INSHORE INVERTEBRATE RESOURCE ASSESSMENT OF RAROTONA ISLAND.

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ABSTRACT.

This study is a report of the diversity, distribution, abundance and harvest potential of twenty-two inshore invertebrate resources at Rarotonga Island. Information for this survey was collected island wide at twenty-one sites covering the reef and lagoon strata. Some survey sites are located at the recently designated Raui (reserve) areas. A wide range of diversity indices (Shannon-Weiner index) was recorded, including, significantly different ($P<0.05$) indices among sites within the Raui area. The highest resource index is at the Rarotongan Hotel area where the benthic habitats are relatively undisturbed. In contrast the least diverse site is located at the main township area which is subject to more intensive human pressures. The distribution pattern of some resources indicates that the density differs depending on the distance from the reef edge. For instance, the significantly ($P<0.05$) greater densities of Rori Pua close to the reef edge is attributed to its ability to occupy this high wave action zone. In contrast, the Kina and Rori Toto are less tolerant of wave action and were found further back from the reef edge. Among-site differences were also detected at the Raui areas - notably at the Nikao Raui, whereby Black Rock site had significantly greater densities of Karikao, Kina, Matu Rori and Trochus then the Social Center or Sea Wall. In addition, site and distance factors interactively affected distribution as was the case of Aroko Raui for the Paua, Vana, Avake, Etu and Rori Puakatoro. An assessment of population abundance indicates that about 98% of the resources numbers comprise of Matu Rori, Kina, Rori Toto, Rori Pua, Rori Matie and Trochus. The population estimate for these individual resources range from about 9 million Matu Rori to half a million Trochus. It is suggested that these six resources are sufficiently abundant to sustain a commercial harvest. This equates to 13 tons of Trochus shell worth NZ$133 thousand and 15 tons of dried Rori with a value of NZ$73 thousand and 570 thousand Kina worth NZ$115 thousand.

INTRODUCTION.

In 1995 the contribution to the Cook Islands gross domestic product (GDP) from agriculture and fisheries (including pearls) was 21 percent. Of this the nominal value of the subsistence fishery was estimated at about 5%.

Presently, few invertebrate resources on Rarotonga are exploited for commercial purposes. In other islands of the Cook group some inshore invertebrates that are commercially harvested include the black-lip pearl oyster, trochus and sea-cucumbers. Harvesting of invertebrates on Rarotonga is most typically for subsistence purposes.

Subsistence fishing (ranging from shellfish collection to deep-sea fishing) is practised widely throughout the Cook Islands. In a 1996 census (Government Statistics Dept) it was reported that 67% of the households were engaged in this activity. At Rarotonga (which comprises more then half of the resident population), 30% of those >15 years old were engaged in some sort of fisheries subsistence activity. On Rarotonga, inshore and reef gleaning for invertebrates is most often carried out by womenfolk. Particular attention is given to edible invertebrates such as the giant clam, sea-cucumbers, sea-urchins and shellfish.

Although inshore fisheries are of significant social-economic importance, relatively little is known of their status. Baquie (1997) provides a description of subsistence harvesting of some invertebrate resources on Rarotonga. The Natural Heritage Project (Government of the Cook Islands) has identified >280 reef invertebrate species in the Cook Islands, accounting for most species at Rarotonga (McCormack, pers. comm.). Some information of the trochus and sea-cucumber at Rarotonga has been collected (Zoutendyk, 1988; Bertram and Maruraii, 1993; Roi and Raumea, 1997; Ponia and Raumea, 1998; Roi, 1998 *unpub data*).

The Ministry of Marine Resources has the legislated responsibility for management of the marine resources. In reality, many small-scale inshore fisheries are often managed at the island council level. On the capital island of Rarotonga, a recent revival of a traditional management system has resulted in the implementation of five Raui (temporary marine reserve) areas by the authority of a traditional leadership council (Te Koutu Nui). To maintain effective linkages with local Government bodies the Ministry of Marine Resources provides technical advice and assistance when required.

The purpose of this paper is to provide an assessment of the inshore invertebrate resources at Rarotonga, i.e, an identification of resource types, their distribution, abundance and harvest quota. The long-term aim of such an effort is to encourage sustainable subsistence and commercial usage of these resources.

GENERAL MATERIALS AND METHODS.

Ministry of Marine Resources staff undertook field work for this survey on various occasions in 1998. A total of twenty one sites were surveyed, 16 were located on the fringing reef and the remaining five within the lagoon area. Landmarks of the reef survey sites (in clockwise order) include the Catholic Church, Club Raro Resort, Matavera Raui – Turepu, Matavera Raui - Whittiker, Aroko Raui – Motutapu, Aroko Raui – Oneroa, Aroko Raui - Koromiri, Tikioki Raui – Tikioki Road, Tikioki Raui – Packing Shed, Rutaki Raui – Avaiti Passage, Rutaki Raui – Rutaki Passage, Rarotongan Hotel, Tumunu Restaurant, Nikao Raui – Black Rock, Nikao Raui – Social Center, Nikao Raui – Sea Wall (**Figure 1**). The lagoon sites were adjacent to the reef sites with the exception of Matavera Raui, Rutaki Raui and Tumunu (**Figure 1**).

At the Raui areas, more intensive reef (i.e two or three sites) sampling was performed because this information was intended as a baseline reference of the invertebrate resource.

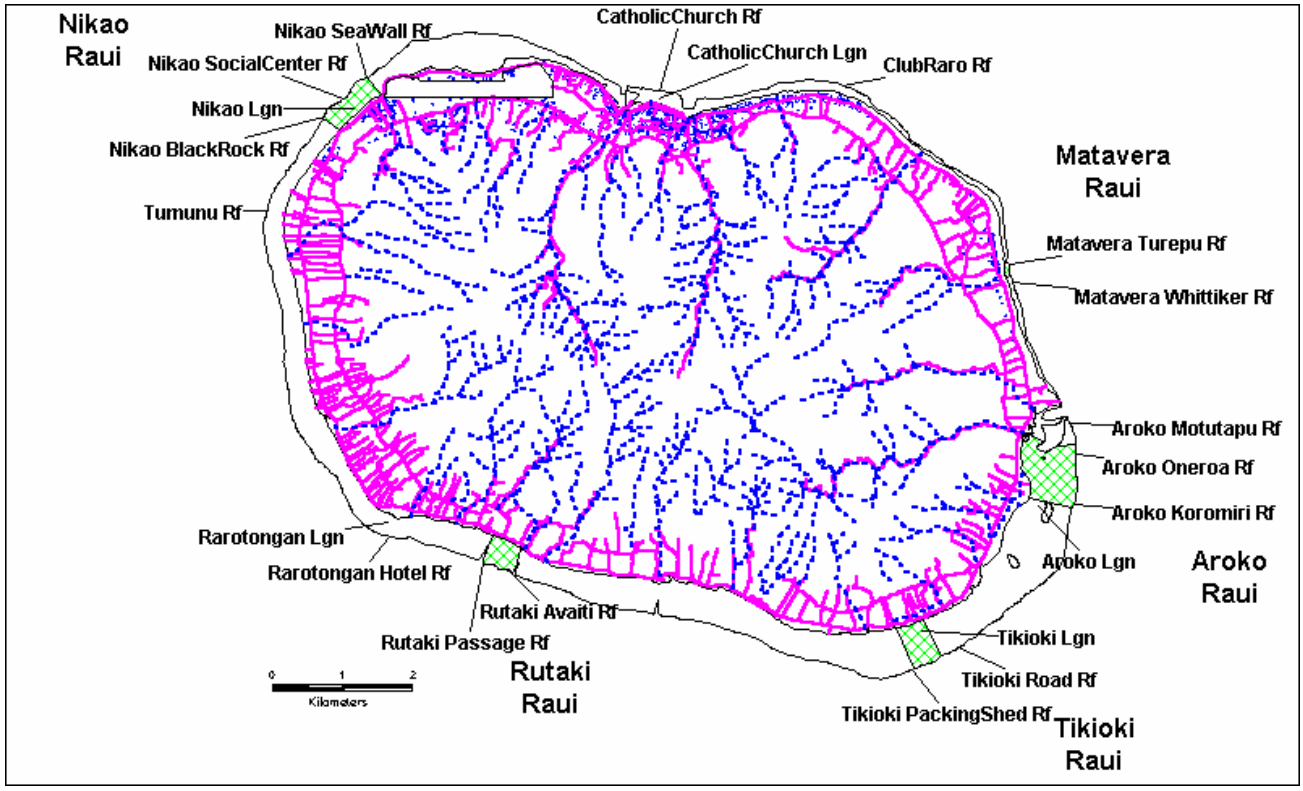

Figure 1. Map of Rarotonga Island showing the Survey Sites. Also shown (shaded) are the Raui (Reserve) Areas.

At reef sites, four replicate line transects of 50 meter length were placed perpendicular to the reef (as close as possible to the reef edge and about 30 meters apart). In the lagoon, six replicate transects were placed, perpendicular to the shoreline (randomly located from the shore). After securing the transect, two observers would systematically search a 2 meter band on either side of the line. At each 5 meter length they would stop to report the resource types and counts. Invertebrate resources being broadly defined as invertebrate species of edible, cultural or possible commercial values.

