Appendix 2

REPORT ON THE TRAPPING AND MARK AND RECAPTURE OF REEF FISH IN THE CAC MARINE RESERVE AND THE VISUAL CENSUS OF THE FISH POPULATIONS ON THE CAC PROTECTED REEF AREA AND AN ADJACENT AREA OF REEF SUBJECTED TO LOCAL FISHING

Introduction

There has been substantial interest in the effects of protection of coral reef areas on the populations of reef fish. The main arguments behind establishing coral reef reserves is that they could provide a sanctuary area for reef fish and invertebrates which are able to reproduce without harvest pressures, and that the fisheries in adjacent areas will benefit from the migration of fish from protected areas to adjacent reef areas where they will enter the exploitable stock.

Despite the frequent use of this argument, only a relatively limited amount of quantitative work has been carried out to assess the role of reef reserves in enhancing local fisheries. Several studies have been carried out on the effects of protection on coral reef fishes (Alcala, 1988; Alcala & Luchavez, 1988; Craik, 1981; Russ, 1984, 1985; White 1987) and these have indicated a significantly larger number of individuals of reef fish and, in some cases, a greater species richness in areas with little or no fishing pressure compared to heavily fished sites.

This study was undertaken as part of a project to investigate the effects of a reef reserve on fish and invertebrate populations in Guadalcanal, Solomon Islands. This was initiated in July 1989 as a collaborative project executed by ICLARM (International Centre for Living Aquatic Resource Management) and the South Pacific Regional Environmental Programme (SPREP). The main objectives of this project were :

1. To test the effect of a small marine reserve on the abundance of fish and invertebrate stocks in adjacent reef areas; and

2. To examine the change in the composition and abundance of fish stocks in response to protection from harvesting.

With regard to these objectives, the aim of the present study was to collect information on the species composition and abundance of coral reef fish within a marine reserve and an adjacent area of fished fringing reef which possesses similar habitat characteristics but is subjected to a varying level of fishing pressure by local artisanal and subsistence fishermen.

Methods

Study sites

The International Centre for Living Aquatic Rrsource Management has a leasehold over 4.5 ha of fringing reef and shallows fronting ICLARM's Coastal Aquaculture Centre (CAC) on the north-west coast of Guadalcanal, Solomon Islands. Fishing is not permitted in this area, which is primarily used for maintaining giant clam broodstock and a giant clam ocean nursery system. The reef has been protected since the establishment of the CAC in 1986 and therefore provides a small, but useful comparison with the adjacent areas of fringing and patch reefs which are exploited to a varying extent by local artisanal and subsistence fishermen using primarily hook and line, local spear guns and, occasionally, nets.

Trapping and tagging

The trapping and mark-recapture programme was carried out during June - July 1991 and September - October 1991 in the ICLARM marine reserve utilizing antillean z and double chevron traps as described by Munro et al (1971) and Munro (1986).

The traps were constructed from 1-1.5" diameter brush wood sticks for the frames fastened with galvanized nails and 16 gauge tie wire, and galvanized chicken wire mesh which was sewn together with 16 gauge tie wire. The trap funnels had an outer opening of 350mm x 200mm, decreasing to 250mm x 150mm on the inner opening.

The traps were baited with either sweet potatoes and coconut or chunks of tuna held in wire mesh boxes or net bags and were set at randomly selected points along the fringing reef at depths between 3 - 8m. The traps were left soaking for a minimum period of 24 hours and were checked daily by free diving. After hauling, fish were removed from the trap into a 20l bucket filled with sea water. All fish were identified (using Gloerfelt-Tarp & Kailola (1981); Allen & Talbot (1985); Grant (1987); Myers (1989)), examined for any abnormalities and their fork length (FL) measured to the nearest mm. Fish with FL <10cm or those in poor condition were returned to the sea without tagging, while the remainder were tagged using either T-bar tags or dart tags depending on their size. Fish were always returned to within 10m of the trap position, and the traps were reset in the same place each time.

Visual census

The visual census of fish populations was carried out between October and December 1991 in the CAC reef and the area of fringing reef lying to the west and bordering with the CAC site.

