5 Reef fish assemblages and management interventions in Vanuatu and Fiji

5.1 Introduction

This Chapter of the report relates to multivariate analyses of data gathered during the fisheries monitoring programme. The background to this study has been outlined in Chapter 1 of this volume. The principle aim of this component of the study was to test for significant differences in species assemblages inside and outside managed areas and to attempt to explain any differences by examining correlations between sample similarities and the following abiotic factors *a priori* hypothesised to affect species assemblages:

(i) fishing intensity - can cause ecosystem overfishing
(ii) reef area - may affect ecosystem, production/unit area
(iii) Distance from landing site (reefs far from landing site may only be fished by professional/experienced fishermen with higher q's).

5.2 Materials and Methods

Sampling methodologies and available data were described in Volume 1. For the purposes of this study, it was assumed that all sites were of nominally similar habitat.

5.2.1 Vanuatu

Species assemblages inside and outside MPA's were compared using species abundance data, (aggregated to family level) in the form of CPUE for three gear types: (i) handlines, (ii) gillnets and (iii) spears sampled at 22 sites in the following islands/regions of Vanuatu: Atchin, Wala, Uripiv, Pellonk, Lelepa Island and Emua (see Volume 2, chapter 1) during 1996/1997 and 1997/98.

Non-parametric multidimensional scaling (MDS) was used to analyse the species (family) abundance data for each gear and year combination based on a strategy proposed by Clarke (1993). The approach aims to construct a map or ordination of sites (samples) such that their placement reflects the rank similarity of their species assemblages. Sites positioned in close proximity to each other in the ordination have very similar species assemblages whilst sites that are far apart share few common species or have the same species but at very different levels of abundance. A 'stress' measure indicates how well the ordination satisfies the (dis)similarities between the sites. Stress values below 0.2 indicate acceptable fits of the data.

The null hypothesis (H_0: there are no differences in species assemblages at sites inside and outside the MPA's) was tested for each gear/year combination using a non-parametric 'permutation' (analysis of similarity or ANOSIM) test based upon the difference in the average rank similarity within and between groups of replicate sites (*R* statistic). The significance level of the test is calculated by referring the observed value of the *R*-statistic to its permutation distribution generated from randomly sampled sets of permutations of the site labels. The species most responsible for statistically significant ($P < 5\%$) site groupings were then determined by computing the average contribution of each species to the overall average dissimilarity between all pairs of inter-group sites using the ‘indicator species analysis’ (SIMPER) approach (Clarke & Warwick, 1994).

In addition to the simple in/out comparisons, correlations between the assemblage similarities summarised in the ordinations for each gear/year combination, and univariate (abiotic) factors (fishing intensity, reef area, and distance of reef from the main landing site) *a priori* hypothesised to affect the species assemblages, were examined in two ways. Firstly by simply superimposing symbols (circles) onto the species (biotic) ordinations of the corresponding samples with diameters proportional to the value of each factor and then visually examining the ordinations for any consistent differences in the abiotic factor between biotic clusters or a smooth relationship with ordination gradients (Clarke & Warwick, 1994). Correlations were then tested more formally using the BIONENV procedure (Clarke & Warwick, 1994) which selects a subset of the abiotic variables which maximises the weighted Spearmen rank correlation coefficient between the biotic and abiotic sample (dis)similarity matrices.

All the MDS and ANOSIM analyses were performed with the PRIMER (Plymouth Routines in Multivariate Ecological Research) software (Clarke & Warwick, 1994) on 4th root transformed data and employing the Bray-Curtis (Bray & Curtis, 1957) similarity coefficient as the measure of similarity between pairs of sites. For the BIOENV procedure, all abiotic factors were found to be log-normally distributed and therefore a $\log_{10}$ transformation was applied before calculating sample dissimilarities using Euclidean distance.

5.2.2 Fiji

For Fiji, in addition to management interventions there was also the division of sites between commercial and semi-commercial activities. The following 5 additional hypotheses were tested.

Hypothesis 1: Species assemblages caught(sampled) from handlines between Nov 97- April 98 at commercial fishing sites (2,5,7,8,9,12) are not correlated with fishing intensity (all gears), numbers of fishing licenses or access fees at the sites.

Hypothesis 2: Family assemblages caught by all gear types between April - July 97 at subsistence fishing sites (16, 18, 20, 21 201) are not significantly different inside and outside the MPA (site 201), and not correlated with fishing intensity (all gears).