The Shannon-Weiner diversity index was calculated at each site to measure the diversity of resources (Zar, 1984) (**Appendix I**). The index is a measure of both, the number of species and their abundance (maximum diversity for n species is $\log_{10}(n)$). It also serves as measure of evenness or spread (evenness = diversity index/maximum diversity). A statistical t-test was used to determine whether the diversities between the two sampled populations were the same.

At reef sites, the resources were examined statistically for density distribution patterns. At the Raui areas a two-way ANOVA model was used that tested the two factors of (1) distance from reef and (2) among site differences. At the single reef sites, outside the Raui, a one-way ANOVA was utilised, only testing the effect of distance. Where significant differences ($P < 0.05$) in density were found the data was further differentiated *a posteriori* using Tukeys HSD test. (To improve homoscedasity of variance the raw data for some species had to be log + 1 transformed prior to statistical analysis. Resources that rarely occur were not examined for a distribution pattern because the statistical power of these tests would be unacceptably low. The lagoon sites were not tested statistically for distribution patterns because transects were randomly laid within the lagoon strata).

The resource population size was determined simply as the product of its density and habitat area. The reef and lagoon strata were calculated separately first and then combined as a simple stratified assessment for the whole inshore area of Rarotonga. Estimates of area were derived from Geographical Information System (GIS) rectified aerial images and a digital map of the island. The reef area on Rarotonga (1.75 km^2) was calculated as the product of the outer reef perimeter (35 km) and a width of 50 meters. The area of lagoon strata, (8.4 km^2), was the difference between the total inshore area (10.2 km^2) and the reef strata.

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 (**Appendix I**).

RESULTS.

RESOURCE DIVERSITY.

A total of twenty-two different resources were recorded during the survey (**Table 1**), (this study has adopted the island's traditional system of taxonomy that may not differentiate among species). Most of the resources fit into the broad categories of edible shellfishes, sea-urchins, sea-cucumbers and sea-shells, (Refer to **Template A**).

Table 1. Invertebrate Resources Surveyed at Rarotonga.

Cook Island Name	Standard Name	Scientific Name
Edible Shell-fish		
Ariri	Rough Turban shell	*Turbo setosus*
Karikao	Rose Mouthed Turban-shell	*Astrea rhodostoma*
Mangeongeo	Muricidae Family.	Most common is *Drupa morum* and *D. ricinius ricinus.*
Paua	Rugose Giant-clam	*Tridacana maxima.*
Paua Kura	Large Pacific Jewel-Box shell	*Chama pacifica*
Trochus	Trochus	*Trochus niloticus*
Ungakoa	Large Worm snail	*Dendropoma maxima*
Sea-Urchin		
Atuke	Pencil Sea-urchin	*Heterocentrotus mammillatus,* and *H. trigonarius*
Avake	Short-spine Sea-urchin	*Tripneustus gracilla*
Kina	Pink Sea-urchin	*Echinometra mathaei (3 spp.)* and *E. oblonga*
Vana	Long-spine Sea-urchin	*Echinothrix diadema* and *E. calamaris*
Sea-Cucumber		
Matu Rori	Soft Black Sea-cucumber	*Holothuria leucospilota.*
Rori Kananae		*Holothuria Hilla, H. pervicax and H. fuscocinera*
Rori Pua	Flower Sea-cucumber	*Holothuria cinerascens*
Rori Ngata		*Stichopus horrens*
Rori Matie	Green Sea-cucumber	*Stichopus chloronotus*
Rori Puakatoro	Red Surf-fish	*Actinopyga mauritiana*
Rori Toto	Sandy Sea-cucumber	*Holothuria atra*
Sea Shells		
Popoto	Conidae family, Mollusc	Most common is *Conus ebraeus, M. eburne* and *M. chaldaeus*
Poreo	Cowrie sp., Cypraeidae family	Most common is *Cyprea tigris*
Pupu	Drupa genus, Muricidae Family, Mollusc.	Most common is *Morula uva* and *M. grandulata.*
Other		
Etu	Blue Star-fish	*Linckia laevigata*

The highest index of diversity was recorded at the reef site adjacent to the Rarotongan Hotel (H = 0.740). This site also had the greatest evenness or spread of resource distribution. The Catholic Church lagoon had the lowest recorded diversity (H = 0.060). Only 3 different resource types (mostly Trochus) were found at the site. Also, the Catholic Church reef had the lowest diversity of all the reef sites, (it was dominated by Kina). A low diversity and the least evenness of resources was recorded at Aroko lagoon (J = 0.087) which had few resources except the Rori Toto. Generally higher diversity was observed on the reef compared to adjacent lagoon sites (**Table 2**).

A statistical t-test to compare diversity concluded that the diversity between the Catholic Church site and the Rarotongan hotel were significantly different (P > 0.05). But, diversity also varies within much a smaller spatial scale as it also differed significantly amongst the neighbouring sites sampled in the Raui areas (Nikao, Aroko, Tikioki and Rutaki).

Table 2. Diversity of Invertebrate Resources at Rarotonga.

Site	Nos.	H'	H_{max}	J
Reef Sites				
Aroko-Motutapu	11	0.513	1.041	0.492
Aroko-Koromiri	9	0.479	0.954	0.502
Aroko-Oneroa	9	0.392	0.954	0.411
Catholic Church	9	0.479	0.954	0.502
Club Raro Resort	10	0.632	1	0.632
Matavera-Turepu	10	0.444	1	0.444
Matavera-Whittiker	10	0.584	1	0.584
Nikao-Black Rock	10	0.358	1	0.358
Nikao-Social Center	10	0.531	1	0.531
Nikao-Sea Wall	10	0.617	1	0.617
Rarotongan Hotel	10	0.740	1	0.740
Rutaki-Avaiti	10	0.589	1	0.589
Rutaki-Passage	10	0.426	1	0.426
Tikioki-Packing Shed	10	0.638	1	0.638
Tikioki-Road	10	0.665	1	0.665
Tumunu	9	0.479	0.954	0.502
Lagoon Sites				
Nikao	13	0.392	1.114	0.352
Aroko	6	0.067	0.778	0.087
Tikioki	11	0.571	1.041	0.548
Rarotongan Hotel	9	0.307	0.954	0.322
Catholic Church	3	0.060	0.477	0.125

The availability and type of habitat appears to affect the resource diversity. And explains why sites such as the Rarotongan Hotel, that possess a diverse habitat (corals, reef crevices, sandy flats, etc) invariably have a diverse invertebrate resource. In contrast, the low resource diversity sites (e.g Catholic Church and Aroko lagoon) have a barren benthos cover. The Catholic Church site is mostly boulders and rubble whilst the substrate at Aroko lagoon was dominated by sand flats. The wide of resource diversity around Rarotonga may reflect the habitat heterogeneity of the island (**Figure 2**).

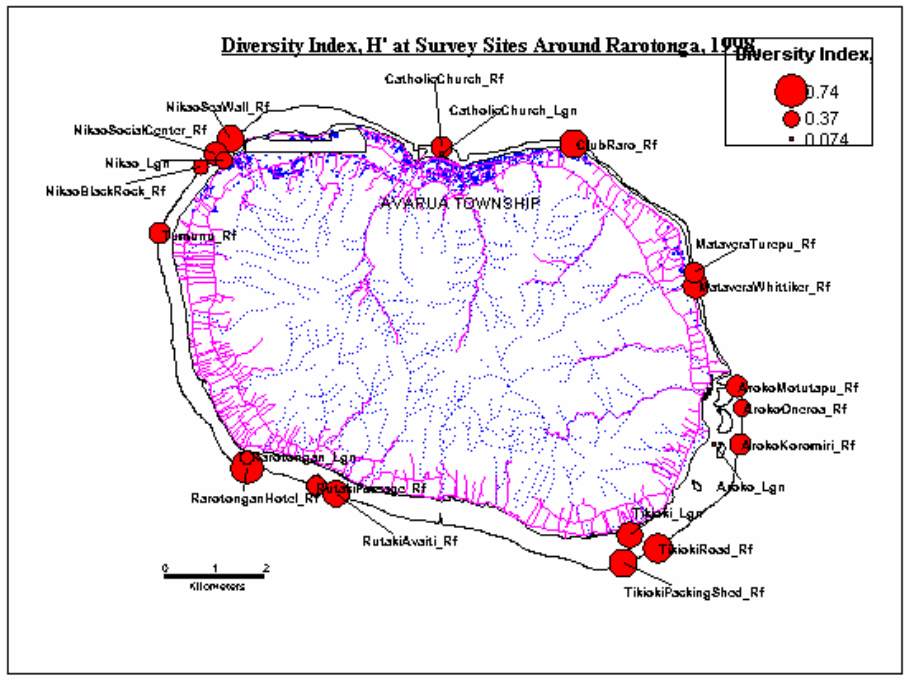

Figure 2. Diversity Index at Survey Sites around Rarotonga.

