Phoenix Islands Conservation Survey 2006
Marine Survey Report

Vince Kerr[1] and Graham Wragg[2]

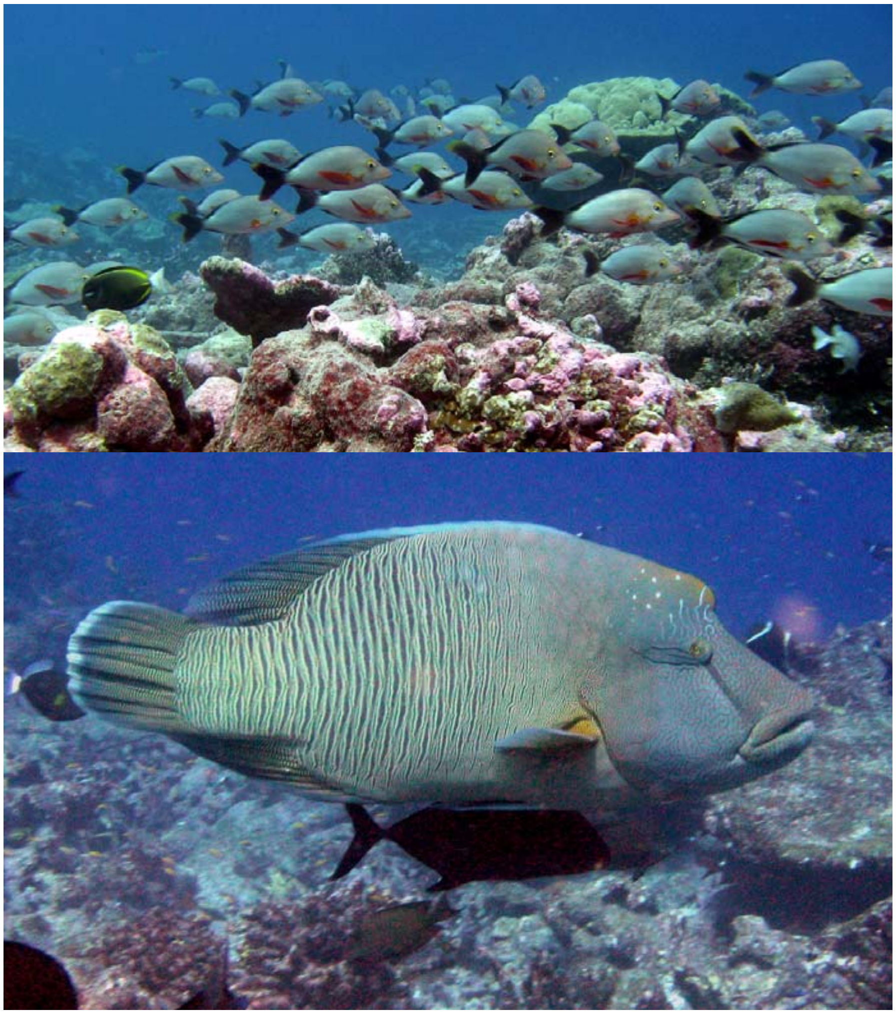

Photo: Paddle tail snapper at Orona (top), Humphead wrass at Nikumamoro (Bottom)

[1]Vince Kerr, PO Box 4267,
Kamo, Whangarei, New Zealand
Phone: 64 9 4351518
Email: vincek@igrin.co.nz

[2]Graham Wragg,
email: info@pacific-expeditions.com

Summary

Marine investigations and monitoring work were carried out as part of the 2006 Phoenix Islands conservation survey on an opportunistic basis. It was recognized that scientific visits to these Islands are rare and the substantial work of the NEAQ marine survey team could be supported with even some limited monitoring data from our expedition. In cooperation with the NEAQ team we prioritized our marine work around abundance and diversity surveys of fish and coral health assessments at key permanent monitoring sites established previously by the NEAQ team. Seven of the Phoenix Islands were surveyed; omitting Kanton Island. Where possible beaches were surveyed for turtle nests and tracks and records were kept of all marine mammal sightings. Reference sites were also surveyed at three Tokelau Islands, Swains, Fakalofo and Atafu to provide a basis of comparison with unfished Phoenix Islands sites. Forty three individual survey dives were completed.

Rapid assessment survey results for the Phoenix Island reef species were generally consistent with the NEAQ results of the 2000 and 2002 expeditions. Orona appeared to be the exception and is believed to be affected by recent fishing and is recommended as an ideal monitoring site for future monitoring. Comparison of Phoenix Island monitoring results with 'fished' reference sites at the Tokelau Islands was useful with the Tokelau Islands sites showing significantly less abundance and diversity of fish species. Rapid assessments of coral health were made on seven islands. Results of this work are still being analyzed, Initial interpretation indicates that there has been some damage to corals as a result of coral bleaching events recorded in 2002. McKean Island especially had very low (estimated < 10%) levels of live coral at lee side outer reef slope sites. Turtle nest counts at Enderbury indicated that this is a significant island for green turtle breeding. Counts on the other islands were low however our survey period was in the non-breeding season which could result in turtle signs having been destroyed by storms etc. No whales were recorded from the entire journey which is a concern considering the extensive time we spent observing in Phoenix Island waters. Most Islands had resident dolphins populations which were recorded. Taken as a whole the marine values of the Phoenix Islands are significant on an international scale. There are few oceanic atolls in the world that can be observed in a virtually unfished state. The Phoenix Islands offers us this precious opportunity.

Introduction

The past and recent history of marine surveys and marine biological information is reviewed and summarized in the publications which have followed the New England Aquarium expeditions in 2000, 2002 and 2005 (Stone et al. 2001, Obura & Stone 2003, Stone 2004, Obura 2006a, 2006b). The Islands were also visited and surveyed by marine biologists of the Planetary Coral Reef Foundation in 2004 (Alling 2006, http://www.pcrf.org/phoenix.html).

The Island group is described as pristine with abundant marine life. Previous work by Stone and Obura highlights how valuable these islands are to our understanding of oceanic atolls and coral reef ecology. Their work also identifies impacts from fishing activity on the Islands and records a significant bleaching event in 2002.

The 2006 Phoenix Island Conservation Survey brought together a diversified science team. One of the goals of our science team is to integrate marine and terrestrial survey work on all remote islands wherever possible and practical. Visits to these islands are often so rare it is vital that even the most basic rapid surveys are done. With the critical threat of coral bleaching affecting these systems it is crucial that we have regular information on the impacts of these events, or whole systems could be lost before the world is informed there is a problem. Similarly, isolated remote islands are particularly vulnerable to illegal fishing, which can be detected with rapid survey techniques. The conservation values of the Phoenix Islands certainly justify making every effort to continue regular monitoring. The significant baseline studies and rapid survey methods established there in 2000 and 2002 greatly increase the value of future work, thus strengthening the case for continuation of a monitoring effort.

In co-operation with the New England Aquarium marine survey team, our science team planned to conduct marine survey work and record general observations on an ‘opportunistic’ basis. When the two expedition members experienced in marine survey were free from the various duties relating to the terrestrial survey work, marine survey work could be attempted. Following advice from the New England Aquarium team we focused on the previous dived sites that had been designated as ‘permanent’ monitoring sites and we used identical methods to the 2002 expedition to enable direct comparison in a time series. As the expedition progressed we found we were getting time to do marine work at priority sites without compromising our terrestrial objectives. This is due in part to favorable weather and swell conditions at most sites, the efficiency of the terrestrial survey effort, and the backup capacity we had created in our team to cope with adverse contingencies.

Traveling from Samoa to the Phoenix Islands and back we stopped at three of the Tokelau Islands and conducted rapid survey dives at one site at each island. We used identical methodology to that used in the Phoenix Islands, thereby creating a set of ‘reference sites’ from similar inhabited islands that can be compared to the Phoenix Islands. Seven of the eight Phoenix Islands were surveyed with Kanton Island being the only exception. Due to the limitations of time and of the anchorages used we concentrated on lee shore outer reef edge and slope habitats consistently. We also recorded observations of marine mammals and turtles throughout the expedition. Tables 1 & 2 below detail the dive sites and individual survey dives completed.