Hypothesis 3: Family assemblages caught by handlines, gillnets and spears in both 1996/7 and 1997/98 are not significantly different at subsistence fishing sites (16,17,18,20,21).

Hypothesis 4: Family assemblages caught by handlines and gillnets in open access subsistence fishing sites (20, 21) in June 1998 are not significantly different from assemblages caught within the MPA (201) with the same gears in July 1998.

Hypothesis 5: Family assemblages caught by handlines between Nov 97 and April 98 are not significantly different at commercial (2,5,7,8,9,12) and subsistence (16,17,18,20,21) fishing sites.

5.3 Results

5.3.1 Vanuatu

Differences in species assemblages sampled from inside and outside the MPA's were tested separately for each gear/year combination. Species assemblages sampled from gillnets in 1997/98 were found to be significantly different (*P* = 3.5 %) inside and outside the MPA's (Table 5.1), although the low value of the *R*-statistic and the large spread of sites (samples) within the ordination suggests considerable assemblage variation within the two groups of sites. Although the remaining comparisons were statistically testable at the 5 % level, none suggested that species assemblages were significantly different inside and outside the MPA's (Table 5.I).

The results of the indicator species analysis (SIMPER) revealed that differences between the species assemblages inside and outside the MPA sampled from gillnets in 1997/98 was due largely to greater average abundance of the following species (families): Siganidae, Scaridae, Lutjanidae, Scads, Mullidae, Lethrinidae, Carangidae, Scombridae,Belonidae, Sphyraenidae and Gerreidae, and a lower average abundance of Mugilidae, Acanthuridae, Kyphosidae, Balistidae and Holocentridae inside the MPA's compared to outside (Figure 5.1).

Table 5.I Summary of the results of the one-way ANOSIM test for differences in species assemblages sampled from sites inside and outside MPA's in Vanuatu for each gear and year combination; significant statistics - permutated *R* values exceeding observed *R* statistic; significance level- percentage of permutated *R* values exceeding observed *R* statistic.

H_0: There are no significant differences in species assemblages inside and outside MPA's for the same gear and year combination

Gear	Year	*R* statistic	Permutations	Significant statistics	Significance level (*P*)	H_0:	Maximum attainable significance level
Handline	1996/97	0.22	231	29	12.6 %	Accept	<0.01 %
	1997/98	-0.11	1540	1005	65.3 %	Accept	<0.01 %
Gillnet	1996/97	-0.40	20	19	95.0 %	Accept	5 %
	1997/98	0.34	1330	47	3.5 %	Reject	<0.01 %
Spear	1996/97	0.04	171	73	42.7 %	Accept	<0.01 %
	1997/98	0.06	210	72	34.3 %	Accept	<0.01 %

