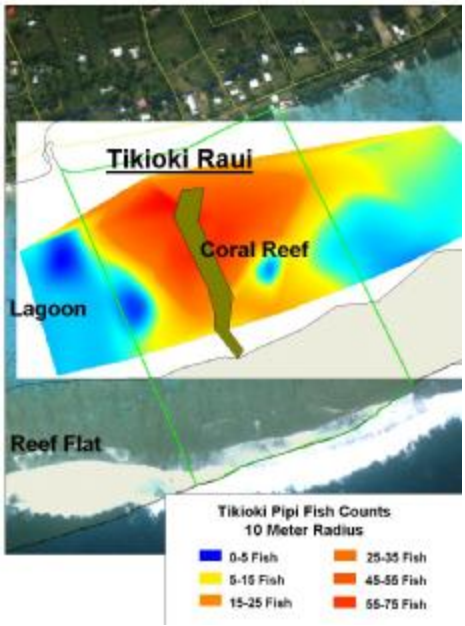
2ND MONITORING SURVEY OF THE RAROTONGA RAUI



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SUMMARY

This is second annual monitoring survey since the implementation of the Raui on Rarotonga Island. It also incorporates the baseline information collected prior to the implementation of the Raui.

The invertebrate resource at the Raui reef sites was identified as a key indicator species for monitoring. Utilising belt transects, information of abundance and diversity was collected. At Tikioki Raui a survey of fish abundance and diversity was also carried out.

The results suggest that the diversity of the invertebrate species at the reef has increased at all of the Raui sites monitored. This reflects more number of species being reported and more evenness in distribution among populations. This suggests that perhaps as a result of the Raui some species previously being over harvested and uncommon to the area are now starting to become re-established.

There were variable changes in invertebrate population abundance. This would partially reflect the natural attraction of the different Raui areas as a reserve for invertebrate types.

The result indicates that Nikao Raui to be an ideal site for the reef invertebrates. Eighteen species were recorded in the area compared to 14 species during the baseline surveys. Almost half of the species reported had the greatest density compared to the other Raui areas. Notable densities include the *Kina* (4.5 ind.m^{-2}) and the *Trochus* (0.83 ind.m^{-2}) These two invertebrates dominated the Nikao reef and account for 70% and 13% of the total population of invertebrates, or a population size of 200 thousand and 38 thousand respectively. The *Kina*, *Trochus*, *Matu Rori*, *Avake* and *Paua* all show dramatic increases in population size. Whereas initially the *Avake* and the *Ungakoa* only numbered several hundreds, the present population is four thousand and eight thousand respectively. And in the case of *Trochus* and *Vana*, the population may now be approaching its upper limits. A sustainable quota of 2 tons harvest of the *Trochus* resources was estimated. These resources, the Kina and Trochus account for 70% and 13% of the total population of invertebrates, or a population size of 200 thousand and 38 thousand respectively.

The area of Matavera Raui is mostly reef flat and relatively small compared to other Raui areas. There were 15 species reported compared to 11 initially. Large increases in the *Kina*, *Trochus*, *Matu Rori*, Rori Matie, *Paua* and *Rori Puakatoro* have occurred. The *Kina* make up for half of the total invertebrates with a population of 66 thousand. The *Rori Pua*, *Rori Toto* and *Trochus* cumulatively account for one quarter.

Aroko Raui is sited adjacent to a major river outlet and reef passage and is located in the vicinity of small islets. Probably as a result of these features the benthic reef habitat is more heterogeneous compared to other Raui areas. This is reflected in the composition of the total invertebrate population. Whereas other areas are dominated by the *Kina*, it differs at Aroko. The largest proportion is accounted by the *Rori Pua* (21%) or 23 thousand. The *Kina* is responsible for 19% of the proportion and the *Trochus* is 15% and *Rori Toto* is 14%. Five of the invertebrate species at Aroko had the highest densities

recorded at the Raui sites. Over the duration of the Raui large increases of the *Kina*, Rori Matie, *Rori Toto*, *Trochus*, *Avake*, *Etu*, *Ungakoa* and *Vana* occurred. *Rori Pua* has significantly declined but this may be attributed to a sampling inaccuracy.

Tikioki Raui is located at a relatively large and deep lagoon area. The reef area does appear to support the same abundance of invertebrate species as Nikao area. This may reflect its windward location and therefore the reef is affected by high wave energy. Also the reef flat is not as prominent as other Raui such as Nikao. The *Matu Rori* and *Ungakoa* have the most evident increase in population size, whereas *Vana* and *Rori Puakatoro* declined. The major components of the invertebrate population comprised of *Kina* (36%), *Matu Rori* (15%), *Rori Toto* (17%) and *Rori Puakatoro* (14%).

Tikioki Raui is one of the best lagoon type ecosystems of the Rarotonga Raui, it possess a large, deep lagoon and encompasses a large stretch of patch reef. The fish survey results at Tikioki found that there are more fish inside the Raui area compared to outside. More specifically these fish are aggregated around a large coral patch-reef found within the area. The species used to distinguish this distribution pattern was the Pipi (*Kyphosus cinerascens*), a common target species. Aggregations of this fish reached up to an average of 60 fish within a 10 meter radius compared to 0.25 fish at sites outside the Raui area. In addition, more fish species were observed at Raui sites compared to outside. Between 27 to 31 species were seen within the radius inside the Raui compared to 14 to 21 species outside.

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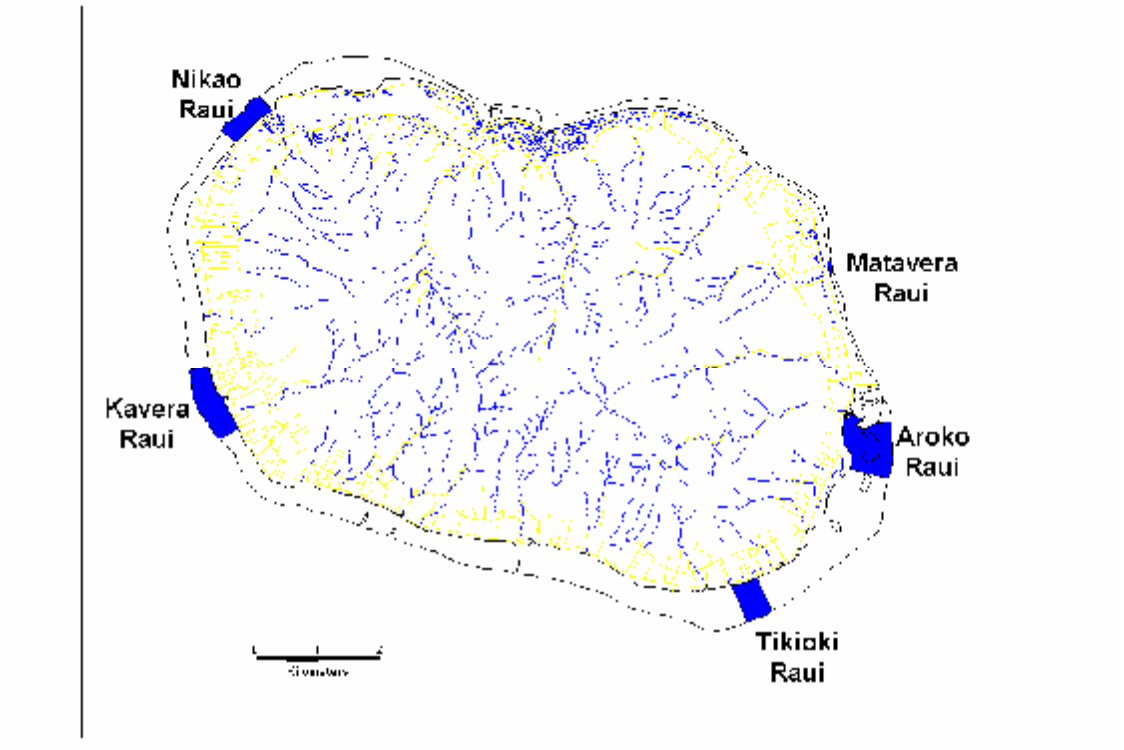
INTRODUCTION

The Rarotonga Raui is a revival of a traditional system of managing natural resources. The Raui is a method whereby harvesting of species or in an area was prohibited for a designated period. It also gave ceremony to declarations on the harvesting of seasonal target species. Under the present regime, five Raui have been declared by community leaders and establishing areas where harvesting of all marine species is banned. The intention of the Raui was to allow marine species to rejuvenate as the reef ecosystem was perceived to be under threat by over harvesting. The Raui system relies on compliance by the community because as it has no legislative powers.

Four of the Raui sites were designated in February 1998. The Ministry of Marine Resources has been involved in various aspects of this program. One includes the provision of technical information. Prior to the establishment of the Raui a comprehensive baseline assessment of the Raui areas was carried out (Ponia et al, 1998). Thereafter, a program to monitor ecological changes was adopted (Ponia et al, 1999). This monitoring program recognised that the invertebrate species at the reef flat was a potentially good indicator of changes. Routine surveys of these resources have been established and now form the basis of the monitoring program.

FIGURE 1 Map of Rarotonga showing the five Raui areas.



This report is the result of the most recent monitoring program carried out at four Raui areas, Nikao, Matavera, Aroko and Tikioki. The intention is to collect ecological information that will assist the community in evaluating the benefits of the Raui. It is also information that is disseminated to the general public and formal education system as a means to raise awareness of marine environmental issues. It is also the basis of one of the best long term data-sets of the marine ecosystem on Rarotonga and the information collected is an invaluable reference.

MATERIALS AND METHODS

For the purposes of monitoring it was decided to focus on the invertebrate (animals without backbones) species. This was partially because invertebrates are slow moving and easy to count. The assumption is that the change to the invertebrate populations should reflect changes occurring within the reef ecosystem. Therefore monitoring this component will serve as a key indicator to the impacts that the Raui has a means to rejuvenate the reef.

The methodology adopted in this survey was identical to that of the baseline surveys conducted in February 1998 (Ponia and workers, 1998). To recap, the reef invertebrates were quantified using a 50 meter belt transect of 4 meter width. The belt transect was laid perpendicular to outer reef as close to the reef edge as possible. Observers would systematically search the transect stopping every 5 meters to report the counts of invertebrates found within the area. At each survey site, 4 replicate 50 meter transects were surveyed. Depending on the area of the Raui, up to three sites were chosen to be surveyed.