It does not appear coincident that the low diversity area of the Catholic Church was located in the main township (Avarua). Urban pressures on the resource habitat in this area could include, direct destruction from engineering works or reef gleaning activities, smothering by sedimentation, man-made structures affecting tidal flushing and poor water quality caused through sewage runoff, port discharges and surface rain runoff. As diversity is affected by abundance, over harvesting a resource will also lower the diversity index.

RESOURCE DISTRIBUTION PATTERNS.

Some resources had distribution patterns affected by the distance from the reef edge (**Table 3**). Wave energy and tidal flows may be an important factor influencing this pattern. For example, at several sites the Rori Pua had significantly greater densities close (<10 meters) to the reef edge. This was evident at Aroko Raui (**Figure 3**). This sea-cumber is not affected by the high wave action in this zone because it is firmly lodged into the reef crevices by it pores on its underside. In contrast, resources such as the Kina and Rori Toto are not as suited to being exposed to high wave action and had a significantly greater densities further back (>20 meters) from the reef edge (**Figures 4** and **5**).

Differences in density amongst sites at the Raui areas also were found (**Table 3**). This was notable at Nikao Raui where the Black Rock site had consistently greater densities than the Social Center or Sea Wall for resources such as Karikao, Kina, Matu Rori and Trochus. For example at the Black Rock the density of Kina was 6.2 per sqm compared to 1.2 and 0.6 per sqm at the Social Center and Sea Wall sites, respectively. Similarly, at Matavera Raui, the Whittiker site had greater densities then Turepu site for Rori Matie, Rori Pua and Rori Toto. Furthermore, within the Raui areas some resources display

distribution patterns that are affected by both site and distances from the reef, factors. This was evident at Aroko Raui area.

Table 3. Resource Distribution Patterns at Reef Sites at Rarotonga.

Resource Type	Catholic Church	Club Raro Resort	Rarotongan Hotel	Tumunu Resturant	Nikao Raui. Black Rock (BR), Social Center (SC), Sea Wall (SW).	Matavera Raui. Turepu (T), Whittiker (W).	Aroko Raui. Motutapu (M), Oneroa (O), Koromiri (K).	Tikioki Raui. Tikioki Road (TR), Packjng Shed (PS).	Rutaki Raui. Avaiti Passage (AP), Rutaki Passage (RP).
Ariri		-	-	-	-	-	-		
Etu		-	-	-	-	-		-	**X**
Karikao			-	-	**BR > SC, SW**			-	-
Kina	**X**	**X**	**X**	**15-20 meter**	**BR > SC, SW**	**5-15 meter**	**n.s**	**X**	**RP > AP**
M'ngeo							-		
Paua	-		**X**	**X**		**X**	**Site x Distance**	**50 meter**	**RP > AP**
Paua Kura			-						
Popoto						-			
Poreo							-		
Pupu				-					
Rori Matie			**0-5 meter**		**X**	**W > T**	**Site x Distance**	**X**	**AP > RP**
Matu Rori	**X**	**X**	**X**	**X**	**BR > SC, SW**	**X**	**Site x Distance**	**X**	**X**
Rori P'katoro	-	-	-	-	**X**	**45 meter**	**Site x Distance**	**X**	**Site x Distance**
Rori Pua	-		**X**	**10 meter**	**10 meter**	**W > T**	**0-5 meter**	**X**	**X**
Rori Toto	**X**	**X**	-	**X**		**W > T**	**25-30 meter**	**Site x Distance**	**AP > RP**
Trochus	-	-	-	-	**BR > SC, SW**	**X**	**X**	**X**	**AP > RP**
Ungakoa			-					-	
Vana	-	-	-	-	**10 meter**	**X**	**X**	**Site x Distance**	**X**

Key to abbreviations: **-** = no tests carried out; **X** = no significant result (P>0.05) found; **Site x Distance** = significant (P<0.05) interactive effect amongst factors; **n.s** = Resource not studied; Distances with a significant Tukey's test are indicated; Significantly different survey sites within the Raui areas are indicated by their respective initials.

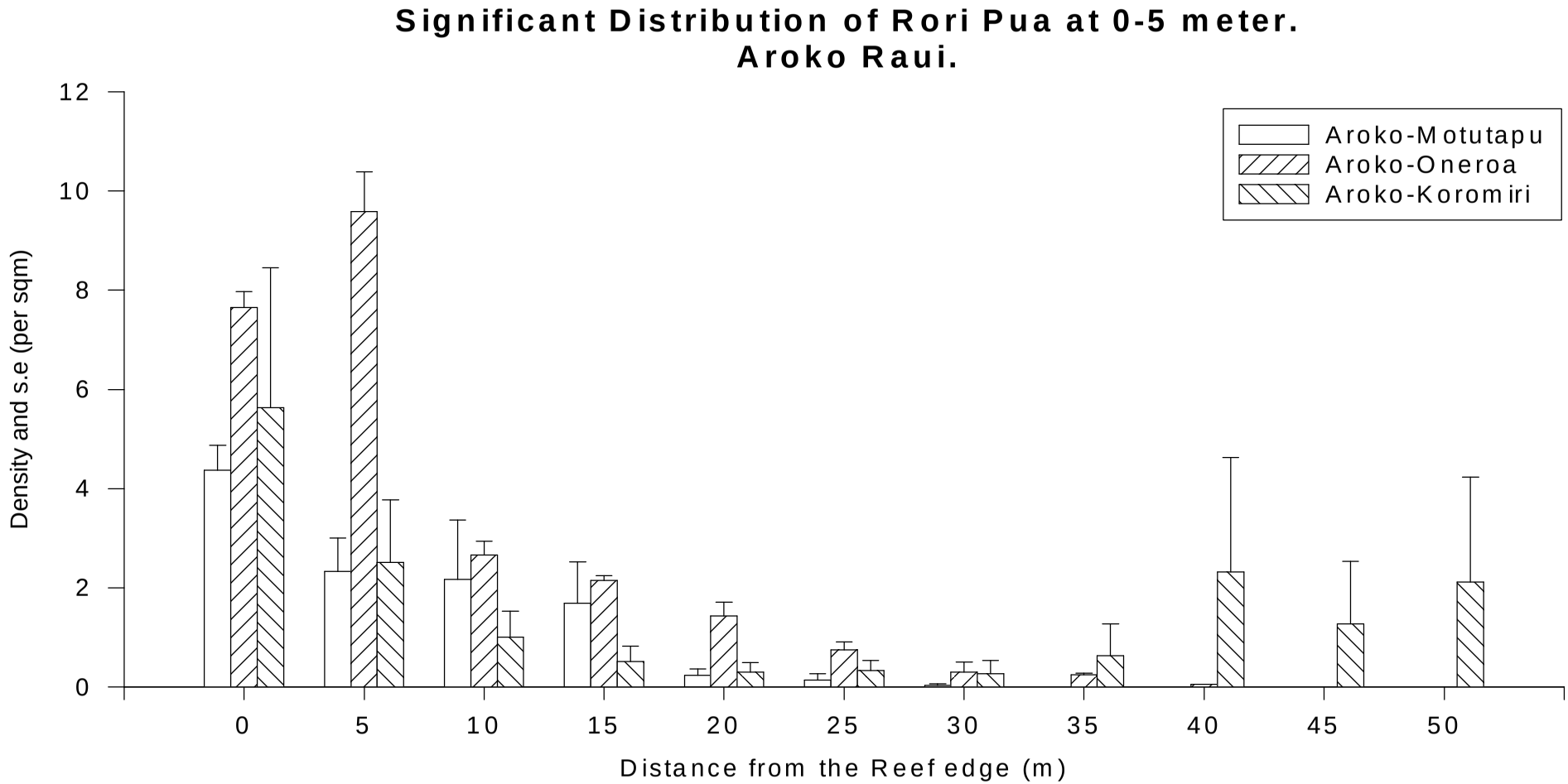

Figure 3. Distribution Pattern of Rori Pua at Aroko Raui. Significantly Different ($P<0.05$) Densities occur at 0-5 meters from the Reef Edge.