Tokelau Islands surveyed (Leeward outer reef all sites)					
Island	**Dive site**	**# of Dives**	**Latitude**	**Longitude**	**Date**
Swain	Castaway reef	3	S 11 03.410	W 171 07.500	15 April
Fakaofo	Bigeye reef	2	S 9 22.500	W 171 16.500	16 April
Atafu	Vailima reef	2	S 8 34.100	W 172 30.700	8 May

Table 1. Survey sites Tokelau Islands

Phoenix Islands surveyed (Leeward outer reef all sites)					
Island	**Dive site**	**# of Dives**	**Latitude**	**Longitude**	**Date**
Manra	Harpoon Corner	4	S 4 26.475	W 171 15.901	18 April
Rawaki	Deepwater	4	S 3 43.275	W 170 43.051	20-21 April
Enderbury	Observation spot	4	S 3 8.539	W 171 5.549	22-24 April
Birnie	Puff magic	4	S 3 35.363	W 171 31.093	25 April
McKean	Guano hut	5	S 3 35.860	W 174 7.690	29 April - 1 May
	Rush hour	2	S 3 35.520	W 174 7.650	
Orona	Algae corner	3	S 4 31.112	W 172 13.616	2-3 May
	Transition reef	2	S 4 30.683	W 172 13.531	
	Aerials	2	S 4 31.961	W 172 12.953	
Nikumamoro	Amelia's lost causeway	5	S 4 40.477	W 174 32.616	5-6 May
	Norwich city	1	S 4 39.652	W 174 32.847	

Table 2. Survey Sites Phoenix Islands

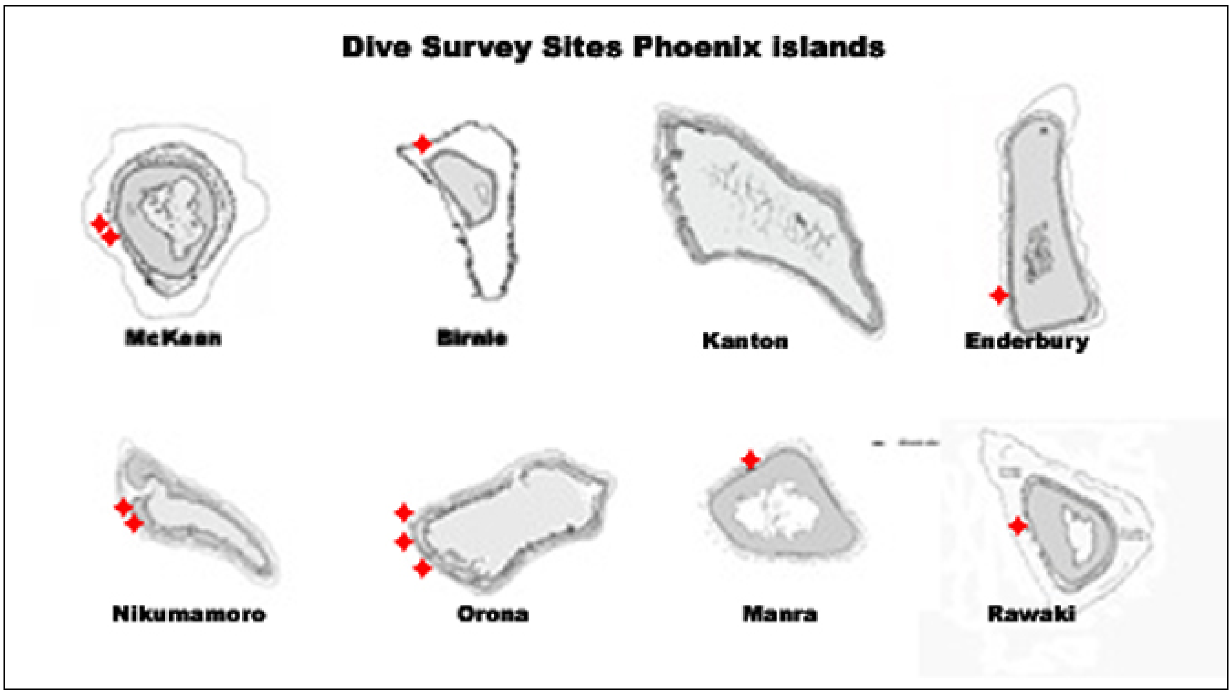

Figure 1. Composite map of Phoenix Islands dive sites (indicated in red)

Methods

The rapid survey methods used were taken from the methodologies described in the New England Aquarium 2002 expedition (Obura and Stone 2003), and are described below along with some minor modifications and additions. All SCUBA dives were carried out by Vince Kerr and Graham Wragg.

Large Indicator Fish Abundance (30 minute swim)

Twenty-one species of large fish species have been selected as being potential indicators of fishing activity and other impacts on the coral reef ecosystem. In our study we added the milkfish *Chanos chanos* to the list created by Stone & Obura (2003). Milkfish is an important food fish to island people and can reach quite large sizes in unfished systems.

This method was a derivation of an internationally standard method referred to as the 'roving diver technique' (Bohnsack 1994 and Hall & Wilkinson 2004), which has been used by the authors in similar surveys in the Cook Islands. A single SCUBA diver swims for 30 minutes at a consistent depth range between 25m and 12m and records the numbers of fish of the species listed in Table 3 below. For each dive we recorded the depth of the survey to allow for more detailed examination of differences in fish abundance as affected by depth. Considerable care was taken to avoid double counting certain species that have a tendency to follow divers. We recorded estimated sizes of all sharks to enable further analysis of the shark populations. We recorded turtle sightings on all dives. This method has certain advantages over stationary census methods as the diver covers a considerable distance (several hundred meters). As a result, large more mobile predator fish, which could easily be missed in standard transect type monitoring, can be observed more consistently. Ideally this method is used in combination with more quantitative stationary fish counts, as was done in this study.

Family	**Scientific name**	**Common name**
Scombridae	*Gymnosarda unicolor*	Dogtooth tuna
	Euthynnus affinis	Mackerel tuna
Carangidae	*Scomberoides lysan*	Doublespotted queenfish
	Elegatus bipunnulata	Rainbow runner
	Caranx sexfasciatus	Bigeye trevally
	Caranx malanpygus	Bluefin trevally
	Caranx lugubris	Black trevally
	Caranx ignoblis	Giant trevally
	Chanos chanos	Milkfish
Sphyraenidae	*Sphyraena genie*	Chevron barracuda
	Sphyraena barracuda	Great barracuda
Labridae	*Cheilinus undulatus*	Napoleon wrass
Serranidae	*Epinephelus fuscoguttatus*	Brownmarbled grouper
	Plectropomus laevis	Blacksaddle grouper
Lutjanidae	*Aprion virensis*	Green jobfish
	Lutjanus bohar	Twinspot snapper
	Macolor macularis	Midnight snapper
Carcharhinidae	*Carcharihinus melanopterus*	Blacktip reef shark
	Carcharihinus amblyrhynchos	Grey reef shark
Hemigaleidae	*Triaenodon obesus*	Whitetip reef shark
Mobulidae	*Manta birostris*	Manta ray

Table 3. Species counted in 'Large Indicator Fish Abundance 30 Minute Swim' surveys

Abundance of Key Fish Families (150m^2 stationary circular transect)

Ecologically important fish families were surveyed by a single diver on SCUBA. The method used was taken from Obura and Stone (2003). Circular transects 150m^2 were haphazardly selected at depth ranges of 25m, 12-15m and 6-9m. The selected depth ranges consistently correspond to the reef habitats described as 'surge zone', 'shallow platform' and 'edge' by Obura (2006b). These habitats cover the most productive and diverse parts of the outer reef environment. The diver counted all fish of the families listed in Table 4 and estimated length in size classes 10-20cm, 21-30cm, 31-40cm, and 41-50cm. Fish under 10cm in length were not counted. The number of transects completed at each site was limited by the diver's air time. We aimed for a minimum of 10 transects at each site including at least 6 at the 12-15m depth range. The fish families counted and their ecological roles are listed in Table 4. The numbers of surveys completed for each island and dive site are detailed below in Tables 5 & 6.

Family	**Common Name**	**Ecological Roles** ***(listed by approximate importance to family***
Acanthuridae	Surgeonfish	Herbivores, Planktivores, Detrivores
Scaridae	Parrots	Corallivores, Herbivores
Labridae	Wrasses	Invertivores, Planktivores, Corallivores, Cleaners, Piscivores
Lutjanidae	Snappers	Invertivores, Piscivores, Planktivores
Lethrinidae	Emperors	Invertivores, Piscivores, (benthic feeders)
Haemulidae	Grunt/Sweetlips	Invertivores
Carangidae	Jacks	Piscivores, Planktivores
Serranidae	Groupers	Piscivores, Invertivores
Balistidae	Triggerfish	Invertivores, Piscivores, Planktivores
Chaetodontidae	Butterflyfish	Corallivores, Invertivores, Herbivores
Pomacanthidae	Angelfish	Planktivores, Herbivores, Invertivores,
Sphyraenidae	Barracuda	Piscivores
Carcharhinidae/ Hemigaleidae	Sharks	Piscivores, Invertivores

Table 4. List of fish families and ecological role on coral reefs (Randall 2005)

Coral Health Rapid Assessment

Coral descriptive work was done on a time available basis and was typically the third [???] priority behind the two fish survey methods used. Two methods described below took very little time and were done at all sites. The third method was a coral transect method described below. At each (SCUBA) dive site, visual estimates of the percentage of the live coral cover were made and recorded. Notes were taken of any sightings of recent coral bleaching, coral disease, crown of thorns starfish *Acanthaster planci* present, and crown of thorns starfish damage. At each site a set of 'landscape' digital photographs was taken at typical locations in three depth ranges: surge zone 5-

9m, reef flat 10-15m, and slope 16-50m. The landscape photographs were taken from a single spot, about 2m above the reef surface, at an oblique angle. The diver rotated 360 degrees taking 5-12 photographs looking out along the reef at different angles.

