SUMMARY.

The purpose of this baseline survey of Manuae Island is to identify and describe the marine environment. The survey includes, coral and benthos cover at patch reefs inside the lagoon and at the outer reef. Underwater video footage was also collected at survey sites. Fish types and abundance were recorded at several sites inside the lagoon. The reef area was also studied and the various types of edible and/or commercially valuable resources present were enumerated.

Coral and benthos cover inside the lagoon is composed mostly of non *Acroporoa* coral of the encrusting and soft coral forms. At the three sites surveyed, this accounts for 45% - 65% of total cover. Another common cover was algal assemblages, which represents 25% - 40% of the total cover. Coral cover on the outer reef slope at the two survey sites is dominated by hard coral forms of both *Acropora* (30% - 40% cover) and non acroporid species (20% - 25% cover). The coral types include, coralline algae, table corals, submassive corals, branching corals and digitate corals.

The fish survey inside the lagoon recorded 12 fish families - all of them typically robust types found elsewhere in the Pacific. The most abundant species is of the surgeon fish family, known in the Cook Islands as Maito (densities up to 0.20 fish.m^{-2}). Other common species are of the Goatfish family (C.I = Koma), Squirrelfish (Ku), Damselfish (Katoti) and Snapper (Paru). A high abundance of Trevally (Titiara) were also observed in the lagoon - although not at the survey sites.

The highest diversity of reef resources are at the windward side of the island. However, the greatest abundance of Paua, Rori toto and Kina occurs at the southern leeward side around Nanupoto area. The abundance of resources is similar inside the 50 meter band close to the reef edge except for Mapi and Ariri, which are mostly found within 5 meters of the reef edge. Resource abundance can be categorised as; (1) highly abundant species (up to 5 million animals) which include the Paua, Rori toto, Ungakoa and Pupu. (2) medium abundance (up to 300 thousand animals) and includes Kina, Vana, Mangeo, Poreo, Matu rori, Rori puakatoro and Etu. And (3) low abundance species (less then 10 thousand animals), which include the Trow Pitar Venus, Karikao, Mapi, Koura and Ariri. The 95% confidence intervals were also calculated.

Consideration is given to selecting areas inside and outside the lagoon as a marine reserve. The area between Arekai and Ruakau have the most patch reefs in the lagoon, (elsewhere it is mostly sandy bottom). The patch reefs are an important habitat and should be granted some protection status. To maintain a reserve of reef resources, areas from either the southern leeward side of Motu Manuae or at the southern windward side of Motu Te Au Outu could be chosen. Either of these areas have a high abundance and diversity of resources. In conjunction with the reef reserve the adjacent outer reef zone could also be designated a marine protected area.

ACKNOWLEDGEMENTS.

Field surveys at Manuae were capably assisted by Ministry of Marine staff members, Koroa Raumea, Sonny Tatuava and John Ngu. Assistance in marine taxonomy and standardisation of local names was provided by Gerald McCormick, Natural Heritage Project. Valuable support was given by the Marine Resources Secretary Raymond Newnham, the Manuae Island Councillor, Junior Maoate and New Zealand Development Assistance (NZODA) administrator, Dr. Peter Phillips. Major funding for this survey was provided under the NZODA program for the Cook Islands Tourism Master Plan.

INTRODUCTION.

Manuae Island is an uninhabited coral atoll about 100 kilometres south east of Aitutaki Island. The waters offshore of Manuae are reputed to be good fishing grounds for demersal and pelagic fish species. Manuae comprises of two main islets (Motu Manuae and Motu Te Au Otu) and a lagoonal area extending approximately 7 km x 4 km. The island once supported a small copra industry with a settlement established adjacent to the small reef passage at Turakino. Remarkably, the island also possess an airfield, although this has not been used for several years. Manuae lagoon is shallow and subject to large shifting sand banks. The lagoon has few coral patch reefs.

This survey is a baseline assessment of the marine environment at Manuae Island. The purpose being to describe and quantify the corals, fish and reef resources present. Some suggestions are made for selecting areas to be designated a marine reserve.

MATERIALS AND METHODS.

Field surveys at Manuae were undertaken during a visit in October 1997. Field staff comprised of Ministry of Marine Resources personnel from Aitutaki and Rarotonga.

Coral/benthos survey.

A coral and benthos survey was conducted to assess the percentage cover at the lagoon patch reefs and the outer reef slope. Monitoring the amount of coral cover is a useful indicator of the state of health of the marine system. Corals are sensitive to the surrounding environment. Anthropological impacts which result in eutrophication (excess nutrients in the water), sedimentation and breakage are two common causes of coral mortality. Since Manuae is relatively undeveloped the results of the survey represent natural conditions.

Coral and benthos cover at patch reefs were surveyed using a line intercept transect technique (see English et al, 1994 for details). A total of five survey sites were chosen, three sites inside the lagoon and two sites on the outer reef slope (**Figure 1**). At each site, two replicate 10 m transects were surveyed. Inside the lagoon the transects were placed 1.5 m below the surface. At the outer reef sites the 6 m depth was chosen (the survey depths are where the most coral abundance/diversity occurs). The transect was classified in 1 cm increments into various categories of benthos/coral cover. The categories can be broadly classified as; dead coral, dead coral with algae, *Acropora* coral, non *Acropora* coral, algae, abiotic, other fauna and others (see **Template A**). (*Acropora* species corals are the most common species among Pacific Islands and is characterised by a central polyp at the base of the coral).

Underwater video photography was filmed along the length of the transect using a Sony Handycam recorder in a underwater housing.

Fish survey.

Underwater visual census of fish abundance was conducted simultaneously with the coral survey at the same survey sites (**Figure 1**). Two replicate 50 m transects were laid and a diver would search a 1 m band on either side. Fish counts were grouped as family types but if a particular species was common, then it was recorded to the lowest taxonomy.

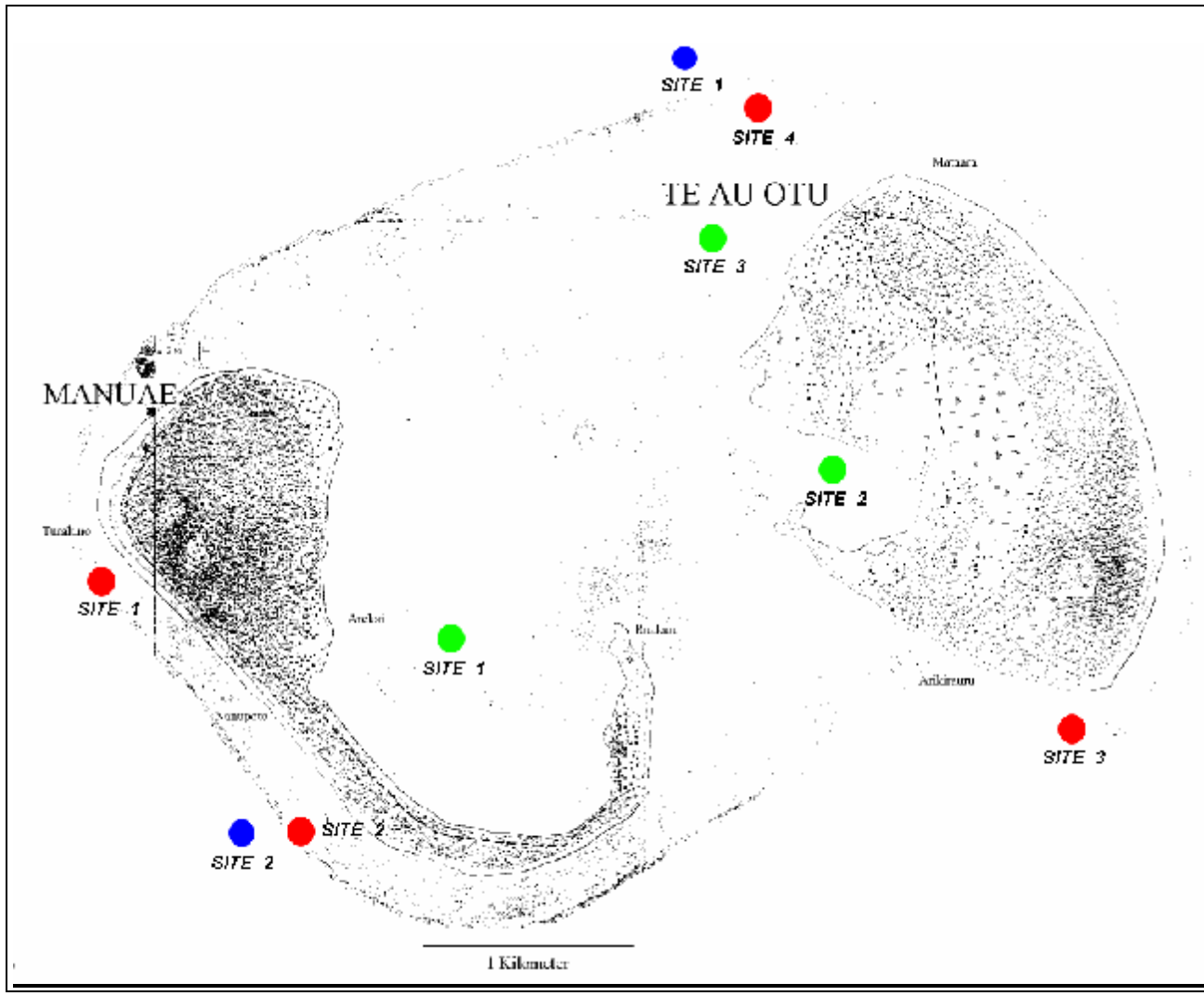

Figure 1 Map of Manaue Island showing Location of Sampling Sites. Blue Spheres are Outer Reef Survey Sites. Red Spheres are Reef Survey Sites. Green Spheres are Lagoon Survey Sites.

Reef resource survey.
The distribution and abundance of reef resources (of edible or potential commercial value) was studied at the reef flat at four sites (**Figure 1**). At each site, four replicate transects of 50 m length and sectioned every 5 m length were laid. Transects were placed perpendicular to the reef edge and two observers would search a 2 m band on either side. The observer would record the resource types and counts within the 5 m section of the transect side (each 5 m section equivalent to a "quadrant" of 20 m^2 area).

