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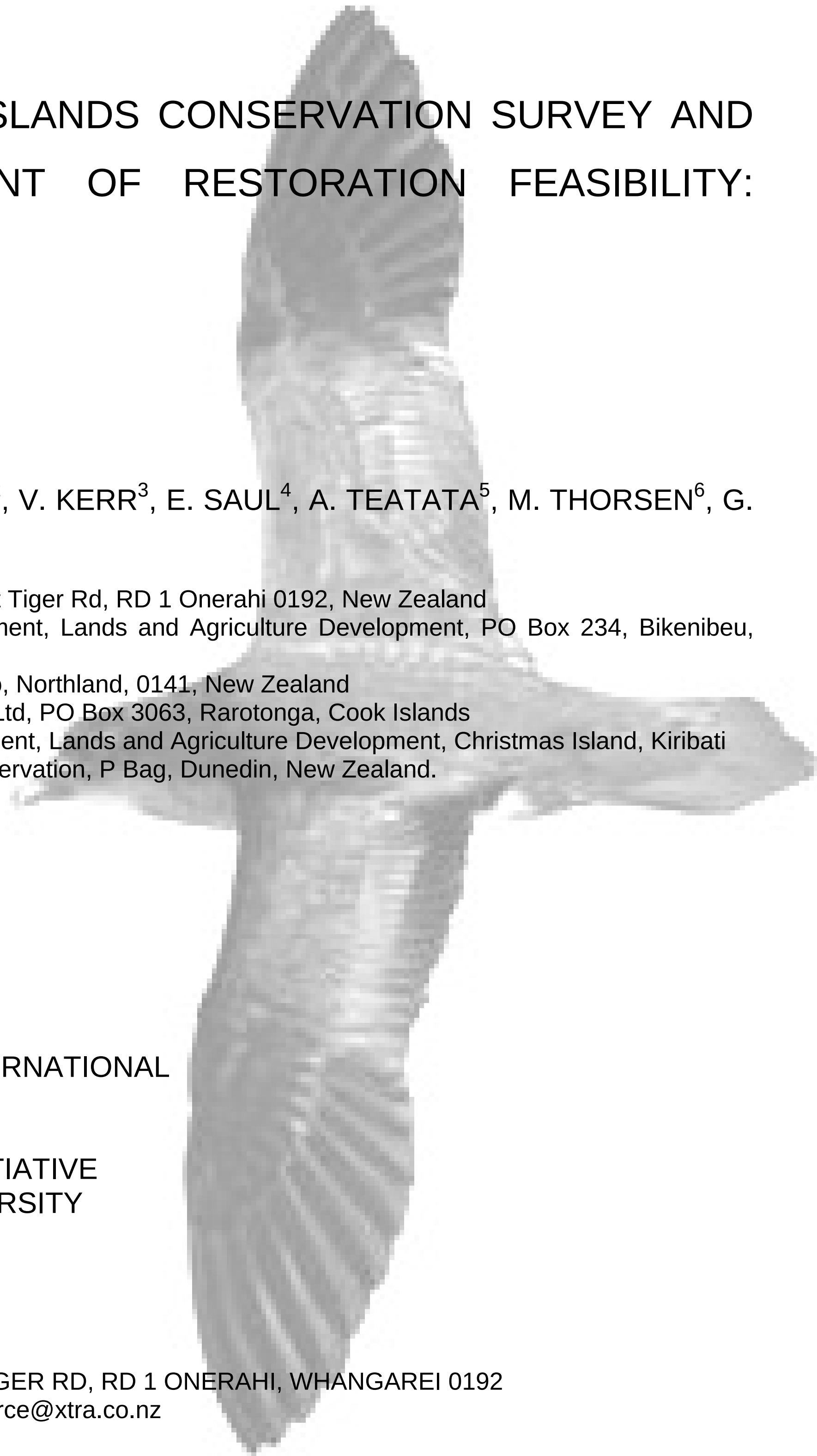

PHOENIX ISLANDS CONSERVATION SURVEY AND ASSESSMENT OF RESTORATION FEASIBILITY: KIRIBATI

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JUNE 2006

Report prepared for:

CONSERVATION INTERNATIONAL
SAMOA
and
PACIFIC ISLANDS INITIATIVE
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EXECUTIVE SUMMARY

The Phoenix Islands, Kiribati, are identified as a Key Biodiversity Area in Conservation International's Ecosystem Profile for the Polynesia/Micornesia Hotspot under the CEPF (Critical Ecosystem Partnership Fund) and an Important Bird Area by BirdLife International. These and other designations reflect the very high marine and terrestrial values which are inextricably linked and many of these values are under threat. The Government of Kiribati has recognized this and established the Phoenix Islands Protected Area in March, 2006 and is preparing an integrated management plan. One of the current barriers to effective terrestrial management is the lack of recent comprehensive terrestrial data on the islands, particularly on the status of invasive mammal species and sensitive bird species.

The overall goal of the current project is to restore the biota present on the Phoenix Island Group. The specific objective of the April-May 2006 conservation survey was to determine the feasibility of pest eradication on priority atolls in the Phoenix Islands Group. Expected results were as follows:

1. Determine the status of invasive species on priority atolls in the Phoenix Group.
2. Provide improved information on invasive species distributions and their impacts in the Group.
3. Determine priority sites for invasive species management in the Group.
4. Determine non-target issues and other atoll issues relevant to invasive species eradication.
5. Determine the feasibility of eradicating pest mammals and other invasives from priority atolls in the Group.
6. Complete operational workplan(s) for invasive species management including pest eradication.
7. Training of local Kiribati staff.
8. Some baseline ecological data collected for future monitoring.

The 2006 Conservation survey was funded by CEPF to determine the priorities for terrestrial restoration and the feasibility of eradicating pests in the Phoenix Group. Key outcomes included the following:

- Report on the terrestrial values present, particularly seabird diversity and abundance
- Report on the mammalian fauna and other invasive alien species (IAS) present
- Report on priorities for restoration and feasibility of pest eradications and maintaining pest-free status
- Draft operational plans prepared for pest eradication and maintenance.

The survey was a rapid assessment programme undertaken between 14 April and10 May 2006 and transport was provided by the RV Bounty Bay. All eight of the Phoenix Islands were visited, seven of which were landed on and surveyed for periods of time ranging from a few hours (Birnie) to up to four days (McKean). We spent 2-3 nights on each of

the high priority islands of Rawaki, Enderbury and McKean and 1-2 nights on two other islands (Orona and Nikumaroro). Surveys comprised many complementary day and night survey techniques for terrestrial mammals (e.g. spotlight transects, lures), birds (e.g. pelagic transects, colony counts, evening fly-on to islands, spotlight transects, war-whooping), crabs (transects) and ants (protein and sugar-based lures).

There have been significant changes in the status of mammal and bird species in the Phoenix Islands since the last comprehensive fauna surveys in the 1960s. The greatest change has been on McKean where the large Asian rat (*Rattus tanezumi*) has arrived recently coinciding with a 40% decline in seabird species diversity, including the total loss of blue noddies (blue-grey ternlets; *Procelsterna caerulea*) and most procellariiform species. Most of the seabird species that were still persisting on McKean in 2006 were present in greatly reduced numbers and were generally breeding unsuccessfully. In contrast, some pest species have disappeared from at least two of the larger islands including house cat (*Felis catus*) from Enderbury and Nikumaroro, and apparently Pacific rats (*Rattus exulans*) from Orona, but the precise status of pests on the last two islands need confirmation. Pacific rats are present on Birnie.

The island with the highest diversity (18 species) of seabirds in 2006 was Rawaki. This is the only island in the Group that still supports a breeding population of blue noddies and the Endangered Phoenix petrel (*Pterodroma alba*) and the Vulnerable white-throated storm petrel (*Nesofregetta albigularis*), while many other species also breed here, as was the case in the 1960s. These seabird populations on Rawaki are critically important. The very high density of rabbits (*Oryctolagus cuniculus*) is however impacting on many seabirds on Rawaki through competition for burrows and shaded shelters with associated trampling of eggs and nestlings. Rabbits are also impacting on the vegetation with the loss or decline of the more palatable species; this in turn reduces nest site availability and burrow stability for burrowing seabirds and impacts on the ecosystem as a whole.

Pests should be removed from all eight of the Phoenix Islands, but the most urgent management actions required for the islands are to remove rabbits and Asian rats from Rawaki and McKean respectively. The removal of rabbits will secure a nucleus of recovering populations of the key threatened seabird species on Rawaki from which dispersal and recolonisation will occur to neighbouring islands in the Group when they become pest-free. Removal of rats from McKean will enable the recovery of existing populations on the island and more particularly allow birds currently attempting to breed or recolonise (e.g. storm-petrels and 3 shearwater species) to survive and breed successfully.

A three-island package of eradications would be feasible during one austral winter expedition and this should comprise removing rabbits from Rawaki, Asian rats from McKean and Pacific rats from Birnie. Two of the larger islands – the 600 ha Enderbury and 500 ha Orona – should then be considered for restoration via pest eradication as both islands provide extensive areas of semi-pristine habitat suitable for seabirds, lizards, invertebrates and plants. Indeed these islands are the ecological gems of the Phoenix Group and are a very high priority for restoration, but they will also need significantly improved biosecurity measures implemented to prevent unauthorized landings and other threats. The most cost-effective way forward in dealing with rats on the larger islands is likely to be aerial application of baits. However, the most urgent action is required on the three smaller islands, with the Birnie rat operation potentially being treated as a trial and precursor to eradicating rats from the much larger Enderbury Island. The initial three-island package would be ground operations, but the proposed actions would need to be very carefully planned and professionally implemented. Technical issues for the eradications include very high densities of crabs, particularly hermit crabs, present on some of the islands. A draft operational plan for the three small islands is appended.

Significant training and capacity building was achieved during the survey with the participation of two Kiribati Government staff members, both of whom learned several new survey and monitoring techniques for indigenous biota and invasive alien species.

Marine investigations and monitoring work were carried out opportunistically during the survey. With the NEAQ marine team we prioritized our marine work around abundance and diversity surveys of fish and coral health assessments at key permanent monitoring sites on seven islands of the Group, omitting Kanton Island. 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. This island is recommended as an ideal site in which to monitor recovery of fish populations. Rapid assessments of coral health were made on seven islands. 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 (*Chelonia mydas*) breeding. No whales were seen during the entire journey, which is a concern considering the extensive time we spent observing in Phoenix Island waters, including 80 hours of pelagic seabird transects. 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 this precious opportunity.

ACKNOWLEDGEMENTS

This project is supported by the Australian government’s Regional Natural Heritage Programme through the Critical Ecosystem Partnership Fund. The Critical Ecosystem Partnership Fund is a joint initiative of Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation.

We thank the Government of Kiribati for authorizing the 2006 conservation survey and feasibility study. In particular we acknowledge Minister Puta Martin Tofinga and Tererei Abete-Reema for their ongoing support and for allowing Tiare Etei and Aobure

Teatata to participate in the full survey. We thank the many PII members for their support throughout this operation, in particular Alan Saunder's team in Auckland, and CI staff, particularly James Atherton and Sue Miller Taei. We thank the Department of Conservation (DOC), New Zealand, for making Mike Thorsen available for the survey and the ensuing reporting and restoration planning phases. We thank Elizabeth Matisoo-Smith of Auckland University for confirming the genetic identity of the McKean rats and Darren Ward of School of Biological Sciences, Auckland University who provided ant identifications for the complete sample of Phoenix Islands ants. We thank Nina, Peter and Losaline Lomas of Apia for their hospitality to expedition members before and after the expedition. The professionalism of the crew of the RV Bounty Bay (i.e. Huub van Buchem, Hamish Thorpe and Ross Clarke) was appreciated throughout, including during the often tricky landing situations, while the gourmet meals and good humor were a bonus. We thank the many people who have provided information and specialist comment that has greatly assisted this study – notably Angela Kay Kepler (Pacific Wide Consulting) who has been an endless source of information about the Phoenix Islands, Bill Simmons (Animal Control Products) for pest eradication advice; David Obura and Greg Stone (New England Aquarium) for advice and mapping information; Terry Conaghan (DOC) who provided mapping support and Jessica Kerr and Mick Buckley provided editorial support. David Priddel (Department of Environment and Conservation, NSW) and Karen Johns (PII, Auckland University) provided peer review comment.

PART A: RESEARCH FINDINGS OF THE 2006 CONSERVATION SURVEY

1. INTRODUCTION

The Phoenix Islands are one of three groups of islands comprising the Republic of Kiribati and are located at 3-5 degrees south latitude in the central Pacific Ocean. Owing to their remoteness and a harsh climate they are little disturbed by people and only one of the islands (Kanton) is currently inhabited. The vegetation and terrestrial habitats of most of the islands are in a near pristine condition. The islands have been identified as a Key Biodiversity Area (KBA) in Conservation International's (CI's) Critical Ecosystem Partnership Fund Ecosystem Profile for the Polynesia/Micronesia Hotspot (#133) and is also an Important Bird Area (Birdlife International). Further to this, in 2006 the Phoenix Islands were designated a protected area (marine and terrestrial), the third largest MPA in the world.

The Phoenix Islands are internationally recognized as a seabird haven. Petrels, tropicbirds, boobies, frigatebirds and terns collectively are estimated to have numbered in the millions during the last comprehensive surveys which were undertaken in the 1960s (Garnett 1983). Some of these colonies represented what may have been the largest concentrations of their species in the world, including for Audubon's shearwater (*P. l'herminieri*), white-throated (Polynesian) storm petrel (*Nesofregetta albigularis*), lesser frigatebird (*Fregata ariel*) and blue noddy (*Procelsterna caerulea*). Other species with a significant presence include wedge-tailed shearwater (*Puffinus pacificus*), Christmas Island shearwater (*P. nativitatis*), Bulwer's petrel (*Bulweria bulwerii*), Phoenix petrel (*Pterodroma alba*), masked booby (*Sula dactylatra*), grey-backed tern (*Sterna lunata*) and sooty tern (*Sterna fuscata*). These seabird colonies reflect firstly the availability of little-disturbed breeding grounds, and secondly the availability of diverse and abundant marine food in the form of fish and crustaceans. The islands are also important for dolphin species and other marine fauna such as the threatened green turtle (*Chelonia mydas*).

As with most Pacific Island groups, however, the Phoenix Islands have been impacted on in different ways, e.g. exploitation of fisheries and the arrival of invasive alien species (IAS). Feral populations of several mammalian species are known to have been present for a century or centuries at the Phoenix Islands and these include rabbits (*Oryctolagus cuniculus*), Pacific rats (*Rattus exulans*) and cats (*Felis catus*). These species all impact in various ways on indigenous biota, including birds, lizards, turtles, invertebrates and plants. In recent decades, however, visits to the islands have been brief and the status of most fauna (particularly mammals and birds) has not been precisely established. Understanding and planning of the potential for ecological restoration of the islands, therefore, requires an evaluation of current values, threats, opportunities and risks.

2. OBJECTIVES

2.1. Overall objectives

The 2006 Conservation Survey was funded by the Regional Natural Heritage Programme (RNHP) of Australia via CEPF with the specific aim to: “Contribute to advancing the nomination of the Line and Phoenix Islands of Kiribati as a serial World Heritage Site.” The overall goal of the current project is to restore the biota present on the Phoenix Island Group. The specific objective of the April-May 2006 conservation survey was to determine the feasibility of pest eradication on priority atolls in the Phoenix Islands Group. Expected results were as follows:

1. Determine the status of invasive species on priority atolls in the Phoenix Group.
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6. Complete operational workplan(s) for invasive species management including pest eradication.
7. Training of local Kiribati staff.
8. Some baseline ecological data collected for future monitoring.

Opportunistically, additional data were collected on coral reef communities present in the Phoenix Islands, turtle and marine mammal sightings and pelagic bird observations between Samoa and the Phoenix Islands. These components assisted in providing a more integrated picture of terrestrial and marine communities and ecology. The marine observations support ongoing work by the Governemnt of Kiribati/New England Aquarium/CI (D. Obura and G. Stone, pers. comm.).

The current report is presented with four main terrestrial foci that address Results 1-8 above:

- Report on the biodiversity (especially seabirds) present or potentially present on the islands (Results 3, 4, 7 and 8 above)
- Report on the mammalian fauna and other IAS present (Result 1-2 above)
- Report on restoration opportunities and priorities, and the feasibility of pest eradications and maintaining pest-free status (Result 3 and 5 above)
- Prepare operational plans for pest eradication and maintenance (Result 6 above).

2.2. Atolls visited

Target atolls were prioritized based on historical data, anticipated biodiversity values, likely threats and on the need for more ecological information. For example, Rawaki, Enderbury and McKean were rated Priority 1 islands (Table 2.1) because of combinations of high seabird diversity recorded in the past, scant recent information and perceived opportunities for restoration. However, we managed to visit all 8 islands, 7 of which were landed on and 5 camped on for 1-3 nights each (refer Fig 2.1, Table 2.1). Transport and landing was provided courtesy of the Pacific Expeditions and the RV Bounty Bay.

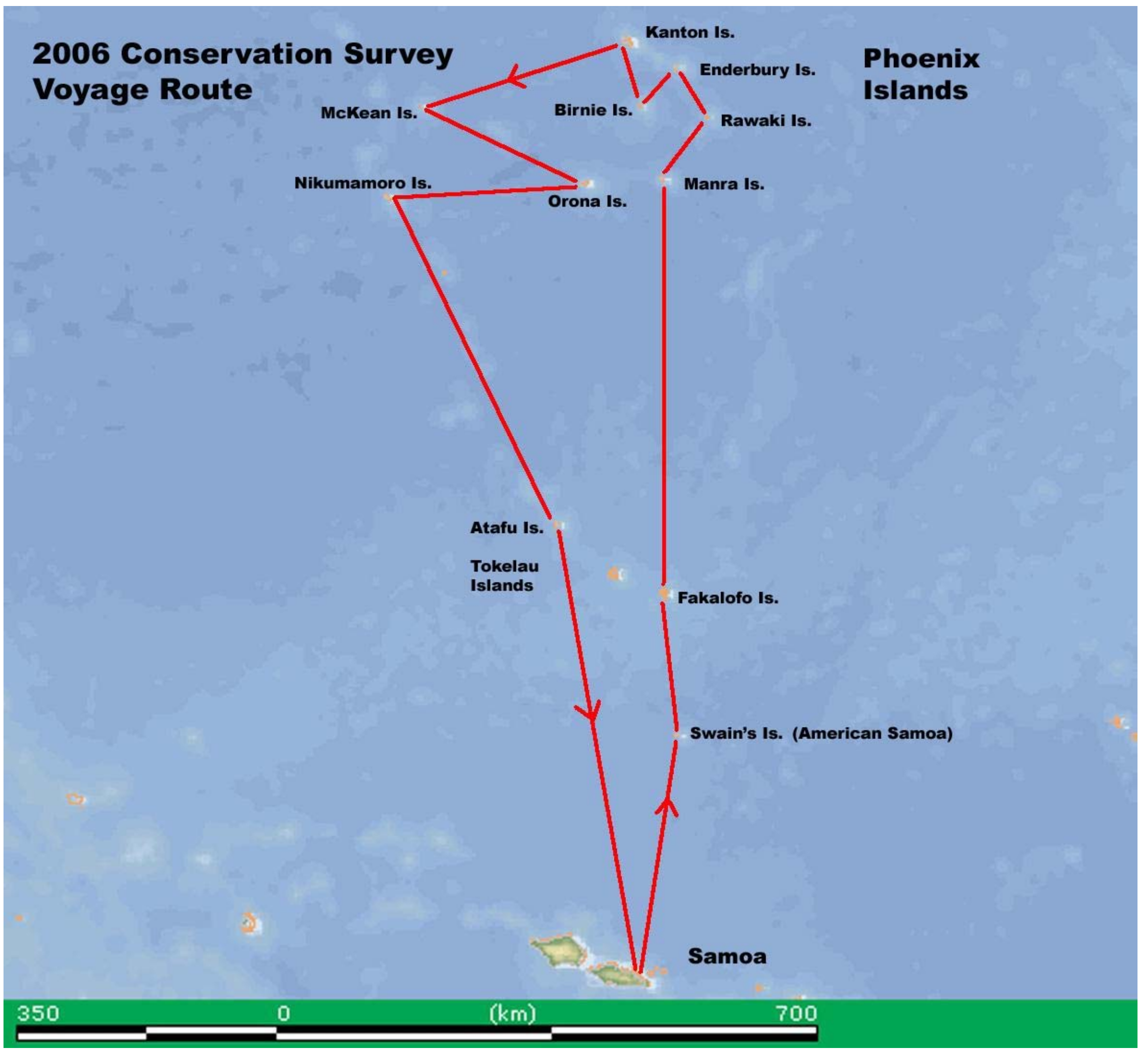

Figure 2.1 – Route taken by the 2006 Phoenix Islands Conservation Survey

Table 2.1 – Atolls visited in 2006 Conservation Survey

Atoll and priority	Landed (dates)	Time ashore
Manra (Sydney) 2	No (18 April)	0
Rawaki (Phoenix) 1	Yes (19-21 April)	2.5 days
Enderbury 1	Yes (22-24 April)	2.5 days
Birnie 2	Yes (25 April)	3 hours
Kanton 4	Yes (26 April)	6 hours
McKean 1	Yes (28 April-1 May)	3.5 days
Orona (Hull) 3	Yes (2-4 May)	2 days
Nikumaroro (Gardner) 3	Yes (5-6 May)	1.5 days

3. GENERAL DESCRIPTION OF PHOENIX ISLANDS

3.1. Physical

Key physical features of the individual islands are summarized in Table 3.1. The islands are small to medium sized atolls with the windward (eastern) sides being strewn with coral rubble boulders, but the interior and especially the lee sides often comprise large areas of coral sands. The large Enderbury Island has extensive areas of soft sand and luxuriant low herbaceous shrubland suitable for seabirds that burrow and/or seek vegetation for nesting cover.

Table 3.1 – Key physical features and vegetation of the islands

Island	Total area (ha)	Land area (ha)	Lagoon	Substrate	Vegetation
Manra	-	c.500	Closed	Not visited	Forest, scrub, coconut
Rawaki	73.24	58.14	Closed	Rubble, c.50% sand	Grass, low scrub
Enderbury	596.6	500+	Closed	Rubble, extensive sand	Grass, low scrub
Birnie	50.95	48.2	Closed	Rubble, limited sand	Grass, low scrub
Kanton	-	c.900	Open	Varied, extensive sand	Forest, scrub, coconut
McKean	74.32	48.77	Closed	Rubble, < 30% sand	Grass, low scrub
Orona	-	c.600	Open	Rubble, sand	Forest, scrub, coconut
Nikumaroro	-	c.400	Open	Rubble, sand	Forest, scrub, coconut

Note: Land areas are total atoll area minus lagoon area; Rawaki, McKean and Birnie data courtesy of T. Conaghan, NZ Department of Conservation, others from Garnett (1983). Note that some land area estimates are significantly greater than previously reported, notably Birnie (48.2 ha, c.f. 20 ha in Garnett 1983).

Figure 3.1 – Rawaki (Phoenix Island) and lagoon

Figure 3.2 – Orona; one of many small motu in foreground; lagoon and large motu behind

Four of the five atolls in the north and east of the Group have small land-locked hypersaline lagoons (Fig 3.1), with the c.600 ha Enderbury supporting a network of small interconnecting saline lagoons. Two of the southern atolls – Orona and Nikumaroro - have large lagoons that are connected to the sea (Fig 3.2), but tidal flushing is weak, particularly at Nikumaroro. Only the large Kanton Island in the north has high rates of tidal flushing.

3.2. Vegetation

The vegetation of the islands is generally little-modified, but contrasts between the southern and north-eastern islands (Stoddart 1994). The low rainfall islands of the north and east support few or no trees, but a low number of grasses (e.g. *Lepturus*) and prostrate shrubs such as *Tribulus*, *Portulaca*, *Boerhavea*, *Sesuvium* and the parasitic vine *Cassytha* are present (Fig 3.3, 3.4). The higher rainfall islands of the south and south-west do support indigenous forest, including *Pisonia*, *Cordia*, and *Pandanus*, with the forests of Orona being the most intact and extensive of the Group (Fig 3.5). However, these southern islands also support coconut plantations that were planted during a resettlement programme between the 1930s and 1960s (Maude 1937, Garnett 1983). Appendix 2 provides a full list of the flora recorded during the 2006 Conservation Survey.

Figure 3.3 – Typical vegetation of Rawaki; prostrate *Boerhavia*, *Portulaca* and *Letpturus*

Figure 3.4 – Extensive area of *Tribulus* on Enderbury; shearwater burrow in foreground

3.3. Human visits and settlement

The islands were visited and/or settled by Melanesian and/or Polynesian peoples in the past, but were uninhabited during the period of earliest European visits in the early 19^{th} century (Maude 1937, Garnett 1983). Whalers and guano collectors visited in the early and mid 19^{th} century respectively and the coral-slab walls of guano collectors' buildings are still standing (Fig 3.5). Up to 1000 people lived on each of Manra, Orona and Nikumaroro during the period from the late 1930s to the 1960s (Garnett 1983). Since the 1960s only Kanton has had permanent inhabitants, but Orona was settled by c.200 people in 2001-04, during which time sharks and other fish were harvested along with other fauna (T. Etei pers. obs.). Successive human visits over the centuries have resulted in the introduction of many invasive species including Pacific rats, rabbits, cats, pigs (*Sus scrofa*) and dogs (*Canis familiaris*) (Garnett 1983).

Figure 3.5 – Ruins on McKean

3.4. Past biological and ornithological surveys

The Pacific Ocean Biological Survey Programme undertook comprehensive biological surveys of the Phoenix Islands between March 1965 and July 1965 including multiple visits to some islands (Clapp and Sibley 1967), although the results of this work remain largely unpublished (A Kepler pers. comm.). Most of the more recent accounts of Phoenix Island biota, including the Phoenix Islands Management Plan (Garnett 1983) and some other publications on frigatebirds and unusual sightings (Clapp and Sibley 1967, Sibley and Clapp 1967) are derived from the 1960s surveys. Other surveys have included vegetation surveys (Stoddart 1994) and marine biological surveys (D. Obura and G. Stone unpublished data).

Two significant recent surveys of avifauna took place in January 2000 and March 2002. The first of these was the Millenium Sunrise Line and Phoenix Islands Expedition (Kepler 2000) which enabled bird observers to land for a few hours on each of four islands – Kanton, Manra, Orona and Nikumaroro. The second was a Kiritimati Government expedition (Bukaireiti and Rabaua 2002) which enabled ornithological counts to be made during a few hours on most of the 8 Phoenix Islands. Although these two expeditions were limited to daytime surveys (and so excluded complete assessment of procellariiform species in particular) and to a few hours per island, they nevertheless provided accurate data on many Phoenix Islands avifauna species. The findings of the latter report assisted in the interpretation of changed pest status, particularly in the case of McKean Island.

