table 3 below. Planned contrast results are shown in table 4. The key factors year, reef and habitat, along with the interactions between these factors, are shown graphically in figures 2 to 8. Means and standard deviations for the density of the organisms surveyed are summarised in appendix 2. Anova tables for the analyses are included in appendix 3. The lengths of all coral trout counted in each group of transects are recorded in appendix 4, and length frequencies tabulated in appendix 5.

3.3. LARGE FISHES

3.3.1. Coral Trout

3.3.1.1. *Plectropomus leopardus*: Total Numbers

There was a further 25% fall in overall common coral trout numbers between May 1996 and July 1997, giving a significant year effect in the 96/97 comparison (table 3, figure 2). This fall was consistent over all reefs except Lodestone where densities remained similar, and the reef x year interaction was not significant. At the time of the 1997 survey there were significantly higher densities on Bramble and Lodestone compared with John Brewer and Davies, with the other three reefs intermediate between these pairs. As a result total coral trout densities were significantly higher on Bramble at the 0.05 probability level compared to the six controls at this time (table 4). Average densities in 1997 were nominally lower than those recorded during the baseline survey in 1991. In general, overall densities were about half or less of those recorded during the coral trout density peak in 1994.

Habitat patterns have changed over the five years covered by these surveys. In 1991 and 1992 there were significantly more coral trout on the back reef slope than on the front reef slope. Over the next three years density differences between the two habitats were not significant but by 1996 there were significantly higher numbers on the front than on the back, and these differences were even greater by 1997, with habitat differences significant at the 0.01 level (figure 7). This change was most pronounced on Bramble where there were at least twice as many on the back compared to the front between 1991 and 1994, nominally more on the front than the back in 1996, and similar number in both habitats in 1997. There were substantial biases toward front reef densities on all six other reefs in 1997 (appendix 2). In spite of this the reef x habitat interaction was not significant in 1997 (table 3).

Table 3. Summary of the Anova Results.

Results are shown from the analyses of the seven reef data set for a comparison between 1996 and 1997 survey results. NS = not significant; * = $0.01<p<0.05$; ** = $0.001<p<0.01$; *** = $p<0.001$.
‡ indicates that results for these factors are from the separate analyses of the 1997 data only as there are no appropriate F ratios in the combined analysis.

Factor:	Trans-form-ation	Habitat (H) ‡	Reef (R) ‡	Year (Y)	Reef x Year	Site (S)	Site x Year	Other significant interaction terms
Large Fishes								
SERRANIDAE								
Plectropomus leopardus	log10	***	NS	***	NS	NS	NS	nil
P. leopardus >38 cm TL	log10	NS	*	NS	NS	*	NS	nil
P. leopardus recruits	none	NS	NS	***	NS	*	NS	nil
Plectropomus laevis	none	NS	*	NS	NS	NS	NS	nil
LETHRINIDAE								
Lethrinids - total	log10	*	NS	***	NS	NS	NS	nil
Lethrinus miniatus	sqrt	*	*	***	*	NS	NS	H*Y
LUTJANIDAE								
Lutjanids - total	sqrt	**	***	NS	NS	NS	NS	HxR
Lutjanus carponotatus	none	NS	***	NS	NS	*	NS	RxHxY
CHAETODONTIDAE								
Chaetodontids	sqrt	NS	***	***	**	*	***	HxR,RxHxY
Coral feeding chaets	sqrt	NS	***	***	*	NS	***	HxR,RxHxY
Small Fishes								
Pomacentrids - total	sqrt	NS	***	***	*	NS	***	nil
Pomacentrus moluccensis	sqrt	NS	***	NS	NS	NS	***	HxR, HxY
Amblyglyphid. curacao	sqrt	**	**	*	NS	NS	***	RxHxY
Chrysiptera rollandi	log10	***	NS	***	NS	NS	***	HxR, HxY
Encrusting Organisms								
Hard coral cover	log10	***	***	***	NS	NS	***	nil
Soft coral cover	log10	***	**	***	NS	NS	***	HxY,RxHxY

Table 4. Planned Contrast Results.

Indicates whether density of each species or group on Bramble Reef is significantly different to mean density on the other six reefs (three for 1991-92) for each survey. Direction of difference for significant results is shown: ↑ = Bramble density greater than controls; ↓ = Bramble density less than controls. NS = not significant; * = $0.01<p<0.05$; ** = $0.001<p<0.01$; *** = $p<0.001$.

Year	1991	1992	1993	1994	May 1995	Aug 1995	1996	1997
Bramble Status	open	closed	closed	closed	closed	open	open	open
Large Fishes								
SERRANIDAE								
Plectropomus leopardus	NS	NS	* ↑	* ↑	*** ↑	** ↑	NS	*↑
P. leopardus >38 cm TL	NS	** ↓	NS	NS	*** ↑	NS	NS	NS
P. leopardus recruits	NS	* ↑	** ↑	NS	** ↑	na	*** ↑	NS
P. laevis	** ↓	*** ↓	* ↓	NS	NS	* ↓	NS	NS
LETHRINIDAE								
Lethrinids - total	NS	NS	NS	NS	NS	NS	NS	NS
Lethrinus miniatus	*** ↓	*** ↓	NS	NS	NS	NS	NS	NS
LUTJANIDAE								
Lutjanids - total	*** ↑	NS	NS	NS	NS	NS	NS	* ↓
Lutjanus carponotatus	*** ↑	* ↑	* ↑	*** ↑	** ↑	* ↑	** ↑	*** ↑
CHAETODONTIDAE								
Chaetodontids	* ↓	*** ↓	NS	NS	* ↑	*** ↑	*** ↑	** ↑
Coral feeding chaets	** ↓	*** ↓	NS	NS	* ↑	*** ↑	*** ↑	** ↑
Small Fishes								
Pomacentrus moluccensis	NS	* ↑	*** ↑	*** ↑	*** ↑	NS	*** ↑	*** ↑
Amblyglyphid. curacao	* ↓	NS	NS	NS	NS	*** ↓	NS	** ↓
Chrysiptera rollandi	** ↓	NS	NS	NS	NS	NS	NS	NS
Encrusting Organisms								
Hard coral cover	NS	*** ↓	*** ↓	NS	* ↓	NS	** ↓	NS
Soft coral cover	*** ↑	NS	*** ↓	NS	NS	NS	NS	** ↑

Figure 2. Distribution of Targeted Fishes for 1991 to 1997: Coral Trout

Graphs show grand mean density per ha from all sites on each reef. Error bars are standard errors. Significance of tests for year and the 1997 reef differences are shown. M=May; A=August.

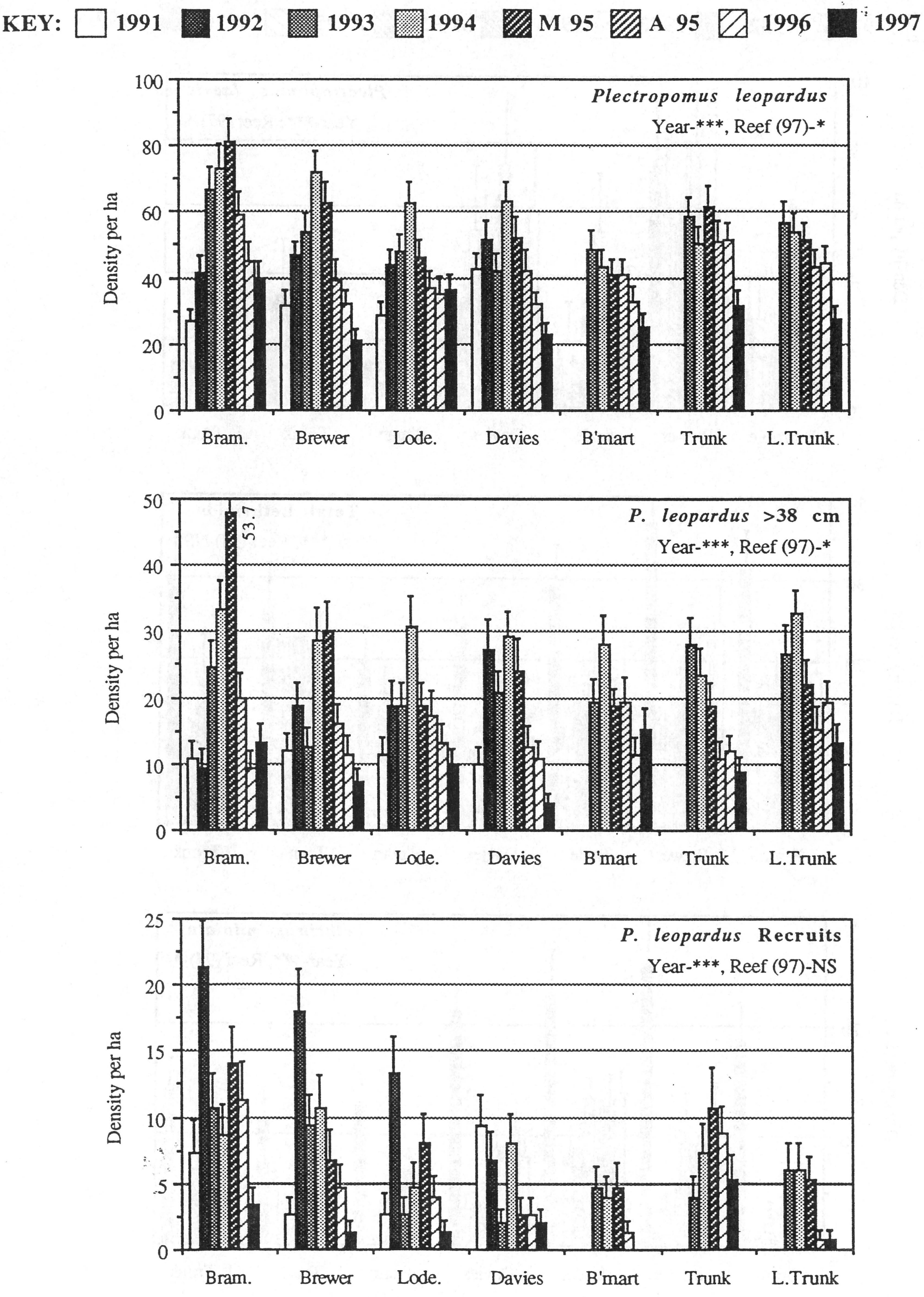
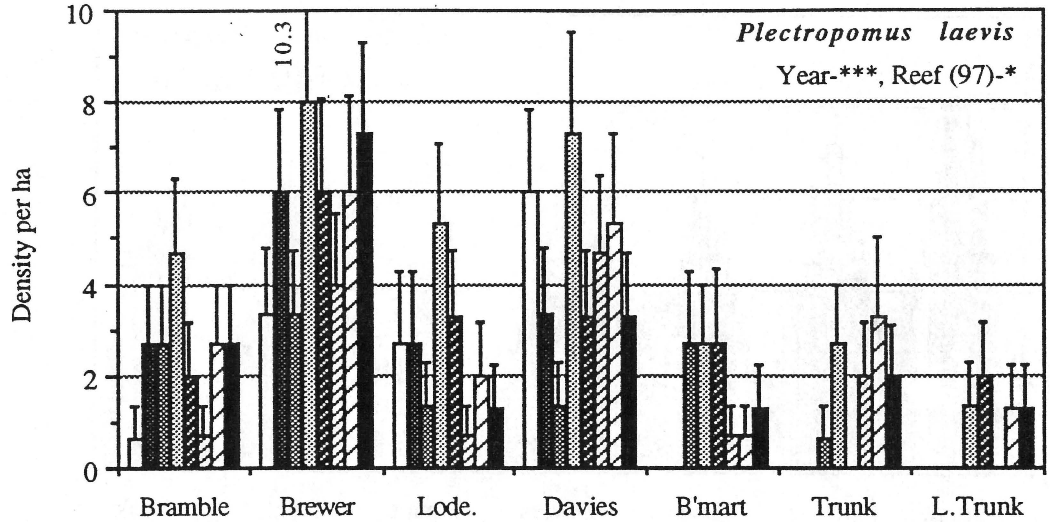
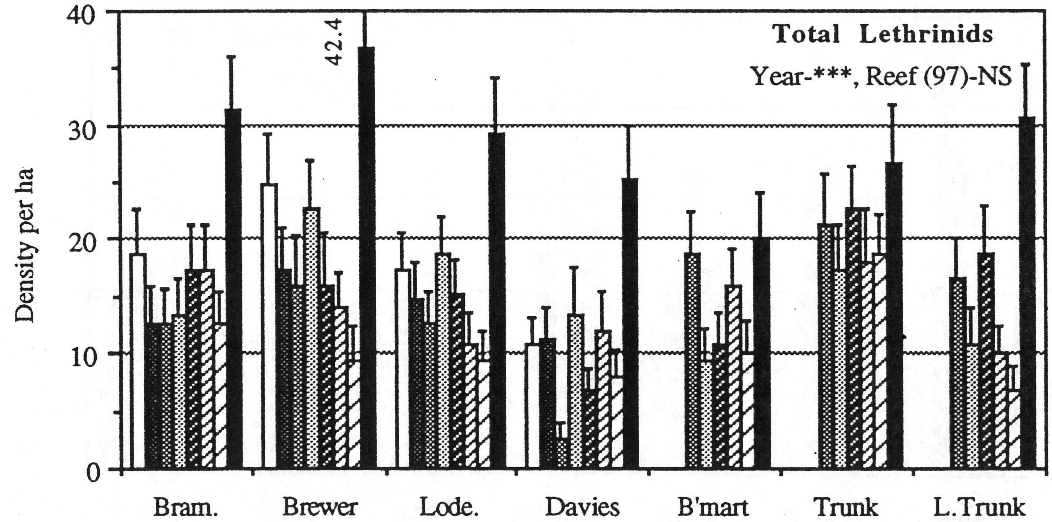


Figure 3. Distribution of Targeted Fishes for 1991 to 1997: Coral Trout, Lethrinids.

Graphs show grand mean density per ha on the vertical axis for all sites on each reef. Error bars are standard errors. Significance of tests for year and the 1997 reef differences are shown.

KEY: 1991, 1992, 1993, 1994, M 95, A 95, 1996, 1997





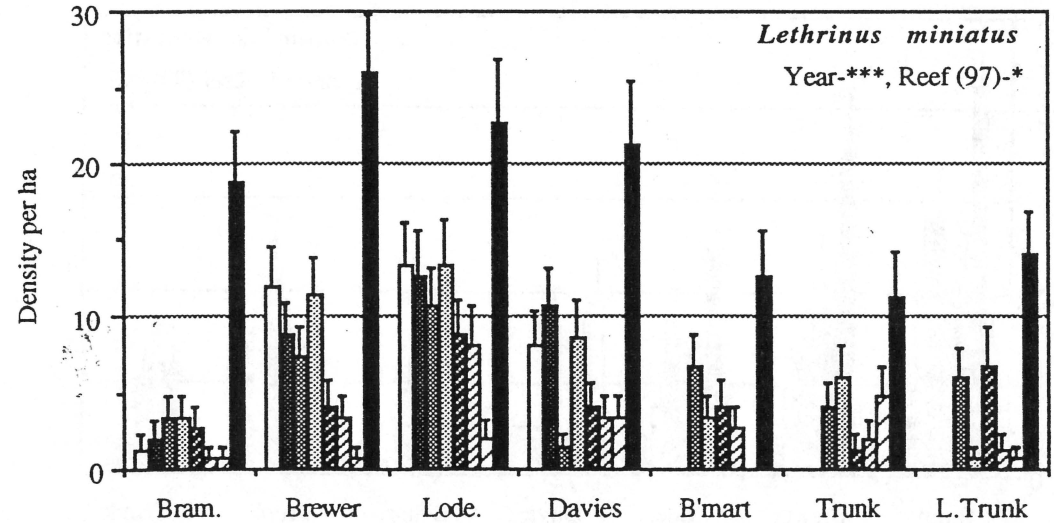
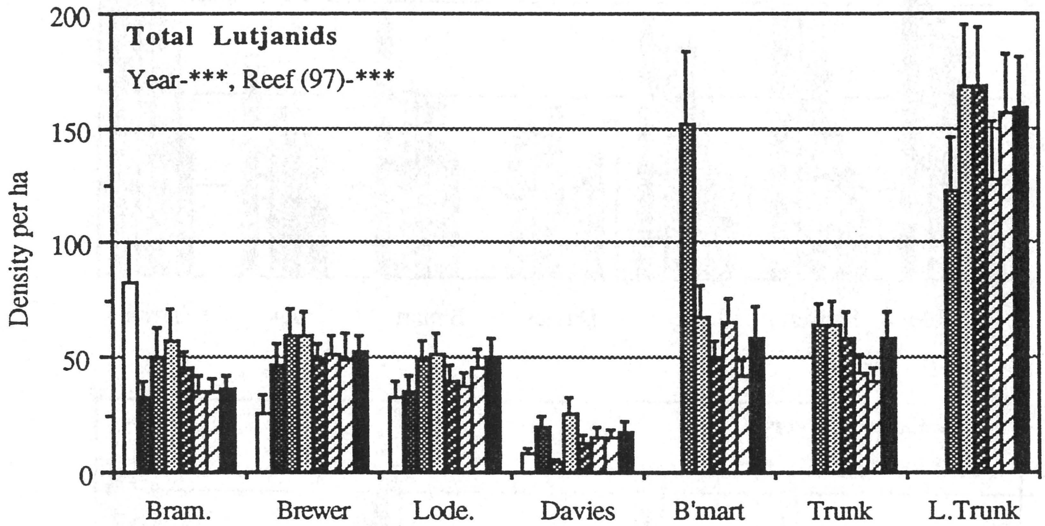


Figure 4. Distribution of Targeted Fishes for 1991 to 1997: Lutjanids.