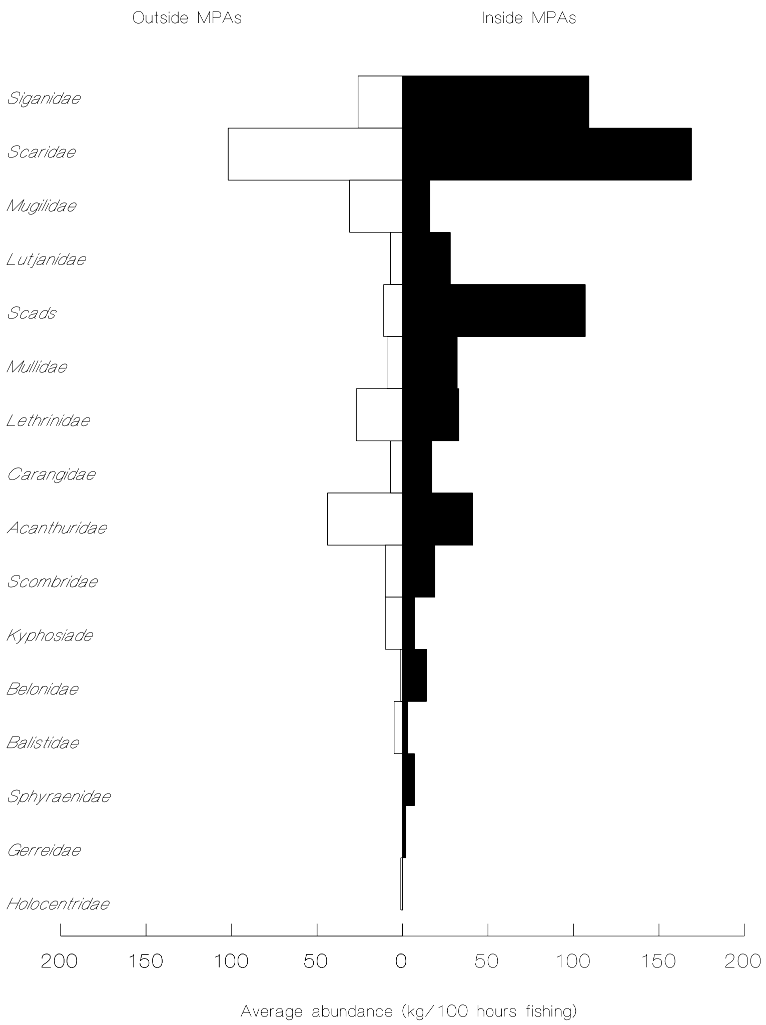

Figure 5.1Average abundance [gillnet catch per unit effort (kg 100 h^{-1})] of species (families) sampled from inside (solid bars) and outside (open bars) MPA's in Vanuatu. Species are arranged from top to bottom in descending order of their contribution to the average dissimilarity between the two groups of sites. Only those species contributing to 90% of the cumulative average dissimilarity are shown.