To measure the diversity of resources at the reef the Shannon-Weiner diversity index (Zar, 1984) was calculated. If a reef is dominated by only a few species then a low diversity index occurs. Accordingly, the distribution is not even and the index also becomes a measure of heterogeneity or evenness. The index also has a special test to compare whether the diversities of two sampled populations are the same (Hutcheson in Zar, 1984). The equations relating to diversity are appended in **Append. 1**.

The resource species were each examined statistically for density distribution patterns among the survey sites and with distance from the reef edge (in 5 m increments). A two-way ANOVA model was used which tested the factors (1) site and (2) distance from reef. Where significant differences ($P < 0.05$) in density were found the data set was further examined *a posteriori* with Tukeys HSD test to differentiate between different subsets.

General materials and methods.
Statistical treatment of data was performed using *SPSS version 6* software package. Whenever possible, means are presented with the standard error (s.e), which is a measure of variability associated with the mean. Assuming normality of the data distribution, the standard error can be used to derive confidence intervals (CI) about the mean estimate. For instance, a 95% confidence interval provides a range of values for the estimated mean that has a 95% probability to encompass the true mean. The working equations for standard error and confidence intervals are appended in **Append. 1**.

RESULTS.

Lagoon coral/benthos cover.

The different coral/benthos categories are shown in **Template A**. The dominant cover at the three lagoon reefs surveyed was non *Acropora* coral cover (**Figure 2**). At *site 1*, the mean (and s.e) of cover was 45.0 (4.2)%, being comprised of mostly encrusting coral forms (75%), but also soft corals (19%) and lesser amounts of coralline algae or submassive forms. At *site 2*, the non *Acropora* cover was 43.7 (18.1)%, mostly submassive corals (77%), but also soft corals (13%). The third site had a mean non *Acropora* coral cover of 65.7 (2.5)%. The coral forms being soft corals (61%), submassive corals (21%) and encrusting corals (17%).

Algal assemblages were also a common cover. The mean (and s.e) of cover at *site 1* was 28.5 (4.3)%. At *site 2* it was 38.3 (10.5)% and at *site 3* the cover was 24.6 (3.8)%. Lesser dominant cover include abiotic forms (sand, rubble, water etc) which account for 10.7 (8.4)%, 21.6% and 7.3 (1.4)% of the cover at *sites 1, 2* and *3*, respectively. *Halimidea* attributed to 12.9 (0.8)% of the cover at *site 1*. The least common cover recorded was turf algal and fauna (mostly Paua) which accounted for less then 3% of the total cover.

Outer reef coral/benthos cover.

Coral/benthos cover at the 6 m depth (30 feet) on the outer slope was composed mostly of hard coral forms (**Figure 3**). Non *Acropora* sp. corals were responsible for a mean (and s.e) cover of 34.4 (1.9)% at *site 1* and a mean cover of 41.9 (13.2)% at *site 2*. The non *Acropora* corals at *site 1* were comprised of, coralline algae (34%), table coral (22%), encrusting corals (16%) and submassive corals (15%). At *site 2* the composition of non *Acropora* corals was, coralline algae (45%), submassive corals (17%), encrusting corals (16%) and table corals (13%). Soft corals were rarely encountered and only recorded at *site 1* (< 1% cover).

Acropora corals were also a major coral cover. It accounted for 25.6 (3.)% of the cover at *site 1* and 18.7 (4.8)% of the cover at *site 2*. The branching and digitate forms made up all the *Acropora* sp. corals. *Acropora* branching accounted for 51% of the *Acropora* at *site 1*. The digitate form accounted for 49% of *Acropora* at *site 1* and 97% at *site 2*.

The cover from algal assemblages at the outer reef was not as large compared to patch reefs inside the lagoon. It comprised 10.9 (2.9)% of the total cover at *site 1* and 13.2 (9.8)% of the total cover at *site 2*. Abiotic cover accounted for 10.0 (4.2)% and 10.3% of the cover at sites 1 and 2, respectively. Dead coral with algae was responsible for 11.8 (0.4)% of the coral cover at *site 1*. *Halimidea* accounted for 7.9 (2.2)% of the benthos at *site 2*.

Fish.

Unfortunately the fish survey results were lost for the outer reef surveys so only the results of the lagoon reef surveys can be reported.

A total of 11 fish families were encountered during the fish survey (see **Template B**). They include, Boxfishes, Ostraciidae (scientific name), U'e (C.I maori); Butterflyfishes, Chaetodontidae, Taputapu pepe (C.I); Damselfishes, Pomacentridae, Katoti (C.I); Garfishes, Hemiramphidae, Miromiro (C.I); Goatfishes, Mullidae, Koma (C.I); Parrotfishes, Scaridae, Pakati (C.I); Rockcod (Grouper subfamily), Epinephelus, Patuki (C.I); Snapper, Lutjanus, Paru (C.I); Squirrelfishes, Holocentridae, Ku (C.I) and Surgeonfishes, Acanthuridae, Maito (C.I) (**Figure 4**).

insert **Template A**

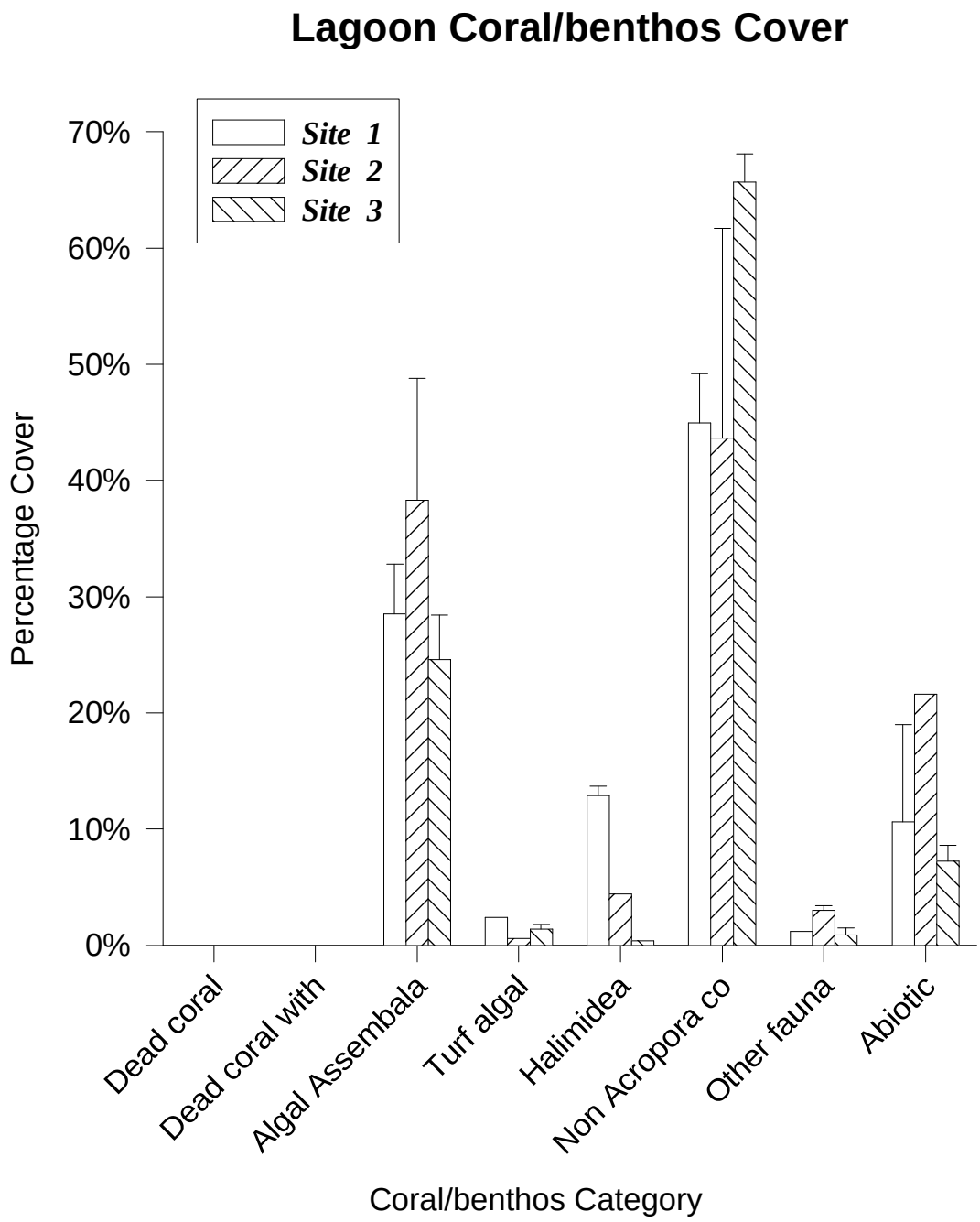

Figure 2 Coral/benthos Cover at Patch Reefs surveyed inside Manuae Lagoon.

