

4 Univariate analyses of data from the fisheries monitoring programme

FIJI

As described in Volume 2, chapter 2 study sites in Fiji fall into two distinct categories:

- the commercial fishing sites of Vitogo and Tavua, where management action (licensing, although no limit to the numbers of licences have been applied) is applied to all sub-areas; and,
- the semi commercial sites of Verata and Naweni/Tacilevu. Management actions relate to a ban on commercial fishing by Indo Fijians at sub-area 16 (in Verata) and a closure at sub-area 201 (Naweni/Tacilevu).

Table 4.1 summarises this information.

Table 4.1 : Summary details of the study fishing sites in Fiji, indicating the management actions applied by sub-area.

Site	Sub-area	Description	Tabu / management action	Other details
Vitogo	2	Commercial	Licensing applies	/ goodwill payment F\$ 100-150
	3	Commercial	?	
	4	Commercial	?	
	5	Commercial	Licensing applies	/ goodwill payment F\$ 20-100
	6	Commercial	Licensing applies	/ goodwill payment F\$ 300/500
	7	Commercial	Licensing applies	/ goodwill payment F\$ 200
	8	Commercial	Licensing applies	/ goodwill payment F\$ 200
	9	Commercial	Licensing applies	/ goodwill payment F\$ 300
	Tavua	121	Commercial	Licensing applies
122		Commercial	Licensing applies	/ goodwill Offshore reef area payment F\$ 50 +extras
Vearata	14	Semi -commercial		
	15	Semi -commercial		
	16T	Semi -commercial	Ban on commercial fishing by Indo Fijians	
	17	Semi -commercial		
	18	Semi -commercial		
Naweni	19	Semi -commercial		
	20	Semi -commercial		

201T	Semi-commercial	Tabu, Feb 96-Dec 96, July 97-June 1998	Data available following re-opening in July 1998
Tacilevu	21	Semi-commercial	Tacilevu / Naweni = Adjacent sites

The types of fishing activity undertaken in the commercial and semi-commercial sites differ significantly (see Volume 2, chapter 2), and the species composition of the catch also differs significantly. Hence it has not always been possible to examine data across all sites, and uni-variate analyses have been presented for these two distinct categories separately. Where appropriate and possible, data across all sites has been compared.

In addition to the division of information according to fishing practice, data is not available for all sites throughout the two year study period. Volume 2, chapter 2 indicates the availability of data over time, and relates this to management actions.

The following provides details of uni-variate analyses of catch rate, and biological parameters for key species from sites in Fiji. As was the case for the Vanuatu data, detailed analyses are presented in Annexes (Annexes F1-F5), with summary details given in the following text.

4.1 Abundance indices and fishing effort

In order to compare catch rates at different sub-areas within sites and across sites, aggregate (all species) catch rate data was examined for both the case of all fishing gears combined and that of representative gear types. Handlines were the only representative gear employed commonly at all fishing locations, but within the semi-commercial sites gill-nets, and spears were also used. For combined gear analyses, effort data was standardised for seasonal and gear variation. Where representative gear types were examined the data was unstandardised.

Mean aggregate (all) species catch rate data for representative gear types, and that for all gear standardised for seasonal and gear variation was generated for each study year (July 1996-June 1997, and July 1997-June 1998) by sub-area. This data was analysed using a GT2 test and Gabriel's approximation (Sokal and Rohlf, 1995) for within site comparisons (Annex F1, and Table 4.2). Of interest is whether tabu (managed) areas have significantly different catch rates (abundance) to open access areas. Differences between sub-areas across sites were explained in relation to fishing intensity with a Munro-Thompson plot (Munro and Thompson, 1983), equivalent to a Fox surplus production model for spatial rather than time-series data.

GT2 and Gabrielle's approximation tests

Annex F1 and Table 4.2 indicate that only small sub-area differences in catch rate occur within semi commercial sites, and that the observations for the tabu areas (16 in Verata, and 201 in Naweni/Tacilevu) are inconsistent across the gears examined. Area 16 is only significantly different than sub-area 18 (in both years, for all gears combined), but not different from other sub-areas at that site. Area 201 was little different from most other areas in Naweni/Tacilevu in 1996/7 but catch rates in 1997/8 were significantly greater than elsewhere for all gears combined (Figs 4.1-2), and for the individual gear types examined, in particular, handlines (benefits of closure being realised? - discussion). Some across site differences occurred but these were small. No sub-area or site differences were observed for commercial sites (Table, 4.2, Fig. 4.3). Catch rates at the commercial and open access semi commercial sites were similar and did not vary by year (semi-commercial sites only).

As indicated previously, tabu area 201 was only significantly different from other sites during 1997/8 (Fig 44).

Table 4.2 A summary of the results of the GT2 test and Gabrielle's approximation to test for significant differences (at the 5% level) in mean catch rate observed between sub-areas within sites in Fiji for different years and different gear.