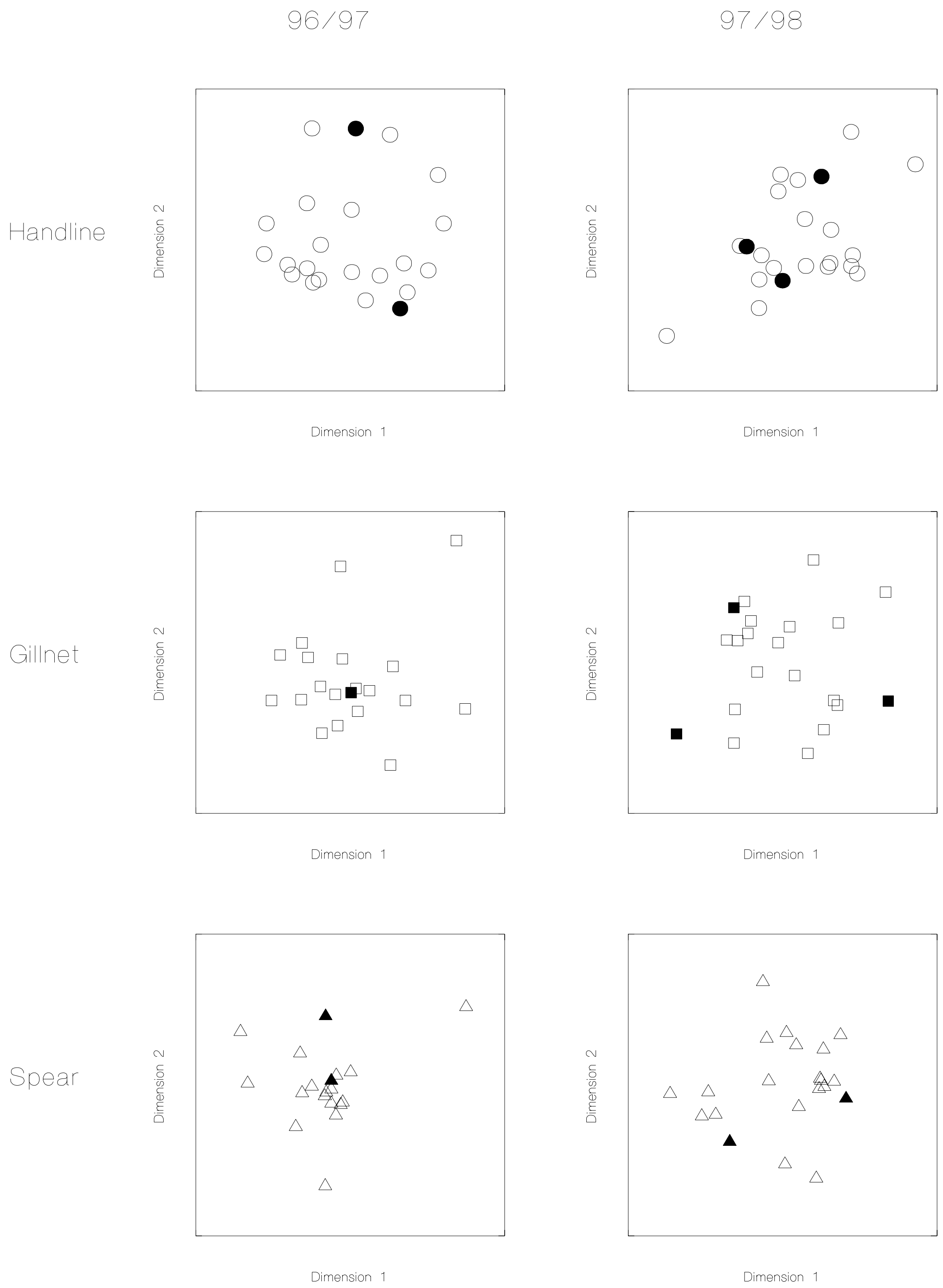

Figure 5.2 MDS ordinations comparing species assemblages inside and outside MPA's in Vanuatu for each gear/year comination. ○ - handline; □ - gillnets; △ - Spears. Solid and open symbols denote inside and outside the MPA's respectively. Stress values for each ordination from left to right and top to bottom; 0.15,

0.14, 0.14, 0.14, 0.11, 0.12.

Visual examination of the ordinations revealed little evidence of any significant or consistent relationships between any of the three environmental factors and the biotic ordinations for the six gear/year combinations (Figures A1a-A1f). The results of the BIOENV procedure (Table II) for which rank correlations ranged from just -0.21 to 0.20, confirmed the absence of any significant correspondence between the assemblage (dis)similarities and the environmental factors. Of the three environmental factors considered, assemblage (dis)similarities were correlated most strongly with reef area (0.13-0.20).

The environmental variables were strongly inter-correlated. Standard Pearson correlations between fishing intensity was strongly negatively correlated with reef area, with values of *r* ranging between -0.73 and -0.80. Fishing intensity was also found to be strongly negatively correlated with the distance of the reef from the main landing site (*r* = -0.46 to -0.75). Reef area and distance were found to be positively correlated with values for *r* ranging between 0.49 and 0.72. Given this mullticollinearity, correlations between the assemblage similarities and combinations of environmental variables should be treated with caution.

Table 5.2 Weighted Spearman rank correlation coefficients (ρ_ω) between assemblage similarity and environmental variables (fishing intensity, reef area and distance of reef from main landing site) sampled from the Vanuatu study sites for each gear/year combination.

Gear	Year	Fishing Intensity	Area	Distance from Landing Site	Best Combination (ρ_ω)
Handline	1996/97	0.09	0.13	0.07	Area (0.13)
	1997/98	0.19	0.20	0.11	Fishing Intensity, Area, Distance (0.28)
Gillnet	1996/97	0.09	-0.02	0.02	Fishing Intensity (0.09)
	1997/98	-0.21	-0.14	-0.14	Distance (-0.14)
Spear	1996/97	0.10	0.01	-0.10	Fishing Intensity (0.10)
	1997/98	-0.13	-0.15	-0.05	Distance (-0.05)

5.3.2 Fiji

No evidence, either formal (Table 5.3) or informal was found to suggest that the differences in species assemblages sampled from sites in Fiji correlated either with fishing intensity or reef area.

Table 5.3 Weighted Spearman rank correlation coefficients (ρ_ω) between the assemblage similarities and environmental variables (fishing intensity and reef area) sampled from the Fijian study sites between Nov XX and July XX.

Gear	Year	Fishing Intensity	Area	Best Combination (ρ_ω)
Handline	1996/97???	-0.01	-0.33	Fishing Intensity (-0.01)

Hypothesis 1: The pattern of species assemblages among the commercial fishing sites (Figure 5.3), was uncorrelated (r = -0.03) with fishing intensity (Figure 5.1, Table 5.4), weakly correlated (r = 0.24) with the numbers of fishing licenses issued at each site (Figure 5.1, Table 5. 4) and moderately correlated (r = 0.46) with access fee (Figure 5.1, Table 5.4).

Hypothesis 2: The pattern of family assemblages among the subsistence fishing sites (Figure 5.4), was not significantly different inside and outside the MPA (Table 5.5) and uncorrelated (r = -0.35) with fishing intensity (Figure 5.4, Table 5.6).

