Reef fish of the Sugar Loaf Islands (Ngā Motu) Marine Protected Area, New Zealand

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ABSTRACT

Sugar Loaf Islands (Ngā Motu) Marine Protected Area (SLIMPA) is situated off the west coast of the North Island, New Zealand. It is not a marine reserve, but fishing restrictions there create a conservation area and a partially protected area. In the conservation area, a circular area 500 m radius, all fishing is prohibited except for trolling and spearfishing for kingfish (*Seriola lalandi*) and kahawai (*Arripis trutta*). Within the remaining area, all commercial fishing (except trolling for kingfish and kahawai), recreational set netting, and longlining are prohibited. During 2001–03, reef fish species were surveyed by underwater visual census inside SLIMPA and at adjacent, similar reference sites. More reef fish, and a greater diversity of reef fishes, were found inside SLIMPA than at the reference sites. The greater abundance and variety of species that are not targeted either by commercial or recreational fishers inside SLIMPA indicates that habitat complexity rather than the fisheries restrictions is probably responsible for this difference. Species with small home ranges such as blue cod (*Parapercis colias*) were more abundant in the no-take conservation area than in either the partially protected sites in SLIMPA or the no-protection sites outside SLIMPA. We conclude that the fishing restrictions within the small conservation area may provide a degree of protection for these obligate reef dwellers, but that this is not so in the rest of SLIMPA which has only partial protection.

Key words: reef fish monitoring, species protection, underwater visual census, blue cod, reef fish communities, biodiversity, natural character, Sugar Loaf Islands (Ngā Motu) Marine Protected Area, New Zealand.

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1. Introduction

Sugar Loaf Islands (Ngā Motu) Marine Protected Area (SLIMPA) is located between the Port Taranaki breakwater and Herekawa Stream, Back Beach, New Plymouth, off the west coast of North Island, New Zealand. The offshore islands provide a unique partially sheltered environment along a coastline that is generally very exposed. The subtidal marine habitats include caves, rock faces with crevices and overhangs, large pinnacles, boulder fields, and extensive areas of soft sediments. The area is influenced by the northeasterly-flowing Tasman Current, and seasonally by the southeast flow of the West Auckland Current.

SLIMPA covers 749 ha of seabed, foreshore and water around the Sugar Loaf Islands (Ngā Motu). It is not a marine reserve. Regulations under the Fisheries Act 1983 controlling commercial and recreational fishing in the area were gazetted in 1986. Further protection for the area from risks of oil prospecting and development was established with the passing of the Sugar Loaf Islands Marine Protected Area Act (SLIMPA Act) in 1991.

The SLIMPA Act protects the islands, seabed, foreshore, and water around the Sugar Loaf Islands (Ngā Motu). The conservation management plan prepared for the marine protected area notes that it was established in order to preserve and protect the natural character of the seabed and foreshore within SLIMPA, and ensure the diversity of seabed and foreshore habitats is not reduced (Fechney 1997). It was hoped that research and survey carried out within SLIMPA would contribute to a better understanding of the functioning of the habitats, species, and ecosystems there (Fechney 1997).

SLIMPA comprises two fisheries management zones (Fig. 1). The fisheries conservation area is a circular area with a 500 m radius around Waikaranga/Seal Rocks. In the conservation area all fishing is prohibited except for trolling and spear fishing for kingfish and kahawai. In the remaining area, commercial fishing (except trolling for kingfish and kahawai) and recreational set netting and longlining are prohibited. Recreational fishing, diving and potting for rock lobster are common activities in this area. Spoil dumping and activities that may disturb the foreshore and seabead, including anchoring by commercial vessels, mining and drilling, are prohibited throughout SLIMPA.

A total of 88 species of fish has been recorded from SLIMPA, of which about 52 are reef fishes (Hardy 1985; New Plymouth Underwater Club 1989; Fechney 1997; Duffy et al. 2000). Most of these are common, widespread coastal species, although there is a small subtropial component represented by species such as silver drummer, blue maomao, demoiselles and magpie morwong (refer to Appendix 2 for scientific names of species referred to in this report). Over half (58%) of the reef fishes are small cryptic or nocturnal species (Hardy 1985; New Plymouth Underwater Club 1989; Duffy et al. 2003). Density and diversity of the larger reef fishes is relatively low. The most common species being sweep, scarlet wrasse, demoiselles, butterfly perch, spotty, snapper, blue cod, red moki, marblefish and banded wrasse (Duffy et al. 2003). Of these snapper and blue cod are popular recreational species.

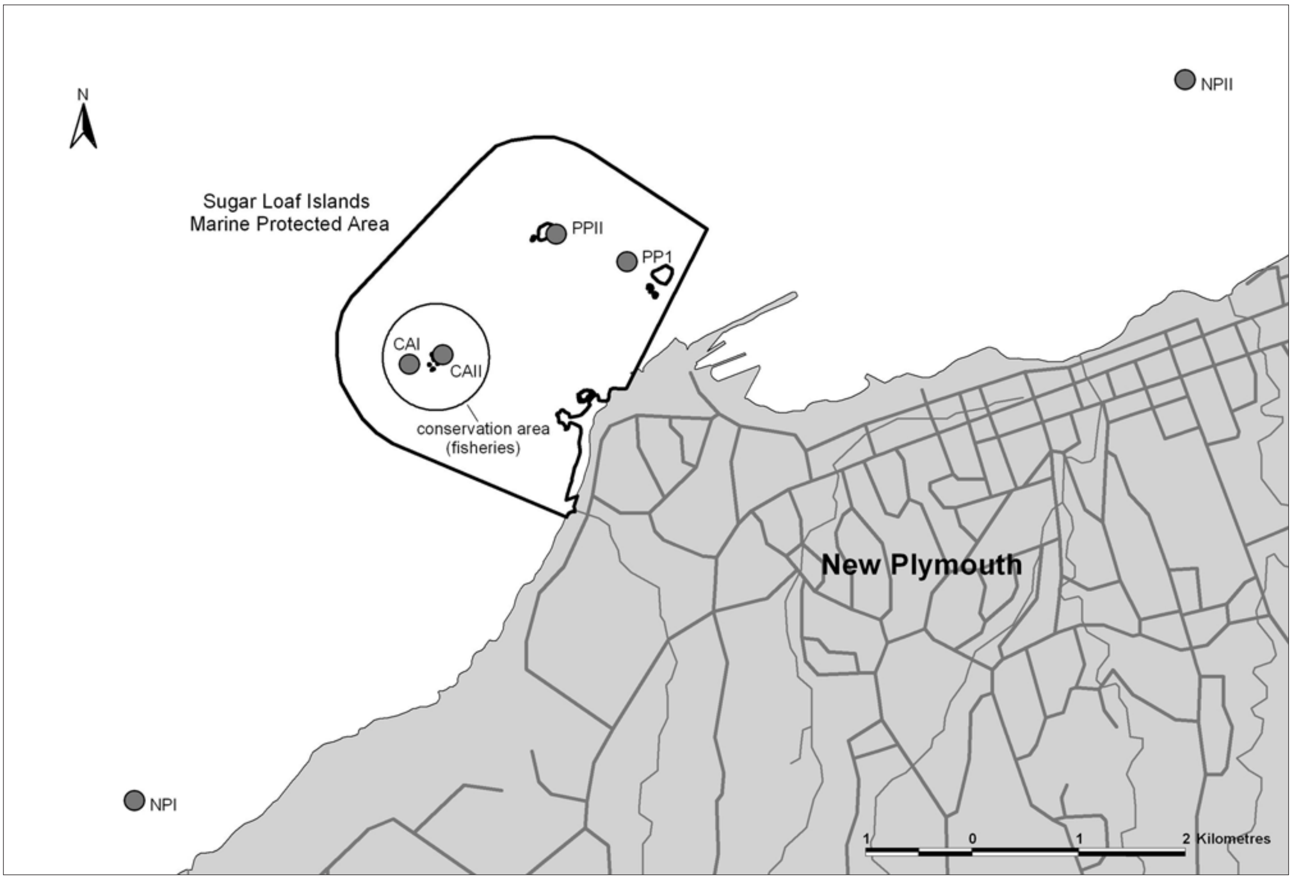


Figure 1. Samping sites from: conservation areas CAI (Post Office) and CAII (Seal Rock, Snapper Bay); the partially protected areas PPI (Bills Rock) and PPII (Saddleback); and the reference sites from the no-protection areas NPI (Tapuae reef) and NPII (Waiwhakaiho reef).