Species	Gear	Year	Site	Observations
All	All	1996/7	Vitogo	na
All	All	1996/7	Tavua	na
All	All	1996/7	Verata	14 and 16T>18, but much overlap
All	All	1996/7	Naweni/Tacilevu	21>20, but 20=201T=21
All	All	1997/8	Vitogo	No sub-area differences
All	All	1997/8	Tavua	No sub-area differences
All	All	1997/8	Verata	16T>18, rest =
All	All	1997/8	Naweni/Tacilevu	201T>>20=21
All	Gill nets	1996/7	Verata	na, too few data
All	Gill nets	1996/7	Naweni/Tacilevu	No sub-area differences
All	Gill nets	1997/8	Vitogo	na
All	Gill nets	1997/8	Tavua	na
All	Gill nets	1997/8	Verata	na, too few data
All	Gill nets	1997/8	Naweni/Tacilevu	201T>20=21
All	Handlines	1996/7	Verata	na, too few data
All	Handlines	1996/7	Naweni/Tacilevu	No sub-area differences
All	Handlines	1997/8	Vitogo	No sub-area differences
All	Handlines	1997/8	Tavua	No sub-area differences
All	Handlines	1997/8	Verata	16T=17, few data
All	Handlines	1997/8	Naweni/Tacilevu	201T>>20=21
All	Spears	1996/7	Verata	14>15, rest =
All	Spears	1996/7	Naweni/Tacilevu	201T<20=21
All	Spears	1997/8	Vitogo	na
All	Spears	1997/8	Tavua	na
All	Spears	1997/8	Verata	No sub-area differences
All	Spears	1997/8	Naweni/Tacilevu	20>21=201T

Figures 4.1-4 Gabriel's approximation to the GT2 test applied to aggregated (all species) standardised catch per unit effort for semi commercial sites in 1996/7 (4.1), 1997/1998 (4.2) and commercial sites in 1997/8 (4.3). Pairs of means are significantly different when the upper and lower comparison limits do not overlap. Fig 4.4 summarises the mean aggregate standardised catch rate by site for open access areas (closed squares and circles) and tabu areas (open squares and circles).

Fig 4.1

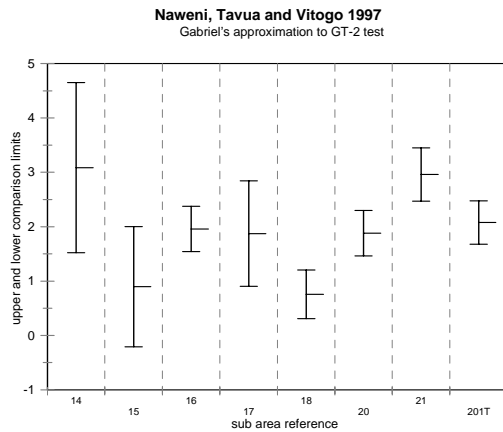


Fig. 4.2

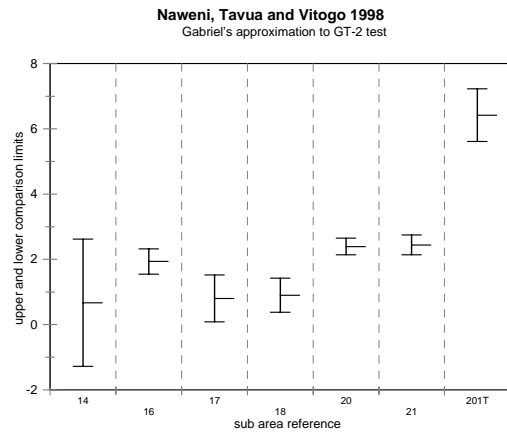


Fig. 4.3

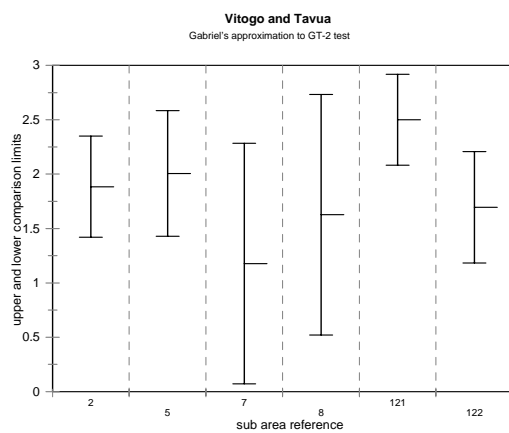
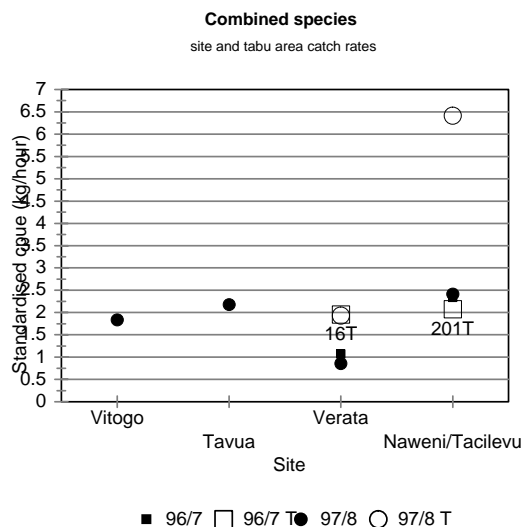


Fig. 4.4



Summary: Results of GT2 and Gabrielles approximation tests to compare mean catch rates within sites indicated few sub area differences. Tabu areas in semi commercial sites did not differ from open access areas except for 201 at Naweni/Tacilevu during 1997/8. This was consistent for the different gear types studied, and may relate to the benefits of closure. All commercial sub-areas were subject to 'management' (licensing) but did not indicate significant differences in catch rate.