Only invertebrates of social or biological significance were recorded. These species were categorised according to local taxonomic description, which may combine different species by the same name. A list of the invertebrate species with their local, common and scientific names is provided;
Ariri (Rough Turban-shell, *Turbo setosus*),
Atuke, (Brown Pencil-urchin, *Heterocentrotus mammillatus*),
Avake (Short spine urchin, *Tripneustes gratilla*)
Belligerent Rock-shell or Trumpet shell, (*Thais armigera*),
Etu (Blue Starfish, *Linckia laevigata*),
Karikao, (Rose Mouthed Turban-shell, *Astrea rhodostoma*),
Kina (Pink Sea-urchin, *Echinometra mathaei*),
Mangeongeo, (Mollusc, Muricidae family, Drupa genus – most common species is the Mulberry drupe, *Drupa morum* and *Drupa ricinius ricinus*),
Matu Rori, (Soft Black Sea-cucumber, *Holothoria leucospilota*),
Paua, (Rugose Giant-clam, *Tridacana maxima*),
Popoto, (Mollusc, Conidae family – most common species are *Conus ebraeus*, *Conus eburneus* and *Conus chaldaeus*),
Poreo, (Cowrie sp., Cypraeidae family, *Cyprea tigris* most common species),
Rori Pua, (Flower Sea-cumber, *Holothuria cinerascens*),

Rori Puakatoro, (Red Surf-fish, *Actinopyga mauritiana*),
Rori Toto, (Sandy Sea-cucumber, *Holothuria atra*),
Trochus, (*Trochus niloticus*), (introduced)
Ungakoa, (Large Worm shell, *Dendropoma maxima*),
Vana (Long Spine urchin, *Echinothrix diadema*).

There are inherent sampling weakness of the belt transect technique. This is because species such as *Ariri* and *Rori Pua* have been shown (Ponia et al, 1998) to be concentrated along the fringe of the reef edge and the perpendicular direction of the transect may not adequately cover this strata. In addition wide confidence intervals of low density species or patchy aggregated species is to be expected with the area of coverage. It is possible to reduce the confidence intervals by increasing the sampling area. Else in the case of species concentrated at specific strata a stratified design using quadrants may have been applied. But it was felt that for monitoring purposes that the level of precision attained for all species overall is sufficient.

At Tikioki Raui, fish counts were collected. This is because the site is one of the best lagoonal systems and is habitat to a large fish population. Fish species were counted within a 10 meter radius. Simultaneously, the number of fish species was also recorded.

Surveys of coral cover were also carried out at Tikioki and Nikao coral patch reefs using underwater video digital footage. This technique was adopted by the Ministry of Marine Resources based on methodology developed elsewhere (English et al, 1994). The results of the coral survey are being reported separately.

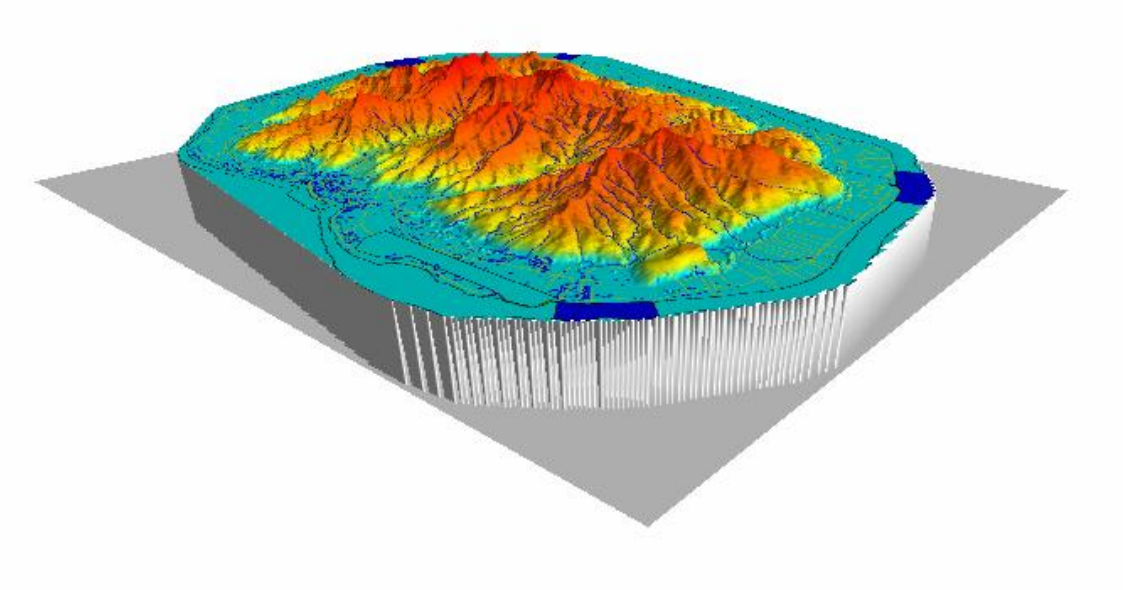
Estimates of diversity were made based on the Shannon-Weiner Diversity index (H). This is diversity is related to both the number of categories and the counts within each category (Zar, 1984). Another diversity statistic also calculated was evenness (J). Where, the maximum evenness occurs when all categories have the same number of counts. Since the maximum value for diversity is equal to the log of the number of categories (i.e $H_{max} = \log(F_i)$, where F_i = nos of categories). The measurement of evenness (J) is simply the ratio of diversity over maximum diversity possible (i.e $J = H/H_{max}$).

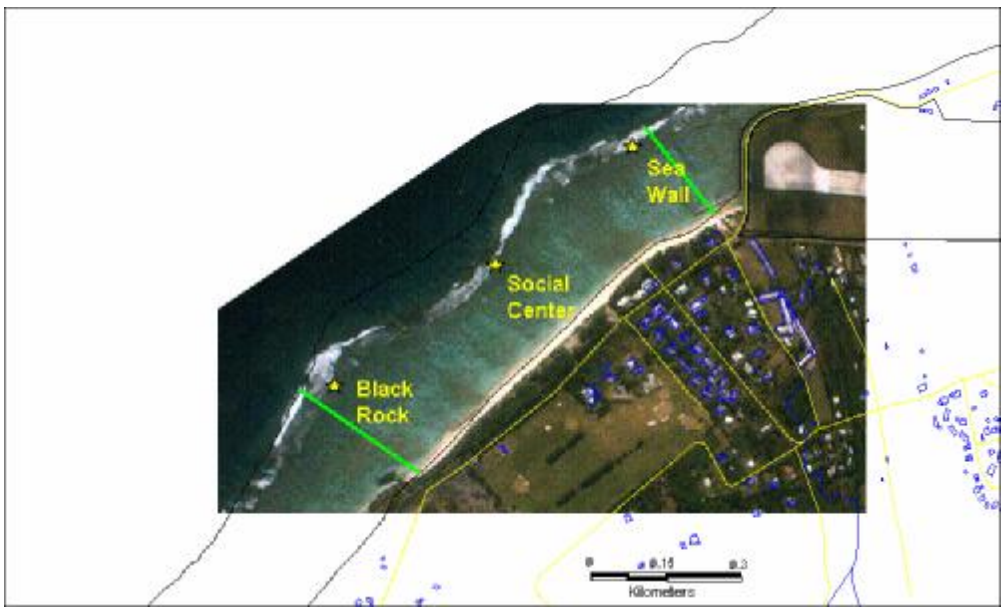
In addition estimates of invertebrate population size were calculated. This was derived simply from the average density among sites multiplied the reef area (calculated as the length of the outer reef and a 50 meter width). Confidence intervals with 95% probability that the mean is within the true figure were also derived. (refer **APPENDIX** for equations).

NIKAO RAUI

Geography

FIGURE 2 *Map of Rarotonga showing Nikao Raui.* (Top) The Raui area (shaded blue in the foreground) is on the north-western, leeward side of the Island. The reef is relatively sheltered. The Raui encompasses a lagoon area of 25 hectares and has beachfront of 800 meters. The beachfront is a popular area known as the Nikao Social Center. (Bottom) Displayed is an aerial picture showing the position of the sampling sites within the Raui boundaries, delineated green.





Diversity

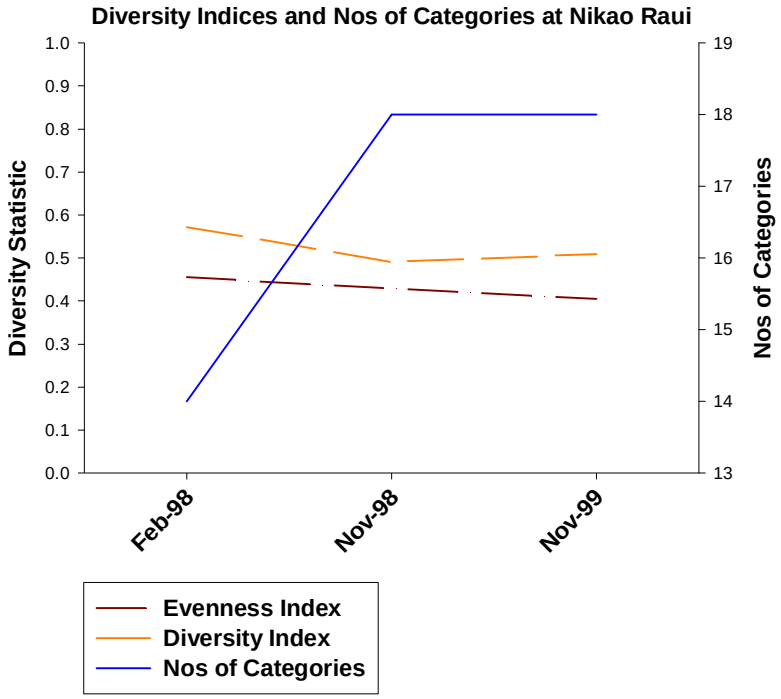
TABLE 1 *Survey counts of reef invertebrates at Nikao Raui sampling sites.* Eighteen species or categories of invertebrate types were observed during the survey. The largest counts being attributed to the *Kina*.