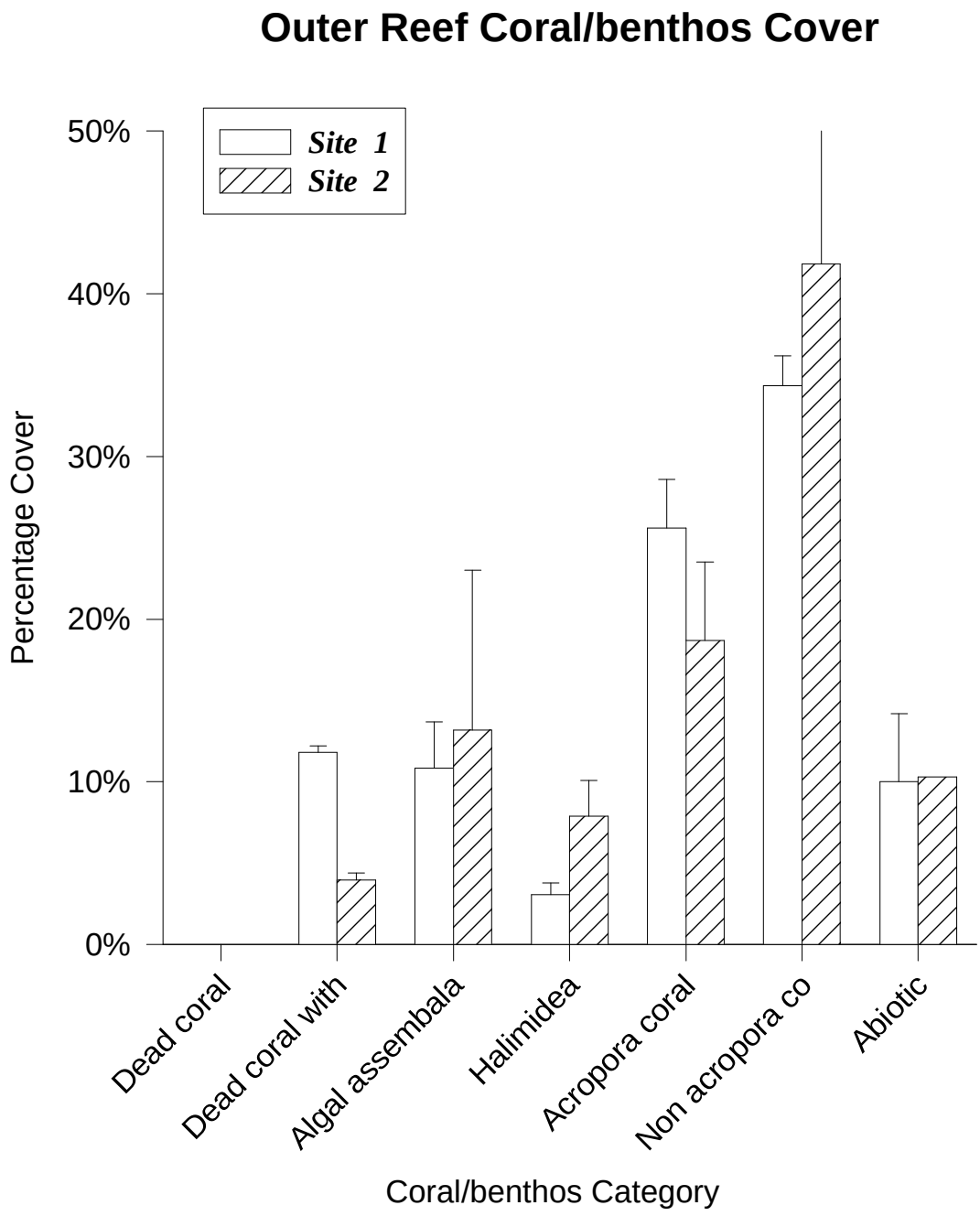

Figure 3 Coral/benthos Cover at the Outer Reef Slope at Manuae Island.

Surgeonfishes were the most abundant fish family seen at *site 1* (**Table 1**). The mean (and s.e) of density of surgeonfish was 0.2 (0.02) fish.m^{-2}. Surgeonfish species consisted of the Lined bristletooth surgeonfish, *Ctenochaetus striatus*, Maito (C.I) (0.19 fish.m^{-2}) and the Convict surgeonfish, *Acanthurus triostegus*, Manini (C.I) (0.02 fish.m^{-2}). Lesser abundant fish families at *site 1* included the Damselfishes (0.07, 0.03 fish.m^{-2}); Boxfishes (0.04 fish.m^{-2}); Rockcods (0.04, 0.01 fish.m^{-2}) and Snappers (0.04, 0.01 fish.m^{-2}). The Rockcod family was comprised of two species, the Brown cod, *Epinephelus merra*, Patuki (C.I) (0.03 fish.m^{-2}) and the Peacock cod, *Cephalopholis argus*, Patuki roi (C.I) (0.01 fish.m^{-2}). The Snapper family was mostly comprised of two species, the Yellow-mariginated sea bream, *Lutjanus fulvus*, Tangau (C.I) (0.03 fish.m^{-2}) and the Goldlined sea bream, *Gnathodentex aurolineatus*, Taraki'i (C.I) (0.01 fish.m^{-2}).

At *site 2* the most dominant fish family was the Surgeonfishes (0.2, 0.05 fish.m^{-2}) (**Table 1**). It comprised mostly of the Lined bristletooth surgeonfish, (0.14 fish.m-2), the Convict surgeonfish (0.01) and the Archilles tang, *Acanthurus achilles*, Ikutoto (C.I) (0.03 fish.m^{-2}). Other abundant families included, the Garfishes (0.1 fish.m^{-2}); Squirrelfishes (0.08, 0.01 fish.m^{-2}); Goatfishes (0.07, 0.03 fish.m^{-2}) and the Snapper (0.05, 0.01 fish.m^{-2}). The Snapper species were the same found at *site 1*, i.e, the Yellow-marginated sea bream (0.04 fish.m^{-2}) and the Goldlined sea bream (0.01 fish.m^{-2}). The Rockcods (0.04 fish.m^{-2}) consisted entirely of the Brown cod. The Unicornfish family comprised solely of the Orangespine unicornfish, *Naso lituratus*, Ume (C.I) (0.02, 0.02 fish.m^{-2}).

The lagoonal waters possess some of the highest numbers of Trevallies (Family Carangidae, C.I name Titiara) observed in any of the Cook Island lagoons. For example 6 large fish (up to 70 cm length) were caught after casting along Nanupoto beach for approximately half an hour.

Shown in **Template C** are some of the common fish species found reported in the survey.

Table 1 Fish Species and Abundance recorded at Manuae Lagoon.

Family	Species	Scientific name	Local name	avg	se
Boxfish		Ostraciidae spp.	U'e	0.04	0
Butterflyfish		Chaetodontidae spp.	Taputapu pepe	0.02	0
Damselfish		Pomacentridae spp.	Katoti	0.065	0.025
Drummer	*Topsail drummer*	*Kyphosus cinerascens*	Pipi	0.07	
Garfish	*Dussumier's garfish*	*Hyporphamphus dussumieri*		0.2	
Goatfish	*Yellow-stripe goatfish*	*Mulloides flavineatus*	Koma	0.07	0.02
Parrotfish		Scaridae spp.	Pakati	0.01	
Rock Cod				0.035	0.005
	Brown cod	*Ephinephelus merra*	Patuki	0.03	
	Peacock Cod	*Cephalopholis argus*	Patuki roi	0.005	
Snapper				0.035	0.005
	Yellow-marginated sea-bream	*Lutjanus fulvus*	Tangau	0.03	0.01
	Goldlined sea bream	*Gnathodentex aurolineatus*	Taraki'i	0.005	
Squirrelfish		Myripristis spp.	Ku		0.15
Surgeonfish				0.2	0.02
	Lined b'tooth surgeonfish	*Ctenochaetus striatus*	Maito	0.185	
	Convict surgeonfish	*Acanthurus triostegus*	Manini	0.015	
	Achilles tang	*Acanthurus achilles*	Ikutoto	0.04	
Unicornfish	*Orangespine unicornfish*	*Naso lituratus*	Ume	0.05	

Insert **Template B.**

insert **Template C.**

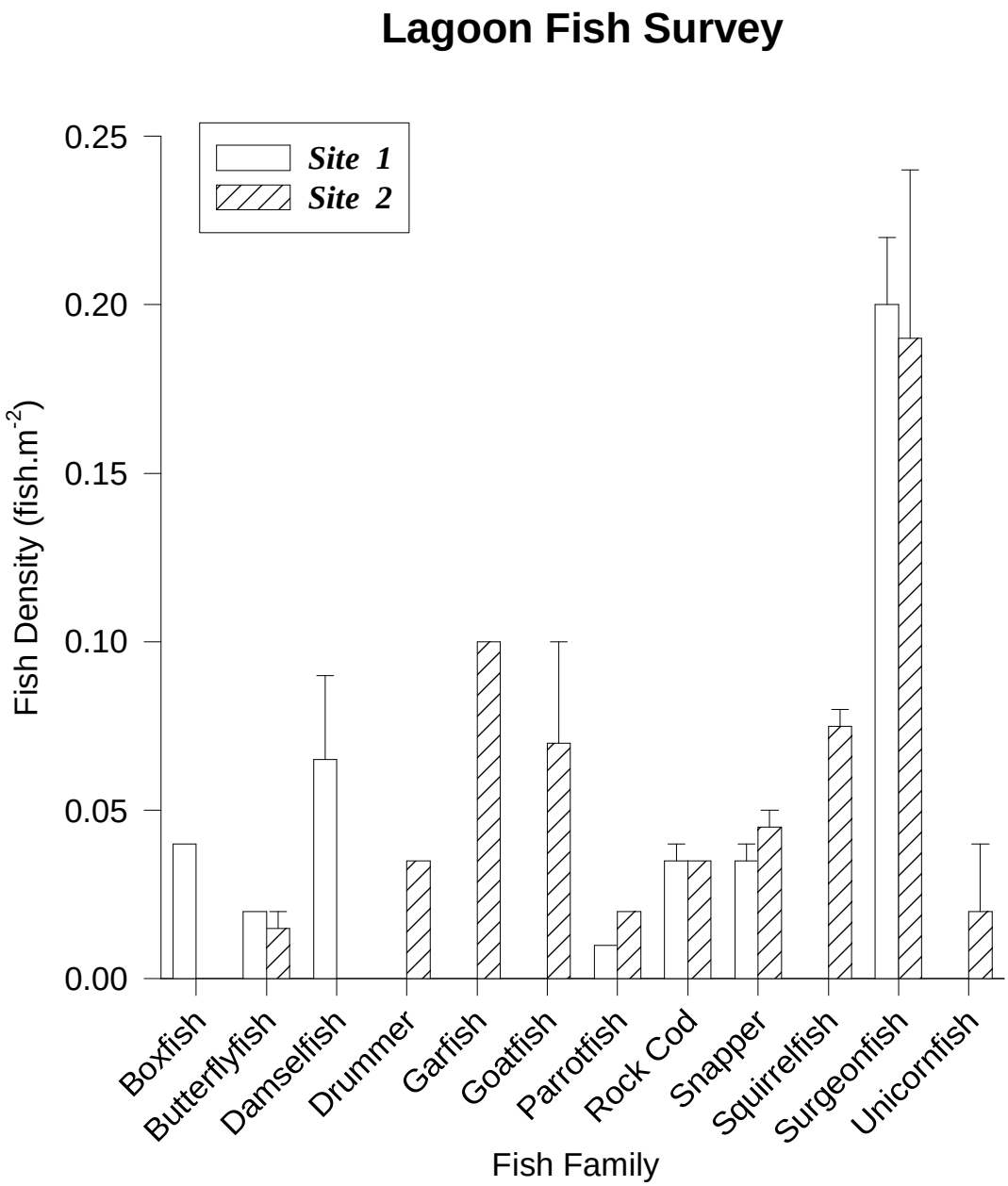

Figure 4 Fish Family Types and Abundance recorded inside Manuae Lagoon.