Correlation of catch rates and fishing intensity

Table 4.3 and Annex F2 indicate the results of correlation of catch rate against standardised fishing effort. Details are presented for commercial and semi-commercial sites separately. The standard Munro-Thompson plot indicated no significant correlations except for gill nets at semi-commercial sites in 1997/8 (Table 4.3). Log transformation of the data did not improve the correlation (Annex F2). There was no significant correlation between catch rate (abundance) and effort when all commercial and semi-commercial sites were compared (Table 4.3, Figure 4.5). Catch rates in tabu areas relative to the fishing intensity at that area showed no consistent trend. For gill nets in 1997/8, the only significant correlation, catch rates in both tabu areas (16 and 201) were as predicted for the level of fishing effort applied.

Table 4.3 Results of the regression of Ln.catch rate by sub area against standardised total effort for representative gear types and all gears in 1996/7 and 1997/8. The column 'Tabu' highlights the status of tabu areas relative to others at similar levels of fishing intensity. Sig? indicates the level of significance of the regression. N is >0.1.

Gear	Year	Within site	Effort		R ²	Sig?
			Trend	Tabu		
Gill net	1996/1997	Naweni, Verata	Decrease	201 no difference, 16 high	0.180	N
	1997/1998	Naweni, Verata	Decrease	16 and 201 on predicted line	0.984	0.004
Handline	1996/1997	Naweni, Verata	Decrease	201 no difference, 16 high	0.114	N
	1997/1998	Naweni, Verata	Decrease	201 high, 16 low	0.104	N
	1997/1998	Vitogo, Tavua	Decrease	n/a	0.066	N
Spear	1996/1997	Naweni, Verata	Increase	201 high, 16 as might be predicted	0.114	N
	1997/1998	Naweni, Verata	Increase	16 and 201 no difference	0.044	N
All gears	1996/1997	Naweni, Verata	Increase	16 and 201 no difference	0.027	N
	1997/1998	Vitogo/Tavua	Decrease	na	0.034	N
	1997/1998	Naweni, Verata	Decrease	201 no difference, 16 low	0.197	N
	1997/1998	All sites	Decrease	201 high, 16 as might be predicted	0.016	N

Summary: Observed catch rate data from fishing surveys were poorly correlated with fishing intensity for commercial and semi commercial sites examined separately, and for all sites together. Tabu areas showed no consistent trend relative to fishing intensity except for gill nets in 1997/8 whancatch rates at 16 and 201 were consistent with the level of effort applied.

Figs. 4.5 Thompson-Munro plot of standardised spatial catch rate data (kg/hour) by sub area

(indicated) against standardised total effort (hours.km⁻²) for all gear types and all commercial and semi-commercial sites in 1997/8 (Fig. 4.5) and for gill net at semi commercial sites only in 1997/8 (Fig. 4.6).

Fig. 4.5

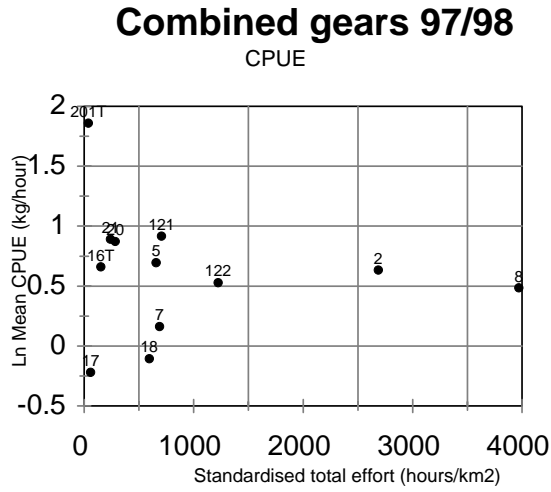
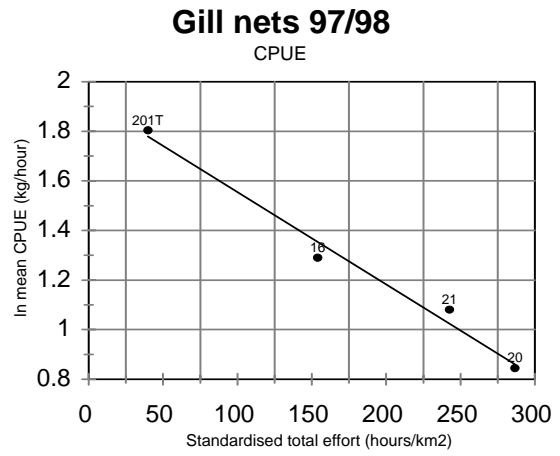


Fig4.6



4.2 Population demographic variables

As was the case for Vanuatu, key species from the Fiji fishery were identified based on sample size by location and gear. Mean length and mortality were estimated.