4. PELAGIC BIRDS

Objectives

- Determine species diversity and abundance of seabirds within and to the south of the Phoenix Islands in April-May 2006.

Methods

Continuous or semi-continuous pelagic bird counts were undertaken between Samoa and the Phoenix Islands (Fig 4.1). These were undertaken by RJP, with support from VK, AT and MT, and followed standard methods of observation (e.g. Kepler et al. 1992). Observers were seated near the stern of the RV Bounty Bay and c.1.5 m above sea-level. One side (generally the shaded side which also provided best lighting conditions) of the Bounty Bay was surveyed for c.300 m out from the boat. Transects were divided into hourly periods with boat speed, direction, sea condition and viewing conditions being recorded at the start and finish. Observations ceased within c.10 km of land, i.e. near Samoa, Swain's Island, Tokelau Islands and the individual members of the Phoenix Islands.

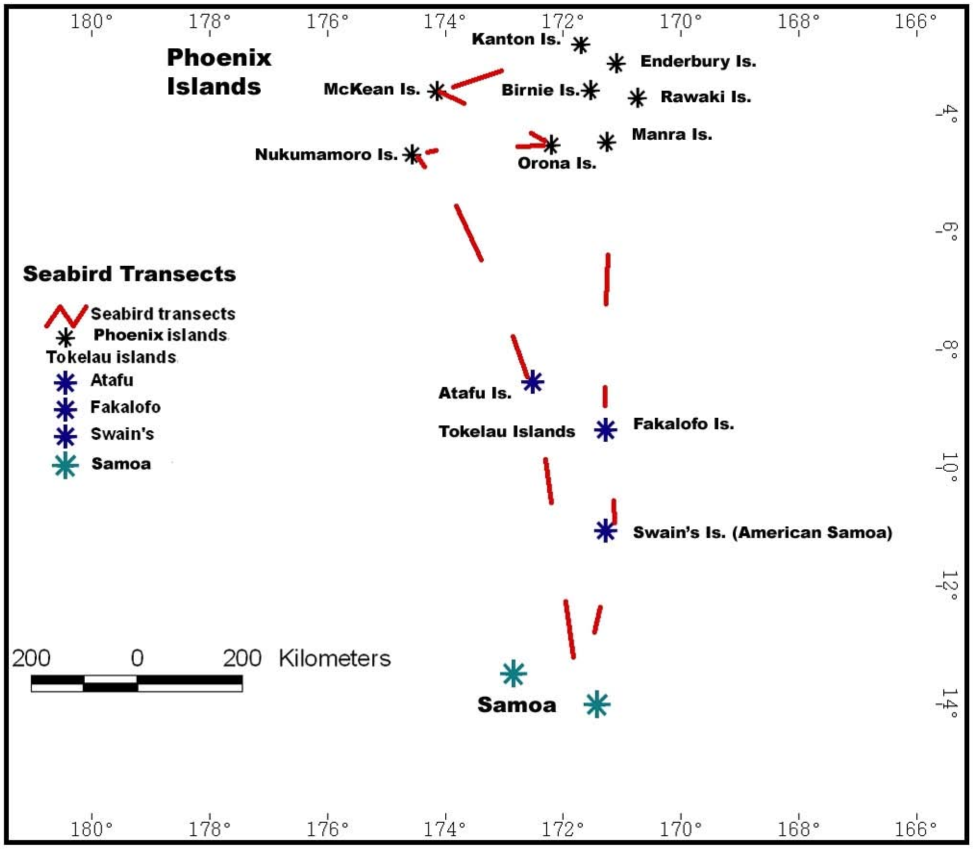

Figure 4.1 – Locations of seabird transects April-May 2006.

Analyses comprised a comparison of total seabird numbers per hour and seabird diversity per day in 11 segments of the journey comprising:

- Samoa to eastern Phoenix Islands (4 days)
- Within the Phoenix Islands Group (3 days)
- Western Phoenix Islands to Samoa (4 days).

Results and Discussion

A. Seabird diversity

A total of 31 species of seabirds (including 17 procellariiform species) was seen from the RV Bounty Bay, 29 species of which were recorded during formal transects. The diversity of seabird species recorded during open ocean transects was greater within the Phoenix Islands Group than in the open ocean to the south of the islands (refer Figure 4.2). Some of the species recorded within the Phoenix Islands were not recorded on the more southerly transects closer to Tokelau and Samoa (e.g. white-throated storm-petrel, brown booby, grey-backed tern and blue noddy) indicating that they occur in significantly lower densities there than in the Phoenix Islands. Not all pelagic birds were local residents: many New Zealand- and Australian-breeding species were on migration through the Samoa-Tokelau-Phoenix area at the time of the surveys, notably significant numbers of flesh-footed shearwater (*Puffinus carneipes*), sooty shearwater (*P. griseus*), short-tailed shearwater (*P. tenuirostris*) and mottled petrel (*Pterodroma inexpectata*) (refer Appendix 3 for complete data set). Flesh-footed shearwaters were previous;y not known from these waters (Wattling 2004), but clearly this is an important migration route for this and severeal other austral species.

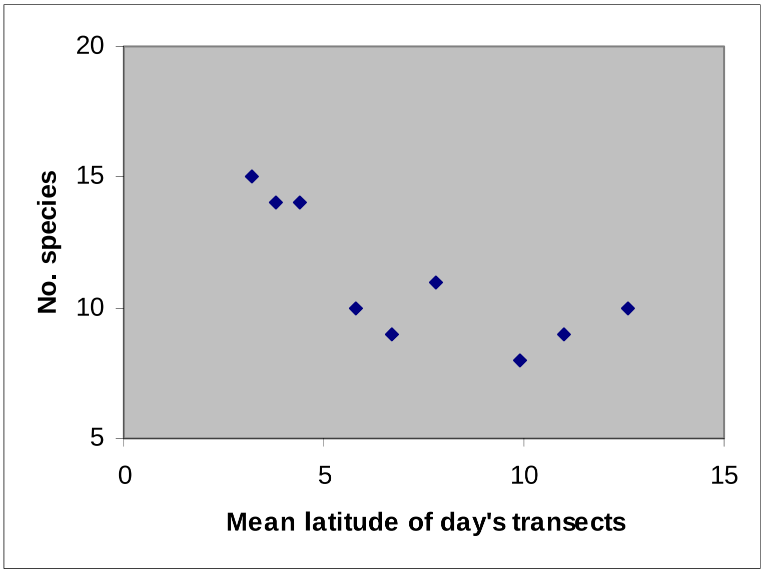

Figure 4.2 – Total species recorded per day between Phoenix Islands (3-5^{o}S) and Samoa (13^{o}S)

B. Seabird abundance

The total numbers of birds observed in the Phoenix Islands transects was also greater than that observed in transects to the south (refer Figure 4.3). Much of this was the result of high numbers of sooty terns which were often encountered in large feeding flocks. These flocks often also contained individuals or groups of other bird species, e.g. wedge-tailed shearwater (*Puffinus pacificus*), flesh-footed shearwater, red-footed booby (*Sula sula*), white tern (*Gygis alba*), brown noddy (*Anous stolidus*) and black noddy (*A. minutus*). More feeding flocks were encountered per hour in the Phoenix Islands transects than in transects to the south, but average flock size was highly variable (refer Table 4.2).

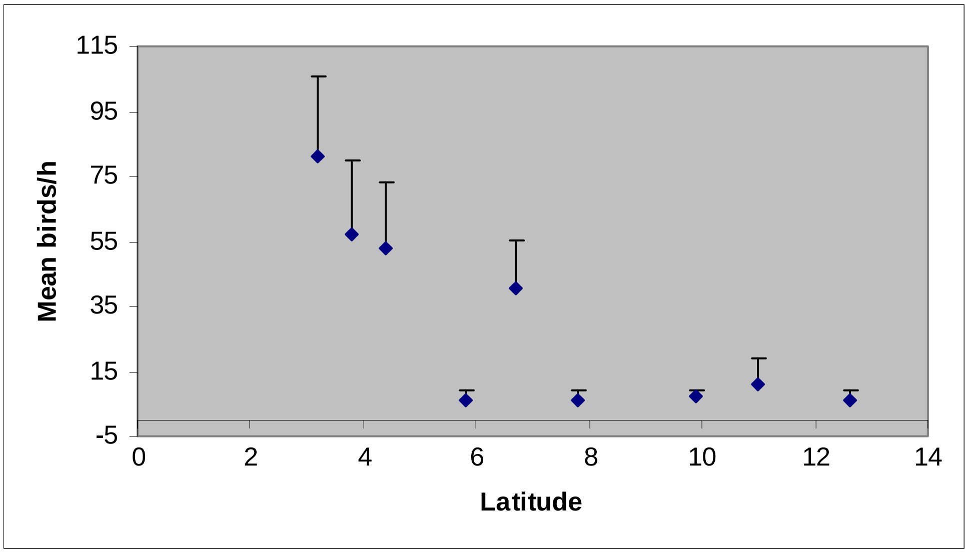

Figure 4.3 – Mean +/- 1 SE total pelagic birds observed per hour (n = 80 hours) in relation to latitude, Samoa-Phoenix Islands return April-May 2006

Table 4.1 – Number and size of feeding flocks in relation to latitude

Mean latitude	General transect location	Date (and hours of observation)	Mean no. flocks/h	Mean flock size (and range)
12.7	North of Samoa	10 May (9)	0	0
11.0	Samoa-Swain's Is	14-15 April (8)	0.125	25
10.2	Tokelau	9 May (8)	0.125	14
8.1	N Tokelau	8 May (7)	0	0
6.8	N Tokelau- Phoenix	17 April (8)	0.62	58 (21-140)
6.0	Phoenix-N Tokelau	7 May (10)	0.6	42.2 (14-79)
4.7	SW Phoenix	4-5 May (9)	0.89	15.4 (6-28)
4.0	W Phoenix	1-2 May (8)	0.62	47.3 (25-117)
3.2	N Phoenix	27 Apr (8)	0.38	161 (32-c.366)

5. TERRESTRIAL FAUNA VALUES

5.1. Breeding seabirds

Objectives

- Determine species diversity on priority islands of the Phoenix Islands

- Determine abundance of all seabird species, but with particular emphasis on threatened species
- Determine patterns of breeding and evaluate vulnerability of populations and opportunities for species recovery.

<u>Methods</u>

Five methods were used to estimate total bird populations present on individual atolls. These were observations from the RV Bounty Bay while circumnavigating islands prior to landing, evening observations from boat of birds flying ashore, colony counts (day and evening), transect counts of diffuse breeding species, and spotlight transects at night. These methods are described in more detail below.

A. Circumnavigation of islands

We circumnavigated all or part of the larger islands prior to landing in order to locate bird colonies and search for uncommon and conspicuous atoll species, e.g. white-tailed tropicbird (*Phaethon lepturus*).

B. Evening observations from boat

Between 1700 h and 1900 h we carried out observations of birds returning to the atolls, all from the RV Bounty Bay anchored c.150 m offshore on the leeward side. Species lists were compiled and individuals of the less common species were counted. The species richness determined by these evening observations were subsequently correlated with species richness determined by the day and night land-based transects (refer Fig 5.1). The graph indicates a close correlation between the two methods, but some species were missed during the evening observations: the few species that were missed on the evening observations were generally rare on that particular atoll and little-represented in shore sampling methods, e.g. Christmas shearwater and Phoenix petrel at Enderbury where only 1-2 individuals were detected ashore. Therefore the evening assessment was considered a valid way of rapidly assessing the composition of island seabirds, particularly if time was limited or weather prohibited safe landings as was the case at Manra.

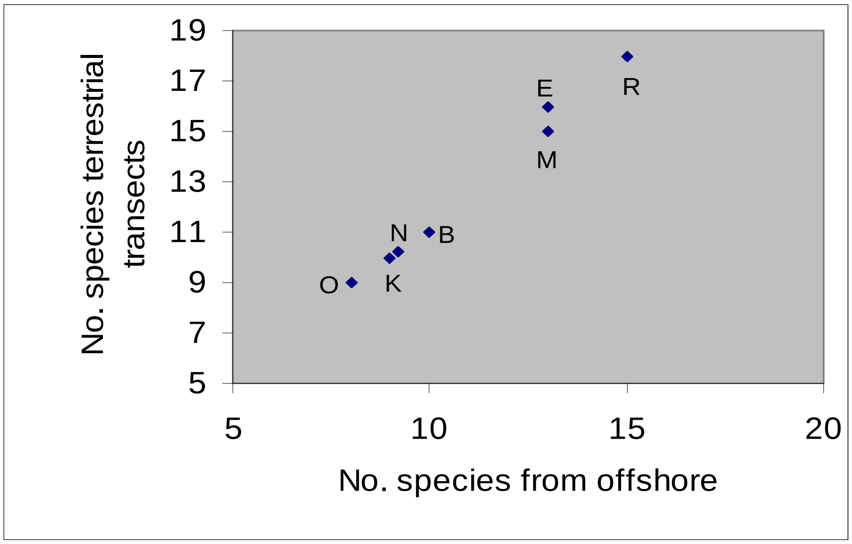

Figure 5.1 – Relationship between seabird diversity recorded from offshore and that established from terrestrial surveys, Phoenix Islands. O = Orona, K = Kanton, N = Nikumaroro, B = Birnie, M = McKean, E = Enderbury, R = Rawaki.

C. Island transects during the day

Randomly selected transects 60 m wide were completed on several islands by three observers (RJP, AT, ES or VK) who walked parallel to each other 20 m apart, and each of whom surveyed 10 m either side of their individual transect line. This method was particularly useful for quantifying numbers and density of pairs of diffusely distributed species, e.g. boobies (*Sula* spp.) and blue noddies (*Procelsterna caerulea*), and relatively cryptic nesters, e.g. red-tailed tropicbird (*Phaethon rubricauda*).

D. Colony counts

Total numbers of pairs were able to be estimated by individual head counts in some colonies, e.g. lesser frigatebirds (*Fregata ariel*) and most tern colonies. Exceptions included sooty tern (*Sterna fuscata*) colonies on Orona where colony areas were determined by measuring boundaries by GPS and nesting density was estimated from density transects (1 x 100 m) and quadrants (2 x 2 m), thereby allowing broad estimates of total numbers of breeding pairs. Additional counts of many species were completed in the evening to assess overnight roosting numbers. Locations of seabird colonies and some individual nest sites were fixed by GPS and mapped in Appendix 1.

E. Nocturnal spotlight counts and war-whooping

For cryptic seabirds, particularly procellariiform species, an index of abundance was developed by carrying out spotlight transects at night in potential nesting areas. On all islands widespread sampling occurred in likely nesting habitat comprising areas of *Tribulus* and *Portulaca* (beneath which shearwaters often nest), vegetated sandy areas (in which shearwaters and petrels dig their burrows) and areas of coral rubble (in which storm-petrels and others often nest). Inter-island comparisons were made on the basis of birds seen per spotlight hour. All large burrows were “war-whooped” following

Tennyson and Taylor 1990) in order to elicit responses from *Pterodroma* petrels if present. All Phoenix petrels (males and females) that were seen on the surface did in fact respond to war-whooping with a sharply repeated “kek-kek-kek-kek-kek-kek”, and other individuals and pairs in underground burrows were also detected using this method.

F. Population estimates

Where possible the populations of seabirds present on the islands are expressed as breeding pairs as this provides an accurate representation of an island’s use and importance. However, in cases where few individuals of a species were breeding, estimates are provided as total numbers of individuals. The accuracy of species counts are rated as high, medium and low for each island. “High accuracy” includes complete colony counts and where a species has a conspicuously high visbility or responsiveness, e.g. boobies and Phoenix petrel. “Medium accuracy” includes indexing methods, e.g. spotlighting of storm-petrels, while “low accuracy” includes most counts on islands that were not landed on (Manra) or incompletely covered (Kanton). These population estimates (and indices of abundance e.g. spotlight transects) go some way towards providing a coarse baseline for measuring population responses to future management.

G. Training

One objective of the survey was to train local staff and the two Government of Kiribati staff benefitted from being paired with individual specialists. One staff member focussed on the indigenous fauna component of this survey and participated in all of the avifauna survey methods A-F above, together with pelagic seabird surveys (the latter focusing on idenditification) (Refer Section 4) and surveys of ants and crabs (Refer Section 5.4 and 5.5). The second staff member worked collaboratively on surveys of invasive alien species, including mammals and plants (refer Section 6) and on some aspects of indigenous fauna surveys.

Results and Discussion

A. General patterns

Nineteen species of seabirds representing three orders and six families were found ashore during the 2006 Phoenix Island Conservation Survey (refer Table 5.1). This diversity of breeding species was identical to that of the 1960s (Garnett 1983), but the populations of many species have changed significantly (Table 5.2).

Table 5.1 – The diversity of seabirds ashore at the Phoenix Islands in 2006

Order	Family	Common names	No. species
Procellariiformes	Procellariidae	shearwaters and petrels	5
Procellariiformes	Hydrobatidae	storm-petrels	1
Pelecaniformes	Phaethontidae	Tropicbirds	2
Pelecaniformes	Fregatidae	Frigatebirds	2
Pelecaniformes	Sulidae	gannets/boobies	3
Charadriiformes	Sternidae	terns, noddies	6

Table 5.2 – Phoenix Islands Seabirds – preliminary estimate of number of pairs present in April-May 2006

Common name	Scientific name	Rawaki	Ender-Bury	McKean	Birnie	Kanton	Orona	Nikum-aroro	Manra	Approx total pairs
Audubon's shearwater	*Puffinus l'herminieri*	800+	50	60	0	0	0	0	0	910+
Christmas shearwater	*P. nativitatis*	500+	2	0	0	0	0	0	0	500+
Wedge-tailed shearwater	*P. pacificus*	250+	47	2 i	0	0	0	0	0	300+
Phoenix petrel	*Pterodroma alba*	11+	1 i	0	0	0	0	0	0	20+
Bulwer's petrel	*Bulweria bulwerii*	1 i	0	0	0	0	0	0	0	1i
White-throated storm petrel	*Nesofregetta albigularis*	20+	0	10+	0	0	0	0	0	30+
Red-tailed tropicbird	*Phaethon rubricauda*	70	500+	34	4	0	50+	100+	<10	760+
White-tailed tropicbird	*P. lepturus*	0	0	0	0	0	0	5	0	5+
Masked booby	*Sula dactylatra*	700	500+	400	109	0	1	4	100+	1814+
Brown booby	*S. leucogaster*	24	100+	75	9	50 i	0	0	0	230+
Red-footed booby	*S. sula*	3	100+	60	3	100	500+	200+	<50	1000+
Great frigatebird	*Fregata minor*	5	300+	400	0	1 i	50+	2 i	0	755+
Lesser frigatebird	*F. ariel*	4300	4000+	1500	20 i	50+	600	60	100+	10,610+
Sooty tern	*Sterna fuscata*	10000	3000+	500 i	P	50+	600,000	9 i	4000	617,000
Grey-backed tern	*S. lunata*	1000+	500+	800 i	300	2000+	0	0	600	4800+
Black noddy	*Anous minutus*	<10	100+	6	1 i	50+	2000	500	500	3150
Brown noddy	*A. stolidus*	4000	1000+	1630	2000	800+ i	10	20	<50 i	9400+
Blue noddy	*Procelsterna caerulea*	2500 (7000 i)	7 i	1 i	2 i	5+ i	0	0	1 i	2500 (7000) i
White tern	*Gygis alba*	20+	50+	100	27 i	20+	300	200	100	900+
Approx total pairs		24,500+	10,000	5,000	2,500	3000+	600,000	1000	5000	650,000
Total species		18	16	15	11	10	9	10	10	19

Note: all figures represent estimated total pairs except where "i" indicates "individuals" Red indicates threatened species, green = important populations, yellow = numbers have greatly declined since 1960s.

Although timing of surveys and methods varied between the 1960s and 2006 surveys, some striking changes in bird status are apparent. A few of these (e.g. lesser frigatebird) may partly reflect differences in seasonal timing of surveys and further analysis is required to help interpret those data. This should include direct comparisons with season-specific data collected in the 1960s.

However, most major changes cannot be explained by differences in timing of surveys or survey methodology. Of the 19 species, only 7 were recorded in the same order of magnitude as in the 1960s, with the other 12 species apparently having experienced serious or catastrophic declines (refer Table 5.3).

Table 5.3 – Summary of apparent population changes of Phoenix Islands seabirds since 1960s

Approx similar populations 1960s – 2006	Apparent serious decline, i.e. 2-10 x decline	Catastrophic decline, i.e. over 10 x decline
Both tropicbird species, all 3 booby species, sooty tern, black noddy	All 3 shearwaters, Phoenix petrel, both frigatebirds, grey-backed tern, brown noddy, blue noddy, white tern	Bulwer's petrel, white-throated storm-petrel

Despite the general trend towards large population declines since the 1960s, the Phoenix Islands continue to be regionally important for nearly all of these 19 species of seabirds and internationally important for several of them. Patterns of change are discussed under each species in the following section (B) and causitve effects of declines are evaluated in Section 6.

B. Species patterns

This section describes the status of each of the 19 seabird species recorded in April-May 2006, including comparisons with previous surveys where relevant.

i) Audubon's Shearwater (Te Nna)

<u>IUCN status</u>

Not threatened, but many populations greatly reduced; widespread tropical oceans with many subspecies; taxonomy incomplete.

<u>2006 data</u>

This species was detected ashore via daytime surveys, evening arrivals and spotlight transects, but only on three islands – Rawaki (lacking rats) and smaller numbers present on Enderbury and McKean (refer Table 5.4). At Rawaki all nesting concentrations occurred along the western side and adjacent central part of the island, where many nesting burrows had been dug in sand and others placed beneath bushes (e.g. *Portulaca*), *Lepturus* and coral. At Enderbury and McKean, most nests and prospecting sites were on the surface of the ground beneath the cover of dense *Tribulus* bushes, which was absent from Rawaki. Based on counts of all occupied burrows in colonies the population is estimated to be at least 800 pairs at Rawaki, 50 pairs at Enderbury and 60 pairs at McKean. Breeding stages varied between the islands reflecting different intensities of mammalian predation (refer Section 6).

Comparisons with previous data

Previous observations in the 1960s suggest that Audubon's shearwaters were once more common on two of the Phoenix Islands, Rawaki and McKean (refer Table 5.4). The decline on both islands is not surprising given the high level of habitat loss (plant dieback) and interference incurred by rabbits on Rawaki, and from the clearly high level of predation of eggs and chicks from the rats on McKean (refer Section 6). The lack of past records of Audubon's shearwaters on Enderbury may indicate that this species is now recolonising that large island now that cats have disappeared. Recolonisation may not completely succeed there however, given that Pacific rats can bring about population declines via nest predation of a similar sized shearwater, the little shearwater (*Puffinus assimilis*) (Pierce 2002).

Table 5.4 – Estimates of past and present abundance of Audubon's shearwater at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki[1]	Enderbury	McKean
1960s (Garnett 1983)	12,000 i	3 i	5,000 i
2006 (this study)	800+ pairs	50 pairs	60 pairs
2006 count accuracy	High	High	High
2006 census methods[2]	CC; SL; EFO	CC; SL; EFO	CC; SL; EFO
2006 – birds/spotlight hour	60+ (5 h)	5.25 (6 h)	4.5 (8 h)
2006 – evening fly on	43 (31 & 55)	11	36 (31 & 41)

Note 1: i = individuals;
Note 2: CC = colony counts, SL = spotlight; EFO = evening fly-on; refer to Section 5.1 for detail of methodology.

ii) Christmas shearwater (Te Tinebu)

International status

Not threatened. Breeds tropical Pacific between Hawaii and Phoenix Islands and Pitcairn Group and Easter Island.

2006 data

Apart from two individuals found nest prospecting during the night at Enderbury Island, this species was found only on Rawaki. An estimated 500+ pairs were nesting at Rawaki, based on accurate counts that covered the entire breeding colony. Breeding was concentrated among the Audubon's shearwater-dominated colony in the western part of Rawaki and in *Lepturus* in the central part of the island. Nest chambers were mainly beneath dense vegetation or rubble. Although breeding was at a variety of stages (prospecting, eggs, pulli, juveniles), overall it appeared to be more synchronized than that of Audubon's shearwaters, with a high proportion of downy chicks and fewer older chicks.

Comparisons with previous data

Previous observations in the 1960s suggested that c.3000 individual Christmas shearwaters were present at Rawaki and c.50 at McKean (Table 5.5). Numbers at Rawaki are broadly similar between the two surveys, but the species has become locally extinct at McKean, which is consistent with the downward trend in Audubon's shearwater numbers on that island.

Table 5.5 – Estimates of past and present abundance of Christmas shearwater at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki	Enderbury	McKean
1960s (Garnett 1983)	3,000 i	0 i	50 i
2006 (this study)	500+ pairs	1-2 pairs	0 pairs
2006 count accuracy	High	High	High
2006 census methods	CC; SL; EFO	SL; EFO	SL; EFO
2006 - birds/spotlight hour	20+ (5 h)	0.2 (6 h)	0 (8 h)
2006 – evening fly on	21.5 (20 & 23)	0	0 (0 & 0)

iii) Wedge-tailed shearwater (Te Tangioua)

IUCN status

Not threatened. Breeds tropical Pacific and Indian Oceans.

2006 data

An estimated 250+ pairs of wedge-tailed shearwaters were present at Rawaki and a small colony of 47 active burrows was present at the south end of Enderbury (refer maps in Appendix 1). Most of the Rawaki birds were present on the surface at night and others were in burrows suggesting that nest-prospecting was occurring. Some pairs may have been incubating, but this could not be confirmed given the long length of burrows. The only other individuals seen over land in the entire Group were two singles seen flying during spotlight transects at McKean, but no evidence was found of breeding on that island.

Comparisons with previous data

Data in the 1960s suggested wedge-tailed shearwaters were particularly common at Rawaki with fewer at McKean and Enderbury. In 2006 no evidence was found for these former large numbers at either Rawaki or McKean (Table 5.6), with large shearwater burrows being entirely absent at the latter island indicating that they were now effectively absent there as a breeding species. At Rawaki most large shearwater burrows were in fact "active", suggesting that overall numbers are well down on the 10,000 birds estimated to be present in the 1960s. However, the presence of 47 active burrows at Enderbury (and no derelict burrows) is encouraging.