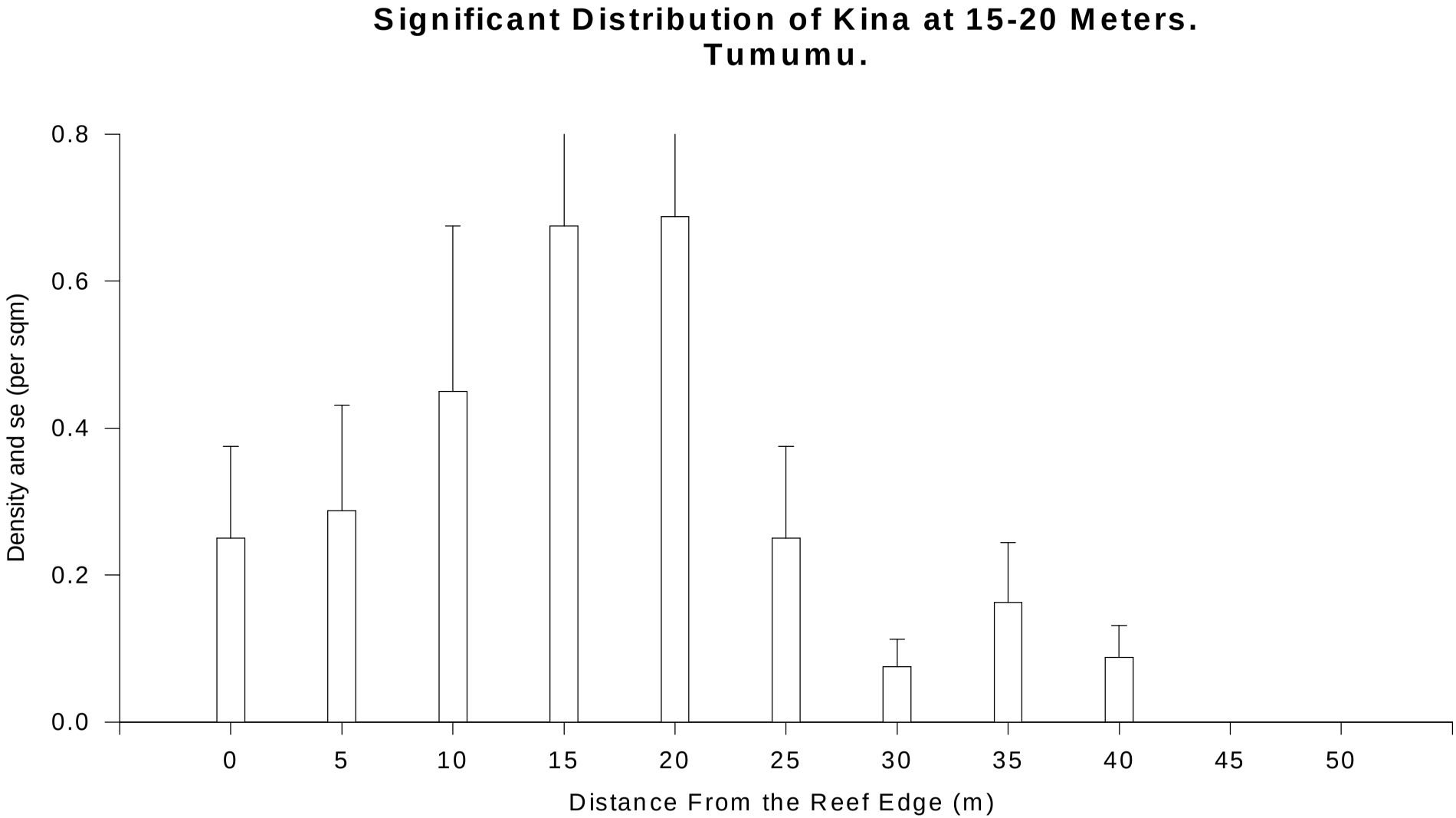

Figure 4. Distribution Pattern of Kina at Tumunu. Significantly Different ($P<0.05$) Densities occur at 25-30 meters from the Reef Edge.

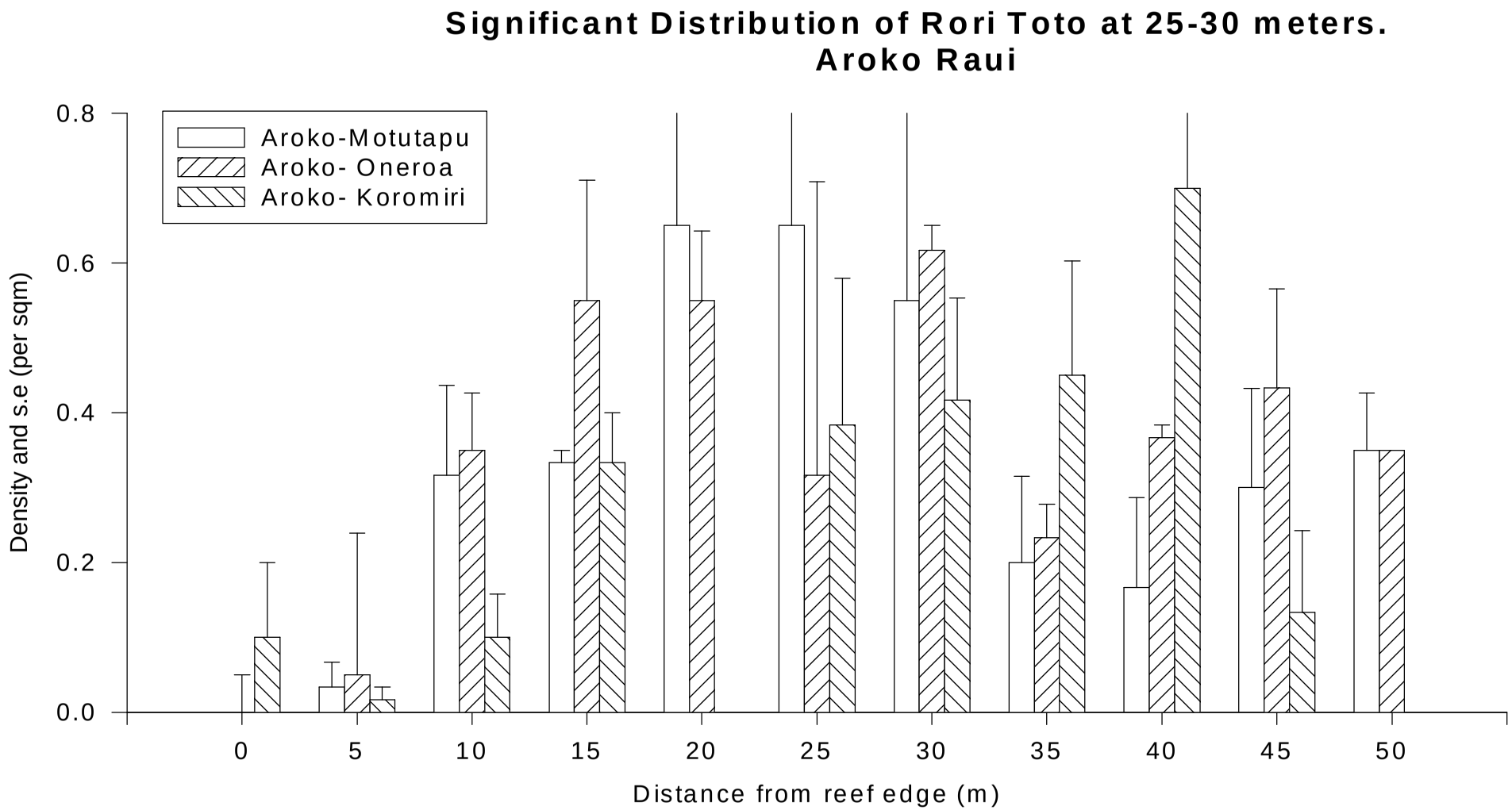

Figure 5. Distribution Pattern of Rori Toto at Aroko Raui. Significantly Different ($P<0.05$) Density occur at 25-30 meters from the Reef Edge.

POPULATION SIZE.

The largest resource populations are that of the Matu Rori (8.8 million), Kina (5.8 million), Rori Toto (5.3 million), Rori Pua (1.1 million), Rori Matie (500 thousand) and Trochus (450 thousand). The 95% confidence intervals of abundance are wide and reflect the patchy distribution of resources. In contrast scarce resources number <5000 in total. These include Atuke, Mangeongeo, Paua Kura, Popoto, Pupu, Rori Kanaenae and Rori Ngata (**Table 4**).

Table 4. Population Size of Invertebrate Resources at Rarotonga.

Resource	Density Nos/m^2	Reef (000's)	Lagoon (000's)	Total (000's)	95% C.I (000's)
Ariri	0.002	7	6	13	16
Atuke	<0.001	2		2	2
Avake	0.010		79	79	182
Etu	0.005	8	36	44	53
Karikao	0.003	9	2	11	18
Kina	0.885	2 302	3 458	5 760	7 420
Mangeongeo	<0.001	2		2	2
Paua	0.017	46	66	111	161
Paua Kura	<0.001	2		2	
Popoto	0.001	3	2	4	9
Poreo	<0.001	2	5	7	10
Pupu	<0.001	2		2	2
Rori Kanaenae	0.001		4	4	10
Rori Matie	0.076	202	273	475	885
Matu Rori	0.696	529	8 279	8 808	21 113
Rori Ngata	0.001		4	4	10
Rori P'katoro	0.307	39	2	40	39
Rori Pua	0.011	1 075	2	1 077	765
Rori Toto	0.459	491	4 830	5 321	9 853
Trochus	0.096	179	269	448	553
Ungakoa	0.002	3	23	26	60
Vana	0.016	43	60	103	154

Collectively, the six most abundant species account for 98% of the resource pool while all other resources make up the remaining 2%. In the others category, the Paua, Vana, Avake, Etu and Rori Puakatoro represent about 85% of the sum of the population numbers (**Figure 6**).