The visual census technique employed followed the stationary sampling technique described by Bohnsack and Bannerot (1986). This method is based on the censusing of reef fishes by a diver within a cylinder of 7.5m diameter at randomly selected, stationary points. For each sample, the first five minutes involved listing all the species observed in the pre-set radius within the field of view. This was followed by recording the estimated number of individuals of the species listed in the initial 5-min sampling period. All other observed species were ignored. To investigate the effect of sampling duration on the cumulative number of species and individuals, the sampling duration of 13 samples from the two reefs was increased, with the initial listing period being extended to 10 minutes.

The majority of samples were taken at depths of 2-10m, although a few samples were obtained from depths of 10-20m. The distance between a series of sampling points taken consecutively was based on a number of swimming kicks determined from a table of random numbers. A total of 24 samples were taken on the CAC reef and 25 samples on the fished reef.

Results

Trapping and tagging

A total of 423 fish from 19 families and 57 species were caught in the traps. An inventory of the fish species captured is given in Appendix 1.

The Acanthuridae was the most abundant family (57.7% of the total catch) with four species constituting 53.2% of the total catch. The Chaetodontidae (12.1%) and the Pomacentridae (7.3%) were the next two most abundant families. *Ctenochaetus striatus* and *Zebrasoma scopas* were the most common acanthurids, making up 59.4% of the fish from this family caught in the traps. A summary of the % catch composition by numbers for each family caught and the number of species per family is given in Table 1.

A total of 179 fish from 37 species were tagged and a total of 23 fish were recaptured (see Appendix 1) with one of the recaptured fish (*Balistapus undulatus*) having been tagged in a an initial tagging programme implemented in 1990. Some tagged fish were recaptured more than once, with two individuals (*Balistapus un-*

Table 1. Summary of the % catch composition by numbers for each family and the number of species per family

Family	% of catch	Number of species
Acanthuridae	57.5%	7
Balistidae	4.5%	2
Chaetodontidae	12.2%	7
Dasyatididae	0.7%	1
Echeneididae	0.2%	1
Holocentridae	0.9%	3
Labridae	0.2%	1
Lethrinidae	2.8%	5
Lutjanidae	1.9%	5
Monocanthidae	0.7%	1
Mullidae	3.6%	2
Muraenidae	0.2%	1
Nemipteridae	0.2%	1
Pomacentridae	7.3%	5
Pomacanthidae	0.5%	1
Scaridae	2.4%	6
Serranidae	1.7%	5
Siganidae	1.9%	2
Tetradontidae	0.5%	1

dulatus and *Ctenochaetus binotatus*) being recaptured three times. Table 2 shows a list of the species recaptured and the time that they spent at sea between tagging and recapture.

The average rate of recapture of tagged fish was 12.8%. However, in all but two cases, the individual species recapture rates were higher than this (Appendix 1).

Over the 220 traps days of the study, the mean catch rate was 2.60 +/- 1.85 fish/trap/day. The maximum catch for any one trap was 21 fish/trap/day over a one day soak, which was achieved twice during new and full moon. The lowest catch for any one trap was 0.17 fish/trap/day over a six day soak.

Of the fleet of 10 traps, two were of the double chevron design and the other eight were z-traps. A comparison of the mean catch rates for the two designs showed no significant differences, with the mean catch rate for the double chevron traps being 2.03 +/- 0.90 fish/trap/day and for the z-traps 2.76 +/- 0.85 fish/trap/day.

Visual census

Abundance and species richness

The total mean abundance and number of species occuring in the two areas and by family are shown in Tables 3, 4 and 5. There were no significant differences in the total mean numbers of individuals or species between the CAC reserve and the adjacent reef. However, the CAC reef had a significantly higher number of individuals and species of Lutjanidae, Haemulidae and Pempheridae. The latter are not an important food fish and no haemulids were observed in the samples from the fished reef. Figures 1 and 2 show the mean number of individuals and species for selected families in the CAC and fished reefs.

The numerically dominant families at both sites were the Acanthuridae, Caesionidae, Chaetodontidae, Labridae and Pomacentridae, which together accounted for 89% and 94% of the mean number of individuals censused at the CAC and fished reefs, respectively. Excluding the caesionids, these families comprised 64% and 72% of the mean number of species sampled at the CAC and fished reefs, respectively.

