2 Fishery-independent assessment of management effects on community fishery resources in Fiji and Vanuatu data

2.1 Introduction

The objectives of the present component of the Project were to:

- provide habitat data as a basis for rough estimation of potential fisheries yields per unit area of each site (Project Memorandum, section 10, 3i), and;
- provide indices of target fish abundance independently of fishery catch data, using underwater visual census (Project Memorandum, section 10, 4iii).

The present report is an analysis of underwater visual data on fish abundances and reef habitat characteristics, aimed at comparing sites and fishing areas subject to managed or incidental differences in fishing pressure. The abundance data involved in such work are normally gathered at species level, but for various reasons analysis of the data at this level is not expected often to detect actual differences where they exist. Among other things, the visual sample areas are perforce small and will tend to be smaller relative to home range the bigger the fish get, yet large fish are the focus of most fishing; the statistical power to detect differences at species level is likely therefore to be smaller than that to detect differences at aggregate levels. Consequently the principal focus here is on family and trophic grouping of species, but the possibility of species-level differences attributable to fishing was also considered. Also, the latter data might reflect relaxation of fishing by indicating increases in biomass or mean body size.

The specific objectives of this report are therefore to:

- determine if any species showed biomass and/or length differences among fishing areas which might reflect exploitation effects;
- compare biomass data at family and trophic-group levels to ascertain any broad ecological differences among fishing areas which might be attributable to fishing;
- compare reef habitat data among sites and areas, and assess the potential influence of habitat variables on any fish biomass differences found at aggregate levels; and,
- evaluate the extent to which biomass differences are attributable to management-driven or incidental variations in fishing pressure.

2.2 Methods

Fishing-sites and fishing areas were selected on the basis of the initial frame survey of fishing villages and dive-locations within sites were chosen on the basis of that frame survey and subsequent field visits. Four sites were ultimately selected in Fiji, with one closed area being identified in the Naweni site (Table 2.1). Six sites were ultimately selected in Vanuatu, and four closed areas were identified within these (Table 1). Within each site, a variable number of reef-front study dive-locations was chosen for underwater visual census (UVC) (Table 2.1). The level of UVC replication within dive-locations was similar to that attained in previous such work (Jennings & Polunin 1995, 1996; Polunin & Jennings 1997), but the number of dive-locations sampled within sites and fishing areas was generally small. Because the UVC work was done before the detailed fishery descriptions; some UVC data (Polunin 1997) were not used because relevant data were not subsequently generated by the fishery study or expectations of management measures derived by MRAG from the frame survey did not materialise. Comparisons were possible to some extent in both countries at three spatial scales, namely those of sites, fishing areas within sites, and dive-locations within areas; the terms ***site***, ***area*** and ***dive-location*** are so used consistently throughout this report.

Table 2.1 The sites studied in Fiji and Vanuatu, with details of the fishing areas, the estimated total standard fishing effort per unit area of reef within them, management status and number of UVC areas sampled. (Source: MRAG Ltd)

Site	Fishing area (code)	Fishing effort ($h.km^{-2}.y^{-1}$)	Status of area	Number of UVC dive-locations
FIJI				
Tavua	121	707	Open	3
“	122	1225	Open	3
Vitogo	5	658	Open	6
Naweni	20	130	Open	2
“	201	139	Closed	2
Tacilevu	21	310	Open	5
VANUATU				
Lélépa	243	165	Open	2
“	246	3514	Closed	3
“	247	1115	Open	1
“	248	133	Open	4
“	249	3503	Open	1
Emua	262	0	Open	3
“	263	336	Closed	3
“	264	281	Open	3
Atchin	201	7182	Open	1
“	202	912	Open	1
“	203	939	Open	1
“	204	2410	Open	1
Wala	211	18178	Open	2
“	212	7854	Open	1
“	215	3815	Closed	1
Uripiv	221	311	Open	2
“	222	0	Closed	1
“	223	2893	Open	1
Pellonk	231	38	Open	3
“	232	739	Open	3

Fishes

Underwater trials using lengths of electrical flex laid on the bottom, both in a swimming-pool and on the reef, were used to gauge and increase accuracy of visual estimation of fish lengths under water (e.g. Polunin & Roberts 1993); observers had to estimate the lengths from distances up to 7 m. The UVC method was based on that of Samoilys (1992) and Samoilys and Carlos (1992), who have reviewed the pros and cons of the technique as a whole and of its variants. Although some species, including all cryptic species and some important fishery-target species such as *Lethrinus* emperors (Polunin & Jennings 1995), are undoubtedly sampled ineffectively, fishery depletion may still be detected (Polunin & Jennings

1996). The UVC methodology was essentially the same as that employed by Jennings and Polunin (1995, 1996) and Polunin and Jennings (1997), which has at group level described target-fish depletion similar to that depicted by catch per unit biomass data from an independent fishery study. The method involved visually designating circles of approximately 7 m radius and making immediate counts on approach and from a distance of large species which might be diver-wary. Only fishes >12 cm long were recorded. Counts were made of all relevant species in 11 families containing an array of target species, with estimates of the lengths of all individuals, within each sample area. The species actually recorded varied between the two countries. The less common species of reef fishes were identified primarily using the book of Randall *et al*. (1990). Upon completion of each count, the radius of the UVC circle was checked against a tape measure.

Habitat data

The percentages of the substratum with living hard coral, soft coral, macroalgae (Vanuatu only), 'bare' rock, rubble and sand, were estimated by eye at the same time as the fish UVC was carried out and for the same areas. The bottom relief (rugosity) was also assessed visually on a scale from one (completely flat) to five (very high relief)(Polunin & Roberts 1993), as was the depth of the reef sampled, to the nearest 0.1m. The consistency in collecting these habitat data was checked among divers in the preparatory work in 1996.

Data preparation and analyses

Fish lengths were converted to estimated weights for all individuals using the length-weight relationships summarised by Kulbicki *et al*. (1993). In many cases (e.g. *Scarus* spp, *Lutjanus* spp), length-weight data from other species in the same genus had to be used; in only few cases were weights based on such data from other genera, and the basis of weight estimation was similar to that of Jennings and Polunin (1996). Weights were summed by species and sample to derive an index of biomass for each species per sample. The species data were aggregated into taxonomic families and trophic groups, and reanalysed at these levels. Fish species, family and trophic group data were log (x+1) transformed and subjected to nested analyses of variance (ANOVA, a=0.05; sites, fishing areas within sites, and dive-locations within areas and sites) within the framework of general linear models (GLMs), since the overall sampling designs were unbalanced (Table 2.1). Least squares estimates of marginal means (LSMs) were calculated and pair-wise comparisons made with *t* tests where significant differences (a=0.05) were found at any level. Pearson correlation coefficients were used to assess the extent of association (two-tailed, a=0.025) between area mean species, family and trophic-group biomasses on the one hand, and area means of habitat variables on the other. A forward-selection multiple regression technique was used to determine the relative contribution (a=0.05) of habitat and fishing effort variables both individually and in combination to dive-location-to-dive-location variations in mean biomasses of species, family and trophic-group data. Spatial variation in area means of habitat variables and fish biomass data was assessed graphically using MDS and one-way Anosim tests conducted on the data; pair-wise tests (a=0.05) made no allowance for multiple comparisons (Clarke & Warwick 1994, Carr 1997).

Table 2.2 Fiji: reef fish species recorded by underwater visual census, with comparisons of biomass (i) overall (df = 209), among sites (df = 3) and among areas (df = 2), and (ii) between areas with different levels of fishing pressure (* p<0.05 **p<0.01 ***p<0.001 ****p<0.0001)

FAMILY ***SPECIES***	**ANOVA comparisons:**			***t*-test comparisons:**	
	Overall	**Among sites**	**Among fishing areas**	**Tavua area H_0 122=121**	**Naweni area H_0 20=201**
ACANTHURIDAE					
Acanthurus. auranticavus	**	***	*	121>122	NS
A. lineatus	****	****	****	121>122	NS
A. nigricauda	NS	NS	NS	NS	NS
A. nigrofuscus	NS	NS	NS	NS	NS
A. nigricans	NS	NS	NS	NS	NS
A. thompsoni	**	NS	NS	NS	NS
A. triostegus	NS	NS	NS	NS	NS
A. xanthopterus	NS	NS	NS	NS	NS
Acanthurus spp	NS	NS	NS	NS	NS
Ctenochaetus binotatus	NS	NS	NS	NS	NS
C. strigosus	NS	NS	NS	NS	NS
C. striatus	****	****	****	121>122	20>201
N. annulatus	NS	NS	NS	NS	NS
N. brachycentron	*	NS	NS	NS	NS
N. brevirostris	**	NS	*	121>122	NS
N. lituratus	****	***	NS	NS	NS
N. tuberosus	****	*	**	121>122	NS
N. unicornis	****	**	****	121>122	NS
Zebrasoma scopas	****	****	****	121>122	NS
Z. veliferum	NS	NS	NS	NS	NS
BALISTIDAE					
Balistapus undulatus	****	***	****	121>122	NS
Balistoides viridescens	NS	NS	NS	NS	NS
Pseudobalistes flavimarginatus	NS	NS	NS	NS	NS
Rhinecanthus rectangulus	NS	NS	NS	NS	NS
Sufflamen chrysopterus	NS	NS	NS	NS	NS
S. fraenatus	NS	NS	NS	NS	NS
HAEMULIDAE					
Plectrorhynchus chaetodontoides	NS	NS	NS	NS	NS
KYPHOSIDAE					
Kyphosus spp	**	***	NS	NS	NS
LETHRINIDAE					
Gnathodentex aurolineatus	**	*	**	NS	20>201
Lethrinus atkinsoni	NS	NS	NS	NS	NS
L. erythracanthus	NS	NS	NS	NS	NS
L. harak	NS	NS	NS	NS	NS
L. olivaceus	NS	NS	NS	NS	NS
Monotaxis grandoculis	****	****	**	121>122	20>201
LUTJANIDAE					
Aphareus rutilans	NS	NS	NS	NS	NS
Aprion virescens	NS	NS	NS	NS	NS
Lutjanus argentimaculatus	****	**	NS	NS	NS
L. biguttatus	***	**	NS	NS	NS
L. bohar	NS	NS	NS	NS	NS
L. ehrenbergi	NS	NS	NS	NS	NS
L. fulviflamma	*	NS	NS	NS	NS
L. fulvus	****	****	*	121>122	NS
L. gibbus	**	NS	NS	NS	NS
L. kasmira	NS	NS	NS	NS	NS
L. monostigma	*	**	NS	NS	NS