4.2.1 Mean Length

Mean length comparisons across areas

Length frequency data was generated by species for each gear type and sub area aggregated over the sampling period, and mean fork length (cm) was compared using a GT2 test and Gabrielle's approximation (Sokal and Rohlf, 1995). Details for each species are indicated in Annex F3, and summarised in Table 4.4 for within site comparisons and Table 4.5 for across site comparisons. Data were compared for representative gear types, but not between different gear.

Considering the commercial fishing sites, most species caught by handline at site 122 were significantly larger than those caught at site 121 in Tavua. However, no consistent differences were observed by species at this site for fish caught by gillnets, and no consistent differences between sub areas in Vitogo occurred for fish caught by handlines (Table 4.4). Across both of the commercial sites, those fish caught in sub-area 122 tended to be larger than elsewhere (Table 4.5).

For the semi-commercial sites, data was available for a greater number of gear types. Within Naweni-Tacilevu fish caught in sub-area 21(Tacilevu) tended to be larger than those caught at sites 20 or 201T (both Naweni) for both handlines and gillnets, and fish within the Tabu (201) area were not significantly different from those caught in area 20. With spear guns there were no sub-area differences in mean length for the species studied. At Verata similarly there were no consistent differences for fish caught by spearguns. Handline and gillnet caught species from sub area 18 were, however, larger than fish caught at any other sub area within this site, including those from the Tabu area 16T. Fish caught in the Tabu area were not consistently different in size than those from other areas at this site except 18 (Table 4.4). Comparing mean length of fish caught in the sub areas across semi-commercial sites no sub area differences were observed between Naweni/Tacilevu and Verata apart from *Lethrinus harak* where fish in area 21(Naweni) were largest (Table 4.5).

Comparing mean length of fish caught in semi-commercial sites with those from commercial sites, no consistent differences were observed across the species studies for gillnets. The single most common feature was that fish from site 18 (Semi commercial, Verata) tended to be larger than those from any other area. For handlines, fish caught from commercial areas were consistently larger than those from semi-commercial areas, with a few minor exceptions such as *Lethrinus atkinsonii* from area 18, and *Lethrinus harak* from area 18 and 21 (Table 4.5).

Summary : No consistent differences were observed in the size of fish caught within or across commercial fishing sites except for those at site 122 in Tavua which were larger. This probably relates to environmental differences (122 is the offshore reef area) rather than any effects of licensing and access. Within semi commercial sites few differences in mean length were observed for any species or gear type, except that fish in area 18 and 21 in Verata and Tacilevu respectively tended to be larger. There was no evidence that the size of fish caught in tabu areas (16 and 201) differed from those in other areas (except 18 and 21). Fish caught by handlines from the commercial sites were larger than those from semi commercial sites.

Table 4.4 A summary of the results of the GT2 test and Gabrielle's approximation to test for significant differences (at the 5% level) in mean length of fish between sub-areas within sites, by species and fishing method (Refer to Annex F3 for details).

Species	Gear	Within Site comparison	Across site comparison	Observations
<i>Lethrinus harak</i>	Gillnets	Tavua		121=122
<i>Lethrinus nebulosus</i>	Gillnets	Tavua		121=122
<i>Lutjanus fulviflamma</i>	Gillnets	Tavua		121=122
<i>Lutjanus quinquelineatus</i>	Gillnets	Tavua		122>121
<i>Valamugil seheli</i>	Gillnets	Tavua		121=122
<i>Epinephelus areolatus</i>	Handlines	Tavua		122>121
<i>Lethrinus elongatus</i>	Handlines	Tavua		121=122
<i>Lethrinus harak</i>	Handlines	Tavua		121=122
<i>Lethrinus nebulosus</i>	Handlines	Tavua		122>>121
<i>Lutjanus argentimaculatus</i>	Handlines	Tavua		122>121
<i>Lutjanus fulviflamma</i>	Handlines	Tavua		122>121
<i>Lutjanus gibbus</i>	Handlines	Tavua		122>121
<i>Lutjanus quinquelineatus</i>	Handlines	Tavua		122>121
<i>Plectropomus leopardus</i>	Handlines	Tavua		122>121
<i>Lethrinus atkinsonii</i>	Handlines	Tavua		122>121
<i>Epinephelus areolatus</i>	Handlines	Vitogo		7<9, 10; 2<10, rest =
<i>Epinephelus merra</i>	Handlines	Vitogo		No sub area differences
<i>Lethrinus atkinsonii</i>	Handlines	Vitogo		No sub area differences
<i>Lethrinus elongatus</i>	Handlines	Vitogo		4>10,7,6,5,2, rest =
<i>Lethrinus harak</i>	Handlines	Vitogo		No sub area differences
<i>Lethrinus nebulosus</i>	Handlines	Vitogo		4>2, 5-11; 5<2,7-9, rest =
<i>Lutjanus argentimaculatus</i>	Handlines	Vitogo		5<2,4,7-10; 2<4; rest same
<i>Lutjanus gibbus</i>	Handlines	Vitogo		9>5, rest=
<i>Lutjanus quinquelineatus</i>	Handlines	Vitogo		No sub area differences
<i>Plectropomus leopardus</i>	Handlines	Vitogo		No sub area differences
<i>Lutjanus fulviflamma</i>	Handlines	Vitogo		No sub area differences
<i>Ctenochaetus striatus</i>	Gillnets	Naweni		No sub area differences
<i>Lutjanus quinquelineatus</i>	Gillnets	Naweni		20=201T
<i>Acanthurus triostegus</i>	Spearguns	Naweni		20=201T
<i>Ctenochaetus striatus</i>	Spearguns	Naweni		20>201T
<i>Epinephelus merra</i>	Spearguns	Naweni		20=201T
<i>Acanthurus triostegus</i>	Gillnets	Naweni-Tacilevu	Naweni-Tacilevu/Verata (17 only)	(21>201T>20)=17
<i>Epinephelus merra</i>	Gillnets	Naweni-Tacilevu		20=21
<i>Lethrinus harak</i>	Gillnets	Naweni-Tacilevu		21>20=201T
<i>Lutjanus fulviflamma</i>	Gillnets	Naweni-Tacilevu		21>20
<i>Valamugil seheli</i>	Gillnets	Naweni-Tacilevu		21>201T>20
<i>Epinephelus merra</i>	Handlines	Naweni-Tacilevu		20=21=201T
<i>Lethrinus atkinsonii</i>	Handlines	Naweni-Tacilevu		21>20=201T
<i>Lethrinus harak</i>	Handlines	Naweni-Tacilevu		21>20=201T
<i>Lutjanus argentimaculatus</i>	Handlines	Naweni-Tacilevu		21>20
<i>Lutjanus gibbus</i>	Handlines	Naweni-Tacilevu		21>20
<i>Lethrinus atkinsonii</i>	Spearguns	Naweni-Tacilevu		20=21
<i>Plectropomus leopardus</i>	Spearguns	Naweni-Tacilevu		No sub area differences
<i>Lethrinus harak</i>	Gillnets	Verata		18>19>16T
<i>Lethrinus nebulosus</i>	Gillnets	Verata		18>>16T
<i>Lutjanus fulviflamma</i>	Gillnets	Verata		18>16T>19