Graphs show grand mean density per ha on the vertical axis for all sites on each reef. Error bars are standard errors. Significance of tests for year and the 1997 reef differences are shown.

KEY: 1991 1992 1993 1994 M 95 A 95 1996 1997



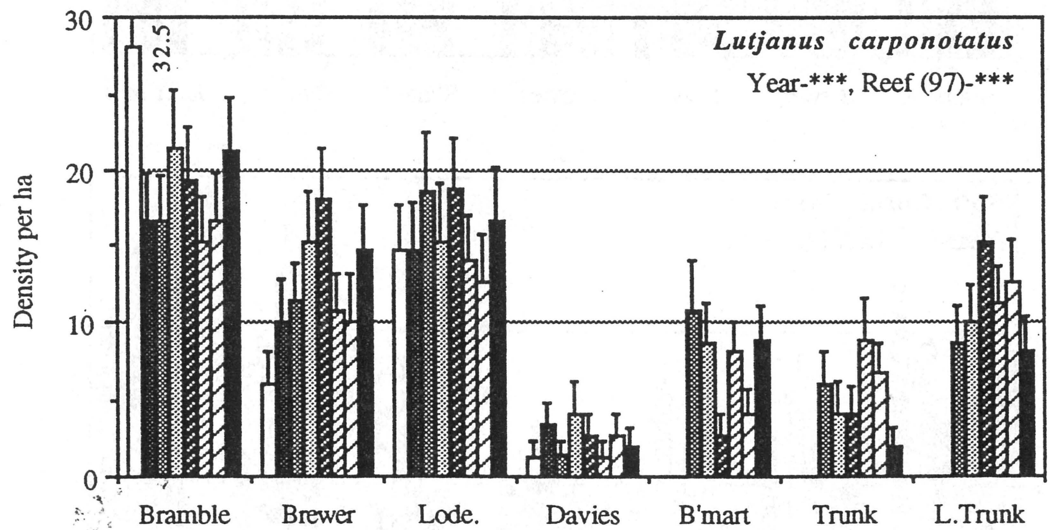


Figure 5. Distribution of Chaetodontids, and Hard and Soft Coral for 1991 to 1997.

Graphs show grand mean density per ha or % cover on the vertical axis for all sites on each reef. Error bars are standard errors. Significance of tests for year and the 1997 reef differences are shown.

KEY: 1991 1992 1993 1994 M 95 A 95 1996 1997

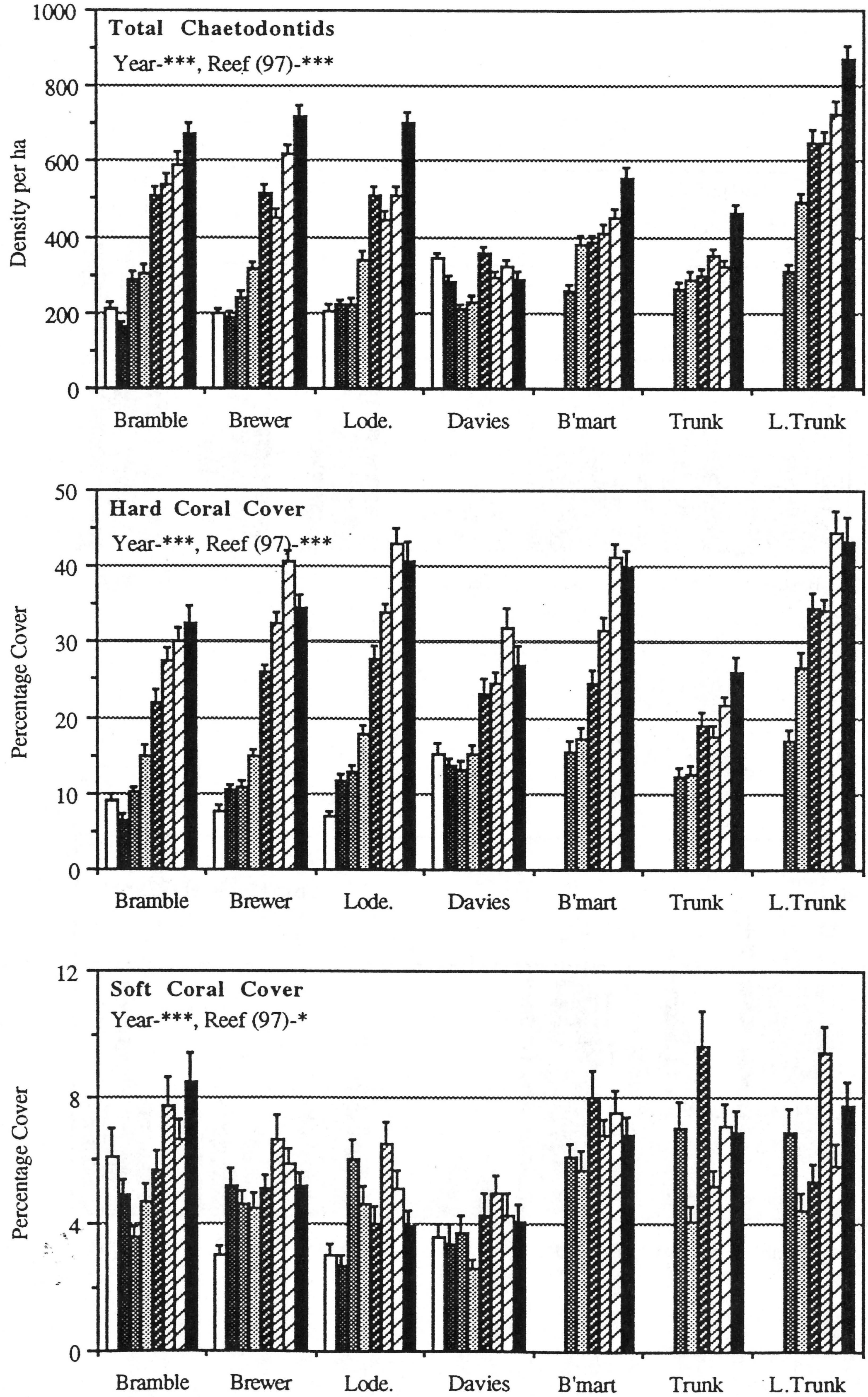


Figure 6. Distribution of Pomacentrids for 1991 to 1997.

Graphs show grand mean density per 100 sq m on the vertical axis from all sites on each reef. Error bars are standard errors. Significance of tests for year and the 1997 reef differences are shown.

KEY: 1991 1992 1993 1994 M 95 A 95 1996 1997

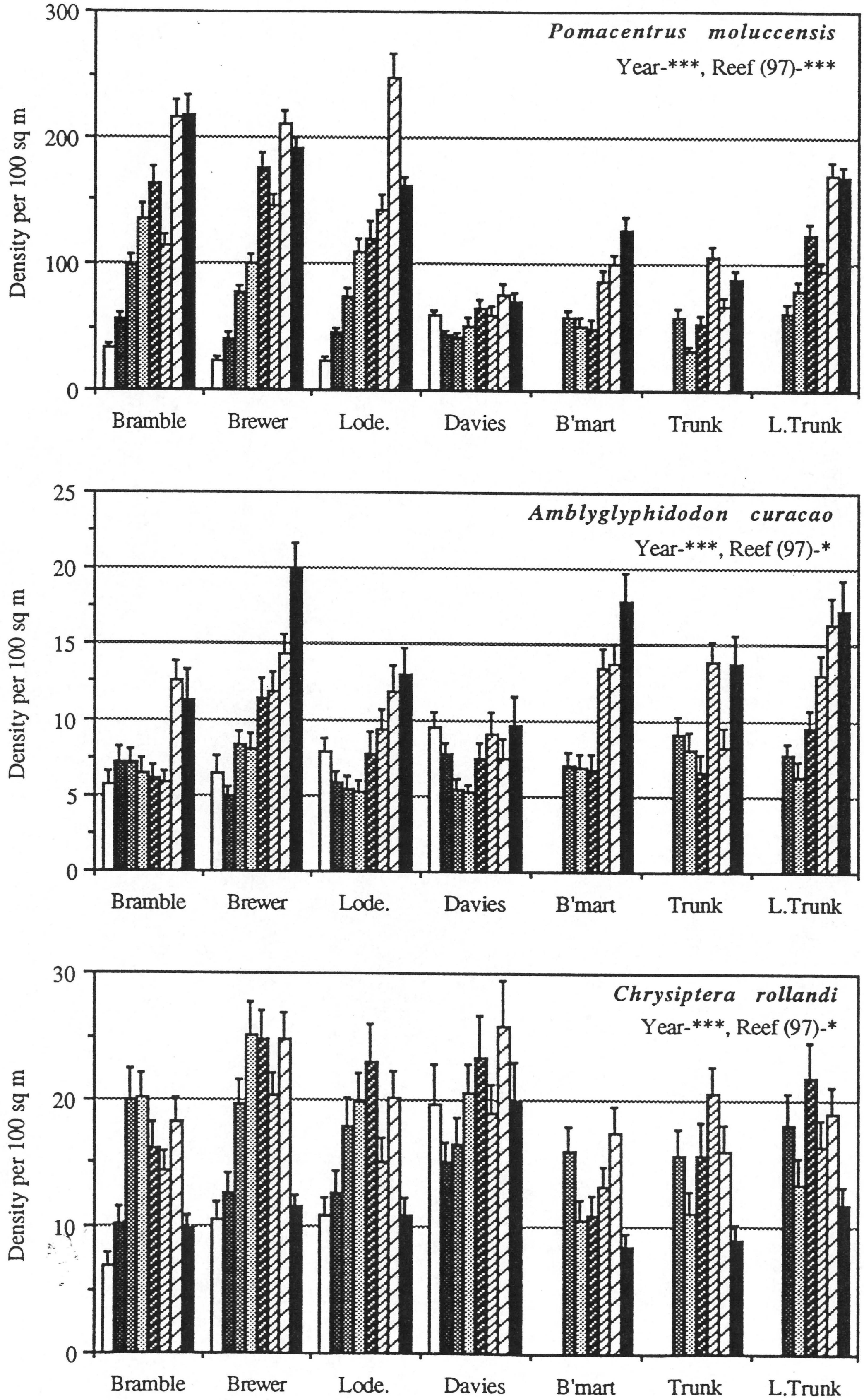


Figure 7. Within Reef Distribution of Targeted Fishes for 1994 to 1997

Coral Trout, Lethrinids and Lutjanids: Graphs show grand mean density per ha on the vertical axis for all sites in each habitat for each year. Error bars are standard errors. Significance of tests for habitat differences for 1997 and the HxY interaction are shown.

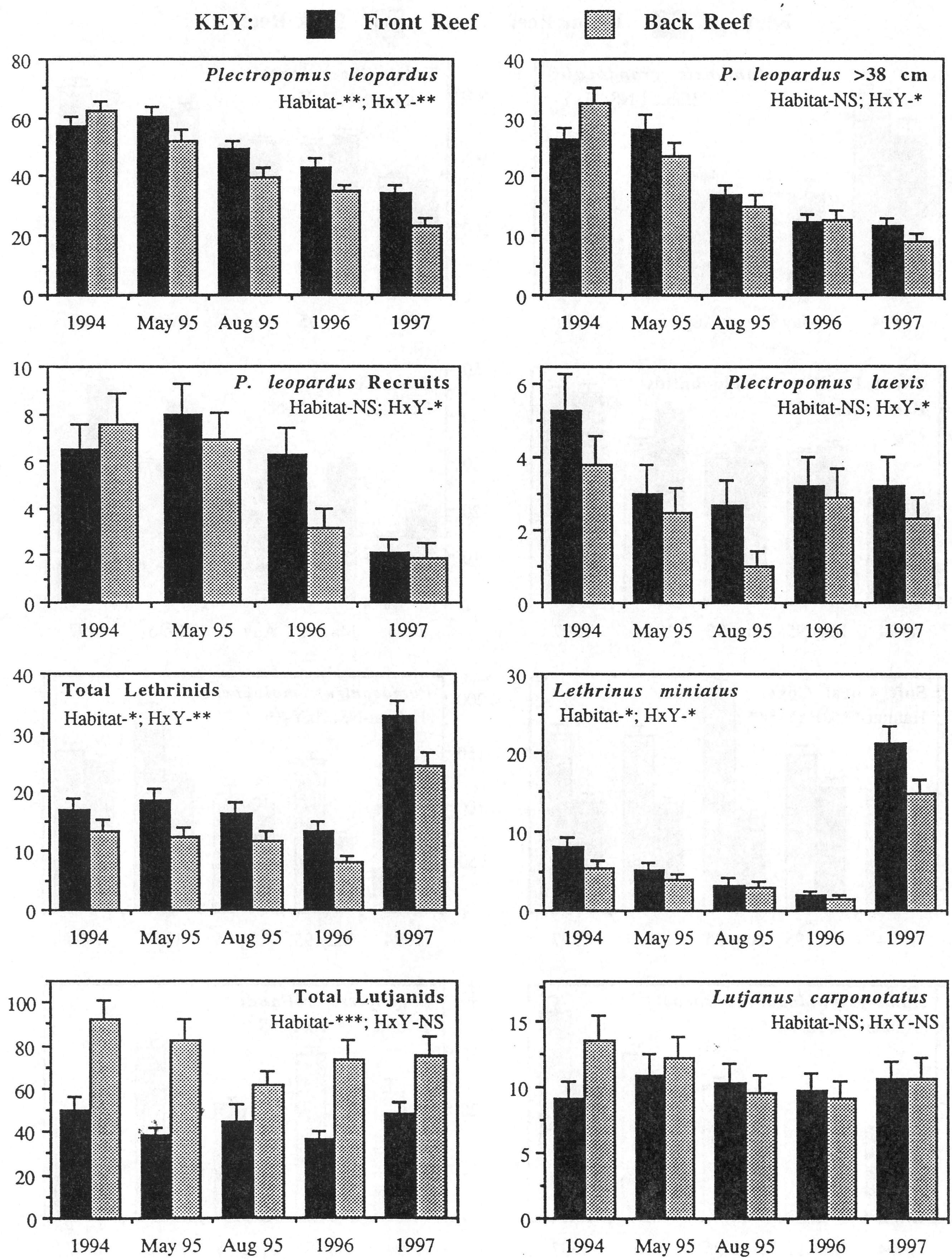
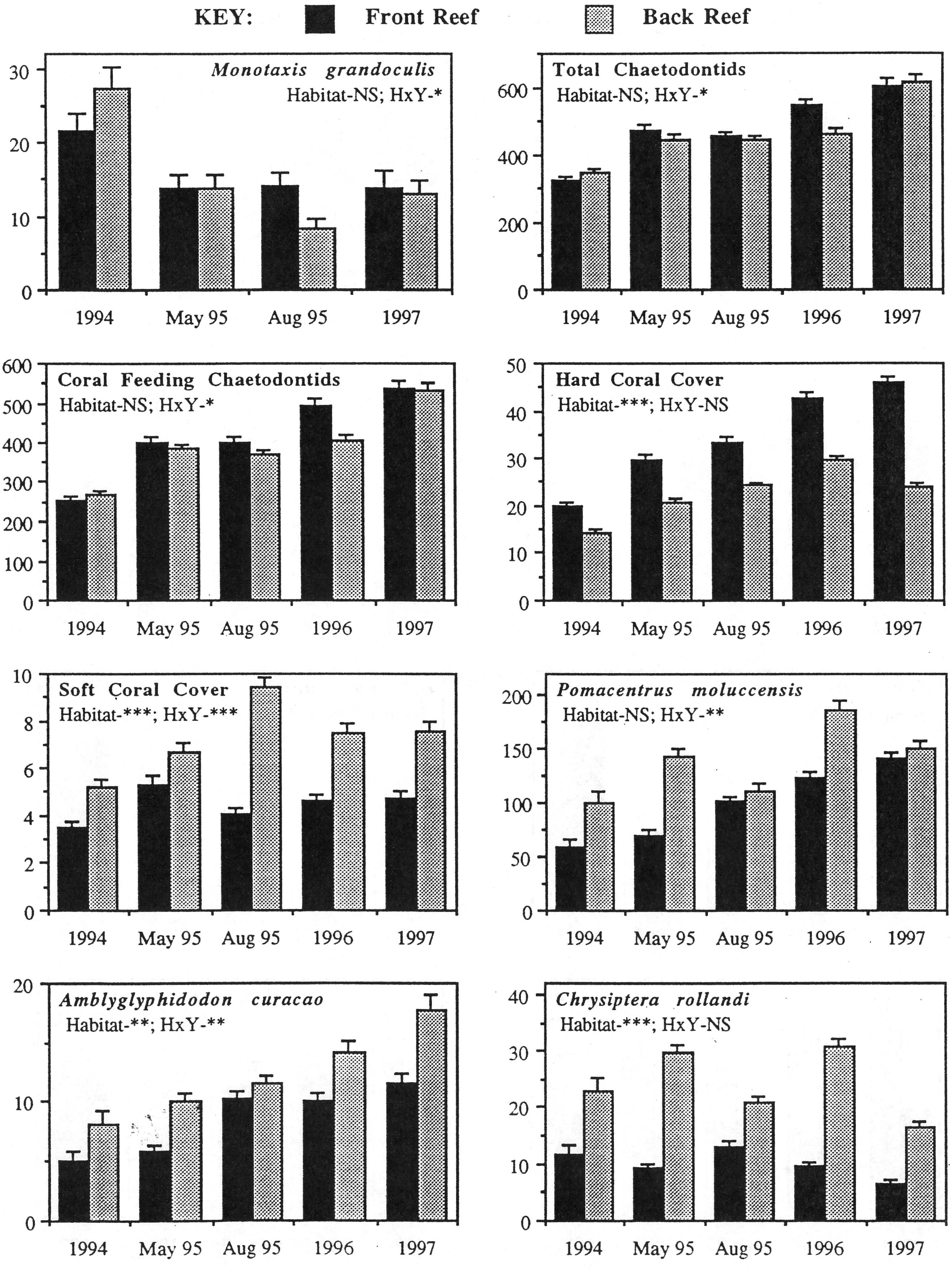