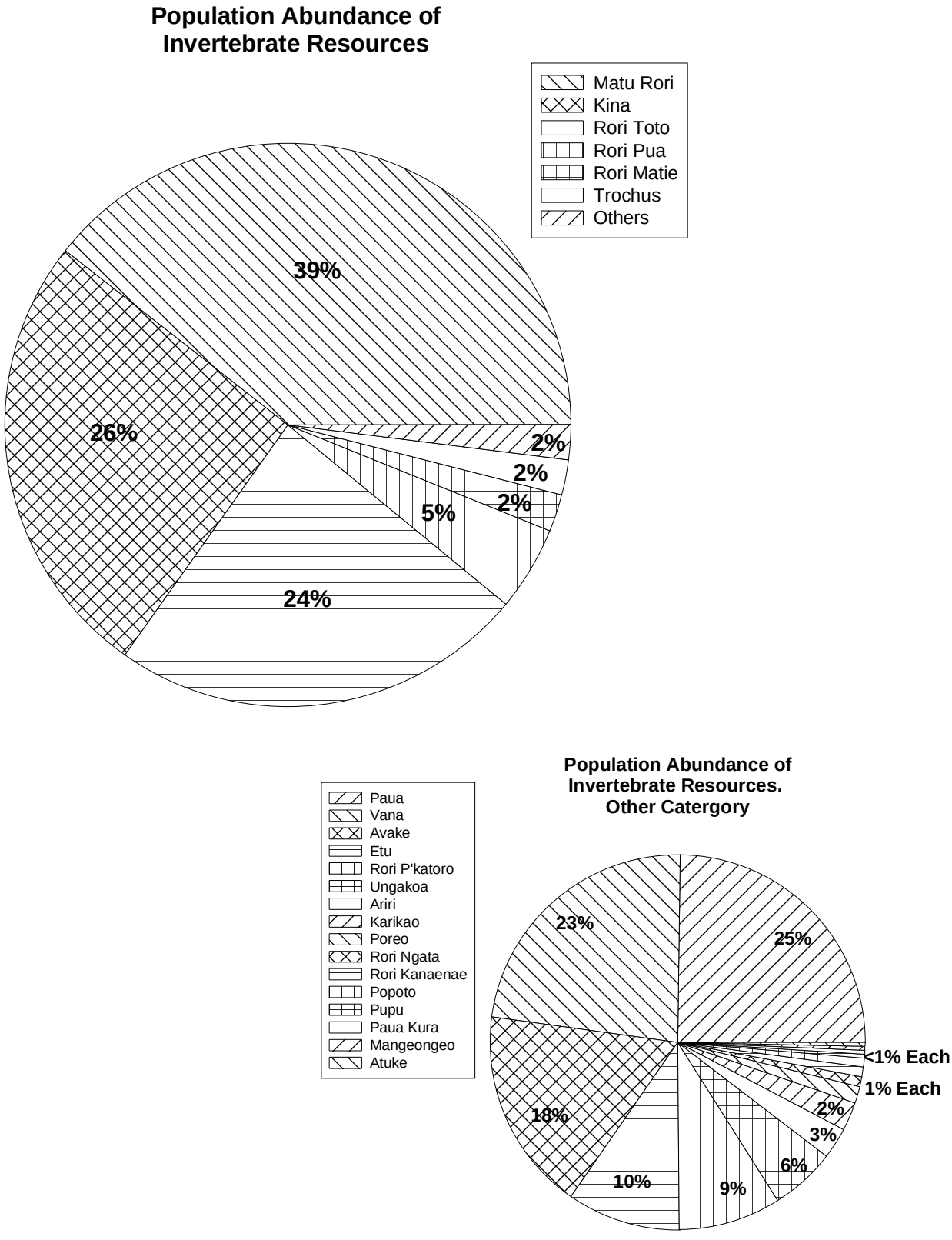

Figure 6. Proportion of Resource Abundance at Rarotonga.

The proportion of the population for the six most abundant resources was not always equally shared among the lagoon and reef strata. More then 90% of the Matu Rori and Rori Toto were estimated to be present in the lagoon. While the Rori Pua were almost entirely at the reef. But equal proportions of Kina, Rori Matie and Trochus were calculated at the reef and lagoon (**Figure 7**).

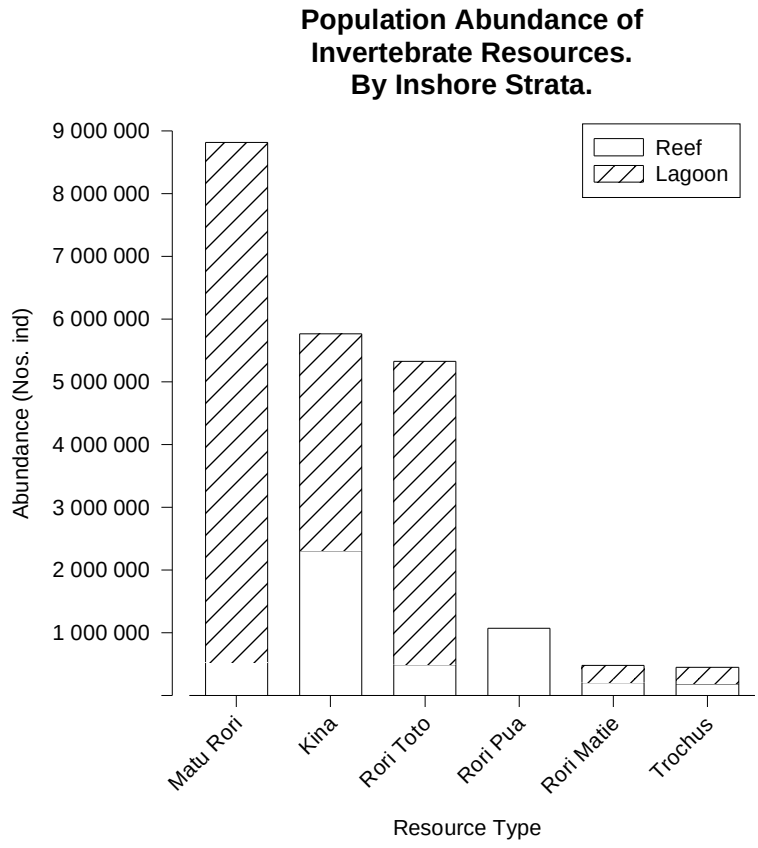

Figure 7. Abundance of the Six Dominant Resources at the Reef and Lagoon Area.

The great abundance of Matu Rori, Kina and Rori Toto suggests that their habitat types are a common feature of the inshore area. The Matu Rori are found mostly under and around coral outcrops and rocks. The Kina commonly inhabit crevices in the reef flat or patch reefs. The Rori Toto is often found on sandy flats.

The habitat preference of these resources may reflect their spatial abundance around Rarotonga (**Figure 8**). The highest density of Kina was at the reef sites (where there are many crevices). The Matu Rori reaches its highest density at the lagoon sites (where patch reefs are found). Rori Toto occurred at variable densities around the island.

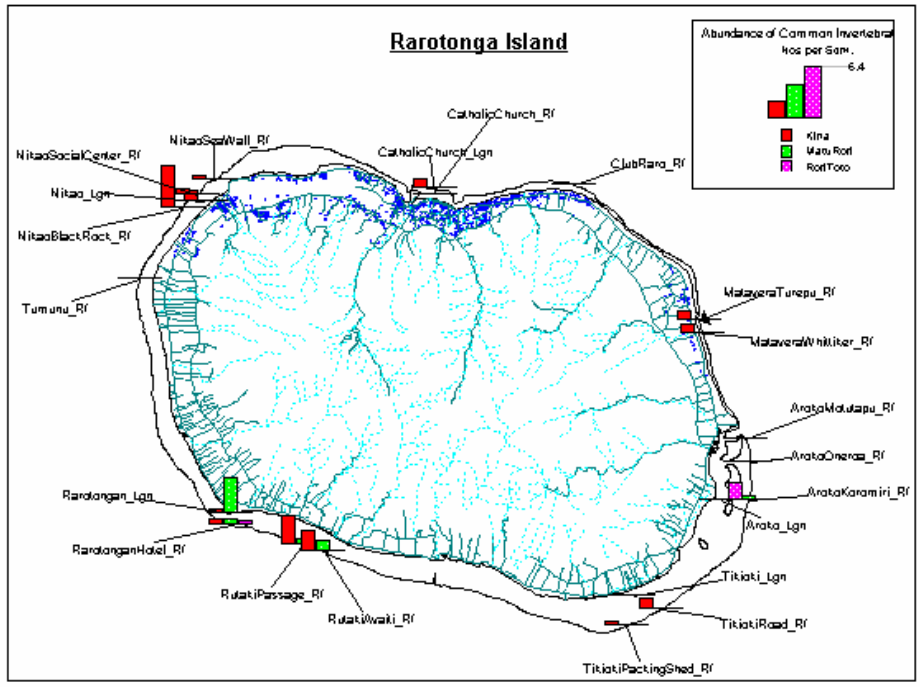

Figure 8. Abundance Patterns of Kina, Matu Rori and Rori Toto around Rarotonga.

SUSTAINABLE HARVESTS.