<i>Lutjanus gibbus</i>	Gillnets	Verata	16T < 18=19
<i>Valamugil seheli</i>	Gillnets	Verata	16T > 19, both=17
<i>Lethrinus harak</i>	Handlines	Verata	18 >> 16T=17
<i>Lethrinus atkinsonii</i>	Handlines	Verata	18 >> 16T=17
<i>Lethrinus atkinsonii</i>	Spearguns	Verata	16T < 18, 17 = 16T, 18
<i>Lutjanus gibbus</i>	Spearguns	Verata	16T=18
<i>Plectropomus leopardus</i>	Spearguns	Verata	No sub area differences (incl. 16T)

Table 4.5 A summary of the results of the GT2 test and Gabrielle's approximation to test for significant differences (at the 5% level) in mean length of fish between sub-areas across sites, by species and fishing method (Refer to Annex F3 for details) (S= Semi-commercial sites, C = Commercial sites).

Species	Comparison	Gear	Across site comparison	Observations
<i>Lethrinus atkinsonii</i>	S vs S	Gillnets	Naweni/ Verata (16 only)	No sub area differences
<i>Lethrinus elongatus</i>	S vs S	Gillnets	Naweni/Verata	No sub area differences
<i>Lutjanus fulviflamma</i>	S vs S	Handlines	Naweni-Tacilevu/Verata	No sub area differences
<i>Lethrinus harak</i>	S vs S	Spearguns	Naweni-Tacilevu/Verata	21 > 18, rest =
<i>Lethrinus nebulosus</i>	S vs S	Spearguns	Naweni-Tacilevu/Verata	No sub area differences
<i>Epinephelus areolatus</i>	C vs C	Handlines	Vitogo/Tavua	Additional to in site differences, 122 > 2-10, 121; 121 > 2,7
<i>Lutjanus argentimaculatus</i>	C vs C	Handlines	Vitogo/Tavua	121 < 2,4,7-10; 122 122 > 2,5
<i>Lutjanus argentimaculatus</i>	S vs C	Gillnets	Naweni/Verata vs Vitogo/Tavua	SC (18=20) > C(5=121)
<i>Valamugil seheli</i>	S vs C	Gillnets	Naweni-Tacilevu/Verata vs Vitogo(5)/Tavua	No consistent differences between Comm / SC
<i>Lethrinus nebulosus</i>	S vs C	Gillnets	Verata vs Vitogo (5) / Tavua	SC 18 > 16 (SC) = C (5, 121, 122)
<i>Lutjanus quinquelineatus</i>	S vs C	Gillnets	Naweni/Verata vs Tavua	SC areas < commercial areas
<i>Lethrinus harak</i>	S vs C	Gillnets	Naweni-Tacilevu/Verata vs Tavua	No consistent differences between Comm / SC, 18 > most
<i>Lutjanus fulviflamma</i>	S vs C	Gillnets	Naweni-Tacilevu/Verata vs Tavua	No consistent differences between Comm / SC
<i>Lutjanus argentimaculatus</i>	S vs C	Handlines	Naweni/ (Vitogo/Tavua)	20 < 4,9; 21 > 5
<i>Lethrinus elongatus</i>	S vs C	Handlines	Tacilevu vs Vitogo/Tavua	21 (SC) < all commercial areas
<i>Epinephelus merra</i>	S vs C	Handlines	Naweni vs Vitogo	Vitogo >> Naweni
<i>Lethrinus atkinsonii</i>	S vs C	Handlines	Naweni-Tacilevu/Verata vs Vitogo/Tavua	18 > all areas; SC(16, 1720, 201T) < C(1-11 and 121, 122)
<i>Lethrinus harak</i>	S vs C	Handlines	Naweni-Tacilevu/Verata vs Vitogo/Tavua	SC areas < commercial areas except 18 and 21
<i>Lutjanus fulviflamma</i>	S vs C	Handlines	Naweni-Tacilevu/Verata vs Vitogo/Tavua	SC areas < commercial areas
<i>Lutjanus gibbus</i>	S vs C	Handlines	Naweni-Tacilevu/Verata vs Vitogo/Tavua	No consistent differences between Comm / SC, 122 > most