Figure 8. Within Reef Distribution of Other Groups for 1994 to 1997

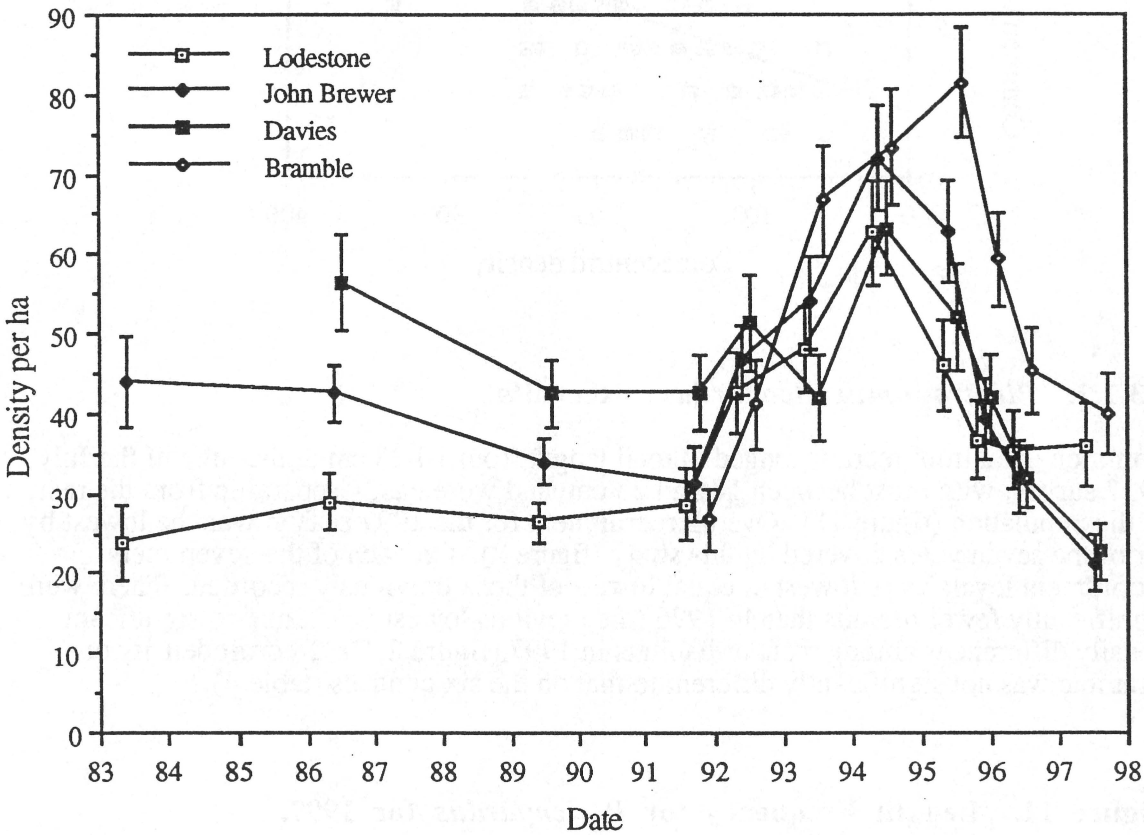
Chaetodontids, Corals and Small Fishes: Graphs show mean density per ha, % cover or density per 100 sq m (small fishes) on the vertical axis for all sites in each habitat. Error bars are standard errors. Significance of tests for habitat differences for 1997 and the HxY interaction are shown.



Overall common coral trout densities on Bramble and the three original controls were similar in 1996 and 1997 to those recorded between 1983 and 1991. Densities on all four reefs showed a sharp increase between 1992 and 1994, that was followed by an equally sharp decline between 1995 and 1997 (figure 9).

Figure 9. Long Term Changes in Coral Trout Density on the Four Original Survey Reefs.

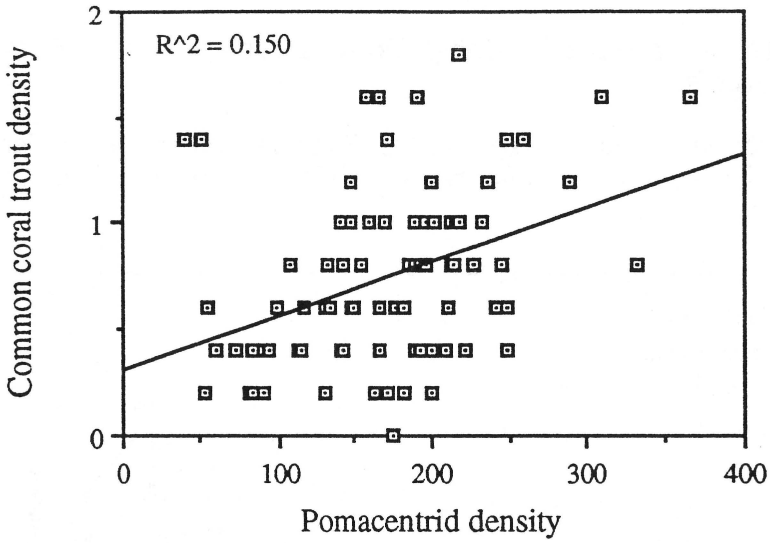
Densities are all converted to mean number per ha. Error bars are ± one standard error. Means from ten 50 x 20 m transects at two sites (1983-89), or five 50 x 5 m transects at 12 sites (1991-97).



Pomacentrids are an important prey group for coral trout and previous surveys have suggested that there may be a relationship between pomacentrid density and coral trout density. There was also a significant positive relationship between total pomacentrid numbers and coral trout numbers, at the site level, in data from the present survey (figure 10). If we separate data from front and back reefs the relationship between these two groups is more strongly significant for back reef sites ($p<0.001$), than for front reef sites ($p=0.05$).

Figure 10. Relationship Between Pomacentrid Density and Coral Trout Density for the 1997 Survey.

The graph compares density at the site level for the two groups. Density per ha for coral trout, and per 100 sq m for pomacentrids.

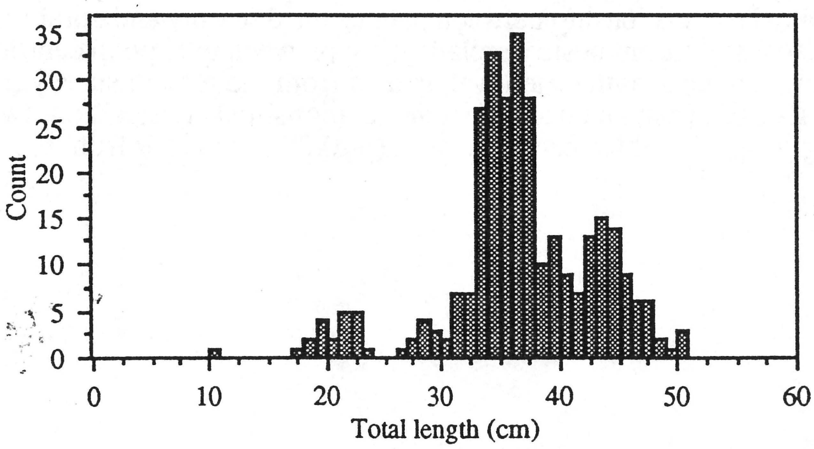


3.3.1.2. *Plectropomus leopardus*: Recruits

Common coral trout recruits ranged in total length from 10-23 cm at the time of the July 1997 survey, with most between 17 and 23 cm, and were easily separable from the rest of the population (figure 11). Overall recruitment for the 1997 season was the lowest by far of the seven years covered by this study (figure 2). On each of the seven reefs recruitment levels were lowest or equal lowest of those previously recorded. There were significantly fewer recruits than in 1996 (the previous lowest year), but no significant density differences among reefs or habitats in 1997 (figure 2, 7). Recruit density on Bramble was not significantly different to that on the six controls (table 4).

Figure 11. Length Frequency for *P. leopardus* for 1997.

Combined length frequency from all reefs shown. Note the small 0+ recruitment peak centred on 20 cm TL.

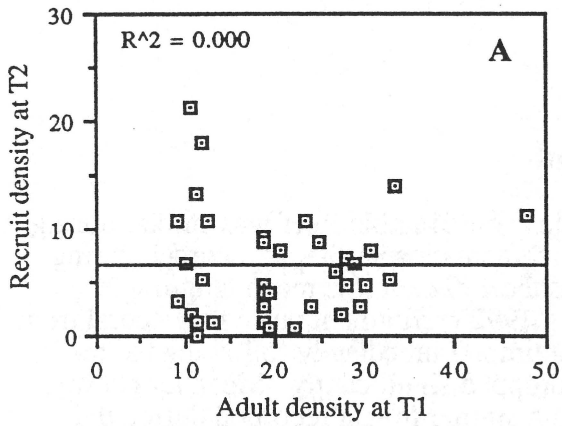


A number of our previous studies have suggested that the recruit density of common coral trout on a particular reef is negatively correlated to adult density (Ayling et al. 1992). Plots of recruit density against adult density during the same survey, and against adult density from the previous year for all the survey data (figure 12) suggest that this relationship may not be as robust as previous work had suggested. The results from this series of surveys indicate that there has been no relationship between recruit density and adult density for these reefs during this time period.

Figure 12. Relationship of Coral Trout Recruit Density to Adult Density.

A. Adults (>38 cm) density for each year (T1) and recruit density for the following year (T2). Figures are grand mean per ha for each reef and each year.

B. Adults (>38 cm) with recruit density from the same survey.



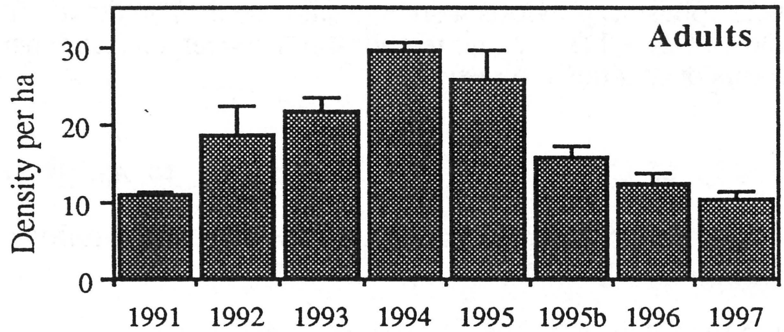
3.3.1.3. *Plectropomus leopardus*: Adults

Adult coral trout numbers were separated from the total population using the estimated length data. At the time of the 1997 survey there were slight but significant differences in adult coral trout density among the seven reefs, with Davies having lower numbers than all other reefs (table 3, figure 2). Adult density on Bramble was not significantly different to that on the controls at this time (table 4). Overall adult density in 1997 was not significantly different from that recorded in 1996, or from that on the four original survey reefs at the time of the baseline survey in 1991. Adult density on most reefs peaked in 1994, with numbers 2.5 times those recorded in 1991 and 1997. At the time of this peak there were also no density differences among the seven reefs. This suggests that all reefs, including Bramble, showed a similar temporal pattern in adult coral trout density, increasing from 1991 to 1994 and decreasing between 1994 and 1996 (figure 13).

There were no habitat differences in adult coral trout density in 1997 (figure 7). Site was significant at the p=0.05 level (table 3).

Figure 13. Annual Patterns in Adult Common Coral Trout Density.

Graph shows grand mean adult density for the combined survey reefs for each year.



3.3.1.4. *Plectropomus leopardus*: Length

The mean length of common coral trout populations on Bramble Reef was similar during three of the four surveys made during the replenishment closure to that recorded during the baseline survey (table 5). The exception was the 1992 survey: mean length was significantly lower at this time because the strong 1992 recruitment pulse of 0+ coral trout made up 52% of the coral trout population at that time. Immediately following the re-opening mean length of coral trout on Bramble dropped significantly. Mean length was also low in 1996. By 1997 mean length was again similar to that recorded during the baseline and throughout the 1993-95 density peak (table 5).

Table 5. Changes in Coral Trout Mean Length on Bramble Reef During this Project.

Solid horizontal lines link years when mean lengths were not significantly different at the p=0.05 level. 95b = August 1995; mean TL in cm is shown, along with the percentage of 0+ fish in the population for each year.

Year	95	94	97	91	93	95b	96	92
Mean TL	36.5	36.2	36.1	36.0	34.5	32.3	30.3	27.3
% 0+ fish	17	12	6	27	16	12	25	52

At the time of the baseline survey there were no significant differences in the mean length of coral trout between Bramble and any of the control reefs (tables 6, 7). There were also no differences in mean length between Bramble and the controls during most of the replenishment closure (in 1992 mean length was higher on Lodestone and Davies than on Bramble because the recruitment pulse was not as strong on these two reefs). In August 1995, two months after the re-opening, mean coral trout length on Bramble was significantly lower than on three of the controls, while a year after the re-opening mean length on Bramble was lower than on all but one of the controls (tables 6, 7). By the time of the 1997 survey, mean length of common coral trout on Bramble (36.1 cm) was very similar to that recorded on the controls (36.3 cm).

Table 6. Summary of Length Data for Common Coral Trout.

All lengths in cm. Mean lengths are shown along with the standard deviation in italics below. nr - not recorded.