Many of the invertebrate resources identified in this survey are presently subject to subsistence harvest pressure. And the ability to sustain additional harvesting for commercial purposes must be carefully considered. A harvest regime should not adversely affect the breeding power of the exploited population.

In the lack of information, (biological, logistical and economical), it is conservatively suggested that the invertebrate resource abundance should be at least in the order of several hundreds of thousands to sustain a commercial harvest. This condition denies all but six (Matu Rori, Kina, Rori Toto, Rori Pua, Rori Matie and Trochus) of the resources identified in the survey as being suitable for a commercial harvest.

Trochus.

Trochus have been commercially harvested at Aitutaki for more then 15 years. The harvest regime (30% of population in the 8–12 cm size class) has proved to be sustainable and these parameters are included in the Rarotonga model. The harvest quota at Rarotonga is assessed using a normal size- distribution population model (based on a field sample, n = 2348) (**Figure 9**).

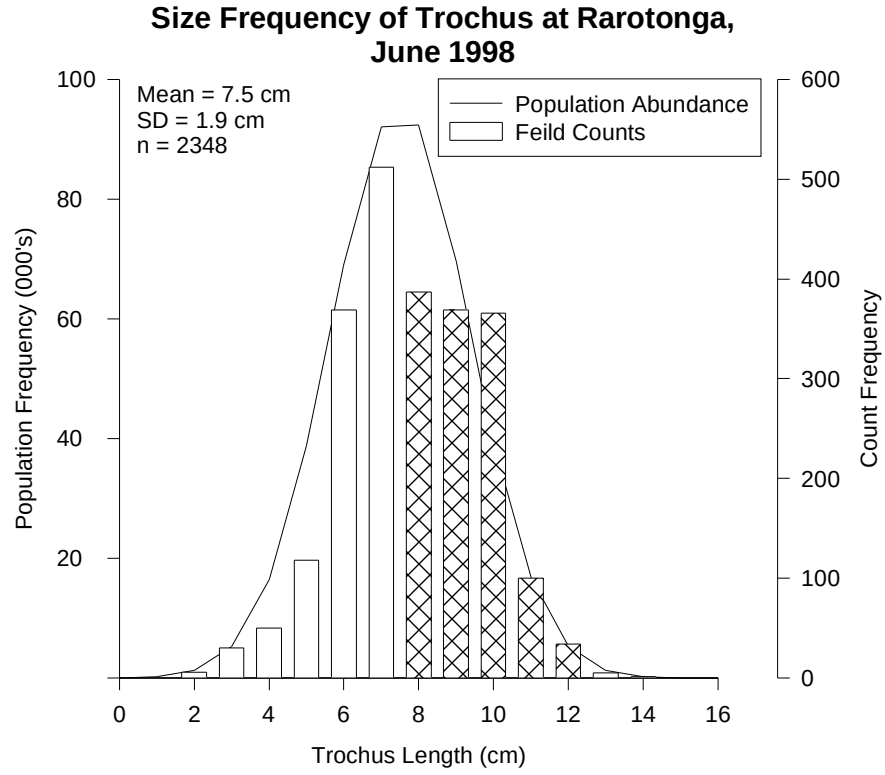

Figure 9. Harvest Characteristics of Trochus at Rarotonga. Shaded Portions indicate the Size Range that is Harvestable.

A 30% harvest quota of shell between 8-12 cm equates to 67 thousand trochus. Based on a relationship of dry shell weight and length (Weight = ($3.4x10^{-4}$) $Length^{2.943}$) (Ponia et al, 1997) a total harvest of 13 tons is derived. The value of this harvest (@NZ$10 kg^{-1}) is estimated to be worth NZ$133 thousand (**Table 5**).

Table 5. Trochus Harvest Size and Value.

Size class	Abundance (000's)	30% harvest (000's)	Shell weight (tons dry)	Value (NZ$000)
8	92	28	0.7	
9	70	21	1.7	
10	40	12	3.1	
11	17	5	4.0	
12	6	2	3.8	
Total	**223**	**67**	**13.3**	**$133**

Rori – Matu, Pua, Matie and Toto.

All three Rori species are harvested for subsistence use (MMR Resource Profile, No. 6, 1989). Their skin (with the exception of the Matu Rori) when dried has a commercial value. A simple estimate of dried skin harvest weight and value can be made derived from a conservative harvest quota (15% of the standing population) with an average dry weight and value (40 grams/ind @ NZ$5.00 kg^{-1}). The value of this harvest is estimated to be NZ$73 thousand (**Table 6**).

Table 6. Harvest of Matu Rori, Rori Pua, Rori Matie and Rori Toto at Rarotonga.

Species	Reef Pop. Size (000's)	Lagoon Pop. Size (000's)	Total Pop. Size (000's)	Harvest Number (000's)	Harvest Weight (Ton dry Wt)	Harvest Value (000's NZD$)
Rori Matie	200	300	500	75	3.0	15.0
Rori Matu	500	8 300	8 800	1 320		
Rori Pua	1 100	< 100	1 100	165	5.0	24.8
Rori Toto	500	4 800	5 300	795	6.6	33.0
Total			**15 700**	**2 355**	**14.6**	**72.8**

Kina

The prospects of a commercial market for the Kina have not been fully investigated. The roe of the animal is occasionally harvested at Rarotonga and is also reputed to be delicacy in other pacific islands. It is also valued for shell craft markets in the United States. As the animal is often burrowed into a rock cavity it can be difficult to remove without damage to its surroundings. Although it is not known what percentage of the population can be practically removed, it is conservatively estimated that 10% of the population can be harvested. Since the Kina at Rarotonga number approximately 5.8 million, this is equivalent to a harvest of 580 thousand animals. Assuming each Kina were valued at NZ$20 cents, a 10% harvest would have a value of NZD$115 thousand (**Table 7**).

Table 7. Harvest Size and Value of Kina.

Strata	Population (000's)	Harvest (000's)	Value (NZ$000's)
Reef	2 302	230	$46.0
Lagoon	3 458	346	$69.2
Total	**5 759**	**576**	**$115.2**

DISCUSSION.

Little information is known of many of the twenty-two invertebrate resources identified in this study. An interesting exercise in taxonomy occurred because many of the same resources have different names depending on the source. Amongst the fifteen islands of the Cook Group there are often different local names for the same resource. Therefore, inward migration to Rarotonga has made it difficult to settle on a common taxonomy.

The diversity of resources at Rarotonga is varied. This may be influenced by several factors, namely, natural habitat diversity and human impacts. The high diversity site at the Rarotongan Hotel is attributed to this area harbouring a variety of benthic habitats that in turn will accommodate a diverse invertebrate population. In contrast, Aroko lagoon has a sandy floor and a low diversity and spread of resources occurred because few invertebrates (with the exception of the Rori Toto) prefer such substrate. The lowest diversity index was at a site located in the township area. This low diversity may indirectly be caused human pressures that result in habitat degradation. Or directly, the site may be affected by higher harvest pressure would reduce diversity.

Only two factors were analysed for distribution patterns. The common factor of distance from the reef edge indirectly includes the effect of wave action and tidal flushing. Some invertebrate resources with

distribution patterns related to distance from the reef edge have adapted to such conditions. For example, the high density of Rori Pua within 10 meters of the reef edge (where there is high wave action) is possible because the animal is able to adhere to the reef using pores on its underside. In contrast the Rori Toto has no such pores and was often recorded further back from the reef where there was less wave motion.

At the Raui areas the distribution patterns amongst sites within its boundaries were also analysed. Significant among-site differences were found, notably at Nikao Raui where higher densities of Karikao, Kina, Matu Rori and Trochus were found at the Black Rock site compared to the other sites. The distribution pattern of resources was also affected by distance and site factors, as was the case at Aroko Raui for the Paua, Rori Matie, Matu Rori and Rori Puakatoro.

The Matu Rori, Kina, Rori Toto, Rori Pua, Rori Matie and Trochus account for 98% of the invertebrate numbers. The population estimates range from about 9 million Matu Rori to half a million Trochus. Among these, most of the Matu Rori and Rori Toto are found in the lagoon area while the Rori Pua is at the reef. The remaining 2% of resources are comprised mostly of Paua, Vana, Avake, Etu and Rori Puakatoro.

It is suggested to limit commercial harvests to resources with a population of at least several hundred thousands. In this regard, only the six most numerous populations qualify. It is estimated that a harvest of up to 13 tons of trochus shell (in the size range 8–12 cm length) can be sustained. The value of a harvest of this size is NZ$133 thousand. Up to 15 tons of dry skin product of the sea-cucumber species (with the exception of Matu Rori) may be harvested. The cumulative value of this harvest is worth NZ$73 thousand. Less is known about the value of Kina but assuming each were worth NZ$20 cents a sustainable harvest of 570 thousand animals would be worth $115 thousand.

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APPENDICES.