Correlation of mean length with fishing intensity and abundance

The mean length of fish sampled by key species and sub-area was correlated for representative fishing gears against standardised total fishing effort and standardised catch rate (Annex F4 and Tables 4.6-7). The relationship between fishing intensity and mean length

was significant in only 4 cases: *Lutjanus argentimaculatus*, *Lutjanus gibbus* and *Lutjanus quinquilineatus* caught with gillnets, and *Lutjanus fulviflamma* with handlines. Only *L. argentimaculatus* indicated a decrease in mean length with increasing fishing pressure as would be predicted (Table 4.6). The results of correlation of mean length with catch rate were similarly inconsistent with prediction, and the correlation was only significant in 7 cases (4 at the 10% level, 3 at 5%): *Lethrinus elongatus* (handlines and spear), *Lutjanus fulviflamma* (handlines), *Lutjanus gibbus* (spear), *Lethrinus nebulosus* (gill net and spear), and *Epinephelus merra* (handlines). All showed a decrease in mean length with increasing catch rate except for *L. elongatus* with spears which showed an increase in mean length as might be predicted with increasing abundance (Table 4.7). Whilst there was little or no correlation of mean length against effort or catch rate, mean length of fish from tabu areas (16 and 201) did not indicate any differences from other areas.

Summary : The majority of species and gear combinations examined revealed no significant correlation between the mean length of fish and either fishing intensity or (effort) or abundance (catch rate). Where significant correlations did occur they were inconsistent with expectation except in two cases. Factors other than fishing intensity and abundance may explain these observations, such as environmental differences by site, or different fishing practices particularly between commercial and semi-commercial sites. Mean length of fish in tabu areas did not differ from expectation.

Table 4.6 Summary table of regression analyses of mean fork length against total standardised effort. The column 'Tabu' highlights the status of tabu areas relative to others at similar levels of fishing intensity. Sig? Indicates the level of significance of the regression. N is >0.1.

Species	Within site		Accross site	Gear	Trend		Standardised effort		R ²	Sig?
							Tabu			
Lutjanus argentimaculatus	Tavua	Yes		Gill net	Decrease	n/a		0.992	0.002	
				Hand lines	Increase	n/a		0.006	N	
Lethrinus atkinsonii	Tavua	Yes		Gill net	Increase	16 low		0.492	N	
				Hand lines	Increase	201 no difference		0.052	N	
				Spear	Increase	16 low		0.623	0.06	
Lethrinus elongatus	Tavua	Yes		Gill net	Decrease	16 no difference		0.35	N	
				Hand lines	Increase	n/a		0.12	N	
				Spear	Decrease	n/a		0.553	N	
Lutjanus fulviflamma	Tavua	Yes		Gill net	Increase	16 no difference		0.135	N	
				Hand lines	Increase	16 low		0.229	0.06	
				Spear	Increase	n/a		0.747	N	
Lutjanus gibbus	Tavua	Yes		Gill net	Increase	16 as predicted		0.914	0.02	
				Hand lines	Decrease	n/a		0.008	N	

			Spear	Increase	16 no difference	0.515	N
Lethrinus harak	Tavua	Yes	Gill net		16, 201 no difference		
			Hand lines	Increase	201 no difference, 16 low	0.067	N
			Spear	Decrease	16 no difference/as expected.	0.275	N
Lethrinus nebulosus	Tavua	Yes	Gill net	Decrease	16 no difference	0.171	N
			Hand lines	Increase	n/a	0.004	N
			Spear	Decrease	16 no difference	0.077	N
Plectropomus leopardus	Tavua	Yes	Hand lines	Increase	n/a	0.004	N
			Spear	Decrease	16 low	0.001	N
Acanthurus triostegus	No	Yes	Hand lines	Increase	201 no difference	0.420	N
Ctenochaetus striatus	No	Yes	Gill net	Increase	201 low	0.350	N
Epinephelus areolatus	Tavua	Yes	Hand lines	Decrease	n/a	0.014	N
Epinephelus merra	No	Yes	Hand lines	Increase	201 no difference	0.182	N
Lutjanus quinquilineatus	Tavua	Yes	Gill net	Increase	201 no difference	0.965	0.001
			Hand lines	Increase	16 low	0.069	N
Valamugil seheli	Tavua	Yes	Gill net	Increase	201 no difference	0.147	N
			Hand lines	Increase	n/a	0.038	N

Table 4.7 Summary of regression analyses of mean fork length against standardised catch rate. The column 'Tabu' highlights the status of tabu areas relative to others at similar levels of fishing intensity. Sig? Indicates the level of significance of the regression. N is >0.1.