Reef Resources.
Shown in **Template D** are some of the common resources found at Manuae.

Diversity.
A total of 12 different resources were recorded at *sites 1, 2* and *3* and 11 resources at *site 4* (**Table 2**). The resources include, Ariri (Rough Turban shell, *Turbo setosus*), Etu (Starfish, *Linckia laevigata*), Koura (Golden Rock Lobster, *Panulirus penicillary*), Kina (Echinoderm, *Echinometra mathaei*), Karikao (Rose mouth Turban shell, *Astrea Rhodostoma*), Mangeo (Murex family), Mapi (Star shaped Limpet, *Patelloidea conoidalis*), Matu rori (Holothoria, *Holothoria leucospilota*), Paua (Rugose Giant Clam, *Tridacana maxima*), Poreo (Cone shell), Pupu (Cone shell), Rori puakatoro (Red surf fish, *Actinopyga mauritiana*), Rori toto (Lollyfish, *Holothuria atra*), Ungakoa (Small worm snail, *Sertulorbis gramdis*, note this species is the smaller of the two found in the Cook Islands), Vana (Echinoderm, *Diadema savignyi*).

Table 2 Count of Reef Resources at the Survey Sites within Four Replicate 50 m transects.

Resource	*Site 1*	*Site 2*	*Site 3*	*Site 4*	Total
Ariri			1		1
Etu				4	4
Koura		1			1
Kina	3	114	10	32	159
Karikao		1		1	2
Mangeo	5	3	28	43	79
Mapi				1	1
Matu rori	9		2		10
Paua	312	2075	312	92	2790
Poreo	9	20	1		29
Pupu	26	12	149	112	300
Rori P'katoro	2	5	6	1	14
Rori toto	94	1232	472	478	2276
Trow Pitar Venus	1			1	2
Ungakoa	342	13	293	1333	1981
Vana	1	25	56		82

If less then 4 transects were laid the resulting count was standardised with an equalising multiple.

Among the sites surveyed there was not a large difference in diversity of reef resources (**Table 3**). Statistical tests (special t-test) failed to find significant differences of diversity among the sites ($P > 0.05$). The index of diversity, H', was greatest at *site 3* ($H' = 0.691$) indicating that this site had the most diverse range of reef resource species. The diversity index at the other sites was 0.563, 0.407 and 0.473 for *sites 1, 2* and *4*, respectively.

Site 3 also had the greatest index for evenness, J' ($J' = 0.640$). This is in contrast to *site 2* which had the lowest value for evenness (i.e $J' = 0.377$). At *site 2* the level of heterogeneity is affected by the large numbers of Paua and Rori toto.

Table 3 Diversity Indices of Reef Resources.

Statistic	*Site 1*	*Site 2*	*Site 3*	*Site 4*
Diversity, H'	0.563	0.407	0.691	0.473
Maximum diversity, H'max	1.079	1.079	1.079	1.041
Evenness, J'	0.522	0.377	0.640	0.454

Insert **Template D**.

Distribution patterns.
Density distribution patterns at the survey sites and with distance from the reef are shown in **Figures 5, 6, 7 and 8**. Statistical analysis was not performed on species which rarely occurred. This includes, Ariri, Koura, Trow Venus, Mapi and Etu. The means by levels of site and distance are shown with details of the ANOVA tests of distribution (**Appendix II**). A transformation of $\log_{10} + 1$ was applied to raw data prior to computation to improve homoscedasity of the data. The results are summarised in **Table 4**.

Site 2 located on the leeward side of the island had significantly higher ($P < 0.05$) abundance of Paua, Poreo and Rori toto. This reef site occurs adjacent to a relatively deep lagoonal area with numerous small patch reefs and a sandy bottom. The patch reefs and rocky bottom are ideal habitat for the Paua population. The high density of Rori toto may be influenced by the depth of the lagoon water and sandy bottom. *Site 3* had a significantly greater density of Pupu and Rori puakatoro. This area is on the windward side and the bottom cover is mostly of hard, smooth coral. It may explain the high density of Pupu shells. The greatest abundance of Ungakoa were recorded at the leeward side at *site 4*.

Among the species analysed only the Mangeo had significant density distribution patterns affected by distance from reef edge. High densities were found in the 5 meter strata closest to the reef edge.

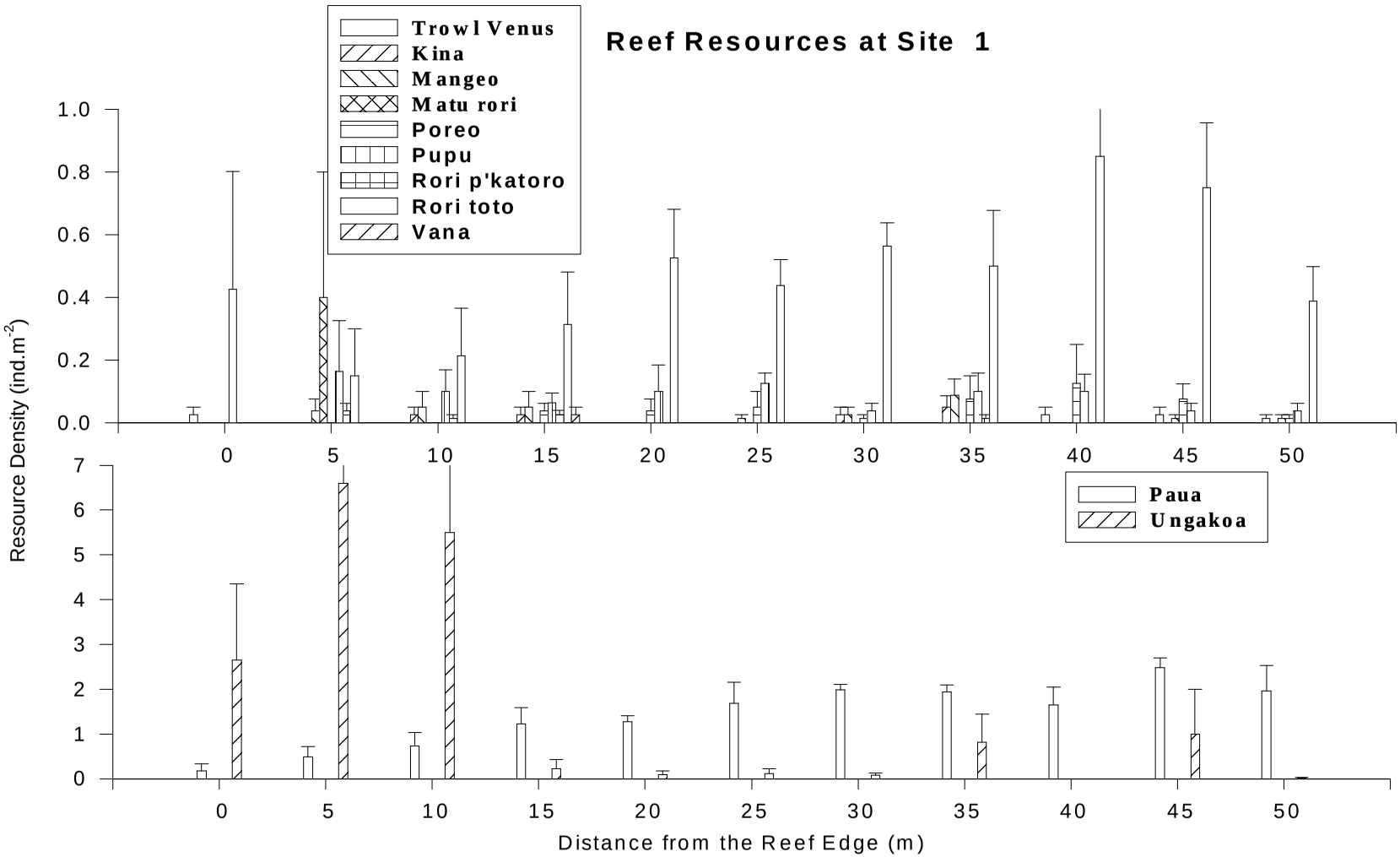

Figure 5 Reef Resource Types and Distribution Patterns at *Site 1*.