The objective of monitoring at SLIMPA is to detect long-term trends over time at specific sites within the different management zones. The monitoring programme was not designed to test differences between management zones. The reef fish monitoring is part of a larger programme that also includes monitoring of benthic invertebrate and algal communities and rock lobster populations.

This report presents the results of reef fish monitoring for 2001, 2002, and 2003.

2. Methods

2.1 STUDY SITES

Two sampling sites were selected for the monitoring programme from each management type (Table 1): within the conservation area (CAI and CAII), from the partially protected SLIMPA area (PPI and PPII), and two reference sites outside SLIMPA with no protection (NPI and NPII) (Table 1, Fig. 1). Sites within

SLIMPA were selected on the basis that they contained habitats typical of the protected area. The reference sites were selected so that they contained, as far as possible, reef habitats similar to those found within SLIMPA; these two sites, which are a short distance from SLIMPA (Fig. 1), are exploited by commercial and recreational fishers.

2.2 DATA GATHERING

Reef fish densities were estimated using the underwater visual census methodology (Kingsford & Battershill 1998; Willis 2000; Denny et al 2003). All divers were trained in species identification and size estimation. Three divers were simultaneously deployed at each site and counted reef fishes along 25 m transects, each haphazardly located at least 5–10 m from the previous transect. Fish were counted as the diver unwound the tape. To avoid counting diver-positive fish, each diver swam the first 5 m of the tape before commencing counts. The diver counted fish observed within a strip estimated 2.5 m either side of the centre of the dive path. Fish following or overtaking the diver were not counted. A constant speed was maintained throughout the count, and the diver did not stop to search beneath overhangs or in caves. Counts and size estimates were recorded on a pre-printed datasheet as the diver swam along the transect (Appendix I and Table 2). Species noted when the diver was recovering the tape were also recorded on the datasheet, but have not been included in the analysis.

Counts were not conducted when the underwater visibility (assessed using a Secchi disk) was less than 4 m. Sites being used by other diving parties were

TABLE 1. SITE DESCRIPTIONS FOR MONITORING SITES FOR REEF FISH SPECIES, SUGAR LOAF ISLANDS MARINE PROTECTED AREA.

MANAGEMENT ZONE	SITE	CODE	HABITAT DESCRIPTION
Conservation area	Post Office	CAI	Reef top at 6 m depth covered with *Carpophyllum maschalocarpum*. Surrounding seabed is a mixture of lava reef and broken rock to the north and a lava base covered in part by large boulders, cobbles, shell fragments and sand.
Conservation area	Snapper Bay	CAII	Seabed is lava with a cover of large bare rocks and boulders at 6–15 m depth and *Ecklonia radiata* forest below 15 m. Study area is surrounded by rock walls, whose intertidal portion is covered with *C. maschalocarpum*.
Partial protection	Bills Rock	PPI	An isolated volcanic reef surrounded by sand/mud. The western face of the reef slopes down to the seabed and has a 70% cover of *E. radiata*, while the eastern face is a drop of 7.5 m; at northern end, this drop is a small cave with a mud bottom.
Partial protection	Saddleback	PPII	Exposed to westerly swells. It consists of a boulder bank, which runs north–south with the slope east at 16 m depth and west at 8 m depth (closest to the island). There are clumps of *E. radiata* at the base of the boulder bank.
No protection (outside SLIMPA)	Tapuae	NPI	Low volcanic reef rising to 1 m above the surrounding sea floor. Overhangs, large boulders up to 1 m diameter, small boulders, pebbles, sand and shell fragments. High percentage cover of silt over parts of the reef. Small clusters of *E. radiata*. Sponges abundant.
No protection (outside SLIMPA)	Waiwhakaiho	NPII	A large flat volcanic reef with an overhang approx. 1.5 m high, which generally runs east–west and is in the form of a horseshoe. At its base is a mud pebble bottom.

TABLE 2. SIZE INTERVALS (TOTAL LENGTH) RECORDED FOR FIVE FISH SPECIES.

BLUE COD	BLUE MOKI	MARBLEFISH	RED MOKI	SNAPPER
< 150 mm	< 200 mm	< 300 mm	< 200 mm	< 100 mm
150–400 mm	200–400 mm	> 300 mm	200–400 mm	100–400 mm
> 400 mm	> 400 mm		> 400 mm	> 400 mm

avoided in order to ensure the counts were not confounded by the activities of other divers.

About 20 transects were sampled per site, a number designed to reduce the variability of the reef fish counts and maximise the statistical power to detect change at a site over time (Duffy et al. 2003).

All sampling was carried out between 1 December and 1 April. The actual timing of sampling was determined by weather and sea conditions.

2.3 DATA MANAGEMENT AND STATISTICAL ANALYSIS

The original datasheets are stored in the New Plymouth Area Office of the Department of Conservation (DOC). Data were entered into Microsoft Excel workbooks and stored on DOC's electronic document manager system, as well as on CD. The latter are held in the New Plymouth Area Office.

Triplefins (Trypterygiidae) and blennies (Blennidae) were not identified to species and have been excluded from the analysis. Slender roughy, and scorpion fish were also excluded from the analysis because the visual census methodology used is inappropriate for sampling these cryptic species.

Average number of species (± 1 standard error of the mean (SEM)) was used as a simple index of species richness. The total number of epibenthic fish (obligate reef dwellers) was used as an index of overall reef fish abundance. For a range of species (including but not limited to those expected to respond to management differences), the average number of fish per transect was used to assess temporal trends in abundance.

Anderson's (2003) Canonical Analysis of Principal co-ordinates (CAP) a constrained ordination technique, was used to examine patterns in reef fish community structure. This program first examines patterns inherent in the data through an unconstrained ordination, namely Principal Coordinate Analysis (PCA). It then undertakes a Canonical Discriminant Analysis on the resulting PCA axes to produce a constrained ordination. Unconstrained ordination allows broad patterns to be observed, whereas constrained ordination uses an *a priori* hypothesis to produce the plot and maximise group separation. In examining these data, our hypothesis was that there would be no significant difference in multivariate location among the management regime groups (CA, PP, and NP) (Anderson & Willis 2003).

For this analysis, the data for each year were ln(x + 1) transformed to remove large differences in scale of the fish abundances (Anderson & Willis 2003). A Bray–Curtis dissimilarity matrix was then calculated. For each year, over 80% of the variation was explained in the first five PCA axes, and so $m = 5$ was used as the basis of the analysis (Anderson & Willis 2003). The plots of the first two canonical axes for each year were then examined for differences between groups, and for correlations of species with the axes to assess which species were responsible for any grouping observed.

An estimate of how distinct the groups were was made by using the 'leave-one-out' approach to establish the misclassification error, i.e. a goodness-of-fit test to see how 'accurate' the grouping of the transect data was, derived from the classification, compared with the original grouping of the data (by management zone) (Anderson & Willis 2003).