Year	Bramble	Brewer	Lode.	Davies	B'mart	Trunk	L.Trunk
1991	36.0	37.3	38.0	34.1	nr	nr	nr
	11.1	*9.3*	*9.0*	*8.3*			
1992	27.3	34.4	31.2	36.6	nr	nr	nr
	12.1	*13.5*	*12.0*	*8.8*			
1993	34.5	32.9	37.1	36.8	34.5	37.5	36.7
	10.7	*10.0*	*10.1*	*7.8*	*9.2*	*9.5*	*8.5*
1994	36.2	35.0	37.5	34.5	39.0	35.5	37.4
	9.5	*9.7*	*8.1*	*8.5*	*8.6*	*9.7*	*9.6*
May 95	36.5	35.7	34.5	36.6	36.2	32.4	35.4
	11.4	*8.9*	*10.8*	*8.2*	*9.4*	*9.4*	*9.9*
Aug 95	32.3	35.4	37.2	35.0	35.8	30.4	34.5
	9.4	*7.5*	*8.9*	*6.3*	*7.5*	*8.8*	*7.4*
1996	30.3	34.2	34.4	34.2	35.4	31.2	37.0
	10.6	*9.7*	*8.9*	*8.1*	*9.7*	*8.3*	*5.6*
1997	35.9	35.6	36.4	34.5	39.6	33.2	38.5
	6.5	*5.9*	*5.7*	*6.6*	*4.5*	*7.8*	*5.9*

Table 7. Comparisons of Coral Trout Mean Length Between Bramble and Each of the Control Reefs for the Different Surveys.

Table shows results of t tests comparing mean length for each pair of reefs. Note: ns = not significantly different; * = $0.01<p<0.05$; ** = $0.001<p<0.01$; *** = $p<0.001$.

Bramble cf ⇒	Brewer	Lode	Davies	B'mart	Trunk	L.Trunk
1991	ns	ns	ns	-	-	-
1992	ns	**	***	-	-	-
1993	ns	ns	ns	ns	ns	ns
1994	ns	ns	ns	ns	ns	ns
May 1995	ns	ns	ns	ns	**	ns
Aug 1995	*	**	ns	*	ns	ns
1996	*	*	*	**	ns	***
1997	ns	ns	ns	**	*	*

There was no increase in adult coral trout size on Bramble compared to the controls during the closure. Mean length of coral trout >38 cm TL on Bramble in May 1995 was 44.0 cm (sd 5.0), compared with a grand mean of 43.3 cm (sd 5.2) on the six controls (Ayling and Ayling 1997). However, there was a slight but significant reduction in the mean length of this age class on Bramble Reef between the May and August 1995 surveys. Mean length had been reduced from 44.0 to 41.9 cm during the heavy post-opening fishing pulse (single factor anova: f=3.994; df=1/100; p=0.048). Mean length of this size class was 42.4 cm on the combined controls in August 1995, not significantly lower than in May 1995 (43.3 cm). However, at the time of the 1996 and 1997 surveys, adult length on Bramble was not different from that on the controls.

Length frequencies for common coral trout populations on each reef were constructed by grouping estimated lengths into 10 cm intervals (appendix 5). Comparisons between pairs of these length frequencies were made using Kolmogorov-Smirnov tests (tables 8, 9). With only a few exceptions, length frequencies on Bramble were similar to those on the controls during each survey (table 8). These exceptions generally resulted from Bramble having a higher recruitment peak than one of the controls (figure 14). Length frequencies were relatively consistent on the control reefs between surveys, but were often significantly different between years on Bramble (table 9, figure 14). The 91/92 and 92/93 differences for Bramble resulted from the high 1992 recruitment peak. Similarly, the significant 96/97 differences reflected differences in the recruitment peak. Recruits made up 25% of the coral trout population on Bramble in 1996 but only 8% in 1997 (figure 15). However, the differences between the 1995 pre- and post-opening surveys were probably due to the post-opening peak in fishing pressure on Bramble, with a marked reduction in the 40-50 cm length class.

Table 8. Comparisons of Coral Trout Length Frequencies Between Bramble and Each of the Control Reefs for the Different Surveys.

Table shows results from Kolmogorov-Smirnov Tests between each pair of length frequencies. Note: ns = not significantly different; * significantly different at least at the p = 0.05 level; 95b = Aug 95 survey.

Bramble cf ⇒	Brewer	Lode	Davies	B'mart	Trunk	L.Trunk
1991	ns	ns	ns	-	-	-
1992	ns	ns	*	-	-	-
1993	ns	ns	ns	ns	ns	ns
1994	ns	ns	ns	ns	ns	ns
1995	ns	ns	ns	ns	*	ns
1995b	ns	ns	ns	ns	ns	ns
1996	ns	ns	ns	ns	ns	*
1997	ns	ns	ns	ns	ns	ns

Table 9. Comparisons of Coral Trout Length Frequencies for Each Reef Between Subsequent Pairs of Surveys.

Table shows results from Kolmogorov-Smirnov Tests between each pair of length frequencies. Note: ns = not significantly different; * significantly different at least at the p = 0.05 level; 95b = Aug 95 survey.

Years compared	Bramble	Brewer	Lode	Davies	B'mart	Trunk	L.Trunk
1991/92	*	*	*	ns	-	-	-
1992/93	*	ns	ns	ns	-	-	-
1993/94	ns	ns	ns	ns	ns	ns	ns
1994/95	ns	ns	ns	ns	ns	ns	ns
1995/95b	*	ns	ns	ns	ns	ns	ns
1995b/96	ns	ns	ns	ns	ns	ns	ns
1996/97	*	ns	ns	ns	ns	ns	ns

Figure 14. Coral Trout Length Frequency Comparisons.

Frequency (n) on the vertical axis against TL in cm. Control reef graphs shown only if significantly different from Bramble (table 8). Significant differences for Bramble are 91/92; 92/93; 95/95b; 96/97.

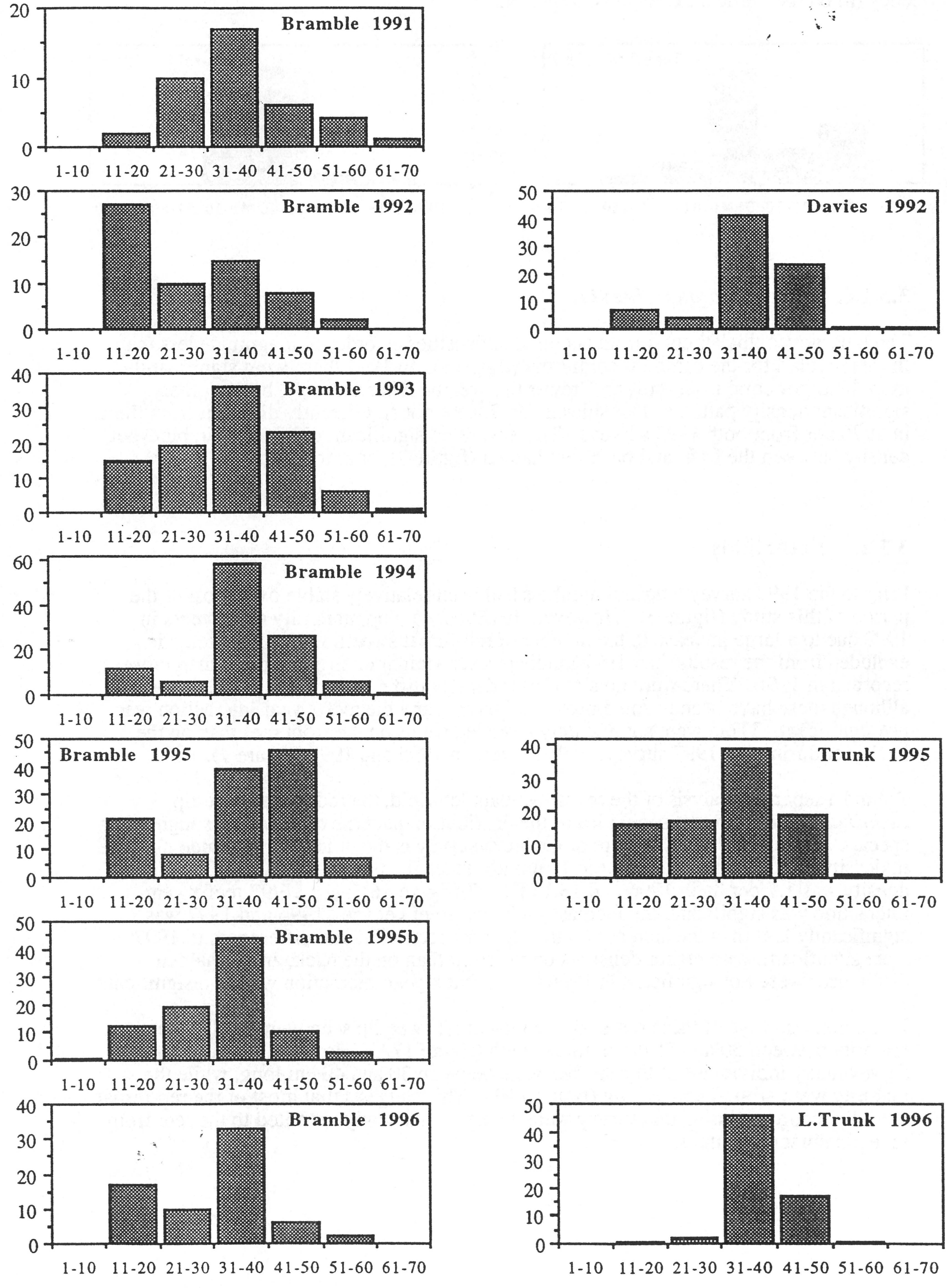
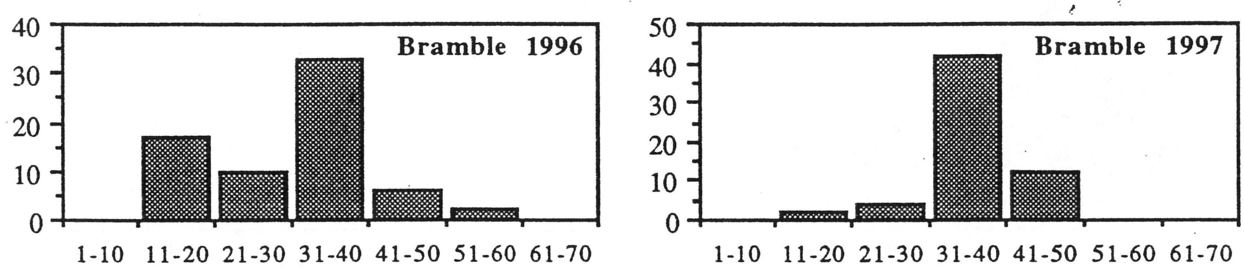


Figure 15. Comparison of Coral Trout Length Frequencies for Bramble 1996/1997.

Frequency (n) on the vertical axis against TL in cm.



3.3.1.4. *Plectropomus laevis*

The bluespot/footballer coral trout occurred at densities an order of magnitude less than those recorded for the common coral trout (figure 3). In 1997 there were significantly more bluespot coral trout on John Brewer than on the other six reefs, but no other significant density patterns. Densities in 1997 were not significantly different from those in 1996 nor from both 1995 surveys. There were no significant differences in bluespot density between the front and back reef habitat (figure 7), or among sites.

3.3.2. Lethrinids

Prior to the 1997 survey lethrinid numbers had been relatively stable over most of the period of this study (figure 3). However, densities were up markedly on all reefs in 1997 due to a large increase in the number of red-throat sweetlip. If this increase is excluded from the results then 1997 numbers were similar or slightly lower than those recorded in 1996. There were no significant density differences among reefs in 1997, although there have been in some previous surveys, and the reef x year interaction was not significant. There were significantly more lethrinids on the front reef than on the back reef during the 1997 survey, as there were in 1995 and 1996 (figure 7).

We did a separate analysis of the most abundant lethrinid, the red-throat sweetlip *Lethrinus miniatus*, to get some idea of the distribution patterns of this most sought after species. The most obvious feature of the latest survey is the order of magnitude increase in density that has taken place in the 12 months since the previous survey. Grand mean density was 1.7 per ha in 1996 and 18.1 in 1997 (figure 16). The 96/97 reef x year interaction was significant; the increase on Trunk Reef between 1996 and 1997 was significantly less than the increase on the other six reefs. Habitat differences in 1997 were significant, with higher densities on the front than on the back, and as habitat differences were not significant in 1996 the habitat x year interaction was also significant.

In previous surveys of these reefs, all the red-throat sweetlip seen were adults, the majority between 50 and 55 cm in total length (figure 17A). However, during the 1997 survey many individuals of this species were between 30 and 40 cm long, while the majority were around 45 cm long (figure 17B). This suggests that most of the red-throat sweetlip recorded during this survey were young adults newly recruited to the reef from juvenile nursery grounds.

Figure 16. Changes in Overall Red-Throat Sweetlip Density.

Graph shows grand mean density for the combined survey reefs for each year.

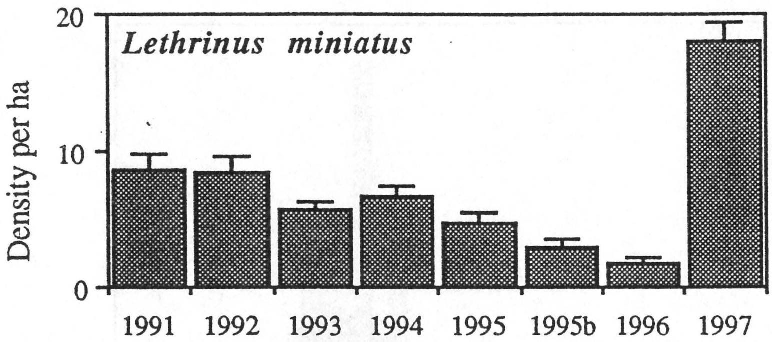
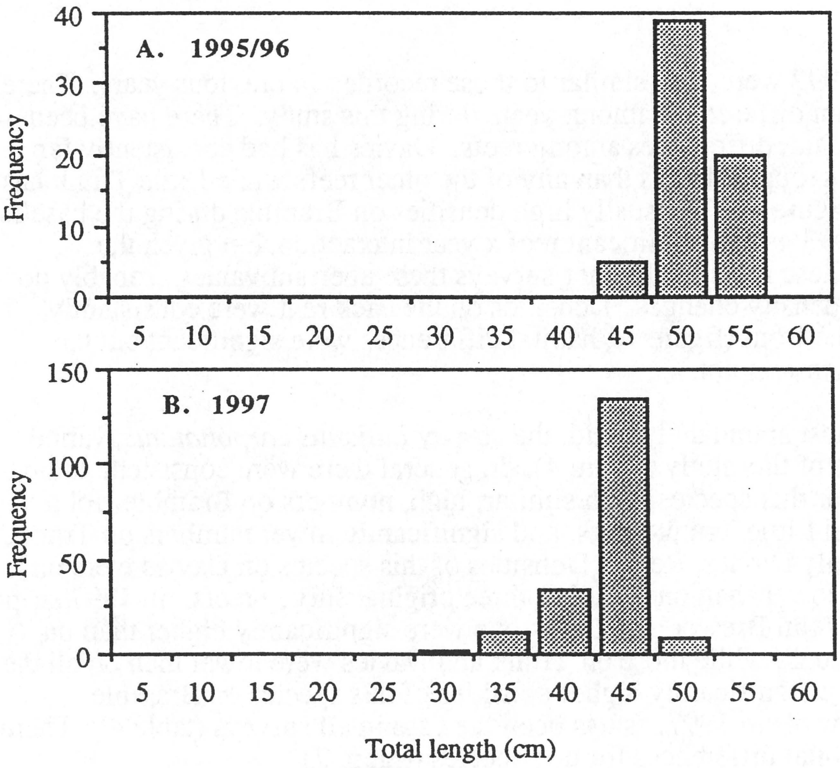


Figure 17. Red-Throat Sweetlip Length Frequency Comparison.

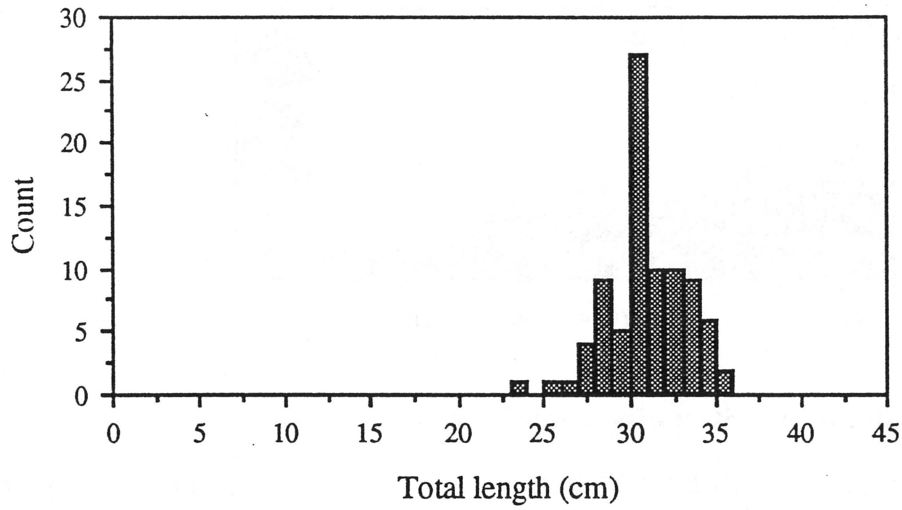
The combined length frequency from all reefs is shown for 1995/96 combined, and for 1997.