Sampling duration

In general, the number of species detected per sample increased slowly after the initial 5 minutes of sampling (Figure 3), although at two sites in the fished reef, there was a substantial

Table 2. Species recaptured and the time each individual was at sea between being tagged and recaptured

Species	Time at sea (days) to 1st recapture	2nd recapture	3rd recapture
Acanthurus nigricauda	9		
A. nigricauda	16	17	
A. pyroferus	6		
A. pyroferus	3		
A. pyroferus	6		
A. pyroferus	2	6	
A. pyroferus	3		
Balistapus undulatus	354		
B. undulatus	9	17	28
Cephalopholis miniata	85		
Ctenochaetus binotatus	7		
C. binotatus	91	114	117
C. striatus	7		
C. striatus	12		
C. striatus	12		
C. striatus	3	4	
C. striatus	6		
C. striatus	3		
C. striatus	10		
Lethrinus lentjan	10	15	
Paraglyphidodon melas	3	21	
P. melas	3		
Zebrasoma scopas	5		

Table 3. Total mean number of individuals and species / ha at the CAC and adjacent fished reef

Site	Mean number of individuals / ha	Mean number of species / ha
CAC	17,996 ± 3,671	1,584 ± 162
Fished Reef	19,403 ± 4,310	1,433 ± 162

Table 4. Mean number of individuals / ha by family at the CAC and adjacent fished reef

Family	Mean number of individuals / ha CAC	Fished Reef
Acanthuridae	1,099 ± 294	1,016 ± 209
Apogonidae	0	47 ± 89
Balistidae	153 ± 40	186 ± 57
Caesionidae	943 ± 846	797 ± 803
Carrangidae	23 ± 4	16 ± 27
Chaetodontidae	573 ± 208	455 ± 128
Cirrhitidae	4 ± 6	4 ± 6
Haemulidae	19 ± 32	0
Holocentridae	4 ± 6	11 ± 9
Kyphosidae	125 ± 152	47 ± 89
Labridae	816 ± 177	957 ± 220
Lethrinidae	50 ± 37	23 ± 24
Lutjanidae	243 ± 101	50 ± 27
Monocanthidae	26 ± 19	27 ± 28
Mullidae	517 ± 214	253 ± 114
Nemipteridae	156 ± 98	45 ± 29
Pempheridae	2 ± 4	0
Pomacentridae	12,558 ± 3,243	15,048 ± 3,919
Pomacanthidae	151 ± 79	113 ± 71
Saridae	89 ± 34	158 ± 70
Serranidae	354 ± 513	54 ± 102
Anthinnae	337 ± 514	52 ± 102
Epinenphelinae	16 ± 19	2 ± 5
Siganidae	28 ± 23	50 ± 37
Tetrodontidae	10 ± 14	2 ± 4
Zanclidae	38 ± 35	34 ± 19

Table 5. Mean number of species / ha by family at the CAC and adjacent fished reef

Family	Mean number of species / ha CAC	Fished Reef
Acanthuridae	205 ± 34	217 ± 36
Apogonidae	0	4 ± 6
Balistidae	75 ± 19	57 ± 16
Caesionidae	21 ± 15	16 ± 16
Carrangidae	4 ± 6	2 ± 4
Chaetodontidae	172 ± 47	167 ± 31
Cirrhitidae	4 ± 6	4 ± 6
Haemulidae	4 ± 6	0
Holocentridae	4 ± 6	13 ± 10
Kyphosidae	10 ± 8	4 ± 6
Labridae	290 ± 50	285 ± 56
Lethrinidae	21 ± 11	11 ± 9
Lutjanidae	94 ± 32	36 ± 18
Monocanthidae	14 ± 10	14 ± 13
Mullidae	59 ± 14	52 ± 21
Nemipteridae	42 ± 15	23 ± 14
Pempheridae	2 ± 4	0
Pomacentridae	351 ± 37	367 ± 83
Pomacanthidae	45 ± 19	36 ± 14
Scaridae	66 ± 21	70 ± 27
Serranidae	21 ± 15	7 ± 10
Anthinnae	11 ± 11	6 ± 11
Epinenphelinae	11 ± 11	2 ± 6
Siganidae	16 ± 12	18 ± 14
Tetrodontidae	7 ± 10	2 ± 4
Zanclidae	16 ± 11	23 ± 11