Hypothesis 3: This hypothesis could not be tested with the ANOSIM permutation test because of the absence of replicates at any of the sites. However, visual examination of the ordinations (Figure 5.5) reveals some evidence that two groups of sites (Group 1: 16, 17 & 18; Group 2: 20 & 21) may have similar family assemblages. No ordinations could be produced for handline and gillnet data because only three sites were available for analysis. The MDS procedure requires at least 4 data points to construct an ordination.

Hypothesis 4: This hypothesis could not be examined using either MDS or ANOSIM because only three sites were available for analysis (see above).

Hypothesis 5: Family assemblages caught by handlines at commercial and subsistence fishing sites were significantly (P = 0.001) different (Figure 5.5, Table 5.4). These differences were due to greater abundances (catch rates) of Sphyraenidae, Scrombridae, Carangidae, Belonidae, Epinephelinidae and Lutjanidae at the commercial fishing sites, and greater abundances (catch rates) of Scaridae, Nemipteridae, Tetraodontidae, Mullidae, Lethrinidae, Etilidae and Labridae at the subsistence fishing sites (Table 5.5).

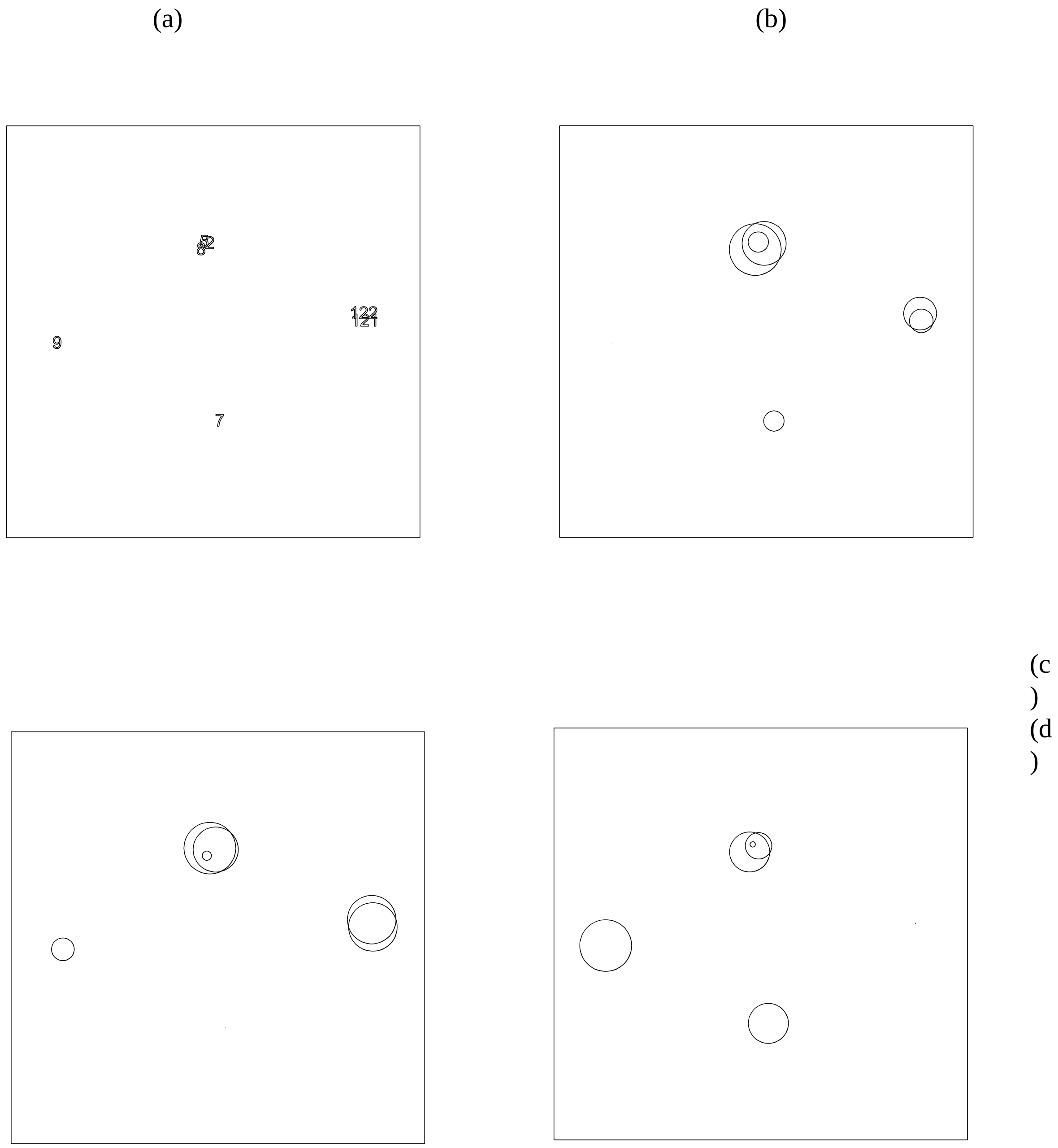

Figure 5.3 a) MDS ordination of species abundance data from handlines sampled from the Fijian commercial fishing sites (Stress = 0.02). (b)-(d) the same ordination but with superimposed circles with diameters proportional to log transformed fishing intensity (h km^{-2}), numbers of licences and access fee (\$ y^{-1}), respectively.

Table 5.4. Results of BIOENV procedure to examine the correlation between the species assemblage pattern among the commercial fishing sites in Fiji caught using handlines and explanatory variables, fishing intensity (FI), numbers of licences and access fee.