L. rivulatus	NS	NS	NS	NS	NS
L. russelli	NS	NS	NS	NS	NS

Table 2.2 contd

FAMILY ***SPECIES***	**ANOVA comparisons:**			***t*-test comparisons:**	
	Overall	Among sites	**Among fishing areas**	**Tavua area H_0 122=121**	**Naweni area H_0 20=201**
L. semicinctus	**	****	*	121>122	NS
Lutjanus spp	NS	NS	NS	NS	NS
Macolor macularis	****	****	****	NS	20>201
M. niger	NS	NS	NS	NS	NS
Symphorichthys spilurus	NS	NS	NS	NS	NS
MULLIDAE					
M. vanicolensis	NS	NS	NS	NS	NS
Parupeneus barberinoides	****	****	***	NS	20>201
P. barberinus	*	NS	NS	NS	NS
P. bifasciatus	**	****	NS	NS	NS
P. cyclostomus	NS	NS	NS	NS	NS
P. multifasciatus	****	****	NS	NS	NS
NEMIPTERIDAE					
Scolopsis bilineatus	**	**	*	NS	NS
SCARIDAE					
Cetoscarus bicolor	NS	NS	NS	NS	NS
Chlorurus bleekeri	****	****	NS	NS	NS
C. microrhinos	**	**	***	121>122	NS
C. sordidus	****	****	NS	NS	NS
Hipposcarus longiceps	****		**	121>122	NS
S. chameleon	****	****	NS	NS	NS
S. dimidiatus	NS	NS	NS	NS	NS
S. flavipectoralis	NS	NS	NS	NS	NS
S. forsteni	NS	NS	NS	NS	NS
S. frenatus	**	*	*	121>122	NS
S. ghobban	****	****	NS	NS	NS
S. globiceps	****	**	**	121>122	NS
S. niger	****	****	****	121>122	201>20
S. oviceps	****	****	NS	NS	NS
S. psittacus	***	**	**	121>122	201>20
S. pyrrhurus	***	NS	*	121>122	NS
S. rivulatus	****	**	***	NS	NS
S. rubroviolaceus	NS	NS	NS	NS	NS
S. schlegeli	****	****	****	NS	NS
S. spinus	**	***	NS	NS	NS
Scarus spp	**	**	****	121>122	NS
SERRANIDAE					
Cephalopholis argus	NS	NS	NS	NS	NS
C. microprion	NS	NS	NS	NS	NS
C. urodeta	****	****	NS	NS	NS
Epinephelus caeruleopunctatus	****	NS	NS	NS	NS
E. hexagonatus	NS	NS	NS	NS	NS
E. maculatus	NS	NS	NS	NS	NS
E. merra	****	****	NS	NS	NS
Epinephelus spp	NS	NS	NS	NS	NS
Plectropomus areolatus	**	*	**	NS	201>20
P. laevis	*	*	*	121>122	NS
P. leopardus	****	****	NS	NS	NS
P. maculatus	*	NS	NS	NS	NS
Variola louti	NS	NS	NS	NS	NS

SIGANIDAE					
Siganus corallinus	**	****	NS	NS	NS
S. doliatus	NS	NS	NS	NS	NS
S. lineatus	NS	NS	NS	NS	NS
S. punctatus	NS	NS	NS	NS	NS

Table 2.3 Fiji: reef fish families and trophic groups recorded in UVC samples, with comparisons of biomass data (i) overall (df = 209), among sites (df = 3) and among fishing areas (df = 2), and (ii) between areas differing in fishing pressure (Tavua, n = 3 each area) or management (Naweni, n = 2 each area) within sites (significance levels: *p<0.05 **p<0.01 ***p<0.001 ****p<0.0001)

GROUP	ANOVA comparisons:			*t*-test comparisons:	
	Overall	**Among sites**	**Among fishing areas**	**Tavua area H_0: 122=121**	**Naweni area H_0: 20=201**
ACANTHURIDAE	****	****	****	121>122	NS
BALISTIDAE	**	NS	**	121>122	NS
HAEMULIDAE	NS	NS	NS	NS	NS
KYPHOSIDAE	**	***	NS	NS	NS
LETHRINIDAE	****	****	**	121>122	20>201
LUTJANIDAE	***	*	**	121>122	NS
MULLIDAE	****	****	NS	NS	NS
NEMIPTERIDAE	**	**	*	122>121	NS
SCARIDAE	****	**	**	121>122	NS
SERRANIDAE	****	****	**	121>122	NS
SIGANIDAE	NS	NS	NS	NS	NS
HERBIVORE	****	****	****	121>122	NS
INVERTEBRATE-FEEDER	***	***	NS	NS	20>201
PISCIVORE	***	NS	****	121>122	NS
PLANKTIVORE	****	****	****	NS	20>201

Table 2.4 Fiji: mean percentage contribution of the fish families to total mean biomass estimated by UVC for each area.

Fishing area	Acanthuridae	Balistidae	Haemulidae	Kyphosidae	Lethrinidae	Lutjanidae	Mullidae	Nemipteridae	Scaridae	Serranidae	Siganidae
5	6%	3%	1%	0%	3%	19%	4%	6%	35%	22%	1%
20	21%	1%	0%	0%	22%	18%	11%	1%	20%	5%	0%
21	24%	2%	0%	2%	2%	23%	3%	1%	36%	4%	3%
121	32%	6%	0%	0%	4%	10%	1%	0%	39%	7%	1%
122	12%	8%	0%	0%	3%	11%	6%	6%	50%	1%	3%
201	18%	1%	0%	0%	6%	10%	8%	1%	42%	12%	2%
Mean	19%	4%	0%	0%	7%	15%	6%	3%	37%	9%	2%

Table 2.5 Mean (±SE) bottom cover of live hard coral, soft coral, 'bare' rock, rubble and sand, and mean rugosity (1-5 scale) and depth in the UVC samples in the six fishing areas in four Fijian sites

Site	Area	Coral (%)	Soft (%)	Rock (%)	Rubble (%)	Sand (%)	Rugosity	Depth (m)
Vitogo	5	17.3±1.8	02.5±0.5	32.8±2.3	21.4±2.1	25.3±2.3	3.5±0.1	6.2±0.1
Naweni	20	28.6±4.1	12.1±2.5	29.2±4.4	15.0±2.4	13.9±2.8	3.6±0.2	6.0±0.1
	201	42.4±4.9	15.9±3.2	21.2±3.3	06.1±2.4	13.3±3.2	4.0±0.2	6.3±0.2
Tacilevu	21	56.2±2.6	36.2±2.8	06.9±1.0	00.5±0.3	01.9±1.1	3.3±0.1	7.1±0.1
Tavua	121	12.4±1.5	10.1±1.4	61.8±5.2	06.1±2.3	06.7±3.3	4.2±0.1	5.9±0.1
	122	05.4±1.8	14.2±1.0	37.7±3.3	20.0±3.1	22.0±3.0	4.0±0.1	5.8±0.2

Table 2.6 Fiji: results of one-way Anosim comparing habitat variables among areas (* = p < 0.05, ** = p < 0.01)

Site/area ® ¯	Vitogo	Naweni (open)	Naweni (closed)	Tacilevu	Tavua (inshore)	Tavua (offshore)
Vitogo			*	**	*	
Naweni (open)				*		
Naweni (closed)				*		
Tacilevu					*	*
Tavua (inshore)						
Tavua (offshore)						

Table 2.7 Fiji: results of multiple regression of dive-location mean biomass (n = 21) of fish families and trophic groups on habitat variables and fishing effort (significance levels: **p<0.01)