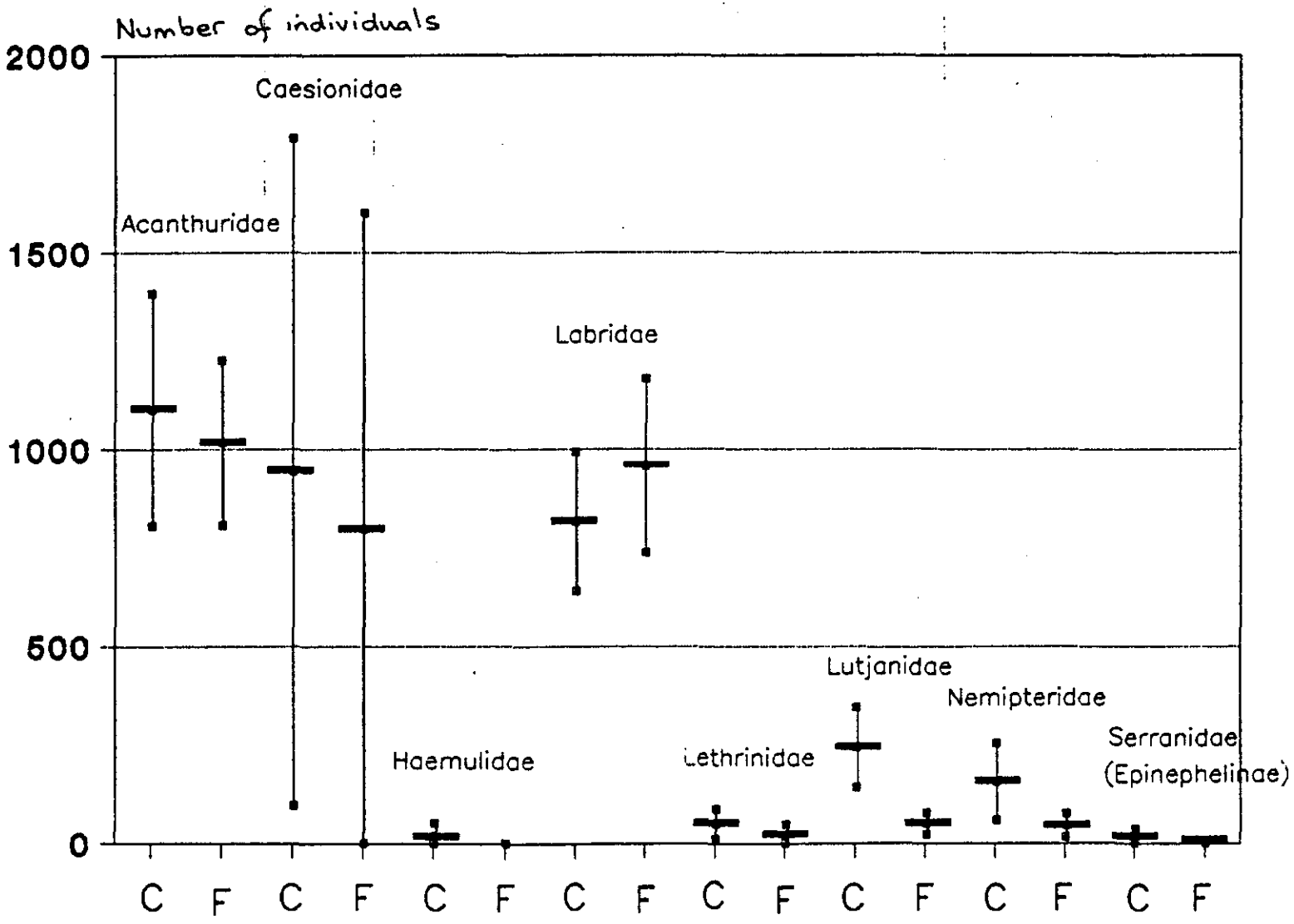

Fig. 1. Mean number of individuals / ha for selected families at the CAC and fished reefs.
C = CAC reef, F = Fished reef. Horizonatal lines show means, and vertical lines show 95% confidence limits.