n	r	FI	LICENCES	FEE
1	0.456			3
1	0.240		2	
1	-0.033	1		
2	0.431		2	3
2	0.317	1		3
2	0.111	1	2	
3	0.235	1	2	3

MAXIMUM CORRELATION:

1	0.456			3

a) b)

Figure 5.4. a) MDS ordination of family abundance data from all gears sampled from subsistence fishers inside and outside the MPA at the Fijian study location (Stress = 0.01). (b) the same ordination but with superimposed circles with diameters proportional to log transformed fishing intensity (h km^{-2}).

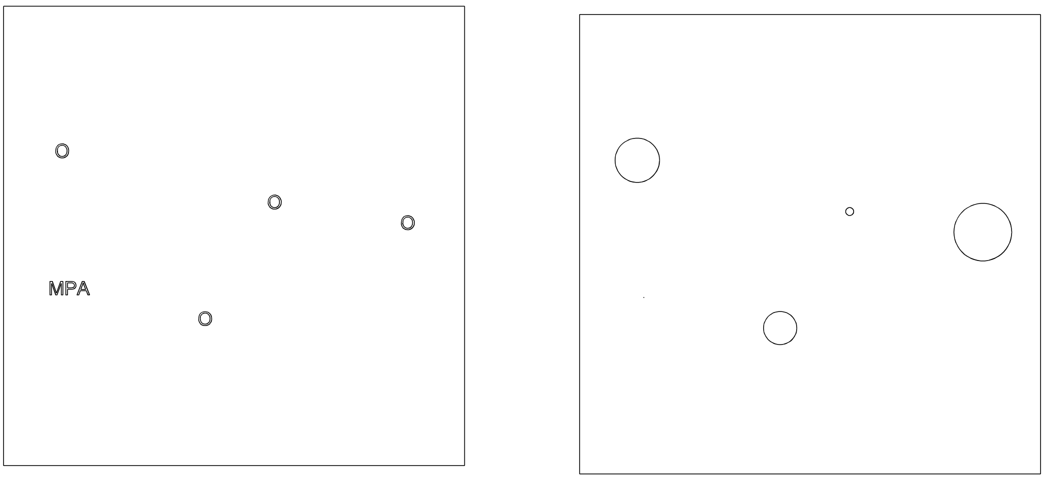

Table 5.5 Results of ANOSIM to test for significantly different family assemblages inside and outside the MPA:

```
                    ONE-WAY ANOSIM
                    ================

Date: 11/ 5/1999
Similarity matrix: E:\XCT\ASH\FIJI\FIJIXTRA\CPUE2.SIM

 Group | Size | Samples
-------+------+------------------------------
   1 |   4  | 1-4
   2 |   1  | 5

Number of samples used:   5 from a possible   5



GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): -0.333

Number of permutations:     5  (ALL POSSIBLE PERMUTATIONS)
Number of permuted statistics greater than or equal to global R:     5

Significance level of sample statistic: 100.0%

Therefore DO NOT reject the null hypothesis.
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Table 5.6 Results of BIOENV procedure to examine the correlation between the family assemblage data pattern among the subsistence fishing sites and fishing intensity (FI) in Fiji.

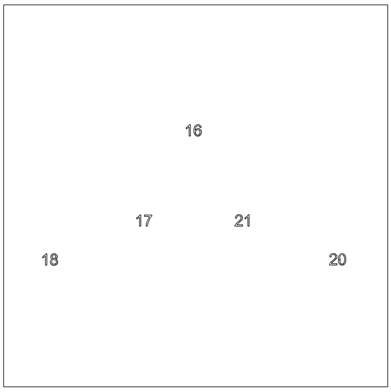
```
          +--+--+
          |     |
          |     |
          |     |
          |    D|
          |    U|
          |    M|
+--+------+ F  M|
| n|   r  | I  Y|
+--+------+--+--+
| 1| 0.324|    2|
| 1|-0.348| 1   |
+--+------+--+--+
| 2|-0.115| 1  2|
+--+------+--+--+