Table 5.6 – Estimates of past and present abundance of Wedge-tailed shearwater at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki	Enderbury	McKean
1960s (Garnett 1983)	10,000 i	24 i	500 i
2006 (This study)	250+ pairs	47 pairs	1-2 seen flying
2006 count accuracy	Medium	High	High
2006 census methods	CC; SL; EFO	CC; SL; EFO	SL; EFO
2006 - birds/spotlight hour	50+ (5 h)	0.6 (6 h)	0.25 (8 h)
2006 – evening fly on	5	0	0 (0 & 0)

iv) Phoenix petrel (Te Ruru)

IUCN status

Endangered (IUCN 2006), previously considered Vulnerable (BirdLife 2000), but confirmed breeding only at the Phoenix Islands and at Kiritimati in the Line Islands (currently in the order of 500 birds and under threat from people and predators, A Teatata pers. obs., 2006). Recent Pitcairn, Tuamotu and Tonga records (Birdlife 2000) are unconfirmed (Pierce et al. 2003, G. Wragg pers. obs.), although pelagic sightings have occurred in the first two of these groups in recent years (Pierce et al 2003, G. Wragg pers. obs. 2006).

2006 data

Recorded on Rawaki (11 pairs) and one bird on Enderbury. On Rawaki birds were observed from c. 1500 h in the afternoon of 19 and 20 April retuning to and landing at burrows on the island. Peak observations were after dark when 11 pairs were confirmed present on the second night. All pairs observed on the first night were relocated the second night along with a few new pairs mainly in areas not covered the first night. All were prospecting in the central part of the island (refer Fig 5.2). Most were present in areas of *Lepturus* (7 pairs) or in areas where *Boerhavia* had recently died off (3 pairs) and live *Boerhavia* (1 pair). This, together with the 100% responsiveness of all birds to "war-whoops" and the scarcity of unused burrows, suggests that the population is very low, and possibly only in the order of 20 pairs. The Enderbury bird was seen flying and circling over the SW corner of the island at c.1500 h on 22 April.

Comparisons with previous data

Data collected in the 1960s suggested 225 birds were present on Rawaki (refer Table 5.7). This may no longer be the case with the population now appearing to be critically low. Pelagic observations support this view with no individuals being seen during 80 hours of transects (refer Section 4). However, because our visit coincided with the pre-laying period it is likely that some additional pairs could breed at Rawaki.

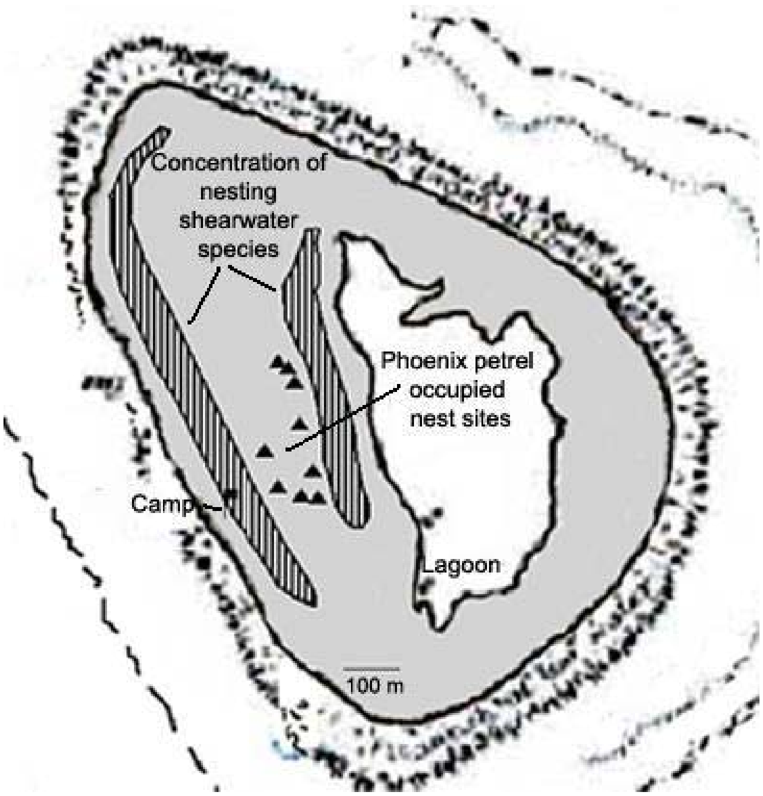

Fig 5.2 – Distribution of Phoenix petrel pairs and shearwater colonies on Rawaki 2006.

Figure 5.3 – Phoenix petrel at burrow entrance, Rawaki

Table 5.7 – Estimates of past and present abundance of Phoenix petrel at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki	Enderbury	McKean
1960s (Garnett 1983)	225 i	0	0
2006 (this study)	11-20 pairs	1 prospecting	0
2006 count accuracy	High	High	High
2006 census methods	CC; SL/WW	SL/WW; EFO	SL/WW; EFO
2006 - birds/spotlight hour	6 (5 h)	0 (6 h)	0 (8 h)
2006 – evening fly on	0.5 (1 & 0)	0	0 (0 & 0)

v) Bulwer's petrel

IUCN status

Not threatened. Breeds tropical islands in Pacific, Atlantic and possible Indian Oceans.

2006 data

One bird was seen on the ground in the Phoenix petrel colony area (*Lepturus*-dominated area) on the night of 19 April 2006.

Comparisons with previous data

During the 1960s c.500 and c.200 were recorded on Rawaki and McKean respectively where they were seen breeding in areas of coral rubble and walls (Garnett 1983). No birds were found in these areas of rubble in 2006 at a time when breeding birds should have been prospecting, which suggest a near total loss of this species.

Table 5.8 – Estimates of past and present abundance of Bulwer's petrel at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki	Enderbury	McKean
1960s (Garnett 1983)	500 i	0	200 i
2006 (this study)	1 i	0	0
2006 count accuracy	High	High	High
2006 census methods	SL; EFO	SL; EFO	SL; EFO
2006 - birds/spotlight hour	0.2 (5 h)	0 (6 h)	0 (8 h)
2006 – evening fly on	0.5 (1 & 0)	0	0 (0 & 0)

vi) White-throated storm petrel (Te Bwebwe ni Marawa)

IUCN status

Vulnerable (BirdLife 2000), but there are few data, and may warrant Endangered status. They breed at decreasing numbers of islands in tropical Pacific at Line, Phoenix, Gambier, Marquesas, Austral Islands and Sala y Gomez Island.

2006 data
White-throated storm-petrels were found only on Rawaki and McKean islands. On Rawakai birds were prospecting and incubating, with one of three birds handled possessing a brood patch. An average of 7 birds were seen per hour of nocturnal spotlighting on Rawaki with birds being clustered in the central *Lepturus* grasslands (Fig 5.4), and fewer birds were seen in areas of rubble and shearwater burrows. On McKean an average of 1 bird was seen per spotlight hour, mostly in areas of rubble and stone walls. Birds on McKean were noticeably more wary than those on Rawaki.

Figure 5.4 – White-throated storm-petrel, Rawaki

Comparisons with previous data
During the 1960s white-throated storm-petrels were considered to be abundant with 12,000 and 1,000 on Rawaki and McKean respectively. This is no longer the case, with a few 10s of pairs present on Rawaki and even fewer on McKean where they are threatened with immediate extinction locally (refer Section 6). One bird was seen off Enderbury in January 2000 (Kepler 2000). The low numbers of storm-petrels present in 2006 cannot be explained by seasonal differences in observations as this species has a protracted egg-laying period (Harrison 1985).

Table 5.9 – Estimates of past and present abundance of White-throated storm-petrel at Phoenix Islands and baseline monitoring data

Date and Source	Rawaki	McKean
1960s (Garnett 1983)	12,000 i	1,000 i
2006 (this study)	20-50 pairs	10+ pairs
2006 count accuracy	Medium	Medium
2006 census methods	SL; EFO	SL; EFO
2006 - birds/spotlight hour	7 (5 h)	1.1 (8 h)
2006 – evening fly on	4.5 (7 & 2)	0.5 (0 & 1)

vii) Red-tailed tropicbird (Te Taake)

<u>IUCN status</u>
Not threatened. Confined to tropical Indian and Pacific Oceans, the latter represented by *P. r. melanorhynchos*.

<u>2006 data</u>
Present on all islands within the Phoenix Group. Densities were highest on the northern and eastern islands with Enderbury supporting the highest population of c.500 pairs (refer Table 5.10). Breeding was asynchronous with eggs, young chicks and pulli present on all islands.

<u>Comparisons with previous data</u>
Numbers of pairs present in 2006 approximate those recorded in the 1960s, except for McKean where the data suggest a decline from 500 individuals to 34 pairs. The McKean population was also low in 2002 when Bukaireiti and Rabaua (2002) recorded 8 adults and one chick during a stay of several hours on the island. However, numbers appear to have increased on both Orona and Nikumaroro since the 1960s (refer Table 5.10).

Table 5.10 – Estimates of past and present abundance of Red-tailed tropicbird at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s	175 i	1,000 i	500 i	50 i	10 i	Few?	May breed	?
2006	70 P	500+P	34 P	4 P	0	50+P	100+P	<10 P
2006 accuracy	High	High	High	Med	Low	Med	Med	Low
2006 methods	T	T	CC	T; EFO	EFO	T; EFO	T; EFO	EFO

viii) White-tailed tropicbird (Te Ngutu)

<u>IUCN status</u>
Not threatened. Confined to tropical Atlantic, Indian and Pacific Oceans, with *P. lepturus dorothea* widespread in the Pacific.

<u>2006 data</u>
Recorded ashore only at Nikumaroro where 5-10 pairs were present. Birds were undertaking aerial courtship displays and individuals were seen on the ground in two south-western parts of the island under *Pisonia/Cordia* and coconuts respectively.

<u>Comparisons with previous data</u>
Individuals or pairs have been reported from Nikumaroro (Garnett 1983), Orona (Garnett 1983, Kepler 2000) and Manra (Garnett 1983). In 2006, birds were present only at

Nikumaroro. Had several pairs been present at Orona and Manra in 2006 they are almost certain to have been detected by our sampling given their conspicuous aerial displays.

Table 5.11 – Estimates of past and present abundance of White-tailed tropicbird at Phoenix Islands and baseline monitoring data

Date and Source	Orona	Nikumaroro	Manra
1960s (Garnett 1983)	Possibly breeds	Possibly breeds	Possibly breeds
2000 (Kepler 2000)	1 pair	-	0
2006 (this study)	0	5-10 pairs	0
2006 count accuracy	High	Medium	Medium
2006 census methods	T; CN; EFO	T; CN; EFO	CN; EFO

ix) Masked booby (Te Mouakena)

IUCN status

Not threatened, but many colonies have declined in size. Confined to tropical Atlantic, Indian and Pacific Oceans, with S. *dactylatra personata* widespread in the central and western Pacific.

2006 data

Common on Rawaki, Enderbury and McKean with 400-700 pairs present on each island. Breeding was asynchronous with eggs, pulli and juveniles present and flocks of up to 55 non-breeders at Rawaki. Fewer birds (c.100 pairs) were present at Manra and Birnie and few or none on the large cat-frequented or recently human-frequented islands of Kanton, Orona and Nikumaroro.

Comparisons with previous data

The numbers of pairs recorded approximated those recorded in the 1960s (refer Table 5.12).

Table 5.12 – Estimates of past and present abundance of masked booby at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s	850 i	2,000 i	700-1500 i	350-800 i	0	0	0	180-200
1979[1]	-	-	-	-	Present	-	-	
2000[2]	-	Present	-	-	0	6	0	120+
2002[3]	2020	-	280	1,500	1	0	50	21
2006	700 P	500 P	400 P	109 P	0	1 P	4 P	100+P
2006 accuracy	High	High	High	High	Med	High	High	Low
2006 methods	T; CC	T; CC	T; CC	T; CC	EFO	T; CC	T; CC	CN;EFO

Note: 1 = Garnett 1983, 2 = Kepler 2000, 3 = Bukaireiti and Rabaua 2002.

x) Brown booby (Te Kibui)

IUCN status

Not threatened, but as with masked booby, many colonies have declined in size and typically comprise a few 10s of breeding pairs. They are confined to tropical Atlantic, Indian and Pacific Oceans, with S. *leucogaster plotus* widespread in the Indian Ocean and the central and western Pacific Ocean east to the Gambiers.

2006 data

Uncommon throughout with greatest numbers (75-100+ pairs) being present on McKean and Enderbury respectively (Fig 5.5). Other small cat-free islands supported many pairs (refer Table 5.13). Surprisingly, many were present at Kanton, but significantly fewer juveniles were seen there than at the other islands (juvenile to adult ratio1:11, c.f. 1:4 elsewhere). None were present ashore at Orona and Nikumaroro. Breeding was asynchronous with eggs, pulli and juveniles present and many juveniles were seen at sea.

Figure 5.5 – Nesting brown booby on McKean

Comparisons with previous data

The numbers of pairs recorded in 2006 were in the same order of magnitude as those recorded in the 1960s (refer Table 5.13). 100-120 birds including juveniles were recorded on Orona in 2000 (Kepler 2000), but none were present in 2002 (Bukaireiti and

Rabaua 2002) and 2006 during and following a human re-settlement period, whilst there are no records of birds ashore at Nuikumaroro.

Table 5.13 – Estimates of past and present abundance of brown booby at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	100 i	300 i	50-100 i	50-100 i	0	0	0	0
2000[2]	-	Present	-	-	30+ i	100+ i	0	0
2002[3]	30 i	-	100 i	30 i	125 i	0	0	0
2006[4]	24 P	100+ P	75 P	9 P	50+ i	0	0	0
2006 acc	High	High	High	High	Med	High	High	Med
2006 method	T; CC	T; CC	T; CC	T; CC	EFO	T; CC	T; CC	CN;EFO

Note: 1 = Garnett 1983, 2 = Kepler 2000, 3 = Bukaireiti and Rabaua 2002, 4 = this report.

xi) Red-footed booby (Te Kota)

IUCN status

Not threatened. Pan-tropical with *Sula sula rubripes* widespread and common in the Pacific and Indian Oceans.

2006 data

Present and breeding on all atolls in the Group, being commonest (100-500+ pairs) on Enderbury and the well-forested islands of Kanton, Orona and Nikumaroro. Orona had the largest population in April-May 2006. Breeding was asynchronous with eggs, pulli and juveniles present and many juveniles were seen at sea. Most nests were in trees or tall shrubs, but on the treeless or near treeless islands (Rawaki, Birnie, McKean) some nests were in low shrubs, e.g. *Sida* and *Tribulus*.

Comparisons with previous data

The numbers of pairs recorded were in the same order of magnitude to those recorded in the 1960s (Garnett 1983, Kepler 2000).

Table 5.14 – Estimates of past and present abundance of red-footed booby at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumar-oro	Manra
1960s	100-350i	2,000 i	180-500i	0	0	200 i	500 i	4 i
2006	3 P	100+P	60 P	3 P	100 P	500+P	200+P	<50 P
2006 acc	High	High	High	High	Med	Med	Med	Med
2006 meth	T; CC	T; CC	T; CC	T; CC	EFO	T; CC	T; CC	CN;EFO

xii) Great frigatebird (Te Eitei)

IUCN status

Not threatened. Mainly Indo-Pacific distribution with *Fregata minor palmerstoni* breeding on islands in the Pacific.

2006 data

Present in small numbers at most atolls, but breeding only at three – Enderbury, McKean (400-500 pairs each) and Orona. Breeding was asynchronous with eggs, pulli and juveniles present in nests located in trees, tall shrubs and low shrubs, particularly *Sida,* and *Tribulus*. Only one bird was seen at sea.

Comparisons with previous data

In the 1960s large numbers were recorded at Enderbury and Orona and moderate numbers at Rawaki and McKean (refer Table 5.15). Relatively few were present in 2002 and 2006 suggesting an overall decline in the Phoenix Islands population since the 1960s.

Table 5.15 – Estimates of past and present abundance of great frigatebird at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumar-oro	Manra
1960s[1]	1,000 i	8,000 i	1500 i	0	225 i	20,000 i	800 i	6 i
2002[2]	105 i	-	200 i	0	0	0	1 i	0
2006[3]	5 P	300+ P	400 P	0	1 i	50+ P	2 i	0
2006 acc	High	High	High	High	Med	Med	Med	Med
2006 meth	T; CC	T; CC	T; CC	T;EFO	EFO	T; CC	T; CC; EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = Bukaireiti and Rabaua 2002, 3 = this report.

xiii) Lesser frigatebird (Te Eitei)

IUCN status

Not threatened. Mainly Indo-Pacific distribution with *Fregata ariel ariel* breeding on islands in the Indian and Pacific Oceans.

2006 data

Colonies numbering in the hundreds or low thousands of pairs were present on Rawaki, Enderbury, McKean and Orona, with fewer present on Manra. Breeding was asynchronous on all islands. On McKean lesser frigatebirds had abandoned the largest colony site where c.110 dead late-stage pulli and/or fledglings were found with the birds apparently having died in the past few weeks. The cause(s) of death and colony abandonment could not be determined. Few frigatebirds were seen at sea during seabird transects (refer Appendix 3).

Comparisons with previous data

In the 1960s large numbers (15,000-45,000) were recorded at each of Rawaki, Enderbury and McKean, but data collected since then suggests an overall significant decline in the Phoenix Islands population (refer Table 5.16). Data from the 1960s suggested that lesser frigatebirds were seasonally absent from the Phoenix Islands during a non-breeding period of December-April (Clapp and Sibley 1967), however, the presence of well-established colonies in April-May 2006, including late stage pulli and juveniles suggests that biennial nesting (common in this species, Orta 1992) was taking place in the Phoenix Islands during 2006. Visits at other times of the year would be needed to further evaluate seasonality of breeding and population fluctuations.

Table 5.16 – Estimates of past and present abundance of lesser frigatebird at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	16,000+i	15,000+i	30,300+i	0	0	0	800 i	0
2002[2]	3,500 i	-	0	0	0	0	0	0
2006[3]	4,300 P	4,000+P	1,500 P	20 i	50+P	600 P	60 P	100+P
2006 acc	Med	Med	Med	Med	Med	Med	Med	Low
2006 meth	CC	CC	CC	EFO	EFO	T; CC	T; CC; EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = Bukaireiti and Rabaua 2002, 3 = this report.

xiv) Sooty tern (Te Keeu)

IUCN status

Not threatened. Sooty terns have a pan-tropical distribution with *Sterna fuscata serrata* breeding on islands off Australia and in the South Pacific Ocean east to Easter Island.

2006 data

Five colonies on Orona totalled c. 600,000 pairs with c.1.5 million birds estimated to be present on the island in five widely separated colonies (Fig 5.6). Smaller colonies were present on Rawaki, Enderbury and apparently Manra. Breeding was synchronized within each atoll, e.g. all nests on Orona were incubating or had downy chicks, while all pairs on Enderbury and most pairs on Rawaki had nearly fledged pulli. All breeding attempts on McKean had failed (refer Section 6). Sooty terns were common at sea and were the predominant species seen on seabird transects within the Phoenix Group.

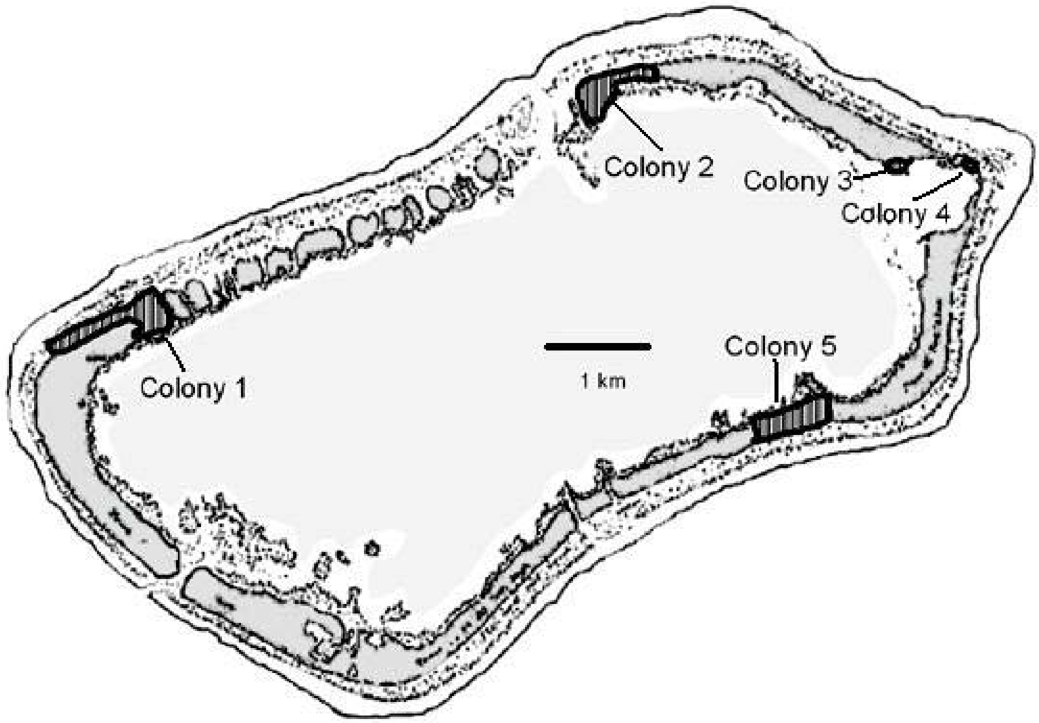

Fig 5.6 – Distribution of sooty tern colonies on Orona 2006.

Comparisons with previous data

In the 1960s colonies containing hundreds of thousands of birds were recorded at Rawaki, Enderbury and McKean and c. 3 million birds at Orona (Garnett 1983). The overall numbers present in the Phoenix Group appear to be in the same order of magnitude as that in the 1960s.

Table 5.17 – Estimates of past and present abundance of sooty tern at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	250,000i	400,000i	250,000i	0	100i	3,000,000i	0	5,000+i
2002[2]	750,000i	-	1,100i	5	0	100,000+i	0	0
2006[3]	10,000P	3,000+P	500 i	P	50+P	600,000 P	9 i	4,000 P
2006 acc	Med	Med	Med	Low	Low	Med	Med	Low
2006 meth	T; CC	T; CC	T; CC	EFO	EFO	CC;EFO	T; CC;EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = Bukaireiti and Rabaua 2002, 3 = this report.

xv) Grey-backed tern (Te Tarangongo)

IUCN status
Not threatened, but narrow range in central tropical Pacific Ocean.

2006 data
Grey-backed terns were recorded at six of the eight islands in the Phoenix Group with up to 2,000 pairs on each island (Table 5.18). Unlike sooty terns, breeding was relatively asynchronous at all colonies, with eggs, downy chicks and pulli being present. Except for the immediate vicinity of islands, few grey-backed terns were seen at sea.

Comparisons with previous data
During the 1960s a large colony was found on McKean Island (23,400 birds), and although distribution is now wider than in the 1960s, total numbers (4400+ pairs) in 2006 were significantly lower for the Group.

Table 5.18 – Estimates of past and present abundance of grey-backed tern at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	1,800 i	0	23,400 i	0	Present?	0	0	0
2002[2]	100 i	-	0	0	10 i	0	0	0
2006[3]	1,000+P	500+	800 i	300	2,000+P	0	0	600
2006 acc	Med	Med	Med	Med	Low	High	High	Low
2006 meth	T; CC	T; CC	T; CC	EFO	EFO	CC;EFO	T; CC;EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = Bukaireiti and Rabaua 2002, 3 = this report

xvi) Black noddy (Te Mangkiri)

IUCN status
Not threatened. *Anous minutus* occurs in the western and central tropical Pacific.

2006 data
Black noddies were common on Orona (2,000+ pairs) and smaller numbers occurred on all other atolls (Table 3). Nesting was taking place mainly in tall trees and shrubs and was asynchronous throughout.

Comparisons with previous data
During the 1960s several thousands of birds were estimated to be present at Orona, Nikumaroro and Enderbury. Overall numbers appear to be lower in 2006 than in the 1960s, particularly on McKean, but birds are now present at Kanton and Manra where few or none had been recorded earlier.

Table 5.19 – Estimates of past and present abundance of black noddy at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	200 i	4,000 i	1,000 i	0	Few	10,000i	5,000 i	0
2006[2]	<10 P	100+ P	6 P	1 i	50+ P	2,000P	500 P	500 P
2006 acc	High	Med	High	High	Low	Med	Med	Low
2006 meth	T; CC	T; CC	T; CC	T;EFO	EFO	CC;EFO	T; CC;EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = this report

xvii) Brown noddy (Te Io)

<u>IUCN status</u>

Not threatened. *Anous stolidus pileatus* occurs in the Indian and Pacific Oceans.

<u>2006 data</u>

Brown noddies were present on all islands in the Phoenix Groups but never in large numbers with 4,000 pairs on Rawaki being the highest count (Table 3). Breeding was asynchronous with nests on the ground, in low shrubs and amongst coral rubble and coral walls. Many pulli died following storms and driving rain that we experienced on each of Rawaki and McKean.

<u>Comparisons with previous data</u>

During the 1960s many thousands of birds were counted on Rawaki, McKean and Kanton (refer Table 5.20). Since then, numbers have clearly declined greatly on McKean and possibly also on Kanton.

Table 5.20 – Estimates of past and present abundance of brown noddy at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumar-oro	Manra
1960s[1]	7,700 i	500 i	20,000 i	3000 i	10,000 i	1,000 i	1,000 i	1,200i
2006[2]	4,000 P	1,000+P	1,630 P	2,000 P	800+ i	10 P	20 P	<50 i
2006 acc	Med	Med	Med	Med	Low	Med	Med	Low
2006 meth	T; CC	T; CC	T; CC	T; EFO	EFO	CC; EFO	T; CC; EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = this report

xviii) Blue noddy (Blue-grey ternlet; Te Raurau)

<u>IUCN status</u>

Not currently classified as threatened but, but most populations are greatly depleted and potentially threatened, including those in the Phoenix Islands. They occur throughout the tropical Pacific Ocean, with *Procelsterna caerulea nebouxi* breeding in Phoenix Islands, Tuvalu and Samoa.

2006 data
Blue noddies were common only on Rawaki in 2006 where an estimated 7,000 birds were present at night (Refer Fig 5.7, 5.8). Results from daytime transects suggested that over 2,000 pairs were present on the island. Nesting was fairly synchronized with most pairs courting or incubating (nests on ground) and only two chicks were seen. No more than seven individuals were seen on each of the other atolls, including only one on McKean where they were once common (refer Table 5.21). These few individuals present on other islands were seen mainly in the evening when they roosted on high structures, e.g. walls and monuments, whereas the Rawaki birds roosted on the ground or on prostrate plants.