The smaller lethrinid *L. atkinsoni* was only recorded as an adult in this survey, with a mean length of 30.5 cm and a range from 24-35 cm (figure 18). Mean length on the seven reefs ranged from 29.4 on Bramble, to 31.5 on Davies with no significant differences among reefs, and no significant difference between 1995, 1996 and 1997. No other lethrinid species were common on these reefs.

Figure 18. Length Frequency for *Lethrinus atkinsoni* for 1997.

Combined length frequency for all reefs in shown.



3.3.3. Lutjanids

Lutjanid numbers in 1997 were very similar to those recorded in previous years. There have been no significant differences among years during this study. There have been consistent, and significant, differences among reefs. Davies has had consistently far lower densities of this group of fishes than any of the other reefs while Little Trunk has had higher densities (figure 4). Unusually high densities on Bramble during the baseline and on Britomart in 1993 gave a significant reef x year interaction, but given the consistent density on these reefs in all other surveys these aberrant values probably do not represent any real density changes. Densities on the back reef were consistently about twice those on the front (figure 7); habitat differences were significant but the habitat x year interaction was not.

Mean density of the most abundant lutjanid, the stripey *Lutjanus carponotatus*, varied little over the six years of this study (figure 4). In general there were consistent among-reef density patterns for this species, with similar, high, numbers on Bramble, John Brewer, Lodestone and Little Trunk Reefs, and significantly lower numbers on Trunk, Britomart, and especially Davies, Reefs. Densities of this species on Davies were on average about 6 times lower than on the other three original survey reefs. In 1997 stripey densities on Bramble, John Brewer and Lodestone were significantly higher than on Britomart and Little Trunk, while those on Trunk and Davies were lower than on all the other reefs. There were significantly higher densities of this species on Bramble compared with the controls in 1997, as has been the case in all surveys (table 4). There were no significant habitat differences for this species (figure 7)

Mean total length of the stripeys *Lutjanus carponotatus*, recorded each year during this project has fluctuated only slightly, ranging from 30.5 to 31.3 cm. The majority of individuals of this species recorded each year were adults between 28 and 36 cm in length with a few juveniles smaller than this (figure 19). Occasional juveniles 8-12 cm in length have been recorded; this species is found on the reef during its entire post-larval life history, but unlike the common coral trout recruitment is low compared to adult density.

The red bass *Lutjanus bohar* has not been abundant on these reefs over the period of this project with grand mean densities of 2.6 per ha in 1995 and 4.9 in 1996. Usually a range of size classes are represented up to a maximum of about 60 cm TL, including a few juveniles between 10 and 20 cm (figure 20A). However, during the 1997 survey we recorded large numbers of juveniles of this species, between 10 and 25 cm in length, with densities of about 6 per ha (figure 20B). As a result overall densities were 8.7 per ha, almost twice those recorded in 1996.

Figure 19. Length Frequency for *Lutjanus carponotatus* for 1997.

Combined length frequency for all reefs in shown.

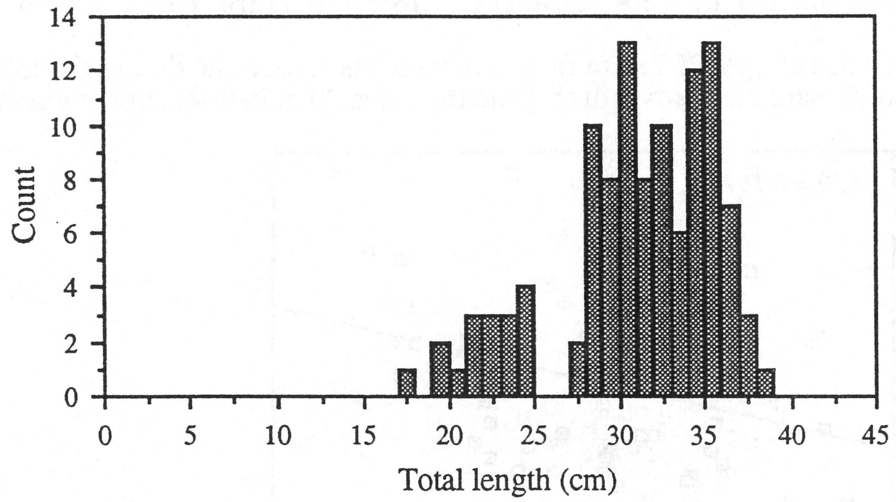
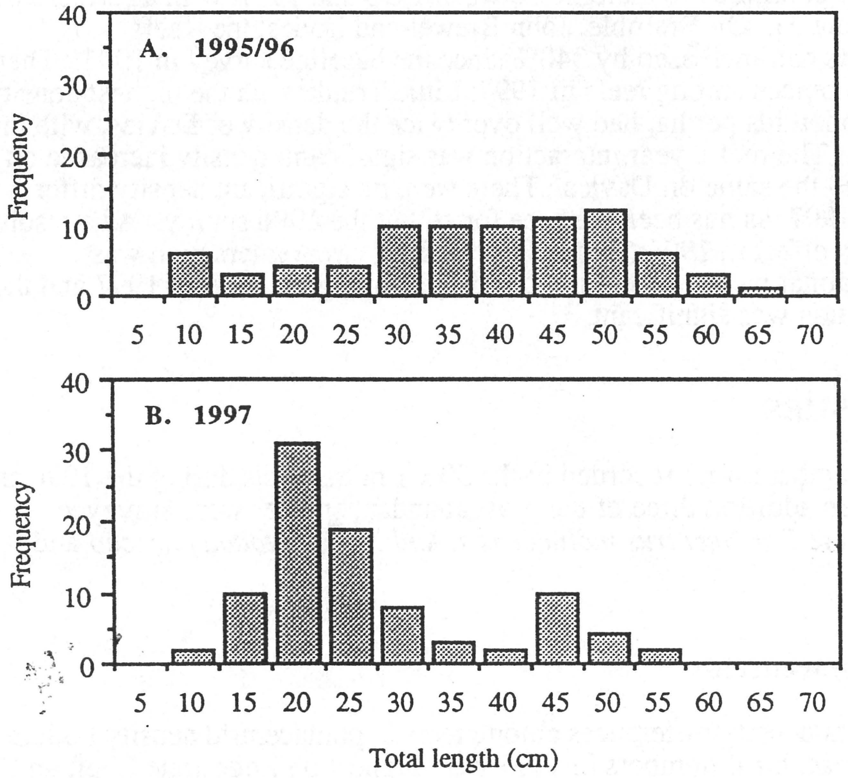


Figure 20. Red Bass Length Frequency Comparison.

The combined length frequency from all reefs is shown for 1995/96 combined, and for 1997.

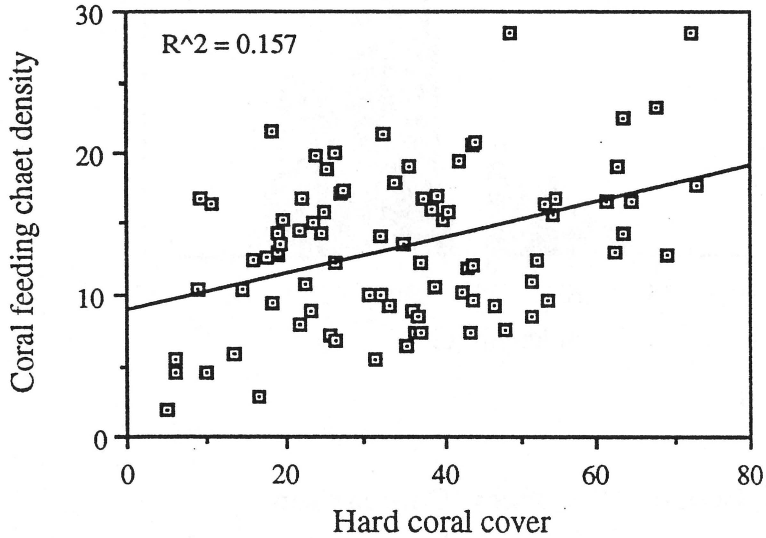


3.3.4. Chaetodontids

There was a positive relationship between hard coral cover and chaetodontid density at the site level for the 1997 survey (figure 21), as has been found in all previous surveys we have made. As a result, total density of the combined species of chaetodontid, and of the combined hard coral feeding chaetodontids, showed similar patterns of density that followed closely the cover of hard corals on the reefs (figure 5, 8).

Figure 21. Relationship of Chaetodontid Density to Hard Coral Cover.

Mean chaetodontid density per 250 sq m from five transects at each site during the 1997 survey is related to % hard coral cover at that site from five 20 m intersect line transects.



Chaetodontid density continued to increase between 1996 and 1997, with a further 20% overall increase (figure 5). On Bramble, John Brewer and Lodestone Reefs, chaetodontid numbers had increased by 340% since the baseline survey in 1991. There were significant differences among reefs in 1997: Little Trunk, with the highest density of almost 870 chaetodontids per ha, had well over twice the density of Davies, with the lowest at 289 per ha. The reef x year interaction was significant: density increased on six of the reefs but stayed the same on Davies. There were no significant density differences between habitats in 1997, as has been the case for all but the 1996 survey. As a result of the significant habitat effect in 1996 (figure 8) the habitat x year interaction was significant. These habitat patterns were not consistent among the reefs in 1997 and the reef x habitat interaction was significant.

3.4. SMALL FISHES

Total pomacentrid numbers were recorded in the 50 x 1 m transects during the 1996 and 1997 surveys only. In addition three of the most abundant species were surveyed separately. These were *Pomacentrus moluccensis, Amblyglyphidodon curacao* and *Chrysiptera rollandi.*

3.4.1. Total Pomacentrids

There were significant density differences among reefs in pomacentrid density both in 1996 and 1997. Pomacentrid numbers in 1997 were highest on Lodestone Reef, and lowest on Trunk Reef, with moderately high numbers on Bramble, John Brewer and Little Trunk (figure 22). There was a significant drop in pomacentrid density between 1996 and 1997, with at least nominal falls on all seven reefs, and significant falls on five reefs. There were no significant habitat effects on pomacentrid density. There was a significant relationship between hard coral cover and pomacentrid density (figure 23).

Figure 22. Total Pomacentrid Density on the Survey Reefs in 1996/97.

Graph shows mean density from 60 transects of 50 x 1 m per reef, converted to number per 100 sq m. Error bars are standard errors.

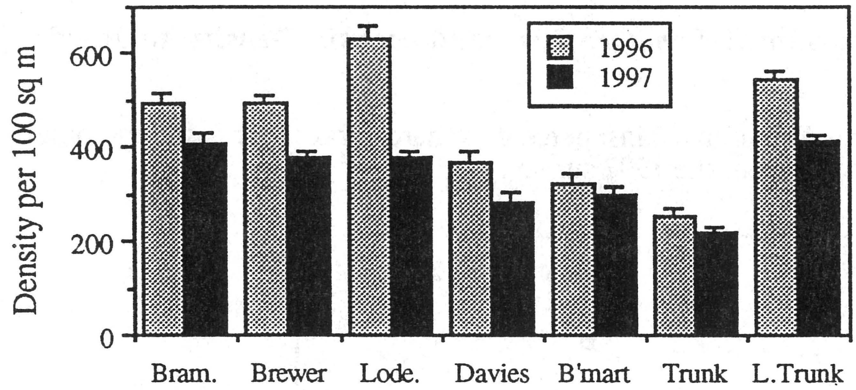
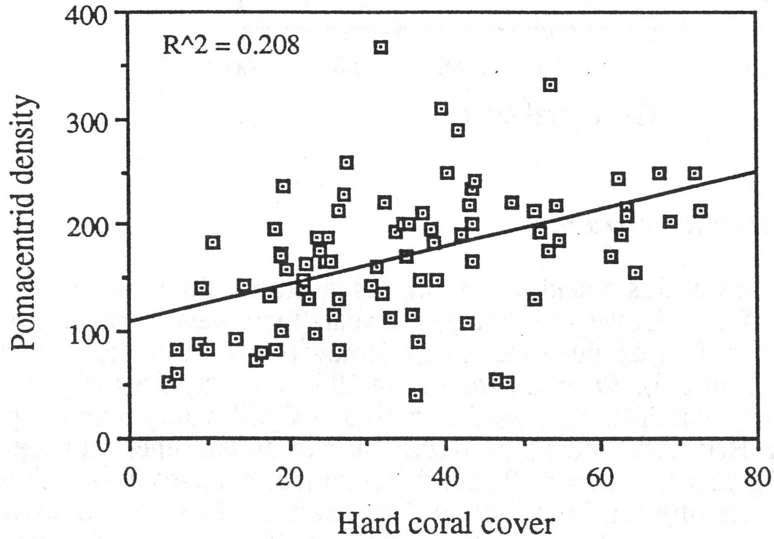


Figure 23. Relationship of Pomacentrid Density to Hard Coral Cover.

Comparisons at the site level are shown for all sites on all reefs in 1997. Pomacentrid densities per 100 sq m are shown along with percentage hard coral cover.



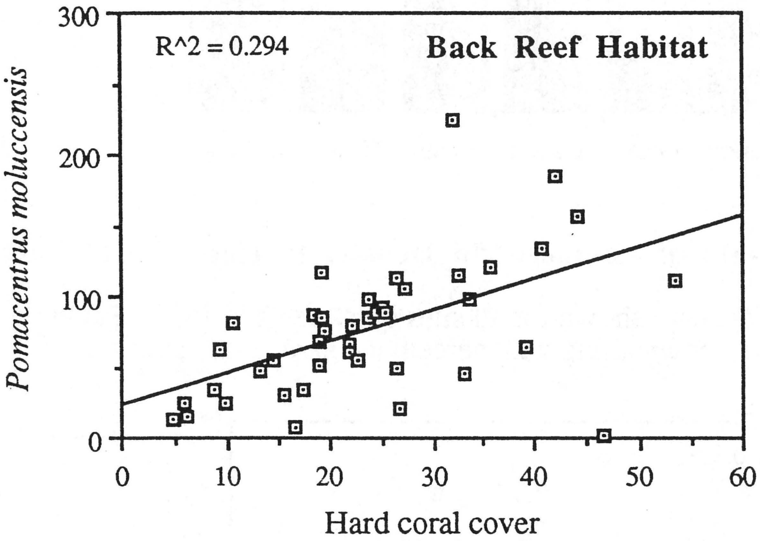
3.4.2. *Pomacentrus moluccensis*

Densities of this common, bright yellow pomacentrid have increased markedly over the period of this project, with order of magnitude increases on Bramble, John Brewer and lodestone since the baseline survey in 1991 (figure 6). However, this increase did not continue over the 12 months between the 1996 and 1997 surveys: numbers did not differ significantly on all reefs except Lodestone (decrease) and Britomart (increase), and the overall change was not significant. In all but one of the previous surveys there have been higher densities of this pomacentrid on the back reef habitat compared to the front, but in 1997 densities were similar in both habitats (figure 8). Between 1996 and 1997, densities had increased slightly in the front reef habitat but decreased markedly in the back reef. As a result both the reef x habitat, and habitat x year interactions were significant.

In the 1997 survey there was a positive relationship between hard coral cover and the density of this species, especially on the back reef (figure 24). The 1997 densities of *Pomacentrus moluccensis* were much higher on Bramble, John Brewer, Lodestone, Britomart and Little Trunk than on the other two reefs (figure 6), differences that were probably partly due to differences in coral cover among the reefs (figure 5).

Figure 24. Relationship of *Pomacentrus moluccensis* Density to Hard Coral Cover.

Pomacentrid density per 100 sq m against percentage hard coral cover is shown for all back reef sites for all reefs from the 1997 survey.