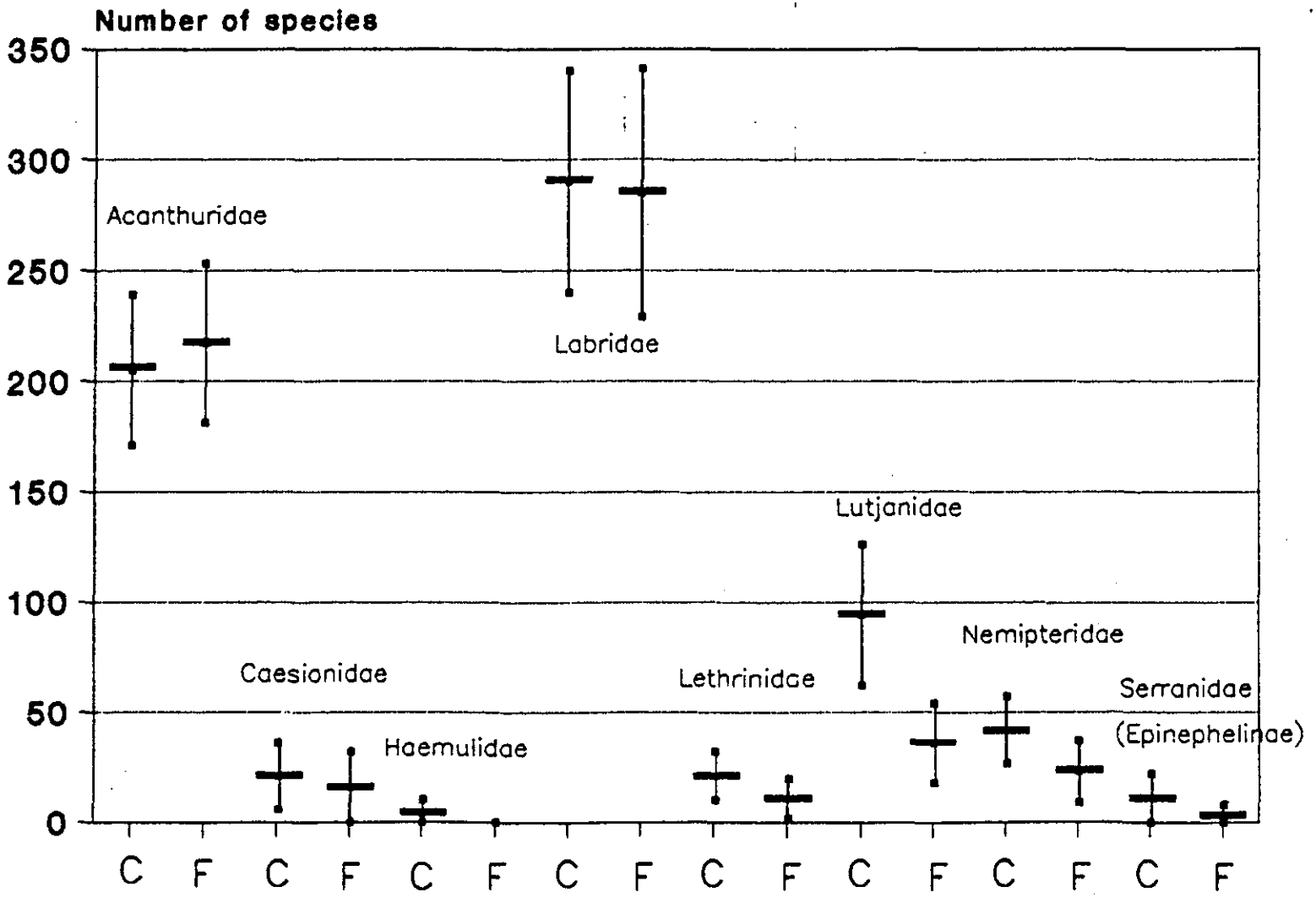

Fig. 2. Mean number of species / ha for selected families at the CAC and fished reefs.
C = CAC reef, F = Fished reef. Horizontal lines show the means, and vertical lines show the 95% confidence limits.

and without reliable lenth-weight relationships for the species concerned catch rates connot be expressed in terms of weight/trap. However, the mean catch rate of 2.60 +/- 1.85 fish/trap/day does appear low when compared with the results of a trapping study carried out in Australia (Davies, 1989) where the mean catch rate for antillean z-traps was 4.52 +/- 0.489 fish/trap/day.