Figure 5.7 – Blue noddy, Rawaki

Comparisons with previous data
During the 1960s 10,000 and 15,000 birds were counted on Rawaki and McKean respectively (refer Table 5.21). Clearly, the McKean population has been eliminated.

Table 5.21 – Estimates of past and present abundance of blue noddy at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	10,000i	0	15,000i	100i	0	0	0	0
2002[2]	100 i	-	0	0	0	0	0	0
2006[3]	7,000 i	7 i	1 i	2	5+ i	0	0	1 i
2006 acc	Med	High	High	High	Med	High	High	Med
2006 meth	T; SL	T; SL	T; SL	T; EFO	EFO	T; EFO	T; EFO	CN;EFO

Note: 1 = Garnett 1983, 2 = Bukaireiti and Rabaua 2002, 3 = this report

Figure 5.8 – Nocturnal roosting concentration of blue noddies, Rawaki

xix) White tern (Te Matawa)

IUCN status

Not threatened. Circumequatorial, *Gygis alba candida* occurs throughout tropical SW Pacific.

2006 data

White terns were present on all islands, being most common on the forested islands of Orona (c.300 pairs) and Nikumaroro (c.200 pairs).

Comparisons with previous data

During the 1960s numbers of white terns counted were in the same order of magnitude to the 2006 data, except for the two highest counts. The high 1960s counts were McKean (7000) and Rawaki (3000), with these islands now supporting only 20-100 pairs.

Table 5.22 – Estimates of past and present abundance of white tern at Phoenix Islands.

Date	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
1960s[1]	3,000 i	20 i	7,000 i	500 i	Few	1,000i	1,000 i	40-60i
2006[2]	20+ P	50+ P	100 P	27 i	20+ P	300 P	200 P	100 P
2006 acc	Med	Med	Med	Med	Low	Med	Med	Low
2006 meth	T	T	T	T;EFO	EFO	T	T	CN;EFO

Note: 1 = Garnett 1983, 2 = this report

5.2. Shorebirds and landbirds

Non-seabird species recorded included Pacific reef heron (*Egretta sacra*), six species of holarctic-breeding wader, great crested tern (*Sterna bergii*) and long-tailed cuckoo (*Eudynamis taitensis*). Details of total numbers recorded per island are provided in Table 5.21. Numbers of waders were relatively high on the first few atolls visited, but fewer were seen on later atolls, probably reflecting a north-bound migratory exodus of birds during our survey. This interpretation was supported by the observation that the proportion of Pacific golden plover (*Pluvialis fulva*) in breeding plumage dropped from over 50% on Rawaki and Enderbury (19-24 April) to less than 10% on McKean, Orona and Nikumaroro (29 April-6 May). These observations of landbirds are consistent with those of earlier surveys (Garnett 1983).

Table 5.21 - Phoenix Islands shorebirds and landbirds April-May 2006 – total no. seen

Species	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro	Manra
Dates	19-21/4	22-24/4	28/4-1/5	25/4	26/4	2-4/5	5-6/5	18/4
Pacific reef heron *Egretta sacra*	0	0	0	0	0	0	1	-
Pacific golden plover *Pluvialis fulva*	100+	200+	30	Prese-nt	2+	10+	6	Present
Bristle-thighed curlew *Numenius tahitiensis*	c.60	c.50	6	2 anvil sites	10+	5	2	Present
Ruddy turnstone *Arenaria interpres*	120+	100+	60	20+	2+	20+	70+	Present
Wandering tattler *Heteroscelus incanus*	2	Present	30	2+	2+	30+	15	Present
Sharp-tailed sandpiper *Calidris acuminata*	1							
Great crested tern *Sterna bergii*		1		1				
Long-tailed cuckoo *Eudynamis taitensis*							2	

5.3. Reptiles

<u>Lizards</u>

Species of lizards recorded are listed in Table 5.31. As no detailed survey of lizards was undertaken, it is possible that some species were missed.

Table 5.31 – Lizard species recorded during April-May 2006.

Species	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro
Lepdodactylus lugubris; mourning gecko	0	P	0	-	P	0	P
Gehyra oceanica; Polynesian gecko	0	0	P	-	-	P	P
Hemidactylus frenatus; house gecko	0	0	0	-	P	0	0
Emoia cyanura/impar; azure-tailed skink	0	0	0	-	-	P	P
Cryptoblephorus boutoni; snake-eyed skink	0	P	0	-	-	P	P

Turtles

The survey coincided with the non-breeding season and no evidence was found of turtles having been ashore during the previous 1-2 months. However, the previous breeding season's nests were visible and complete counts of these were made around the full perimeter of each of four atolls (Table 5.32). Enderbury had extensive suitable nesting habitat (Fig 5.10) and this was where the greatest sign of past nesting was found, although Birnie also had high densities of nests. Turtles had been consumed recently by people on Kanton. Numbers observed during dives (22 green turtles *Chelonia mydas* and one hawksbill turtle *Eretmochelys imbricata*) were not considered to be high (refer Marine report).

Figure 5.9 – Upper beach of sheltered eastern side of Enderbury

Table 5.32 – Number of recent turtle nests observed on islands in April-May 2006.

Island	% shoreline covered	No. nests	Comments
Rawaki	100	0	Beach unsuitable
Birnie	100	120	Lee side
Enderbury	100	293	252 on lee side, 41 windward
McKean	100	0	Little suitable habitat
Orona	c.10	1	Lee shore
Orona lagoon	c.10	0	
Nikumaroro S & SW	c.10	0	
Nikmaroro NW	c.10	1	

5.4. Crabs

<u>Objectives</u>

- Determine species diversity on each atoll visited
- Estimate densities of hermit crab (*Coenobita* spp.), land crabs (*Cardisoma* spp.) and coconut crabs (*Birgus latra*) where relevant to pest eradication operations

<u>Methods</u>

The species present on each island were recorded. A series of transects were undertaken on several islands where rodents may be targeted in future eradication. Except for some larger quadrants completed on Enderbury, the transects were 2 x 10 m, either delineated with flagging tape and string beforehand, or spot transects during which a 2 m long pole was used as a gauge of width. Transects were completed at night, or in some cases in the late afternoon during heavily overcast conditions or light rain.

<u>Results</u>

Species of crabs recorded are listed in Table 5.4. The common hermit crab *Coenobita perlatus* was present on all islands. Night transects revealed that hermit crab densities exceeded that of all other crabs collectively, with up to an equivalent of c.5000 individuals per ha in some areas on McKean. After McKean, highest densities of crabs per hectare were on Rawaki, followed by Nikumaroro, Enderbury and Orona, although we saw abundant *Cardisoma* by day elsewhere on the last island. The scarcity of large hermit crabs on Orona is consistent with the recent human occupation of that island.

Some key points about crabs in relation to mammal eradications are listed below:

- On Rawaki crab densities were low except in *Lepturus* and *Sesuvium* fringing the lagoon.
- On some islands, e.g. on Enderbury and McKean, local densities were particularly high, e.g. hundreds of individuals beneath one or two *Scaevola* and other trees.

- Late afternoon and evening convergence of hermit crabs on the outer sheltered beach (to saturate brachial apparati) was evident at Rawaki, Birnie and Enderbury, beginning at c. 1600 h on overcast days.
- In normal sunny conditions there was little activity during the day, with most being clustered at shady spots, e.g. beneath trees, shrubs (e.g. *Tribulus*) and driftwood (Fig 5.10).
- During overcast conditions or rain hermit crabs were active throughout the day, especially mid afternoon onwards, but there was less activity at night during wet weather.
- One adult *Coenobita cavipes* was seen on McKean, and juveniles were widespread on this island.
- *Cardisoma* sp. (tupa) was present on all islands particularly on the forested Orona and Nikumaroro.
- Coconut crabs (*Birgus latra*) were common only at Nikumaroro with night observations suggesting densities in the order of 40-50 per ha. They are rare or absent on McKean, Orona, Rawaki (single found on Rawaki in *Lepturus*/seabird colony) and Enderbuy (single sub-adult in *Tribulus-Portulaca*).
- Refer Section 7 for information on rat baiting and crabs.

Figure 5.10 – Hermit crabs at Birnie

Table 5.4 - Crab species recorded per island and average numbers per 100 m^2 in April-May 2006. (P = present, but not recorded on transects/transects not completed, U = unknown/incomplete survey).

Species	Rawaki	Enderbury	McKean	Birnie	Kanton	Orona	Nikumaroro
Habitat	*Lepturus*	*Portulaca*	*Tribulus*	-	-	*Cocos*	*Cocos*
Time (h)	>2100	>2200	>1600 > 1900 (rain)			>2100	>2000
Coenobita perlatus	6	19	46 , 25	P	P	<1	4
Coenobita cavipes	0	0	P	0	0	0	0
Geograpsus crinipes	3	1	0	U	U	0	0
Geograpsus grayi	2	0	0	U	U	0	0
Cardisoma sp.	P	P	P	U	U	P	2
Birgus latra; coconut crab	P (1)	P (1)	0	0	0	0	<1

5.5. Ants

Objectives

- Determine whether invasive ant species are present on each of the islands visited
- Determine the diversity of ant species in areas of highest human use.

Methods

Sampling methods followed MAF (2006) with some modifications adapted for local conditions. The regime comprised:

- Landing sites and especially camp sites were sampled
- Five paired stations of protein-based and sugar-based small plastic containers were placed on or near the ground
- Protein comprised peanut butter and soya bean oil
- Sugar comprised a plug of cotton wool soaked in 20% sugar solution
- Stations were operated for 0.5-2 hours depending on temperature, ant activity and crab impacts
- In addition, ants at two colonies were sampled directly
- Ants were analysed by Darren Ward, School of Biological Sciences, University of Auckland
- Note that appropriate precautions were taken during this expedition to ensure ants and other invertebrates were not inadvertently introduced. This included spraying insecticide into all drybags and supplies to be taken ashore.

Results and Discussion

All seven islands that were sampled supported ants. Species occurrence is summarized in Table 5.5.

Table 5.5 – Occurrence of ant species on seven islands sampled May-June 2006 (data courtesy of Darren Ward; refer Appendix 4 for complete data set)

Species	Rawaki	Birnie	Enderbury	Kanton	McKean	Orona	Nikumaroro
Carnud	P						P
Mondes	P		P	P	P		P
Monflo			P		P		P
Parlon			P		P	P	P
Parvag						P	P
Phemeg						P	P
Tapmel			P				
Tetsim		P			P		

Species key: Carnud = Cardiocondyla nuda, Mondes = Monomorium destructor, Monflo = Monomorium floricole, Parlon = Paratrechina longicornis; Parvag = Paratrechina vaga; Phemeg = Pheidole megacephala, Tapmel = Tapinoma melanocephalum; Tetsim = Tetramorium simillimum

None of the species recorded is considered invasive (D. Ward pers. comm.). It is likely that other species of indigenous ants occur on the islands, because of our focus on likely invasion points only.

Other ant observations included:

- They were predominantly active during the daytime
- Some ants were attracted to freshwater moisture without bait/food (1 observation only, Nikumaroro Island)
- Sampling protocols - cotton wool resulted in ants becoming entangled. It is recommended that blotting (or other absorbent but relatively cohesive) paper be used for sugar baits in future. There was a similar problem with peanut butter – could resolve this by limiting to spam or make drier and less penetrable by mixing it with flour, rolled oats, etc. The protocols could also consider using locally available coconut meat (preferably toasted) which ants would encounter naturally on many islands.

6. INVASIVE ALIEN SPECIES AND THEIR IMPACTS

6.1. Mammals

Objectives

- Determine which alien mammal species are present on target islands.
- Determine population status and conservation implications of these species.
- Plan management activities needed to mitigate conservation impacts.
- Trial aspects of eradication methodology.
- Learn as much as possible about the biology of these species on these islands.

Methods

On each island, the presence and identity of alien mammal species was determined by using visual searches during the day and at night (spotlight), trapping, baiting, and searching for field sign (faecal deposits, footprints, feeding marks on plant or animal material). For each alien mammal species detected an effort was made to determine population size, demographic information, food sources and distribution within the island. The method(s) used to determine these varied by species and are discussed further below.

Population size and distribution
These were determined primarily by counting the number of animals encountered within variable length transects (length recorded by hand-carried GPS) with a width of 40 m for diurnal rabbits, 20 m for nocturnal rabbits and 4 m for nocturnal rats. Transect width was measured several times later in operations to determine accuracy. A spotlight was used for nocturnal transects. Transects were sited within predetermined habitat types, with a new transect beginning as another habitat type was entered. The number of transects in each habitat type was chosen to reflect the abundance of that habitat type on the island. Start and finish time, distance and number of individuals detected were recorded. These were then used to calculate animal numbers per hectare for each habitat type and the total density for the island determined by calculating area coverage of each habitat type using GIS.

Cat population size was calculated using a sight-resight methodology using animal size and coat patterning as unique identifiers. Index trapping for rodents (sensu Cunningham and Moore 1996) was not undertaken due to the very high incidence of crab bycatch (particularly the common red hermit crab *Coenobita perlatus*) and the presence of many ground-nesting and tree-nesting birds on most islands.

Validation of population size methodology
The use of transects to estimate population densities of mammals appeared to be accurate, more so than visual estimates. On Rawaki Island it was estimated visually that there were approximately 500 rabbits on the island. From day transects, the number of rabbits estimated for the island was close to this figure, being 686 rabbits (± 428). However from nocturnal transects the total estimated population size was much greater, being 2074 (± 779). Further evidence for the accuracy of the nocturnal transect method is from repeated counts on consecutive nights (Table 6.1). Further work is needed to determine transect feasibility on islands, such as Nikumaroro, where complex tall and dense vegetation makes detection ranges smaller and passage disturbance greater.

Table 6.1 - Results of repeated transect counts.

Island	Species	Night 1	Night 2	Night 3
Rawaki	Rabbit	38.1 ± 23.3	44.5 ± 21.4	
Enderbury	Pacific rat	82.0 ± 23.9	73.3 ± 22.6	
McKean	Asian rat	38.2 ± 11.4	42.4 ± 12.8	44.0 ± 14.1

Demography
The demography of each population was determined using the proportion of individuals seen in size classes judged to be juvenile or adult. A proportion of individuals were captured either by hand (rabbits, rats) or trapping (rats) and age class, sex, body length, weight, and reproductive status was determined by dissection.

Food sources and behaviour
The foods utilised by each mammalian species on each island was determined by direct observation of feeding animals and by searching for feeding sign on plants and animals. Other behaviour was determined by direct observation.

Results

The species and population sizes of alien mammals previously recorded and recorded in this survey on each island are given in Table 6.2.

Table 6.2. Alien mammal species previously recorded and recorded during the current survey and survey effort.

Island	Previously recorded species[1]	Species recorded in 2006 survey	2006 survey effort
Rawaki	Rabbit *Oryctolagus cuniculus*	Rabbit	3 days' sightings. 7761m transects (2 nights). 4 hrs night sightings (2 nights). Feeding sign & droppings. 27 rabbits captured.
Birnie	Pacific rat *Rattus exulans*	Unidentified rodents (probably Pacific rat)	3 hours day search, 0 seen. Feeding sign. Droppings (rare).
McKean	Probably Pacific rat or none (King 1973)	Pacific rat absent	4 days' sightings. 9903m transects (3 nights). 5 hrs night sightings (3 nights). Feeding sign, droppings, tracks & pathways. 22 Asian ship rats captured.
		Asian ship rat *Rattus tanezumi*	
Enderbury	Pacific rat	Pacific rat	3 days' sightings. 9053m transects (2 nights). 5 hrs night sightings (2 nights). Cat trapping (1 night). Cat baiting (2 nights). Feeding sign & droppings. 8 Pacific rats captured.
	Cat *Felis catus*	cat not found	
Orona	Pacific rat	Pacific rat/mouse? (one possible sighting)	3 days' sightings. 3410m transects (1 night). 2 hours night sightings (1 night). Rodent trapping. Incidental observations (1 rodent, 4 cats sighted). Cat feeding sign & footprints.
	Cat	Cat	
	Dog *Canis familiaris*	dog not present	
	Pig *Sus scrofa*	pig not present	
Nikumaroro	Pacific rat	Pacific rat	2 days' sightings. 2791m transects (1 night). 2.25 hrs night sightings (1 night). Feeding sign. Cat and dog footprint searches. 3 Pacific rats captured.
	Cat	cat not present? (no sign seen)	
	Dog	dog not present? (no sign seen)	

[1] Information from Garnett (1983)

The relative abundance of individuals of each species in main habitat types is given in Table 6.3.

Estimated population densities on each island are given in Table 6.4.

Key morphometric measurements are given in Appendix 6.

1. **Rabbits** (*Oryctolagus cuniliculus*)

1.1. *Distribution in the Phoenix Island group*

During this survey rabbits were only found on Rawaki where they have been present since the 1860's (Garnett 1983) (Table 6.2).

1.2. *Distribution and habitat usage within islands*

Rabbits on Rawaki were present throughout the island with highest densities in *Boerhavia*/*Portulaca* shrubland (Table 6.3). Within this habitat type, highest densities (120-130 animals ha^{-1}) were recorded in *Boerhavia*-dominated areas on coral sands (Fig. 6.1). Densities were lowest in the drier, coral rubble based, habitats on the windward side of the island.

Table 6.3. Relative abundance in habitat types[1] based on nocturnal transects (n, **mean**, 95% confidence interval).

Habitat type	**Rawaki (rabbits)**	**McKean (Asian ship rat)**	**Enderbury (Pacific rat)**
Boerhavia/*Portulaca* shrubland[2]	23, **55.0**, ± 17.7	38, **43.4**, ± 10.0	18, **80.0**, ± 25.1
Lepturis grassland	7, **17.4**, ± 26.4	-	-
Sesuvium herbfield	4, **5.7**, ± 6.5	13, **63.9**, ± 13.6	8, **93.3**, ± 56.3
Tribulus vineland	-	14, **35.4**, ± 21.4	6, **97.4**, ± 39.8
Triumfetta vineland	-	-	6, **42.5**, ± 17.9
Ipomoea vineland	-	-	8, **67.9**, ± 36.5
coral block wall	-	4, **41.4**, ± 10.4	-
coral sand substrate	20, **62.6**, ± 19.8	49, **49.5**, ± 8.7	43, **80.1**, ± 17.0
coral rubble substrate	14, **11.3**, ± 6.4	27, **26.5**, ± 11.2	3, **42.6**, ± 41.9

[1] Species composition varies within a habitat type. Dominant plant species are used to separate habitat types.
[2] On Enderbury Island this habitat type included varying quantities of *Sida fallax.*

1.3. *Population size*

Estimated population density is given in Table 6.4.

Figure 6.1 – Rabbits and masked boobies in dead *Boerhevia* area, Rawaki

Table 6.4. Estimated population densities of mammal species on the Phoenix Islands.

Island	Species	Estimated 2006 population mean density ha^{-1} and 95% confidence interval
Rawaki	Rabbit	41.5 ± 15.6
Birnie	Pacific rat	Low
McKean	Pacific rat	0
	Asian rat	41.3 ± 7.3
Enderbury	Pacific rat	77.7 ± 16.3
	Cat	0
Orona	Pacific rat/mouse?	<0.1
	Cat	4 seen. Total population c. 10-15 animals
	Dog	0
	Pig	0
Nikumaroro	Pacific rat	11.7 ± 13.8
	Cat	0?

1.4. *Demography*

The rabbit population on Rawaki consisted of approximately 95-97% adult animals based on visual surveys. No very small juveniles were seen. Dissection of 17 adult females determined that none were pregnant containing embryos of any stage and none showing signs of lactation (indicating parent-dependant young). Adult weight was 1254 g and body length of 374 mm for males and 1339 g and 383 mm for females (refer Appendix 6). Sexual maturity appears to be reached at a body length of about 300 mm and 1000 g weight. All individuals captured had full to very full stomachs. One individual was found freshly dead and on dissection was found to have abnormally small lungs with a third, ancillary lung. The bladder was also greatly distended.

This rabbit population has the appearance of the Dutch tri-coloured breed. They have a distinct colouration pattern of brown or black patterning of varying quantities on the hindquarters, head, and sometimes body (Fig 6.2). Some 70.7% of individuals have a white with brown, grey, or tan colouration, while the remaining 29.3% have a black and white colouration pattern. The proportion of the body covered by dark colouration varied, with 1.3% of individuals being purely white, 2.3% with 1-5% dark colouring, 21.4% with 5-10% dark colouring, 55.5% with 10-50% dark colouring, 17.4% with 50-75% dark colouring, and 2% having 75-100% dark colouring. Overall, 80.6% of individuals had less than 50% dark colouring.

Figure 6.2 – Rabbit amongst *Portulaca*, Rawaki

1.5. *Food sources*

The rabbits on Rawaki were observed feeding on the stems of the succulent low shrub *Portulaca lutea* (Portulacaceae), the stems and roots (accessed by burrowing) of the lianoid *Boerhavia albiflora* (Nyctaginaceae), the stems of the succulent herb *Sesuvium portulacastrum* (Aizoaceae), and, in one instance, on the desiccated skeleton of a brown noddy chick. It is likely that they are also feeding on new growth of the grass *Lepturus pilgerianus* (Poaceae). In sandy areas of the island this browsing has frequently caused the death of *Portulaca* and particularly *Boerhavia* plants. The procumbent to erect shrub *Sida fallax* (Malvaceae) was restricted to two seedlings on the island, probably a result of rabbit depredation. Droppings were relatively uncommon, suggesting a high degree of coprophagy.

1.6. *Behaviour*

On Rawaki the most remarkable behaviour of the rabbits is their tameness. Animals were frequently able to be approached to within 4-5 m during the day, and 1-2 m at night. When startled animals during the day moved to the next nearest retreat (often >100 m distant) and at night mainly moved away a distance of 2->100 m. During these movements the path was direct and rapid, frequently brushing ground-based seabirds and rolling (and possibly crushing) eggs from nests. During the day 60% of rabbits were not visible (calculated from the difference in density estimates obtained during day transects (27.9 animals ha^{-1}) and night transects (41.5 animals ha^{-1}), presumably because of sheltering in burrows. Of the above-ground animals during day transects, 26.9% were in the open and the remainder in shaded retreats (rocks 51.8%, shrubby vegetation 21.9%, grass 20.2%, logs 6.1%). Within shaded retreats animals were usually densely accumulated to the extent of the shade provided and sometimes in close contact with ground-dwelling seabirds such as red-tailed tropic birds. Activity increased from 1-2 hours before dark and continued to at least 0200 hrs. During the night animals were seen as scattered individuals or in small groups of 4-6 animals. Little inter-rabbit interaction was seen at night, mainly consisting of one animal moving towards another which would then move away. Fighting scars were not seen on ears. At night, the rabbits were often within less than 0.5 m of ground-based seabirds. The interaction of seabirds towards rabbit presence varied from flight (noddies and terns) to little visible reaction (frigate birds) to attempted pecks and alarm calls (red-tailed tropic birds and boobies). Vocalisation during capture by hand was very infrequent. During rain animals remained in retreats except for some individuals in the open which adopted a hunched posture. A rainstorm appeared to cause the death of several individuals, presumably by hypothermia.

2. **Pacific rats** (*Rattus exulans*)

2.1. Distribution in the Phoenix Island group

During this survey Pacific rats were confirmed to still be present on Enderbury and Nikumaroro Islands and probably on Birnie Island, but the short stay on the latter island precluded confirming the identity of the rodents present. However, feeding sign on Birnie was consistent with that observed by Pacific rats on Enderbury Island (Table 6.2).

On McKean Island the population of rats assumed by Garnett (1983) to be Pacific rats has been replaced by the Asian ship rat *Rattus tanezumi* (see below). No rodents were seen by survey personnel on Orona Island, but a member of the boat crew made an unconfirmed sighting of one small rodent at the village. The described body size is within the range of a juvenile Pacific rat or adult mouse (*Mus musculus*). Pacific rats have been recorded from this island previously (Garnett 1983).

2.2. *Distribution and habitat usage within islands*

Pacific rats on Enderbury Island had little apparent habitat preference (Table 6.3). Again, densities were lowest in drier, coral rubble based, habitat on the windward side of the island. Densities were sometimes very high in some areas of *Boerhavia*/*Portulaca* shrubland on coral sands, reaching 120 animals ha^{-1}.

Too few Pacific rats were encountered on Nikumaroro Island to draw conclusions about habitat preference. Numbers appeared highest in tall mixed *Pisonia*-dominant forest habitats and a high number of juvenile individuals were encountered amongst coconut seed accumulation within tall coconut forest where 4-6 individuals could be seen within an area of c.20 m^2.

2.3. *Population size*

Estimated population density is given in Table 6.4.

2.4. *Demography*

The Pacific rat population on Enderbury Island appeared visually to consist of predominantly adult individuals, and this appears to be confirmed by the limited trapping results. None of 11 adult females were found to have any evidence of current breeding activity. All individuals captured had full to very full stomachs. The limited number (c. 30) of Pacific rats seen or captured on Nikumaroro Island appeared to indicate a similar pattern. On Enderbury Island, adult weight was c. 54 g and body length of 128 mm for both sexes (Refer Appendix). From the limited data from Nikumaroro Island, it appears that average weights and body sizes were similar. Sexual maturity of Pacific rats on these two islands appears to be at a body length of around 120 mm and 50 g weight.

No demographic or morphometric data is available for the Pacific rat population on Birnie Island.

2.5. *Food sources*

The Pacific rats on Enderbury Island were observed feeding on the stems and nectar or *Tribulus cistoides* (Zygophyllaceae), on a freshly dead lesser frigate bird chick, and on unidentified egg remains. Feeding sign was also found on the stems of *Portulaca lutea* and *Boerhavia albiflora*, the bark of the trees *Cordia subcordata* (Boraginaceae) and *Pisonia grandis* (Nycatginaceae), the fruit of the lianoid *Triumfetta procumbens* (Tiliaceae), and the perigynous tube of the flowers of the vine *Ipomoea macrantha* (Convolvulaceae).

On Nikumaroro Island, Pacific rats were observed feeding on the lamina of fallen green *Pisonia grandis* leaves and the nectar of the tall shrub *Scaveola taccada* (Goodeniaceae). Feeding sign was seen on the fruit of *Cordia subcordata* and the bark of *Pisonia grandis*. Pacific rats on these islands are also possibly consuming some seed of *Tournefortia argentea* (Boraginaceae), but this was difficult to determine. No feeding sign was seen on the fibrous seeds of the trees *Pandanus tectorius* (Pandanaceae) or *Guettardia speciosa* (Rubiaceae). Feeding sign on the stems of *Boerhavia* and *Portulaca* was targeted towards certain individual plants, but less so than by the Asian ship rats on McKean Island. Trails were evident on Enderbury (Fig 6.3).