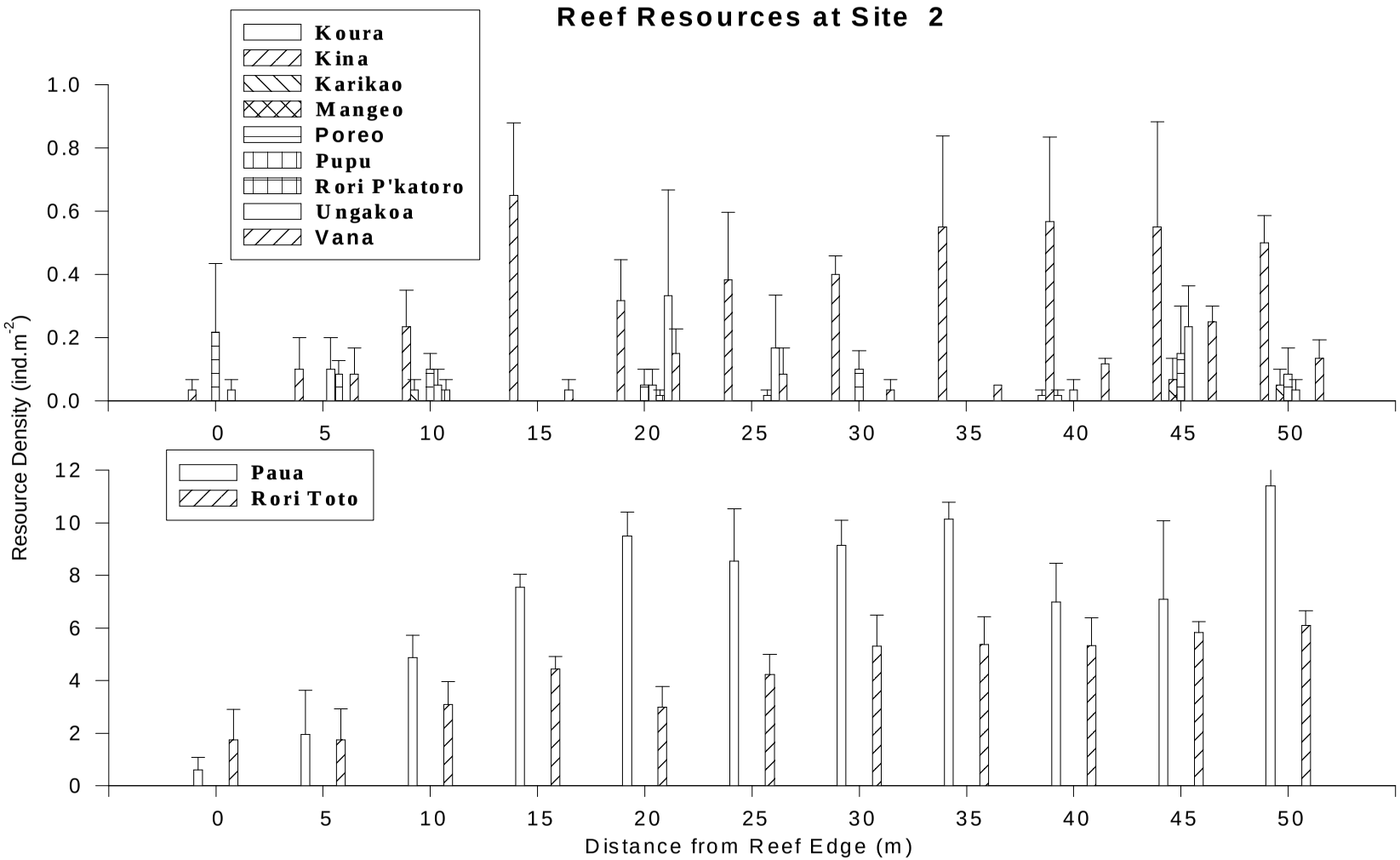

Figure 6 Reef Resource Types and Distribution Patterns at *Site 2*.

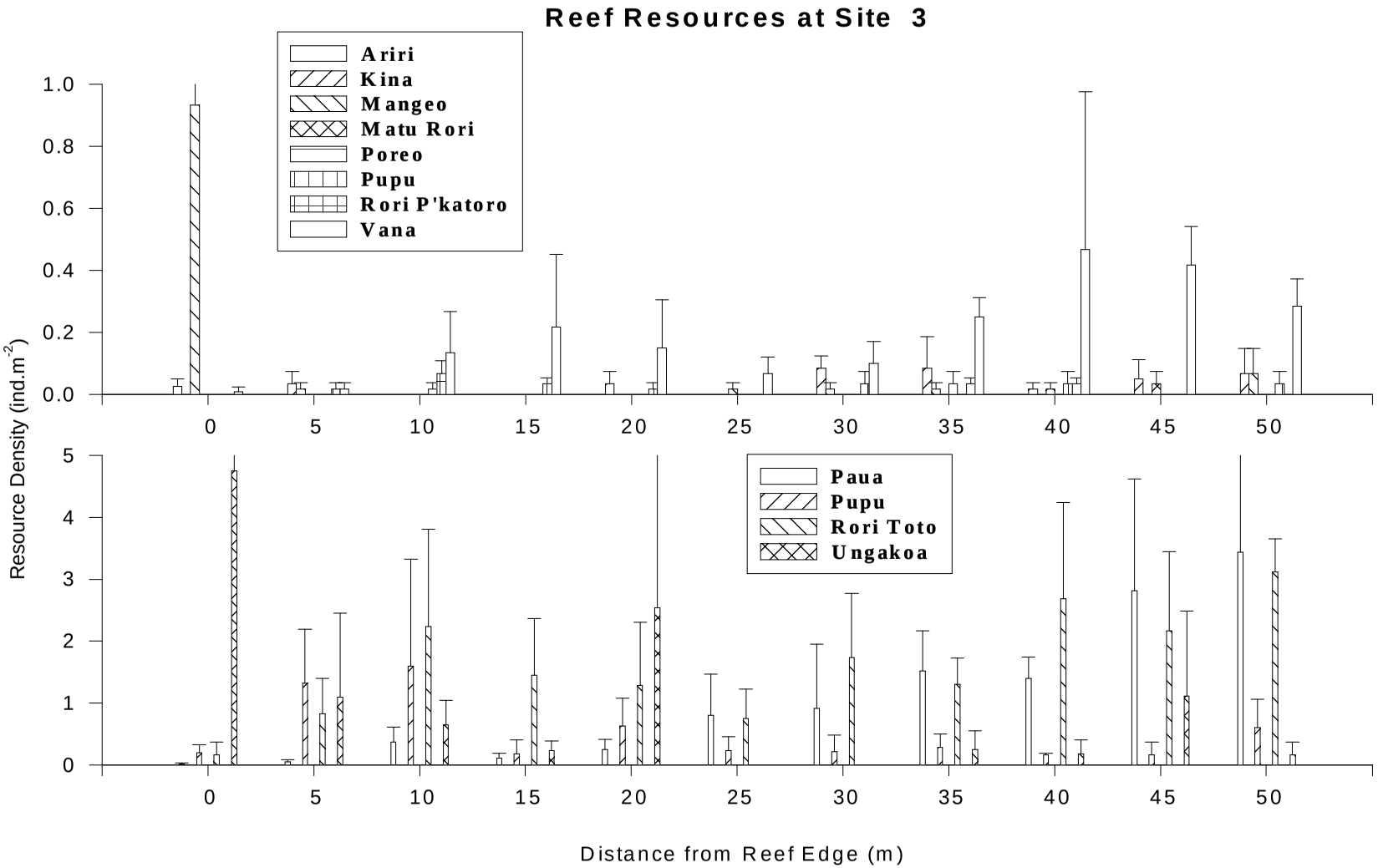

Figure 7 Reef Resource Types and Distribution Patterns at *Site 3*.

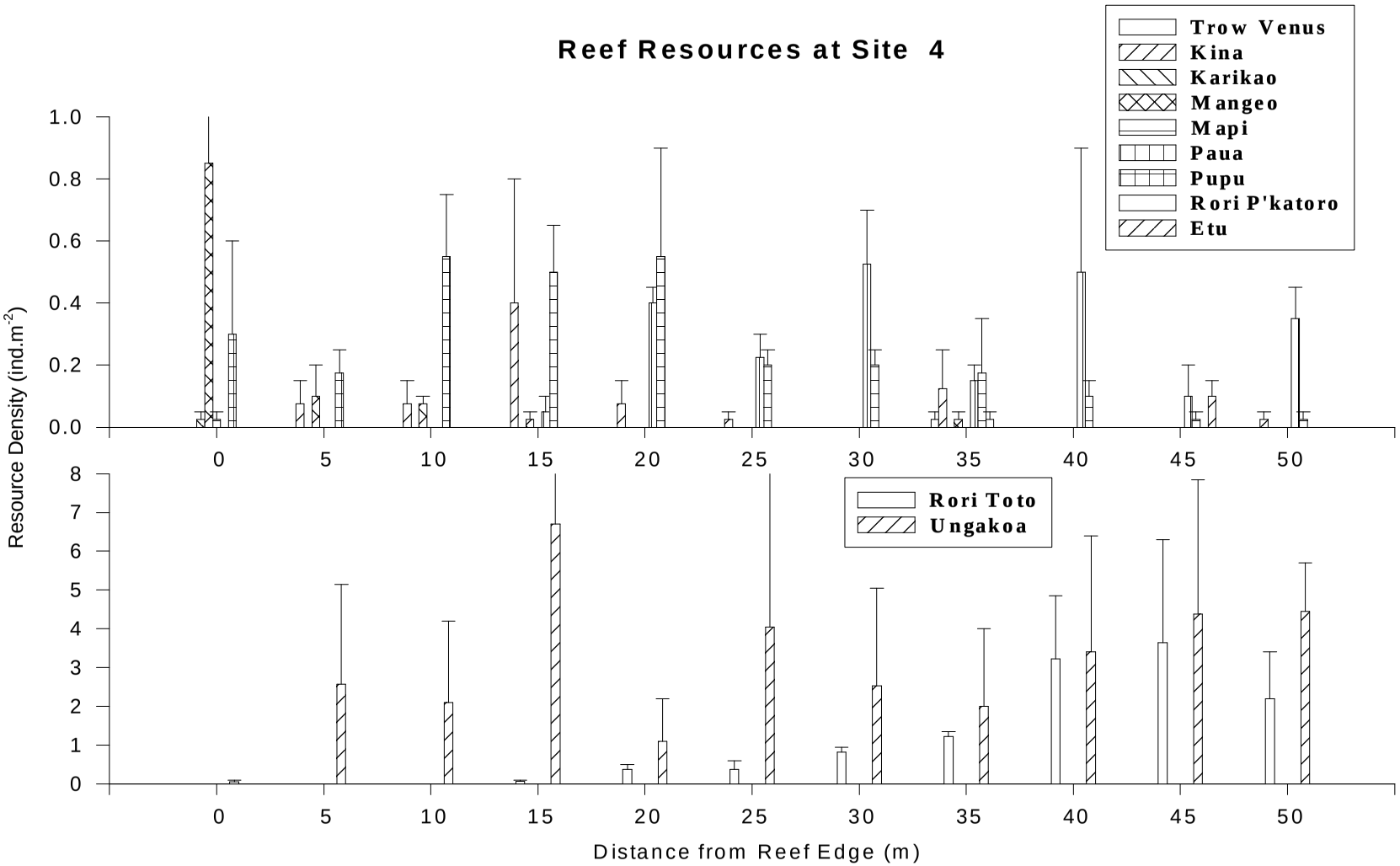

Figure 8 Reef Resource Types and Distribution Patterns at *Site 4*.

Table 4 Resource distribution patterns at Manuae reef with site and distance from reef.