GROUP	First significant variable	Second significant variable	R^2 of significant variables combined	Regression on fishing effort alone
ACANTHURIDAE	Sand	Rock	0.45	NS
BALISTIDAE	Rock	-	0.21	NS
HAEMULIDAE	Rubble	Depth	0.51	**
KYPHOSIDAE	Soft coral	-	0.62	NS
LETHRINIDAE	-	-	NS	NS
LUTJANIDAE	-	-	NS	NS
MULLIDAE	-	-	NS	NS
NEMIPTERIDAE	Rubble	-	0.51	NS
SCARIDAE	Rock	-	0.22	NS
SERRANIDAE	-	-	NS	NS
SIGANIDAE	-	-	NS	NS
HERBIVORE	Rock	Sand	0.42	NS
INVERTEBRATE-FEEDER	-	-	NS	NS
PISCIVORE	-	-	NS	NS
PLANKTIVORE	Depth	-	0.24	NS

2.3 RESULTS

2.3.1 Fiji

Comparisons of fish species, family and trophic-group biomass data among fishing sites and areas

Ninety-seven species of reef fishes which were likely fishing targets were recorded in UVC samples from the four Fijian sites, and of these, 51 showed overall spatial differences (ANOVA) in biomass, with 41 differing at site level, 27 at fishing area level within sites and 33 at dive-location level within areas (Table 2.2). The 97 species were distributed across 11 families and 4 trophic groups (Table 2.2). Nine of the families showed overall spatial differences (ANOVA) in biomass, with eight differing at site level, seven at area level and five at dive-location level (Table

2.3). All four trophic groups showed overall spatial differences (ANOVA) in biomass, with three of these exhibiting differences among sites and among areas within sites, and two differing among dive-locations within areas (Table 2.3). The greatest contribution to the total UVC biomass was made by the Scaridae (mean 37%), Acanthuridae (mean 19%) and Lutjanidae (mean 15%)(Table 2.4).

Potential influence of habitat variables on fish biomass differences

One-way Anosim indicated that there was an overall difference (Global $R = 0.816$, $p < 0.01$) in habitat features among areas (Table 2.5). Tacilevu differed from all the other areas, and Vitogo was different from two other areas (inshore reefs at Tavua and the closed area at Naweni)(Table 2.6). The Tavua areas were thus considered similar to each other in habitat characteristics, as were those in Naweni (Table 2.6). Rock, sand, rubble, soft-coral cover, and depth, were all factors which showed significant regressions with fish biomass at family and trophic-group levels (Table 2.7). Fishing effort did not significantly contribute to explaining variations in mean biomass among dive-locations by family or trophic group (Table 2.7).

Fig. 2.1 Fiji: MDS plot of fish species biomass data at dive-location level (stress = 0.14)(closed symbols = fishery closure, open symbols = fishery open; diamonds = Tavua, circles = Vitogo, squares = Naweni [open = offshore reefs, grey = inshore reefs), triangles = Tacilevu)

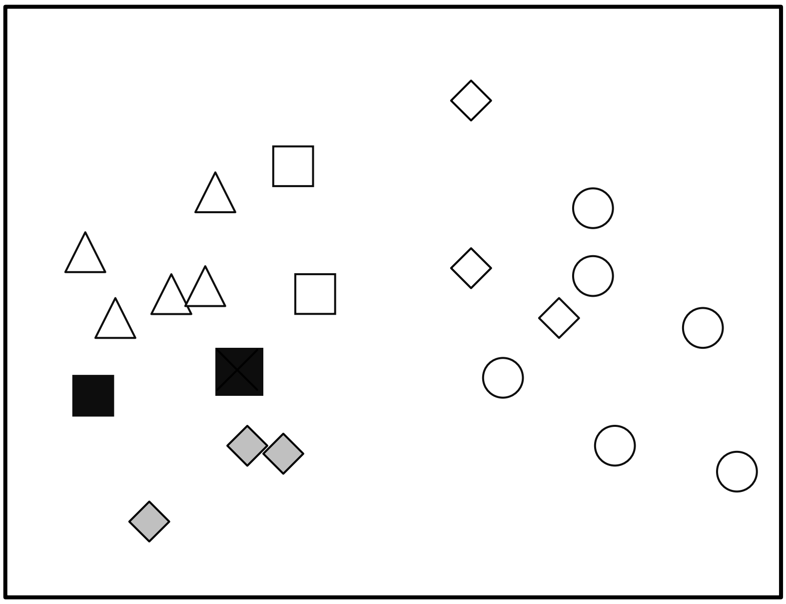


Fig. 2.2 Fiji fishing areas: plots of mean (±SE) biomass density (g/154 m2; except parrotfishes which are kg/154 m2) of seven families of fishes against fishing effort (h.km-2.y-1)

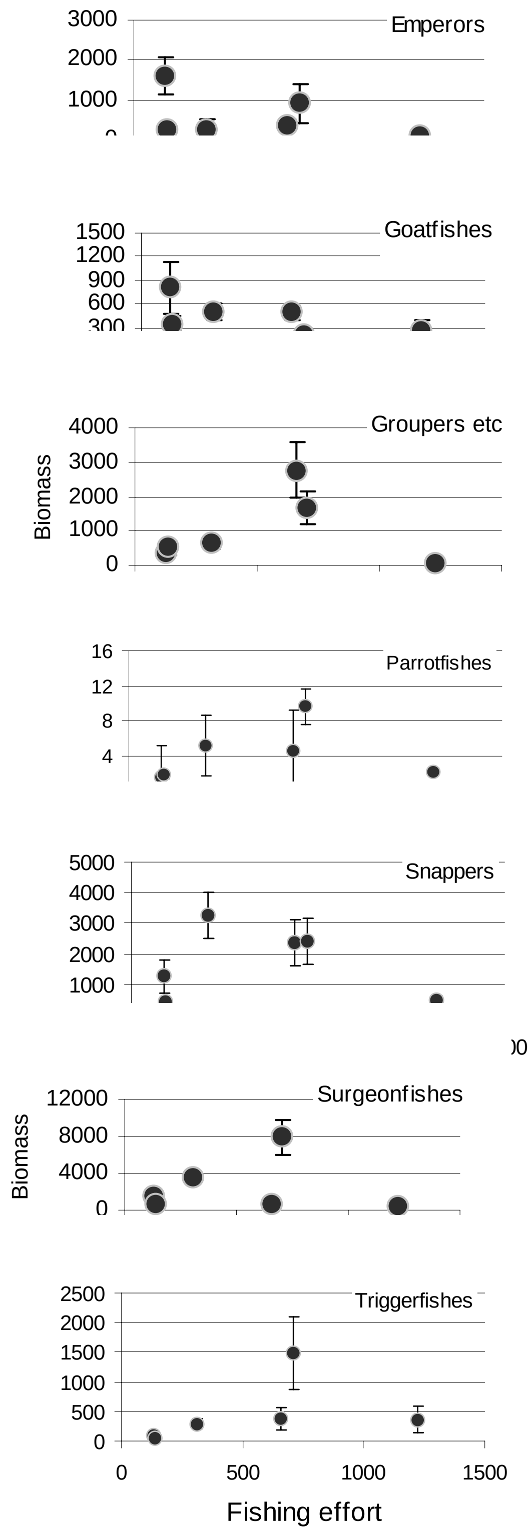
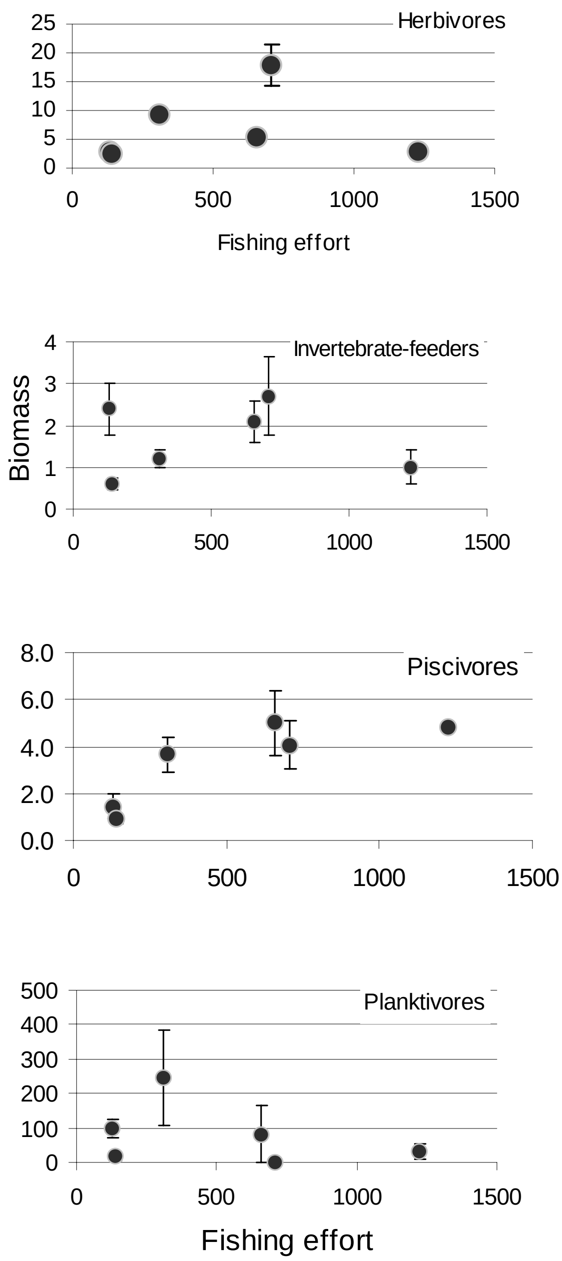


Fig. 2.3 Fiji fishing areas: plots of mean (±SE) biomass density (kg/154 m^2) of the four trophic groups of fishes against fishing effort (h.km^{-2}.y^{-1}).