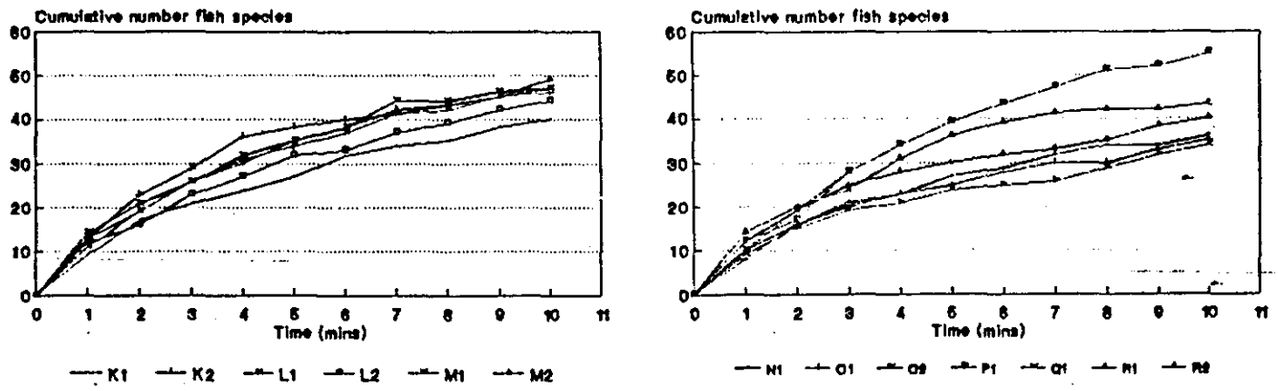

Fig. 3. Effect of sampling time on cumulative observed species at a) 6 randomly selected sites on the CAC reef, and b) 7 randomly selected sites on the fished reef.

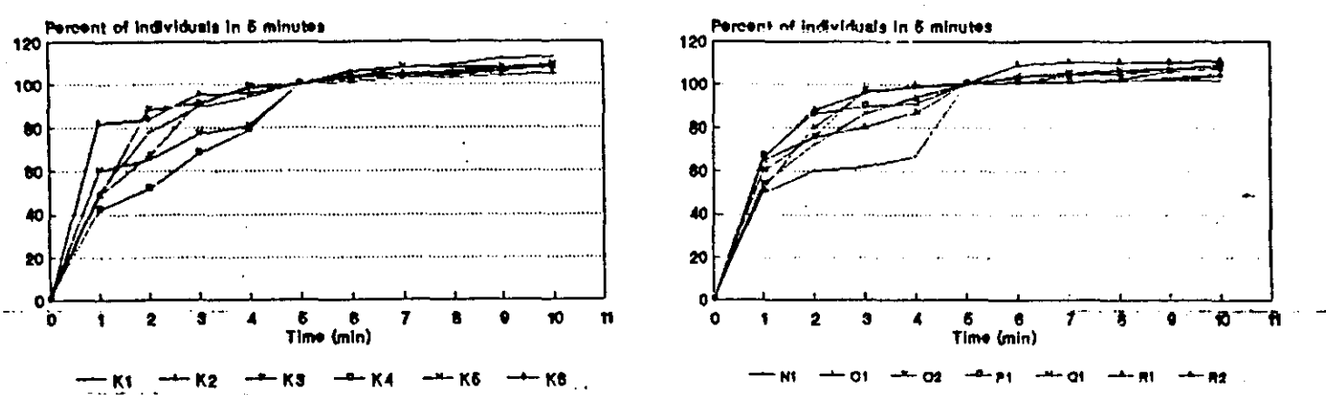

Fig. 4. Percent of individuals represented by species counted per minute during a) 6 samples on the CAC reef. amd b) 7 samples on the fished reef. Data were standardized by having 100% equal the number of individuals in 5 minutes.