Species	Within site		Across site	Gear	Trend	Standardised catch
						Tabu
Lutjanus argentimaculatus	Tavua	Yes		Gill net		n/a
				Hand lines	Increase	n/a
Lethrinus atkinsonii	Tavua	Yes		Gill net	Increase	16 low
				Hand lines	Decrease	201 no difference
				Spear	Increase	16 no difference
Lethrinus elongatus	Tavua	Yes		Gill net	Decrease	16 no difference
				Hand lines	Decrease	n/a
				Spear	Increase	n/a
Lutjanus fulviflamma	Tavua	Yes		Gill net	Decrease	16 no difference
				Hand lines	Decrease	16 low
				Spear	Decrease	n/a
Lutjanus gibbus	Tavua	Yes		Gill net	Decrease	16 no difference
				Hand lines	Increase	n/a
				Spear	Decrease	16 as predicted
Lethrinus harak	Tavua	Yes		Gill net	Decrease	16, 201 no difference
				Hand lines	Decrease	201 no difference, 16 low
				Spear	Increase	16 no difference/as expected
Lethrinus nebulosus	Tavua	Yes		Gill net	Decrease	16 no difference
				Hand lines	Decrease	n/a
				Spear	Decrease	16 no difference
Plectropomus leopardus	Tavua	Yes		Hand lines	Increase	n/a
				Spear	Increase	16 low
Acanthurus triostegus	No	Yes		Hand lines	Increase	201 no difference
Ctenochaetus striatus	No	Yes		Gill net		
Epinephelus areolatus	Tavua	Yes		Hand lines	Increase	n/a
Epinephelus merra	No	Yes		Hand lines	Decrease	201 below predicted line
Lutjanus quinquilineatus	Tavua	Yes		Gill net	Decrease	201 no difference
				Hand lines		16 low
Valamugil seheli	Tavua	Yes		Gill net	Decrease	201 no difference
				Hand lines	Increase	201 no difference

4.2.2 Growth parameter estimates

Length frequency data were aggregated for all gear types and all sub-areas within sites in order to generate sufficiently large monthly data sets for estimation of growth parameters using length based methods of assessment. Only a limited number of species had sufficiently large sample size and time series of information. Growth parameter estimates are indicated in Table 4.8. No attempt was made to determine growth by sub-area or to correlate these data with fishing intensity.

Table 4.8 : Growth parameter estimates derived from length monthly frequency data by site in Fiji with the LFDA package using the ELEFAN routine.

Species	Parameter	Site				
		Naweni	Tacilevu	Tavua	Verata	Vitogo
<i>L. argentimaculatus</i>	Linf	77.08	46.62			78.9

	K	0.076	0.146			0.101
	to	-0.5	-0.21			-0.74
<i>L. atkinsonii</i>	Linf	60	54.29	63.31	57.5	48.62
	K	0.051	0.064	0.29	0.063	0.184
	to	-0.12	-0.96	-0.94	-0.61	-0.76
<i>L. elongatus</i>	Linf	55.7	52.05	83.35	45.39	88.91
	K	0.132	0.15	0.168	0.134	0.127
	to	-0.65	-0.31	-0.6	-0.81	-0.12
<i>L. fulviflamma</i>	Linf			55.18	46.84	42.49
	K			0.297	0.226	0.301
	to			-0.24	-0.92	-0.61
<i>L. gibbus</i>	Linf	36.93	45.51	53.88	55.53	
	K	0.161	0.194	0.171	0.128	
	to	-0.4	-0.97	-0.47	-0.49	
<i>L. harak</i>	Linf	52.52			37.94	54.51
	K	0.078			0.348	0.369
	to	-0.56			-0.96	-0.53
<i>L. nebulosus</i>	Linf			74.97	55.53	76.86
	K			0.261	0.128	0.165
	to			-0.84	-0.49	-0.32
<i>P. leopardus</i>	Linf			68.8	58.97	67.97
	K			0.151	0.117	0.142
	to			-0.13	-0.26	-0.72

4.2.3 Fishing mortality

Mortality estimates were derived for key study species by sub area from length converted catch curve analysis using both input growth parameter estimates from the present study, and those from the literature. Mortality by sub-area was correlated with fishing intensity (standardised effort) and an index of abundance (catch rate) (Tables 4.9 - 4.10).

Mortality was negatively correlated to catch rate for *Lethrinus harak* (with estimated growth parameters) and *Lethrinus nebulosus* (with both estimated growth parameters and those from the literature). It was positively correlated with standardised effort for *Lethrinus harak* and *Plectropomus leopardus*, but negatively correlated to effort for *Lethrinus elongatus* (with both estimated growth parameters and those from the literature in each case). With the exception of *L. elongatus* these observations were consistent with expectation. The remaining species showed considerable variation.