Invertebrate Species	Seawall	Social Center	Black Rock	Overall
Ariri	3			3
Atuke	6		13	19
Avake	1	51	151	203
Poreo	4			4
Kina	980	3618	6190	10788
Karikao	6		2	8
Matu Rori	28	124	99	251
Paua	46	233	26	305
Popoto	9	2		11
Rori Pua	1	38	195	234
Rori Matie	3	104	225	332
Rori Puakatoro	6	3	8	17
Rori Toto	76	280	93	449
Etu	2	1		3
Trochus	430	1014	554	1998
Trumpet Shell	3			3
Ungakoa	7	63	364	434
Vana	45	56	175	276

TABLE 2 *Diversity Indices of Reef Invertebrates at Nikao Raui.* The maximum number of species types was found at Seawall site and the highest diversity was calculated for that site. The Social Center has the highest evenness of species numbers. Black Rock has the lowest diversity and the evenness of distribution is low, as a result of having a dominant count of the *Kina*.

Statistic	Seawall	Social Center	Black Rock	Overall
Nos of Categories	18	13	13	18
Evenness	0.431	0.473	0.397	0.405
Diversity, H	0.542	0.527	0.442	0.509
Max Diversity	1.255	1.114	1.114	1.255

FIGURE 3 *Diversity of Nikao Raui.* The number of invertebrate species has increased from 14 types recorded during the initial survey to 18 types at present. The index of evenness and diversity has declined in the same period. This reflects the increasing dominance of the *Kina* and *Trochus* counts.



Abundance

TABLE 3 The invertebrate type with the highest density is the *Kina* which exceeds 4 individuals per square meter. The lowest density in the order of 1 individual per 1000 square meters is recorded for *Ariri*, *Etu* and Trumpet shell. There was a broad range of population sizes with the maximum of 200 thousand and minimum of 100 for the *Kina* and *Ariri* respectively. The density of nine species types recorded at Nikao is the highest recorded at the Rarotonga Raui, these species include *Atuke*, *Avake*, *Kina*, *Paua*, *Poreo*, *Trochus*, Trumpet Shell and *Vana*.

Resource	Density (per m2)		Population Size	
	Average	S.E	Total	95% C.I
Ariri	0.001	0.001	100	200
Atuke	0.008	0.005	400	1,200
Avake	0.085	0.055	3 900	12,300
Etu	0.001	0.001	100	200
Karikao	0.003	0.002	200	500
Kina	4.495	1.880	204 500	650,900
Matu Rori	0.105	0.036	4 800	15,200
Paua	0.127	0.082	5 800	18,400

Popoto	0.005	0.003	200	700
Poreo	0.002	0.002	100	300
Rori Matie	0.138	0.080	6 300	20,000
Rori Pua	0.098	0.074	4 400	14,100
Rori Puakatoro	0.007	0.002	300	1,000
Rori Toto	0.187	0.082	8 500	27,100
Trochus	0.833	0.222	37 900	120,600
Trumpet Shell	0.001	0.001	100	200
Ungakoa	0.181	0.139	8 200	26,200
Vana	0.115	0.052	5 200	16,700

FIGURE 4 *Population change of abundant resource types at Nikao Raui.* The *Kina*, *Trochus* and *Matu Rori* showed consistent increases over the duration of the Raui surveys. The *Trochus* population appears to have reached a plateau and suggests that the area has reached its carrying capacity. A probable limiting factor is the space of benthic-rock habitat available to the *Trochus*. There has been a significantly large increase in the *Ungakoa* population. Where previously it only numbered several hundred, the current population was estimated at about 8 thousand. The decrease in *Rori Pua* population is partially attributed to the rough seas sampling conditions where it is thought that the survey counts may have underestimated the true figure.

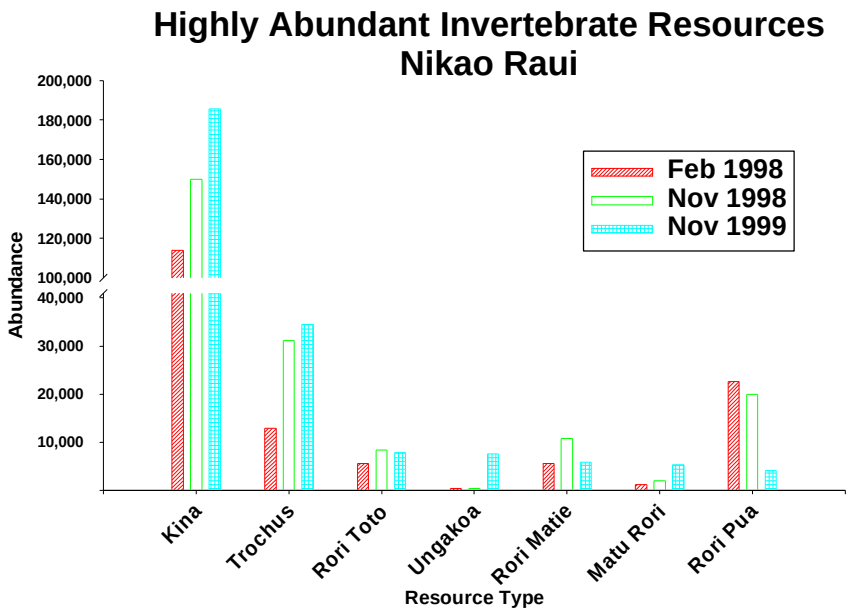


FIGURE 5 *Population size of lesser abundant invertebrates at Nikao Raui*. Among the less abundant resources (those with a population size not exceeding 6 thousand) there was a large increase of the *Avake* and *Paua* population. The *Avake* was not observed prior to the Raui and since then has attained a population size of about 4,000 animals. The *Paua* population has increased almost 6-fold. The *Vana* population has remained consistent with the last assessment indicating that the carrying capacity of the area for this resource may have been achieved also.

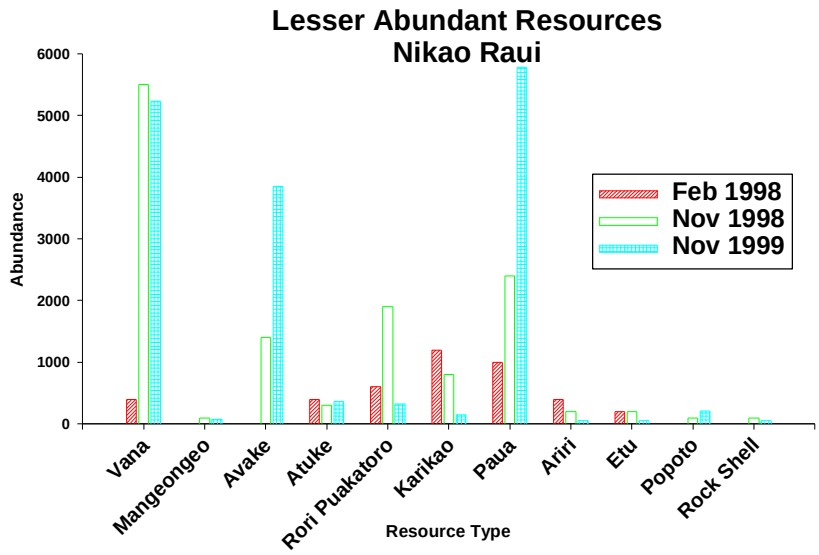


FIGURE 6 Percentage abundance of reef invertebrates at Nikao Raui. The *Kina* accounts for 70% of the total invertebrate population. The other major resource commonly encountered is the *Trochus*, responsible for 13% of the total proportion.

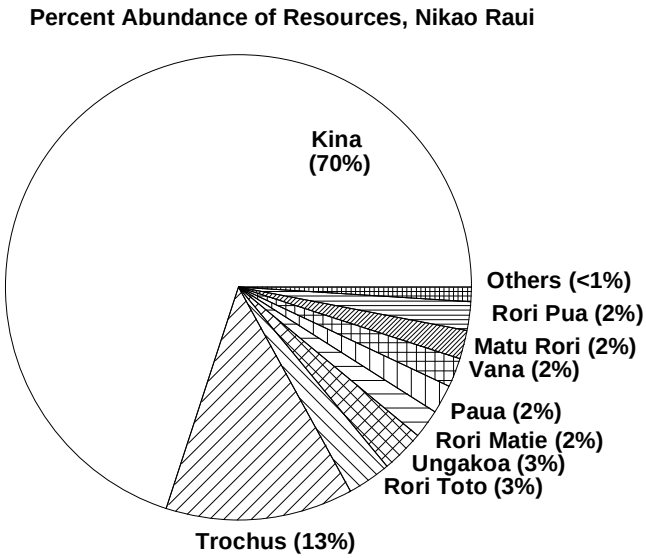
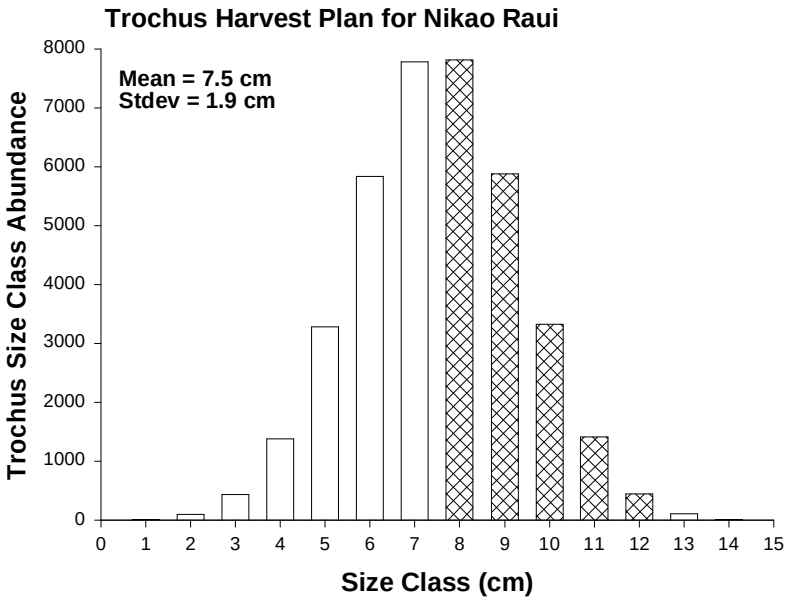