Figure 6.3 – Aobure examining kiore trail, Enderbury

Feeding sign on Birnie Island, presumably from Pacific rats, was seen on the stems of *Portulaca lutea* and *Boerhavia albiflora*. No husking stations were found on islands inhabited by Pacific rats (c.f. Campell et al. 1984).

2.6. *Behaviour*

Pacific rats on Enderbury Island were relatively tame, though they would usually move once an observer got within 2-5m. At night some individuals were able to be approached to within 10 cm when feeding. This species was predominantly nocturnal on this island, but animals were frequently seen moving and occasionally foraging during the day. Activity increases 1-2 hours before dark and continues to at least 2400hrs. Movement is indirect and slow-paced with frequent pauses for grooming and sniffing air. Movement when startled is by a bouncing run and usually involves investigating several retreats before selecting one, or retreating to a thin screen of vegetation. Den sites were found under logs, beneath vegetation, and under small coral plates and are small sparely lined hollows. During the night animals were usually seen singly or in loose groups of 2-5 individuals. No inter-rat or inter-bird interaction was seen, even when in very close proximity to ground-based seabirds. Vocalisations were not heard.

Little observation of the behaviour of Pacific rats on Nikumaroro Island was possible, but they appeared shyer than those on Enderbury Island. Juveniles seemed to be very social and were often following or chasing each other. Activity was high. When startled animals would move to the nearest retreat (usually less than 1 m distant), but would reappear after c. 1 minute.

3. **Asian ship rats** (*Rattus tanezumi*)

3.1. *Distribution in the Phoenix Island group*

The Asian ship rat (Fig 6.4) was found only on McKean Island where it has probably replaced a population rats assumed by Garnett (1983) to be Pacific rats (Table 6.2). Identity of this rodent was confirmed using genetic analysis (L. Matisoo-Smith, University of Auckland). Wreckage of a Korean fishing vessel (F/V Chance No 301) grounded in c.2001 indicates the probable avenue of invasion. The genetic sample matched those from the Japan and Hong Kong regions, giving further credence to this hypothesis.

Figure 6.4 – Asian ship rat, McKean

3.2. *Distribution and habitat usage within islands*
Asian ship rats on McKean Island were present throughout the island except for areas of bare coral rubble. This species had a preference for *Sesuvium* herbfield (Table 6.3). Again, densities were lowest in drier, coral rubble based, habitats on the windward side of the island. Densities in some areas of *Boerhavia*/*Portulaca* shrubland on coral sands reached 110 animals ha^{-1}. Animals were usually encountered in open areas within dense vegetation. A proportion of animals were associated with man-made coral block walls.

3.3. *Population size*
Estimated population size is given in Table 6.4.

3.4. *Demography*
The Asian ship rat population on McKean Island comprised mainly adults with less than 1% of individuals seen being of obviously smaller body-sized juveniles. About 15% of individuals captured were found to be juvenile, all near adult size. One adult female was found to have very early stage embryos and the remaining 10 were found to have no evidence of current reproduction. Adult weight was 145 g and body length of 155 mm for males and 146 g and 163 mm for females (refer Appendix 6). Sexual maturity appears to be reached at a body length of around 150 mm and 120 g weight. The liver appeared pale in colouration in most dissected individuals. All individuals captured had very full stomachs.

3.5. *Food sources*
The rats on McKean Island were observed feeding on the stems of *Portulaca lutea*, the leaves, stems and roots of *Boerhavia albiflora*, the stems of *Sesuvium portulacastrum*, the nectar of *Tribulus cistoides*, and on presumed scavenged brown noddy eggs and the hermit crab *Coenobita perlatus*. No fruit of *Tribulus* was found on the plant or ground, and it is possible that rats are consuming all of these spiny fruits. Feeding sign on the stems of *Boerhavia* and *Portulaca* is targeted to individual plants.

3.6. *Behaviour*
Asian ship rats on McKean Island were shy, moving rapidly away from people and rarely could be approached closer than 5m. This species is predominantly nocturnal on this island, though some individuals are seen at times during the day. Activity increased c.1 hr before dark and continues to at least 2400 h. Movement when startled is direct, rapid and to the nearest retreat. Movement when feeding is constant, pausing only during food consumption. Movement in *Sesuvium* herbfield is via visibly worn pathways, even when startled and requiring movement towards the observer. The tail during movement is held above the ground and parallel to the body. This species appears to be a relatively poor or reluctant climber as traps set higher on walls were not successful. Den sites were found in man-made coral block walls, under logs and large coral boulders and under dense *Tribulus* mats. Dens were poorly lined. During the night animals are usually seen singly or occasionally in pairs. No inter-rat or inter-bird interaction was seen. Some scarring is present on the ears of both female and male rats, indicative of fighting. Vocalisations were not heard. Nocturnal activity ceases during rain, but is not apparently affected by showers.

4. **Cats** (*Felis catus*)

4.1. *Distribution in the Phoenix Island group*

A small population of cats has persisted on Orona Island (Table 6.2). Cats have become extinct on Enderbury Island and possibly also on Nikumaroro Island (but the short duration of stay there precluded confidence in this assessment).

4.2. *Distribution and habitat usage within islands*

Indications of cat presence on Orona Island were encountered only on the previously settled islet and two adjacent islets to the west. Their presence was conspicuous from sightings and footprints on the upper beach and supralittoral zone.

4.3. *Population size*

Estimated population size is given in Table 6.4.

4.4. *Demography*

No demographic or morphometric data is available for the cat population on Orona Island.

4.5. *Food sources*

One cat on Orona Island was recorded scavenging in the abandoned village rubbish deposits. Feeding sign attributed to cats included sooty tern eggs (though this was often difficult to confidently separate from the sign left by feeding crab species), adult sooty terns, and possibly shore crabs. The latter had the tail flap removed and the body contents eaten through the ventral surface. Cats are undoubtedly consuming other bird species, lizards, fish, and invertebrates on this island.

4.6. *Behaviour*

The cats on Orona Island were seen too infrequently to make many behavioural observations. One individual at the village was relatively tame, approaching people to within 3 m at night. This animal was calling frequently.

5. **Other mammal notes**

Dogs *Canis familiaris* and pigs *Sus scrofa* (reported as abundant in 1937 [Garnett 1983]) have vanished from Orona Island and dogs appear to have also disappeared from Nikumaroro Island.

Only one instance of an external parasite was found - ticks on a juvenile Asian rat at McKean Island.

Discussion

Changes have occurred in the alien mammal fauna of the Phoenix Islands over the past 40 or so years. Extinctions have occurred of cats on Enderbury Island, dogs and pigs on Orona Island, dogs on Nikumaroro Island, and possibly Pacific rat on Orona Island and cats on Nikumaroro Island. The Asian ship rat has invaded McKean Island and apparently caused the extinction of the Pacific rat population there. Persistent populations are rabbit on Rawaki, Pacific rat on Enderbury, Nikumaroro and (probably) Birnie Islands, and cat on Orona Island.

The reasons for the extinction of these populations are unknown. The cats and Pacific rats in conjunction on Enderbury Island may have depleted nesting seabird populations to the point that the cat population was unable to maintain itself on the remaining Pacific rat population, which may be of lower nutritional or body water value than seabirds and their eggs, or are energy-intensive to capture. The same reasoning may explain the possible disappearance of cats from Nikumaroro Island. The dog and pig populations on Orona Island were probably not truly feral (feral pig populations can persist on similar islands such as Swains in American Samoa [local residents' verbal report]) and were either removed when human occupation ceased in 2003, or died out soon after due to lack of familiar food. The Pacific rat population on Orona Island appears to have disappeared or been dramatically reduced or eliminated following a Warfarin® toxin application to control rats around habitations and in coconut plantations (Tiare Etei pers. comm.). Details of this operation are currently unknown. The extinction of Pacific rat on McKean Island is undoubtedly due to direct predation and, to a lesser extent, competition following invasion of the island by Asian ship rats. Displacement of Pacific rats by other rat species is considered to occur (Russell and Clout 2004). There was some evidence that the long persistence of rabbits on Rawaki is causing inbreeding effects.

It is likely the invasion of McKean Island by Asian rats occurred following the grounding of the Korean vessel F/V Chance 301 in c.2001 (Fig 6.5). Rat feeding sign was found in the wreck which could indicate that rats were present on the vessel before grounding. Contradictory evidence regarding the timing of Asian rat arrival is the lack of large seabirds, e.g. wedge-tailed shearwater, for which no breeding sign was found on the island (c.f. breeding burrows common at Rawaki and locally at Enderbury). Also, a brief visit to the island in March 2002 (Bukaireiti and Rabaua 2002) revealed a very similar composition of diurnal bird species to that of the 2006 survey, suggesting that the invasion event may have occurred earlier than in c.2001. Regardless of timing, this is a highly noteworthy occurrence as invasion of wildlife refuge islands by rats via ship groundings have been cited of considerable concern and risk (Moors et al. 1986, Cunningham and Moors 1996), but this is the most recent documentation of this type of event occurring. This is the first time that this species has been recorded as invasive on an island since World War II, and is a considerable extension of range from the nearest known population on the Marshall Islands. This species (often noted as the "Asian" rat or *Rattus rattus flavipectus*) is often considered by conservation managers to be a high risk of future invasion (e.g. Moors et al. 1986, Cunningham and Moors 1996).

Fig 6.5 – Wreck of F/V Chance, McKean

Density of alien mammal species on these islands are generally high with the exceptions of the unidentified rodent species and cats on Orona Island, and possibly all species on Nikumaroro Island and Pacific rat on Birnie Island. The population of the unidentified rodent on Orona Island is either a remnant following the recent poisoning operation or, if mice, may be at naturally low densities or newly arrived. The low rodent densities found on Nikumaroro and Birnie Islands are possibly a result of the limited survey effort achieved. The apparently low density of Pacific rats on Birnie Island is possibly also due to the extreme aridity and related paucity of vegetation on this island. Cats on Orona Island appear to be confined by reef passes to the recent settlement islet and adjacent motu (islets) to the west. However, they have crossed similar passes to reach the islets they do occur on and these passes should not be considered barriers to further expansion to other islets.

Habitat usage for the various species was similar, e.g. there is higher usage of the leeward coral sand based habitats. This is probably due to the availability of day time retreat sites rather than differences in nutrient availability. Densities vary between habitats for each species and this is probably a reflection of the cover and/or nutrition available in each. The *Sesuvium* herbfield habitat is probably only used for feeding.

The use of bounded-width nocturnal transects to estimate population size and density within habitats was very effective on open islands. Population densities of rodents and rabbits have rarely been calculated for entire islands.

Most facets of the biology of the alien mammal species on the Phoenix Islands appears to be heavily influenced by rainfall and food supply. Breeding in rabbits, Pacific rats and to a slightly lesser extent Asian rats appears to be strictly seasonal (c.f. Strecker et al. 1962), occurring in the wetter months of December to March. The population carrying capacity is probably also influenced by rainfall through increasing food and water availability and exposure related mortality (as observed in the rabbit population on Rawaki following a storm event there during this survey). Mortality of both adult and juveniles is likely to be high and lifespan short. It is likely that populations (especially of rabbits) undergo considerable fluctuations in numbers. The observation of Asian ship rats ceasing activity during nocturnal rain is contrary to that observed by Strecker et al. (1962). Ectoparasite infestation appears unusually low (c.f. Strecker et al. 1962), possibly because the environment is too hot for survival of normal ectoparasite species or a founder effect, if the low number of founding individuals did not have parasites to begin with.

The diet of rabbits and rats on these islands at the time of visit was primarily vegetation. This is consistent with previously published studies of Pacific rats (Strecker et al. 1962, Wirtz 1972, Newman and McFadden 1990, Atkinson and Towns 2001), ship rats (usually *R. rattus rattus*) (Strecker et al. 1962, Best 1969, Gales 1982), and rabbits (Bullock et al. 2001). Feeding on the stems and roots of plants is unusual, and in New Zealand is frequently considered a sign of a population under food stress. Stems and roots may have a higher water and starch content than foliage, which may be why it is being utilised by rabbits and rats. Seeds were a common food item of Pacific rats and seedlings are also likely to be eaten. Obtaining water through food items is particularly important for cats that are limited in their ability to extract it from plant material in the absence of fresh water. This may be forcing them to focus on eggs and to kill surplus adult birds and consuming just the higher moisture body parts. Other food sources, such as seabird regurgitation, fish, invertebrates and reptiles are undoubtedly utilised by both cats and rats. The observation of a rabbit gnawing on a bird skeleton may indicate a pathway for obtaining locally unavailable minerals.

6.2. Impacts of mammalian pests

Impacts on birds

The impact that alien invasive mammals are having on the ecology of the Phoenix Islands are consistent with the severe and pervasive impacts occurring elsewhere (Atkinson 1977, Imber 1978, Moors and Atkinson 1984, Atkinson 1985, Bullock et al. 2001). The most obvious impacts in the Phoenix Islands are the reduced population densities (and absences) of seabird species caused by direct predation from rats and cats on eggs, young and adults.

Differences in seabird species composition and trends in abundance among the islands indicates that pest impacts are still occurring and that they vary for both the pest species and the bird species. Figure 6.6 compares mammalian pests present and the number of breeding species that were present in the 1960s (if known) and 2006. The chart illustrates that there was high seabird diversity on the rabbit-infested island (Rawaki) in both the 1960s and in 2006, and on McKean Island in the 1960s, whereas seabird diversity was considerably lower on all the rat-infested and/or cat-infested islands in the 1960s and 2006. The one dramatic change in seabird diversity during these 40 years has been on McKean where the recent arrival of Asian rats has caused a decline of 40% in seabird species diversity, with greatest impacts on procellariiform and tern species. This McKean catastrophe has seen blue noddies plummet from c.15,000 birds to one individual (whereas the population on Rawaki has been retained; c.10,000 in 1960s, c.7000 in 2006) and several procellariiforms have also been eliminated and red-tailed tropicbirds have declined (refer Section 5).

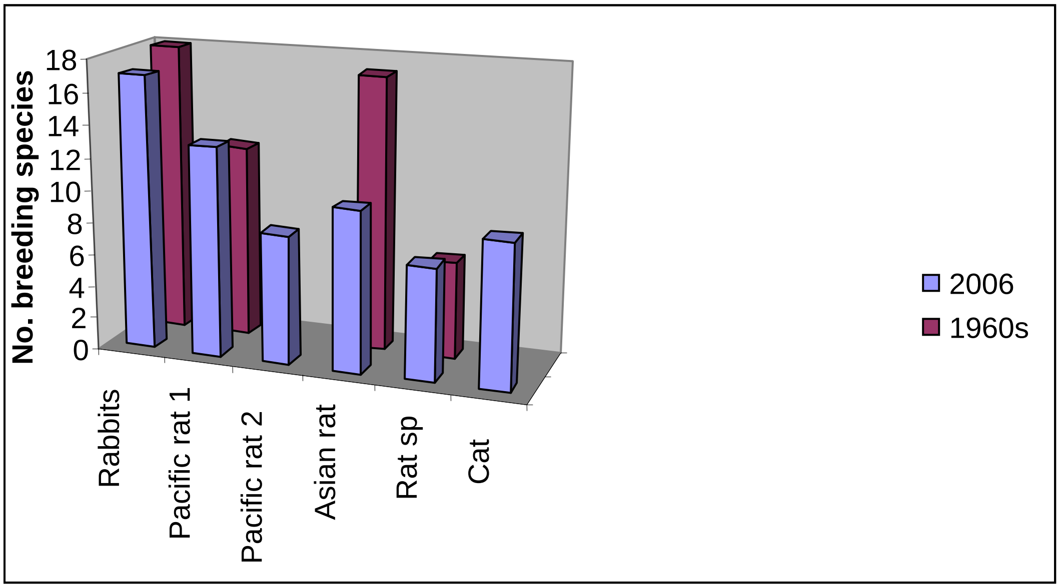

Figure 6.6 – A comparison of seabird diversity in relation to pest species on the Phoenix Islands in 1960s and 2006 - data for Rawaki/Rabbits, Enderbury/Pacific rat 1, Birnie/ Pacific rat 2, McKean/Asian rat, Nikumaroro/Rat sp. and Orona/Cat. Birnie and Orona lack data from 1960s.

This inter-island pattern of pest impact was supported by data collected on seabird breeding success between islands in 2006. The most complete dataset was that for Audubon's shearwater on three islands (Table 6.5). Pairs of shearwaters at rabbit-infested Rawaki were relatively successful with a wide range of breeding stages being encountered from egg-laying to fledging and over 50% of burrows contained pulli or fledged young. At Enderbury (containing Pacific rats), however, only 17% of sampled nests had pulli and or fledglings, with most birds appearing to be vocal, suggesting they were failed breeders or pre-breeders. On McKean (Asian ship rat) this pattern of failure was even more severe with only one pulli being found and there was a high rate of nest failure. One of three eggs seen on McKean disappeared during our three-night stay. The low ratio of young birds at Enderbury and especially McKean is consistent with high levels of egg and/or chick predation by rats observed on other islands (Atkinson and

Towns 2001, Pierce 2002). Unfortunately the pattern of crab abundance (very abundant on McKean) was such that crab predation could not entirely be ruled out as a cause and effect agent either, although it is most likely that seabirds can deal with hermit crabs having coexisted with each other for millennia.

Table 6.5 – Breeding status of Audubon's shearwaters on three islands with different pest species

Island	Rawaki	Enderbury	McKean
Pest present	Rabbit	*Rattus exulans*	*Rattus tanezumi*
No burrows/nests sampled	42	24	17
No. empty (%)	6 (14%)	17 (71%)	15 (88%)
No. with egg (%)	13 (31%)	5 (21%)	1 (gone later) (6%)
No. with pullus (%)	15 (36%)	3 (13%)	1 (6%)
No. with fledgling (%)	8 (19%)	1 (4%)	0
Total with pulli or fledglings	23 (55%)	4 (17%)	1 (6%)

The apparent success of Audubon's shearwaters on Rawaki does not mean that rabbit impacts are minor on all seabirds. Rabbits appear to be having a disproportionately high impact on seabirds with large burrows, i.e. Phoenix petrel and wedge-tailed shearwater, many potential burrows of which were occupied or visited by rabbits. It would be impossible for these seabirds to avoid significant proportions of eggs and chicks being trampled and killed by rabbits. Even surface-nesters, such as red-tailed tropicbirds and blue noddies are in competition with rabbits because they favour well-shaded nest sites or nest in vegetated areas (Fig 6.7) and eggs of both these seabird species were observed to be rolled by rabbits. Furthermore, the loss of vegetated habitat on Rawaki due to combinations of drought and rabbit browse is resulting in large areas of open sandy habitat, which is not favoured by petrels, shearwaters, storm-petrels or blue noddies. The incidence of all these species breeding in open areas was much lower than in vegetated areas, presumambly because of burrow instability (petrel/shearwater) and less cover being available for nests (storm-petrel/blue noddy).

The presence of rats on some islands may be having an indirect local effect on the productivity of some of the larger seabird species, notably the two frigatebird species. Both frigatebird species gain significant proportions of their food by forcing terns and noddies to disgorge their fish prey. The low numbers of terns and noddies now present on McKean and their low breeding success there may have contributed to the now low breeding population of frigatebirds and the recent die-off of late stage pulli (refer species account in Section 5).

On cat-infested Orona, the only ground-nesting birds were masked boobies, red-tailed tropicbirds and sooty terns, the last species of which nested in enormous colonies with synchronized breeding timetables. Cats were consuming many eggs, chicks and adults at these colonies, but it is likely that large numbers of terns will still breed successfully by sheer weight of numbers.

Figure 6.7 – Rabbits compete with many seabird species for shade

Based on seabird population trends between the 1960s and 2006, together with known pest status, it is possible to rank the relative impact of each of the pest species on each seabird species or group. This is summarized in Table 6.6.

Table 6.6 – Likely severity of impacts of different pests on seabirds in the Phoenix Group

Severity of impact	Rabbit	Pacific rat	*Rattus tanezumi*	Cat
Low-moderate	Most species	Pelecaniformes – all 6 local species	Pelecaniformes, except red-tailed tropicbird (serious)	Possibly tree nesters, i.e. red-footed booby, black noddy, white tern
Serious	Procellariiforms, blue noddy, perhaps red-tailed tropicbird	Procellariiforms (except perhaps wedge-tailed shearwater), terns	Tropicbirds, all terns, brown and black noddies (or higher impact)	All other seabird species are at this level of impact or higher
Catastro-phic		Storm-petrel, blue noddy	Blue noddy, all procellariiforms, possibly all 6 spp. of terns and noddies	Procellariiforms, ground-nesting pelecaniforms, blue noddy, most terns/brown noddy

Ecosystem impacts

There are less visible but insidious effects of the presence of invasive mammal species on the islands' ecology. Feeding frequency on some plants has been intense enough to cause mortality of these species, particularly rabbit feeding on *Boerhavia* and *Portulaca* on Rawaki (Fig 6.8, 6.9) and to a lesser extent by rats on Enderbury and McKean Islands. Seeds were a common food item of Pacific rats and this may be limiting recruitment of these plant species. Seedling predation is also likely to be occurring, further limiting recruitment. Therefore, the rat species and rabbits are likely to be altering the vegetation composition of the islands through direct predation on adult, seedling and seeds of some plant species as found elsewhere (Campbell and Atkinson 1999, Bullock et al. 2001, Campbell and Atkinson 2002). For Pacific rats, seabird predation is thought to increase as plant food supply decreases (see Moors and Atkinson 1984 and references therein). Invertebrate and reptile populations on these islands are likely to be impacted through direct predation by rats.

No positive effects of these invasive alien mammal species was noted on any of these islands.

<u>Fig 6.8 – Example of rabbit browse on *Portulaca*, Rawaki</u>

Figure 6.9 – Phoenix petrels at burrow in area of dieback, now suboptimal habitat

Rat baiting trials

Baiting trials using non-toxic rat baits manufactured by Animal Control Products Ltd (Wanganui, New Zealand) were undertaken on Enderbury and McKean. Small quantities of baits were used at Enderbury to test whether hermit crabs could consume large baits (10 g) overnight and to gauge distances over which they were attracted to the baits. Subsequently at McKean Island, c.5-6 g baits were placed out on a c.1 m bait grid (equivalent of 40 kg/ha) over an area of 50 x 20 m and in area of representative vegetation and crab density. Additional bait (0.5 g size) was spread outside the perimeter of the grid in an attempt to intercept incoming crabs (and rats). Crab densities were measured throughout the grid at the start of baiting, and re-measured the following evening. Crab densities were assessed by a series of walk-through transects measuring 2 x 10 m and supplementary crab data were collected on other islands containing rabbits or rats (refer Section 3.4). Surviving baits were counted on the subsequent two mornings. Heavy and persistent rain (estimated 50+ mm) fell the day after the baits were laid out.

The results of the trial are summarised below:

- Hermit crabs and rats (Pacific and Asian rats) are attracted to the baits, hermit crabs from distances of several tens of metres
- A single hermit crab can consume a bait weighing up to 10 g in a single night and probably several 0.5 g baits

- Crabs clamp onto baits from which they are difficult to prize off, so these baits are probably unavailable to Pacific rats at least
- Using c.10 g baits on a 10/100 m^2 (10 kg/ha) grid and at crab densities of c.20/100 m^2 (c.2000/ha) all baits were consumed the first night probably mainly by crabs – but this experiment was compromised by additional crabs from outside the area being attracted to baits within the grid
- Using c.5-6 g baits on a 80/100 m^2 (c.40 kg/ha) grid and at pre-bait and post-bait crab densities of c.40/100m^2 (c.4000/ha), 81% of baits were consumed the first night and the remaining baits disappeared the second night. Heavy rain on the second day reduced the remaining baits to mush and they did not re-harden after the rain.

The results of these trials indicate that standard bait loadings of 10-20 kg/ha may be inadequate to eradicate rats in many situations on these islands, particularly on McKean (Fig 6.10). For the small islands it will be advisable to present baits in crab-proof stations or develop other means of bait presentation, e.g. on wire pegs. Alternatively, higher bait densities could be trialed in order to determine bait densities that would achieve rat eradication on large islands, e.g. Enderbury (Refer draft operational plan for pest eradication).

Fig 6.10 – Hermit crabs congregating on non-toxic bait crumbs at McKean

6.3. Other invasive pests

Pest plants

On each island visited, plant surveys were undertaken and some specimens collected for subsequent identification.

Pest plant issues are localized on the Phoenix Islands, with Kanton not surprisingly being the only significantly impacted island. Here lantana (*Lantana camara*) extends over a large part of the village and former military bases centred on 02 46.616S, 171 43.039W. Lantana was also recorded on Orona (Garnett 1983), but no sign of this infestation was found in 2006. The mangrove on Enderbury is invasive in other situations, and whether it is a possible problem on Enderbury is unknown, but as a precautionary measure it should be removed.

Invasive ants

No invasive ants have been identified in preliminary assessments (refer Section 5).

7. RECOMMENDATIONS FOR PEST ERADICATION PRIORITIES AND BIOSECURITY

The Phoenix Islands still support a wide diversity of seabird species, but this diversity is under continuing and serious threat from pest mammals. The high level of threat has only just become apparent from the 2006 Conservation Survey and a number of seabird species are likely to become extinct in the Group in the near future. There are however, clear opportunities for not only rectifying this problem, but also reinstating a far more healthy terrestrial ecosystem than has been present in the Group for over 100 years and which can support high and diverse seabird populations.

The Government of Kiribati, in conjunction with the New England Aquarium, is currently devloping a management plan for the protection of marine and terrestrial biodiversity in the Phoenix Islands Protected Area. The results of the 2006 Conservation Survey indicate that the overall goals of the management plan should include the removal of alien pest species generally, including mammalian pests from at least two of the largest and most pristine atolls – the shrubland-dominated Enderbury and one of the forested atolls, ideally Orona. These islands support the most extensive areas of indigenous habitats that will ultimately support large and diverse seabird populations and other fauna species. Enderbury is strategically located near to Rawaki and is currently being visited by many sensitive seabird species, including Phoenix petrels, and so recolonisation of this island will be more rapid than that for more distant islands, including Orona.

However, these are not the most urgent islands to restore. The most urgent attention should be given to Rawaki and McKean, the former of which supports the highest seabird diversity (but several key species are under pressure from rabbits). McKean has lost nearly half of its seabird diversity in recent years and individuals of many species (including white-throated storm-petrel) visiting the island will be being killed by the recently invading Asian rats. A third island, Birnie, could be added to this priority list to make up a three-island eradication package in which Birnie would provide a strategic learning site for the subsequent removal of Pacific rats from the larger and more valuable Enderbury Island.