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The double chevron trap design was described by Munro (1986). Although the effectiveness of this design has not been thoroughly examined, the greater size of this trap and its double chamber should both act to decrease escapement rates. Although no significant difference was observed between the catch rates of the two trap models, the effectiveness of the double chevron trap was not subjected to rigorous examination during the study and this is an area where additional work would be beneficial.

Although the average rate of recapture of tagged fish was high for certain species the results were, in some cases, based on only a very few tagged individuals, e.g. *Lethrinus lentjan* and *Cephalopholis miniata* (Appendix 1). Compared with other tagging studies the overall number of tagged and recaptured fish was low and due to this no population estimates for the dominant species in the trap catches has been made. For further studies it would be necessary to undertake the trapping and tagging programme over a longer period of time so that a greater number of fish could be trapped and tagged.

No quantitative estimate of tag loss was made during the study. However, from the presence of scars on the fish it was noticed that some recaptured individuals had lost their tags. During any future tagging programme, a quantitative investigation into the rate of tag loss would be important.

There are a number of aspects associated with using traps as a quantitative fish sampling method that were not examined during the present study and provide important areas for future research to further investigate the mode of operation of fish traps, specifically in the Solomon Islands. These include the optimal soak period, effect of the depth of set, effect of bait type on catch rate and species composition and the effective fishing area of the traps.

Visual census

Abundance and species richness

This is the first study on coral reef fish undertaken in this particular area and therefore no data were available on the abundance of fish before the CAC reserve was established.

The lack of an overall significant difference in the total mean number of individuals and species between the CAC reserve and the adjacent fished reef may possibly be attributed to a number of factors, e.g. the limited number of samples obtained and, related to this, the fact that a restricted list of species was not used and the high abundance of certain families (particularly the pomacentrids) could therefore mask any differences between the sites which could only be detectable at the family level. It has been suggested (Russ, 1985) that species richness is not a very sensitive comparative parameter in areas with differing fishing pressure, unless particularly habitat-damaging fishing methods are employed. The abundance of the fishermen's more favoured 'target' species, such as serranids, lutjanids and lethrinids, has been infered as more useful in detecting the effect of reducing fishing pressure on coral reefs (Randall, 1982), and the results of greater abundance and species richness of lutjanids and haemulids in the CAC reserve would tend to conform to this.

Russ (1985) suggests that the abundance of serranids is a good indicator of fishing pressure on coral reefs. No significant difference was detected in this study, but this could very well be due to the limited number of samples obtained, and possibly a generally low abundance of serranids in the two areas. Epinephalus merra accounted for 62.5% of all serranid (Ephinephenilae) individuals censused.

The level of fishing effort in the adjacent reef area has not been quantified. There are several villages within close proximity, and this particular stretch of shoreline is frequently used for recreation as well as fishing. Owing to the wide availability of similar reef areas for fishing, including some nearby offshore patch reefs, the degree of fishing activity does not appear to be particularly intense and this may be an additional factor explaining why only slight differences were observed between the two localities. An interesting point is that fishermen will often fish close to the boundaries of the CAC reserve in the apparant belief that they will obtain a better catch.

No estimates of the lengths of fishes were obtained during the census samples, and this, together with estimates of biomass of fish in the two localities is an interesting area for future research.

Carpenter et al (1981) showed evidence of strong positive corelations for fish abundance and diversity with living coral cover and for biomass with an index of surface complexity in four Philippine reefs. Also, Bohnsack and Bannerot (1986), utilizing the stationary sampling technique in Looe Key National Marine Sanctuary found that the average number of species and individuals censused during a sample was roughly proportional to habitat complexity. In this present study, although samples were

taken from a variety of habitats within the two sites, the sample numbers per habitat type were not sufficient to test for any differences between the sites. There is substantial evidence indicating greater fish abundance, diversity and biomass with increasing live coral cover and topographical reef complexity, and this is an area of potential further study at the CAC reserve and adjacent reefs.