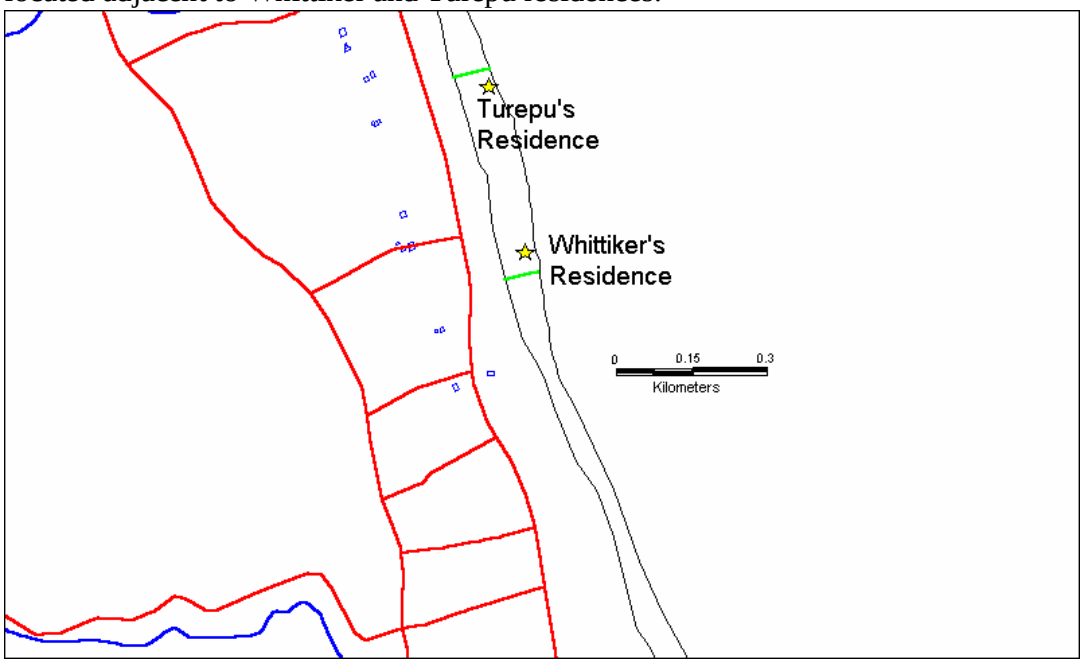
FIGURE 7 Given the large *Trochus* population size at Nikao Raui area, a sustainable harvest of this resource has been calculated. Using length-frequency data collected previously (Ponia et al, 1997) a size distribution of the *Trochus* population (38,000) has been displayed. Assuming a 60% of the harvest of the size range between 8 cm to 12 cm length the total number of *Trochus* and weight that can be harvested is 11,500 animals or 2.2 tons dry shell weight. This is the equivalent of a total harvest of 30 flour sacks (50 kg sacks) of *Trochus*.



MATAVERA RAUI

Geography

FIGURE 8 *Map of Matavera Raui*. This is the smallest Raui on Rarotonga and has almost no lagoon being comprised mostly of reef. It has an area of 5 hectares along a coastal strip of 715 meters length. Shown are the two reef sampling sites within the Raui area, these were located adjacent to Whittiker and Turepu residences.



Diversity

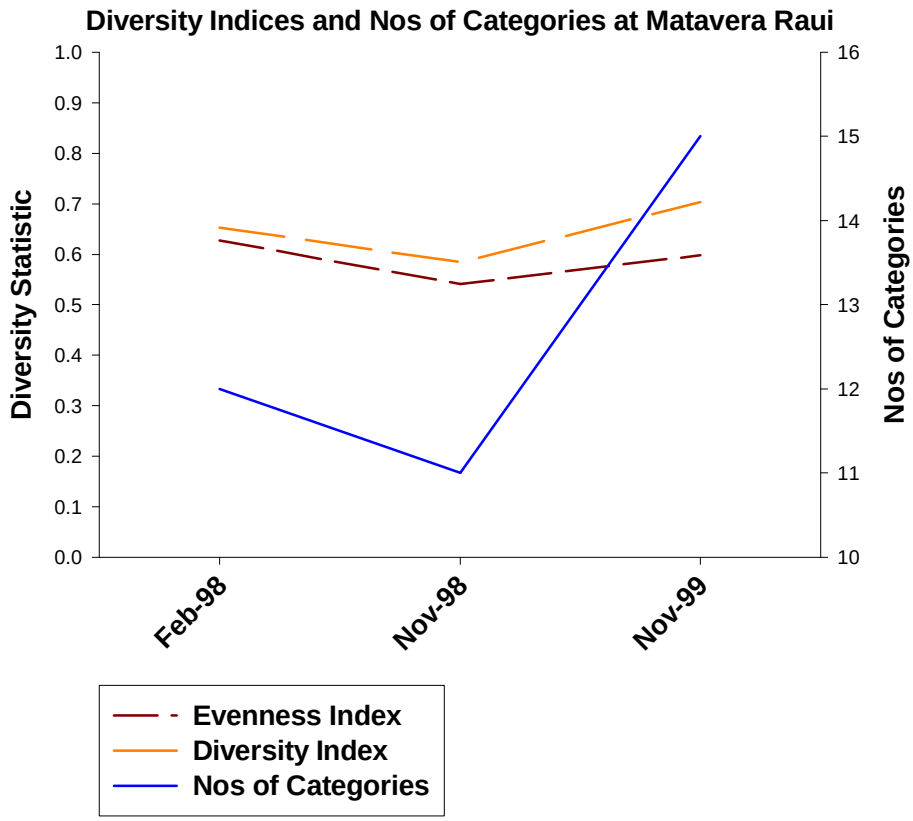
TABLE 4. *Survey counts of reef invertebrates at Matavera Raui sampling sites*. A total of 15 species were reported within the area. At each site 14 species were recorded.

Resource	Whittiker	Turepu	Overall
Ariri		7	7
Atuke	3	1	4
Avake	54	25	79
Etu	1	1	2
Karikao	4	14	18
Kina	1591	1375	2966
Matu Rori	199	58	257
Paua	88	106	194
Rori Matie	170	41	211
Rori Pua	910	63	973
Rori Puakatoro	5	67	72
Rori Toto	468	140	608
Trochus	285	117	402
Ungakoa	2		2
Vana	23	23	46

TABLE 5 *Diversity indices of reef invertebrates at Matavera Raui.* Higher diversity and evenness occurs at Whittiker compared to Turepu site. This because at Whittiker site the dominance of the *Kina* species is less skewed due to the presence of large counts of several other species such as *Rori Toto* and *Trochus*.

Statistic	Whittiker	Turepu	Overall
Nos of Categories	14	14	15
Evenness	0.628	0.508	0.598
Diversity, H	0.720	0.582	0.703
Max Diversity	1.146	1.146	1.176

FIGURE 9 *Diversity at Matavera Raui.* The survey recorded the highest number of species categories and levels of evenness and diversity since February 1998. It was attributed to the increase in the number of invertebrate species, i.e. 15 species compared to 11 species in November 1999 and 12 species observed in February 1998.



Abundance

TABLE 6 *Abundance of reef invertebrates at Matavera Raui.* The *Kina* was the most abundant species with a population size of about 66 thousand animals or a density of 1.8 individuals per square meter. The *Rori Pua* and *Rori Toto* were the only other resources with a population exceeding 10 thousand. The density of *Ariri* was the highest recorded at the Rarotonga Raui. High confidence intervals occurred for the *Rori Pua* population as there was a large difference in density between Whittiker and Turepu sites (i.e 1.2 ind.m^{-2} compared to 0.08 ind.m^{-2}, respectively).

Resource	Density (per m2)		Abundance	
	Average	S.E	Total	95% C.I
Ariri	0.004	0.004	200	700
Atuke	0.003	0.001	100	200
Avake	0.049	0.018	1,800	3,000
Etu	0.001	0.000	100	0
Karikao	0.011	0.006	400	1,000
Kina	1.854	0.135	66,300	20,800
Matu Rori	0.161	0.088	5,800	13,600
Paua	0.121	0.011	4,400	1,800
Rori Matie	0.132	0.081	4,700	12,400
Rori Pua	0.608	0.529	21,800	81,500
Rori Puakatoro	0.045	0.039	1,600	6,000
Rori Toto	0.380	0.205	13,600	31,500
Trochus	0.251	0.105	9,000	16,200
Ungakoa	0.001	0.001	100	200
Vana	0.029	0.000	1,000	0

FIGURE 10 *Population change of abundant resource types at Matavera Raui.* The *Kina* and *Trochus* populations have increased 1.5 fold since the first survey in February 1998. All resource types recorded low abundance during the November 1998 survey. With hindsight, this may be the result of a standard sampling error. The *Rori Pua* also displays considerable fluctuations with the November 1998 result included. As this species is often concentrated along the fringe of the outer reef flat the sample counts are easily underestimated under rough sea conditions.

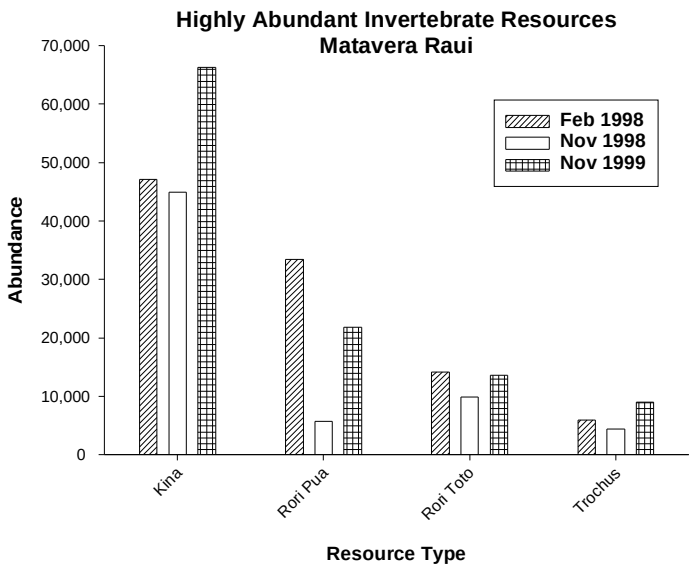


FIGURE 11 *Population change of lesser abundant resource species at Matavera Raui*. The *Matu Rori*, Rori Matie, *Paua* and *Rori Puakatoro* had large increases in their population sizes. Large fluctuations in population size also occur, particularly among the sea cucumber species.