3.4.3. *Amblyglyphidodon curacao*

Prior to May 1995 densities of this plankton feeding pomacentrid did not show significant time or reef effects. However in the past 2 years there have been significant increases on all reefs except Davies, due to an influx of new recruits into the populations (personal observations) (figure 6). Overall densities in 1997 were significantly higher than in 1996 (table 3). At the reef level, densities increased significantly over the past 12 months on John Brewer, Britomart and Trunk Reefs, but not on the other four reefs, giving a significant reef x year interaction. These different reef changes gave a significant reef effect in 1997, with densities on John Brewer, Britomart and Little Trunk higher than on the other reefs. There was also a significant habitat effect, with higher densities on the back reef compared with the front (figure 8). As would be expected the site x year interaction was also significant.

3.4.4. *Chrysiptera rollandi*

This small pomacentrid lives close to the bottom (the previous two species are usually seen plankton feeding up to a metre above the bottom) and is usually most abundant over small silty patches of substratum. As a result it is always more abundant on the back reef than the front (figure 7). At the time of the 1997 survey this species was significantly more abundant on Davies Reef than on the other six reefs (figure 6). Densities decreased significantly on all reefs over the 12 months between the 1996 and 1997 surveys, and this reduction was more pronounced on the back reef than on the front (figure 8), giving a significant habitat x year interaction. As would be expected, given that sites were random, the site x year interaction was significant.

3.5. ENCRUSTING ORGANISMS

3.5.1. Hard Corals

Up until 1996 hard coral cover had been increasing markedly on all these reefs following crown-of-thorns outbreaks in the 1980s. On the original four survey reefs coral cover had increased almost 4 times since the baseline survey in 1991 (figure 5). However, although coral cover increased slightly on the front reefs between 1996 and 1997, there was a significant decrease on the back reef (figure 8) and overall coral cover did not change significantly over this period. At the time of the 1997 survey coral cover was significantly higher on Lodestone, Britomart and Little Trunk Reefs than on the other four reefs, and coral cover was lowest on Davies and Trunk Reefs. As has always been the case, there was a significantly higher cover of hard coral in the front reef habitat than in the back (figure 8).

3.5.2. Soft Corals

Soft coral cover has been less than 10% on all reefs over the time of this study. Cover has apparently fluctuated on most of the reefs, and in 1997 soft coral cover was significant lower on John Brewer, Lodestone and Davies compared with the other reefs (figure 5). There was significantly more cover of soft coral on the back reef compared to the front in 1997, and this pattern has been consistent over the past two years (figure 8); the habitat x year interaction was not significant.

4. DISCUSSION

4.1. Closure Summary.

The Bramble Reef replenishment area was closed to fishing for 3.5 years from the 1st January 1992, sufficient time for recovery of coral trout populations at least. The reef was re-opened to fishing on 1st July 1995 a month after the May 1995 survey, and the first post-opening survey was made two months later in August 1995. This third post-opening survey was made approximately 2 years after the re-opening.

Although enforcement patrols of the Bramble Reef area were carried out throughout the closure, the evidence from Coastwatch vessel sightings on Bramble and the controls suggests that fishing levels were higher on Bramble, both before and during the so-called closure, than on all but Britomart Reef (Ayling and Ayling 1997).

4.2. Coral Trout.

At the time of the baseline survey adult coral trout density was similar on all survey reefs with a grand mean of 10.7 per ha. As has been discussed previously (Ayling and Ayling 1997), there was also no difference in adult coral trout density between Bramble and any of the controls at the time of the 1994 survey, 2.5 years after the Bramble closure. At this time adult density was almost 30 per ha, about 3x that recorded during the baseline. Over the final 12 months of the closure adult numbers increased by 44% on Bramble, while there was an approximately 25% mean reduction on the six controls. Density of this important size class on Bramble was therefore about double that on the controls at the time of the re-opening.

The increase in adult numbers on Bramble was probably a result of continued movement of the strong 1992 recruitment peak into this size class, along with some of the moderately high 1993 recruitment (10.7 per ha). Although this increase also suggests that there was good compliance with the replenishment closure by fishermen over the last 12 months of the closure the information on vessel sightings does not confirm this. As mentioned above, there were at least as many potential fishing vessels on Bramble during this period as there were pre-closure and during the first half of the closure. It is possible that the increase in adult coral trout on Bramble over the controls was primarily due to the higher recruitment of young fish onto Bramble, rather than to a relative reduction in fishing pressure caused by the replenishment closure. Total recruitment of coral trout onto Bramble was on average about twice that on the controls; this may have been the major factor responsible for the increase of adult numbers on Bramble relative to the controls during 94/95.

The effect of the opening of Bramble Reef on the population of adult coral trout was dramatic. Almost 60% of these legal sized common coral trout were removed from Bramble over a period of only eight weeks. We used a detailed map of Bramble taken from an aerial photograph to calculate the approximate area of reef habitat available to coral trout. If we combine this with the mean densities recorded prior to the opening, it is possible to come up with a rough estimate of 12,000 adult coral trout removed from the reef during the eight week opening rush. Information is available from the CRC catch surveys of Bramble for the first 30 days following the re-opening (J. Higgs personal communication). The estimate of the combined recreational and commercial catch of coral trout for this period was between 6,140 and 9,440 fish. Our estimate of approximately 12,000 fish (95% ci 7,850-16,150) for the first 2 months is certainly in the correct range.

At the time of the 1996 survey, almost 12 months after the Bramble re-opening, common coral trout density on Bramble was not significantly different from the controls, an 80%

reduction in the 12 months following the May 1995 survey. There had also been an average 52% reduction on the controls in the 2 years since the peak in coral trout density during the 1994 survey. Adult trout numbers remained stable over the second year following the re-opening, both on Bramble and the controls. Presumably catch rates at the current low densities are approximately balanced by movement of young coral trout into the adult population. Commercial fishing effort in this area is still relatively high and 8 boats were seen on the study reefs during the field work for the 1997 survey, including 3 boats on Bramble.

Although the peak in density on Bramble was higher, and the following decrease more abrupt, due to the intense surge in fishing activity that followed the opening, the overall pattern of density changes was generally the same on all seven reefs. From a low during the baseline, overall adult numbers increased by about 70% by the 1992 survey, probably as a result of good recruitment in the 1989/90 season. There was a further increase of about 40% between the 1993 and the 1994 surveys as the high recruitment peak of 1991/92 reached adult size. Since then numbers have dropped on all reefs and at the time of the 1996 and 1997 surveys they were similar to those recorded during the baseline.

There is no evidence that the patterns of density change on the three new controls was any different to that outlined in the preceding paragraph. These reefs were added to the survey in 1993 after suggestions that there may have been a transfer of fishing activity from Bramble to the adjacent reefs Britomart, Trunk and Little Trunk, following the Bramble closure. Although they were not sampled during the baseline or in 1992, adult coral trout densities on these reefs were not significantly different to those on Bramble and the other three controls during the abundance peak in 1994. All three reefs have also shown a similar decline in density following this peak, to that recorded on Bramble and the other three controls.

Although information on commercial fishing catch from individual reefs is not available, the Sunfish database maintained by the Qld DPI can provide information from 30' latitude and longitude squares. One such square covers Bramble, Britomart, Trunk and Little Trunk Reefs, along with about 8 other reefs, another covers John Brewer and Lodestone, along with 8 other reefs, and a third includes Davies and about 20 other reefs. Catch data from these three squares (reported in Ayling and Ayling 1997), suggested that there was an increase in commercial fishing in the area during 1994/95, with a 60% increase in commercial catch during the second half of the closure and in the six months following the re-opening, compared with the first half of the closure (there is no comparable source of recreational fishing catch data but this is generally much less than the commercial catch). We observed commercial boats on Britomart, Trunk, John Brewer and Davies during the May 1995 survey, more sightings than during previous surveys, and discussion with one of the fishermen suggested that commercial boats had been working in the area over this period. This fishing increase probably contributed to the reduction in adult coral trout densities on five of the six controls.

If the coastwatch vessel sighting information is any indication of fishing pressure then the replenishment closure did not reduce fishing pressure on Bramble Reef. If this is the case, and the increases in adult coral trout density on Bramble and the controls are largely a result of several good recruitment episodes, then it may be argued that the only effect of the replenishment closure has been to create an intense burst of fishing pressure on Bramble, and possibly on some of the controls, following the opening.

If the protection afforded Bramble Reef by the replenishment closure had given rise to an increase in common coral trout in the larger size classes normally reduced by fishing pressure then it might be expected that the mean length of fish would increase on Bramble relative to the controls. In some previous studies there have been increases in mean length resulting from fishing protection (Ayling and Ayling 1986, 1991) but for others there has been no increase in length (Ayling and Ayling 1992a, 1994a, 1994b). As has been pointed out, there was no change in mean total length on Bramble or the controls over the 3.5 years of the closure. Mean length was significantly lower on Bramble at the time of the 1996 survey compared with the previous 4 surveys, but was up again in 1997. This was probably due to the moderately high percentage of new recruits in the population compared with previous years in 1996 when about 25% of the Bramble coral trout population were new recruits, slightly more than the number of adults. In 1997 recruits only accounted for 6% of the Bramble coral trout population.

The length information further suggests that the fishing regime on Bramble during the closure was no different from that on the controls. However, the fishing peak following the Bramble re-opening removed a lot of adults from the population, changing the length frequency distributions of coral trout populations on Bramble, and reducing the mean length of adults during the first post-opening survey. This change was short lived and in the 1996 and 1997 surveys adult length on Bramble was not different from that on the controls.

Previous work has suggested a negative relationship between recruitment levels of coral trout and protection from fishing, with the highest recruitment occurring on heavily fished reefs (Ayling et al 1992). The results from this project have not supported this idea; there seems to have been no relationship between adult density and recruit density, either in the same year or the following year, for these eight surveys. As adult densities have been low on all reefs over most of the past 2 years it may be expected that the 1997 recruitment would be high if adult numbers were having any effect. However, the 1997 coral trout recruitment levels were lower than in any previous survey in this project, and it is clear that adult density levels are not a primary influence on recruitment levels.

In the report on the 1994 survey (Ayling and Ayling 1994b) we suggested that the increase in coral trout density on Bramble and some of the controls since 1991 may have been at least partly due to corresponding increases in pomacentrids, their major prey group on these northern reefs (St John 1994). At the time of the May 1995 survey there was a significant positive relationship between total pomacentrid density and total coral trout density (Ayling and Ayling 1997), adding further support to the suggestion that coral trout density may be affected by prey density. In the 1996 survey there was a good positive relationship between pomacentrid density and coral trout density in the back reef habitat, where pomacentrids are probably the most common prey item and other prey items such as bait fish and fusiliers are not abundant. However there was no relationship between these two groups in the front reef habitat where fusiliers and other small pelagic species are most abundant (A.M. Ayling personal observations). The present survey found a positive relationship between pomacentrid density and coral trout numbers in all sites. While it is possible that the density of both pomacentrids and coral trout are showing a common response to some other factor eg the increase in coral cover, further studies should probably direct some attention to looking at this question.

4.3. Other Target Species.

After 3.5 years of protection there was no evidence that red-throated sweetlip numbers had increased on Bramble Reef. This species is the second most important reef dwelling fishing target species (Trainor 1991). As this species is extremely site attached (Beinssen and Beinssen 1989), and is only found as adults on these reefs any increase on Bramble is likely to be slow.

Like coral trout, the density data for this species suggest that fishing pressure increased on the controls during the 1994/95 period, with a significant 52% reduction in grand mean density. At the time of the 1996 survey densities of this species were consistently low on all 7 reefs with a grand mean of only 1.7 per ha.

Between 1996 and 1997 there was an order of magnitude increase in red-throat sweetlip density on all reefs, with the movement of large numbers of small adults, mainly 40-45 cm TL, into the population. Although there were significant differences in the density of this influx among reefs at the time of the 1997 survey, it was clear that the same process had affected all reefs. Although densities on Bramble were an order of magnitude lower than on the three original controls at the time of the baseline survey, suggesting that Bramble may have been subjected to a different recruitment regime, there was no evidence from this recruitment episode that Bramble was in any way different to the other six reefs. On all control reefs, 1997 densities were more than twice those recorded during the baseline, while on Bramble the increase was an order of magnitude over the baseline level.

Although juvenile red-throat sweetlip (15-25 cm TL) have been seen in *Acropora* staghorn thickets on GBR reefs south of Mackay (personal observations) they have not been recorded on reefs off Townsville. The smallest recorded during this survey was around 30 cm TL. During an April 1997 trip to the mid shelf Townsville area we caught many small red-throat sweetlip (15-20 cm TL) in 25-30 m of water off the back reef, and scuba exploration found these juveniles to be living in *Acropora* staghorn thickets over sand in depths of 15 m plus. It seems likely that the influx of red-throat sweetlip onto these reefs has resulted from one or two extremely good recruitment years, with the young adults only recently moving from the juvenile nursery grounds in deep-water *Acropora* staghorn thickets onto the reef slope. It seems possible that red-throat sweetlip populations in this area are replenished at irregular intervals and then slowly decrease due to fishing pressure.

Total lethrinid numbers were up markedly in 1997, due to the increase in *Lethrinus miniatus* density. Total lutjanid numbers remained relatively stable on all the survey reefs between the 1994 and 1997 surveys. Although adults of both groups are retained by fishermen there is no evidence that the replenishment closure, or the re-opening, has had any effect on the overall density of these two groups.

Although lethrinid density was usually not significantly different on any of the seven reefs, the consistent, apparently natural, differences in lutjanid density between reefs is remarkable. In 1997 densities of this group ranged over more than an order of magnitude, from only 17 per ha on Davies to almost 160 per ha on Little Trunk. Further research on the life histories of this important family is necessary before any reasons for these large among-reef differences can be suggested.

The stripey, *L. carponotatus*, is the most abundant of the lutjanids and this species is solitary and never found in schools in this region. It is regularly caught by fishermen and retained either for bait or for eating if large enough. Numbers of this species were consistently very low on Davies, Britomart and Trunk, but as with overall lutjanid numbers there was no evidence that numbers had been affected by the Bramble closure or re-opening.

4.4 Other Reef Attributes.

The information collected on encrusting organisms, chaetodontids and prey species (pomacentrids), has proven useful in a number of respects. The increase in coral cover as all the survey reefs recover from crown-of-thorns devastation has provided a framework to understand changes in other organisms such as chaetodontids and pomacentrids, which in turn has suggested relationships with coral trout numbers.

Tropical Cyclone Justin affected the study reefs when it passed south along the coast in late March after its landfall near Cairns. Strong winds in the study area were from the north and probably did not exceed 50 knots. This brief strong wind episode had a noticeable affect on many populations on the study reefs. Hard coral cover on the back reef habitat probably decreased around 30% (a 20% decrease as opposed to a 10% increase on the front reef). At many sites exposed to the north drifts of freshly dead broken coral colonies were observed around bommie margins. There was also some damage at front reef sites where waves were able to pass across the reef flat but this had not caused measurable coral cover reduction. Total pomacentrid numbers were also down, especially in the back reef habitat, where the decrease was about 28%. Of the pomacentrid species counted individually, *Pomacentrus moluccensis* numbers were down 20% on the back reef and *Chrysiptera rollandi* were down 46% in the same habitat, but *Amblyglyphidodon curacao* numbers increased on both the front and back habitats. There was no evidence that this strong wind episode had any effect on large fishes in this area.

5. IMPLICATIONS FOR MANAGEMENT.

5.1. Closure Enforcement.

There are two major implication for reef managers that arise from this project. The first concerns the apparent problem of closure enforcement. The evidence from Coastwatch vessel sightings suggests that there was not in fact a replenishment closure on Bramble Reef. While the protocol of sighting reports is not particularly rigorous, fishing vessel sightings on Bramble throughout the closure were higher than on all but one of the controls. If this can be regarded as a measure of relative fishing effort then the fishing level on Bramble was not lower than on the controls during the supposed closure. Although we visited Bramble on only eight days during the closure, we saw commercial mother boats with actively fishing dories on the reef on two occasions and dories fishing on Bramble from a mother vessel anchored on Trunk Reef on another occasion. This tends to support the evidence from the Coastwatch vessel sightings.

Discussion with fishermen and other reef users suggests that this is a universal problem. It is well known that some fishermen deliberately target closed reefs. If the supposed zones allowing for different usage of different areas of the GBR are nominal only, then the entire premise that the marine park is based on is called into doubt. An increase in the level of enforcement, and/or a dramatic increase in fines for offenders is obviously necessary. It may be that a reduction in the number of protected reefs, and perhaps their relocation to areas where enforcement is easier, will be the only way around this problem.