The coral transect method used was a standard method (Obura 2006b, Obura peers. Com), where the diver records the depth and lays a transect line horizontally or along the contour of the reef. Approximately 40 digital photographs are taken along the transect line with the camera held vertically 60cm above the surface of the reef. The photo set for each transect can be analyzed quantitatively for a variety of benthic community measures and coral condition factors. Coral species analysis can be done typically to the family and genus level but not reliably to the specie level. We also took a series of 'overview' photographs at each transect, which involved the the diver swimming over the transects at about 3m above the bottom taking a combination of vertical and oblique shots to assist the post dive analysis and understanding of the site.

Photographs for the coral description work were taken with an A540 Canon 6mb digital camera in a standard Canon underwater housing.

Results

The number of fish surveys and methods used are detailed for each island and site in Tables 5 & 6.

Island	**Dive site**	**30 minute Survey Dives**	**Number of 150m^2 transects**
Swain	Castaway reef	2	2
Fakalofo	Bigeye reef	1	2
Atafu	Vailima reef	2	6

Table 5. Tokelau Islands fish survey sites and methods used

Island	**Dive sites** (Obura & Stone 2003)	**30 minute Survey Dives**	**Number of 150m^2 transects**
Manra	Harpoon Corner	3	7
Rawaki	Deepwater	4	11
Enderbury	Observation spot	4	10
Birnie	Puff magic	3	11
McKean	Guano hut	3	10
	Rush hour	2	0
Orona	Algae corner	2	10
	Transition reef	3	6
	Aerials	2	6
Nikumamoro	Amelia's lost causeway	4	10
	Norwich city	2	0

Table 6. Phoenix Islands fish survey sites and methods used

Large Indicator Fish Abundance (30 minute swims)

Figure 2 shows the sum of the number of species seen from the list of large indicator fish (see Table 3) across all surveys completed for each island. A pattern is clearly seen from this data of the Tokelau Island sites having fewer species present than the Phoenix Islands. This pattern is repeated in virtually all the analysis of fish data we collected. All three Tokelau Islands had people living on the lee shores where our survey sites were located indicating that local fishing activity was significant. Fakalofo and Atafu Islands had significant populations easily running into hundreds of people. The degree of fishing on and in the proximity of the reef systems by non-resident boats is unknown but may also be a significant impact on these islands. In contrast all seven Phoenix Islands that we surveyed have no local residents at present. Enderbury, Nikumamoro and Orona Islands have the highest species counts. These islands are much larger than the other Phoenix Islands surveyed, with Orona and Nikumamoro Islands having significant open lagoon systems. It would be expected that larger atolls and atolls with lagoons would support higher diversity of reef associated fish species. With this in mind it is significant that the very small islands, Birnie, MacKean and Rawaki, had greater diversity of species than the much larger Tokelau Islands, Fakalofo and Atafu, which are of substantial size with large open lagoon systems similar in size to Kanton.

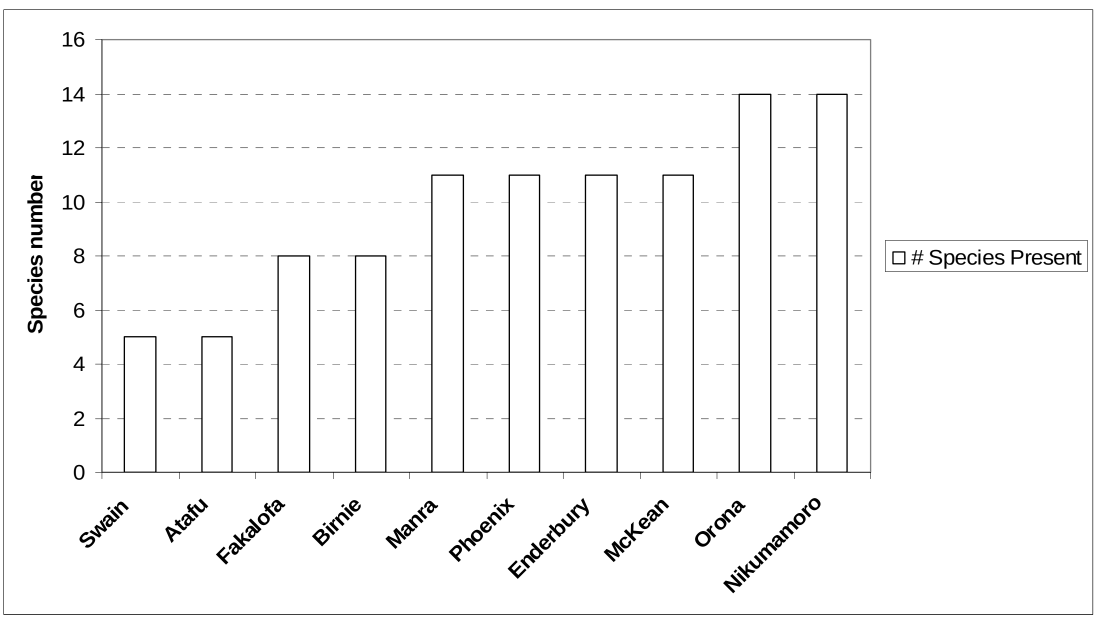

Figure 2. Species present in rapid survey counts, 30 minute swims for each island

By calculating the mean of all indicator fish counts done for all of the Phoenix Islands surveyed, and comparing this figure with the mean of the counts completed in the Tokelau Islands, an overall comparison of species abundance can be attempted. Figure 3 shows the result of this comparison. In this graph there are two calculations. The first looks at all species and shows a very large difference between the two island groups. This large difference reflects the greater number of species present in the

Phoenix Islands, as depicted in Figure 2. Overall, in general, higher densities of fish greater presence of large schools of fish were encountered in the Phoenix Islands. To illustrate the effect on the data of the occurrence of large schools of some species we made the calculation with rainbow runner and bigeye trevally removed from the data set. These two species were the main species appearing in large numbers at some sites, which skewed the data in relation to the other species. In this second calculation the means abundance values were still significantly different, with the Phoenix Islands remaining far more abundant in the indicator species.

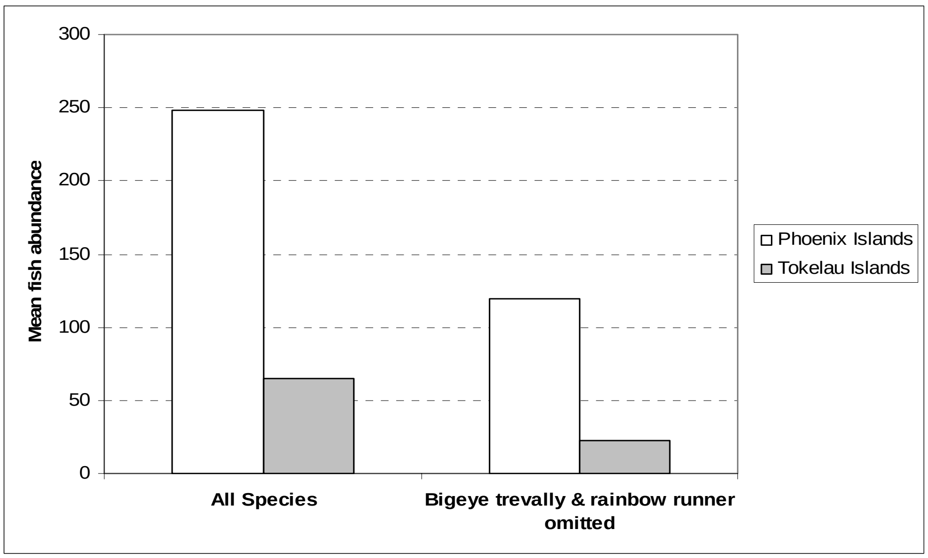

Figure 3. Comparison of Tokelau and Phoenix Island mean indicator fish abundance, 30 minute swims

Figure 4 below shows a comparison of the Tokelau mean for 30 minute indicator fish counts and the means of all seven Phoenix Islands surveyed. This treatment of the data again demonstrates the general pattern of the difference between the two island groups. The exception here is Orona which had a mean very close to the overall Tokelau mean. This result may indicate that the density of the indicator fish species surveyed was impacted at Orona by the resident fishing activity, which ceased in 2004 when the Orona settlement was abandoned. In comparison with the other Phoenix Islands Orona had surprisingly low indicator fish counts given that the Island is large and has a substantial open lagoon system. In contrast the very small islands Birnie, MacKean and Rawaki had much higher mean counts. In this result Enderbury also had a very high mean count. This result was affected by the presence of a large rainbow runner school present and also the highest numbers of twinspot snapper recorded. The large error bar for the Enderbury results is a result of the large numbers of these two species occurring on some surveys and not on others in the Enderbury data set. The pattern of large aggregations of these species occurring intermittently in survey dives of this type is expected as they can be quite mobile.