Resource	Tests	Result	Site Density (ind.20m^{-2})	Conclusion
Kina	2-way ANOVA Tukeys HSD	site = ** distance = n.s	*site 1* = 0.2424 (subset 1) *site 3* = 0.6667 (subset 1) *site 4* = 1.4545 (subset 1) *site 2* = 7.7879 (subset 2)	- *site 2* density > *site 1*, *site 3* and *site 4* density. - no difference in density with density.
Karikao	2-way ANOVA	site = n.s distance = n.s	*site 2* = 0.0909 (subset1) *site 4* = 0.0455 (subset 1)	-no difference in density with site. -no difference in density with distance.
Mangeo	2-way ANOVA Tukeys HSD	site = n.s distance = *	*site 1* = 0.4848 (subset1) *site 2* = 0.2121 (subset 1) *site 3* = 1.9091 (subset 1) *site 4* = 1.9545 (subset 1)	-no difference in density with site. -density in the 5 m strata from reef > all other strata.
Matu rori	2-way ANOVA	site = n.s distance = n.s	*site 1* = 1.0000 (subset1) *site 3* = 0.1212 (subset 1)	-no difference in density with site. -no difference in density with distance.
Paua	2-way ANOVA Tukeys HSD	site = ** distance = **	*site 1* = 30.212 (subset1) *site 3* = 21.242 (subset 1) *site 4* = 4.1818 (subset 1) *site 2* = 141.45 (subset 2)	-*site 2* density > *site 1*, *site 2* and *site 3* density. -no difference in density with distance.
Poreo	2-way ANOVA Tukeys HSD	site = * distance = n.s	*site 1* = 0.6667 (subset1) *site 3* = 0.0606 (subset 1) *site 2* = 1.3333 (subset 2)	-*site 2* density > *site 1* and *site 3* density. -no difference in density with distance.
Pupu	2-way ANOVA Tukeys HSD	site = ** distance = n.s	*site 1* = 2.7879 (subset1) *site 2* = 0.8485 (subset 1) *site 4* = 5.0909 (subset 1) *site 3* = 10.181 (subset 2)	-*site 3* density > *site 1*, *site 2* and *site 4* density. -no difference in density with distance.
Rori puakatoro	2-way ANOVA Tukeys HSD	site = * distance = n.s	*site 1* = 0.1212 (subset1) *site 2* = 0.3333 (subset 1) *site 4* = 0.0455 (subset 1) *site 3* = 0.4242 (subset 2)	-*site 3* density > *site 1*, *site 2* and *site 4* density. -no difference in density with distance.

Resource	Tests	Result	Site Density (ind.m^{-2})	Conclusion
Rori toto	2-way ANOVA	site = **	*site 1* = 7.1212 (subset1)	-*site 2* density > *site 1*, *site 3* and *site 4* density.
	Tukeys HSD	distance = n.s	*site 3* = 32.212 (subset 1)	-no difference in density with distance.
			site 4 = 21.727 (subset 1)	
			site 2 = 84.000 (subset 2)	
Ungakoa	2-way ANOVA	site = **	*site 1* = 41.121 (subset1)	-*site 4* density > *site 1*, *site 2* and *site 3* density.
	Tukeys HSD	distance = n.s	*site 2* = 0.9091 (subset 1)	-no difference in density with distance.
			site 3 = 19.970 (subset 1)	
			site 4 = 60.591 (subset 2)	
Vana	2-way ANOVA	site = **	*site 1* = 0.0000 (subset1)	-*site 1* density < *site 2* and *site 3* density.
	Tukeys HSD	distance = n.s	*site 2* = 1.6970 (subset 2)	-no difference in density with distance.
			site 3 = 3.7353 (subset 2)	

n.s = non significant difference found among levels of factor, P > 0.05. * = significant difference found between levels of factors, P < 0.05
** = highly significant difference found between levels of factors, P < 0.001. Unless indicated, no significant interactive effects between site and distance factors found.

Population Abundance.
The population abundance (and 95% confidence interval) of reef species was calculated for the island using a rough estimate of reef circumference (18 kilometres) and reef width (100 m) to derive a total reef area of 1.8 km^2. The total population of species was then based on the overall density at the four sites surveyed multiplied by the reef area (**Table 5**).

In future a more accurate assessment could be performed by applying a stratified design based on the areas of significantly different densities. For example, greater densities of Paua occur at *site 2*. This site could be stratified from the areas at *sites 1* and *3* where medium densities occur and *site 4* where low densities of Paua are found. The precision of the assessment would also benefit by sampling more sites.

Table 5 Total Population and 95% Confidence Intervals of Reef Resources at Manuae Island.

Resource	Overall	se	Abundance	95% CI
Ariri	0.002		3 000	
Koura	0.002		3 000	
Trow Venus	0.004	0.0006	6 700	2 200
Kina	0.14	0.08	253 000	299 000
Karikao	0.004	0.0006	6 800	2 200
Mangeo	0.06	0.02	113 000	78 300
Mapi	0.003		4 500	
Matu rori	0.02	0.009	44 300	31 900
Paua	2.68	1.49	4 830 000	531 000
Poreo	0.04	0.01	71 500	51 000
Pupu	0.25	0.10	457 000	349 000
Rori pk'toro	0.01	0.004	23 800	14 500
Rori toto	2.01	0.79	3 620 000	2 800 000
Etu	0.01		18 000	
Ungakoa	1.55	0.59	2 780 000	2 120 000
Vana	0.10	0.04	185 000	153 000

Note: The abundance of Ariri is underestimated as on the windward side of the island, large numbers were observed to congregate close to the reef edge. Due to the wave action, surveyors were unable to study this zone.

The reef resources were distinguished into three categories of population abundance. Species with a low total population (< 10 000 animals) included, Ariri, Koura, Karikao, Mapi and Trow Venus. Medium abundance species included, Etu, Kina, Mangeo, Matu rori, Poreo, Rori puakatoro and Vana, these number up to 300 000 animals. The species with a high population, i.e up to 5 000 000 animals include Paua, Pupu, Rori toto and Ungakoa. (**Figures 9, 10 and 11**).

Although the total population of a species may be relatively low compared to other reef species with a high population this does not imply that the abundance of that species is low. For instance, although the population of Koura is estimated as fewer then 3 000 animals, a population of this size may be quite abundant for an island of the size of Manuae. Therefore, the term abundance used in this report is only relative to other reef species present on the reef.

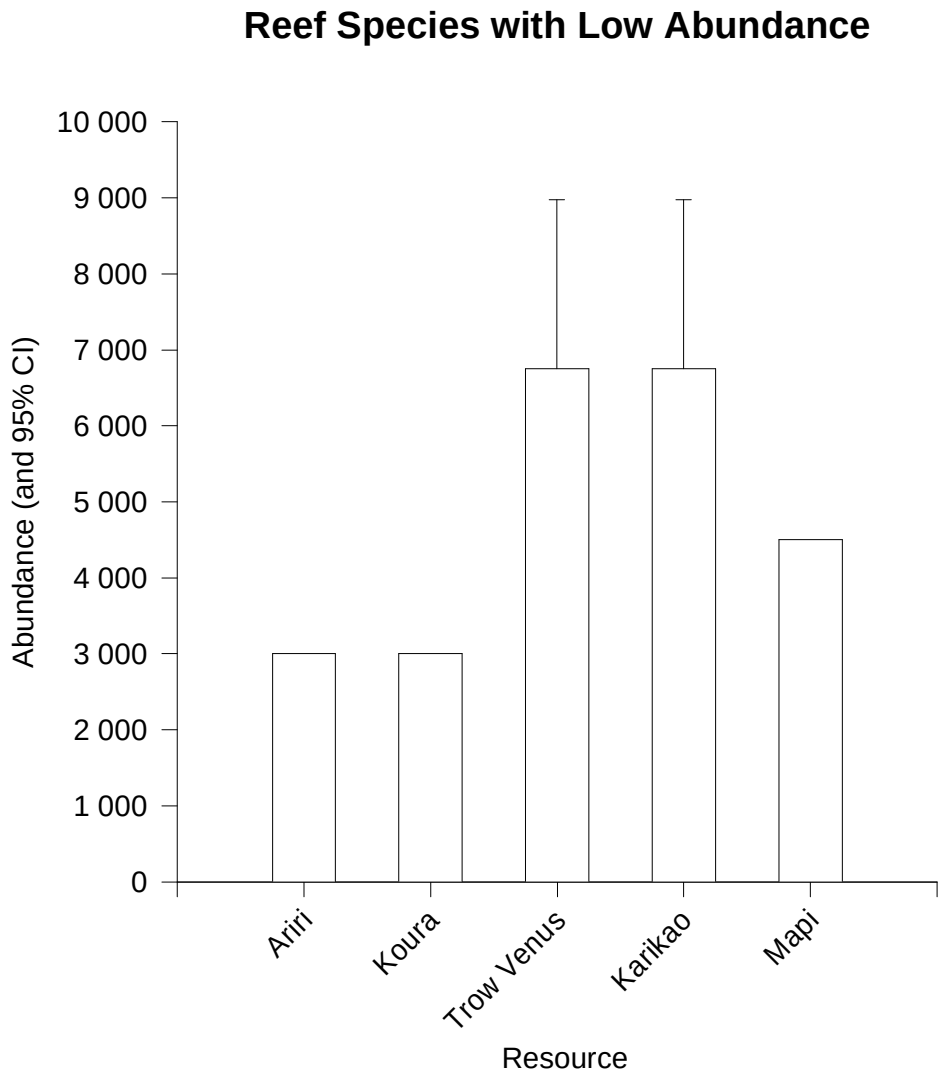

Figure 9 Reef Resources with a Low Total Population at Manuae Reef.