These and other key recommendations are summarized below:

Priority 1 actions

- Incorporate pest eradication planning into the conservation management plans for the Phoenix Islands. This should also include biosecurity measures to prevent reinvasion of mammals and the arrival of invasive ants and pest plants.

- Rawaki – eradicate rabbits which are impacting on the ecosystem and are in competition with Phoenix petrels, white-throated storm petrels and other procellariiform and ground-nesting species. This is the only island on which many of these seabird species currently occur and the recovery of other bird populations elsewhere in the Phoenix Group is dependent on this nucleus continuing to be productive. Rabbit eradication is technically feasible.

- McKean – eradicate *Rattus tanezumi* which has eliminated nearly all procellariiform species and blue noddies from the island. This large rat is capable of be killing adults of small, vulnerable seabirds, e.g. white-throated storm-petrel and blue noddy, which continue to visit the island in greatly diminished numbers. Rat eradication is technically feasible.

- Birnie – eradicate Pacific rats to provide breeding habitat for procellariiform species, blue noddies and terns. Its small size makes eradication of rats relatively simple and low cost. Ideally the techniques used here should determine the feasibility of an aerial eradication programme (probably the only viable option for the larger islands in this group) by mimicking such an operation.

The last three action points above are best considered as a single project as they are all small, technically feasible and of low cost compared to the logistics of getting to these islands on multiple occasions.

Priority 2 actions

- Enderbury – eradicate Pacific rats from this large island which will ultimately provide secure nesting grounds for at least 18 species of seabirds in a large near-pristine ecosystem.

- Complete follow-up surveys of to confirm pest status (Orona, Nikumaroro, Manra) and seabird diversity (Kanton, Manra).

- Monitoring – implement seabird monitoring on priority 1 and 2 target islands. Baseline monitoring should be implemented at the time of pest eradications and at 3-5 year intervals, potentially timed to coincide with biosecurity visits.

- Eradicate cats (and rodents if present) on Orona. This is technically feasible.

Priority 3 actions

- Once follow-up surveys are completed and management priorities agreed, develop eradication plans for pests on Nikumaroro, Manra and potentially the small islets inside the entrance to Kanton Lagoon.

PART B: FEASIBILITY OF ECOLOGICAL RESTORATION OF THE PHOENIX ISLANDS

8. FEASIBILITY OF PEST ERADICATION AND BIOSECURITY

This section examines the feasibility of achieving the priority 1 objectives detailed in the recommendations in Part A above and summarised below. Some of the data on pest-impact in this section are derived from Sections 6-7.

8.1. Priority actions

- Integrate pest eradications and biosecurity needs into management planning for the Phoenix Group
- Pest-free Rawaki – eradicate rabbits
- Pest-free McKean – eradicate *Rattus tanezumi*
- Pest-free Birnie – eradicate Pacific rats

Note that achieving pest-free status on the large islands, especially Enderbury and Orona, is also important (refer Section 7), but should occur later.

8.2. Strategic plans and priorities

The priority objectives above are consistent with both Kiribati and international strategic planning. The vegetation and habitats of most of the islands are in a near pristine condition and the Group has been identified as a Key Biodiversity Area (KBA) in Conservation International's Critical Ecosystem Partnership Fund Ecosystem Profile for the Polynesia/Micronesia Hotspot (#133) and is also an Important Bird Area (Birdlife International). Further to this, in 2006 Kiribati established the Phoenix Islands Protected Area. A management plan is currently being developed for the group as a whole and this will include terrestrial as well as marine components.

The findings of the 2006 Phoenix Islands Conservation Study confirm the general findings of the 1960s surveys that identified the importance of the islands for seabirds. However, the 2006 survey identified the now perilous situation of the Phoenix petrel and white-throated storm-petrel and declining populations of some other species in the Group due to changed pest status, including the recent arrival of *Rattus tanezumi* on McKean. The 2006 survey also identified clear priorities and tasks for the recovery of threatened species and island ecosystems generally (refer Sections 7 and 8.3)

8.3. Environmental

The effects of Invasive Alien species

Invasive alien species (IAS) have caused the decline of many seabird species in the Phoenix Islands. The most graphic illustration of that is the recent arrival of *Rattus tanezumi* on McKean Island and the subsequent loss of nearly half of the island's seabird diversity (refer to Section 6). On Birnie and Enderbury, the seabird diversity is significantly lower than on neighbouring Rawaki because of the presence of Pacific rats on the former two islands (and Enderbury was reported to have had cats in the past). On these two islands inhabited by Pacific rats, the species that are missing are primarily petrels, particularly white-throated storm petrel, small shearwaters and the Phoenix petrel. All of these procellariiform species visit the rat-inhabited islands, but only the larger wedge-tailed shearwater may be establishing a foothold (on Enderbury).

The impact of rabbits is less obvious because the full range of species present on Rawaki in the 1960s are still present, albeit some of them tenuously. However, rabbits are having a direct impact on several species through competition for burrows (and associated egg and chick losses), and an indirect effect through habitat destruction. The latter appears to be extremely important because several species utilise prostrate shrubs as nest sites and are scarce breeders in areas of extensive plant dieback. The continued presence of rabbits will bring about the extinction of Phoenix petrels in the Phoenix Islands and probably also white-throated storm-petrels and most shearwater species.

The overall impact of pests on seabirds is summarized in Table 8.1. To this can be added impacts of rats on lizards, invertebrates and plants.

Table 8.1 – Perceived severity of impacts of three target pest species in the Phoenix Islands.

Severity of impact	Rabbit	Pacific rat	*Rattus tanezumi*
Low-moderate	Most seabird species	Pelecaniformes – all 6 local species	Pelecaniformes, except red-tailed tropicbird (serious)
Serious	Procellariiforms blue noddy	Procellariiforms (except perhaps wedge-tailed shearwater), terns	Tropicbirds, all terns, brown and black noddies (or higher impact)
Catastrophic		Storm-petrel, blue noddy	Blue noddy, all procellariiforms, possibly all 6 spp. of terns and noddies

The biodiversity benefits of eradicating Invasive Alien Species

The perceived benefits of eradicating the three target pests are summarized below.

Rabbits from Rawaki

- Phoenix petrel recovers through improved breeding success and eventually contributes colonists to neightbouring pest-free islands, particularly Enderbury, providing a secure population in the Phoenix Islands for this Endangered species
- Other Procellariiforms recover through increased availability of nest sites (e.g. vegetation for shearwaters, storm-petrels) and improved breeding success (lack of trampling)
- Blue noddies maintain or increase numbers through increased availability of nest sites and higher productivity and provide increased numbers to neighbouring islands when they become pest-free (e.g. Birnie, Enderbury, McKean)
- Rawaki vegetation recovers from rabbit browse and dieback.

Rattus tanezumi from McKean

- White-throated storm-petrel recovers through increased adult survival and productivity providing a second secure population in the Phoenix Islands for this Vulnerable species
- Procellariiform species in general will recolonise and recover on the island
- Terns and noddies, including blue noddies, will recolonise/recover on the island
- Lizards, invertebrates and plants recover.

Rattus exulans from Birnie

- The threatened Phoenix petrel and white-throated storm petrel will recolonise and breed successfully, the former in small numbers, the latter potentially in thousands
- Other small procellariiform species and terns will recolonise (shearwaters, blue noddy) and/or breed more successfully (terns)
- Lizards, invertebrates and plants recover.

Note that removal of Pacific rats from Birnie can be used to refine methods for achieving the same on the nearby 600 ha Enderbury Island. Enderbury is a large island that will ultimately provide secure habitat for two threatened species - Phoenix petrel (could possibly accommodate thousands of pairs) and white-throated storm petrel (tens of thousands of pairs), potentially the largest populations of both species. Other small procellariiform species and blue noddies currently visiting and some attempting to breed there will do so successfully, ultimately providing secure nesting habitat for tens of thousands of pairs of each species. Terns would also breed successfully in colonies of tens of thousands or hundreds of thousands. Lizards, invertebrates and plants would also recover.

Overall benefits of pest eradications from the above islands include restoration of ecosystem processes, including complex food webs involving marine invertebrates and fish. Kleptoparasitic species (frigatebirds) would benefit from increased seabird populations. There are also cultural benefits including potentially ecotourism.

<u>Potential negative environmental effects of eradicating Invasive Alien Species</u>

Potential negative impacts could come about from the methods used in eradicating IAS. These include:

- Rat and rabbit poisoning with anticoagulants and the potential for secondary poisoning of scavenging or predatory species. Frigatebirds and bristle-thighed curlews could take dead/dying rats; curlews could take crabs that have consumed baits; other migratory waders (wandering tattlers, golden plovers, turnstones) feed on invertebrates that could be contaminated
- Potential for damaging petrel and shearwater burrows on Rawaki, particularly during the follow-up phases (spot-lighting/dogging).

Means of mitigating for these effects are described in the draft Operational Plan (refer Section 9).

<u>Sustaining the benefits of the project</u>

The chances of the same pests reinvading are zero (rabbits) to low (rats). The greatest biosecurity risk is from foreign fishing vessels that use the area intensively – rats, mice and invertebrates are likely to occur on these ships and so there is a risk of rodents and invertebrates getting ashore if they are wrecked (as appears to be the case with *Rattus tanezumi* and large cockroaches at McKean) and if ship's people actually land on the islands. The greatest risk of landing is at the larger islands, e.g. Orona, Nikumaroro, but shipwrecks can occur at any. Other vessels that visit the area (recreational and scientific) could also pose biosecurity threats. Thus, maintenance of biosecurity is a key requirement for sustaining pest-free status of target islands in the Group and also keeping new IAS off all islands in the Group.

8.4. Technical approach to eradications

The preferred approaches for each of the target species are outlined below. Details are provided in the Draft Operational Plan for Pest Eradication (refer Section 9).

<u>Rawaki rabbits</u>

- Initially 3 hits with pindone or preferably brodificoum via bait station and hand spread baits (this works well in analagous semi-arid environments, e.g. Central Otago, New Zealand)
- If necessary a follow-up single hit with 1080 impregnated vegetable, e.g. taro, on a stick or wire
- Final hit with rabbit dog and trainer
- Spotlight and rifle (to complement dog if needed).

<u>McKean *Rattus tanezumi*</u>

- Bait stations with brodifacoum (Pestoff 20R) at c.40 m spacing (n = 350)
- Bait stations need to be crab-proof, e.g. Rauzon @ US$12 each, or Climo design
- Pulse poison and monitor bait take and crab and rat access

Birnie *Rattus exulans*

- Measure crab densities
- Hand spread at up to c.40-50 kg/ha
- Marked transect lines at 25 m intervals and throwing stations marked at 25 m a long the transects
- Monitor bait take daily

8.5. Skills and research needed to implement the project

<u>Skills required</u>

The successful implementation of the project requires the following technical skills:

- Operational manager and trainer experienced and skilled in pest eradications preferably from tropical islands. It is expected that a suitable person will be available
- Technically skilled people in completing rat eradications according to prescribed plan – includes Kiribati and e.g. New Zealand operators – these people exist
- Technically skilled people in completing initial phases (poisoning) of rabbit eradications – NZ or Australian operators
- Trained dog and skilled operator/shooter for completing rabbit eradication – NZ dog trainer/operator provisionally available
- Skilled operational monitoring personnel - available
- Skilled non-target and outcome monitoring personnel - available
- Reliable bait source – Animal Control Products, NZ
- Suitable transport and landing skills – Pacific Expeditions Ltd.

<u>Gaps in skills, research needs</u>

There are no skill shortages for this project. However further research is needed and is currently underway to identify:

- optimal timing of eradications (primarily coinciding with low rainfall period)
- crab-proof bait stations for rats (two designs identified)
- baiting densities for Pacific rats in hermit crab areas (trial this on Birnie)
- optimal bait presentation for rabbits (Otago rabbit managers)

<u>Baselines for monitoring</u>

Carefully selected indicator species should be monitored to determine population responses following the eradications. These primarily comprise sensitive species of birds, lizards, turtles and plants. Suitable monitoring species for each of the target islands and one control island (Kanton) are identified below:

- Rawaki

  - Phoenix petrel and white-throated storm petrel (no. pairs and ideally also breeding success every 5 years; priority 1)
  - Blue noddy (no. pairs every 5 years; priority 1)
  - Vegetation (map species and assess health, particularly of *Boerhavia*, from photopoints; priority 1)
  - All other seabirds (no. pairs every 5 years; priority 2).

- McKean
  - All procellariiforms (no. pairs every 5 years; priority 1)
  - Blue noddy (no pairs every 5 years; priority 1)
  - Other seabirds (no. pairs every 5 years; priority 2)
  - Lizard fauna (index of abundance every 5 years; priority 2)

- Birnie
  - Blue noddy (no. pairs every 5 years; priority 1)
  - Other seabirds (no. pairs every 5 years; priority 2)

- Enderbury
  - All procellariiformes (no. pairs every 5 years; priority 1)
  - Blue noddy (no. pairs every 5 years; priority 1)
  - Turtles (nest count every 5 years; priority 1)
  - Other seabirds (no. pairs every 5 years; priority 2)
  - Lizards (index of abundance every 5 years; priority 2)

- Kanton (Control)
  - All seabirds (no. pairs every 5 years; priority 1)
  - Turtles (nest count every 5 years; priority 1)
  - Lizards (index of abundance every 5 years; priority 2)

The optimal timing for monitoring seabirds (especially pairs of Phoenix petrels) is likely to be in May-August (likely peak breeding season), whereas turtle monitoring is best completed in December-January (end of nest-building period). Once monitoring months are selected, this timing should be maintained for subsequent monitoring.

8.6. Economic and social implications of pest eradication

No direct economic benefits are likely to occur in the short term. In the longer term, however, there is potential for eco-tourism, but this is not evaluated here. There are no social implications because the islands are uninhabited.

8.7. Institutional support

The Government of Kiribati will be supported in the proposed pest eradication package by a range of institutions and other bodies including:

- Conservation International – funding support through CEPF
- Pacific Islands Initiative – project facilitation and technical support through Invasive Species Specialist Group
- Department of Conservation – technical advice and practical support through PII initiative
- Technically skilled pest managers and ecologists in the private sector
- New England Aquarium via collaboration in planning and field work.

9. PEST ERADICATION FOR THE RESTORATION OF RAWAKI, MCKEAN AND BIRNIE ISLANDS, PHOENIX ISLANDS, KIRIBATI

9.1. Operational Summary

The following table summarises details of the proposed pest eradications on Rawaki, McKean and Birnie Islands, Phoenix Group.

Location	Rawaki (Phoenix) Island (c.58 ha); Mckean (c.49 ha); Birnie (c.48 ha), Phoenix Islands
Target pest species	Rabbits (*Oryctolagus cuniculus*); Asian rat (*Rattus tanezumi*); Pacific rats (*Rattus exulans*)
Timing	2 months in period May-Aug 2007
Target benefit species	Phoenix petrel (*Pterodroma alba*) EN; White-throated storm-petrel (*Nesofregata albigularis*) VU; four other petrel/shearwater species; Blue noddy (*Procelsterna caerulea*); five other tern species; red-tailed tropicbird (*Phaethon rubricauda*); Bristle-thighed curlew (*Numenius tahitiensis*) VU and other migrant waders
Vegetation type	Shrubland, grassland
Climate characteristics	Oceanic; winter-spring dry season
Community interests	Uninhabited
Historic sites	Guano collecting ruins from 1860s-1870s
Project Coordinator	To be decided
Operational Manager	To be decided
Start and end date	Eradication planned to commence in May 2007
Methods	Hand broadcasting brodifacoum bait
Biodiversity/conservation outcomes	Recovery of threatened seabird populations, plus lizard, invertebrate and plant species
Socio-economic benefits	Securing natural heritage, other potential projects in future
Capacity development	• Training and skills-sharing • Develop quarantine and contingency procedures

	• New partnerships and initiatives in IAS management
Management history	None

9.2. Executive Summary

The Phoenix Islands, Kiribati, are located in the central Pacific due north of Samoa at latitude 2-5^{o} S. They are identified as a Key Biodiversity Area (KBA) in Conservation Internationals Critical Ecosystem Partnership Fund Ecosystem Profile for the Polynesia/Micronesia Hotspot and they are also an Important Bird Area (Birdlife International). The three target islands of Rawaki (Phoenix), McKean and Birnie are small oceanic islands of shrubland and grassland that support important seabird populations, including notably the Phoenix petrel (EN), white-throated storm-petrel (VU) and blue noddy. All three islands are however being impacted on by pest mammals – rabbits, Asian rats and Pacific rats respectively. This proposal seeks funding to:

1. Eradicate rabbits from Rawaki which will allow the recovery of Phoenix petrels, white-throated storm petrels, several shearwater species and the maintenance of what is probably the largest blue noddy population.
2. Eradicate Asian rats from McKean which will allow the recovery of white-throated storm-petrel and other petrels, shearwaters and blue noddies all of which have been virtually eliminated by the recent arrival of this large rat. Other species (terns and tropicbirds) will also benefit.
3. Eradicate Pacific rats from Birnie which will allow the natural recolonisation and/or recovery of shearwaters, petrels and noddies and enable a method of rat eradication to be trialed in support of eradicating Pacific rats off larger islands in the Group.

For rabbit eradication it is proposed to use bait stations and hand-lay brodifacoum poison baits to achieve an initial knockdown, followed by dogging using a trained dog and handler. For Asian rat eradication it is proposed to use crab-proof bait stations containing brodifacoum. For Pacific rat eradication it is proposed to hand-spread brodifacoum baits, which will assist in planning for a much larger island (Enderbury, 600 ha) containing Pacific rats and crabs.

9.3. Introduction

The Phoenix Islands are one of three groups of islands comprising the Republic of Kiribati and are located at 3-5 degrees south latitude in the central Pacific Ocean. Owing to their remoteness and a harsh climate they are little disturbed by people and only one of the islands (Kanton) is currently inhabited. The vegetation and terrestrial habitats of most of the islands are in a near pristine condition and the islands have been proposed for inclusion as a World Heritage Site by UNESCO. The Phoenix Islands have also been identified as a Key Biodiversity Area (KBA) in Conservation International's Critical Ecosystem Partnership Fund Ecosystem Profile for the Polynesia/Micronesia Hotspot (#133) and is also an Important Bird Area (Birdlife International). Further to this, in 2006 the Phoenix Islands were designated a marine reserve, the third largest in the world.

The Phoenix Islands are internationally recognized as a seabird haven. Petrels, tropicbirds, boobies, frigatebirds and terns collectively are estimated to have numbered in the millions during the last comprehensive surveys which were undertaken in the 1960s (Garnett 1983). Some of these colonies represented what may have been the largest concentrations of their species in the world, including of Audubon's shearwater (*P. l'herminieri*), white-throated (Polynesian) storm petrel (*Nesofregetta albigularis*), lesser frigatebird (*Fregata ariel*) and blue noddy (*Procelsterna caerulea*). Other species with a significant presence include wedge-tailed shearwaters (*Puffinus pacificus*), Christmas Island shearwaters (*P. nativitatis*), Bulwer's petrels (*Bulweria bulwerii*), Phoenix petrel (*Pterodroma alba*), masked boobies (*Sula dactylatra*), grey-backed terns (*Sterna lunata*) and sooty terns (*Sterna fuscata*). These seabird colonies reflect firstly the availability of little-disturbed breeding grounds, and secondly the availability of diverse and abundant marine food in the form of fish and crustaceans. The islands are also important for dolphin species and others such as the threatened green turtle (*Chelonia mydas*).

As with most Pacific island groups, however, the Phoenix Islands have been impacted on in different ways, e.g. exploitation of fisheries and the arrival of invasive alien species. Feral populations of several mammalian species are known to have been present for a century or centuries at the Phoenix Islands and these include rabbits (*Oryctolagus cuniculus*), Pacific rats (*Rattus exulans*) and cats (*Felis catus*) (Garnett 1983). The 2006 Conservation Survey revealed significant recent changes in the status of pest species in the Phoenix Islands including the arrival of a new and more damaging species of rat, the Asian rat (*Rattus tanezumi*). Meanwhile cats appear to have died out on two islands. The 2006 survey also prioritized the restoration of the islands according to threatened species requirements and feasibility of pest eradications.

9.4. Flora and Fauna

Vegetation and habitats

The target islands are small atolls with the windward (eastern) sides being strewn with coral rubble boulders, logs and debris, but the interior and especially the lee sides often comprising large areas of coral sands. Each island has a small land-locked hypersaline lagoon, flanked by extensive beds of the luxuriant plant *Susuvium*. The flora is depauperate on all three atolls, comprising sprawling shrubs, e.g. *Portulaca* and *Boerhavia*, and the grass *Lepturus*. On Mckean, the shrubs *Tribulus* and *Sida* and a few trees were also present.

The upper beach comprises infrequently inundated slopes of coral rubble of widely variable size, ranging from coarse sand to large “boulders”. The shore profile is generally gentle on the north and western sides of the atoll.

Indigenous fauna

Vertebrate fauna comprises skinks, geckos, seabirds and waders. Birds present in 2006 are listed in Table 2 and invertebrates and lizards are listed in Table 3.

Table 1. Pest animals and avifauna observed on Rawaki, McKean and Birnie in April-May 2006

Species	Rawaki	McKean	Birnie
Total area	c.58 ha	c.49 ha	c.48 ha
Pest	Rabbit	Asian rat	Pacific rat
Audubon's shearwater	800+	60	0
Christmas shearwater	500+	0	0
Wedge-tailed shearwater	250+	2 i	0
Phoenix petrel	11+	0	0
Bulwer's petrel	1 i	0	0
White-throated storm petrel	20+	10+	0
Red-tailed tropicbird	70	34	4
White-tailed tropicbird	0	0	0
Masked booby	700	400	109
Brown booby	24	75	9
Red-footed booby	3	60	3
Great frigatebird	5	400	0
Lesser frigatebird	4300	1500	20 i
Sooty tern	10000	500 i	P
Grey-backed tern	1000+	800 i	300
Black noddy	<10	6	1 i
Brown noddy	4000	1630	2000
Blue noddy	2500 (7000 i)	1 i	2 i
White tern	20+	100	27 i
Pacific golden plover	100+	30	Present
Bristle-thighed curlew	c.60	6	2 anvils seen
Turnstone	120+	60	20+
Wandering tattler	2	30	2+
Sharp-tailed sandpiper	1	0	0
Approx total pairs seabirds	24,500+	5,000	2,500
Total species seabirds	18	15	11

Note: all figures represent estimated total pairs except where "i" indicates "individuals" Red indicates threatened species, green = important populations, yellow = greatly declined since 1960s.

Species of lizards and crabs recorded are listed in Table 2. The common hermit crab *Coenobita perlatus* was present on all islands. Night transects revealed that hermit crab densities exceeded that of all other crabs collectively, with up to an equivalent of c.5,000 individuals per ha in some areas on McKean. Rawaki and Birnie also had substantial numbers of hermit crabs but densities were not measured on Birnie. Other invertebrates included spiders, ants and moths.

Some key points about crabs in relation to mammal eradications are listed below:

- On Rawaki crab densities were relatively low except in *Lepturus* and *Sesuvium* fringing the lagoon.
- On some islands, e.g. locally on McKean, densities were particularly high, i.e. up to 4000/ha.
- Late afternoon and evening convergence of hermit crabs on the outer sheltered beach (to saturate brachial apparatus) was evident at Rawaki and Birnie beginning c. 1600 h on overcast days.
- In normal sunny conditions there was little activity during the day, with most being clustered at shady spots, e.g. beneath trees, shrubs (e.g. *Tribulus*) and driftwood and rubble.
- During overcast conditions or rain hermit crabs were active throughout the day, especially mid afternoon onwards, but there was less activity at night during wet weather.
- One adult *Coenobita cavipes* was seen on McKean, and juveniles were widespread on this island.
- *Cardisoma* sp. was present on all islands but not in high densities.
- One coconut crab (*Birgus latra*) was seen on Rawaki.

Table 2- Lizard and crab species recorded per island and average numbers of crabs per 100 m^2 in April-May 2006. (P = present, but not recorded on transects/transects not completed, U = unknown/incomplete survey; refer Part A for details).

Species	Rawaki	McKean	Birnie
Gehyra oceanica; Polynesian gecko	0	P	-
Coenobita perlatus	6/100 m^2	25-46/100 m^2	P
Coenobita cavipes	0	P	0
Geograpsus crinipes	3/100 m^2	0	U
Geograpsus grayi	2/100 m^2	0	U
Cardisoma sp.	P	P	U
Birgus latra; coconut crab	P (1)	0	0

9.5. Outcomes and Targets

Overall Goal	To restore the indigenous biodiversity of the Phoenix Islands and increase the biosecurity of the Group as a whole
Preliminary goals	1. To restore biodiversity on Rawaki, McKean and Birnie by

	eradicating pest rabbits, Asian rats and Pacific rats respectively and implementing improved biosecutiry
Preliminary targets	Phase 1 1. Complete draft eradication plan (June 30 2006) 2. Revise eradication plan for pest eradications on Rawaki, McKean and Birnie (October 2006) 3. Input to planning of Phoenix Islands management including biosecurity needs (October 2006) 4. Determine whether rare breeds interests will require live specimens for breeding purposes (October 2006). Phase 2 5. Eradicate rabbits, Asian rats and Pacific rats from Rawaki, McKean and Birnie (May-August 2007) 6. Implement baseline monitoring for the recovery of biota on these islands (May-August 2007). Phase 3 7. Evaluate feasibility of eradicating Pacific rats from Enderbury and plan accordingly

9.6. Project Context

There are a number of international, regional and national strategies, policies and plans that this project will contribute to:

International

- There are 2 species listed under the IUCN (2004) Red List of Threatened Species – the Phoenix petrel (*Pterodroma alba*) is endangered and the White-throated storm-petrel (*Nesofregetta albigularis*) is Vulnerable.

Regional

- Kiribati has in 2006 declared the Phoenix Islands a marine reserve.
- UNESCO has proposed the Phoenix Islands as a World Heritage Site.
- Kiribati is a member country of the SPREP Action Strategy for Nature Conservation 2003-07 (SPREP 2004)
- Conservation Internationals Critical Ecosystem Partnership Fund Ecosystem Profile for the Polynesia-Micronesia Hotspot identifies the Phoenix Islands as an important ‘Hotspot’ and Key Biodiversity Area (#133).
- The Phoenix Islands have been identified in BirdLife International’s Pacific Important Bird Areas due to its high seabird diversity and abundance.

9.7. Consultation, Consents and Notification

Key stakeholders are the Government of Kiribati and particularly the Ministry of Environment, Lands and Agriculture Development and PII partners, including CI and ISSG, who are facilitating the preparation of an operational plan for the work. Other stakeholders include DOC and other New Zealand technical experts and conservation support groups, all of whom have a high level of support for the proposal.