Sufficient data were available to estimate mortality for certain species caught in Tabu areas. Fishing mortality in area 16 was consistent with that expected for the level of effort and abundance (cpue), whilst that for 201 (*L. harak* only) was lower than expected.

Summary : Although not consistent for all species, a significant correlation existed between fishing mortality and fishing intensity and an index of abundance for some species. Limited mortality estimates existed for tabu areas, but that available for area 16 indicated that mortality was consistent with the level of fishing effort and abundance at that site, whilst that for 201 was lower than expected (one observation only).

Table 4.9 Summary of regression analyses, for total mortality estimates against standardised catch rate and total standardised effort derived using growth parameter estimates from published sources. The column 'Tabu' highlights the status of tabu areas relative to others at similar levels of fishing intensity. Sig? Indicates the level of significance of the regression. N is >0.1.

Species	Within site	Across site	Gear	Trend	Standardised catch rate		R ²	Sig?
					Tabu			
<i>Lutjanus argentimaculatus</i>	Tavua	Yes	All	Increase	na		0.020	N
<i>Lethrinus atkinsonii</i>	Tavua	Yes	All	Increase	na		0.042	N
<i>Lethrinus elongatus</i>	Tavua	Yes	All	Decrease	na		0.802	N
<i>Lutjanus fulviflamma</i>	Tavua	Yes	All	Decrease	16 as expected		0.464	N
<i>Lutjanus gibbus</i>	Tavua	Yes	All	Decrease	16 as expected		0.208	N
<i>Lethrinus harak</i>	Naweni, Tavua	Yes	All	Decrease	16 as expected, 201 below predicted line		0.055	N
<i>Lethrinus nebulosus</i>	Tavua	Yes	All	Decrease	16 on predicted line		0.494	0.04
<i>Plectropomus leopardus</i>	Tavua	Yes	All	Decrease	na		0.016	N

Species	Within site	Across site	Gear	Trend	Standardised effort		R ²	Sig?
					Tabu			
<i>Lutjanus argentimaculatus</i>	Tavua	Yes	All	Increase	na		0.055	N
<i>Lethrinus atkinsonii</i>	Tavua	Yes	All	Increase	na		0.257	N
<i>Lethrinus elongatus</i>	Tavua	Yes	All	Decrease	na		0.936	0.08

<i>Lutjanus fulviflamma</i>	Tavua	Yes	All	Increase 16 as expected		0.044	N
<i>Lutjanus gibbus</i>	Tavua	Yes	All	Increase 16 as expected		0.004	N
<i>Lethrinus harak</i>	Naweni, Tavua	Yes	All	Increase 16 on predicted line, 201 below line		0.276	0.03
<i>Lethrinus nebulosus</i>	Tavua	Yes	All	Decrease 16 as expected		0.042	N
<i>Plectropomus leopardus</i>	Tavua	Yes	All	Increase na		0.78	0.06

Table 4.10 Summary of regression analyses, for total mortality estimates against standardised catch rate and standardised effort derived using growth parameter estimates calculated from the data. The column 'Tabu' highlights the status of tabu areas relative to others at similar levels of fishing intensity. Sig? Indicates the level of significance of the regression. N is >0.1.

Species	Within site	Across site	Gear	Standardised catch rate		R ²	Sig?
				Trend	Tabu		
<i>Lutjanus argentimaculatus</i>	Tavua	Yes	All	Decrease	na	0.024	N
<i>Lethrinus atkinsonii</i>	Tavua	Yes	All	Increase	na	0.216	N
<i>Lethrinus elongatus</i>	Tavua	Yes	All	Decrease	na	0.802	N
<i>Lutjanus fulviflamma</i>	Tavua	Yes	All	Decrease	16 as expected	0.464	N
<i>Lutjanus gibbus</i>	Tavua	Yes	All	Decrease	16 high	0.233	N
<i>Lethrinus harak</i>	Naweni, Tavua	Yes	All	Decrease 201 below predicted line		0.349	0.04
<i>Lethrinus nebulosus</i>	Tavua	Yes	All	Decrease 16 as expected		0.692	0.02
<i>Plectropomus leopardus</i>	Tavua	Yes	All		na	0.415	

Species	Within site	Across site	Gear	Standardised effort		R ²	Sig?
				Trend	Tabu		
<i>Lutjanus argentimaculatus</i>	Tavua	Yes	All		na	0.001	N
<i>Lethrinus atkinsonii</i>	Tavua	Yes	All	Increase	na	0.067	N
<i>Lethrinus elongatus</i>	Tavua	Yes	All	Decrease	na	0.936	0.08

<i>Lutjanus fulviflamma</i>	Tavua	Yes	All	Increase	16 as expected
<i>Lutjanus gibbus</i>	Tavua	Yes	All		16 high
<i>Lethrinus harak</i>	Naweni, Tavua	Yes	All	Increase	201 below predicted line
<i>Lethrinus nebulosus</i>	Tavua	Yes	All	Increase	16 low
<i>Plectropomus leotards</i>	Tavua	Yes	All	Increase	na