Data gathered through underwater visual census are counts and therefore do not generally satisfy the assumptions of normality and homogeneity of variance that are required by tests of significance such as ANOVA (Willis et al. 2000). Data on reef fish abundance, species richness and abundance of specific species was tested for normality and homogeneity of variance. The data was then transformed (ln(x + 1)). The transformed data was analysed using ANCOVA (analysis of co-variance) (S-Plus 6.1 2002) treating time as a continuous variable and site as a fixed factor.

3. Results

The number of transects conducted at each site is given in Table 3.

3.1 SPECIES RICHNESS

Eighteen species of reef fish were used in the analysis (Table 4). Thirteen were defined as epibenthic (spotty, banded wrasse, scarlet wrasse, red moki, blue moki, blue cod, marble fish, snapper, tarakihi, rock cod, leather jacket, eagle ray, goatfish) and five as planktovorous (sweep, butterfly perch, demoiselle, kahawai, and jack mackerel).

TABLE 3. NUMBER OF REPLICATE REEF FISH TRANSECTS COMPLETED AT EACH SITE.

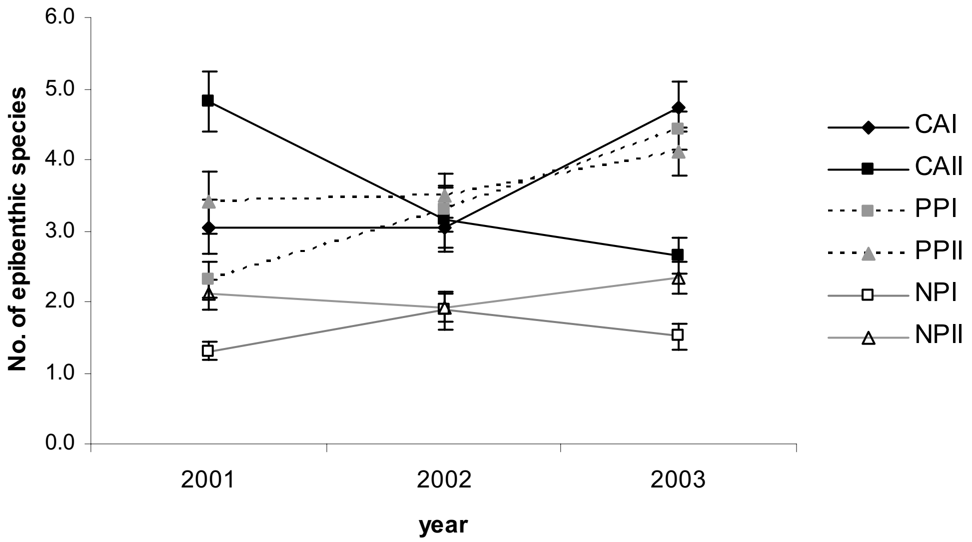
SITE	MANAGEMENT ZONE	CODE	2001	2002	2003
Post Office	Conservation area	CAI	20	21	23
Snapper Bay	Conservation area	CAII	21	18	28
Bills Rock	Partial protection	PPI	22	24	24
Saddleback	Partial protection	PPII	20	27	24
Tapuae	Reference site	NPI	26	24	31
Waiwhakaiho	Reference site	NPII	20	24	24

TABLE 4. FREQUENCY OF OCCURRENCE (%) OF FISH SPECIES, I.E. PERCENTAGE OF TRANSECTS ON WHICH FISH SPECIES WERE OBSERVED. FOR NUMBER OF TRANSECTS, SEE TABLE 3.

SPECIES	YEAR	SITE					
		CAI	CAII	PPI	PPII	NPI	NPII
Epibenthic species							
spotty	2001	5	52	55	15	15	0
	2002	5	17	38	7	8	8
	2003	22	7	33	8	3	0
banded wrasse	2001	10	67	9	35	0	0
	2002	10	33	17	26	25	13
	2003	61	25	13	29	6	88
scarlet wrasse	2001	95	100	86	100	81	95
	2002	95	94	88	100	67	79
	2003	96	100	100	100	74	8
red moki	2001	60	24	45	30	35	5
	2002	38	28	54	30	42	8
	2003	52	29	79	88	26	42
blue moki	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	8	0	0	0
blue cod	2001	40	48	0	35	0	5
	2002	43	33	4	4	8	25
	2003	74	36	46	8	19	25
marblefish	2001	15	14	5	15	0	0
	2002	14	6	13	26	0	4
	2003	26	18	33	54	0	0
snapper	2001	0	38	0	0	0	5
	2002	10	17	0	4	0	0
	2003	26	11	0	0	0	0
tarakihi	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	9	0	0	17	0	0
rock cod	2001	0	0	0	0	0	0
	2002	0	0	4	7	0	0
	2003	0	0	0	4	3	4
leather jacket	2001	5	14	5	0	0	25
	2002	10	17	13	22	0	8
	2003	13	4	8	21	3	8
eagle ray	2001	0	0	0	0	0	0
	2002	0	11	0	0	4	0
	2003	0	0	0	4	3	0
goat fish	2001	5	0	0	0	0	0
	2002	0	0	0	4	0	0
	2003	0	0	0	0	0	0
Planktivorous species							
sweep	2001	30	24	23	25	0	65
	2002	43	6	42	44	4	33
	2003	13	0	38	17	13	50
butterfly perch	2001	30	43	5	80	0	10
	2002	19	28	33	56	4	8
	2003	57	18	71	58	0	8
demoiselle	2001	10	52	0	5	0	0
	2002	14	22	0	4	0	0
	2003	22	14	0	0	0	0
kahawai	2001	0	5	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
jack mackerel	2001	0	0	0	0	0	0
	2002	5	6	25	15	25	4
	2003	4	0	13	4	0	0

The number of epibenthic species recorded (species richness) per transect ranged from 0 to 9. The site with the highest species richness was CAII in 2001. All SLIMPA sites (i.e. CA and PP) had similar species richness in 2002. Over the three years, the species richness decreased at CAII, remained fairly constant at both reference sites, and generally increased at CAI, PPI and PPII (Fig. 2).

Figure 2.
Mean epibenthic reef fish species richness (± 1 SEM) at each sampling site, 2001-03.



Transformed species richness data met the underlying assumptions required for ANCOVA. Trends of species richness through time were significantly different between sites ($F = 31.4$, $p = 0.00$), and between years ($F = 7.12$, $p = 0.01$). There was a significant interaction between site and year ($F = 9.47$, $p = 0.00$) implying that different sites have different trends over time (Crawley 2002). Trends may become clearer when a longer data set is available for analysis.

The results of the discriminant analysis of principal coordinates for each of the three sampling years are shown in Fig. 3. Each mark on the plot represents the assemblage observed at one transect. Marks that are closer together indicate that the reef fish assemblage at those transects were more similar.

Transects from SLIMPA sites (i.e. both within and outside the conservation area) grouped together more to the left of the graph, and transects from the reference sites tended to group more towards the right-hand side of the graph (Fig. 3A–C). Overlap between SLIMPA and non-SLIMPA sites was greatest in 2002.