Consents and Notification	Full consultation with the Government is planned. Permits would be needed for importation of bait and any bird banding

9.8. Project Design Components

Summary	Indicators of change	How change is measured
OVERALL GOAL: To restore the indigenous biodiversity of the Phoenix Islands and increase the biosecurity of the Group as a whole	- Numbers of threatened seabird species - Diversity and abundance of all seabirds - Capacity of management agencies increased in French Polynesia	- Annual and 3-5 year monitoring of colony occupancy and success reported against objectives - Feedback from locals involved
Goal 1: Recovery of specific seabird populations and island ecosystems	- Numbers of threatened seabird species - Diversity and abundance of all seabirds - Vegetation health and diversity	- Annual and 3-5 year monitoring of colony occupancy and success reported against objectives
Output 1.1: Rabbits eradicated from Rawaki Output 1.2: Asian rats eradicated from Mckean Output 1.3: Pacific rats eradicated from Birnie	- No rabbits on Rawaki on completion of the project - No rats on McKean and Birnie at completion of project - Increase in seabird, lizard and invertebrate numbers and diversity per island	- Monitoring and surveillance of rabbits and rats following eradication, annually initially then 3-5 years coinciding with outcome monitoring - Reports from Project Manager - Seabird monitoring
Activity 1.1: Eradication planning		
Activity 1.2: Eradicate rabbits from Rawaki		
Activity 1.3: Eradicate Asian rats from McKean		
Activity 1.4: Eradicate Pacific rats from Birnie		
Activity 1.5: Implement monitoring on the 3 islands		
Activity 1.6: Appropriate biosecurity implemented		
Goal 2: Help develop capacity among Kiribati people to effectively address the threats posed by invasive alien species on islands		
Output 2: Capacity is developed to effectively address the threats posed by invasive alien species on islands	- Awareness of invasive species amongst community and visiting mariners	- Incidence of landings and issues
Activity 2.1: Assist in training of local people to deal with IAS and biosecurity		
Activity 2.2: A process for international cooperation in Phoenix Islands developed and implemented		

9.9. Risks and Management

All risks need to be planned for well in advance and contingencies developed to deal with possible developments. These are described below.

Risks	Management	Effect	Likelihood	Responsibility
Operational risks	Ensure the operation is planned and implemented correctly. Identify problems and develop contingency options. All risks will be updated, minimised, and as far as possible quantified, as the planning for this operation proceeds. Develop a task list during 2006 that identifies specific actions, dates and person responsible.	Failure to kill all rats and rabbits	Medium	PM, OM
Bait transport – main single operational issue that could jeopardize this project	Bait will be transported shrink wrapped on pallets from NZ to Apia. All precautions with bait during transport will be taken including checking the bait prior to leaving the factory, again at the point of departure and ongoing monitoring on the island. A high risk period is during landing of baits at the islands especially if landing conditions are bad. The RV Bounty Bay would hold off landing until conditions were safe.	Failure	Medium	PM, OM
Bait deterioration	The best practical options for bait storage will be used to prevent deterioration from occurring and bait will be inspected every day by the project team for condensation and pest damage and will be dried if necessary.	Failure	Low	PM, OM
Pests not eradicated - there is a chance that not all pests on the islands will come into contact with the baits	Use species-specific methods (refer methodology). Ensure bait coverage over the entire islands and bait is available for long enough to kill target animals.	Failure	Medium	PM, OM
Re-invasion by pests	Risk of reinvasion is zero for rabbits and low for rats. The risk of rat re-invasion will be countered by	Failure	Low	GOK

	contributing biosecurity recommendations for the Phoenix Islands Management Plan, with associated improved quarantine practices for the island, and also by following best practice in setting up an ongoing monitoring and surveillance programme.			
Conservation impact, e.g. loss of some curlews and other waders e.g. Pacific golden plover, turnstone, wandering tattler	Potential impacts on non-target threatened species will be mitigated for as per Methodology. A key approach is to complete eradication at a time of year (May-August) when most waders are absent. Any short-term negative effect on non-target species will be considerably outweighed by the long-term gains for recolonising species and ecosystems.	Dead birds	Medium	PM
Public opposition - concerns about the toxicity and persistence of brodifacoum, non-target impacts, and cultural impacts	To counter potential public criticism, the conservation benefits of eradication (a one-off only operation) will be emphasised in all communications with the public and media. Also, the precautions to be taken will be emphasised.	Delay	Low	PM, OM

9.10. Project Management Structure (Roles and Responsibilities)

Yet to be decided. Ideally a structure involving a Kiribati Programme Manager supported by Operational Manager and key technical staff from NZ (DOC and contract) and technical staff from Kiribati Government; and RV Bounty Bay chartered for this work.

A suitable structure could be as follows:

IMPLEMENTING AGENCY: Either GOK-nominated agency or outside agency that demonstrates necessary attributes (proven project management, technical ability, financial systems, staff management etc) e.g. Pacific Conservation Action Trust
Programme Manager (PM): Either GOK-nominated or PII-nominated
Operational Manager (OM): New Zealand technical expert, e.g. Gideon Climo
Eradication technical advisor (ETA): probably DOC staff, NZ
Additional staff for baiting: 3; 2 Kiribati, 1 NZ – could potentially also use 1-2 crew members of RV Bounty Bay
Contract dog handlers: e.g. Scott Theobold and one other (NZ)

Biota Monitoring Leader (BML): Ray Pierce

Roles and responsibilities are provisionally identified below

Stakeholders	Roles	Responsibilities
Programme Manager (PM)	Overall management and implementation of the project Secure necessary authorisations Coordinate team leaders, plan & manage work (including eradication, monitoring and experimental work) Provide expedition supplies, - food, water equipment etc Emergency procedures	• Recruit staff and workers • Coordinate with Operational Manager • Financial management - payment of expenses/wages etc • Liaison point • Political matters • Public spokesperson & handling media and other enquiries • Authorizations (permits (bait, bird banding etc). • Implementation of island biosecurity, quarantine etc. • Reporting • Supply and equipment list including personal items required by team members – tents, hammocks, sleeping bags, reef footwear, helmets, sunglasses, type of clothing, day packs etc. • Communications plan • Health and Safety Plan and Emergency plan
Operational manager (OM)	Coordinate eradication team Logistics Eradicate target animals Support from ETA Manage shipping of baits Daily communications Monitor rat and crab status and density	• Complete trials in New Zealand as required, i.e. rabbit baits (refer methodology) • Train and manage 2007 eradication and monitoring team members • Order bait, bait quality, ensure packaging ideal, coordinate transport and storage of bait, monitoring quality throughout • Coordinate biosecurity of operation • Set up logistics for baiting operation • Set up monitoring regime of rodents pre, during and post eradication

	Monitor bait take/ availability to rats	• Set up pre-operational crab quadrants to determine areas of different crab densities • Monitoring bait spread & bait take • Facilitating daily debriefs/think-tanks • Ensure all work targets are completed • Record data and provide progress updates to PM
Eradication Technical Advisor (ETA) – probably from NZ	Technical support and advice Reports to OM	• Advises on all tasks of OM and undertakes key roles in several tasks identified for OM above
Biota monitoring leader (BML) Potentially Ray Pierce	Reports to Operational Manager Avoidance and/or research of non-target impacts Baseline data for biota	• Establish baseline data (transects, quadrants) for key biota - seabirds, lizards, plants - on each island • Monitor numbers of curlews and other waders during and following the operation • Monitor other mortality and complete necropsies
PII	Assist Operational Manager	• Help prepare the Operational Plan • Initiate the implementation of the project and provide support.
Government of Kiribati	Provide permits for operational work – toxins and bird banding.	• Process permit applications

There are significant opportunities for local people from Kiribati to participate in the operation, from Programme Manager level to field workers (as part of bait spread and monitoring teams). The participation of local professional people (e.g. GOK staff) will ensure a high degree of training is provided, which will make for more efficient planning and execution of similar projects in the future. For example staff from Kiritimati (Aobure Teatata) and Tarawa would ensure that skills are passed on to both the Line and Gilbert Groups.

9.11. Methodology

Draft eradication methodology prescriptions for Rawaki, McKean and Birnie Islands.

1. RAWAKI (58 ha)

1.1. **Hand-broadcast pollard baits**

Objective:
Achieve initial knock-down of rabbit population using hand-broadcast pollard baits.

Bait type:
Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Bait deployment:
Hand-broadcast on a 50 x 50 m grid over entire island.

Timing and duration:
One-off one day hit at start of programme.

Bait application density:
20 kg/ha in areas of high rabbit densities (c.50% of island), 10 kg/ha in areas of low rabbit densities (coral rubble substrates). (870 kg).

Methodology:
4 people working 50 m abreast on the 50 m bait station grid.

Each person to carry 20 kg bag of bait in pack and 20 litre bucket with bait and bait scoop.

At each bait station of the 50 m bait station grid (see 1.2) spread x g of bait in 5 throws of bait in bait scoop (1 each up, down, and to both sides of grid main axis line and 1 in the immediate vicinity of bait station). Throws should try and achieve an even scattering of bait to 10m from deployment site.

Equipment:
20 litre plastic paint bucket
Pre-measured bait scoop that holds x g of bait.
Task specific personal protective gear: cotton lined plastic gloves.

Task specific issues and solutions:
A drop in team morale could lead to someone not following prescription leading to uneven bait deployment. Solution: only employ experienced and motivated personnel for

the eradication team, monitoring of morale and taking well timed breaks, monitoring of bait coverage.

Locally high crab numbers consuming the bulk of bait, leaving little for target animal. Solution: achieve good spread of bait, having bait presented in bait stations as additional bait source for target animals. Monitor bait take.

Secondary or direct poisoning of non-target wildlife. There is a potential for direct (through bait consumption) and secondary (through consumption of crabs that have recently fed on bait) poisoning of bristle-thighed curlew. Solution: this risk is difficult to eliminate so time the programme for when curlews are at low numbers on the island (austral winter). The short duration of the hand-broadcast portion of the programme (baits only present for c. 3 days before all consumed, toxin passing through invertebrates c.3 days later) lowers the risk of this technique. Other waders could be at risk but numbers are low at the proposed time of year. It is not known if frigatebirds would consume poisoned rats. Though crabs and other invertebrates will eat baits, they are not obviously affected and the toxin passes through their system over a period of several days.

1.2. **Pollard baits in bait stations**

Objective:
Achieve continued pressure on rabbit population using pollard baits presented in bait stations.

Bait type:
Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Bait deployment:
In modified Rat-go (elevated folded plastic design, see attached) bait stations on a 50x50 m grid over entire island. 240 stations.

Timing and duration:
Two hits. First at start of programme for 3 days of rebaiting and 8 days of non-rebaited presence. Second hit 8 days later with 2 days of rebaiting and baits left in stations for duration of programme and following cessation of programme. Remaining bait and bait stations to be removed at post-eradication check 2 years later.

Bait application density:
First hit: 500 g constant supply per station in areas of high rabbit densities (c. 50% of island), 250 g constant supply per station in areas of low rabbit densities (coral rubble substrates) for 3 days. Second hit (8 days later) 250 g constant supply per station in areas of high rabbit densities (c. 50% of island), 150 g constant supply per station in areas of low rabbit densities (coral rubble substrates) for 2 days. Total 150-200 kg.

Methodology:
4 person team.

Mark out, assemble and deploy bait stations on a 50 m grid. Grid should have primary axis perpendicular to the shore line. At 50 m intervals along strand line take compass bearing to centre of island. Follow this bearing and measure 50 m by pegging end of 50 m cord and running this out to end of cord. Assemble and secure bait station on a flat surface. Bait stations need to be secured by weighting or pegging down (sand substrates). Trim any close vegetation that could be used by crabs for climbing access. Number bait station with line number (sequential starting with alphabetical letter of line and number of station from strand line, e.g., A1 to A8, B1 to B10). Mark bait stations obscured by vegetation with coloured tape. Repeat by pulling end of line to remove peg and repeg at bait station at 50 m intervals along bearing until lagoon edge reached. First bait station to be at vegetation boundary of strand line. Last station to be at vegetation boundary of lagoon edge. Note: inter-line spacing at lagoon edge of lines will be closer than 50 m interval).

Each person to carry 20 kg bag of bait in pack and 20 litre bucket with bait and bait scoop.

Fill all stations to level described above once all bait stations deployed. Repeat on consecutive days as described above. Use measured scoop.

Record onto field recording sheet approximate amount of bait take when rebaiting (e.g. untouched, half, ¼ gone).

Equipment:
50 m cord with wire stake attached at end.
Compass.
20 litre plastic paint bucket
Pre-measured bait scoop that holds 100 g of bait.
Rebaiting record sheet.
Task specific personal protective gear: cotton lined plastic gloves.

Task specific issues and solutions:
Team morale as for 1.1. Monitor bait station fill levels.

Some rabbits are behaviourally averse to bait stations causing uneven bait take within the rabbit population. Solutions: monitor rabbit reactions to bait stations and modify station design or presentation if possible. Have alternate technique to target specific station-averse individuals (in this case using 1080 baits and dogs, see below).

High crab numbers consuming the bulk of bait, leaving little for target animal. Solution: having bait presented in elevated bait stations to minimize crab access. Bait stations that crabs manage to access should be modified (e.g. by removing climbing access).

Secondary or direct poisoning of non-target wildlife.
As for 1.1, but invertebrate access to baits will be less.

1.3. **Acute toxin baits**

Objective:
Provide a contingency technique targeting pollard-bait-shy or bait-station-shy rabbits.

Notes: The standard carrot bait used for this technique in New Zealand would not last the length of time necessary for transportation. The technique(s) below will require efficacy trialling in arid Central Otago, New Zealand.

Bait type:
1080 toxin at 0.08% in a gel formulation.

Bait deployment:
1080 gel on the underside of taro discs presented 20cm above ground level on wire stakes. Another possibility is 1080 solution made to 0.08% in sterilised water presented in drinking stations.

Timing and duration:
Prebaiting: One hit at start of programme.
Toxic baits: One 3 day hit 13 days into programme.

Bait application density:
Prebait and toxic baits: One 30 mm thick disc of taro at 50x50 m density over entire island.

Methodology:
4 person team (one of which with appropriate certification) all to wear gloves and to strictly adhere to safety precautions as described by certified user. 1080 is highly toxic and there is no antidote to accidental poisoning.

Using the poison bait station grid establish one bait 25 m from bait stations along major axis line (i.e., intermediate between bait stations along lines). Bait to be skewered onto a 30 cm length of No. 8 galvanised wire that is securely driven into the ground. Bait height should be 15 to 20 cm above ground level and clear of vegetation.

When rebaiting replace taro baits if the bulk of a bait has been consumed or reapply 1080 gel if necessary.

Record bait consumption onto field recording sheet approximate amount of bait take when rebaiting (e.g. untouched, half, 25% gone).

At end of three days of baiting remove all baits and recover rabbit carcasses and dispose of these at least 1 km out to sea or by burial (baits).

Equipment:
20 litre plastic paint bucket for holding taro baits.
Number 8 galvanised wire cut to 30-35 cm lengths.
100 kg of taro for baits.
1080 gel in applicator (commercially available).
Rebaiting record sheet.
Task specific personal protective gear: cotton lined plastic gloves, water for flushing skin if suspected contact, respirator?.

Task specific issues and solutions:
1080 is highly toxic and there is no antidote to accidental poisoning. Solutions: All people involved in this portion of the programme will need to be trained by a person certified in 1080 handling. All safety directions must be followed at all times. In case of suspected poisoning affected person is to advise other members of team who are to seek medical attention from expedition medical officer. Area of contact to be flushed immediately several times with water.

Team morale and solutions as per 1.1.

Some rabbits are behaviourally averse to 1080 and/or taro bait causing uneven bait take within the rabbit population. Solutions: monitor rabbit reactions and modify presentation if possible. Have alternate technique to target specific station-averse individuals (in this case using pollard baits and dogs).

High crab numbers consuming the bulk of bait, leaving little for target animal. Solution: having elevated baits to exclude crabs. Baits that crabs manage to access should be modified (e.g. by removing climbing access).

Weather (particularly rain) affecting toxicity of bait. Solution: have sufficient quantity of 1080 gel available and reapply to all baits immediately following rain.

Secondary or direct poisoning of non-target wildlife.
Bristle-thighed curlew and solutions as per 1.1, plus using elevated bait stations should eliminate this risk. Regular checks for baits knocked over by rabbits or birds.
Crabs and other invertebrates will eat baits if accessible and this could cause mortality of these individuals. The risk of this is low as it would require accessing baits by climbing or from knocked over baits.

1.4. **Final mop up and provisional confirmation of eradication**

Objective:

Eliminate any rabbits remaining following the above techniques and provide provisional confirmation of eradication.

Control type:
Indicator dog, shooting, burrow excavation, limited trapping at burrow entrances.
Note: gassing burrows probably not feasible due to the porous nature of the substrates and presence of Phoenix petrel and other seabirds.

Deployment:
Dog to indicate specific sites (especially burrows) of current rabbit occupancy and to be used to flush rabbits from vegetation cover. Shooting of rabbits active during day or night. Excavation of burrows occupied by rabbits if necessary.

Timing and duration:
Last 10 days of programme, or until 3 consecutive days with no indication of live rabbits.

Methodology:
2 person team and dog. Both to have firearms and first aid certification. Prior to using dogs, determine distribution and occupancy of all Phoenix petrel burrows (using burrowscope) and and surface nests and mark these sites with flagging tape to ensure they are not disturbed by dogs.

Use dog to find specific sites of rabbit occupancy once island clear of 1080 baits and rabbit carcasses. Excavate burrow sites (if not marked as a seabird burrow) using spade and either destroy rabbit by hand or by shooting once flushed. For unexcavable burrows set half-buried leg-hold trap in all detectable entrances. For vegetation retreat sites use dog to flush rabbit and shoot.

During dog rest time and for at least 3 hours each night use a mix of active hunting (using spotlights at night) and stationary hunting from a ladder (to give an elevated view) to shoot active rabbits. Target areas with suspected rabbit presence but also regularly check areas thought to be clear of rabbits.

Record sex and weight of all rabbits destroyed.

Equipment:
Dog with a proven ability to detect rabbits.
Kennel and shade tarpaulin
Dog food, water and feeding equipment
Long lead
Muzzle
Electric shock collar
2 x .22 calibre rifles with scopes and ability to mount spotlights
1 x Semi-automatic shotgun
Ammunition
Scope-mounted spotlights

Head-mounted spotlights
Batteries for spotlights.
Generator for charging spotlight batteries.
Camping equipment, food and water (including surplus).
Comprehensive safety kit
Personal radios and spare batteries
SSB radio, antenna and batteries
Task specific personal protective gear: Fluorescent vests
Burrowscope.

Task specific issues and solutions:

1080 is highly toxic and there is no antidote to accidental poisoning of dogs. Solutions: remove all rabbit carcasses on ground. Use dog on a long leash and/or muzzled to prevent feeding on undetected carcasses.

Activities and dog have the potential to impact seabird use of burrows. Solution: train dog (if necessary use electric shock collar) to avoid birds. Use muzzle at all times. Pre-determine locations of Phoenix petrel burrows and avoid digging these up – use burrow scope to check burrow occupants.

Team morale as per 1.1.

Firearm use is hazardous. Users to have appropriate certification and to follow firearm safety rules, particularly only load rifle when ready to fire, positively identify target and make sure field of fire is clear. Good communication between personnel of areas being hunted and not to be fired into. Wear fluorescent vest at all times. Use radios to communicate change of plans between personnel.

Hunting may cause behavioural alterations in the remaining rabbits. Solution: for this reason the dog team is used at the end of the programme. Prior to use on island dog should only be exercised on the beach and on a lead. Dog to be kennelled at all times when not under direct handler control.

Team will be working in isolation from the rest of team and the boat. Solution: daily radio contact with boat. Have adequate stores and water onshore to last 4 days beyond estimated pick up time.

2. MCKEAN ISLAND (49 ha)

2.1. **Hand-broadcast pollard baits**

Objective:
Achieve initial knock-down and possibly eradication of Asian rat population using hand-broadcast pollard baits.

Bait type:
Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Bait deployment:
Hand-broadcast on a 50 x 50 m grid over entire island.

Timing and duration:
One-off one day hit at start of programme.

Bait application density:
20 kg/ha in areas of high rat densities (c. 60% of island), 12 kg/ha in areas of low rat densities (coral rubble substrates). Total 800 kg.

Methodology:
4 people working 50 m abreast on the 50 m bait station grid.

Each person to carry a 20 kg bag of bait in pack and 20 litre bucket with bait and bait scoop.

At each bait station on the 50 m bait station grid (see 2.2) spread x g of bait in 5 throws of bait in bait scoop (1 each up, down, and to both sides of grid main axis line and 1 in the immediate vicinity of bait station). Throws should try and achieve an even scattering of bait to 10 m from deployment site.

Equipment:
20 litre plastic paint bucket
Pre-measured bait scoop that holds x g of bait.
Task specific personal protective gear: cotton lined plastic gloves.

Task specific issues and solutions:
No eradication projects have targeted Asian ship rat *Rattus tanezumi* and so techniques are unproven against this species. Solutions: model approach on those used successfully against *Rattus rattus*. Use two complementary approaches (hand-broadcast and bait stations). Monitor closely all aspects of the programme.

Eradication team morale as per 1.1.

Very high crab numbers consuming the bulk of bait, leaving little for target animal. Solution: achieve good spread of bait, having bait presented in bait stations as additional bait source for target animals.

Secondary or direct poisoning of non-target wildlife.
As per 1.1.

2.2. **Pollard baits in bait stations**

Objective:
Achieve elimination of rat population (if still present) using pollard baits presented in bait stations.

Bait type:
Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Bait deployment:
In Rat-go (elevated folded plastic design, see attached) bait stations on a 50 x 50 m grid over entire island. 200 stations.

Timing and duration:
Two hits. First hit eight days after hand-broadcast bait with 2 days of rebaiting. Second hit 9 days later with 3 days of rebaiting and baits left in stations for duration of programme and following cessation of programme. Remaining bait and bait stations to be removed at post-eradication check 2 years later.

Bait application density:
First hit: 250 g constant supply per station in areas of high rat densities (c. 50% of island), 150 g constant supply per station in areas of low rabbit densities (coral rubble substrates).
Second hit (9 days later) 100 g constant supply per station in all areas.
Total bait 700 kg.

Methodology:
4 person team.

Mark out, assemble and deploy bait stations on a 50 m grid. Grid to have primary axis perpendicular to shore line. At 50 m intervals along strand line take compass bearing to centre of island. Follow this bearing and measure 50 m by pegging end of 50 m cord and running this out to end of cord. Assemble and secure bait station on a flat surface. Bait stations need to be secured by waiting or pegging down (sand substrates). Trim any close vegetation that could be used by crabs for climbing access. Number bait station with line number (sequential starting with alphabetical letter of line and number of station from strand line, e.g., A1 to A8, B1 to B10). Mark bait stations obscured by vegetation with coloured tape. Repeat by pulling end of line to remove peg and repeg at bait station at 50m intervals along bearing until lagoon edge reached. First bait station to be at vegetation boundary of strand line. Last station to be at vegetation boundary of lagoon edge. Note: inter-line spacing at lagoon edge of lines will be closer than 50m interval).

Each person to carry 20 kg bag of bait in pack and 20 litre bucket with bait and bait scoop.

Fill all stations to level described above once all bait stations deployed. Repeat on consecutive days as described above. Use measured scoop.

Record onto field recording sheet approximate amount of bait take when rebaiting (e.g. untouched, half, ¼ gone).

Equipment:
50 m cord with wire stake attached at end.
Compass.
20 litre plastic paint bucket
Pre-measured bait scoop that holds 100 g of bait.
Rebaiting record sheet.
Task specific personal protective gear: cotton lined plastic gloves.

Task specific issues and solutions:
Eradication team morale as per 1.1 and 1.2.

Some rats are behaviourally averse to bait stations causing uneven bait take within the rat population. Solutions: monitor rat reactions to bait stations and modify station design or presentation if possible. Have alternate technique to target specific station-averse individuals (in this case hand-spread baits, see above).

High crab numbers consuming the bulk of bait, leaving little for target animal. Solution: having bait presented in elevated bait stations to exclude crabs. Bait stations that crabs manage to access should be modified (e.g. by removing climbing access).

Secondary or direct poisoning of non-target wildlife.
As per 1.1.

2.3. **Provisional confirmation of eradication**

Objective:
Provide provisional confirmation of eradication.

Control type:
Nocturnal rat searches

Timing and duration:
Last 3 days of programme.

Methodology:
3+ person team.

Team to search island at night using spotlights to detect any indication of rat presence.

Equipment:
3 x spotlights
Batteries for spotlights.

Task specific issues and solutions:
Working at dark can make refinding camp difficult. Solution: leave lantern alight at camp to allow team to find camp.

3. BIRNIE ISLAND (48 ha)

3.1. **Hand-broadcast pollard baits**

Objective:
Achieve eradication of rat population using hand-broadcast pollard baits as a trial for aerial eradications planned for other islands in the group.

Bait type:
Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Bait deployment:
Hand-broadcast on a 50 x 50 m grid over entire island.

Timing and duration:
One-off one day hit at start of programme.

Bait application density:
20 kg/ha over entire island. (Total = 1000 kg). If twice = 2000 kg.

Methodology:
4 people working line abreast and visually checking the 50 m spacing between team members.

Each person to carry 20 kg bag of bait in pack and 20 litre bucket with bait and bait scoop.

Grid to have primary axis perpendicular to main axis of island. The first line to be marked with flagging tape. At 50 m intervals along strand line follow this bearing (same bearing to be used over all island) and measure 50 m by pegging end of 50 m cord and running this out to end of cord.

On each traverse one member to follow (using compass) a 50 m parallel to the pre-flagged line laid out by team leader, others in a line at 50 m spacing abreast from this person. Last person to be team leader who flags his traverse line.

At each 50 m point spread x g of bait in 5 throws of bait in bait scoop (1 each up, down, and to both sides of grid main axis line and 1 in the immediate vicinity of bait station). Throws should try and achieve an even scattering of bait to 10 m from deployment site.

At termination of line check 50 m spacing still consistent within +/-5m.

Equipment:
20 litre plastic paint bucket
Pre-measured bait scoop that holds x g of bait.
Task specific personal protective gear: cotton lined plastic gloves.

Task specific issues and solutions:
Team morale as per 1.1.