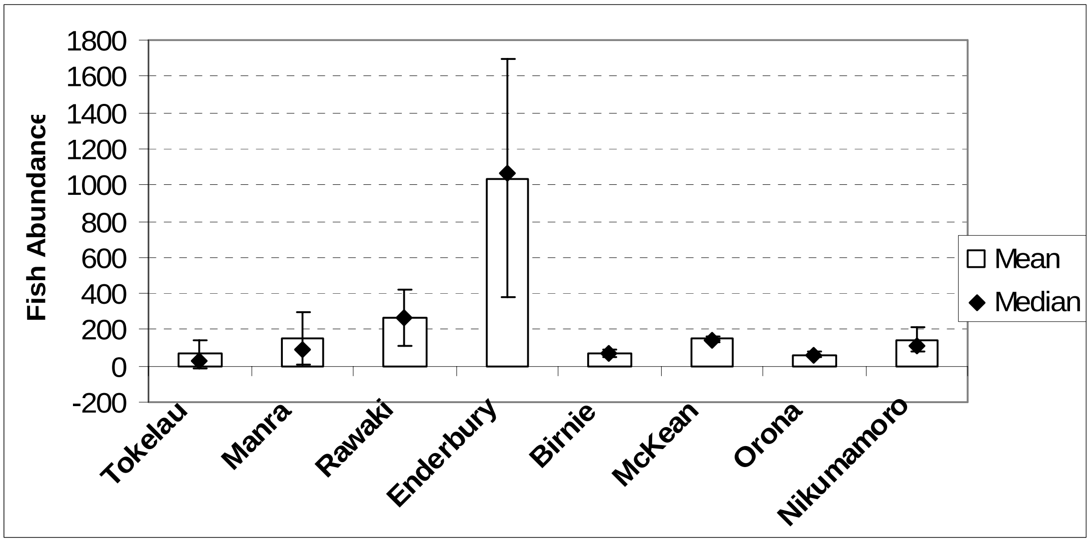

Figure 4. Comparison of Tokelau and individual Phoenix Island indicator fish abundance, all species (plus or minus SE), 30 minute swims

Figure 5 represents the combined mean of indicator species with the two species rainbow runner and bigeye trevally removed. In this summary of the data the difference between the means of the Phoenix islands and the combined Tokelau mean is greater than in the all species analysis (Figure 4). Enderbury Island again has the highest mean and also still has a large standard error. This is a result of some quite large aggregations of twin spot snapper encountered in some of the surveys. Overall the various treatments of mean abundance data show a clear pattern of the Tokelau Islands being substantially lower in abundance than the Phoenix Islands.

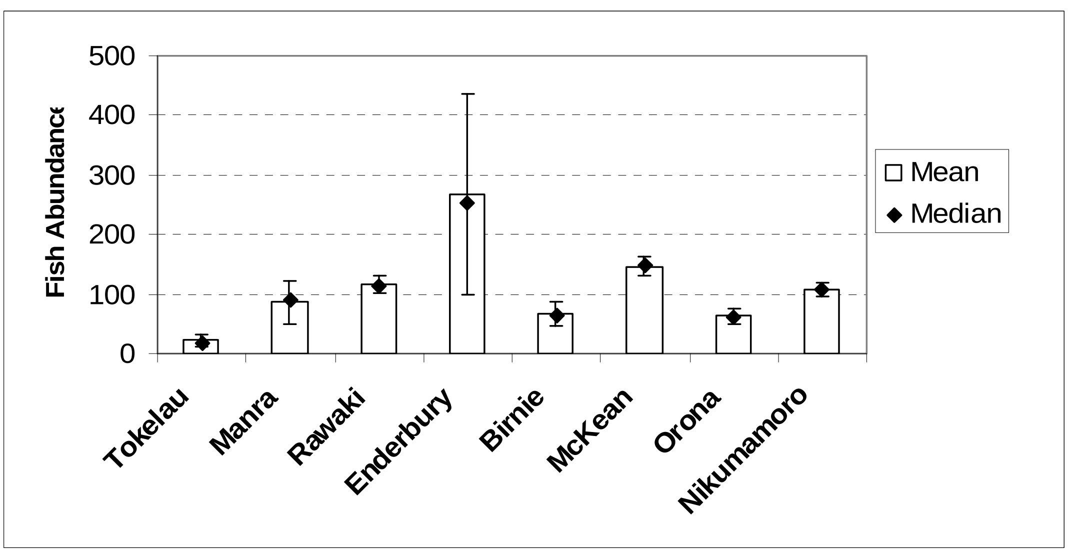

Figure 5. Comparison of Tokelau and individual Phoenix Islands indicator fish abundance with bigeye trevally and rainbow runner omitted from the analysis (plus or minus SE), 30 minute swims

Figures 6-8 show the mean values of 30 minute counts for three important indicator species: twinspot snapper, sharks (white tip, black tip and grey reef sharks combined), and napoleon wrasse. These three species are commonly targeted by fishers. For all three species the pattern of lower values for the Tokelau Islands is maintained. While there is variation between the individual Phoenix Islands, all islands have significant populations of the three reef shark species.

Numbers of twin spot snapper in the Phoenix Islands generally were exceptional and probably represent a good picture of unfished populations of this species. Supporting this interpretation is the frequent observation in the Phoenix Islands of large individuals, sometimes up to 10-15kg in size. Enderbury, McKean and Rawaki Islands stood out as having abundant populations of this species. The large standard error for the Enderbury Island mean count was caused by very large counts in two of four surveys. The maximum count was 378 twin spot snapper counted in one 30 minute swim survey.

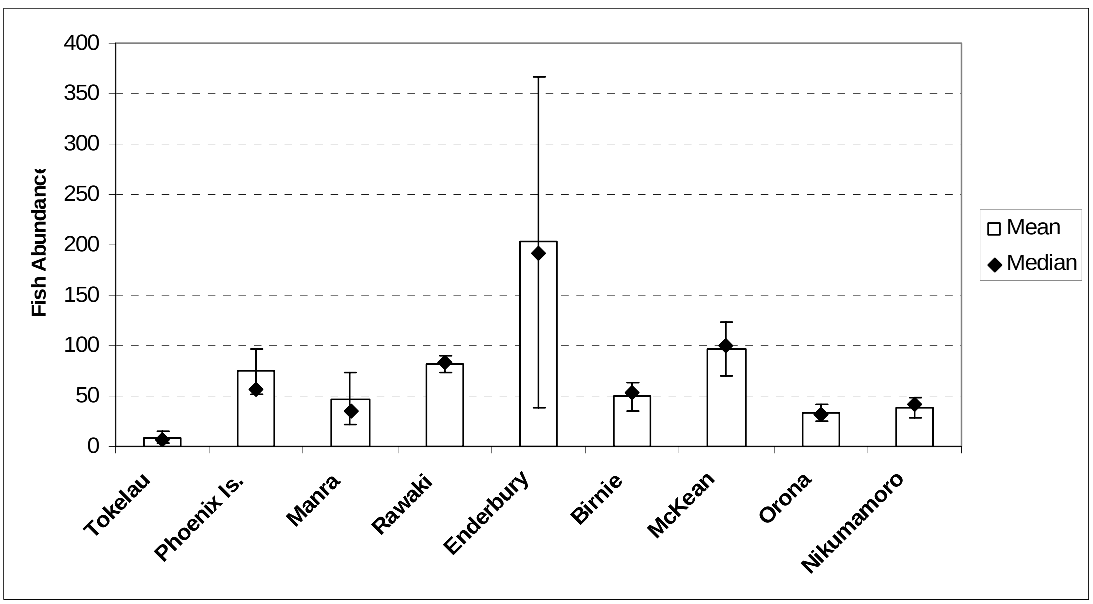

Figure 6. Mean abundance of twin spot snapper (plus or minus SE), Island group means and individual island means, 30 minute swims

For the three reef shark species, Manra and Enderbury had the highest mean abundance on 30 minute swims with counts of, respectively, 19 and 20 sharks per 30 minutes. This level is exceptional and is indicative of a very healthy shark population possibly unaffected by fishing. Sadly there are few coral reefs anywhere that have this level of abundance of reef sharks. The other Phoenix Islands had mean abundance levels of between 3 and 7 sharks per 30 minutes, which is still reflective of a good population but perhaps affected by past fishing, environmental factors or sampling error. The Tokelau sites, by comparison, had a very low mean abundance value of 1 shark per 30 minutes. This difference between the Tokelau and Phoenix Islands sites is likely to be reflective of their relatively fished and unfished states.