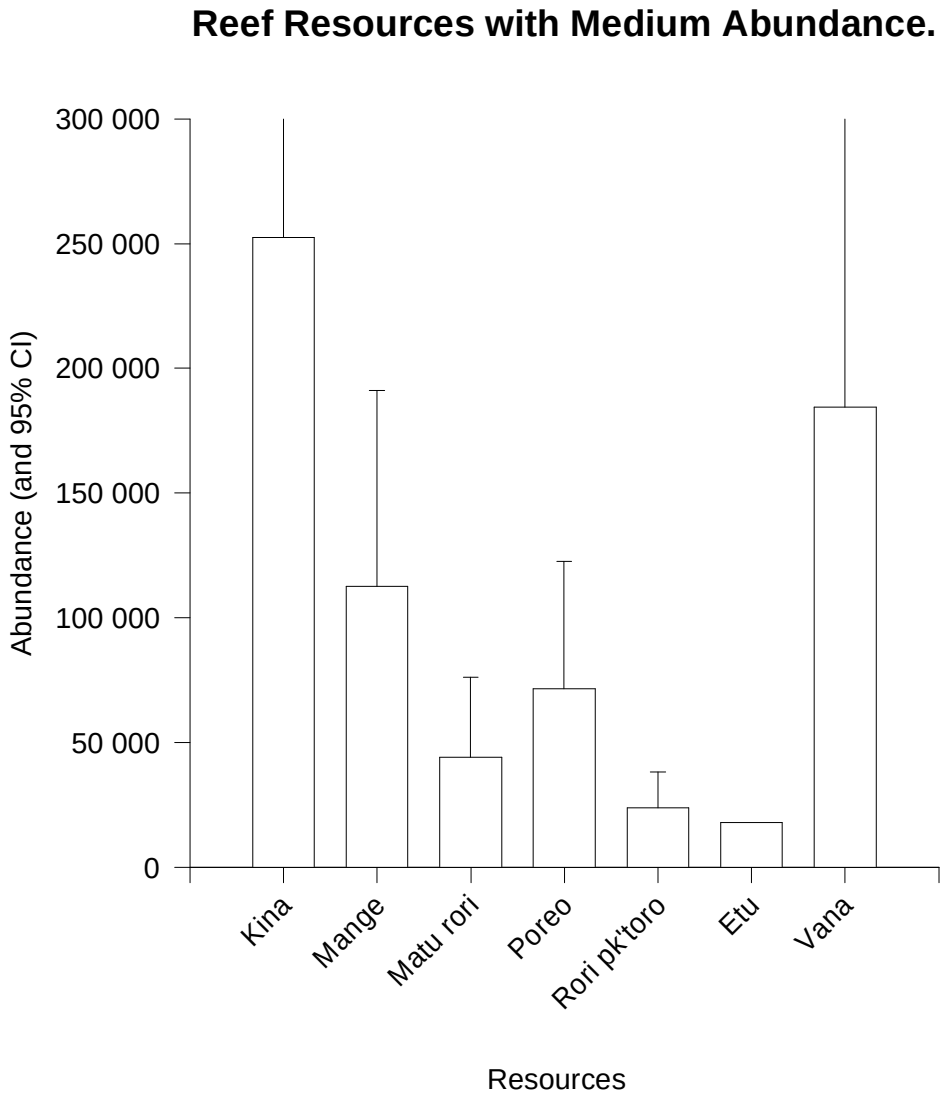

Figure 10 Reef Resources with a Medium Total Population at Manuae Reef.

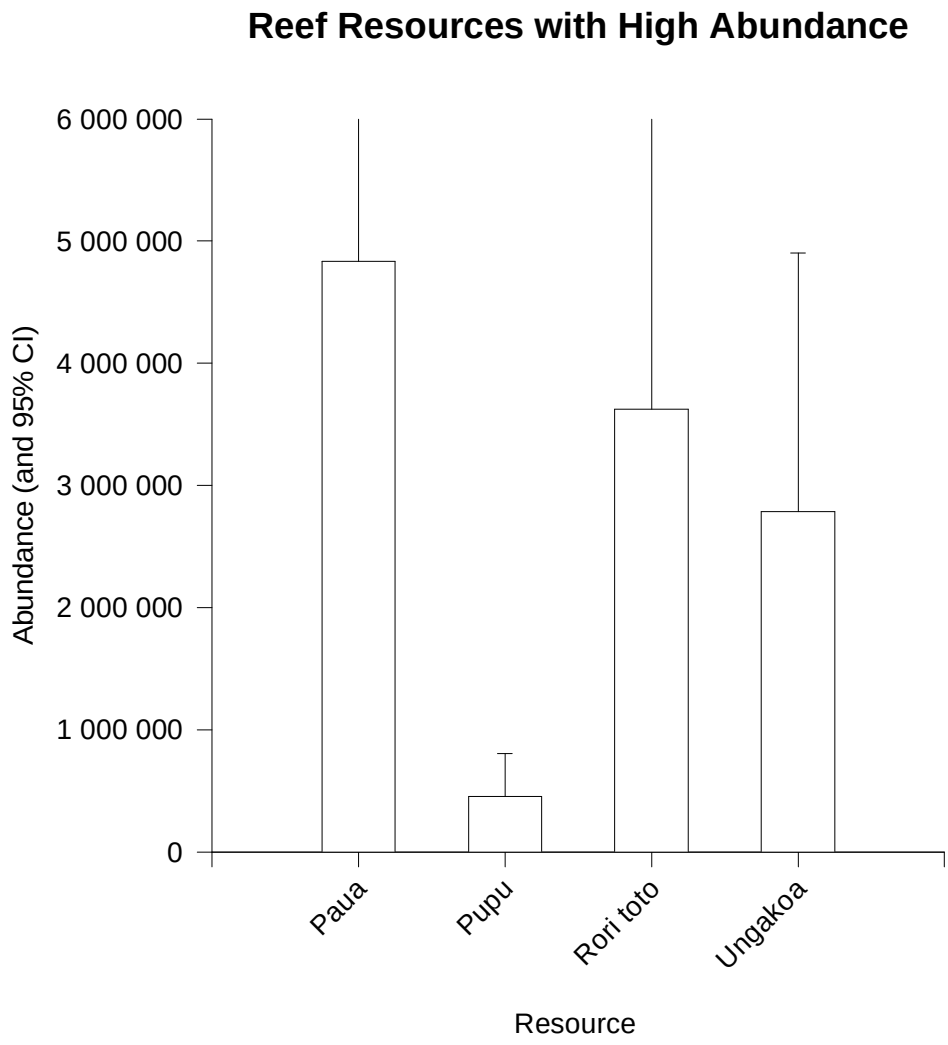

Figure 11 Reef Resources with a High Total Population at Manuae Reef.

DISCUSSION.

Coral cover inside the lagoon comprises mostly of non *Acropora* corals. Particularly, encrusting or soft coral forms. This may reflect the shallow water depth and sandy environmental conditions inside the lagoon. Algal assemblages are also a common benthos/coral cover type. There was little evidence inside the lagoon of recent coral mortality. It was reported by the Aitutakian contingent the survey team accompanied that a total of 230 crown of thorns were removed from the reef areas during this visit, (which only equates to 1.3 animals/hectare, the recent outbreak in Rarotonga recorded densities up to 10 times greater). In view of the survey results the impact of crown of thorn feeding on live coral cover does not appear substantial.

Coral cover on the outer reef slope is abundant and has diverse forms. Hard corals are the dominant cover, both *Acropora* and non *Acropora* species. The non *Acropora* forms included, coralline algae, submassive corals, table corals, and encrusting corals. The *Acropora* corals are comprised solely of branching and digitate forms. No recent coral mortality was observed. Coral succession appears quite rapid as most dead coral is already colonised by algal assemblages.

A total of 12 fish families (or sub family) types were recorded. The families are comprised of robust types that are common throughout the Pacific region. They include, Surgeonfishes (CI name Maito); Squirrelfishes, Ku (C.I); Rock cods, Patuki (C.I); Parrotfishes, Pakati (C.I); Damselfishes, Kaoti (C.I) and Goatfishes, Koma (C.I). From the few sites surveyed in the lagoon it appears that the dominant fish species is the lined bristletooth surgeonfish, known locally as Maito. Other common species include, the Brown cod, Patuki (C.I); the Yellow-mariginated sea bream, Tangau (C.I), and Archilles tang, Ikutoto (C.I). The lagoon possess an abundance of Trevallies, Titiara (C.I).

There were 12 reef resources recorded at the four reef sites surveyed. The site which had the most diverse reef resources is located on the windward side of the island (*site 3*). *Site 2* reef on the leeward side and adjacent to relative deep lagoon waters had a low diversity and evenness index. This is because of the large numbers of Paua, Rori toto and Kina compared to the other sites surveyed.

Statistical analysis of the distribution patterns of the resources suggests that species density remains the same regardless of the distance from the reef edge (up to 50 m). Some differences among the four survey sites was found. For example, *site 2* had significantly greater density of Paua, Poreo and Rori toto. Whereas, *site 3* has the significantly greatest density of Pupu and Rori puakatoro.

The total abundance of reef species at Manuae Island varies and can be categorised as high (up to 5 million animals), medium (up to 300 thousand animals) and low (up to 10 thousand animals). High abundance reef species included, Paua, Rori toto, Ungakoa and Pupu. The species with medium abundance includes, Kina, Vana, Mangeo, Poreo, Matu rori, Rori puakatoro and Etu. Low abundance species include, Trow Pitar Venus, Karikao, Mapi, Koura and Ariri. In addition to abundance estimates, 95% confidence intervals are calculated which can be as large as the abundance figure itself. A stratified design and more intensive sampling may improve the accuracy and precision of abundance estimates.

The results of this study can be utilised to identify areas where the placement of marine reserves may have the most benefit. It is suggested that the large lagoonal patch reef between Arekai and Ruakau lagoonal area be given some protection status as this is the only area where such a reef occurs. These

patch reefs are an important habitat area for the marine life and the coral formations at the reef are the best representation of the diversity to be found in the lagoon. To maintain the reef resources there are two attractive areas which could serve as a reserve. These are the areas at *site 3* (on the windward side) or at *site 2* (on the leeward side). Either area has a diverse range and abundance of reef resources. A factor to consider is that *site 2* area is close to the main settlement area whereas *site 3* is far from it. Although a reserve close to the settlement may be easier to enforce it is also more prone to visits. The outer reef zone adjacent to the reef area selected as a reserve could also be given some protection status. The coral formations are fairly diverse and should be left intact if possible. This zone would only extend out about 50 meters as the ridge is fairly narrow and rapidly descends to deep depths.

REFERENCES.

English, S, Wilkinson, C and Baker, V. (Eds). (1994). Survey manual for tropical marine resources. Australian Institute of Marine Science (AIMS), Australia.

Zar, J. H. (1984). Biostatistical analysis. (2nd Edition). Prentice Hall, New Jersey.

APPENDIX 1

Diversity.

A. Shannon-Weiner diversity index, H' is

$$H' = \frac{n \log n - \sum_{(i=1)}^{(k)} f_i \log f_i}{n}$$

where: n = sample size; f_i = number of observations in category i.

B. Where maximum possible diversity for k categories is

$$H'_{max} = \log k$$

C. Evenness J' may be calculated as

$$J' = \frac{H'}{H_{max}}$$

D. The t -test of the null hypothesis that the diversity of two sampled populations is equal whereby

$$t \text{ statistic} = \frac{H'_1 - H'_2}{s_{H'1} - s_{H'2}}$$

where, $s_{H'1-H'2} = \text{sqrt}(s^2_{H'1} + s^2_{H'2})$ and $s^2_H = \frac{\sum f_i \log^2 f_i - (\sum f_i \log f_i)^2 / n}{n^2}$

Standard Error s.e, or (variance of mean)

Standard error, s.e = sqrt(standard deviation) / n
where n = number of samples.