5.2. Are Replenishment Closures Useful?

Another question concerns the usefulness of replenishment closures as a reef management tool. Adult coral trout densities on Bramble Reef were reduced by 80% in the first year following the re-opening of the replenishment closure. At that stage densities were similar on Bramble and the six controls, and were not significantly different from those recorded on all original reefs during the baseline survey. Any replenishment effect on the major target fish populations that the closure may have had was completely negated within 12 months, with most of this effect occurring in the first 1-2 months. Any such closure has a considerable cost, with extra demands for administration, enforcement, public relations and monitoring components. Is this cost worth it to provide higher than average catches for a few, mainly commercial, reef users for a few months?

If, as we have suggested the increase in adult coral trout density on Bramble Reef (and on the controls) was a natural consequence of several good recruitment episodes, then the major effect of the replenishment closure was negative. The re-opening caused a much more rapid depletion of this increased Bramble coral trout stock than would have occurred without the unusual post-opening fishing effort pulse.

5.3. Red-Throat Emperor Recruitment.

The recent red-throat sweetlip recruitment episode also suggests implications for management. If populations of this species in this part of the GBR are dependent on widely separate recruitment pulses then some extra protection of stocks following such episodes may be useful.

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Appendix 1. Summary of Distance Estimations (m) for Each Transect.

Reef/Site	#1	#2	#3	#4	Mean	Reef mean
Bramble-front						4.97
Site 1	5.2	5.4	5	4.3	4.975	
Site 2	4.4	5.9	4.8	6	5.275	
Site 3	4.8	5	4.8	5	4.9	
Site 4	4.7	4.7	4.8	5.1	4.825	
Site 5	4.3	5.3	5.1	5.2	4.975	
Site 6	4.6	4.5	5.1	5.2	4.85	
Bramble-back						5.09
Site 1	5.5	5.2	4.8	4.9	5.1	
Site 2	5	5.2	5	5.6	5.2	
Site 3	5	5.1	5.5	5	5.15	
Site 4	5	5	5.3	5.4	5.175	
Site 5	4.9	5	5.3	4.8	5	
Site 6	5	5.2	4.9	4.6	4.925	
John Brewer-front						4.99
Site 1	5.2	5.2	5.3	5	5.175	
Site 2	4.6	4.8	5.3	5	4.925	
Site 3	5.2	4.7	5.1	4.5	4.875	
Site 4	5.3	4.9	4.7	5.3	5.05	
Site 5	5.3	4.8	4.7	4.7	4.875	
Site 6	5.1	5.1	4.9	5.1	5.05	
John Brewer-back						4.97
Site 1	4.6	4.6	4.9	4.8	4.725	
Site 2	5	4.8	4.9	5.1	4.95	
Site 3	5	5.1	4.7	5.3	5.025	
Site 4	5.6	4.6	4.8	5	5	
Site 5	5.2	5.4	5	4.8	5.1	
Site 6	5	5	4.5	5.5	5	
Lodestone-front						4.97
Site 1	5.2	4.6	5	4.4	4.8	
Site 2	5	4.5	4.8	5.6	4.975	
Site 3	5	4.9	5	4.8	4.925	
Site 4	5.5	5.2	5.4	5.1	5.3	
Site 5	5.2	5	5.1	4.7	5	
Site 6	5	4.6	4.7	5	4.825	
Lodestone-back						5.00
Site 1	5.3	4.6	4.6	4.8	4.825	
Site 2	4.4	5.5	5	5.2	5.025	
Site 3	5.3	5.2	5	5	5.125	
Site 4	5.1	5.4	5.3	4.9	5.175	
Site 5	4.9	5.1	4.7	4.9	4.9	
Site 6	4.5	5	5.2	5	4.925	
Davies-front						4.97
Site 1	5.1	5.1	5.3	4.7	5.05	
Site 2	5.3	5	5.1	4.9	5.075	
Site 3	5.1	5.1	5.3	5	5.125	
Site 4	5.1	4.7	5.3	4.3	4.85	
Site 5	4.7	5	4.3	5.1	4.775	
Site 6	5	4.5	5.3	4.9	4.925	
Davies-back						5.07
Site 1	4.6	5.3	5	5.1	5	
Site 2	5	5.1	5.1	5	5.05	
Site 3	4.7	5.2	5.1	5.3	5.075	
Site 4	5.3	5.3	4.7	4.9	5.05	
Site 5	5.3	4.9	4.8	5.5	5.125	
Site 6	5.3	5.2	4.8	5.1	5.1	

Grand Mean	**5.01**
Std. Dev.	**0.29**
Max. Est.	**6.00**
Min. Est.	**4.30**

Reef/Site	#1	#2	#3	#4	Mean	Reef mean
Britomart-front						5.02
Site 1	5.5	5.6	4.8	4.9	5.2	
Site 2	4.9	5.3	4.8	4.8	4.95	
Site 3	5.2	4.9	4.7	4.8	4.9	
Site 4	5.2	5.1	4.9	5.3	5.125	
Site 5	4.8	4.9	4.5	5.3	4.875	
Site 6	5.5	5	5.1	4.7	5.075	
Britomart-back						5.00
Site 1	5.7	4.5	4.6	4.7	4.875	
Site 2	4.9	5.3	5.2	5	5.1	
Site 3	5.1	5.2	4.9	4.4	4.9	
Site 4	4.8	5	4.8	5.2	4.95	
Site 5	5.3	5.5	5	4.8	5.15	
Site 6	4.8	4.8	5.2	5.4	5.05	
Trunk-front						4.97
Site 1	5.2	4.8	4.9	5	4.975	
Site 2	4.8	4.5	5.1	5.3	4.925	
Site 3	5	5.3	5	5.1	5.1	
Site 4	5.3	4.8	4.5	5	4.9	
Site 5	5.2	5.2	4.7	5	5.025	
Site 6	5.5	4.7	4.8	4.6	4.9	
Trunk-back						5.08
Site 1	5.5	4.7	4.6	5.5	5.075	
Site 2	4.9	5.2	4.8	5	4.975	
Site 3	5	5	5.1	5.2	5.075	
Site 4	5	5.2	4.7	5.2	5.025	
Site 5	5.2	5.1	5.4	4.7	5.1	
Site 6	5.3	4.9	5.3	5.4	5.225	
Little Trunk-front						5.00
Site 1	5.6	5.6	4.8	5.3	5.325	
Site 2	5.1	5.3	5.2	4.5	5.025	
Site 3	4.7	4.5	5	5.1	4.825	
Site 4	5	4.8	4.8	4.9	4.875	
Site 5	4.7	5	5.3	5	5	
Site 6	5.1	5	5.1	4.6	4.95	
Little Trunk-back						5.04
Site 1	5.1	5.1	5	5	5.05	
Site 2	5.6	5	5.2	4.8	5.15	
Site 3	5.4	4.5	4.8	4.9	4.9	
Site 4	5	5.3	4.6	5.3	5.05	
Site 5	4.9	4.8	5	5.2	4.975	
Site 6	5.2	5.3	5.1	4.8	5.1	

APPENDIX 2. DENSITY SUMMARIES FROM THE JULY 1997 SURVEYS.

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

Figures show means from 50 x 5 m transects from all reefs grouped in various categories with standard deviations in italics. Densities are converted to number per hectare.

	P. leopardus		Trout recruits		Trout >38 cm		*P. laevis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
July 1997 Survey								
Grand mean:	29.1	*33.9*	2.0	*8.7*	10.3	*19.8*	2.8	*10.2*
Habitat Means:								
Front Reef	34.7	*34.4*	2.1	*8.9*	11.6	*20.6*	3.2	*10.9*
Back Reef	23.6	*32.6*	1.9	*8.5*	9.0	*18.9*	2.3	*9.3*
Reef Means:								
Bramble	40.0	*39.7*	3.3	*11.1*	13.3	*21.7*	2.7	*10.1*
John Brewer	21.3	*26.0*	1.3	*7.2*	7.3	*17.3*	7.3	*15.6*
Lodestone	36.0	*40.1*	1.3	*7.2*	10.0	*19.0*	1.3	*7.2*
Davies	22.7	*27.9*	2.0	*8.8*	4.0	*12.1*	3.3	*11.1*
Britomart	25.3	*29.4*	0.0	*0.0*	15.3	*24.5*	1.3	*7.2*
Trunk	31.3	*36.9*	5.3	*13.7*	8.7	*18.2*	2.0	*8.8*
Little Trunk	27.3	*31.7*	0.7	*5.2*	13.3	*21.7*	1.3	*7.2*
Reef Habitat Means:								
Bramble Front	41.3	*41.3*	1.3	*7.3*	13.3	*21.9*	2.7	*10.1*
Bramble Back	38.7	*38.6*	5.3	*13.8*	13.3	*21.9*	2.7	*10.1*
John Brewer Front	28.0	*26.1*	2.7	*10.1*	9.3	*17.2*	8.0	*16.3*
John Brewer Back	14.7	*24.6*	0.0	*0.0*	5.3	*17.4*	6.7	*15.2*
Lodestone Front	41.3	*40.0*	1.3	*7.3*	12.0	*21.4*	1.3	*7.3*
Lodestone Back	30.7	*40.3*	1.3	*7.3*	8.0	*16.3*	1.3	*7.3*
Davies Front	30.7	*31.0*	1.3	*7.3*	4.0	*12.2*	4.0	*12.2*
Davies Back	14.7	*22.2*	2.7	*10.1*	4.0	*12.2*	2.7	*10.1*
Britomart Front	33.3	*33.4*	0.0	*0.0*	18.7	*27.3*	1.3	*7.3*
Britomart Back	17.3	*22.7*	0.0	*0.0*	12.0	*21.4*	1.3	*7.3*
Trunk Front	34.7	*31.0*	6.7	*15.2*	9.3	*17.2*	4.0	*12.2*
Trunk Back	28.0	*42.2*	4.0	*12.2*	8.0	*19.4*	0.0	*0.0*
Little Trunk Front	33.3	*36.5*	1.3	*7.3*	14.7	*22.2*	1.3	*7.3*
Little Trunk Back	21.3	*25.2*	0.0	*0.0*	12.0	*21.4*	1.3	*7.3*

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

Figures show means from 50 x 5 m transects from all reefs grouped in various categories with standard deviations in italics. Densities are converted to number per hectare.

	Lethrinids		*Lethrinus miniatus*		Lutjanids		*Lutjanus carponotatus*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
July 1997 Survey								
Grand mean:	28.6	*37.2*	18.1	*27.5*	61.8	*100.0*	10.5	*21.2*
Habitat Means:								
Front Reef	32.8	*40.4*	21.3	*30.8*	48.2	*79.0*	10.5	*19.7*
Back Reef	24.4	*33.2*	14.9	*23.3*	75.4	*119.6*	10.5	*21.6*
Reef Means:								
Bramble	31.3	*36.1*	18.7	*26.0*	36.7	*39.9*	21.3	*27.0*
John Brewer	36.7	*43.1*	26.0	*30.2*	52.7	*57.3*	14.7	*24.4*
Lodestone	29.3	*37.5*	22.7	*32.4*	50.0	*67.3*	16.7	*26.8*
Davies	25.3	*36.1*	21.3	*32.5*	17.3	*39.2*	2.0	*8.8*
Britomart	20.0	*31.7*	12.7	*22.7*	58.7	*110.1*	8.7	*18.2*
Trunk	26.7	*38.7*	11.3	*22.2*	58.7	*92.4*	2.0	*8.8*
Little Trunk	30.7	*35.6*	14.0	*21.9*	158.7	*173.3*	8.0	*17.7*
Reef Habitat Means:								
Bramble Front	42.7	*40.6*	26.7	*30.3*	26.7	*39.8*	10.7	*18.0*
Bramble Back	20.0	*27.3*	10.7	*18.0*	46.7	*38.0*	32.0	*30.4*
John Brewer Front	37.3	*45.7*	28.0	*35.1*	37.3	*44.5*	13.3	*21.9*
John Brewer Back	36.0	*41.2*	24.0	*24.9*	68.0	*64.9*	16.0	*27.0*
Lodestone Front	36.0	*43.8*	29.3	*37.8*	54.7	*66.0*	22.7	*27.2*
Lodestone Back	22.7	*29.1*	16.0	*24.9*	45.3	*69.5*	10.7	*25.6*
Davies Front	29.3	*41.9*	25.3	*38.6*	26.7	*48.5*	2.7	*10.1*
Davies Back	21.3	*29.2*	17.3	*25.0*	8.0	*24.4*	1.3	*7.3*
Britomart Front	17.3	*27.2*	10.7	*20.8*	68.0	*123.5*	10.7	*18.0*
Britomart Back	22.7	*35.9*	14.7	*24.6*	49.3	*96.1*	6.7	*18.4*
Trunk Front	34.7	*41.7*	16.0	*24.9*	62.7	*118.2*	2.7	*10.1*
Trunk Back	18.7	*34.4*	6.7	*18.4*	54.7	*58.0*	1.3	*7.3*
Little Trunk Front	32.0	*38.5*	13.3	*19.2*	61.3	*60.1*	10.7	*20.8*
Little Trunk Back	29.3	*33.1*	14.7	*24.6*	256.0	*194.7*	5.3	*13.8*

Table iii. Summary of Density of Chaetodontids and Encrusting Organisms.

Figures show means from 50 x 5 m transects (20 m line transects for encrusting organisms) from all reefs grouped in various categories with standard deviations in italics. Densities are converted to number per hectare for fishes and percentage cover for corals. Note: Coral Chaets = hard coral feeding chaetodontids.

	Chaetodontids		Coral Chaets		Hard Coral		Soft Coral	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
July 1997 Survey								
Grand mean:	609.8	*283.6*	534.2	*264.3*	34.8	*19.7*	6.1	*5.3*
Habitat Means:								
Front Reef	605.0	*278.4*	536.6	*268.7*	45.9	*18.0*	4.7	*4.1*
Back Reef	614.7	*289.3*	531.8	*260.4*	23.8	*14.4*	7.6	*6.0*
Reef Means:								
Bramble	670.0	*259.5*	600.0	*232.0*	32.4	*17.5*	8.5	*7.3*
John Brewer	721.3	*224.7*	634.7	*191.3*	34.6	*14.2*	5.2	*3.1*
Lodestone	700.0	*225.5*	623.3	*192.9*	40.7	*20.6*	3.9	*3.9*
Davies	288.7	*145.1*	244.7	*132.2*	27.0	*19.5*	4.1	*4.2*
Britomart	558.0	*210.7*	475.3	*194.9*	39.7	*19.7*	6.8	*4.5*
Trunk	462.0	*175.3*	374.0	*163.5*	26.1	*15.0*	6.9	*5.2*
Little Trunk	868.7	*289.4*	786.3	*289.0*	43.4	*23.4*	7.7	*6.4*
Reef Habitat Means:								
Bramble Front	514.7	*192.2*	472.0	*184.2*	38.8	*16.3*	6.6	*7.0*
Bramble Back	825.3	*223.9*	728.0	*204.1*	26.1	*16.6*	10.5	*7.1*
John Brewer Front	652.0	*221.4*	569.3	*190.7*	41.0	*14.1*	4.4	*3.2*
John Brewer Back	790.7	*209.2*	700.0	*170.9*	28.1	*11.2*	5.9	*2.9*
Lodestone Front	690.7	*224.1*	624.0	*194.1*	58.2	*13.6*	1.4	*1.6*
Lodestone Back	709.3	*230.4*	622.7	*195.0*	23.2	*6.8*	6.5	*3.9*
Davies Front	357.3	*122.5*	297.3	*121.5*	37.9	*8.3*	4.9	*3.1*
Davies Back	220.0	*134.4*	192.0	*122.7*	16.2	*21.6*	3.2	*5.0*
Britomart Front	617.3	*216.5*	532.0	*203.2*	51.6	*17.5*	5.1	*3.2*
Britomart Back	498.7	*190.2*	418.7	*171.2*	27.9	*14.0*	8.4	*5.1*
Trunk Front	418.7	*132.8*	344.0	*125.9*	35.3	*14.5*	5.5	*3.8*
Trunk Back	505.3	*202.5*	404.0	*191.5*	16.8	*8.4*	8.2	*6.0*
Little Trunk Front	984.0	*276.5*	917.3	*282.2*	58.7	*22.0*	4.8	*2.7*
Little Trunk Back	753.3	*257.8*	657.3	*235.0*	28.1	*12.2*	10.6	*7.6*

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

Figures show means from 20 x 2 m transects grouped in various categories with standard deviations in italics converted to number per 100 sq m.