Rough estimates of the sizes of all sharks counted were recorded. These data have not yet been analyzed and will likely not be sufficient to support a rigorous conclusion, but some observations can be made. All the islands had a range of sizes present from medium sized sharks 1.2-1.4m in length to large individuals of around 1.8m in length. There were two exceptions. At the lagoon at Orona, significant numbers of small blacktip sharks under 1m in length were observed but not formally counted. At Manra Island, there were numerous quite small sharks less than 1m in length amongst the medium and larger sharks. A few of the small grey sharks were only 60-70cm in length. This length corresponds to an approximate age of around six months. It is possible that Manra is experiencing a very rapid and extensive rebuilding of its shark population at present, but this is difficult to verify from such a limited survey.

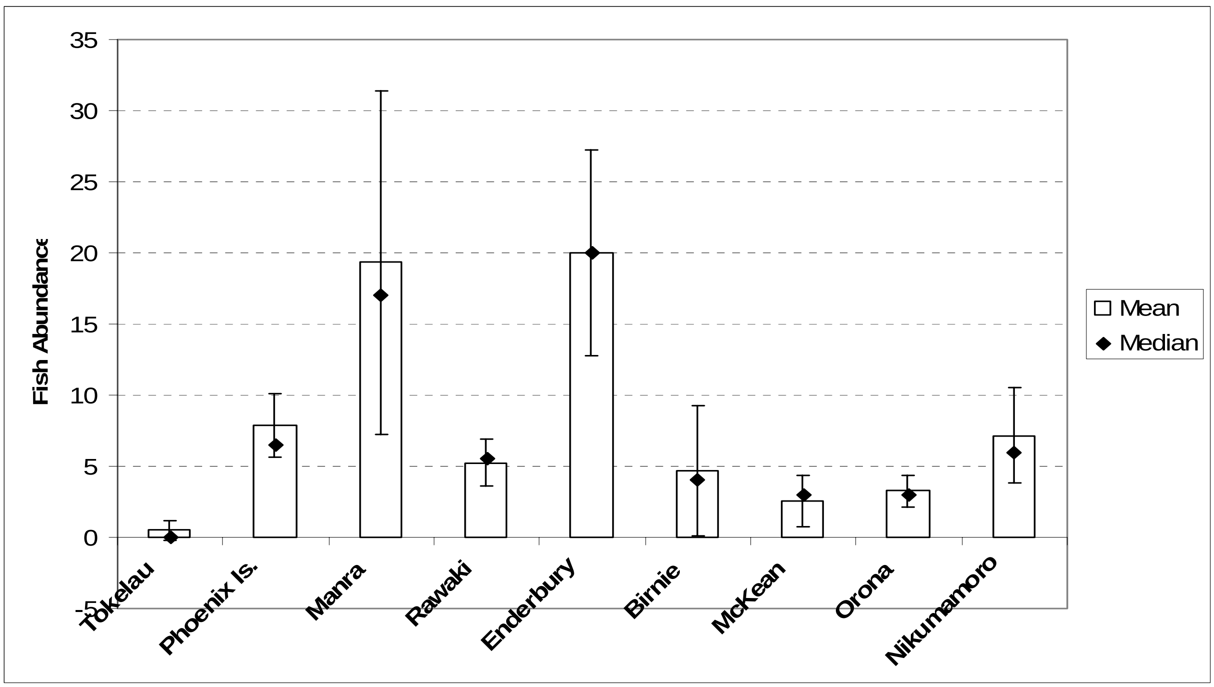

Figure 7. Mean abundance of combined shark species (plus or minus SE), Island group means and individual island means, 30 minute swims

Humphead wrass are an important predator and forager in the coral reef system. They are highly prized by various fishers and quickly caught with line and spear fishing methods. They are slow growers and are long lived. Humphead wrass are therefore an ideal indicator fish for assessing fishing impacts. In our survey mean abundance was 1 fish per 30 minutes for the Tokelau Islands and 5.6 fish per 30 minutes for the Phoenix Islands, (Figure 8). The maximum abundance for one survey was 15 fish recorded at Manra Island. The result for the Phoenix Islands is high compared to the overall means reported in 2000 and 2002 (Stone 2001, Obura 2003), of 3 fish per 30 minutes and 2 fish per 30 minutes respectively. These abundance results are also substantially higher than similar results from other Island groups. In a survey at Laamu Atoll, in the Maldives, mean abundance for outer reef sites was 0.9 fish per 30 minutes with a mean length of 80cm (Suka 2004). The Maldives and Laamu atoll have previously had considerable fishing pressure. Although this specie is now protected there are concerns about continued illegal fishing for the live fish trade in Asia.

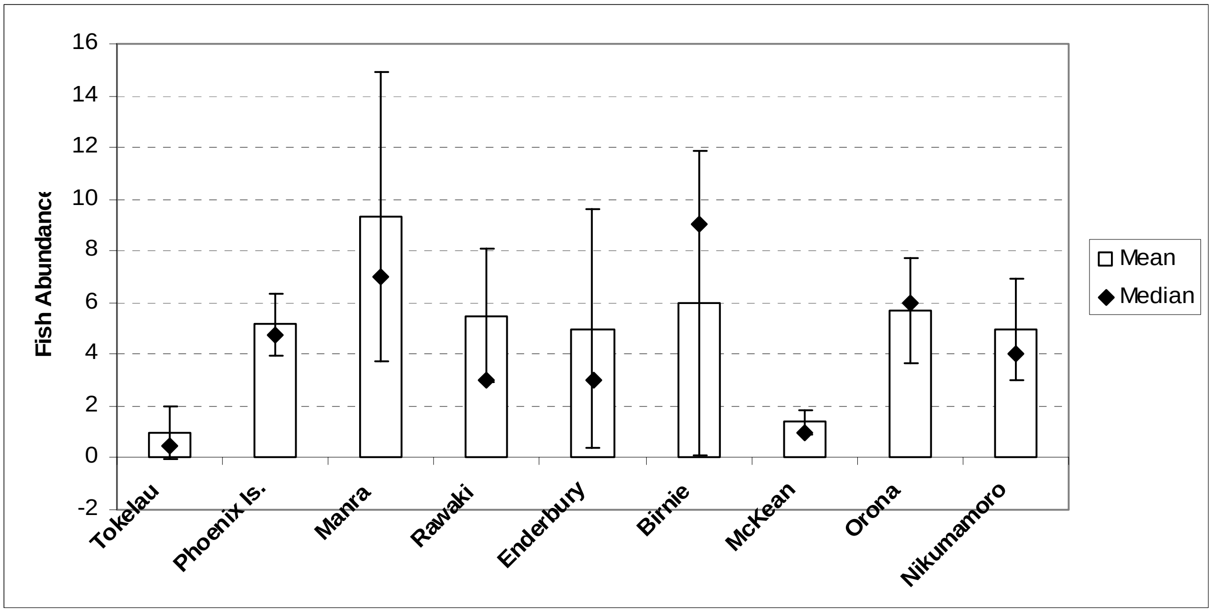

Figure 8. Mean abundance of napoleon wrass (plus or minus SE), Island group means and individual island means, 30 minute swims

Abundance of Key Fish Families (150m^2 circular transects)

The mean abundance of all fish recorded in 11 key families on 150m^2 transects for the Phoenix Islands surveyed was 54.6 fish per 150m^2, compared to 30 fish per 150m^2 for the Tokelau Islands (Figure 9). The difference in the results is consistent with the pattern seen in the indicator fish 30 minute swim surveys. The Phoenix Island abundance values for the 150m^2 transects are consistent with previous surveys (Stone 2001, Obura 2003) and characteristic of an unfished reef system. The Tokelau Islands abundance values are substantially lower than those recorded in the Phoenix Islands with some species and families not present. From preliminary analysis of the size classes of the fish counted it is apparent that there are many more large fish of each species in the Phoenix Islands than the Tokelau Islands. This difference is characteristic of fished versus unfished sites and would have significant ecological implications.