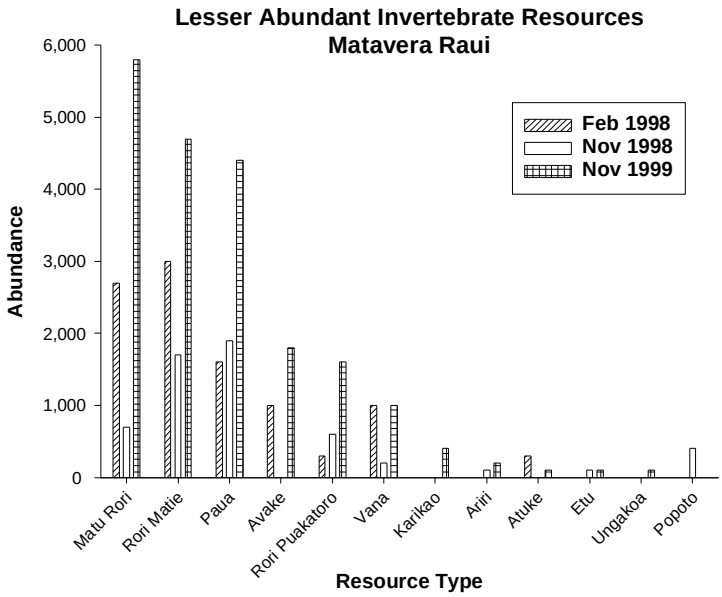
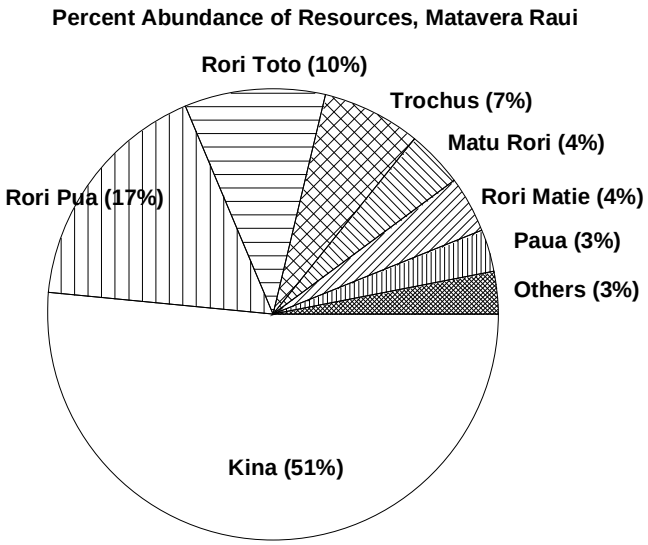


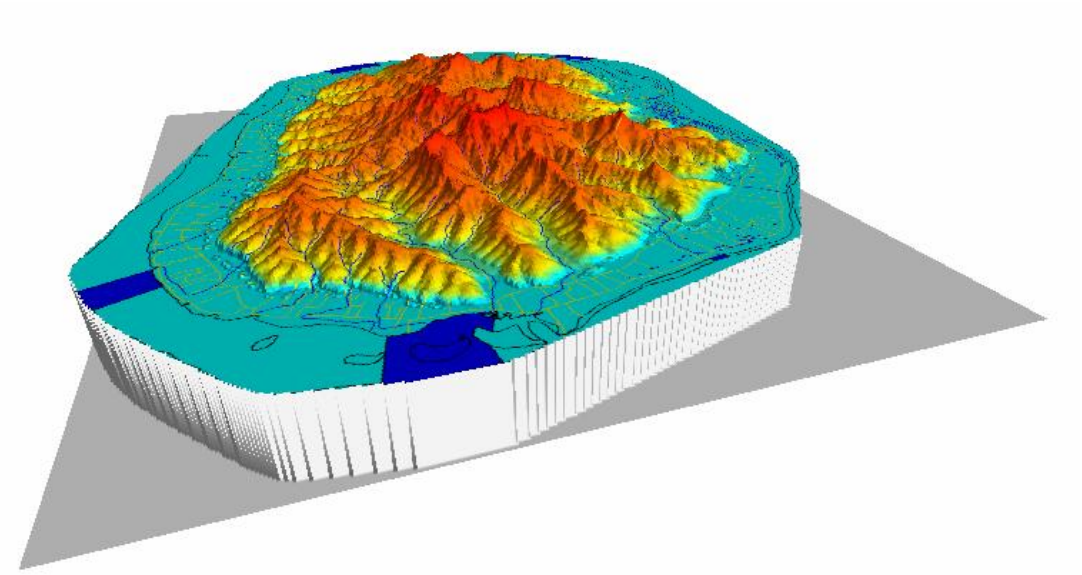
FIGURE 12 *Percentage abundance of resources at Matavera Raui*. The *Kina* was responsible for just over 50% of the total invertebrate population in the Raui area. 25% of the total proportion was cumulatively accounted by the *Rori Pua*, *Rori Toto* and *Trochus*.

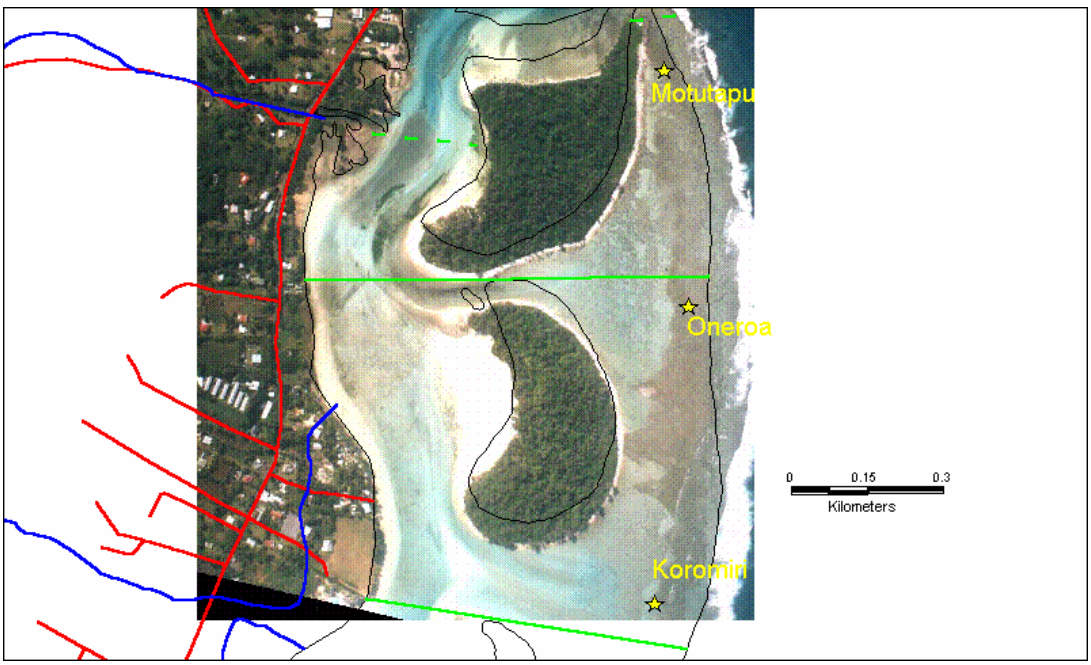


AROKO RAUI

Geography

FIGURE 13 (Top) *Map of Rarotonga showing Aroko Raui in the foreground (shaded blue)*. The Raui area covers 47 hectares and is dominated by three islets. The location is also adjacent to a river and large reef channel. (Bottom) the Raui boundaries delineated with solid green lines and the location of survey sampling sites.





Diversity

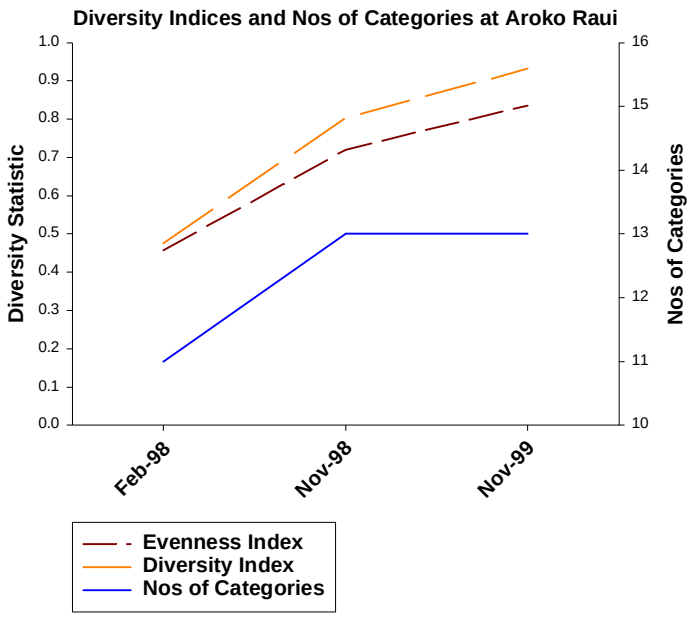
TABLE 7 *Survey counts of reef invertebrates at Aroko Raui sampling sites*. Thirteen reef invertebrate species were recorded at Aroko Raui.

Resource	Nukupure	Motutapu	Oneroa	Total
Avake	4	21	41	66
Etu	115	4	5	124
Karikao		149		149
Kina	100	976	301	1377
Matu Rori	262	136	94	492
Paua	104	76	48	228
Rori Matie	263	309	102	674
Rori Pua	104	744	657	1505
Rori Puakatoro	81	44	15	140
Rori Toto	262	432	310	1004
Trochus	247	492	347	1086
Ungakao		54	13	67
Vana	121	62	20	203

TABLE 8 *Diversity indices of reef invertebrates at Aroko Raui.* The highest number of species was reported at Motutapu site. Although Nukupure site had the least categories of species it had the greatest amount of diversity and evenness of species distribution. This was reflected during the survey where it was found that Motutapu and Oneroa were dominated by *Kina* or *Rori Pua*, in contrast to Nukupure.