The CAP programme was used to test the 'goodness of fit' of the groups resulting from the discriminant analysis compared with the original groups (Table 5). For example, in 2001, there were 41 transects from the conservation area (CAI and CAII). The CAP programme assigned 26 of these transects correctly, assigned 10 to PP and 5 to NP, i.e. overall 63.4% of transects from CA were correctly assigned to this management zone. Across each of the three years, there was a high degree of accuracy in classifying NP sites. Fewer CA and PP sites were correctly allocated, although the percentages correct for CA in 2002 were 82%, and for CA and PP in 2003 were 69% and 73%, respectively. This suggests there was sufficient difference between the management groups to allow correct classification of transects into these groups even though the ordination (Fig. 3) suggested that CA and PP were indistinguishable. Thus the

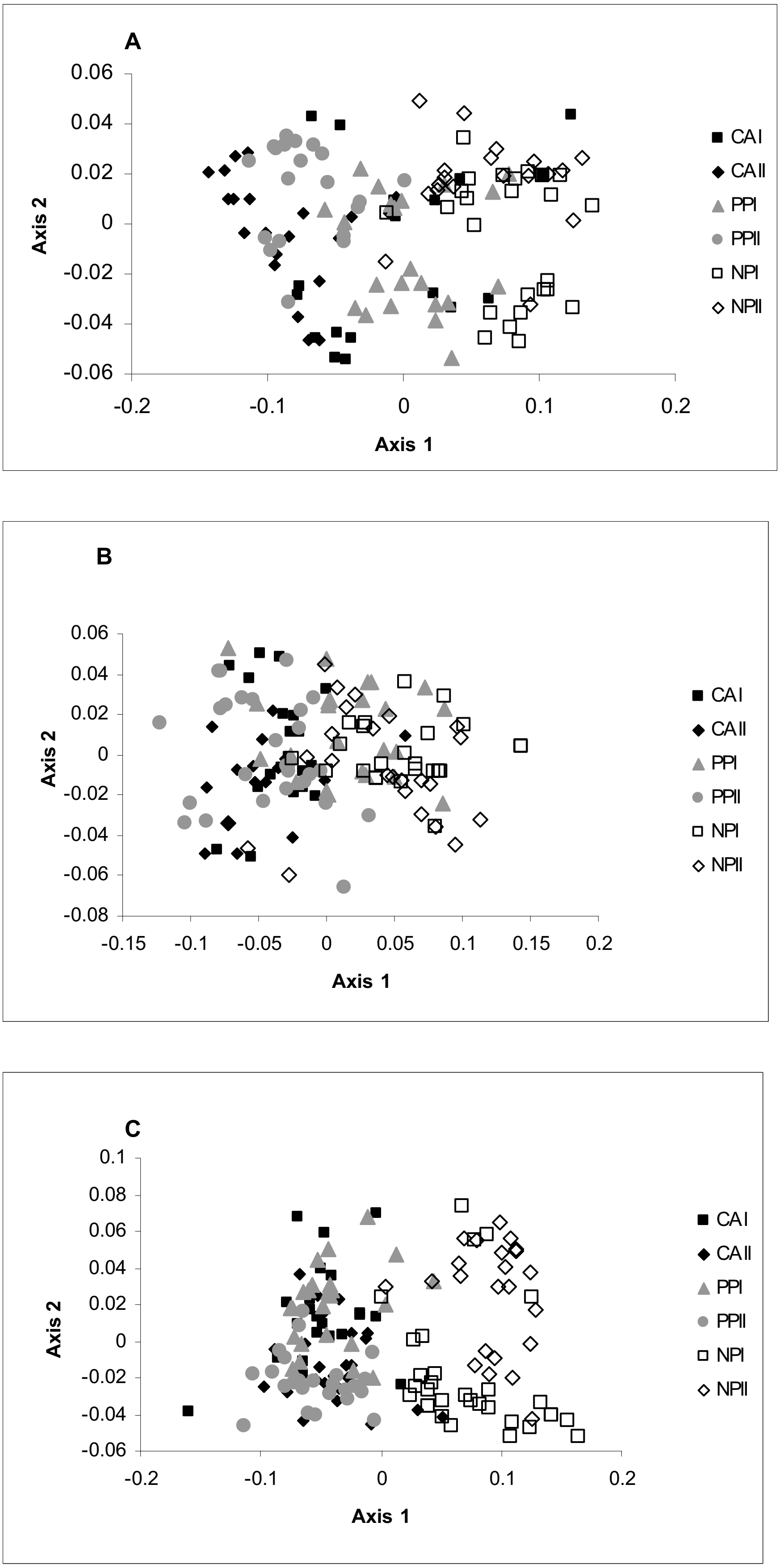


Figure 3. Discriminant analysis of principle component axes of reef fish communities, based on Bray-Curtis dissimilarity and m = 5 A, 2001; B, 2002; C, 2003.

TABLE 5. MISCLASSIFICATION ERROR DERIVED FROM THE CONSTRAINED ORDINATION (DISCRIMINANT ANALYSIS OF THE PRINCIPAL COMPONENTS ANALYSIS).

CA, conservation area; PP, partly protected; NP, non-protected.

YEAR	CLASSIF-ICATION	NO. OF TRANSECTS	MANAGEMENT ZONE ASSIGNED TO			PERCENTAGE CORRECT	MISCLASSIF. ERROR FOR THE YEAR
			CA	**PP**	**NP**		
2001	**CA**	41	26	10	5	63.4	32.6%
	PP	42	19	19	4	45.2	
	NP	46	0	4	42	91.3	
2002	**CA**	39	32	6	1	82.1	38.4%
	PP	51	18	19	14	37.2	
	NP	48	6	8	34	70.8	
2003	**CA**	51	35	14	2	68.6	20.1%
	PP	48	13	35	0	72.9	
	NP	57	1	1	55	96.4	

TABLE 6. CORRELATIONS OF FISH SPECIES WITH AXES (r^2) OF CANONICAL ANALYSIS OF PRINCIPAL COORDINATES.

SPECIES	2001		2002		2003	
	AXIS 1	AXIS 2	AXIS 1	AXIS 2	AXIS 1	AXIS 2
spotty	-0.30	-0.51				0.25
banded wrasse	-0.57	-0.22			0.39	0.78
scarlet wrasse	-0.79	0.24	-0.79		-0.93	
red moki		-0.24		-0.33	-0.40	0.22
blue cod	-0.42					0.38
marblefish					-0.45	
snapper	-0.25		-0.23		-0.23	0.22
rock cod				-0.23		
leather jacket		0.23				
goatfish				-0.23		
sweep		0.65		-0.72	0.20	0.37
butterfly perch	-0.64	0.25	-0.42		-0.50	0.34
demoiselle	-0.37		-0.22			
jack mackerel			0.24			

results from the 'goodness of fit' test suggest some separation between the management zones within SLIMPA.

Table 6 sets out the correlations between species and axes 1 and 2 for those species with an absolute correlation of > 0.20 (as per Anderson & Willis 2003). Species that were negatively correlated with axis 1 in 2003 (indicating a closer association with SLIMPA sites) were: scarlet wrasse, red moki, marble fish, snapper and butterfly perch. Species positively associated with axis 1 in 2003 were banded wrasse and sweep. Three species were negatively correlated with axis 1 for each year: scarlet wrasse, butterfly perch and snapper.

TABLE 7. TOTAL NUMBER OF EACH FISH SPECIES ENCOUNTERED. FOR NUMBER OF TRANSECTS, SEE TABLE 3.