Potential effects of management-driven or incidental variations in fishing pressure

MDS ordination of all fish species biomass data indicated some differences among areas (Fig. 2.1; the stress level of 0.14 indicates the ordination is a reliable interpretation). In particular, the dive-locations within the closed area at Naweni (area 201) evinced some separation from those in the open area at Naweni (area 20), while the more heavily fished offshore reef at Tavua exhibited some differences from the less-fished inshore reefs in the same site (Fig. 2.1). Comparison of the four areas in Tavua and Naweni by one-way Anosim on species biomass data indicated an overall difference (R = 0.92, p = 0.01), but none of the pair-wise comparisons was significant (a = 0.05). Five species of fishes were more abundant in the one Fijian closed area, Naweni, than in the adjacent Naweni open area. These species were the surgeonfish Ctenochaetus striatus, the lethrinids Gnathodentex aurolineatus and Monotaxis grandoculis, the lutjanid Macolor macularis and the goatfish Parupeneus barberinoides (Table 2.2). Three species also had greater biomass in the open area than closed area, and these were the parrotfishes Scarus niger and S. psittacus, and the coral trout (Serranidae) Plectropomus areolatus (Table 2.2). However, three species of fishes (the lethrinid Monotaxis grandoculis, the lutjanid Lutjanus fulviflamma, and the scarid Hipposcarus longiceps) had significantly greater mean length in the open area (area 201) than in the closed area at Naweni (area 20), which was the reverse of what would have been expected if fishing mortality had been greater in the open area than closed area. No cases were detected where fishes had greater mean length in the closed area.

When species biomass data were aggregated, there was greater biomass of emperors (Lethrinidae), and of all invertebrate-feeding and planktivorous fishes in the closed than in the open area at Naweni, while no family or trophic group showed the reverse trend (Table 2.3).

In the Tavua site, greater biomass of many individual species of fishes was found on the inshore reefs (area 121) than on the outer reef at Cakau Masi (area 122); the species included the surgeonfishes Acanthurus lineatus, Ctenochaetus striatus, and Naso spp, the triggerfish Balistapus undulatus, the lethrinid Monotaxis grandoculis, the snappers Lutjanus fulvus and L. semicinctus, several parrotfishes and the coral trout (Serranidae) Plectropomus laevis (Table 2.2). Two parrotfishes (Chlorurus bleekeri and C. sordidus) exhibited significantly greater mean lengths on the less-fished inshore reefs than those offshore.

Aggregation of the species-level data showed that mean biomasses of surgeonfishes (Acanthuridae), triggerfishes (Balistidae), emperors (Lethrinidae), snappers (Lutjanidae), breams (Nemipteridae), parrotfishes (Scaridae), and groupers (Serranidae), were greater on the inshore reefs than on the offshore reef studied, and this was the case also for the herbivorous and piscivorous fishes (Table 2.3).

Possible relationships between fish biomass by family and fishing effort at area level were also explored graphically for all areas combined. For the emperors and goatfishes, there was some indication of greater abundances at low fishing effort (Fig. 2.2), but these were not significant, and overall, no families or trophic groups (Fig. 2.3) which indicated significant differences among dive-locations within areas (Table 2.2) showed clear trends with fishing effort. Excluding the two areas showing substantial habitat differences (Tacilevu and Vitogo; third and fouth points from the left in Figs 2.2-2.3) made no substantial difference to this assessment.

Table 2.8 Vanuatu: reef fish species recorded by underwater visual census, with comparisons of mean biomass (i) overall, among sites and among areas within sites, and (ii) between areas with different levels of fishing pressure (* p<0.05 **p<0.01 ***p<0.001 ****p<0.0001)

FAMILY ***SPECIES***	***ANOVA comparisons:***			***t-test comparisons:***			
	Overall	***Among sites***	***Among fishing areas***	***Wala area H_0 215 = 211,212***	***Uripiv area H_0 222 = 221,223***	***Lélépa area H_0 246 = 243, 247-9***	***Emua area H_0 263 = 262,264***
ACANTHURIDAE							
Acanthurus albipectoralis	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
A. dussumieri	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
A. lineatus	****	*NS*	****	*NS*	*NS*	*NS*	*NS*
A. nigricans	****	*	*NS*	*NS*	*NS*	*NS*	*NS*
A. nigricauda	****	****	*	*NS*	*222>221,3*	*NS*	*NS*
A. olivaceus	*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
A. pyroferus	****	****	****	*NS*	*NS*	*NS*	*NS*
A. thompsoni	**	**	*NS*	*NS*	*NS*	*NS*	*NS*
A. triostegus	****	****	****	*NS*	*222>221,3*	*NS*	*NS*
A. xanthopterus	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Acanthurus spp	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Ctenochaetus binotatus	**	*	**	*NS*	*NS*	*NS*	*NS*
C. striatus	****	****	****	*215>211,2*	*NS*	*NS*	*NS*
N. annulatus	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
N. brachycentron	**	*	**	*NS*	*222>221,3*	*NS*	*NS*
N. brevirostris	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
N. lituratus	****	***	****	*NS*	*NS*	*NS*	*263>262,4*
N. tuberosus	****	*	**	*NS*	*NS*	*NS*	*NS*
N. unicornis	****	**	****	*NS*	*NS*	*NS*	*NS*
Paracanthurus hepatus	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Zebrasoma scopas	**	*NS*	****	*NS*	*NS*	*NS*	*NS*
BALISTIDAE							
Balistapus undulatus	****	***	****	*NS*	*NS*	*NS*	*263>262,4*
Balistoides conspicillum	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
B. viridescens	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Melichthys vidua	****	****	*NS*	*NS*	*NS*	*NS*	*NS*
Pseudobalistes flavimarginatus	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Rhinecanthus rectangulus	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Sufflamen bursa	****	**	*	*NS*	*NS*	*246>243,7-9*	*NS*
Sufflamen chrysopterus	***	***	*	*215>211,2*	*NS*	*NS*	*NS*
HAEMULIDAE							
Plectrorhinchus chaetodonoides	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
P. gibbosus	**	*	*	NS	NS	NS	NS
P. goldmanni	NS	NS	NS	NS	NS	NS	NS
P. obscurum	***	**	**	NS	NS	NS	NS
P. picus	NS	NS	NS	NS	NS	NS	NS
KYPHOSIDAE							
Kyphosus spp	**	***	NS	NS	NS	NS	NS
LETHRINIDAE							
Gnathodentex aurolineatus	**	*	**	NS	NS	NS	NS
Gymnocranius spp	NS	NS	NS	NS	NS	NS	NS
Lethrinus atkinsoni	NS	NS	NS	NS	NS	NS	NS
L. harak	**	NS	**	NS	NS	NS	NS
L. mahseni	NS	NS	NS	NS	NS	NS	NS
L. lentjan	NS	NS	NS	NS	NS	NS	NS
L. obsoletus	NS	NS	NS	NS	NS	NS	NS
L. olivaceus	NS	NS	NS	NS	NS	NS	NS
L. rubrioperculatus	NS	NS	NS	NS	NS	NS	NS