Statistic	Nukupure	Motutapu	Oneroa	Overall
Nos of Categories	11	13	12	13
Evenness	0.923	0.782	0.748	0.836
Diversity, H	0.961	0.872	0.807	0.932
Max Diversity	1.041	1.114	1.079	1.114

FIGURE 14 *Diversity of invertebrates at Aroko Raui.* The trend of diversity indicates the



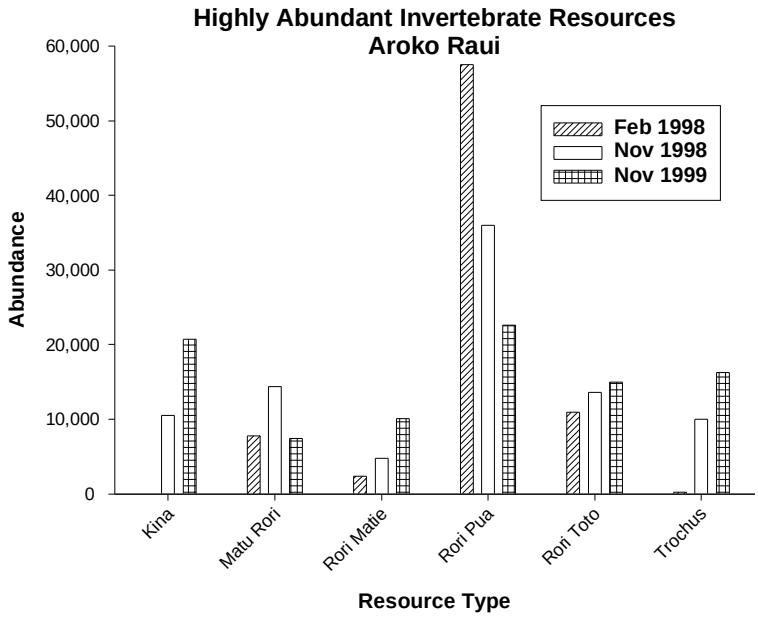
values have increased since February 1998. However, the result is not readily comparable because *Kina* was inadvertently excluded from the February 1998 survey. Nonetheless, the diversity statistics of invertebrate resources are relatively high compared to the other Raui sites on Rarotonga. This might reflect the more heterogeneous benthic habitat types at Aroko reef flat and the nutrients from the adjacent islet and river system.

Abundance

TABLE 9 *Invertebrate resource abundance at Aroko Raui.* The largest population sizes are that of the ***Rori Pua*** and ***Kina***, both in the order of 20 thousand animals. There are five species at Aroko whom the density was the highest recorded at the Rarotonga Raui. These species include the ***Etu***, ***Karikao***, Rori Matie, ***Rori Pua*** and ***Rori Puakatoro***. As noted previously, the heterogeneous benthic habitat and nutrient sources may contribute to the attraction of this area.

Resource	Density		Abundance	
	Average	S.E	Overall	95% CI
Avake	0.028	0.013	1,000	1,500
Etu	0.052	0.046	2,000	5,300
Karikao	0.062	0.062	2,300	7,100
Kina	0.574	0.331	20,700	38,000
Matu Rori	0.205	0.063	7,400	7,300
Paua	0.095	0.020	3,400	2,400
Rori Matie	0.281	0.078	10,100	9,000
Rori Pua	0.627	0.251	22,600	2,900
Rori Puakatoro	0.058	0.024	2,100	2,700
Rori Toto	0.418	0.063	15,000	7,300
Trochus	0.453	0.089	16,300	10,200
Ungakoa	0.028	0.020	1,000	2,300
Vana	0.085	0.037	3,100	4,200

FIGURE 15 *Population change of highly abundant resources types at Aroko Raui*. The *Rori Pua*



shows a consistently declining population over the survey period. This resource is almost a third the size of the population size two years ago. The *Kina*, Rori Matie, *Rori Toto* and *Trochus* all have consistently increasing populations. The increase of *Trochus* has been quite significant from several hundred in February 1998 to over 16 thousand in the present survey.

FIGURE 16 *Population change of lesser abundant resources at Aroko Raui*. The *Avake*, *Etu*, *Ungakoa* and *Vana* have recorded consistent increases in their population. Where initially the population only numbered several hundreds it has increased to about several thousands.

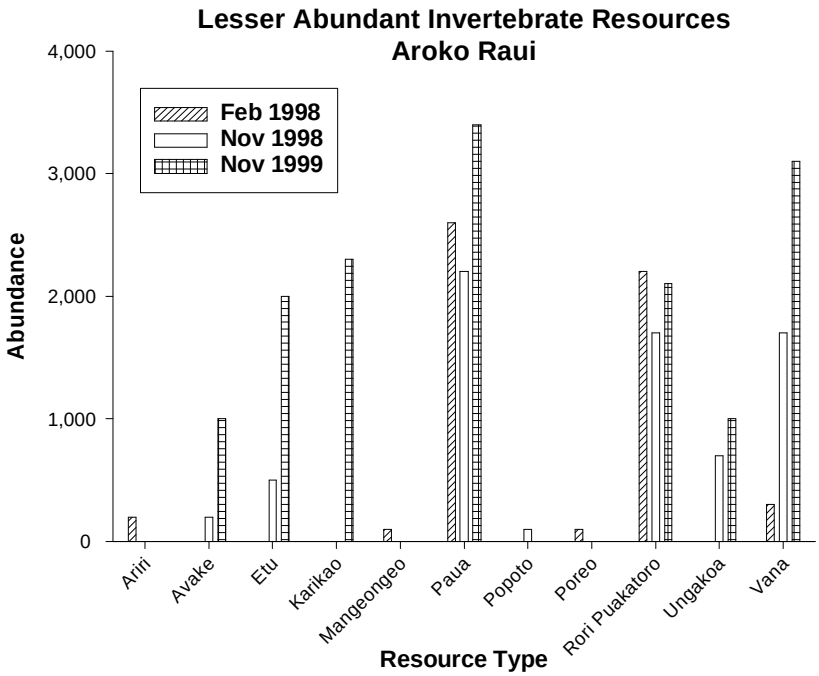
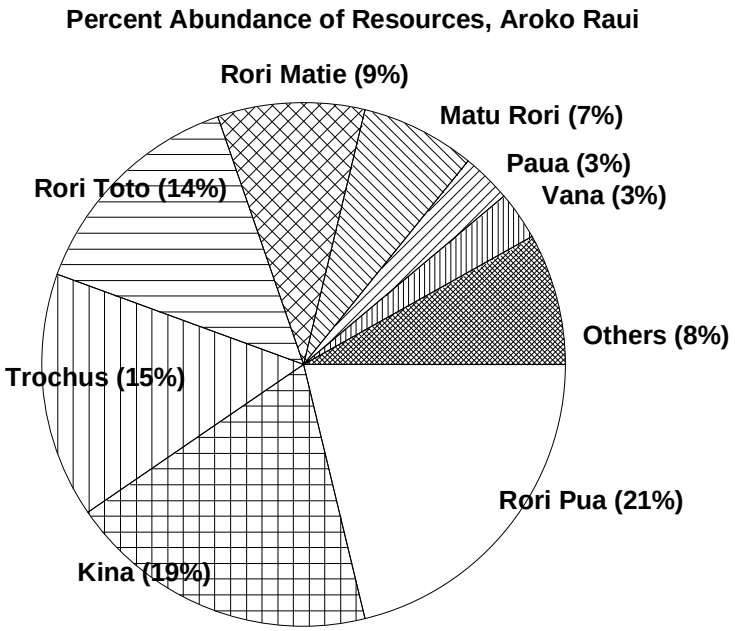


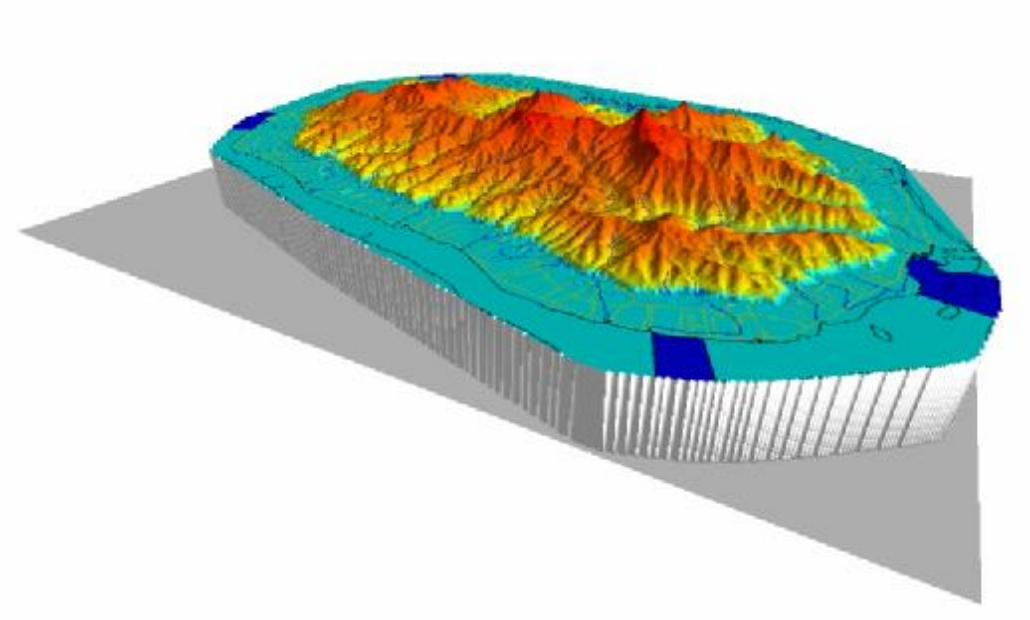
FIGURE 17 *Percentage abundance of invertebrate types at Aroko Raui.* Unlike the other Raui on Rarotonga, the largest proportion of invertebrate population at Aroko site was not the *Kina* resource. Instead this was attributed to the *Rori Pua* which accounts for 21% of the total population. However, the *Kina* is the next most common resource and responsible for 19% of the proportion. The *Trochus*, *Rori Toto* and Rori Matie are also significant components of the invertebrate populations.