Table 1 Resource distribution patterns at Club Raro with distance from the reef edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Ariri	Not done		Overall density = 0.007	-no density patterns with distance.
Etu	Not done		Overall density = 0.001	-no density patterns with distance.
Kina	1-way ANOVA	distance = n.s	Overall density = 0.318	-no density patterns with distance.
Matu Rori	1-way ANOVA	distance = n.s	Overall density = 0.128	-no density patterns with distance.
Paua	Not done		Overall density = 0.001	-no density patterns with distance.
Rori Matie	Not done		Overall density = 0.001	-no density patterns with distance.
Rori Pua	1-way ANOVA	distance = n.s	Overall density = 0.692	-no density patterns with distance.
Rori Puakatoro	Not done		Overall density = 0.001	-no density patterns with distance.
Rori Toto	1-way ANOVA	distance = n.s	Overall density = 0.214	-no density patterns with distance.
Trochus	Not done		Overall density = 0.025	-no density patterns with distance.
Vana	Not done		Overall density = 0.003	-no density patterns with distance.

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.

Table 2 Resource distribution patterns at Tumunu Restaurant with distance from the reef edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Ariri	Not done		Overall density = 0.001	-no density patterns with distance.
Etu	Not done		Overall density = 0.001	-no density patterns with distance.
Kina	1-way ANOVA	distance = *	Overall density = 0.266 0 meters = 0.250 (subset 1) 5 meters = 0.288 (subset 1) 10 meters = 0.450 (subset 1) 15 meters = 0.675 (subset 2) 20 meters = 0.688 (subset 2) 25 meters = 0.250 (subset 1) 30 meters = 0.075 (subset 1) 35 meters = 0.163 (subset 1) 40 meters = 0.088 (subset 1) 45 meters = 0.000 (subset 1) 50 meters = 0.000 (subset 1)	-the greatest density occurs 15-20 meters from the reef edge.
Karikao	Not done		Overall density = 0.001	-no density patterns with distance.
Matu Rori	1-way ANOVA	distance = n.s	Overall density = 0.032	-no density patterns with distance.
Paua	1-way ANOVA	distance = n.s	Overall density = 0.022	-no density patterns with distance.
Pupu	Not done		Overall density = 0.001	-no density patterns with distance.
Rori Pua	1-way ANOVA	distance = *	Overall density = 0.615 50 meters = 0.000 (subset 1) 45 meters = 0.000 (subset 1) 40 meters = 0.000 (subset 1) 35 meters = 0.175 (subset 1) 30 meters = 0.688 (subset 1) 25 meters = 0750 (subset 1) 20 meters = 0.587 (subset 1) 15 meters = 1.113 (subset 1) 10 meters = 1.300 (subset 2) 5 meters = 1.125 (subset 1)	-the greatest density occurs at 10 meters from the reef edge.

			0 meters = 1.025 (subset 1)	
Rori Puakatoro	Not done		Overall density = 0.003	-no density patterns with distance.
Rori Toto	1-way ANOVA	distance = n.s	Overall density = 0.169	-no density patterns with distance.
Trochus	Not done		Overall density = 0.010	-no density patterns with distance.
Vana	Not done		Overall density = 0.010	-no density patterns with distance.
Trochus	Not done		Overall density = 0.008	-no density patterns with distance.

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.

Table 3 Resource distribution patterns at Catholic Church with distance from the reef edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Kina	1-way ANOVA	distance = n.s	Overall density = 1.5	-no density patterns with distance.
Matu Rori	1-way ANOVA	distance = n.s	Overall density = 0.041	-no density patterns with distance.
Paua	Not done		Overall density = 0.017	-no density patterns with distance.
Rori Pua	Not done		Overall density = 0.014	-no density patterns with distance.
Rori Puakatoro	Not done		Overall density = 0.002	-no density patterns with distance.
Rori Toto	1-way ANOVA		Overall density = 0.138	-no density patterns with distance.
Trochus	Not done		Overall density = 0.070	-no density patterns with distance.
Vana	Not done		Overall density = 0.002	-no density patterns with distance.

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.

Table 4 Resource distribution patterns at the Rarotongan Hotel with distance from the reef edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Ariri	Not done		Overall density = 0.001	-no density patterns with distance.
Etu	Not done		Overall density = 0.015	-no density patterns with distance.
Paua	1-way ANOVA	distance = n.s	Overall density = 0.010	-no density patterns with distance.
Paua Kura	Not done		Overall density = 0.001	-no density patterns with distance.
Kina	1-way ANOVA	distance = n.s	Overall density = 1.041	-no density patterns with distance.
Karikao	Not done		Overall density = 0.011	-no density patterns with distance.
Matu Rori	1-way ANOVA	distance = n.s	Overall density = 0.971	-no density patterns with distance.
Rori Matie	1-way ANOVA	distance = *	Overall density = 0.169 0 meters = 0.588 (subset 1) 5 meters = 0.425 (subset 1) 10 meters = 0.139 (subset 2) 15 meters = 0.375 (subset 2) 20 meters = 0.089 (subset 2) 25 meters = 0.025 (subset 2) 30 meters = 0.038 (subset 2) 35 meters = 0.000 (subset 2) 40 meters = 0.000 (subset 2) 45 meters = 0.013 (subset 2)	-the greatest density occurs at 0-5 meters from the reef edge.
Rori Pua	1-way ANOVA	distance = n.s	Overall density = 0.379	-no density patterns with distance.
Rori P'katoro	Not done		Overall density = 0.020	-no density patterns with distance.
Rori Toto	Not done		Overall density = 0.518	-no density patterns with distance.
Trochus	Not done		Overall density = 0.239	-no density patterns with distance.
Ungakoa	Not done		Overall density = 0.008	-no density patterns with distance.
Vana	Not done		Overall density = 0.004	-no density patterns with distance.

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.

Table 5 Resource distribution patterns at Nikao raui at survey sites and with distance from the reef edge.

Resource	Tests	Result	Site Density (per sq.m)	Conclusion
Ariri	Not done		Overall density = 0.010	
Etu	Not done		Overall density = 0.004	
Kina density.	2-way ANOVA	site = **	*Sea Wall* = 0.607 (subet 1)	-*Blk Rock* density > *Sea Wall* and *Soc Center*
	Tukeys HSD	distance = n.s	*Soc Center* = 1.211 (subset 1) *Blk Rock* = 6.182 (subset 2)	-no difference in density with distance from reef edge.
Matu Rori	2-way ANOVA	site = *	*Soc Center* = 0.004 (subset 1)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density.
	Tukeys HSD	distance = n.s	*Sea Wall* = 0.018 (subset 1) *Blk Rock* = 0.063 (subset 2)	-no difference in density with distance from reef edge.
Paua	Not done		Overall density = 0.021	
Rori Pua	2-way ANOVA	site = n.s	30 meters = 0.163 (subset 1)	-no difference in density at survey sites.
	Tukeys HSD	distance = *	35 meters = 0.200 (subset 1) 25 meters = 0.217 (subset 1) 45 meters = 0.279 (subset 1) 40 meters = 0.288 (subset 1) 50 meters = 0.383 (subset 1) 20 meters = 0.696 (subset 1) 5 meters = 0.822 (subset 1) 0 meters = 0.842 (subset 1) 15 meters = 0.850 (subset 1) 10 meters = 1.196 (subset 2)	-density at 10 meter distance > 25, 35 and 30 meter distances.
Rori Matie	Not done		Overall density = 0.486	

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.

Resource	Tests	Result	Site Density (ind.m^{-2})	Conclusion
Ariri	Not done		Overall density = 0.010	
Etu	Not done		Overall density = 0.004	
Kina	2-way ANOVA	site = **	*Sea Wall* = 0.607 (subet 1)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density.
	Tukeys HSD	distance = n.s	*Soc Center* = 1.211 (subset 1) *Blk Rock* = 6.182 (subset 2)	-no difference in density with distance from reef edge.
Karikao	2-way ANOVA	site = *	*Sea Wall* = 0.010 (subset 1)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density.
	Tukeys HSD	distance = 0.371	*Soc Center* = 0.015 (subset 1) *Blk Rock* = 0.055 (subset 2)	-no difference in density with distance from reef edge.
Matu Rori	2-way ANOVA	site = *	*Soc Center* = 0.004 (subset 1)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density.
	Tukeys HSD	distance = n.s	*Sea Wall* = 0.018 (subset 1) *Blk Rock* = 0.063 (subset 2)	-no difference in density with distance from reef edge.
Paua	Not done		Overall density = 0.021	
Rori Pua	2-way ANOVA	site = n.s	30 meters = 0.163 (subset 1)	-no difference in density at survey sites.
	Tukeys HSD	distance = *	35 meters = 0.200 (subset 1) 25 meters = 0.217 (subset 1) 45 meters = 0.279 (subset 1) 40 meters = 0.288 (subset 1) 50 meters = 0.383 (subset 1) 20 meters = 0.696 (subset 1) 5 meters = 0.822 (subset 1) 0 meters = 0.842 (subset 1) 15 meters = 0.850 (subset 1) 10 meters = 1.196 (subset 2)	-density at 10 meter distance > 25, 35 and 30 meter distances.
Rori Matie	Not done		Overall density = 0.486	-no difference in density at survey sites. -no difference in density with distance from reef edge.
Rori Puakatoro	2-way ANOVA	site = n.s	Overall density = 0.012	-no difference in density at survey sites.
		distance = n.s		-no difference in density with distance from reef edge.