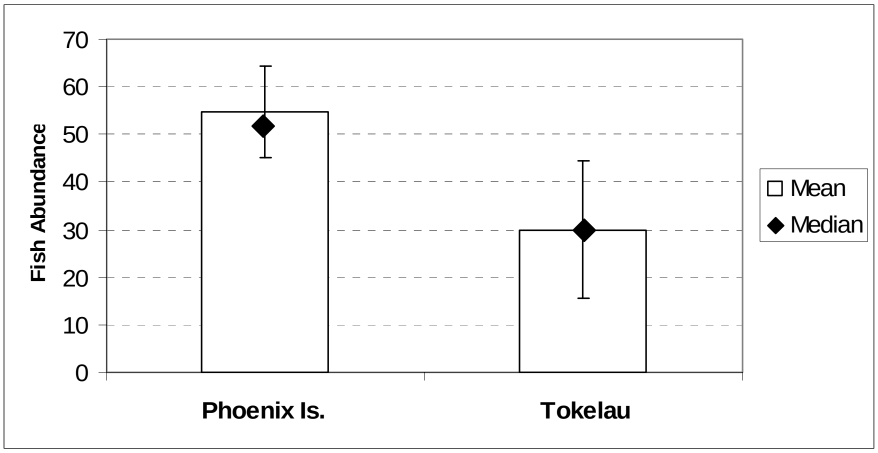

Figure 9. Mean fish abundance all families combined for island groups on 150m^2 transects

Figure 10 details mean fish abundance per 150m^2 transects for each island. MacKean, Enderbury and Nikumamoro Islands have high values, more than double the Tokelau mean. Manra, Rawaki and Birnie Islands were approximately 30% higher and Orona Island had values in between the two Phoenix groupings. This result indicates consistently high abundance of fish in the Phoenix Island group, and is a good measure of overall health of the fish population.

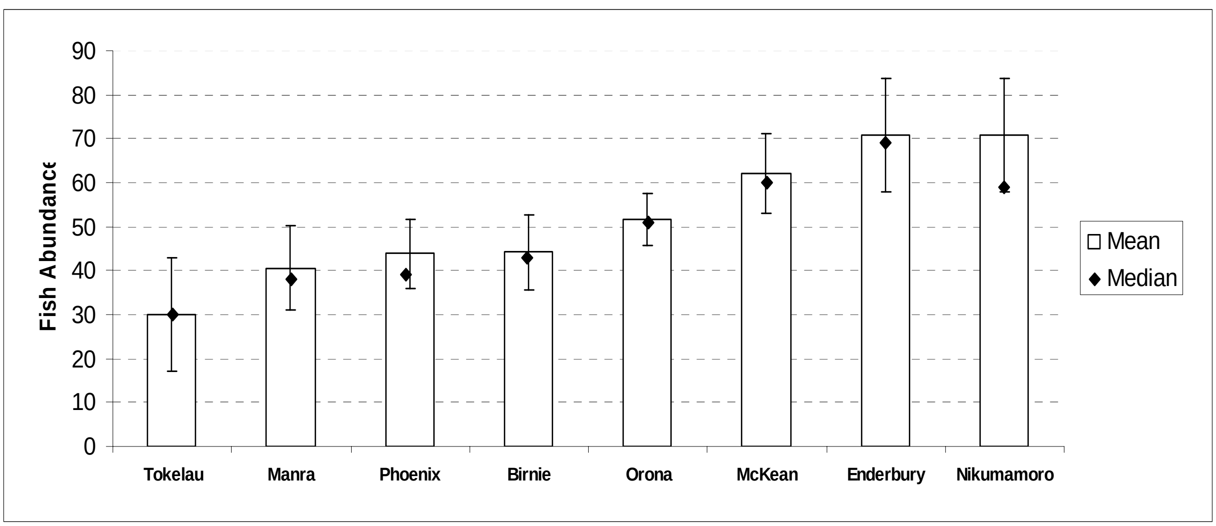

Figure 10. Mean fish abundance all families combined for Tokelau group and individual Phoenix Islands on 150m^2 transects

Mean abundance values for the individual fish families for each Phoenix Island and Tokelau Island are shown in Figure 11. Haemulidae (grunts and sweetlips) are not shown in Figure 11 because there were no fish present at any of the sites surveyed in either of the island groups.

Overall the pattern of greater abundance in the Phoenix Islands compared to the Tokelau Islands is maintained. Among the 11 families counted there were three families which had higher recorded abundance in the Tokelau Island sites compared to the Phoenix Island sites. These exceptions are discussed below.

The Acanthuridae family is the most abundant. The fishes in this family are primarily herbivores and to a lesser extent planktivores, and thus would be expected to thrive where there is algae growth and nutrient supplied either by guano leaching, upwelling or lagoon outflow. A second group, consisting of Lutjanidae, Balistidae and Carangidae, is prominent on the reef but less abundant than the Acanthruidae. This group predominantly contains predators, exploiting a wide range of feeding styles and prey ranging from small invertebrates to fish to zooplankton. This group probably best reflects the overall productivity of the reef system. The next ranking group in abundance includes the Serranidae and Labridae families. Serranidae includes territorial predators with prey ranging from invertebrates to various sizes of fish. The Labridae family is large and diverse and fulfils a number of ecological roles, including species that are invertivores, piscivores, planktivores, corallivores, and cleaners. These two fish families are also good indicators of overall reef productivity and health. Fishes in the Serranidae family are commonly targeted as a food fish and are typically affected where fishing occurs. The next two groups ranked by abundance are the Chaetodontidae and Scaridae. These two groups were recorded in modest numbers compared to what would be expected from a pristine coral reef system and were less abundant in the Phoenix Islands than in the Tokelau Island sites. Both these species apply a range of coral feeding strategies with the some parrotfish also feeding directly on algae. The factors that could contribute to poor representation of these two families are the low levels of live coral found on the reefs surveyed in the Phoenix Island sites and the possible flow on effects of a significant coral bleaching event in 2002 (Obura pers. com & Alling 2006). The remaining three families were present but in low densities of less than 3 per $150m^2$. The Pomacanthidae family was not well represented at Phoenix Islands in terms of diversity or abundance - no clear explanation for this is indicated in this survey. The Pomacanthidae family includes planktivores, insectivores and herbivores. Fishes of the Lethrinidae were present in low numbers. The Tokelau values for this species are difficult to evaluate as there was too much variance between the transects to calculate a standard error. The abundance levels of the combined shark species recorded on the $150m^2$ transects are also very low and variable between transects, therefore very little information can be derived from this survey method as compared to the 30 minute swim method.

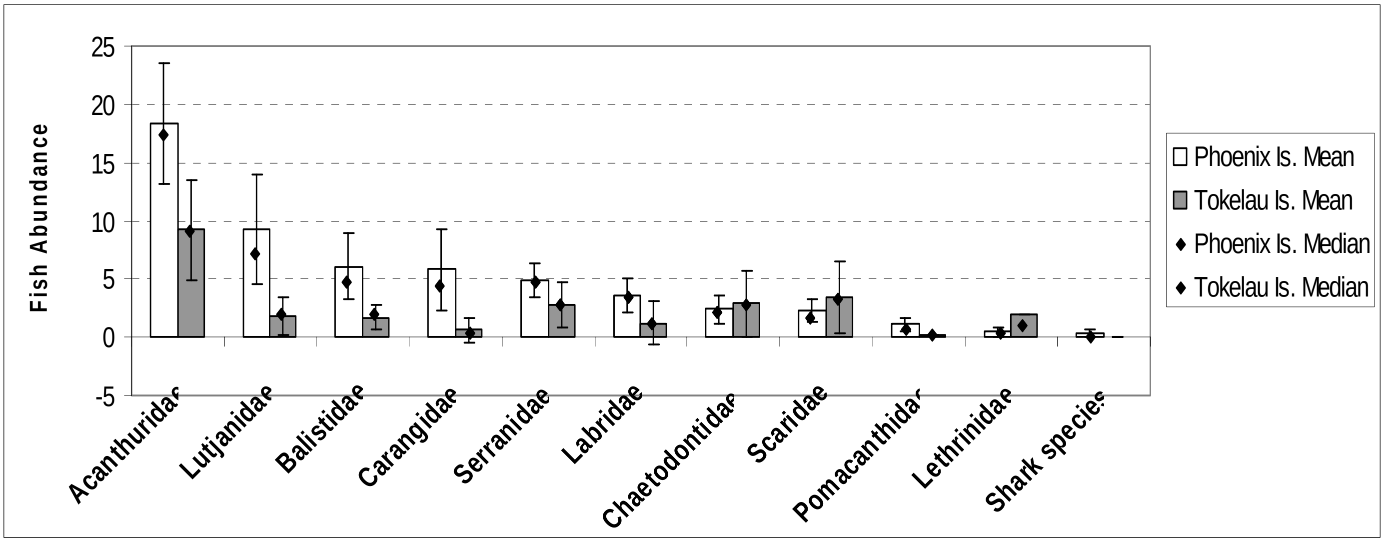

Figure 11 Abundance of key fish families for Phoenix and Tokelau Islands on 150m^2 transects**.**

Coral Health Rapid Assessment

Visual assessment of the coral health of all dive sites was made at three depth/habitat zones, together with a series of 'landscape' photographs as described in the method section. Coral transects completed were Swain Island (2 transects 15m depth), Rawaki Island (1 transect 15m depth and 2 transects 28m depth), Enderbury Island (1 transect 6.5m depth, 1 transect 14m depth, 1 transect 24m depth), McKean Island (1 transect 8m depth, 1 transect 19m depth), and Orona Island (1 transect 6m depth, 1 transect 15m depth).