Lethrinus spp	NS	NS	NS	NS	NS	NS	NS

Table 2.8, contd

FAMILY *SPECIES*	**ANOVA comparisons:**			***t*-test comparisons:**			
	Overall	**Among sites**	**Among fishing areas**	**Wala area H_0 215 = 211,212**	**Uripiv area H_0 222 = 221,223**	**Lélépa area H_0 246 = 243, 247-9**	**Emua area H_0 263 = 262,264**
L. xanthochilus	NS	NS	NS	NS	NS	NS	NS
Monotaxis grandoculis	****	****	****	NS	NS	246>243,7-9	NS
LUTJANIDAE							
Aphareus rutilans	NS	NS	NS	NS	NS	NS	NS
Aprion virescens	NS	NS	NS	NS	NS	NS	NS
L. bohar	*	*	**	NS	222>221,3	NS	NS
L. fulviflamma	**	**	NS	NS	NS	NS	NS
L. fulvus	****	****	****	NS	222>221,3	NS	NS
L. gibbus	****	****	****	NS	222>221,3	NS	NS
L. kasmira	NS	NS	NS	NS	NS	NS	NS
L. monostigma	****	****	****	NS	NS	NS	NS
L. rivulatus	**	****	NS	NS	NS	NS	NS
L. semicinctus	NS	NS	NS	NS	NS	NS	NS
L. vitta	NS	NS	NS	NS	NS	NS	NS
Macolor macularis	****	****	****	NS	NS	NS	NS
M. niger	***	**	NS	NS	NS	NS	NS
MULLIDAE							
M. vanicolensis	NS	NS	NS	NS	NS	NS	NS
Parupeneus barberinoides	NS	NS	NS	NS	NS	NS	NS
P. barberinus	**	****	NS	NS	NS	NS	NS
P. bifasciatus	****	****	****	NS	NS	246>243,7-9	NS
P. ciliatus	NS	NS	NS	NS	NS	NS	NS
P. cyclostomus	*	NS	**	NS	NS	NS	NS
P. multifasciatus	**	NS	***	NS	NS	NS	NS
P. pleurostigma	NS	NS	NS	NS	NS	NS	NS
Upeneus tragula	NS	NS	NS	NS	NS	NS	NS
NEMIPTERIDAE							
Scolopsis bilineatus	****	****	*	NS	NS	NS	NS
S. lineatus	***	****	NS	NS	NS	NS	NS
SCARIDAE							
Bolbometopon muricatum	****	****	NS	NS	NS	NS	NS
Cetoscarus bicolor	NS	NS	NS	NS	NS	NS	NS
Chlorurus bleekeri	****	****	****	NS	222<221,3	NS	NS
C. microrhinos	***	***	*	NS	NS	NS	NS
C. sordidus	****	NS	****	NS	NS	NS	NS
Hipposcarus longiceps	**	NS	*	NS	222>221,3	NS	NS
Scarus altipinnis	**	*	**	NS	NS	NS	NS
S. chameleon	NS	NS	NS	NS	NS	NS	NS
S. dimidiatus	****	****	****	NS	NS	NS	NS
S. flavipectoralis	****	**	****	215>211,2	NS	NS	NS
S. forsteni	****	*	****	NS	NS	NS	NS
S. frenatus	**	**	*	NS	NS	NS	NS
S. ghobban	**	NS	**	NS	222>221,3	NS	NS
S. globiceps	NS	NS	NS	NS	NS	NS	NS
S. longipinnis	NS	NS	NS	NS	NS	NS	NS
S. niger	***	****	*	NS	NS	NS	NS
S. oviceps	****	****	****	NS	NS	NS	NS
S. psittacus	*	NS	NS	NS	NS	NS	NS
S. pyrrhurus	**	***	*	NS	NS	NS	NS
S. rivulatus	NS	NS	NS	NS	NS	NS	NS
S. rubroviolaceus	****	****	**	NS	222>221,3	NS	NS
S. schlegeli	****	****	****	NS	NS	NS	NS

S. spinus	**	**	NS	NS	NS	NS	NS
Scarus spp	NS	NS	NS	NS	NS	NS	NS
SERRANIDAE							
Cephalopholis argus	**	NS	NS	NS	NS	NS	NS
C. microprion	NS	NS	NS	NS	NS	NS	NS
C. miniata	****	NS	****	NS	NS	NS	NS
C. urodeta	****	****	****	NS	NS	NS	NS

Table 2.8, contd

FAMILY **SPECIES**	**ANOVA comparisons:**			***t*-test comparisons:**			
	Overall	**Among sites**	**Among fishing areas**	**Wala area H_0 215 = 211,212**	**Uripiv area H_0 222 = 221,223**	***Lélépa* area H_0 246 = 243, 247-9**	**Emua area H_0 263 = 262,264**
Epinephelus coiodes	NS	NS	NS	NS	NS	NS	NS
E. maculatus	NS	NS	NS	NS	NS	NS	NS
E. merra	*	NS	NS	NS	NS	NS	NS
P.laevis	NS	NS	NS	NS	NS	NS	NS
P. leopardus	NS	NS	NS	NS	NS	NS	NS
P. maculatus	NS	NS	NS	NS	NS	NS	NS
Variola louti	**	*	*	NS	NS	NS	NS
SIGANIDAE							
S. corallinus	****	****	NS	NS	NS	NS	NS
S. doliatus	*	**	NS	NS	NS	NS	NS
S. lineatus	NS	NS	NS	NS	NS	NS	NS
S. puella	****	****	NS	NS	NS	NS	NS
S. punctatus	NS	NS	NS	NS	NS	NS	NS
S. vulpinus	NS	NS	NS	NS	NS	NS	NS

Table 2.9 Vanuatu: reef fish families and trophic groups recorded in UVC, with comparisons of biomass data (i) overall, among sites and among fishing areas, and (ii) between areas subject to management within sites (area 246 in Lélépa, 263 in Emua, 215 in Wala, 222 in Uripiv)(* $p<0.05$ ** $p<0.01$ *** $p<0.001$ **** $p<0.0001$)

GROUP	**ANOVA comparisons**			***t*-test comparisons**			
	Overall	**Among sites**	**Amon g fishing areas**	**Wala area H_0 215 = 211,212**	**Uripiv area H_0 222 = 221,223**	**Lélépa area H_0 246 = 243,247-9**	**Emua area H_0 263 = 262,264**
ACANTHURIDAE	****	****	****	NS	NS	NS	NS
BALISTIDAE	****	****	***	NS	NS	NS	NS
HAEMULIDAE	****	**	***	NS	NS	NS	NS
KYPHOSIDAE	NS	NS	NS	NS	NS	NS	NS
LETHRINIDAE	****	****	****	215<211-2	NS	NS	NS
LUTJANIDAE	****	****	****	NS	222>221-3	NS	NS
MULLIDAE	****	****	**	NS	222>221-3	NS	NS
NEMIPTERIDAE	****	****	**	NS	NS	NS	NS
SCARIDAE	****	****	****	NS	NS	NS	NS
SERRANIDAE	****	****	**	NS	NS	NS	NS
SIGANIDAE	****	****	NS	NS	NS	NS	NS
HERBIVORE	****	****	****	215<211-2	NS	NS	NS
INVERTEBRATE-FEEDER	****	*	****	NS	NS	NS	NS
PISCIVORE	****	***	*	NS	222>221-3	NS	NS
PLANKTIVORE	****	**	**	215<211-2	NS	NS	NS

Table 2.10 Vanuatu: mean percentage contribution of the fish families to total mean biomass estimated by UVC for each area.

Fishing area	Acanthurid	Balistidae	Haemulidae	Kyphosidae	Lethrinidae	Lutjanidae	Mullidae	Nemipteridae	Scaridae	Serranidae	Siganidae
201	22%	8%	0%	0%	16%	18%	7%	2%	22%	0%	4%
202	33%	5%	0%	1%	3%	4%	6%	1%	32%	3%	12%
203	41%	1%	0%	1%	10%	16%	3%	1%	20%	5%	4%
204	19%	2%	0%	1%	18%	18%	5%	1%	25%	1%	10%
211	15%	6%	0%	2%	11%	14%	5%	1%	39%	1%	6%
212	21%	10%	0%	0%	18%	6%	3%	3%	24%	4%	10%
215	27%	6%	0%	0%	1%	5%	6%	5%	39%	10%	2%
221	14%	27%	0%	0%	13%	5%	5%	2%	26%	4%	3%
222	16%	4%	2%	10%	8%	17%	4%	1%	34%	4%	1%
223	12%	17%	0%	0%	4%	5%	6%	5%	41%	0%	11%
231	23%	6%	3%	2%	9%	31%	4%	1%	19%	2%	1%
232	7%	12%	1%	0%	3%	21%	2%	9%	37%	7%	1%
243	42%	5%	0%	0%	3%	1%	7%	0%	37%	6%	0%
246	19%	13%	0%	1%	8%	5%	7%	1%	43%	1%	1%
247	12%	4%	0%	0%	34%	30%	1%	0%	12%	8%	0%
248	28%	13%	0%	0%	2%	11%	3%	1%	32%	10%	0%
249	32%	4%	6%	0%	8%	9%	3%	2%	32%	1%	1%
262	19%	10%	0%	0%	3%	2%	3%	0%	56%	2%	5%
263	19%	13%	1%	0%	1%	16%	3%	1%	39%	2%	5%
264	23%	4%	0%	0%	12%	28%	4%	1%	24%	2%	2%
Mean	22%	8%	1%	1%	9%	13%	4%	2%	32%	4%	4%

Table 2.11 Vanuatu sites and fishing area: mean (± SE) bottom cover of live hard coral, macroalgae, soft coral, 'bare' rock, rubble and sand, and mean rugosity (1-5 scale) and depth in UVC samples