SPECIES	YEAR	SITE					
		CAI	CAII	PPI	PPII	NPI	NPII
Epibenthic species							
spotty	2001	1	19	18	3	5	0
	2002	4	4	17	2	2	3
	2003	16	4	16	2	1	0
banded wrasse	2001	2	21	2	10	0	0
	2002	4	17	5	8	7	8
	2003	37	8	6	7	2	79
scarlet wrasse	2001	195	197	114	339	37	67
	2002	174	157	90	220	46	66
	2003	203	308	253	258	48	10
red moki	2001	45	8	15	12	14	1
	2002	29	8	17	29	17	3
	2003	51	29	41	51	9	14
blue moki	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	10	0	0	0
blue cod	2001	11	24	0	7	0	1
	2002	21	12	1	2	2	6
	2003	38	22	24	3	8	9
marblefish	2001	8	3	1	3	0	0
	2002	3	1	4	9	0	1
	2003	9	6	8	20	0	0
snapper	2001	0	12	0	0	0	3
	2002	3	7	0	1	0	0
	2003	22	4	0	0	0	0
tarakihi	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	3	0	0	4	0	0
rock cod	2001	0	0	0	0	0	0
	2002	0	0	1	2	0	0
	2003	0	0	0	1	1	1
leather jacket	2001	1	3	1	0	0	7
	2002	2	7	3	7	0	17
	2003	3	1	2	5	1	2
eagle ray	2001	0	0	0	0	0	0
	2002	0	3	0	0	1	0
	2003	0	0	0	1	1	0
goat fish	2001	1	0	0	0	0	0
	2002	0	0	0	1	0	0
	2003	0	0	0	0	0	0
Planktivorous species							
sweep	2001	130	59	71	64	0	149
	2002	84	1	222	79	6	24
	2003	52	0	910	4	19	202
butterfly perch	2001	20	37	1	89	0	3
	2002	6	14	20	85	1	2
	2003	43	26	32	73	0	2
demoiselle	2001	39	95	0	6	0	0
	2002	9	29	0	1	0	0
	2003	56	34	0	0	0	0
kahawai	2001	0	1	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
jack mackerel	2001	0	0	0	0	0	0
	2002	30	200	490	102	3811	60
	2003	12	0	170	200	0	0

3.2 DENSITY

The most abundant species encountered during the 3-year monitoring period were jack mackerel, scarlet wrasse, and sweep (Table 7). High numbers of jack mackerel were observed at Tapuae (NPI) during 2002, but none were observed in any sites in 2001. Butterfly perch, spotty, red moki, and demoiselles were the next most abundant species (Table 7).

The total abundance of epibenthic fishes per transect was averaged for each site and year (Fig. 4). Transformed abundance data met the underlying assumptions required for ANCOVA. Trends of abundance through time were significantly different between sites ($F = 102.9$, $p = 0.00$), and between years ($F = 8.2$, $p = 0.01$). There was a significant interaction between site and year ($F = 5.09$, $p = 0.00$) implying that different sites have different trends over time (Crawley 2002). Trends may become clearer when a longer data set is available for analysis.

Figure 4. Total abundance of epibenthic reef fishes (±1 SEM) at each sampling site, 2001–03.

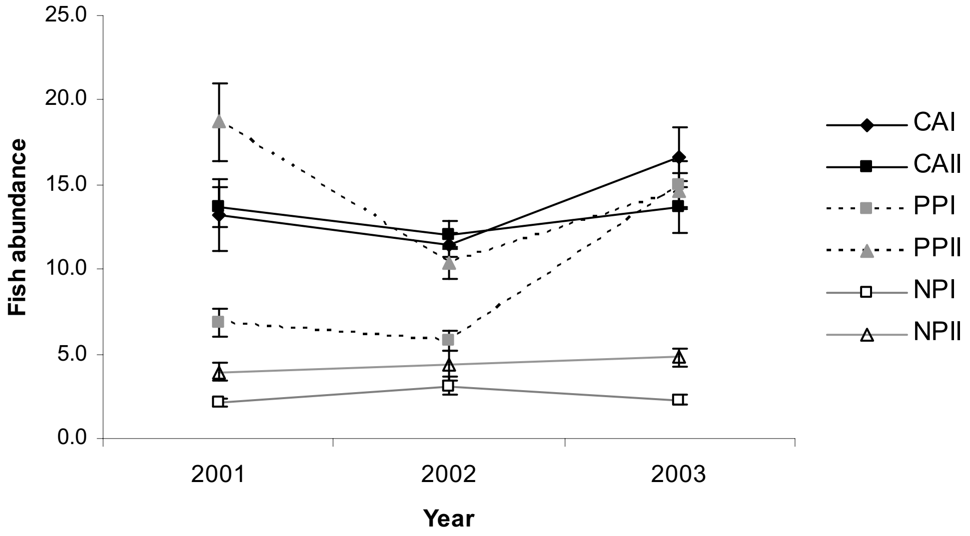


Figure 5. Mean number of blue cod per transect (± 1 SEM) at each sampling site, 2001–03.

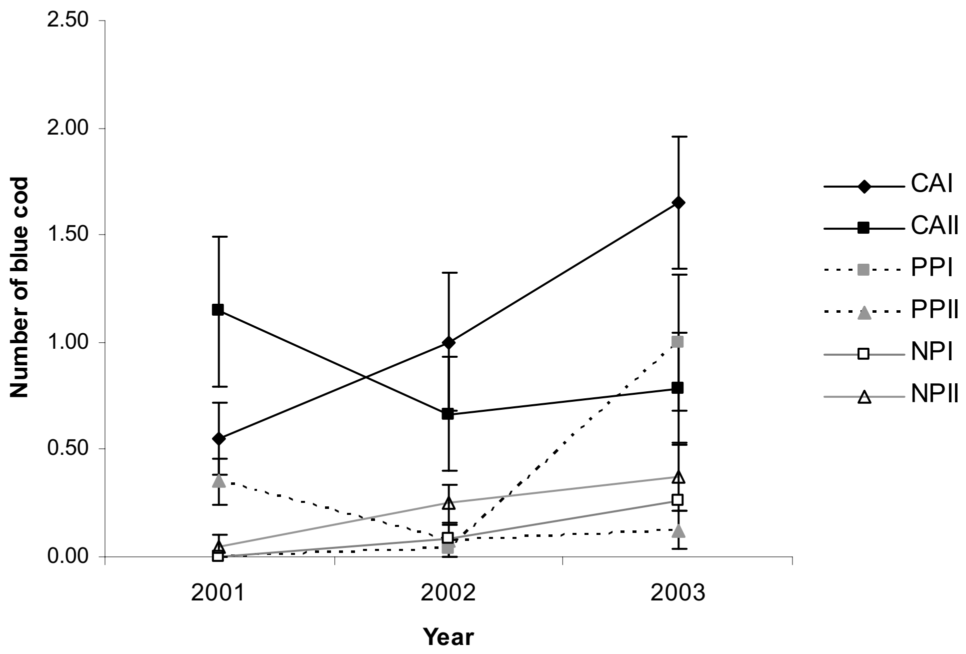


Figure 6.
Mean number of snapper per transect (± 1 SEM) at each sampling site, 2001-03.

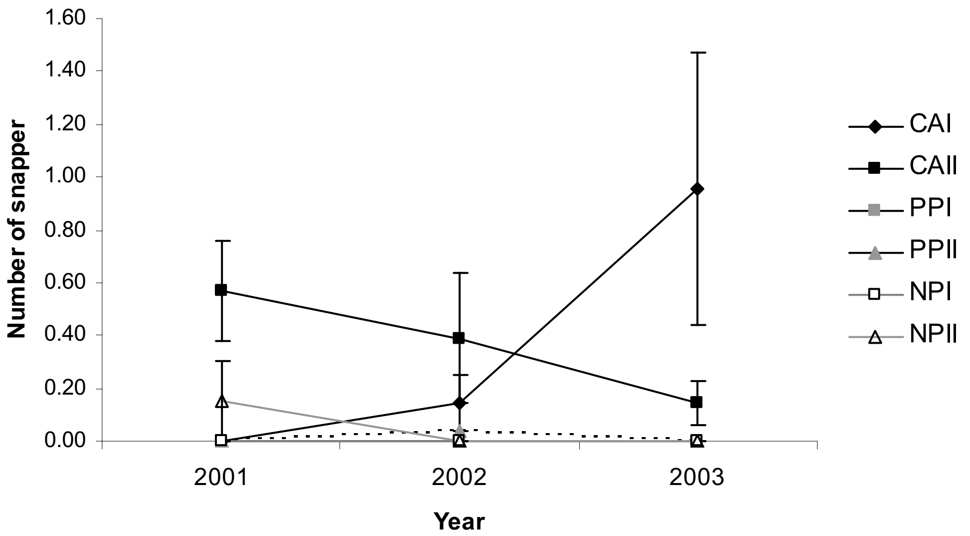


Figure 7.
Mean number of red moki per transect (± 1 SEM) at each sampling site, 2001-03.