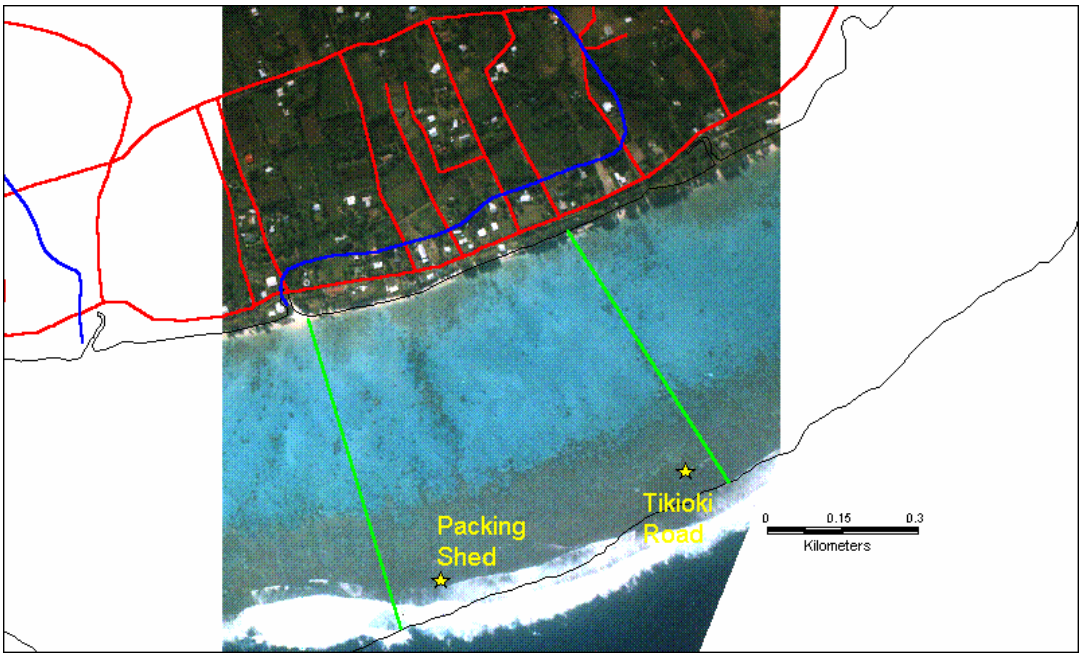


TIKIOKI RAUI

Geography

FIGURE 18 *Map of Rarotonga showing Tikioki Raui.* (Top) The Raui area shown in the foreground as a blue shaded area has a lagoon area of 47 hectares and beachfront of 760 meters. (Bottom) Two reef survey sites were chose within the Raui boundaries, delineated green.





Diversity

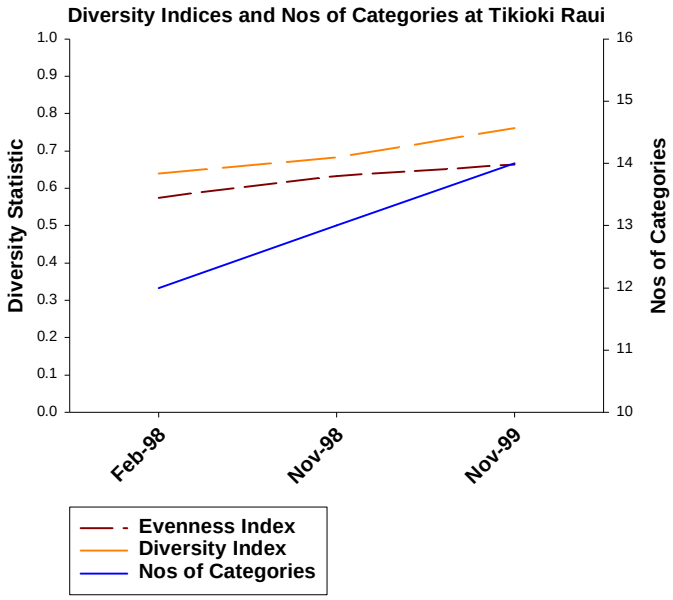
TABLE 10 *Survey counts of reef invertebrates at Tikioki Raui sampling sites*. Fourteen species or categories of invertebrate types were observed during the survey.

Resources	Packing Shed	Tikioki Road	Total
Avake		3	3
Etu	24	8	32
Karikao	26		26
Kina	707	708	1415
Matu Rori	60	761	821
Paua	10	6	16
Popoto	14		14
Rori Matie	7	177	184
Rori Pua	277	262	539
Rori Puakatoro	11	11	22
Rori Toto	247	438	685
Trochus	39	111	150
Ungakoa	21	13	34
Vana	16	4	20

TABLE 11 *Diversity indices of reef invertebrates at Tikioki Raui*. Higher species diversity and distribution at Tikioki Road was attributed to this site being less dominated by the *Kina* resource on account of the high counts of *Matu Rori*, *Rori Toto*, Rori Matie and *Trochus*.

Statistic	Packing Shed	Tikioki Road	Overall
Nos of Categories	13	12	14
Evenness	0.618	0.680	0.664
Diversity, H	0.689	0.733	0.761
Max Diversity	1.114	1.079	1.146

FIGURE 19 *Diversity of Tikioki Raui*. For the duration of the survey period the number of species (i.e number of categories) has increased. In addition the diversity statistics have followed the same trend. This reflects an increase in number of species and a more evenness of distribution among species.



Abundance

TABLE 13 *Reef invertebrate abundance at Tikioki Raui.* The largest population of invertebrate species at the reef was the *Kina* followed by the *Matu Rori* and *Rori Toto*. Tikioki Raui had the highest density of *Matu Rori*, *Popoto* and *Rori Toto* recorded at the Rarotonga Raui.

Resources	Density		Abundance	
	Average	S.E	Overall	95% C.I
Avake	0.002	0.002	100	400
Etu	0.020	0.010	900	1,800
Karikao	0.016	0.016	700	3,000
Kina	0.884	0.001	37,000	100
Matu Rori	0.513	0.438	21,300	78,300
Paua	0.010	0.003	400	500
Popoto	0.009	0.009	400	1,600
Rori Matie	0.115	0.106	5,000	19,000
Rori Pua	0.337	0.009	14,000	1,700
Rori Puakatoro	0.014	0.000	600	0
Rori Toto	0.428	0.119	18,000	21,300
Trochus	0.094	0.045	3,900	8,000
Ungakoa	0.021	0.005	900	900
Vana	0.013	0.008	500	1,300

FIGURE 20 *Population change of the highly abundant resource types at Tikioki Raui*. The *Kina* and *Rori Pua* population has declined from the population size first estimated in February 1998. In contrast, the *Matu Rori* has increased in population size quite considerably (about 10 fold). The *Rori Pua* and *Rori Toto* has remained fairly consistent.

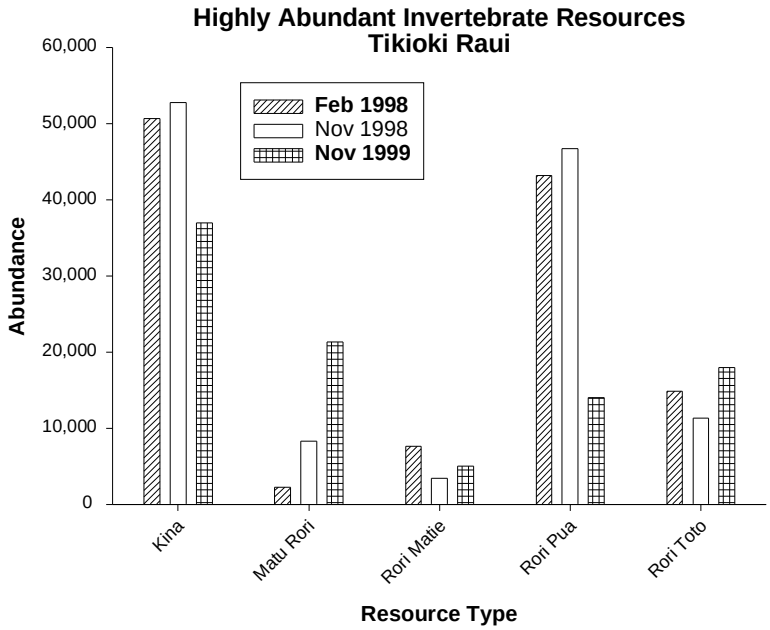
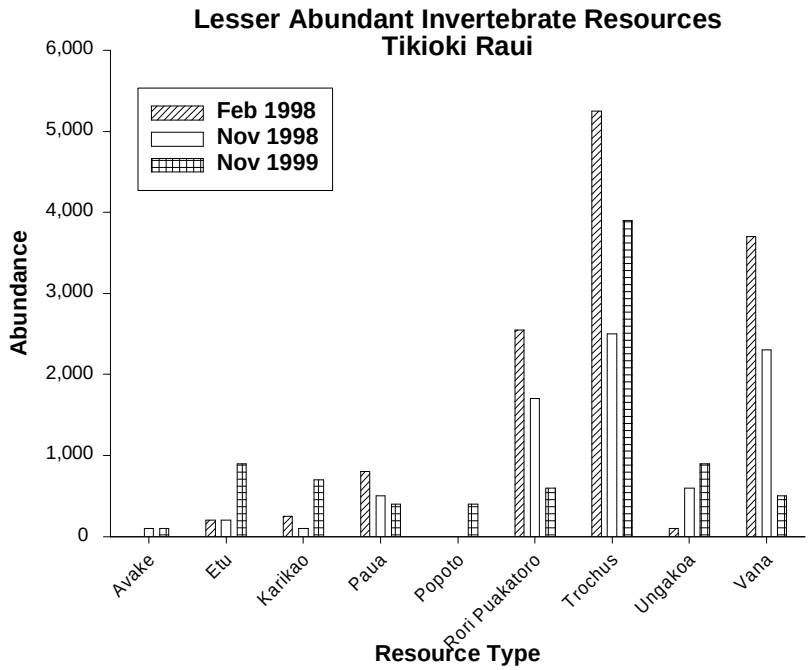
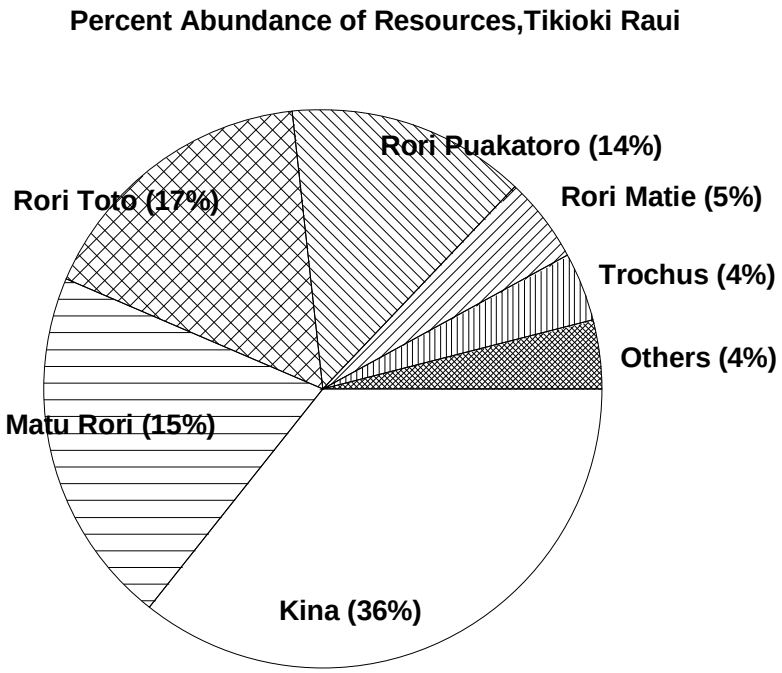