Site	Area	Coral (%)	Algae (%)	Sft coral (%)	Rock (%)	Rubble (%)	Sand (%)	Rugo-sity	Depth (m)
Atchin	201	13.0±2.4	16.5±2.2	01.0±0.0	24.0±1.8	31.0±4.5	13.5±2.6	3.1±0.2	6.1±0.1
	202	13.4±1.7	04.0±1.5	02.1±0.8	39.5±3.1	29.0±2.6	12.5±3.0	3.6±0.3	6.0±0.0
	203	17.3±3.2	00.5±0.5	00.4±0.2	50.8±4.5	13.0±2.7	18.0±1.5	3.3±0.3	6.0±0.0
	204	08.5±1.9	18.0±4.6	00.4±0.3	20.8±5.0	32.8±4.3	19.5±5.2	2.1±0.3	6.0±0.0
Wala	211	17.3±2.3	10.3±2.7	04.5±1.8	45.0±4.9	16.5±6.4	07.8±2.3	2.9±0.2	6.0±0.0
	212	20.0±5.0	00.5±0.5	01.1±0.7	11.5±5.2	46.9±11.2	19.5±5.0	1.6±0.2	6.0±0.0
	215	02.1±0.6	00.0±0.0	00.2±0.2	12.0±4.5	37.7±10.0	48.0±11.	1.5±0.2	6.0±0.0
Uripiv	221	20.3±2.6	02.8±2.1	00.8±0.8	40.5±4.4	18.0±4.1	16.8±3.1	2.9±0.1	6.0±0.0
	222	11.3±3.4	00.5±0.5	12.0±4.3	37.2±4.3	24.5±4.3	12.5±4.3	3.1±0.2	6.0±0.0
	223	05.1±1.9	00.0±0.0	02.6±0.7	00.5±0.5	77.3±9.2	05.2±2.7	2.0±0.2	6.0±0.0
Pellonk	231	43.2±3.9	00.0±0.0	06.4±1.5	17.8±3.5	18.2±3.3	14.7±3.4	2.9±0.2	6.0±0.0
	232	32.5±4.6	00.0±0.0	07.0±2.2	14.0±3.5	41.5±4.4	05.2±1.9	2.2±0.1	6.0±0.0
Lélépa	243	13.5±1.5	01.8±0.7	00.8±0.4	65.5±3.8	13.3±3.9	04.8±1.4	2.9±0.2	5.8±0.1
	246	17.3±1.6	00.0±0.0	00.3±0.3	31.8±4.7	24.5±6.6	26.3±5.1	2.8±0.2	5.7±0.2
	247	07.5±1.7	04.0±1.8	00.0±0.0	16.0±3.6	32.0±9.5	39.0±11.	2.0±0.2	6.0±0.0
	248	16.0±2.0	05.4±1.9	00.5±0.3	57.1±3.6	06.8±2.5	14.0±2.5	3.4±0.1	6.0±0.0
	249	15.5±2.2	00.0±0.0	00.5±0.5	59.5±5.0	10.5±4.3	14.5±4.0	3.3±0.1	6.0±0.0
Emua	262	10.5±1.0	13.8±3.1	03.9±0.9	32.9±3.9	24.8±4.0	14.1±2.6	2.3±0.2	7.1±0.2
	263	11.0±1.0	09.6±1.6	06.1±1.2	30.2±4.4	27.2±4.5	15.7±2.2	2.6±0.2	6.7±0.1
	264	16.4±2.3	08.8±1.9	06.3±1.4	24.3±2.3	26.3±4.4	18.0±3.0	2.8±0.2	7.1±0.2

Table 2.12 Vanuatu: results of multiple regression of dive-location mean biomass (n = 37) of fish families and trophic groups on habitat and fishing effort variables (* p<0.05 ***p<0.001)

GROUP	First significant variable	Second significant variable	Third significant variable	R^2 of significant variables combined	Regression on fishing effort alone
ACANTHURIDAE	rugosity	-	-	0.17	NS
BALISTIDAE	algae	-	-	0.15	*
HAEMULIDAE	soft coral	-	-	0.21	NS
KYPHOSIDAE	soft coral	depth	-	0.17	NS
LETHRINIDAE	-	-	-	-	NS
LUTJANIDAE	soft coral	depth	-	0.35	***
MULLIDAE	depth	soft coral	-	0.37	NS
NEMIPTERIDAE	hard coral	-	-	0.26	NS
SCARIDAE	soft coral	depth	-	0.40	NS
SERRANIDAE	depth	fishing	-	0.21	*
SIGANIDAE	fishing	-	-	0.11	*
HERBIVORE	depth	soft coral	-	0.32	NS
INVERTEBRATE-FEEDER	algae	soft coral	depth	0.41	NS
PISCIVORE	soft coral	depth	-	0.35	NS
PLANKTIVORE	-	-	-	-	NS

2.3.2 Vanuatu

Comparisons of fish species, family and trophic-group biomass data among fishing sites and areas

One hundred and fourteen species were recorded in the seven Vanuatu sites; of these, 62 showed overall differences in biomass by ANOVA, with 49 differing at site level and 46 at area level within sites (Table 2.8). The 114 species were from 11 families, and four major trophic groups. Ten of the families showed significant overall spatial variation in biomass, with all of these showing differences among sites, and nine varying at area level (Table 2.9). Of the four trophic groups, all showed significant spatial variations in biomass at the level of sites and areas (Table 2.9). The main contributors to the UVC biomass were the Scaridae (mean 32% of total biomass), Acanthuridae (22%) and Lutjanidae (13%)(Table 2.10).

Potential influence of habitat variables on fish biomass differences

There was an overall difference among sites in habitat data (Global R = 0.210, p = 0.033)(Table 2.11); the principal difference was between Lélépa and Emua. Lélépa and Emua alone had sufficient replication to compare habitat variables between closed and open areas (nested Anosim) within these two sites, and when this was done no overall difference in habitat was detected (R = 0.091, p = 0.294). This suggests that the closed and open areas within Lélépa and Emua were similar in terms of the habitat data.

Habitat and fishing variables showed significant associations with biomass in all families except the emperors (Lethrinidae) and trophic groups except the planktivores (Table 2.12). On its own, fishing effort data without transformation were significantly linked at dive-location level to spatial variations in biomass of triggerfishes (Balistidae), snappers (Lutjanidae), groupers and relatives (Serranidae) and rabbitfishes (Siganidae), but none of the trophic groups (Table 2.12). In the multiple regressions, fishing was retained as a significant factor for both the serranids and the siganids, but in the case of the other remaining families and trophic groups, the habitat factors rugosity, depth, and algal, soft-coral, and hard-coral cover, played significant roles in predicting variations in biomass at dive-location level (Table 2.12).

Potential effects of management-driven or incidental variations in fishing pressure

MDS ordination of all fish species biomass data at dive-location level indicated that some differences among areas might be attributable to management (Fig. 2.4; the stress level of 0.23 indicates that detailed interpretation from the plot is likely to be unreliable). Thus there is an indication that the closed area in Emua (area 263; Fig. 2.4, solid circles)

Fig. 2.4 Vanuatu: MDS plot (stress = 0.23) of fish species biomass data at dive-location level (solid = closed, open = open, to fishing; diamonds = Lélépa, circles = Emua, +'s = Atchin, squares = Wala, triangles = Uripiv, X's = Pellonk)

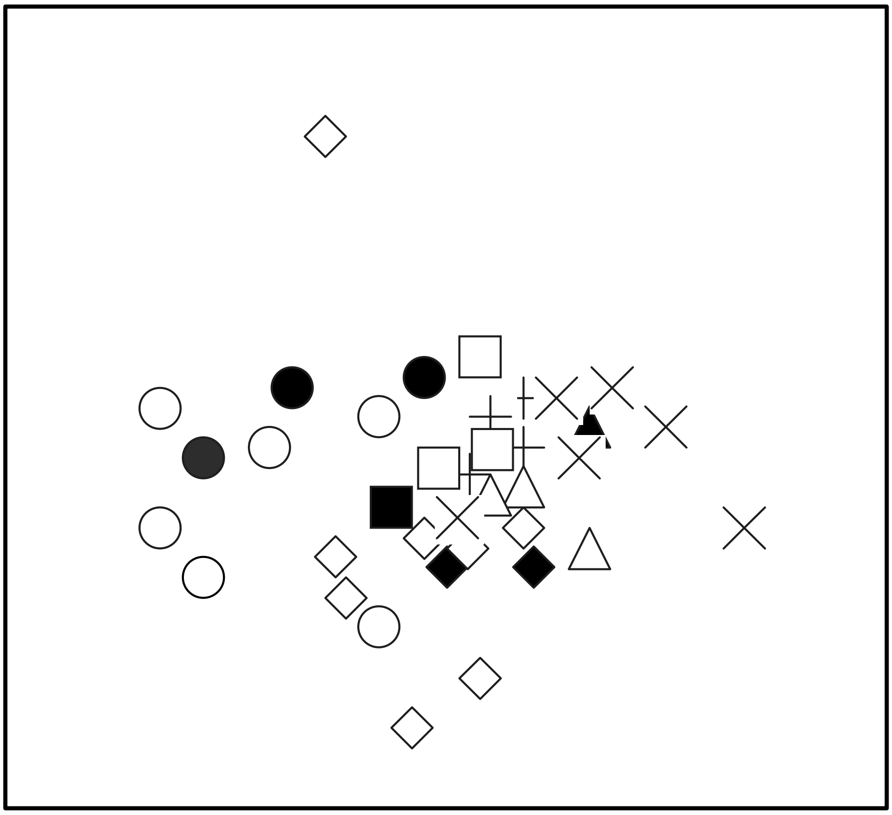
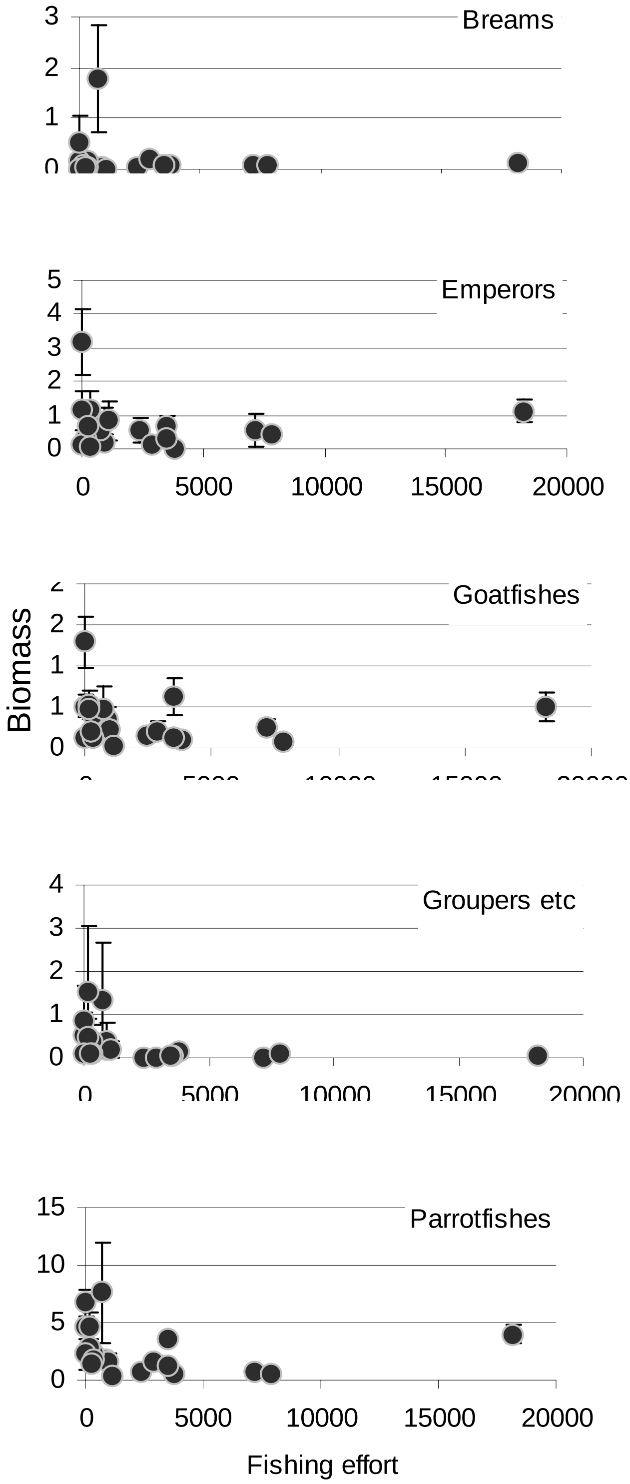