Full analysis of coral transects will take some time and the results of this analysis will ideally be cross-referenced to photographs and recorded notes taken at each site. For this reason only preliminary observations are offered in this report. As previously reported, following the New England Aquarium expedition, even the lee shore locations of these islands show signs of considerable wave exposure, with the shallow surge and reef flat zones dominated by coralline algae and rubble areas and live coral cover at less than 40% ranging downwards to <10% in the surge zone. Our observations are similar for lee shore outer reef sites; however we were surprised at how low the percentage of live coral cover was at some islands. At McKean Island, especially, live coral in the surge and reef flat zone was hard to find and overall would be well below the 10% level. Orona and Nikumamoro Islands also had lower than expected live coral cover in the shallow habitats, albeit not as low as McKean Island. In the deeper reef slope habitat, which is less affected by wave exposure, live coral cover and diversity normally increases noticeably. At McKean Island this was not the case: even down to 50m we observed live coral cover at less than 10%, with soft corals starting to become prominent. Orona and Nikumamoro Islands had some increase of live coral cover on the reef slope but lower than expected live coral cover of approximately 20% at the 15 - 50m depth range.

Manra, Rawaki and Enderbury Islands had higher live coral cover at all depths, closer to what was described in the 2002 New England Aquarium expedition. Rawaki Island had the healthiest coral cover from our initial observations. The three Tokelau Islands had very healthy and diverse coral at all depths, although they too show considerable effects of wave exposure even at lee shore sites. The reef slopes of all three Tokelau Islands were especially diverse and healthy with 70-100% live coral cover.

We saw no evidence of recent (<1yr old) coral bleaching events and no conspicuous examples of coral disease. Crown of thorns starfish were seen at Swain and Atafu in the Tokelau Islands, with 12 starfish seen on 5 dives. Crown of thorns damage was noticeable at Swain Island with some areas having up to 5% damage. In the Phoenix Islands only one crown of thorns starfish was seen in all dives. This sighting was at Nikumamoro Island at 'Amelia's lost causeway'. Generally speaking dead coral we observed looked like it had been dead for several years. We commonly saw quite well formed corals that were completely covered in coralline algae. This condition was especially common at McKean Island. The observations of dead coral are consistent with a serious die-back from coral bleaching which may have occurred in 2002 (Alling 2006, Obura pers. Com.).

The coral health observations should be interpreted with caution as detailed analysis of the information gathered is not yet available. Our survey effort was confined to the lee shore outer reef habitat which is just one of the suite of habitats found at these islands. Having said this, lee shore reefs have some of the best coral growth on many atolls. Also, we did not have the opportunity to survey at Kanton Island, which has a very good set of baseline information to evaluate coral health change over time.

Turtle Sightings

All sightings of turtles were recorded and are summarized in Table 7. 22 turtles were recorded from 43 SCUBA dives. One sighting occurred at sea between McKean and Orona Islands. This sighting frequency is not high and indicates that the population has been reduced by human impacts or by some environmental factor. The sightings record does not include Kanton Island, where we did not dive. At Kanton we saw and heard evidence of turtle consumption by the local residents and were told that turtles were 'commonly seen' in the lagoon.

Location	Sightings	name	Latitude	Logitude
Swain	1	green	S 11 3.410	W 171 5.540
Fakaofo	1	green	S 9 22.500	W 171 16.500
Atafu	1	green	S 8 34.100	W 172 30.700
Manra	2	green	S 4 26.475	W 171 15.901
Rawaki	2	green	S 3 43.275	W 170 43.051
Enderbury	3	green	S 3 8.539	W 171 5.549
Birnie	1	green	S 3 35.363	W 171 31.093
McKean 'Rush hour'	1	green	S 3 35.520	W 174 7.650
At sea	1	green	S 3 43.302	W 173 52.185
Orona 'Algae cnr'	4	green	S 4 31.112	W 172 13.616
Orona 'Algae cnr'	1	hawksbill	S 4 31.112	W 172 13.616
Orona 'Transition reef'	2	green	S 4 30.683	W 172 13.531
Nikumamoro	3	green	S 4 40.477	W 174 32.616
Total	23			

Table 7. Turtle sightings on SCUBA dives and at sea

Where time permitted we completed shoreline surveys to record the number of turtle nests and recent tracks. We attempted to distinguish between ‘old’ nests and ‘recent’ nests that were less than 1 year old. Most nests were considered to be ‘recent’. Those judged as ‘old‘ were not included in the counts. On several occasions we attempted to look for turtle nests from the boat as it traveled along the shore just beyond the reef edge, but found that even with binoculars we could not be sure of identification of nests due to the distance off shore.

No recent tracks were observed on any of the beach surveys, which is consistent with the survey taking place in the non-breeding part of the year. Enderbury Island has suitable habitat along virtually its entire lee shore and about 20% of its windward shore, with the remainder being composed of coral rubble. At Enderbury Island we had a total count of 217 nests on the lee shore and 41 on the windward shore. Birnie Island had 120 nests virtually all on the lee shore with the windward shore being composed of mounds of coral rubble. Rawaki Island had no turtle nests and very little beach suitable with much of its shoreline consisting of coral rubble. McKean Island also had no observed nests and very little suitable beach for nesting. Nikumamoro and Orona Islands had only very limited survey efforts that did not indicate turtle nesting of any significance. Both these islands have large areas of suitable nesting shore habitat and lagoon habitat which should be attractive to turtles. Further survey effort is required to draw conclusions about the abundance of turtle breeding on these two islands. In general terms these results should be taken as indicative only, as it is possible that many nests could have been covered by storms between the time of our visit and the last breeding season which would have been some 5-6 months prior to our visit.

Island	% Shoreline surveyed	Turtle Nests
Enderbury	100	293
Rawaki	100	0
Birnie	100	120
Orona lagoon	Approx 10 %	0
Orona lee shore	Approx 10 %	1
Nikumamoro south & southwest shores	Approx 10 %	0
Nikumamoro northwest shore	Approx 10 %	1
McKean	100	0
Manra	0	0

Table 8. Sightings of turtle nests

Marine Mammal Sightings

Table 9 details marine mammal sightings made over the entire voyage, which included a circular route around all eight of the Phoenix Islands and the north/south voyages from Apia, Samoa to the Phoenix Islands and back (which varied in their east/west path). The voyage to and from Samoa included brief stops at three Tokelau Islands, Swain, Fakalofo and Atafu. Twenty seven days in total were spent at sea or at anchor on lee shores of the islands visited. While at sea there was a crew member on watch at all times and in addition there was virtually always one or more of the crew on deck. All crew were instructed at the beginning of the voyage to immediately signal the presence of any marine mammals. Also while in transit we had seabird watches active for 5-7 hours/day which served the double purpose of watching for marine mammals. When approaching and departing an island we typically circumnavigated it making rapid assessments of seabird colonies. The small islands, Orona, Manra and Nikumamoro Islands were completely circumnavigated. Kanton Island was partially circumnavigated. This provided an ideal opportunity to encounter dolphin species.

Table 9 details the encounters we had with spinner dolphins *Stenella longirostris* and bottlenose dolphins *Tursiops truncatus*. We did not record any sightings of whales over the entire survey voyage. This was unexpected in terms of our experience in other parts of the Central Pacific with whale sightings. Similar results were reported from previous New England Aquarium survey expeditions.