FIGURE 21 *Population change of lesser abundant resource types at Tikioki Raui*. The *Rori Puakatoro* and *Vana* populations have declined considerably in population size. The



Ungakoa resource has increased its population size over the Raui period. With the exception of the *Trochus* the remaining species have populations that have remained in the order of a thousand animals.

FIGURE 22 *Percent abundance of invertebrate resources at Tikioki Raui*. The *Kina* is responsible for 36% of the total invertebrate population at Tikioki reef. The *Matu Rori*, *Rori Toto* and *Rori Puakatoro* each account for about 15% of the total proportion.



Fish

FIGURE 23 *Fish distribution patterns inside and outside Tikioki Raui.* Significantly higher counts of the indicator species fish Topsail Drummer (*Kyphosus cinerascens*) or Pipi as it is locally known, was found inside the Raui compared to outside. The fish tended to aggregate around the large coral reef structure found within the Raui boundaries. Therefore in effect there were more fish inside the Raui compared to areas outside. At one Raui site an average of 61 Pipi were counted within the 10 meter radius compared to 0.25 Pipi outside. The abundance of Pipi during this survey was approximately a 20 fold increase in density compared to the February, 1998 survey.

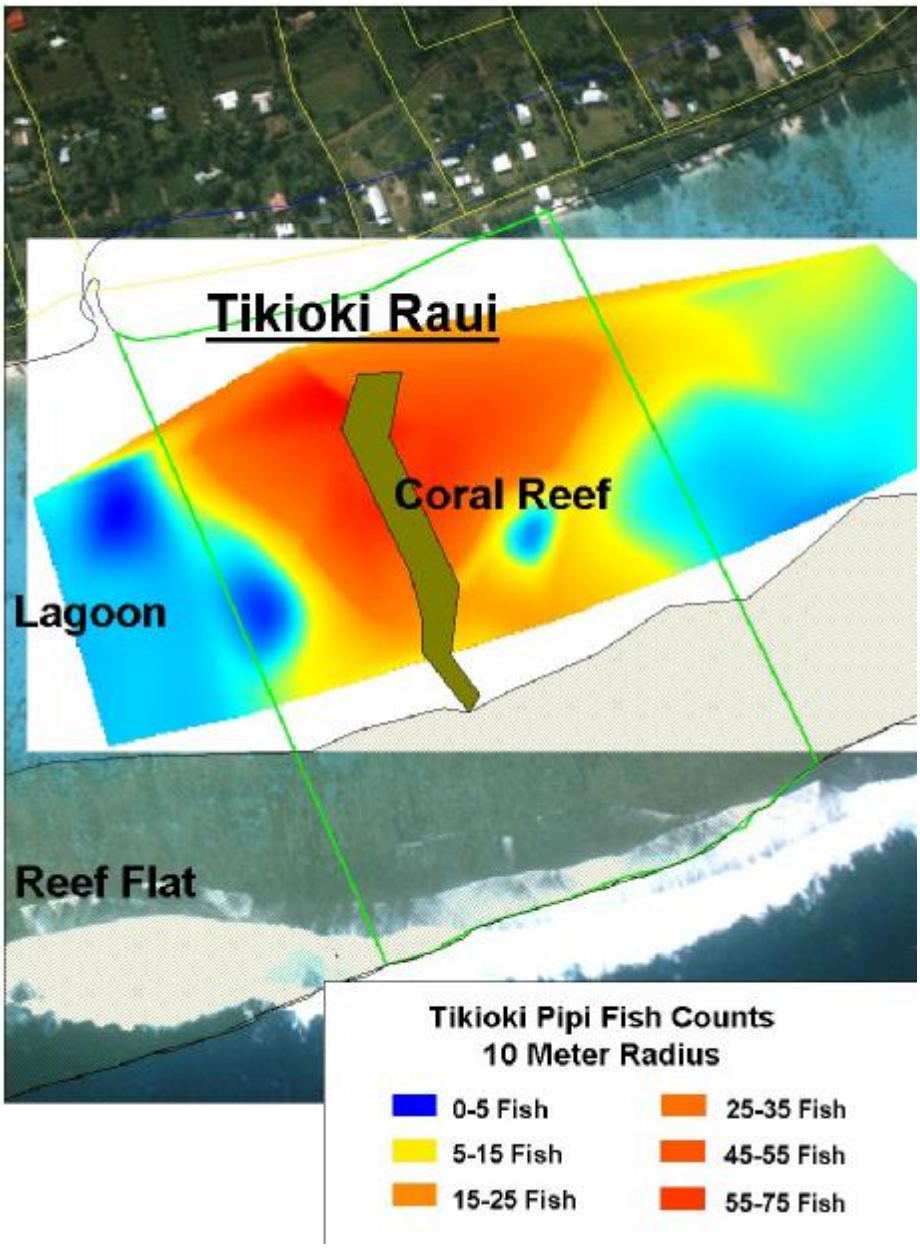
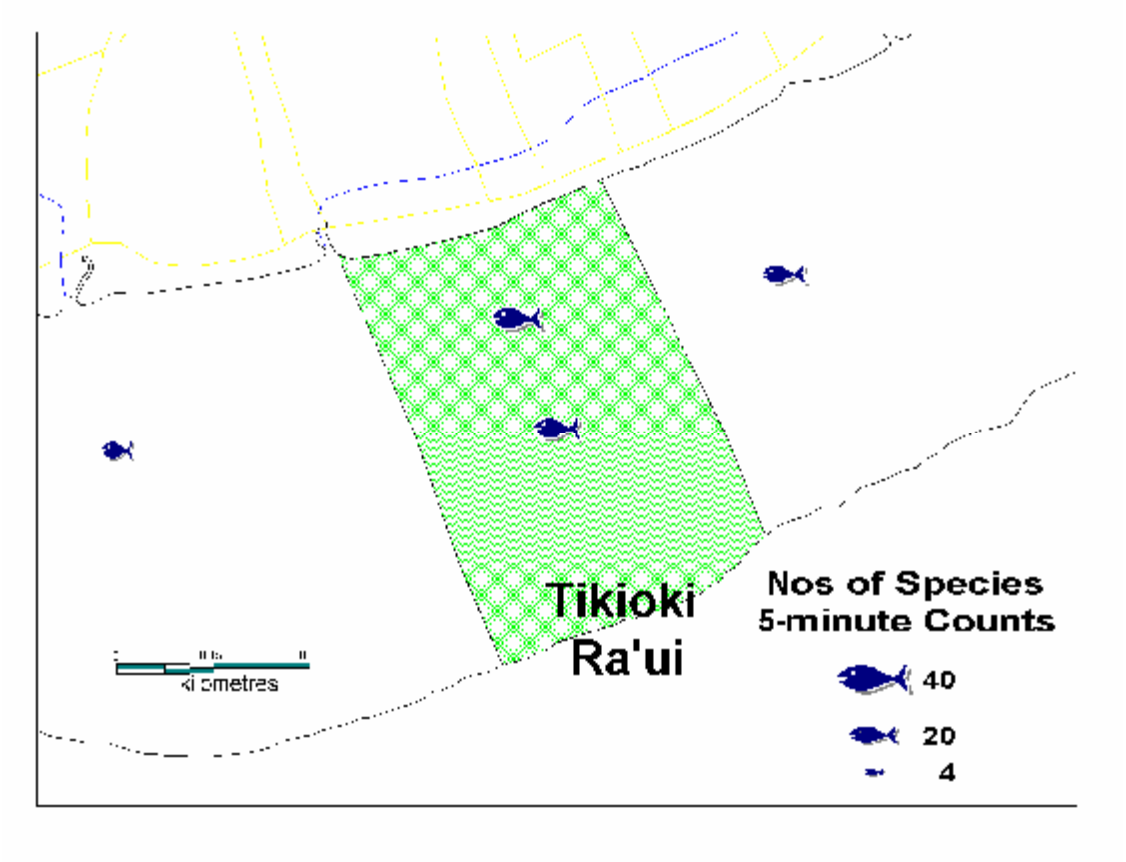


FIGURE 24 *The number of species inside the Raui.* There were more numbers of species seen inside the Raui compared to sites located outside the Raui. Within the survey radius area (10 meter radius) it ranged between 27 and 31 species compared to 14 to 21 species at the sites outside. In total, 80 species of fish have been identified at the Raui area during the baseline survey. It is expected that the number of species has increased since then, but this has not been quantified.



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APPENDIX

Statistical equations
Diversity.
A. Diversity index, H' is

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

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.