Fig. 2.5 Vanuatu fishing areas: Plots of mean (±SE) biomass density (kg/154 m^2) of nine families of fishes against fishing effort (h.km^{-2}.y^{-1})



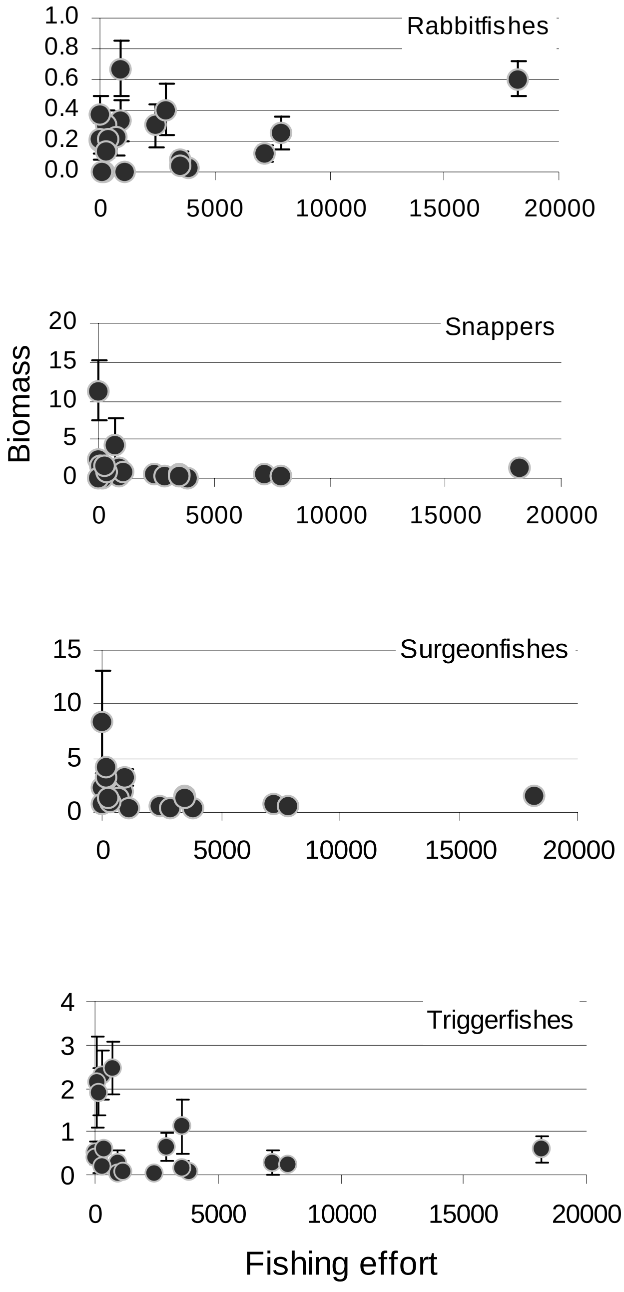
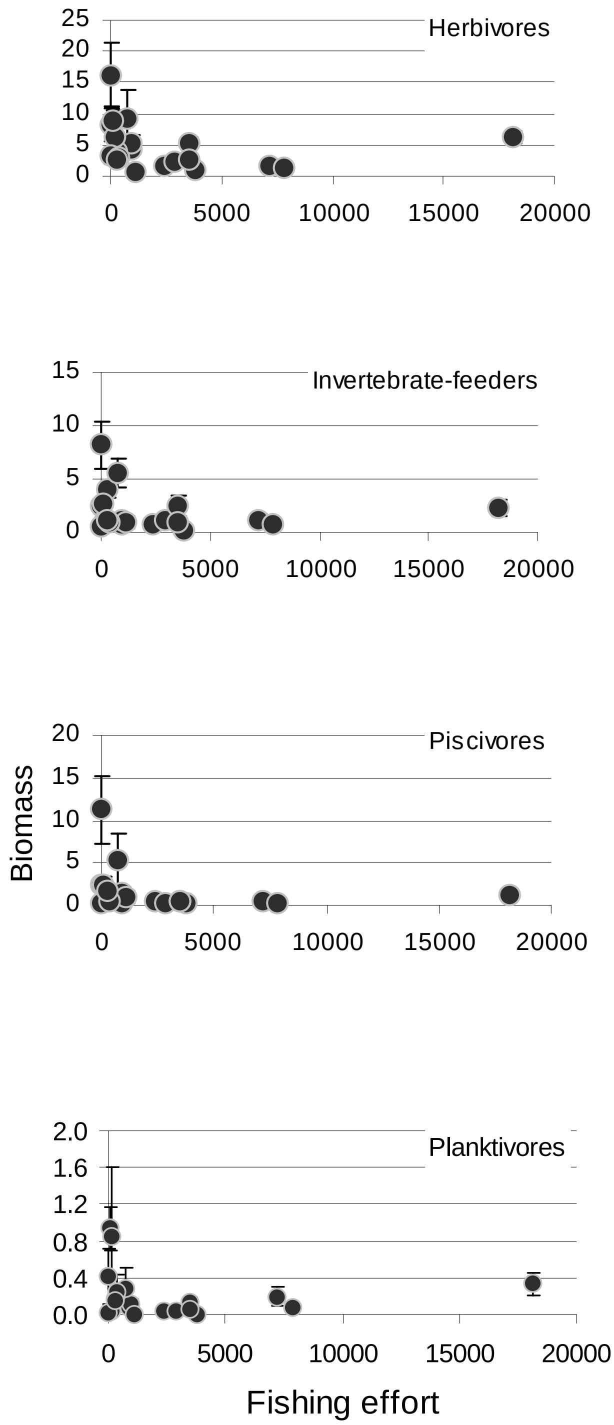

Rabbitfishes
Snappers
Surgeonfishes
Triggerfishes
Biomass
Fishing effort
1.0
0.8
0.6
0.4
0.2
0.0
20
15
10
5
4
3
2
1
0
5000
10000
15000
20000

Fig. 2.6 Vanuatu fishing areas: plots of mean (±SE) biomass density (kg/154 m^2) of the four trophic groups of fishes against fishing effort (h.km^{-2}.y^{-1}).



was different from the other two areas which were fished in the Emua site (areas 262 and 264; Fig. 2.4, open circles). In Lélépa, one open area (area 247; Fig 2.4, the highest point on the vertical axis of the plot) was quite distinct from all the rest in the fish species biomass data, the closed area (Fig. 2.4, solid diamonds) could be viewed as being somewhat different from the other open areas (areas 243 and 248-9; Fig. 4, open diamonds. The fish species biomass data from Wala and Uripiv were also suggestive of possible overall differences between open and closed areas (Fig. 2.4), but due to insufficient replication (Table 2.1), areas differing in management could only be compared for Lélépa and Emua, and this was done using a nested Anosim (open vs closed within the two sites). This showed no significant overall effect of customary management ($R = 0.33$, $p = 0.01$).