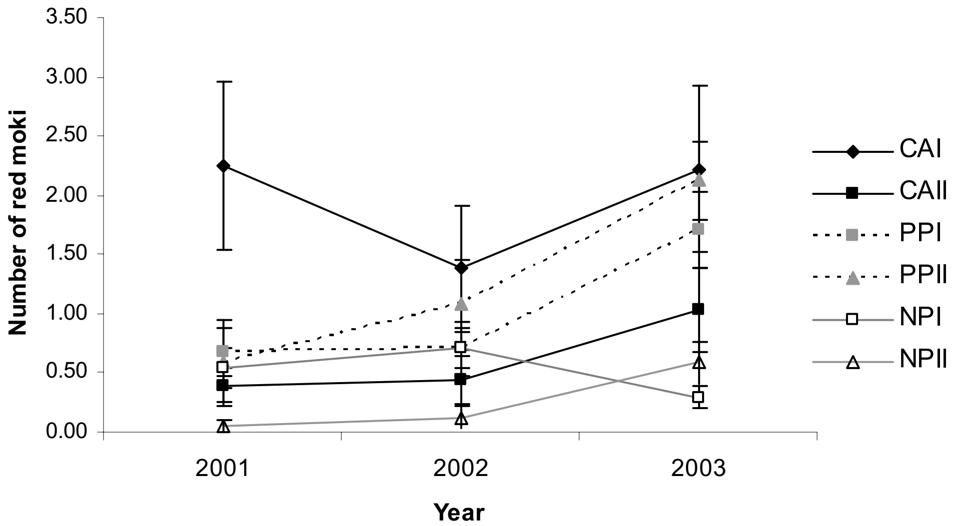
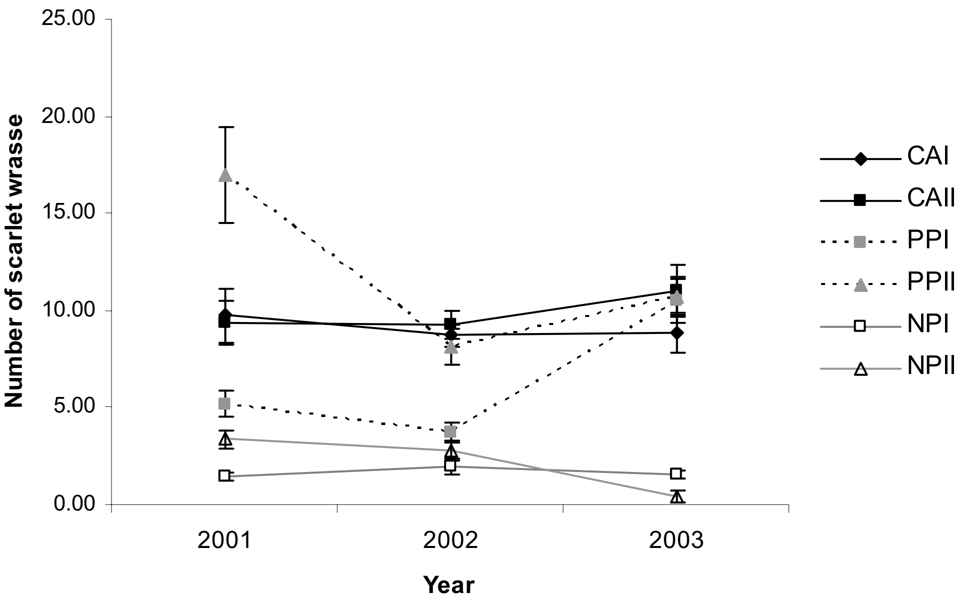


Figure 8.
Mean number of scarlet wrasse per transect (± 1 SEM) at each sampling site, 2001-03.



Over the three years, total reef fish abundance appeared stable at the no-protection sites and consistently lower than at the other four sites. Reef fish abundance was relatively constant in the conservation area sites, whereas it was more variable at the partially protected sites.

The mean abundance at the six sampled sites for each year of blue cod, snapper, red moki, and scarlet wrasse are set out in Figs 5–8. Even when transformed, the data for these species abundances did not meet the requirements for an ANCOVA.

There were generally more blue cod in the conservation area sites than either the partially protected or no-protection sites except for 2003, when numbers of blue cod in PPI were comparable with those in the conservation areas (Fig. 5).

Blue cod size distribution is set out for the three years in Fig. 9. The relatively high numbers of blue cod at the PPI site in 2003 (Fig. 9C) were all < 15 cm. Blue cod in this size category are up to 1 year old.

Average snapper densities were low, but were generally higher at sites within the conservation area than in the partially protected sites, or at the reference sites. No snapper were observed at PPI or NPI.

Red moki numbers appear to have increased over the three-year monitoring period at all sites except NPI and CAI (Fig. 7). Size distribution data for red moki are set out in Fig. 10. There appeared to be some recruitment in 2002, judging by the increased numbers of red moki < 20 cm at both CAI and NPI, and greater numbers of large fish in 2003 at three sites within SLIMPA (Fig. 10).

Scarlet wrasse were more abundant in SLIMPA (CA and PP sites) than in the no-protection sites (Fig. 8). There is the suggestion of a decreasing trend in scarlet wrasse abundance in the no-protection sites.

4. Discussion

As the monitoring programme was primarily set up to detect temporal trends at specific sites, we have been cautious about analysing the data to detect differences between management areas, particularly given the lack of quantitative pre-protection data and the limitations of the non-random selection of sites. However, it is still possible to make some preliminary observations about trends and differences apparent between the monitoring sites.

We have not used the New Plymouth Underwater Dive Club (1989) survey as a baseline due to a different sampling methodology. The NPUDC survey ran transects from low water to the bottom of the reef, sampling a wide range of habitats and depths, whereas we have attempted to sample within a single habitat type in order to reduce variability in the data and increase the ability to detect differences over time.

Figure 9.
Mean number of blue cod in predetermined size classes: A, 2001; B, 2002; C, 2003.