Confidence intervals, C.I (95% confidence)

95% Confidence Interval (CI) = (s.e) $t_{2,0.05}n-1$
with t value derived from t table with n - 1 degrees of freedom.

APPENDIX II.

KINA

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			2.6364
DISTANCE	1.00	(0 m)	.1818
DISTANCE	2.00	(5 m)	1.0000
DISTANCE	3.00	(10 m)	1.5455
DISTANCE	4.00	(15 m)	5.0000
DISTANCE	5.00	(20 m	2.1818
DISTANCE	6.00	(25 m)	2.1818
DISTANCE	7.00	(30 m)	2.8182
DISTANCE	8.00	(35 m)	4.1818
DISTANCE	9.00	(40 m)	3.1818
DISTANCE	10.00	(45 m)	3.4545
DISTANCE	11.00	(50 m)	3.2727
SITE	1.00		.2424
SITE	2.00		7.7879
SITE	3.00		.6667
SITE	4.00		1.4545

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	7.42	77	.10		
SITE	10.30	3	3.43	35.65	.000
DISTANCE	1.46	10	.15	1.51	.151
SITE BY DISTANCE	2.59	30	.09	.90	.622

Multiple Range Tests: Tukey-HSD test with significance level .050

```
                G G G G
                r r r r
                p p p p
                1 3 4 2
  SITE
   .2424   Grp 1
   .6667   Grp 3
   1.454   Grp 4
   7.787   Grp 2     * * *
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

KARIKAO

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			.0727
DISTANCE	1.00		.2000
DISTANCE	2.00		.0000
DISTANCE	3.00		.4000
DISTANCE	4.00		.0000
DISTANCE	5.00		.0000
DISTANCE	6.00		.0000

DISTANCE	7.00	.0000
DISTANCE	8.00	.0000
DISTANCE	9.00	.2000
DISTANCE	10.00	.0000
DISTANCE	11.00	.0000

SITE	1.00	.0909
SITE	2.00	.0455

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	.26	33	.01		
DISTANCE	.05	10	.01	.66	.754
SITE	.00	1	.00	.17	.687
DISTANCE BY SITE	.07	10	.01	.88	.564

- -

MANGEO

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			1.0661
DISTANCE	1.00		8.1818
DISTANCE	2.00		.7273
DISTANCE	3.00		.6364
DISTANCE	4.00		.4545
DISTANCE	5.00		.0000
DISTANCE	6.00		.0909
DISTANCE	7.00		.0909
DISTANCE	8.00		.5455
DISTANCE	9.00		.0000
DISTANCE	10.00		.3636
DISTANCE	11.00		.6364
SITE	1.00		.4848
SITE	2.00		.2121
SITE	3.00		1.9091
SITE	4.00		1.9545

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	4.95	77	.06		
DISTANCE	1.62	10	.16	2.52	.011
SITE	.34	3	.11	1.77	.160
DISTANCE BY SITE	2.77	30	.09	1.44	.104

- -

MATU RORI

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			.5606
DISTANCE	1.00		.0000
DISTANCE	2.00		5.3333
DISTANCE	3.00		.0000
DISTANCE	4.00		.0000

DISTANCE	5.00	.0000
DISTANCE	6.00	.1667
DISTANCE	7.00	.0000
DISTANCE	8.00	.0000
DISTANCE	9.00	.1667
DISTANCE	10.00	.5000
DISTANCE	11.00	.0000

SITE	1.00	1.0000
SITE	2.00	.1212

Matu rori

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1.87	44	.04		
DISTANCE	.39	10	.04	.91	.530
SITE	.01	1	.01	.20	.661
DISTANCE BY SITE	.41	10	.04	.97	.484

- -

PAUA

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			53.3719
DISTANCE	1.00		4.7273
DISTANCE	2.00		13.1818
DISTANCE	3.00		32.3636
DISTANCE	4.00		48.2727
DISTANCE	5.00		62.1818
DISTANCE	6.00		62.9091
DISTANCE	7.00		68.1818
DISTANCE	8.00		74.4545
DISTANCE	9.00		57.4545
DISTANCE	10.00		69.0000
DISTANCE	11.00		94.3636
SITE	1.00		30.2121
SITE	2.00		141.4545
SITE	3.00		21.2424
SITE	4.00		4.1818

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	11.92	77	.15		
DISTANCE	19.41	10	1.94	12.54	.000
SITE	32.69	3	10.90	70.41	.000
DISTANCE BY SITE	5.50	30	.18	1.18	.273

Multiple Range Tests: Tukey-HSD test with significance level .050

G G G G
r r r r
p p p p
4 3 1 2

SITE

4.181 Grp 4
21.24 Grp 3

30.212 Grp 1 * *
141.45 Grp 2 * * *
- -

POREO
Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			.6869
DISTANCE	1.00		1.4444
DISTANCE	2.00		.0000
DISTANCE	3.00		.6667
DISTANCE	4.00		.2222
DISTANCE	5.00		.6667
DISTANCE	6.00		.4444
DISTANCE	7.00		.6667
DISTANCE	8.00		.2222
DISTANCE	9.00		1.3333
DISTANCE	10.00		1.2222
DISTANCE	11.00		.6667
SITE	1.00		.6667
SITE	2.00		1.3333
SITE	3.00		.0606

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	4.64	66	.07		
DISTANCE	.25	10	.02	.36	.961
SITE	.53	2	.26	3.76	.028
DISTANCE BY SITE	1.13	20	.06	.81	.698

Multiple Range Tests: Tukey-HSD test with significance level .050

G G G
r r r
p p p
3 1 2

SITE
.0606 Grp 3
.6667 Grp 1
1.333 Grp 2 *
- -

PUPU
Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			4.6942
DISTANCE	1.00		5.2727
DISTANCE	2.00		9.5455
DISTANCE	3.00		11.6364
DISTANCE	4.00		3.2727
DISTANCE	5.00		6.4545
DISTANCE	6.00		2.7273
DISTANCE	7.00		2.0000

DISTANCE	8.00	2.5455
DISTANCE	9.00	1.8182
DISTANCE	10.00	2.5455
DISTANCE	11.00	3.8182

SITE	1.00	2.7879
SITE	2.00	.8485
SITE	3.00	10.1818
SITE	4.00	5.0909

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	16.30	77	.21		
DISTANCE	1.60	10	.16	.75	.671
SITE	5.70	3	1.90	8.98	.000
DISTANCE BY SITE	4.36	30	.15	.69	.875

Multiple Range Tests: Tukey-HSD test with significance level .050

	G	G	G	G
	r	r	r	r
	p	p	p	p
	2	1	4	3

SITE		
.8485	Grp 2	
2.787	Grp 1	
5.090	Grp 4	*
10.18	Grp 3	* *

- -

RORI PUAKATORO

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			.2479
DISTANCE	1.00		.1818
DISTANCE	2.00		.6364
DISTANCE	3.00		.6364
DISTANCE	4.00		.2727
DISTANCE	5.00		.1818
DISTANCE	6.00		.0909
DISTANCE	7.00		.1818
DISTANCE	8.00		.3636
DISTANCE	9.00		.1818
DISTANCE	10.00		.0000
DISTANCE	11.00		.0000
SITE	1.00		.1212
SITE	2.00		.3333
SITE	3.00		.4242
SITE	4.00		.0455

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1.52	77	.02		
DISTANCE	.28	10	.03	1.40	.194
SITE	.18	3	.06	3.02	.035
DISTANCE BY SITE	.54	30	.02	.91	.603

Multiple Range Tests: Tukey-HSD test with significance level .050

```
                G G G G
                r r r r
                p p p p
                4 1 2 3
SITE
    .0455  Grp 4
    .1212  Grp 1
    .3333  Grp 2
    .4242  Grp 3     *
```

- -

RORI TOTO

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			37.5868
DISTANCE	1.00		10.4545
DISTANCE	2.00		15.1818
DISTANCE	3.00		30.2727
DISTANCE	4.00		33.2727
DISTANCE	5.00		26.9091
DISTANCE	6.00		30.6364
DISTANCE	7.00		44.1818
DISTANCE	8.00		42.6364
DISTANCE	9.00		59.4545
DISTANCE	10.00		60.3636
DISTANCE	11.00		60.0909
SITE	1.00		7.1212
SITE	2.00		84.0000
SITE	3.00		32.2121
SITE	4.00		21.7273

- -

UNGAKOA

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			27.9256
DISTANCE	1.00		45.3636
DISTANCE	2.00		63.3636
DISTANCE	3.00		51.1818
DISTANCE	4.00		27.2727
DISTANCE	5.00		20.2727
DISTANCE	6.00		16.4545
DISTANCE	7.00		9.3636
DISTANCE	8.00		14.0909
DISTANCE	9.00		13.3636
DISTANCE	10.00		29.2727
DISTANCE	11.00		17.1818
SITE	1.00		41.1212

SITE	2.00	9.091
SITE	3.00	19.9697
SITE	4.00	60.5909

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	48.57	77	.63		
DISTANCE	2.20	10	.22	.35	.964
SITE	16.10	3	5.37	8.51	.000
DISTANCE BY SITE	13.31	30	.44	.70	.859

Multiple Range Tests: Tukey-HSD test with significance level .050

	G G G G
	r r r r
	p p p p
	2 3 1 4
SITE	
9.091 Grp 2	
19.96 Grp 3	
41.12 Grp 1	*
60.59 Grp 4	* *

- -

VANA

Means per 20 m^2 quadrant By levels of DISTANCE and SITE

Variable	Value	Label	Mean
For Entire Population			1.8300
DISTANCE	1.00		1.0000
DISTANCE	2.00		.6667
DISTANCE	3.00		.1111
DISTANCE	4.00		1.1111
DISTANCE	5.00		2.4444
DISTANCE	6.00		1.5556
DISTANCE	7.00		.7778
DISTANCE	8.00		1.4444
DISTANCE	9.00		1.8889
DISTANCE	10.00		5.5556
DISTANCE	11.00		3.6667
SITE	1.00		.0000
SITE	2.00		1.6970
SITE	3.00		3.7353

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	5.18	67	.08		
DISTANCE	2.28	10	.23	2.95	.004
SITE	3.89	2	1.94	25.15	.000
DISTANCE BY SITE	1.61	20	.08	1.04	.433

Multiple Range Tests: Tukey-HSD test with significance level .050

	G G G
	r r r
	p p p
	1 2 3
SITE	

.0000 Grp 1
1.697 Grp 2 *
3.735 Grp 3 *
- -