Additional research is also required on the patterns of dispersal and recruitment of coral reef fish in this location to investigate more fully the possibility that the establishment of a small reserve such as that at the CAC will result in the export of fish biomass by the emigration of adult individuals.

Sampling duration

The results of increasing sampling duration on the number of species and cumulative number of individuals per sample were similar to those of Bohnsack and Bannerot (1986). However, their study was carried out in the northern Carribean, and the greater abundance and species diversity of fish in the Indo-Pacific region could justify increasing the sample time to 6 or 7 minutes. Figures 3 and 4 show that in some instances there may be quite a substantial increase in the number of species after the initial 5 minute sampling period, and that maintaining a shorter sampling period may not provide a true sample from each site. As the above authors point out, however, there are drawbacks to increasing the sampling duration as this can increase the bias towards detecting highly mobile species, and increases the difficulty of distinguishing between individuals within the sampling area and those that are continually moving in and out of the sampling area.

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Appendix 1

Species caught during the trapping and tagging programme in the CAC marine reserve

FAMILY/ Species	Number caught	Number tagged	Number recaptured	% rate of recapture
ACANTHURIDAE				
Acanthurus lineatus	2	2	0	
A. nigricauda	14	9	2	22.2
A. nigrofuscus	3	2	0	
A. pyroferus	44	31	5	16.1
Ctenochaetus binotatus	36	11	2	18.2
C. striatus	86	58	7	12.1
Zebrasoma scopas	59	10	1	10.0
BALISTIDAE				
Balistapus undulatus	16	8	2	25.0
Sufflamen chrysoptera	3			
CHAETODONTIDAE				
Chaetodon baronessa	13			
C. citronellus	1			
C. melannotus	8			
C. trifasciatus	10			
C. vagabundus	5			
Heniochus chrysostomus	4	2	0	
H. varius	10			
DASYATIDIDAE				
Taeniura lymma	3			
ECHENEIDAE				
Echeneis naucrates	1			
HOLOCENTRIDAE				
Myripristis sp.	2			
Sargocentron caudimaculatum	1			
S. violace	1	1	0	
LABRIDAE				
Cheilinus diagrammus	1	1	0	
LETHRINIDAE				
Monotaxis grandoculus	2	2	0	
Lethrinus hypselopterus	1	1	0	
L. lentjan	7	2	1	50.0
L. mahsenoides	1	1	0	
Lethrinus sp.	1	1	0	

Appendix 1 (cont.)

FAMILY/ Species	Number caught	Number tagged	Number recaptured	
LUTJANIDAE				
Lutjanus argentimaculatus	1	1	0	
L. bohar	2	2	0	
L. gibbus	3	1	0	
L. monostigmus	1	1	0	
L. reticulatus	1	1	0	
MONOCANTHIDAE				
Cantherines perdalis	3			
MULLIDAE				
Mulloides flavolineatus	14	3	0	
Prupeneus bifasciatus	1	1	0	
MURAENIDAE				
Gymnothorax sp.	1			
NEMIPTERIDAE				
Scolopsis bilineatus	1			
POMACENTRIDAE				
Chromis vanderbiliti	3			
C. viridis	1			
Dascyllus trimaculatus	8	1	0	
Paraglyphidodon melas	16	7	2	28.6
Pomacentrus sp.	3			
POMACANTHIDAE				
Centropyge bicolor	2			
SCARIDAE				
Scarus forsteni	1	1	0	
S. globiceps	3	3	0	
S. niger	2	2	0	
Scarus sp.1	1	1	0	
Scarus sp.2	2	2	0	
Scarus sp.3	1	1	0	
SERRANIDAE				
Cephalopholis miniata	2	2	1	50.0
Epinephelus fuscoguttatus	1			
E. merra	2	1	0	
Plectropomus areolatus	1	1	0	
Plectropomus leopardus	1	1	0	

Appendix 1 (cont.)

FAMILY/ Species	Number caught	Number tagged	Number recaptured
SIGANIDAE			
Siganus argenteus	6	2	0
S. puellus	2	2	0
TETRADONTIDAE			
Arothron nigropunctatus	2		