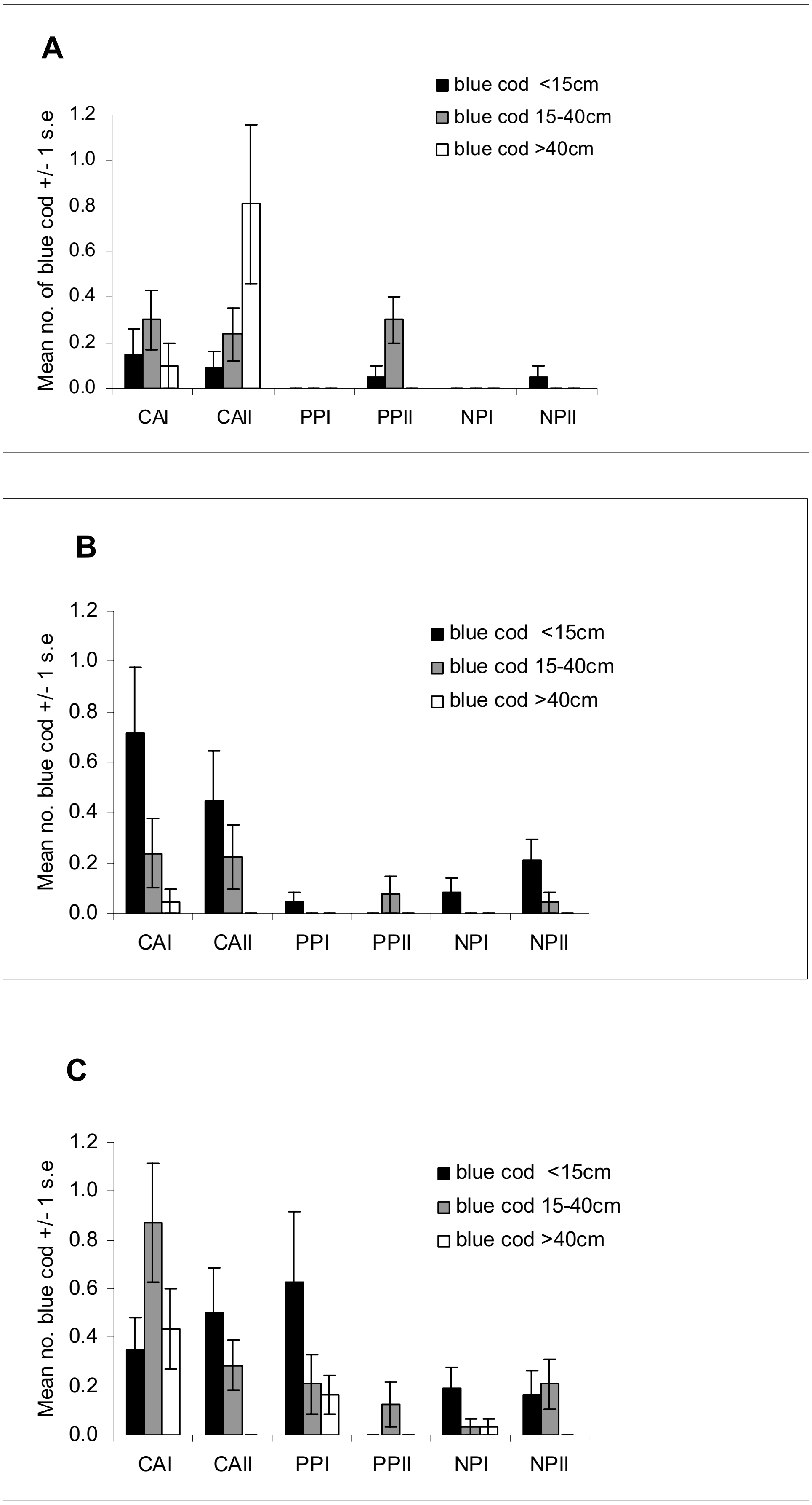
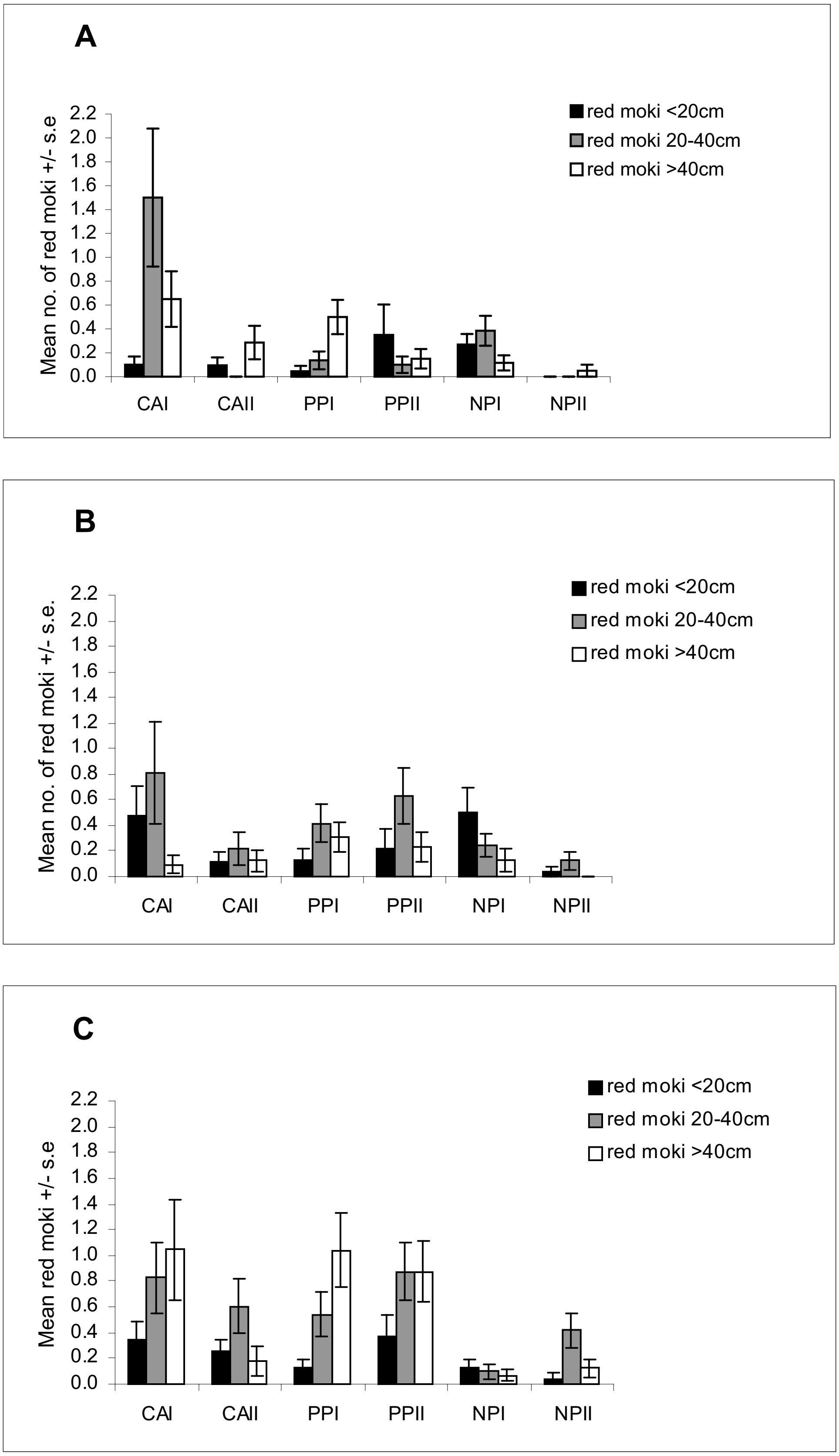


Figure 10. Mean number of red moki in predetermined size classes (error bars = 1 SE): A, 2001; B, 2002; C, 2003.



4.1 REEF FISH COMMUNITY

The ordination analysis and species richness data highlighted differences in reef fish community composition and trends through time between sites in SLIMPA and the reference sites. The monitoring indicates that sites within SLIMPA (both conservation area and partial protection area) provide important fish habitat that supports a greater diversity of reef fishes and abundance of some species than are found at reference sites outside the marine protected area.

Determining the relative strength of habitat v. management in effects on the fish community is beyond the scope of the design of this monitoring programme. Although every effort was made to select reference sites that were comparable to the sites within SLIMPA, it was unavoidable that the topographic relief of the reference reefs differed from that at the SLIMPA sites. The maximum vertical relief at the reference sites was about 1 m compared with about 7–20 m for SLIMPA sites. There is also more shallow weed habitat adjacent to the SLIMPA sites. These two factors probably explain much of the differences in abundance and diversity observed among the sites.

The difference in fish communities observed was almost entirely due to a greater abundance and variety of species that are not targeted by commercial or recreational fishers (i.e. red moki, marblefish, scarlet wrasse, banded wrasse, spotty, butterfly perch, sweep, and demoiselles) within SLIMPA than at the reference sites. This suggests that habitat factors rather than fishing pressure is determining overall community composition.