Some significant differences in fish biomass at species, family and trophic-group levels were nevertheless indicated between closed and open areas identified (Table 2.1) within the four sites.

At Wala, the surgeonfish Ctenochaetus striatus, the triggerfish Sufflamen chrysopterus and parrotfish Scarus flavipectoralis were more abundant in the closed area than the two open areas (Table 6) but no fish species had greater mean length in the closed area than in the open areas. The emperors (Lethrinidae), and herbivorous and planktivorous fishes as a whole had greater mean biomasses in the closed area than open areas at Wala (Table 2.7).

At Uripiv, nine species (the surgeonfishes Acanthurus nigricauda, A. triostegus and Naso brachycentron, the snappers Lutjanus bohar, L. fulvus and L. gibbus, and the large parrotfishes Hipposcarus longiceps, Scarus ghobban and S. rubroviolaceus) showed greater biomass in the closed area than in the two open areas, and only one species (the parrotfish Chlorurus bleekeri) showed greater biomass in the open areas than in the closed area (Table 2.6). No species in Uripiv showed greater mean length in the closed area than in the open areas. The snappers (Lutjanidae), goatfishes (Mullidae), and piscivores as a whole tended to be more abundant in the closed than open areas at Uripiv, while no family or trophic group tended to have greater biomass in the open areas than in the closed area (Table 2.7).

At Lélépa, the triggerfish Sufflamen bursa, the common lethrinid Monotaxis grandoculis and the goatfish Parupeneus bifasciatus were more abundant in the closed than open areas (Table 2.8). There was no evidence of any species being greater in mean length in the closed than in the open areas of Lélépa There were no differences at all in fish biomass data between the closed area and open areas at family or trophic-group level (Table 2.9).

At Emua, the unicornfish Naso lituratus and triggerfish Balistapus undulatus tended to more abundant in the closed area and no species were more common in the open than closed areas (Table 2.6). No species exhibited greater mean length in the Emua closed area than in the open areas. There were no differences at all in fish biomass data between the open areas and closed area (either way) at family or trophic-group level (Table 2.9)

When biomass data were compared with fishing effort data at area level, there was a little evidence of fishing effects. Thus there were significant negative correlations between area-mean biomass and $\log_e$-transformed fishing effort for the surgeonfish Acanthurus triostegus, unicornfish Naso brachycentron, the triggerfish Rhinecanthus rectangulus, the sea chub Kyphosus spp, the grunts Plectorhinchus obscurum and P. goldmanni, the emperors Lethrinus spp and L. mahsena, the goatfish Mulloidichthys vanicolensis, the parrotfishes Bolbometopon muricatum, Chlorurus microrhinos and Scarus ghobban, and the coral trout Plectropomus maculatus and P. laevis. No such correlations using $\log_e$-transformed fishing effort were significantly positive at species level.

There were indications from graphical plots of negative trends of biomass against fishing effort at family and trophic-group levels (Figs 2.5-2.6). Amongst whole families, the groupers and relatives (Serranidae), parrotfishes (Scaridae) and triggerfishes (Balistidae) tended to have greater mean biomass at low levels of fishing effort, but in other cases any such trends were weak (Fig. 2.5). For the trophic groups, there was also an indication from plots of greater biomass at low levels of fishing effort (Fig. 2.6). Correlations between area-mean biomass and $\log_e$-transformed fishing effort were significantly negative for Serranidae and Kyphosidae, and there were no significant positive correlations for any trophic or family group at area level.

2.4 Conclusions

The objective of the overall project is to look for evidence that closure of areas subject to customary tenure leads to increases in abundance and catch. Such 'customary management' is the focus of these conclusions.

In Fiji, only one closed area was identified, that in Naweni. The MDS plot was suggestive of overall fish differences between open and closed areas, but only two dive-locations were sampled in each area (Fig. 2.1). Eight species differed in biomass between the closed and adjacent open area at Naweni, five species being more abundant in the closed area and three in the open; in addition to the latter, three other species were greater in mean length in the open area. Although all of the differences mentioned were statistically significant, species-level data are likely to be more erratic indicators of fishing differences, primarily because of the small areas sampled by UVC. Data from aggregate groups have generally been found (e.g Polunin & Roberts 1993; Jennings & Polunin 1996) more reliably to indicate fishing effects. In the case of Naweni, no family or trophic groups exhibited greater biomass in the open area, while the emperors and invertebrate-feeding fishes generally were more abundant in the closed area. The indication is that closure is likely to have an effect on certain target fishes, or groups of fishes, even though the fishing effort data from the fishery study evinced no differences between the two areas of Naweni (Table 2.1).

In Tavua in Fiji, there was no customaray closure, but 20 species showed greater biomass on the inshore reefs which were less fished than those offshore (Table 2.1), and these differences were evinced by seven families and two trophic groups. The UVC differences at Tavua therefore qualitatively reflected those of the fishery study.

In Vanuatu, four closed areas were identified in the six sites studied, but only two, Lélépa and Emua, had dive-location replication within closed areas. Only two or three species were more abundant in the closed area than in the open areas, and these differences were not evinced by any of the family or trophic-group biomass data for either site (Table 2.9). The inference that overall management at area level had negligible effect is in accordance with the fishery study; fishing effort was in fact greater in the closed areas concerned (Table 2.1) and closure was therefore ineffective. For Wala and Uripiv, several species were more abundant in the closed areas, and, more pertinently, these differences were evinced by UVC family and trophic-group biomass data. These indications of management effects qualitatively reflect variations in fishing effort reported from the fishery study of this project (Table 2.1). Support for fishing (and closure) effects being detectable at site level in Vanuatu was offered by the multiple regression and correlation analyses, the suggestion being that there tends overall to be a negative exponential trend in UVC biomass with increasing effort (Figs 2.5-2.6). The pattern suggested by the latter data is similar to that reported elsewhere in the Indo-Pacific (Jennings & Lock 1996; Polunin &

Jennings 1998), and it appears that the greatest differences in biomass can be expected to be found with change in effort at rather low levels of fishing pressure.

Summary

Management success was examined across a range of fishing pressures at different sites in Fiji and Vanuatu. Managed areas are expected to have low or zero (closed areas) fishing effort and for such locations only UVC data may be available, with none from a fisheries monitoring programme. Underwater Visual Census was employed to examine :

- *Habitat characteristics;*
- *Species and family abundance, & spp. assemblages;*
- *Species length differences.*

Comparisons were made between tabu and open access areas, and variables examined were correlated with fishing pressure.

VANUATU

Habitat characteristics

- *No significant differences in habitat characteristics were detected within or between sites;*
- *Tabu areas were not different from open access areas.*

UVC-Abundance & spp assemblages

Tabu vs open access areas

Multivariate analyses with MDS and ANOSIM indicated that no significant differences occurred in abundance and species assemblage for any tabu areas compared to open access areas.

Univariate analyses indicated that species differences were inconsistent. Family /trophic group differences were observed within areas of fishing sites:

- *Wala, Lethrinids & planktivores more abundant in 215T than in open access areas (The Tabu was respected here in 1998);*
- *Uripiv, Lutjanids, mullidae and piscivores more abundant in 222T than open access areas (This tabu was respected);*
- *Lelepa, Emua, no differences open vs tabu areas and MDS=no significant difference in species assemblage (Tabus at these locations were not respected).*

Fishing effort and abundance

- *Weak trend for increasing biomass at low levels of effort, only significant for Serranidae and Kyphosidae across areas;*
- *Habitat more significant than effort re abundance.*

Summary Continued.

Mean length

- *No significant differences in mean length of any species were detected in closed areas in Wala, Uripiv, Lelepa or Emua compared to open access areas.*

Vanuatu conclusions

Comparisons of tabu and open access areas were inconclusive with respect to indicating the benefits of management. Indications for management effects in closed areas from UVC studies qualitatively reflected fishing effort - ie abundance was consistent with the level of effort.

Correlations with fishing effort was attempted to explain observations. The negative trend of biomass with increasing effort was very weak and only significant for two families, Serranidae and Kyphosidae. The greatest differences in biomass occurred at low levels of effort change, which is consistent with other work from the Indo Pacific by Jennings and Polunin.

FIJI

Habitat characteristics

- *Within sites, habitat characteristics were similar, and tabu areas were not different from open access areas;*
- *Between sites, areas differed. Tacilevu was different from all others*

UVC abundance and species assemblages

Multivariate analyses : Within sites no significant differences were observed by area or dive site in species assemblage or abundance, except for Tavua inshore reefs (121) which had significantly greater biomass than offshore reefs. Across sites significant differences occurred between areas, and between commercial ves semi commercial sites. No significant differences occurred between tabu area 201T and open access area 20/21.

Univariate analyses :

Tabu vs open access areas

- *Greater abundance of lethrinids and planktivores in 201T. Species differences were not conclusive.*

Fishing effort and abundance

- *Mean biomass across sites was not significantly correlated to fishing effort*

Summary continued.

Mean length

No significant differences in mean length of any species were detected in closed area 201T compared to open access areas.