MAXIMUM CORRELATION:
+--+------+--+--+
| 1| 0.324|    2|
+--+------+--+--+
```

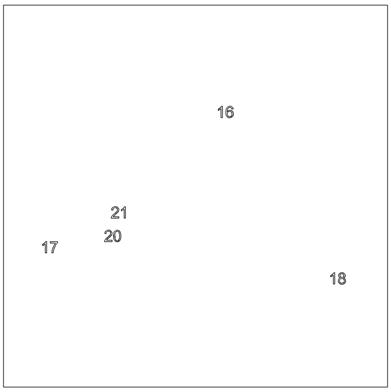
96/97 **9**

7/98

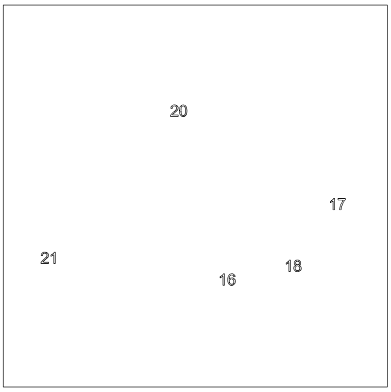
Handline Insufficient data



Gillnet Insufficient data



Spear



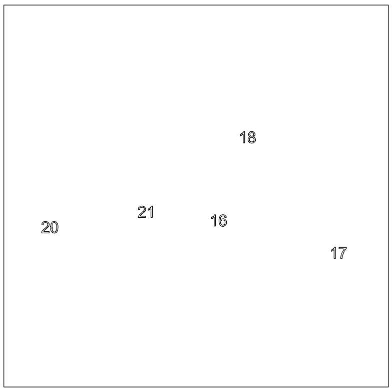


Figure 5.5 MDS ordinations of family abundance data for gear and year combinations sampled from subsistence fishers at sites at the Fijian study location. Stress from left to right and top to bottom: 0.01, <0.01, <0.01, <0.01.

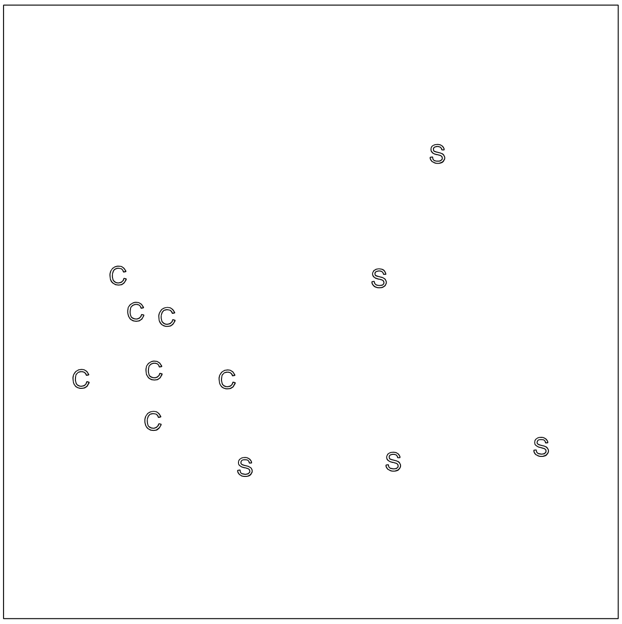


Figure 5.6 MDS ordination of family abundance data sampled from handlines at commercial (C) and subsistence (S) fishing sites between November 1997 and April 1998 at the Fijian study location (See Volume 2b - Fiji Country Report, Page 88). Stress = 0.09.

Table 5.7 Results of ANOSIM to test for significantly different family assemblages sampled from handlines at commercial (Group 1) and Subsistence (Group 2) fishing sites in Fiji.