Obs #	Location	Number of animals sighted	Common name	Notes	Latitude	Longitude
1	Swain	4	bottlenose dolphins	approached boat briefly then swam off rapidly	S 11 9.314	W 171 5.568
2	Fakaofo	40	spinner dolphins	spotted feeding in distance, did not approach boat	S 9 26.000	W 171 13.500
3	Enderbury	8	spinner dolphins	seen moving in distance	S 3 6.704	W 171 4.721
4	Enderbury	5	bottlenose dolphins	swam by boat at sunset while at anchor, didn't stop to approach boat	S 3 8.539	W 171 5.549
5	Kanton	100+	spinner dolphins	large school, very shy of boat moving steadily away	S 2 52.336	W 171 37.345
6	Kanton	5	bottlenose dolphins	approached boat briefly	S 2 53.000	W 171 37.000
7	Orona	100+	spinner dolphins	large school, did not approach boat, moving around the island	S 4 32.650	W 172 11.120
8	Nikumamoro	5	bottlenose dolphins	large animals, very dark in coloration	S 4 41.308	W 174 28.990
9	Nikumamoro	12	bottlenose dolphins	small and medium size animals and medium, quite dark in coloration but not as dark as the larger animals	S 4 41.308	W 174 30.808
10	Nikumamoro	12	bottlenose dolphins	same pod as previously sighted Obs. #9	S 4 41.156	W 174 31.728
11	Nikumamoro	80	spinner dolphins	moving away from boat around island	S 4 39.896	W 174 31.058
12	Nikumamoro	5-7	bottlenose dolphins	think same pod as previously sighted Obs. # 8	S 4 40.688	W 174 29.967
13	Nikumamoro	12	bottlenose dolphins	same pod as previously sighted Obs. #9	S 4 42.053	W 174 29.641
14	Nikumamoro	7	spinner dolphins	small pod swimming by boat at anchor late afternoon	S 4 40.477	W 174 32.616
15	Atafu	10	spinner dolphins	swam by boat while at anchor	S 8 34.100	W 172 30.700

Table 9. Marine mammal sightings

Water Temperature

Water temperature was monitored during the expedition at all dive sites and anchorages. At all sites the temperature 2m below the surface was 28 degrees C. Surface temperatures ranged up to 30 degrees on a few occasions but was usually 28 or 29 degrees C. We did not encounter any significant thermo clines down to 50m depths.

Observation of Reef Slope Erosion Event

While doing a standard survey dive at the dive site, 'Aerials', at Orona Island (May 3 at approx. 1:45 pm), Graham Wragg encountered a dramatic example of reef slope subsidence at 30m depth. In this location the reef slope generally is very steep, plunging down to great depths in near vertical fashion. In an area approximately 100m in length along the reef a large mass of the reef had broken away and slipped off down the slope out of sight, representing a great mass of reef material suddenly gone. It is believed that the event occurred within hours of our finding the site as there were still clouds of coral dust wafting around the cliff face and fish moving in to explore the freshly exposed debris. Interestingly, this was the day on which an earthquake measuring 6.5 on the Richter scale was recorded in the Tonga Trench in the morning and tsunami warnings were issued. We have no way of knowing if the subsidence did happen around the time of the earth quake or seismic shock wave, but are fairly certain it had happened within hours of our arrival. We recorded this very unusual event with digital photographs, which are available for study by interested researchers. At the time of the earthquake and potential shock wave we were at anchor on the lee shore of Orona with approximately 50m of water under the boat. We did not detect any direct signs of shock waves at the time.

Discussion

Our survey effort and experience of the Phoenix Islands supports the view that this Island group exhibits many of the characteristic of an oceanic coral reef system which is close to pristine and free of human impacts, most notably fishing. With some exceptions our data certainly reinforces this description. There were many unique experiences underwater at these islands which our team had not experienced in a decade of diving in the Central Pacific and Eastern Pacific. The impression a diver gets is one of sheer abundance of fish and an almost unsettling presence of many very large fish. In diving there you are immediately aware that these large fish are playing out their ecological role on the reef in an impressive manner. Watching a giant napoleon wrass foraging on a coral, with a swarm of other reef fish in close attendance sorting through the cloud of debris, is an impressive sight. We were 'examined' on several occasions by manta rays spiraling around us within touching distance. We were treated to witnessing trevally schools charging at tremendous speed into clouds of Anthias far too numerous to find cover on the reef. What is so important about the Phoenix Islands is that there are almost no reef systems left where the full range of naturally occurring species and reef ecology is so unaffected. Knowledge and experience of the pristine condition and ecology of a coral reef is the baseline which should inform all coral reef management work but hardly ever does. The Phoenix Islands offer a unique opportunity for coral reef research and conservation which is important on an international scale.

From a marine science perspective these islands are extremely important. They are important because of their near pristine state, but in addition they are uniquely situated in the center of the equatorial Pacific. They may be very important biogeographically. They may play significant roles in movements and dispersal of marine animals and larvae. They are certainly important to international efforts to monitor effects of global warming on equatorial coral reef systems. Very little is known about the effect of these islands on the surrounding pelagic marine species and systems, which in turn support internationally important seabird populations and numerous migratory birds. We observed signs (prolific algae growth) of unusually high nutrient levels for oceanic atolls. This effect could be caused by a combination of lagoon enrichment, leaching of guano deposits or oceanic upwelling caused by deep currents striking the massive seamounts underlying each of the Phoenix Islands. From our observations we suggest that the Phoenix Islands are affecting and supporting the pelagic marine life/seabird ecology by increasing nutrient status, which has a food chain effect reaching outwards for a very long distance off shore.

Previous research and monitoring efforts at the Phoenix Islands have not included a 'fished reference site' which can be compared to the Phoenix Islands. This is important to test the various conclusions that are drawn about the intactness of the Phoenix systems. The comparison to a reference site(s) allows researchers to better quantify and validate the degree of difference between the unfished state and the fished state. Also, change over time and the effects of environmental variables can be more carefully measured and compared. We were fortunate to have the opportunity to use survey sites at the Tokelau Islands as reference sites. Our data suggests that this was a worthwhile effort even with a limited survey and data set. Our data highlights significant differences in species diversity and abundance between the Tokelau sites and the Phoenix Islands and appears to reflect actual fishing impacts.

In general terms we found that the monitoring methods we used in the survey, recommended and adopted from the New England Aquarium team (Obura pers. com.), were appropriate and effective in terms of information gained versus time and effort expended. We added two additional rapid coral assessment methods: first, depth stratified digital 'landscape' photograph sets catalogued by site; and secondly, depth stratified rapid coral health visual assessment at each site. These two methods can be completed very quickly in conjunction with a full fish counting work program. With the local experience now gained by the three research teams, we suggest this would be a good time to review the monitoring approach and methods. With the extent of baseline information completed it is now possible to rationalize the survey sites and make some modifications or additions to the methods to better target species of interest and/or more specific research and management questions.

Orona and McKean Islands stand out from our survey as needing careful consideration for future work. McKean Island had surprisingly low levels of live coral and appears to have been subject to some serious die-off event probably more than 2 years ago. The wreck of a fishing trawler in 2001 could be a factor, as could the coral bleaching event of 2002. What is important now is to observe recovery processes there and monitor for future events. With the extent of damage which has occurred, McKean Island offers a unique opportunity to learn about the recovery capacity of these islands following coral die-off events. The adaptation of the reef system to the drastic change in the coral community is another dynamic that warrants investigation. It could be argued that the scenario of catastrophic coral damage and recovery apparent now at McKean Island will become more the norm in a warming global environment, and thus McKean Island offers us an early preview of the consequences of this change.

Orona is the second island we wish to highlight. Our data indicates that Orona Island is in a process of recovery from fishing impacts. In the absence of human activity (fishing), Orona would be expected to be among the most productive of the islands; it is large in size, has an extensive barrier reef and an impressive open lagoon system. Our results while limited to the outer reef lee shore sites showed that Orona in most measures ranked in the lower third of the Phoenix Islands. Shark populations, for example, were noticeably low. Given the relatively known fishing history of this island and the potential for substantial recovery we suggest Orona would be an ideal monitoring island for the future Marine Protected Area. If it eventuates that there is some form of custodial presence on the island, this would make it even more suitable as a long term monitoring site. The management issues of surveillance, compliance and enforcement should be closely considered in making decisions about where to monitor. In order to effectively interpret monitoring results, fishing history needs to be known.

Recommendations

1. Efforts to document and communicate the scientific, ecological, and conservation significance and importance of the Phoenix Island group should be encouraged and supported wherever possible.

2. Integration of marine and terrestrial survey work should be encouraged in funding and expedition planning. While there are obvious potential conflicts between the very different field work objectives and logistic requirements, there are large gains to be made from integration. Setting clear objectives and priorities, careful personnel selection and planning largely offset any potential conflicts.

3. The coral reef systems should be viewed as connected to the adjacent oceanic marine pelagic/seabird ecosystem and in all management planning a precautionary approach should be practiced, weighted on the side of conservation.

4. Marine monitoring and research priorities and methodological approaches should now be reviewed in the context of the local knowledge gained, baseline work completed and the social/political and management considerations which are developing in conjunction with the establishment of the Phoenix Islands Marine Protected Area.

5. A long term marine monitoring program for the Phoenix Islands should include a set of ‘reference sites’ which can illustrate the difference between the impacts of human activity and absence of human impacts and possibly recovery from cessation of human exploitation activities.

6. Turtle nesting surveys should be conducted at all islands during breeding season to establish an accurate picture of the current turtle populations associated with the islands. Kanton and Enderbury Islands should be the highest priorities based on observations to date. The establishment of a turtle conservation advocacy program for the residents of Kanton Island should be investigated as soon as possible. Ideally, those residents could be supported to conduct a yearly turtle census.

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