Rori Toto	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.129	-no difference in density at survey sites. -no difference in density with distance from reef edge.
Trochus	2-way ANOVA Tukeys HSD	site = ** distance = *	*Sea Wall* = 0.127 (subset 1) *Soc Center* = 0.283 (subset 1) *Blk Rock* = 0.484 (subset 2)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density. -Test unable to differentiate density among distances.
Vana	2-way ANOVA Tukeys HSD	site = n.s distance = *	0 meters = 0.000 (subset 1) 5 meters = 0.000 (subset 1) 35 meters = 0.000 (subset 1) 40 meters = 0.004 (subset 1) 20 meters = 0.004 (subset 1) 30 meters = 0.004 (subset 1) 45 meters = 0.008 (subset 1) 15 meters = 0.008 (subset 1) 25 meters = 0.017 (subset 1) 10 meters = 0.033 (subset 2)	-no difference in density at survey sites. -density at 10 meter distance > 0, 5, 35 and 40 meter distances.

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.

Table 6 Resource distribution patterns at Matavera raui at survey sites and with distance from the reef edge.

Resource	Tests	Result	Site Density (ind.m^{-2})	Conclusion
Rori Puakatoro	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.012	-no difference in density at survey sites. -no difference in density with distance from reef edge.
Rori Toto	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.129	-no difference in density at survey sites. -no difference in density with distance from reef edge.
Trochus	2-way ANOVA Tukeys HSD	site = ** distance = *	*Sea Wall* = 0.127 (subset 1) *Soc Center* = 0.283 (subset 1) *Blk Rock* = 0.484 (subset 2)	-*Blk Rock* density > *Sea Wall* and *Soc Center* density. -Test unable to differentiate density among distances.
Vana	2-way ANOVA Tukeys HSD	site = n.s distance = *	0 meters = 0.000 (subset 1) 5 meters = 0.000 (subset 1) 35 meters = 0.000 (subset 1) 40 meters = 0.004 (subset 1) 20 meters = 0.004 (subset 1) 30 meters = 0.004 (subset 1) 45 meters = 0.008 (subset 1) 15 meters = 0.008 (subset 1) 25 meters = 0.017 (subset 1) 10 meters = 0.033 (subset 2)	-no difference in density at survey sites. -density at 10 meter distance > 0, 5, 35 and 40 meter distances.

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.

Table 7 Resource Distribution Patterns at Aroko Raui at Survey Sites and with Distance from the Reef Edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Ariri	Not done		Overall density = 0.004	-no density patterns with site or distance.
Mangeongeo	Not done		Overall density = 0.001	-no density patterns with site or distance.
Matu Rori	2-way ANOVA	site x distance site = ** distance = n.s	Overall density = 0.217 Motutapu density = 0.059 (subset 1) Oneroa density = 0.070 (subset 1) Koromiri density = 0.521 (subset 2)	-density increases away from reef except at Koromiri. -density at Koromiri > Motutapu and Oneroa.
Paua	2-way ANOVA	site x distance site = * distance = **	Overall density = 0.072 Koromiri density = 0.032 (subset 1) Oneroa density = 0.076 (subset 1) Motutapu density = 0.108 (subset 2)	-highest density at 40 m from reef except at Koromiri. (25 m from reef). -density at Motutapu > Oneroa and Koromiri.
Poreo	Not done		Overall density = 0.001	-no density patterns with site or distance.
Rori Matie	2-way ANOVA	site x distance site = ** distance = *	Overall density = 0.067 Motutapu density = 0.027 (subset 1) Koromiri density = 0.038 (subset 1) Oneroa density = 0.136 (subset 2)	-highest density at 25 m for Motutapu and Koromiri but 30 meters for Oneroa. -density at Oneroa > Motutapu and Koromiri.

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.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Rori Pua	2-way ANOVA	site = *	45 meters = .422 (subset 1)	-highest density in the 0 – 5 meter distance compared to
		distance = **	50 meters = .706 (subset 1)	other distances.
			40 meters = .789 (subset 1)	
			35 meters = .294 (subset 1)	
			30 meters = .200 (subset 1)	
			25 meters = .406 (subset 1)	
			20 meters = .656 (subset 1)	
			15 meters = 1.450 (subset 1)	
			10 meters = 1.944 (subset 1)	
			5 meters = 4.811 (subset 2)	
			0 meters = 5.883 (subset 2)	
Rori Puakatoro Oneroa	2-way ANOVA	site x distance	Overall density = 0.061	-highest density in the 20 meter distance except at
		site = n.s	(10 meter distance).	
		distance = **		
Rori Toto	2-way ANOVA Tukeys HSD	site = n.s	Overall density = 0.303	-highest density at 25 – 30 meter distance.
		distance = **		
Trochus	2-way ANOVA	site = n.s	Overall density = 0.005	-no density patterns with site or distance.
		distance = n.s		
Vana	2-way ANOVA	site = n.s	Overall density = 0.009	-no density patterns with site or distance.
		distance = n.s		

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

Table 8 Resource Distribution Patterns at Tikioki Raui at Survey Sites and with Distance from the Reef Edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Etu	Not done		Overall density = 0.004	-no density patterns with site or distance.
Kina	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.004	-no density patterns with site or distance.
Karikao	Not done		Overall density = 0.006	-no density patterns with site or distance.
Matu Rori	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.054	-no density patterns with site or distance.
Paua	2-way ANOVA Tukeys HSD	site = n.s distance = *	5 meters = .0000 (subset 1) 10 meters = .0000 (subset 1) 20 meters = .0000 (subset 1) 45 meters = .0000 (subset 1) 30 meters = .0063 (subset 1) 35 meters = .0063 (subset 1) 15 meters = 0071 (subset 1) 25 meters = .0313 (subset 1) 0 meters = .0333 (subset 1) 40 meters = .0313 (subset 1) 50 meters = .0875 (subset 2)	-no density patterns with site. -density at the 50 meter > 5, 10, 20, 45 meter.

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.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Rori Pua	2-way ANOVA	site = n.s distance = n.s	Overall density = 1.041	-no density patterns with site or distance.
Rori Matie	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.184	-no density patterns with site or distance.
Rori P'katoro	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.061	-no density patterns with site or distance.
Rori Toto	2-way ANOVA	site x distance site = n.s distance = n.s	Overall density = 0.061	-even distribution with distance at Packing shed but higher distribution further back at Tikioki Road.
Trochus	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.126	-no density patterns with site or distance.
Ungakoa	Not done		Overall density = 0.002	-no density patterns with site or distance.
Vana	2-way ANOVA	site x distance site = n.s distance = n.s	Overall density = 0.089	-even distribution with distance at Tikioki Road but higher distribution towards reef edge at Packing Shed

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.

Table 9 Resource Distribution Patterns at Rutaki Raui at Survey Sites and with Distance from the Reef Edge.

Resource	Tests	Result	Density (per sq.m)	Conclusion
Etu	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.012	-no density patterns with site or distance.
Karikao	Not done		Overall density = 0.001	-no density patterns with site or distance.
Kina	2-way ANOVA	site = * distance = n.s	Avaiti density = 2.635 (subset 1) Rutaki density = 3.926 (subset 2)	-density at Rutaki is greater then Avaiti. -no density patterns with distance from reef edge.
Matu Rori	2-way ANOVA	site = n.s distance = n.s	Overall density = 1.134	-no density patterns with site or distance.
Paua	2-way ANOVA	site = * distance = n.s	Avaiti density = 0.002 (subset 1) Rutaki density = 0.011 (subset 2)	-density at Rutaki is greater then Avaiti. -no density patterns with distance from reef edge.
Rori Pua	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.191	-no density patterns with site or distance.
Rori Matie	2-way ANOVA	site = * distance = n.s	Rutaki density = 0.153 (subset 1) Avaiti density = 0.672 (subset 2)	-density at Avaiti is greater then Rutaki. -no density patterns with distance from reef edge.
Rori Puakatoro	2-way ANOVA	site x distance site = n.s distance = n.s	Overall density = 0.001	-higher density at reef edge for Avaiti but higher density further back from reef edge for Rutaki Passage site.
Rori Toto	2-way ANOVA	site = * distance = n.s	Rutaki density = 0.262 (subset 1) Avaiti density = 0.376 (subset 2)	-density at Avaiti is greater then Rutaki. -no density patterns with distance from reef edge.
Trochus	2-way ANOVA	site = * distance = n.s	Rutaki density = 0.003 (subset 1) Avaiti density = 0.032 (subset 2)	-density at Avaiti is greater then Rutaki. -no density patterns with distance from reef edge.
Rori Pua	2-way ANOVA	site = n.s distance = n.s	Overall density = 0.075	-no density patterns with site or distance.

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.

Diversity.

A. Shannon-Weiner diversity index, H' is

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

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

B. Where maximum possible diversity for k categories is

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

C. Evenness J' may be calculated as

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

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

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

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

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) $t_{2,0.05}n\text{-}1$
with t value derived from t table with n - 1 degrees of freedom.