	Total Poms.		*P. moluccensis*		*A. curacao*		*C. rollandi*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
July 1997 Survey								
Grand mean:	338.4	*149.7*	146.0	*90.6*	14.7	*15.1*	11.6	*12.8*
Habitat Means:								
Front Reef	353.4	*131.1*	141.1	*74.8*	11.5	*11.4*	6.6	*7.2*
Back Reef	323.3	*165.2*	150.9	*103.9*	17.8	*17.4*	16.5	*15.1*
Reef Means:								
Bramble	407.0	*184.7*	217.1	*125.8*	11.2	*16.7*	9.9	*7.2*
John Brewer	378.3	*96.3*	190.8	*66.7*	20.0	*13.4*	11.5	*7.1*
Lodestone	378.6	*83.5*	160.9	*52.7*	13.0	*13.3*	10.9	*10.6*
Davies	280.3	*180.8*	69.4	*60.9*	9.7	*14.4*	19.8	*24.2*
Britomart	296.8	*137.9*	126.6	*81.4*	17.8	*15.0*	8.4	*8.2*
Trunk	215.5	*91.0*	88.2	*51.1*	13.7	*14.5*	9.0	*9.0*
Little Trunk	411.4	*121.3*	168.8	*67.5*	17.3	*15.8*	11.7	*11.1*
Reef Habitat Means:								
Bramble Front	341.5	*166.5*	168.9	*91.0*	6.2	*5.5*	8.8	*6.4*
Bramble Back	473.8	*180.6*	265.3	*138.3*	16.1	*22.0*	11.0	*7.9*
John Brewer Front	378.7	*180.6*	185.6	*66.3*	14.4	*11.1*	12.1	*7.9*
John Brewer Back	377.9	*118.8*	196.0	*67.9*	25.5	*13.4*	10.9	*6.4*
Lodestone Front	370.5	*84.1*	131.9	*38.5*	4.9	*3.6*	3.9	*3.7*
Lodestone Back	386.7	*83.7*	189.9	*49.3*	21.2	*14.4*	17.9	*10.7*
Davies Front	329.5	*110.4*	73.5	*27.4*	9.5	*6.6*	2.8	*3.3*
Davies Back	231.1	*222.1*	65.3	*82.2*	9.9	*19.4*	36.7	*24.1*
Britomart Front	409.9	*84.9*	187.2	*61.4*	25.1	*16.5*	6.9	*7.4*
Britomart Back	183.6	*70.7*	66.0	*45.9*	10.5	*8.9*	9.9	*8.7*
Trunk Front	176.6	*80.3*	67.7	*47.1*	8.1	*6.6*	3.5	*6.5*
Trunk Back	254.4	*85.2*	108.7	*47.1*	19.4	*17.8*	14.5	*7.7*
Little Trunk Front	467.1	*88.6*	172.8	*53.8*	12.7	*11.3*	8.5	*8.6*
Little Trunk Back	355.7	*125.1*	164.8	*79.6*	21.9	*18.3*	14.8	*12.6*

APPENDIX 3. ANALYSIS OF VARIANCE TABLES

See table 2 for analysis details.

A. 1997 Survey - Seven Reefs.

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus			*P. leopardus* >38 cm TL		
Habitat	1	0.517	12.923	<0.001	0.0400	2.299	0.134
Reef	6	0.0778	1.943	0.086	0.0456	2.632	0.023
Site (RH)	70	0.0400	1.082	0.320	0.0173	0.904	0.690
R x H	6	0.0162	0.405	0.873	0.004	0.223	0.968
Residual	336	0.0370			0.0192		
		P. leopardus recruits			*Plectropomus laevis*		
Habitat	1	0.122	1.746	0.123	0.175	2.933	0.013
Reef	6	0.002	0.034	0.854	0.060	1.000	0.321
Site (RH)	70	0.070	1.680	0.0014	0.0595	0.926	0.644
R x H	6	0.052	0.748	0.613	0.021	0.347	0.910
Residual	336	0.0417			0.064		
		Total Lethrinids			*Lethrinus miniatus*		
Habitat	1	0.203	4.507	0.037	0.478	5.551	0.021
Reef	6	0.0612	1.361	0.242	0.239	2.777	0.018
Site (RH)	70	0.0450	1.074	0.335	0.0860	0.893	0.712
R x H	6	0.0459	1.020	0.420	0.102	1.182	0.326
Residual	336	0.0419			0.0963		
		Total Lutjanids			*Lutjanus carponotatus*		
Habitat	1	3.071	6.936	0.010	2.043	8.314	<0.001
Reef	6	5.697	12.866	<0.001	0.000	0.000	1.000
Site (RH)	70	0.443	1.458	0.016	0.246	1.018	0.459
R x H	6	3.117	7.040	<0.001	1.022	4.160	0.0012
Residual	336	0.304			0.243		
		Total Chaetodontids			Coral Feeding Chaetodontids		
Habitat	1	0.0019	0.002	0.963	0.191	0.221	0.639
Reef	6	26.742	30.468	<0.001	27.738	32.139	<0.001
Site (RH)	70	0.878	2.428	<0.001	0.863	2.511	<0.001
R x H	6	5.788	6.594	<0.001	5.150	5.967	<0.001
Residual	336	0.361			0.344		
		Pomacentrus moluccensis			*Amblyglyphidodon curacao*		
Habitat	1	0.166	0.011	0.916	25.566	10.760	0.0016
Reef	6	182.33	12.406	<0.001	9.121	3.560	0.0039
Site (RH)	70	14.697	7.169	<0.001	2.562	2.539	<0.001
R x H	6	76.500	5.205	<0.001	15.874	6.196	<0.001
Residual	336	2.050			1.009		
		Chrysiptera rollandi			Total Pomacentrids		
Habitat	1	12.852	48.451	<0.001	83878.0	6.628	<0.001
Reef	6	0.369	1.391	0.230	23760.2	1.877	0.175
Site (RH)	70	0.265	3.390	<0.001	12655.4	7.156	<0.001
R x H	6	1.685	6.351	<0.001	56765.2	4.485	<0.001
Residual	336	0.078			1768.52		
		Hard Coral Cover			Soft Coral Cover		
Habitat	1	5.658	78.444	<0.001	0.530	14.594	<0.001
Reef	6	0.316	4.382	<0.001	0.117	3.233	0.007
Site (RH)	70	0.0721	5.553	<0.001	0.0363	4.822	<0.001
R x H	6	0.0881	1.222	0.306	0.0730	2.010	0.076
Residual	336	0.0130			0.0075		

B. 1996/97 Comparisons - Seven Reefs.

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus			*P. leopardus* >38 cm TL		
Year	1	0.628	15.757	<0.001	0.051	3.823	0.055
R x Y	6	0.0429	1.076	0.385	0.0289	2.167	0.056
H x Y	1	0.0403	1.012	0.318	0.024	1.799	0.184
Site (RH)	70	0.0422	1.058	0.407	0.0227	1.703	0.014
S x Y (RH)	70	0.0398	0.993	0.497	0.0133	0.653	0.967
R x H x Y	6	0.0191	0.479	0.822	0.0243	1.822	0.107
Residual	672	0.0401			0.0205		
		P. leopardus recruits			*Plectropomus laevis*		
Year	1	1.001	13.697	<0.001	0.011	0.172	0.679
R x Y	6	0.132	1.802	0.111	0.025	0.396	0.879
H x Y	1	0.268	3.665	0.060	0.011	0.172	0.679
Site (RH)	70	0.111	1.521	0.041	0.067	1.077	0.379
S x Y (RH)	70	0.073	0.975	0.538	0.062	0.835	0.826
R x H x Y	6	0.087	1.194	0.320	0.097	1.558	0.172
Residual	672	0.750			0.074		
		Total Lethrinids			*Lethrinus miniatus*		
Year	1	2.385	64.908	<0.001	8.045	158.45	<0.001
R x Y	6	0.0604	1.643	0.148	0.148	2.917	0.013
H x Y	1	0.0066	0.179	0.673	0.210	4.141	0.046
Site (RH)	70	0.0298	0.812	0.807	0.0439	0.864	0.729
S x Y (RH)	70	0.0367	1.203	0.133	0.0508	0.943	0.610
R x H x Y	6	0.0335	0.911	0.492	0.0514	1.013	0.424
Residual	672	0.0305			0.0539		
		Total Lutjanids			*Lutjanus carponotatus*		
Year	1	0.776	2.348	0.130	0.171	0.802	0.374
R x Y	6	0.030	0.091	0.997	0.363	1.698	0.134
H x Y	1	0.158	0.479	0.491	0.019	0.089	0.766
Site (RH)	70	0.468	1.417	0.074	0.365	1.708	0.013
S x Y (RH)	70	0.330	1.166	0.176	0.214	0.923	0.654
R x H x Y	6	0.248	0.752	0.610	0.777	3.636	0.003
Residual	672	0.283			0.232		
		Total Chaetodontids			Coral Feeding Chaetodontids		
Year	1	24.853	36.949	<0.001	18.258	24.026	<0.001
R x Y	6	2.101	3.123	0.009	1.767	2.325	0.042
H x Y	1	4.365	6.489	0.013	4.015	5.283	0.025
Site (RH)	70	1.030	1.532	0.038	1.098	1.445	0.063
S x Y (RH)	70	0.673	1.792	<0.001	0.760	2.094	<0.001
R x H x Y	6	2.250	3.345	0.006	2.023	2.662	0.022
Residual	672	0.375			0.363		
		Pomacentrus moluccensis			*Amblyglyphidodon curacao*		
Year	1	2.538	0.199	0.657	11.624	4.750	0.033
R x Y	6	24.754	1.937	0.087	2.782	1.137	0.350
H x Y	1	116.94	9.151	0.003	0.866	0.354	0.554
Site (RH)	70	16.460	1.288	0.146	2.355	0.962	0.564
S x Y (RH)	70	12.778	5.420	<0.001	2.447	2.641	<0.001
R x H x Y	6	8.298	0.649	0.690	6.297	2.566	0.026
Residual	672	2.358			0.927		
		Chrysiptera rollandi			Total Pomacentrids		
Year	1	9.618	42.748	<0.001	690.274	43.541	<0.001
R x Y	6	0.095	0.423	0.861	35.305	2.227	0.051
H x Y	1	1.553	6.901	0.011	29.976	1.891	0.173
Site (RH)	70	0.294	1.305	0.134	22.840	1.441	0.065
S x Y (RH)	70	0.225	2.851	<0.001	15.853	5.319	<0.001
R x H x Y	6	0.276	1.225	0.304	7.601	0.479	0.821
Residual	672	0.079			2.981		

B. (continued) 1996/97 Comparisons - Seven Reefs.

Source of Variation	df	MS	F	p	MS	F	p
		Hard Coral Cover			Soft Coral Cover		
Year	1	171.08	1881.1	<0.001	64.661	624.45	<0.001
R x Y	6	0.102	1.117	0.361	0.149	1.438	0.212
H x Y	1	0.198	2.181	0.144	0.532	5.142	0.026
Site (RH)	70	0.091	1.003	0.496	0.112	1.082	0.372
S x Y (RH)	70	0.0909	5.629	<0.001	0.104	3.666	<0.001
R x H x Y	6	0.148	1.625	0.153	0.295	2.845	0.015
Residual	672	0.0162			0.0282		

APPENDIX 4. LENGTH DATA.

Length Data for the Common Coral Trout - July 1997.

Reef	Habitat	Site	Fish lengths in cm								
Bramble	front	1	34	35							
		2	21	33	34	37	37	37	38	43	47
		3	31	36	36	37	40	43	43	45	
		4	33	36	37						
		5	34	35	35	36	42	45			
		6	34	36	39						
	back	1	32	34	34	35	41	42	44	50	
		2	18	21	36	37	37	40			
		3	36	37	39						
		4	30	33	35	40	42				
		5	32	37	38						
		6	19	22	34	39					
John Brewer	front	1	33	39	42						
		2	33								
		3	21	31	33	36	45				
		4	17	32	33	34	40	42			
		5	34	35	47						
		6	31	35	39						
	back	1	37	39							
		2	34	36	38	39					
		3	36								
		4									
		5	36	43							
		6	34	35							
Lodestone	front	1	33	34	36	36	37	42	43	46	
		2	22	35	43	44	46				
		3	29	34	35	36	37				
		4	27	36	37	44					
		5	31	34	34	35	39				
		6	34	35	37	44					
	back	1	32	35							
		2	33	34	35	38					
		3	34	36							
		4	44								
		5	33	34	36	37	47	50			
		6	21	27	33	35	36	37	38	44	
Davies	front	1	33								
		2	31	33	34	35	36				
		3	22	32	34						
		4	32	33	33	34	35	38	44		
		5	33	34	36	37	48				
		6	30	35							
	back	1	33								
		2	45	47							
		3	20	31							
		4	28	33	35	36					
		5	22								
		6	50								

Length Data for the Common Coral Trout - July 1997 (continued).

Reef	Habitat	Site	Fish lengths in cm
Britomart	front	1	36 36 37 41 46
		2	37 42 44 45
		3	34 39 42 43
		4	36 37 43 45 46
		5	36 37 38 43 48
		6	33 34
	back	1	42
		2	40 42 44
		3	28 34
		4	34 36 43
		5	40 41
		6	39 44
Trunk	front	1	28 33 39 43
		2	19 20 22 29 35 36 42
		3	18 23 26 34 35 37 38
		4	31 36 43
		5	35 40
		6	36 37 40
	back	1	34
		2	19 21 28 33 34 38 41 44
		3	33 34 36 37 43
		4	35 35 36 44
		5	33
		6	10 39
Little Trunk	front	1	33 36 37 39 40 41 45
		2	44 49
		3	29 35
		4	35 36 46
		5	32 34 37 46
		6	19 33 37 37 38 43 44
	back	1	36 41
		2	33 36 42 45
		3	34 35 42
		4	47
		5	33 41 43 45
		6	35 47

APPENDIX 5. *PLECTROPOMUS LEOPARDUS* LENGTH FREQUENCIES FOR ALL YEARS.

Length intervals are 10 cm TL.

Length	Bramble	Brewer	Lode	Davies	B'mart	Trunk	L.Trunk
1991							
1-10	0	0	0	0			
11-20	2	1	1	3			
21-30	10	8	4	15			
31-40	17	24	25	33			
41-50	6	10	8	10			
51-60	4	4	4	3			
61-70	1	0	1	0			
1992							
1-10	0	1	0	0			
11-20	27	23	16	7			
21-30	10	6	9	4			
31-40	15	22	15	41			
41-50	8	17	17	23			
51-60	2	1	5	1			
61-70	0	0	2	1			
1993							
1-10	0	0	0	0	0	0	0
11-20	15	12	3	3	5	3	6
21-30	19	15	14	9	7	12	9
31-40	36	38	31	33	40	39	42
41-50	23	10	15	17	16	27	24
51-60	6	6	7	1	3	6	4
61-70	1	0	2	0	1	1	0
1994							
1-10	0	1	0	0	0	0	0
11-20	12	15	4	12	5	10	9
21-30	6	9	8	12	2	4	4
31-40	59	53	51	49	29	37	37
41-50	26	28	25	22	25	20	24
51-60	6	1	6	0	4	4	7
61-70	1	1	0	0	0	0	0
May 1995							
1-10	0	0	0	0	0	0	0
11-20	21	8	12	4	6	16	8
21-30	8	13	7	11	7	17	14
31-40	39	44	32	42	27	39	36
41-50	46	27	13	15	17	19	12
51-60	7	2	4	5	4	1	6
61-70	1	0	1	0	0	0	1
August 1995							
1-10	1	0	0	0	0	0	0
11-20	12	3	0	1	2	11	3
21-30	19	11	12	13	13	24	14
31-40	44	32	26	41	26	31	37
41-50	10	13	13	6	20	9	9
51-60	3	0	3	2	0	1	2
61-70	0	0	1	0	0	0	0

Length	Bramble	Brewer	Lode	Davies	B'mart	Trunk	L.Trunk
1996							
1-10	0	1	0	0	0	0	0
11-20	17	7	5	4	2	13	1
21-30	10	2	6	10	9	19	2
31-40	33	28	28	25	28	37	46
41-50	6	10	12	8	10	8	17
51-60	2	1	1	1	0	0	1
61-70	0	0	0	0	0	0	0
1997							
1-10	0	0	0	0	0	1	0
11-20	2	1	0	1	0	4	1
21-30	4	1	5	4	1	7	1
31-40	42	25	37	24	19	28	22
41-50	12	5	12	5	18	7	17
51-60	0	0	0	0	0	0	0
61-70	0	0	0	0	0	0	0