The presence of large schools of sweep, butterfly perch, and demoiselles associated with the more structurally complex reefs in SLIMPA is also consistent with the observation that topographic complexity is positively correlated with species diversity and total density of planktivorous fishes elsewhere in northern New Zealand (Jones 1988).

4.2 SPECIFIC SPECIES

The value of undertaking a reef fish monitoring programme in order to establish a baseline of information and monitor changes in community composition is demonstrated by the demoiselles. This is a sub-tropical species, occurring near the edge of their distribution in New Zealand and are probably dependent on intermittent recruitment from source populations further north. Demoiselles were not recorded in the 1986 survey (New Plymouth Underwater Club 1989), but were included in their species list (a list collected or observed over time). Our observations indicated they had been absent from SLIMPA for a number of years before new recruits were observed at SLIMPA in 1999 (C.D. and B.W. pers. obs.). In subsequent years, schools of up to 50 fish were observed in SLIMPA and spawning was observed in 2003 (B.W. pers.obs.).

Marblefish were notable for their almost total absence from the reference sites, and variable abundances at the sites within SLIMPA. Marblefish are more abundant in shallow reef habitat, particularly *Carpophyllum* fringe habitat within SLIMPA (C.D. pers. obs.). This species feeds on red algae (Duffy 1989), which also occurs in the *Carpophyllum* fringe (Shears et al. 2004). This type of habitat was less common at the reference sites. Marblefish are not a target species for recreational or commercial fishing, although they are vulnerable to gill netting.

Scarlet wrasse are not caught by set nets, but are caught by rod and line techniques and are usually discarded or used as bait. Abundance of scarlet wrasse was higher in SLIMPA than at the reference sites, although their densities were more variable in the partially protected area than the conservation area. Variability in density data can indicate disturbances, and it may be that fishing mortality affects their abundance at some sites within the partially protected area. However, the densities at the no-protection sites were significantly lower than at all sites within SLIMPA, suggesting that the difference in habitat (greater relief and complexity in SLIMPA) is the main factor influencing scarlet wrasse abundance.

Blue cod were more abundant in the conservation area than in the partial protection areas, but their abundance in the partial protection sites was generally similar to that in the no-protection sites (Fig. 4). The exception was in 2003, when there were large numbers of juvenile (< 15 cm) fish at one of the partial protection sites). Denny & Babcock (2003) found that partial protection did not benefit popular exploited species. They observed that snapper numbers were actually lower in the partially protected marine park than in the unprotected control areas and attributed this to higher fishing pressure within the marine park. They suggested this may be due to a perception that fish are larger and more plentiful in the absence of commercial fishing (Denny & Babcock 2003).

The conservation area at SLIMPA is quite small, but about the size of a blue cod home range (300–500 m) (Cole et al. 2000). It covers the entire reef habitat around the Waikaranga rock, i.e. it resembles an underwater island surrounded by a sea of sand, and its boundaries reflect the natural habitat boundaries. It is possible that the results might have been quite different if the conservation area had been a section of continuous reef habitat.

There were a large number of small blue cod in CAI in 2002, a pattern which is paralleled in several of the other sites, including the reference sites. It appears that there was a pulse of small fish in 2002, and ongoing monitoring should determine if this recruitment event results in larger numbers of large fish in the conservation area. This pulse of fish then appears in the next size class the following year in CAI. Further monitoring of blue cod numbers is needed to determine if this recruitment event results in larger numbers of large fish becoming resident in the conservation area. The numbers of large fish observed in 2001 at CAII were not seen again at that site, suggesting either that the conservation area is too small to protect the large fish from fishing pressure in the rest of SLIMPA, or that blue cod are more mobile along this coast than elsewhere. Large blue cod would not be expected to disappear unless they were being caught or emigrating out of the area.

As snapper are widely distributed off north Taranaki and are seasonally abundant off New Plymouth, they can be expected to occur throughout SLIMPA and at the reference sites. It is highly unlikely that the slightly higher number of snapper in the conservation area could be attributed to a protection effect, given the much larger home range of snapper (Bentley et al. 2004). Duffy et al. (2003) raised the possibility of diver habituation having the potential to influence results, particularly as all of the transects at Snapper Bay (CAII) were conducted in an area where fish feeding by local divers occurs. However, feeding of fish is not undertaken at CAI, and yet comparable numbers of snapper (and blue cod and scarlet wrasse) were observed there (Figs 6, 5, and 8, respectively). Furthermore, the observed frequency of snapper (Table 4) suggests that they were seen on different transects and therefore not clumped (e.g. on 38% of transects in CAII in 2001; 10% and 17% in CA sites in 2002; 26% and 11% of transects in CA in 2003).

To get a better picture of snapper numbers within the conservation area, the partially protected sites, and the reference sites, we recommend that underwater baited video surveys be undertaken using the methods of Willis et al. (2000) to verify the conclusions drawn from the visual surveys. This should overcome problems identified with underwater visual census, such as fish avoidance, attraction or habituation.

There is the possibility that the modification of predator populations (i.e. snapper, blue cod) through fishing may result in impacts on species lower in the food chain (i.e. a trophic cascade) and lead to a loss of kelp forests due to increased grazing by urchins (Babcock et al. 1999). Anecdotal evidence from divers indicates that kelp forests dominated by *Ecklonia radiata* were once widespread around the islands. At present they are largely confined to patches on Bills Rock, Corinna Rocks, and reefs below 12–15 m depth inside the conservation area. We recommend mapping the *Ecklonia* beds and monitoring changes to the size and location of these beds in order to try and document these anecdotal observations scientifically.

In conclusion, the first three years of monitoring reef fish at SLIMPA have highlighted the importance of this area for reef fish biodiversity and have established a baseline for future monitoring and future impact assessment.

5. Acknowledgements

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Appendix 1

Reef fish recording form

NAME DATE

SITE N/W/S/E		TIME IN		
			OUT	BACK
spotty banded wrasse scarlet wrasse				
red moki	big medium small	> 40 cm 20 – 40 cm < 20 cm		
triplefins	no.			
blue moki	big medium small	> 40 cm 20 – 40 cm < 20 cm		
sweep	no. no. no.	> 20 fish 5 – 20 fish < 5 fish		
blue cod	big medium small	> 40 cm 15 – 40 cm < 15 cm		
marblefish	big small	> 30 cm < 30 cm		
butterfish	big medium small	> 30 cm 15 – 30 cm < 15 cm		
snapper	big medium small	> 40 cm 10 – 40 cm < 10 cm		
other				

Appendix 2

SCIENTIFIC NAMES OF FISH MENTIONED

banded wrasse	*Pseudolabrus fucicola*
blennies	Blenniidae
blue moki	*Latridopsis ciliaris*
blue cod	*Parapercis colias*
blue maomao	*Scorpis violaceus*
butterfly perch	*Caesioperca lepidoptera*
demoiselle	*Chromis dispilus*
eagle ray	*Myliobatus tenuicaudatus*
goatfish	*Upeneichthys lineatus*
jack mackerel	*Trachurus* spp.
kahawai	*Arripis trutta*
kingfish	*Seriola lalandi*
leather jacket	*Parika scaber*
magpie morwong	*Cheilodactylus nigripes*
marblefish	*Aplodactylus arctidens*
red moki	*Cheilodactylus spectabilis*
rock cod	*Lotella rhacinus*
scarlet wrasse	*Pseudolabrus miles*
scorpion fish	*Scorpaena papillosus*
silver drummer	*Kyphosus sydneyanus*
slender roughy	*Optivus elongatus*
snapper	*Pagrus auratus*
spotty	*Notolabrus celidotus*
sweep	*Scorpis lineolatus*
tarakihi	*Nemadactylus macropterus*
triplefins	Trypterygiidae