```
Similarity matrix: E:\XCT\ASH\FIJI\FIJIXTRA\CPUE5H97.SIM

 Group | Size | Samples
-------+------+------------------------------
    1  |   7  | 1-5,11-12
    2  |   5  | 6-10

Number of samples used:  12 from a possible  12

GLOBAL TEST
~~~~~~~~~~~
```

```
Sample statistic (Global R):  0.740

Number of permutations:   792  (ALL POSSIBLE PERMUTATIONS)
Number of permuted statistics greater than or equal to global R:     1

Significance level of sample statistic:   0.1%
```

Table 5.8 Average family abundance at the commercial and subsistence fishing sites responsible for the assemblage dissimilarity between the two groups of sites.

```
            SIMILARITY PERCENTAGES (SIMPER)
            ===============================


CPUE5H97

NUMBER OF SPECIES (ROWS) IN DATA SET =  23
NUMBER OF COLUMNS IN DATA SET        =  12


SPECIES NAME FILE : E:\XCT\ASH\FIJI\FIJIXTRA\SPPCONV.TXT



GROUP   SIZE   COLUMN NUMBERS
-----   ----   --------------
   1      7    1-5, 11-12        COMMERCIAL

   2      5    6-10              SUBSISTENCE


DOUBLE SQUARE-ROOT TRANSFORMATION
BRAY-CURTIS SIMILARITY


AVERAGE DISSIMILARITY BETWEEN GROUPS  2 &  1 =  47.40
```

SPECIES	NO	GROUP 2 AV ABUN	GROUP 1 AV ABUN	AV TERM	RATIO	PERCENT	CUM %
3=Sphyraen	3	.00	.24	6.51	3.37	13.73	13.73
6=Scombrid	6	.00	.04	3.41	1.48	7.19	20.92
13=Scarida	13	.02	.00	2.76	1.58	5.83	26.75
22=Nemipte	22	.01	.00	2.57	1.89	5.42	32.17
5=Carangid	5	.06	.11	2.54	1.14	5.35	37.52
8=Belonida	8	.00	.02	2.51	1.26	5.30	42.82
21=Tetraod	21	.01	.00	2.43	1.75	5.13	47.95
9=Mullidae	9	.04	.00	2.25	1.20	4.75	52.70
4=Epinephe	4	.14	.28	2.24	1.14	4.72	57.42
1=Lethrini	1	1.07	.60	2.15	1.16	4.53	61.95
7=Etilidae	7	.02	.01	2.07	1.05	4.37	66.32
12=Labrida	12	.02	.00	1.83	.89	3.85	70.17
2=Lutjanid	2	.14	.27	1.76	1.84	3.71	73.88
11=Haemuli	11	.00	.01	1.74	.82	3.68	77.55
14=Gerreid	14	.02	.00	1.71	.72	3.61	81.16
20=Balisti	20	.01	.00	1.63	1.26	3.45	84.61
16=Therapo	16	.00	.00	1.32	.81	2.79	87.39
15=Acanthu	15	.01	.00	1.20	.79	2.54	89.93
10=Siganid	10	.00	.01	1.11	.61	2.34	92.27
17=Kyphosi	17	.01	.00	1.01	.60	2.13	94.40
23=Megalop	23	.00	.00	.99	.81	2.09	96.49
18=Chanida	18	.00	.00	.89	.57	1.88	98.37

5.3.3 Discussion

Species assemblages were not different in closed and open areas of Fiji and Vanuatu from UVC or fisheries data from MDS analysis except for gill net caught fish in 1998 in Vanuatu. Assemblages at closed areas in Uripiv and Emua differed the most from open access areas whilst those at Lelepa were most similar. Species assemblages at commercial Fiji sites were weakly correlated to number and cost of licences. Although significant differences in species assemblages were detected inside and outside the MPA's in Vanuatu, this is unlikely to be attributable to ecosystem fishing or the fishing down effect since no significant ($P = 0.84$) differences in fishing intensity were detected between the two groups of sites overall. Such differences as occurred could be attributed to other factors such as habitat (Vanuatu), inshore or offshore reefs (Fiji), or level of commercialisation (Fiji). Similarly, no differences in reef area or distance from landing site were detected suggesting that some unmeasured variation in biotic or abiotic factors were responsible for the observed differences.