High crab numbers consuming the bulk of bait, leaving little for target animal. Solution: achieve good spread of sufficient bait. Bait density of 20 kg/ha has been used successfully on several tropical islands. However, in one operation a density of 90 kg/ha was necessary. It is unknown whether the density prescribed here is sufficient to achieve eradication on this island. For this reason this eradication should be viewed as experimental to determine bait density required for aerial- or hand-broadcast operations. Collect data (transects) on crab densities around the island.

Secondary or direct poisoning of non-target wildlife.
Curlews and other waders as per 1.1.

3.2 Provisional confirmation of eradication

Objective:
Provide provisional confirmation of eradication.

Control type:
Nocturnal rat searches

Timing and duration:
Last 3 days of programme.

Methodology:
3+ person team.

Team to search island at night using spotlights to detect any indication of continuing rat presence.

At any site with suspected rat presence record GPS location, mark with flagging tape and set 5 snap traps elevated 15cm using wire hoops secured to base of trap. Bait with almond.

Equipment:
3 x spotlights
Batteries for spotlights
GPS for each team member
Snap traps on wire props.
Almonds

Task specific issues and solutions:
Working at dark can make refinding camp difficult. Solution: leave lantern alight at camp to allow team to find camp.

3.3 **Back-up if eradication thought not to be successful**

Objective:
To eliminate unexpected remnants of the rat population located during 3.2.

Control type:
Hand-broadcast Wanganui 20R pollard baits containing 0.05% Brodifacoum died green.

Timing and duration:
Last day of programme.

Methodology:
3+ person team.

Hand-broadcast baits at c. 20 kg/ha into and in a 50 m buffer around areas with suspected rat presence identified during 3.2

Equipment:
As for 3.1

Task specific issues and solutions:
As for 3.1

Confirmation of eradication
Following year.

9.12. Biosecurity

Biosecurity plans will be implemented for both the operational and post-operational phases of this programme:

- Biosecurity of the field operations will include:
  - Boat charter vessel is free of rodents
  - Landing vessels are clean and free of rodents, ants, seeds
  - Clean and sealed poison containers
  - Clean and sealed food and equipment containers, sprayed with insecticide
  - Personal gear and clothing checked for ants and seeds.

- Post operational biosecurity will include advice to the Government of Kiribati including:
  - As for biosecurity during field operation, plus:
  - Landing restricted to authorized parties that have passed quarantine inspection

- Large print "No landing" signs erected at landing sites at all islands
- Ensure rat bait stations are being maintained on foreign fishing vessels working in the area
- Interpretation panels erected at Kanton highlighting values, risks and precautions
- Work with local people to do follow-up biosecurity e.g. training of some people for ongoing biosecurity and restoration projects at Kanton
- Advocacy of values of the Phoenix Islands throughout Kiribati and sea-faring public generally
- Advocate value of rat removal and defense of islands and benefits to economic needs, e.g. coconuts and other crops
- General advocacy (Government, PII generic approaches) of future risks, e.g. increased mice risks following rat removal; risks of other pests, e.g. ants; explain difficulty of removing rats from restored islands where food has become abundant necessitating a wait of many years for depletion of food before rat removal is viable – so key message is to ensure prevention of rat dispersal from source islands. All general facts, but advocated locally via site champions
- Non-landing alternatives provided for ornithologists, birders and adventurers, e.g. watching Phoenix petrels, storm-petrels and other seabirds flying onto the islands in the evening.

9.13. Monitoring and Evaluation

Monitoring will include operational and outcome monitoring, socio-economic benefits and evaluation of the project.

Operational monitoring and evaluation

Operational monitoring is the responsibility of the Operational Manager and will include the following components:

Pre-operational

- Review of past information particularly on rabbit and rat eradication on crab islands – working closely with PII on this aspect
- Trial the use of chronic toxins with taro (central Otago)

During operation

- Pre-operational assessment of crabs – transects counted in representative areas and rest of island calibrated against these as high, medium, low densities of crabs.
- Bait spread – all baited areas checked on day of bait-spread to ensure complete coverage
- Bait survival – high density crab areas and other representative baited areas checked on days1-3 after bait spread to determine availability of baits

- Rat survival 10-20 days post-poisoning– spotlighting to determine if any rats have survived and carry out follow-up control as needed.

<u>Post-operational</u>

- Return to island within 12 months and repeat trapping, luring and spotlighting.

Outcome Monitoring

Outcome monitoring is the responsibility of the Biota Monitoring Leader and it will have the purpose of a) establishing baseline population levels for ongoing monitoring of key biota and b) help determine side-effects on any biota. These are outlined in the table below.

Indicator	Estimated baseline level	Data needed	Method	Timing*	Ongoing responsibility
Phoenix petrel	c.20 pairs on Rawaki	Accurate estimate of no. of pairs	Banding for mark-recapture; burrow occupancy	June-Aug every 3-5 years	Consultant and GOK
White-throated storm-petrel	10+ p McKean, 20-50 Rawaki	Accurate estimate of no. pairs	Banding for mark-recapture	June-Aug every 3-5 years	GOK
Blue noddy	2000+ pairs Rawaki	Accurate estimate of no. of pairs	Nesting pairs	June-Aug every 3-5 years	GOK
Other seabirds	Known species diversity	Accurate estimate of no. pairs	Burrow, nest occupancy	June-Aug every 3-5 years	GOK
Reptiles	Few data	Species diversity and response	Survey, identify, index numbers on transects	June-Aug every 3-5 years	GOK
Plants	Species list	Response	Photopoints, quadrants	June-Aug every 3-5 years	GOK

* Note that data collection could be coordinated with biosecurity work and once the initial monitoring month is selected, this should be replcated in later years.

Project evaluation

Hold a debrief on one or two occasions post-eradication to determine biodiversity gains, design issues (can it be done better), capacity building, training and further ways of moving forward with biodiversity recovery in Phoenix Islands.

Socioeconomic benefits

These aspects will be evaluated with Kiribati Government.

9.14. Tasks, Actions, Responsibilities and Timeframes

Tasks	**Actions**	**Responsibility**	**Date**
Submit Draft Operational Plan to CEPF and GOK	• Submit draft to CEPF and GOK	R. Pierce	30 June 06
Apply for funding	• Complete application to CEPF	R. Pierce, PII	2006
Planning meeting	• Meet in Tarawa	PII, R. Pierce	2006
Advance operational plan	• Consult technical experts • Complete second draft	R. Pierce with support from PII, DOC	2006
Appoint Op Mgr	• Appoint manager		Nov 06
Specific questions	• Rabbit bait trial NZ	OM	January 07
Finalise Draft Plan	• Review, discuss	PII, IEAG (DOC), OM, RP	Feb 07
Final order for baits	• Order baits from ACP, Wanganui	OM	28 Feb 07
Final travel bookings	• Bait, personnel	PM, OM	31 March 07
Bait freighted	• Arrange safe transport to Apia	OM,	To be determined
Poison party rendezvous in Apia	• Bait spread • Monitoring baits etc • Monitoring biota	OM ETA BML	To be decided – possibly June-Aug 07
Follow-up	• Rat monitoring • Quarantine/biosecurity • Outcome monitoring	PM BML	To be determined
Report	• Individual reports to PM for final collation	OM, BML	To be determined

9.15. Budget

Total budget US $192,000 (refer spreadsheet below).

Phoenix eradications budget	**Cost**	**Qnty**	**Total 10 t**

FLIGHTS			
Tarawa planning	2500	2	5000
Expedition members to Apia return	2000	7	14000
ACCOMMODATION			
Fiji, Apia	100	7	700
BOAT COSTS			
RV Bounty Bay for 35 days incl. food	2300	35	80500
LABOUR COSTS			
Programme manager	0	0	0
Operational Manager	150	60	9000
Eradication Technical Advisor (ETA - DOC)	0	30	0
Bait trials Otago	3000	1	3000
Dog handlers	150	80	12000
Biota Monitoring and reporting	150	50	7500
ERADICATION			
4 tonnes of Pestoff 20R	3300	4	13200
Rauzon bait stations	12	200	2400
Rabbit bait stations	10	240	2400
1080 bait	1000	1	1000
Dry bags for getting baits ashore	20	50	1000
Road Freight to Auckland including container lifts and movements	1800	1	1800
Ocean freight baits to Apia	5000	1	5000
Ocean freight bait stations to Apia	400	1	400

NZ Customs and security clearances and shipping documents	180	1	180
Import taxes, freight forwarder, statistic taxes, port taxes	5000	1	5000
Air freight (NZ-Apia)	500	1	500
Containers for storing/carrying bait	10	20	200
Rubber gloves (for bait handling)	5	30	150
Biodegradable tape, marker pens	30	10	300
Vitamin K1, 20mg oral doses (in case of accidental poisoning)	10	10	100
30m tape measure	60	2	120
Compass	20	5	100
Waterproof notebooks	10	10	100
Mapping - aerial photo, GPS and map production	1000	1	1000
Burrowscope	2000	1	2000
MONITORING			
Cooking gear (gas, plates, pans, etc)	1000	1	1000
Generator	500	1	500
Rat traps	5	50	250
MISCELLANEOUS ITEMS			
Administration costs (photocopying, phone & fax costs etc.)	1500	1	1500
Radios	2	300	600
Binoculars	2	200	400
Hire of dog kennels, tents	5	400	2000
Batteries, torches, spotlights	1500	1	1500
Contingency costs @$3000/day	3000	5	15000

TOTAL			191420

9.16. References

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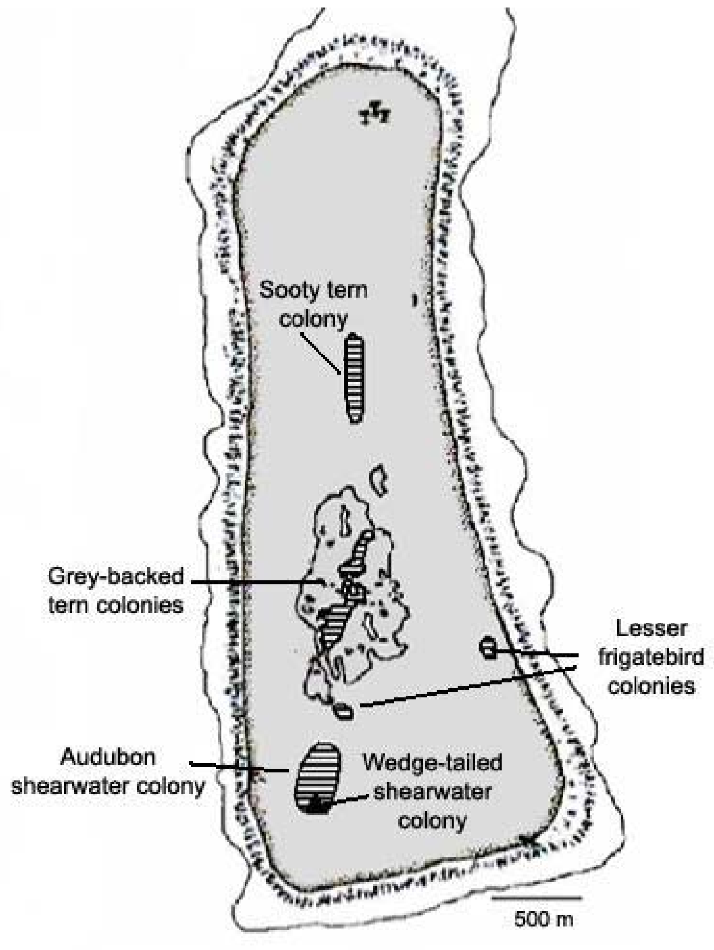
PART C - APPENDICES

Appendix 1 – Enderbury Island seabird colonies 2006



Appendix 2 - List of plant species recorded on six of the Phoenix Islands during previous surveys (Garnet 1983) and in April-May 2006

Note: numbers denote number of individuals of rarely recorded species for that island. “Not seen” denotes specifically searched for but not found. * Denotes presumably re-estblished.

Family	Species	Rawaki	Enderbury	Birnie	McKean	Orona	Nikumaroro
Pandanaceae	*Pandanus tectorius;* te kaina					✓	✓
Rupiacea	*Ruppia maritime*		Not seen				
Graminae	*Cenchrus echinatus*		Not seen			✓	Not seen
	Chloris inflate					Not seen	
	Digitaria pacifica		Not seen		Not seen	Not seen	Not seen
	Digitaria cetigera						Not seen
	Digitaria ciliaris					Not seen	
	Eleusine indica					✓	Not seen
	Eragrostis amabilis (E. tenella)					✓	Not seen
	Eragrostis whitneyi		Not seen			Not seen	
	Lepturus pilgerianus	✓	✓			✓	
	Lepturus repens		✓		✓	✓	Not seen
Cyperaceae	*Cyperus javanicus*						
	Fimbristylis cymosa		Not seen			✓	✓
Palmae	*Cocos nucifera;* nii		✓(14)			✓	✓
Aracea	*Crytosperma chamissonis*						Not seen
Amaryllidaceae	*Crinum asiaticum*					Not seen	✓
Moraceae	*Artocarpus altilis*					✓	
Urticaceae	*Laportea ruderalis*	✓	✓			Not seen	✓
Polygomaceae	*Cocoloba uvifera*					Not seen	Not seen
Nyctaginaceae	*Boerhavia albiflora*	✓	✓	✓	✓	✓	Not seen
	Boerhavia tetrandra					✓	✓
	Mirabilis jalapa					Not seen	
	Pisonia grandis		✓(3)		✓	✓	✓
Alzoaceae	*Sesuvium portulacustrum*	✓	✓	✓	✓	✓	✓
Portulaceae	*Portulaca aff. Lutea*	✓	✓	✓	✓	✓	✓
	Portulaca oleracea		Not seen			✓	Not seen
	Portulaca australis (samoensis)		Not seen				
Lauraceae	*Cassytha filiformis*		✓				
Zygophyllaceae	*Tribulus cistoides*		✓		✓	Not seen	Not seen
Surianaceae	*Suriana maritime*					✓	
Euphorbiaceae	*Euphorbia cyathophora*					Not seen	Not seen
	Euphorbia glomirifera					Not seen	Not seen
	Chamaesyce hirta		Not seen			✓	Not seen
	Chamaesyce prostrate					✓	
	Pedilanthus tithymaloides						Not seen
	Phyllanthus amarus					Not seen	Not seen

Tiliaceae	*Triumfetta procumbens*	Now absent	✓			✓	Not seen
Malvaceae	*Sida fallax*	✓(2)	✓	✓ *	✓	✓	Not seen
	Hibiscus tillaceus					✓	
	Hibiscus x sp.					Not seen	
	Thespesia populnea		Not seen				
Guttiferaceae	*Calophyllum inophyllum*					✓	
Caricaceae	*Carica papaya*					✓	Not seen
Combretaceae	*Terminalia samoensis*						✓?
Cucurbitaceae	*Cucurbito pepo*					✓	
	Cucumis melo						
Lythraceae	*Pemphis acidula*					✓	✓?
Convulvulaceae	*Ipomoea macrantha*		✓			✓	✓
	Ipomoea brasiliensis (or *I. pes-caprae*?)					✓	
Boraginaceae	*Cordia subcordata;* te kanawa	✓(1)	✓	✓	✓(1)	✓	✓
	Heliotropium procumbens					Not seen	
	Tournefortia argentea; te ren		✓			✓	✓
Verbenaceae	*Clerodendrum inerme*					✓(2)	
	Lantana camara					Not seen	
	Physalis angulata					Not seen	
	Pseuderanthemum carruthersii					Not seen	
Rubiaceae	*Guettardia speciosa*					✓	✓
	Morinda citrifolia; te ron					✓	✓
Goodeniaceae	*Scaevola sericea;* te mao		✓			✓	✓
Compositae	*Tridax procumbens*					Not seen	
	Vernonia cinerea					✓	
	Premma serratifolia					✓	
	Ficus tinctoria					✓?	
Combretaceae	*Concocarpus erectus*		✓(1, new addition)				

Appendix 3 – Seabird species recorded on pelagic transects Samoa-Phoenix Islands return April-May 2006

Transect leg	Samoa	Swain's	Tokelau	S Phoenix	N Phoenix	W Phoenix	SW Phoenix	Cardon-et	W Tokelau	S Tokelau	Samoa	Total
No. transects	4	4	5	8	8	8	9	10	7	8	9	80
Date	14-Apr	15-Apr	16-Apr	17-Apr	27-Apr	1-2 May	4-6 May	7-May	8-May	9-May	10-May	
Time start	1252	1331	1225	730	700	1230	950	650	650	650	650	
Time finish	1652	1731	1725	1605	1530	830	1800	1820	1250	1450	1745	
Lat start	12427	10562	8553	7130	3158	3368	4317	5330	7459	9517	12170	
Lat finish	12372	10336	8377	6229	3321	4265	4488	6277	8211	10355	13123	
Long start	171289	171073	171168	171300	173029	174052	172199	173490	172515	172183	171580	
Long finish	171275	171088	171172	171141	173524	174229	174136	173262	172361	172123	171500	
Speed knots	5.5	5.7	5.6	6	7	5.3	6.5	6.2	6.3	6.4	5.7	
Course (degrees)	3	340	348	355	240	105	var	Var	146	161	161	
Viewing conditions	2	1	1	2	3	2	2	2	1	1	1	
Sea	2	1	2	3	3	3	2	2	1	2	2	
Tahiti petrel											1	1
Phoenix petrel								1*				1*
Mottled petrel							2	1	1		2	6
Kermadec petrel							1	1				2
Herald petrel										1		1
White-necked petrel			1						1			2
Black-winged petrel									2			2
Gould's petrel											1	1
Unidentified petrel		2						1				3
Flesh-footed shearwater				2	2		5	3	10	28	32	82
Wedge-tailed shearwater	14	3	6	36	6	4	1	30		6	2	108
Sooty shearwater							2					2
Short-tailed shearwater						3	2	2		2		9
Christmas shearwater					1	3						4
Audubon's shearwater	1	1			7	9		2				20
Unidentified shearwater						2	5					7
White-throated storm-petrel					3	1						4
Leach's storm-pertel				1								1
Unidentified storm-petrel									1	1*		1
Red-tailed tropicbird	2											2
White-tailed tropicbird	1							1	1		2	5
Masked booby	1				2	19						22
Red-footed booby	4	2	1	33	3	3	25		1			72
Brown booby					1	1	3					5
Great frigatebird						1						1

Lesser frigatebird				1	4	4	3		1			13
Great crested tern											1	1
Grey-backed tern					1	17						18
Sooty tern	2		2	167	604	347	273	280	7	7	3	1692
Black-naped tern									1*			
Brown noddy			11	24	1	28	26			4		94
Black noddy		1	16	27	4		97	6	3	2	8	164
Blue noddy					2							2
White tern	19	0	35	34	7	15	33	20	20	8	4	195
Total	44	9	72	325	648	457	478	347	48	58	56	2542
Birds/h	11	2.25	14.4	40.6	81	57.1	53.1	34.7	6.1	7.3	6.2	31.8
SE												
Species	9			9	15	14	14	10	11	8	10	28
Resident species	9			7	14	13	9	6	8	5	6	

* indicates seen outside transect observation periods and excluded from data totals - circling boat at dusk (Phoenix petrel and storm-petrel) or close to islands (black-naped tern at Tokelau Is.).

Appendix 4a – Ant records Phoenix Islands 2006

Ant samples sorted by DWARD, May 2006 | **Nation**

Samples from Phoenix islands, collected by E. Saul, V. Kerr and R. Pierce | Phoenix Group

On request of ISSG, AKL Univ

	Species										
Sample #	**Carnud**	**Mondes**	**Monflo**	**Parlong**	**Parvag**	**Phemeg**	**Tapmel**	**Tetsim**	**Island**	**Date**	**Method**
1		1							Kanton	26/04/2006	PB
2								1	Birnie	2/04/2006	SB
3						1			Orona	3/05/2006	SB
4						1			Orona	2/05/2006	SB
5		1	1	1				1	McKean	28-29/4/06	SB
6		1							Kanton	26/04/2006	PB
7	1	1							Rawaki	19/04/2006	PB
8								1	Birnie	2/04/2006	PB
9		1							Kanton	26/04/2006	SB
10			1	1			1		Enderbury	26/04/2006	SB
11	1		1	1		1			Nikumaroro	5/05/2006	SB
12						1			Orona	2/05/2006	PB
13			1			1			Nikumaroro	5/05/2006	PB
14		1							Kanton	26/04/2006	SB
15				1		1			Orona	2/05/2006	PB
16				1					Orona	2/05/2006	SB
17		1		1					Nikumaroro	6/05/2006	PB
18				1					Nikumaroro	5/05/2006	H
19				1					Nikumaroro	7/05/2006	H
20		1			1				Nikumaroro	6/05/2006	SB
21					1				Orona	3/05/2006	PB
22		1	1						Enderbury	26/04/2006	PB
23						1			Orona	2/05/2006	H
24	1	1							Rawaki	19/04/2006	SB
25						1			Orona	3/05/2006	PB
26				1					McKean	28/04/2006	H

Carnud	Cardiocondyla nuda
Mondes	Monomorium destructor
Monflo	Monomorium floricole
Parlong	Paratrechina longicornis
Parvag	Paratrechina vaga
Phemeg	Pheidole megacephala
Tapmel	Tapinoma melanocephalum
Tetsim	Tetramorium simillimum

Note: SB = sugar bait, PB = protein bait, H = collected by hand.

Appendix 4b - Ant sampling habitats and locations

Sample #	**Island and habitat**	**Grid**

1	Kanton latana weeds, rubbish	2°, 46.616'S; 171°, 43.039'W
2	Birnie campiste, 1330-1400hrs	
3	Orona Pemphis, Tournefortia scrub on lagoon, 0930-1000hrs	
4	Orona	
5	McKean southermost set of ruined walls, 1430-1500hrs	
6	Kanton village, church, coconut plantation	2°, 46.876'S; 171°, 42.950'W
7	Rawaki	3°, 43.383'S; 170°, 42.937'W
8	Birnie	
9	Kanton building and coconut palms	2°, 46.876'S; 171°, 42.950'W
10	Enderbury ruined USA buildings and lighthouse	
11	Nikumaroro	4°, 40.591'S; 170°, 32.294'W
12	Orona	
13	Nikumaroro	2°, 40.591'S; 170°, 32.294'W
14	Kanton	2°, 46.616'S; 171°, 43.039'W
15	Orona Scaevola scrub	
16	Orona beach scrub, Scaevola	2°, 46.616'S; 171°, 43.039'W
17	Nikumaroro Scaevola, Guerterda, Pandanus	4°, 41'S; 174°, 32.294'W
18	Nikumaroro in Tamaru log	4°, 40.591'S; 170°, 32.294'W
19	Nikumaroro off coconut frond brought onto boat	
20	Nikumaroro	
21	Orona Scaevola scrub	
22	Enderbury	
23	Orona under house rubbish	
24	Rawaki	
25	Orona	
26	McKean under rock, colony	

Note: Habitat and site data to come for some sites

Appendix 5 - Results of transects for establishing the density of hermit and other land crabs on five islands of the Phoenix Group, Kiribati, May-June 2006.

(*Coenobita perlatus* is a large red hermit living mainly in *Turbo* shells; Pallid Grapsid is *Geograpsus crinipes*; Kara'i (small grapsid) is *G. grayi*; Small Grey Hermits are unidentifiable juveniles of *Coenobita* spp.).

Island	Date	Time	Location	Area	Results	Nos/ha	Remarks
Rawaki	20 April	2100-2200	Phoenix Petrel colony in *Lepturus* grass 03 43.309 S; 170 42.786 W	5 transects 20 sq. m each = 100 sq. m	11 crabs: 6 *Coenobita perlatus* 3 Pallid Grapsid 2 Kara'i (small grapsid)	1100 600 300 200	Single Coconut Crab *Birgus latro* seen (outside transects) on 2 nights Generally, most crabs found on edge of shallow lagoon in *Lepturus/Sesuvium*
Enderbury	22 April	2200-2300	In *Portulaca* behind beach and camp Camp: 03deg 08.385S 171deg 05.462W	9 transects 20 sq. m each = 180 sq. m	35 crabs: 34 *Coenobita perlatus* 1 Small Grey Hermit	1945 1889 56	
McKean	28 April	1600-1700 2100-2200	*Tribulus* behind camp Camp: 03deg 35.773S 174deg	5 transects 20 sq. m each = 100 sq. m 10	46 crabs: 46 *Coenobita perlatus* 49 crabs 49	4600 4800 2450 2450	Single Chocolate Hermit *C. cavipes* seen in wall at camp Sparse colony of Butcher Crabs *Cardisoma* found

			07.535W Ditto	transects 20 sq. m each = 200 sq. m	*Coenobita perlatus*		on edge of shallow lagoon at south end in *Portulaca/Sesuvium*
Island	**Date**	**Time**	**Location**	**Area**	**Results**	**Nos/ha**	**Remarks**
Orona	3 May 4 May	2100-2200 0930-1030	Camp in old settlement GPS 04deg 31.169S 172deg 13.453W Ditto	10 transects 20 sq. m each = 200 sq. m Ditto	1 crab: 1 *Coenobita perlatus* NO CRABS	50 50 0	Many Small Grey Hermits active around camp in late afternoon Many Butcher Crabs *Cardisoma* in swampy areas near lagoon One Pallid Grapsid seen
Nikumaroro	5 May	1500-1600 2000-2100	Beach camp to derelict house in coconuts Camp 04deg 40.552S 174deg 32.278W Ditto	10 transects 20 sq. m each = 200 sq. m 15 transects 20 sq. m each =300 sq. m	NO CRABS 18 crabs: 12 *Coenobita perlatus* 5 *Cardisoma* 1 *Birgus latro*	0 600 400 167 33	No sign of crabs anywhere during day

Appendix 6 - Morphometric measurements and condition of invasive mammals Phoenix Islands 2006

Island	Species	No.	Mean body length (snout – pelvis, mm)	Mean weight (g)	Breeding status (no. animals)	Kidney fat
Rawaki (rabbit)	male female juvenile female juvenile male	7 17 2 0	374.3 383.8 290 -	1254.3 1339.1 627.5 -	- none - -	- none to moderate - -
McKean (Asian ship rat)	male female juvenile female juvenile male	7 11 2 1	155.3 163.1 128 146	144.6 146.4 80 117	- embryos (1) - -	- none none -
Enderbury (Pacific rat)	male female juvenile female juvenile male	2 4 1 -	128 126.3 115 -	53.7 54.3 35 -	- none - -	- none - -
Nikumaroro (Pacific rat)	male female juvenile female juvenile male juvenile – unknown	1 - 1 - 1	142 - 123 - 105	86 - 42 - 45		

Appendix 7 - Phoenix Islands Conservation Survey 2006 Marine Survey Report

Phoenix Islands Conservation Survey 2006
Marine Survey Report

Vince Kerr[1] and Graham Wragg[2]

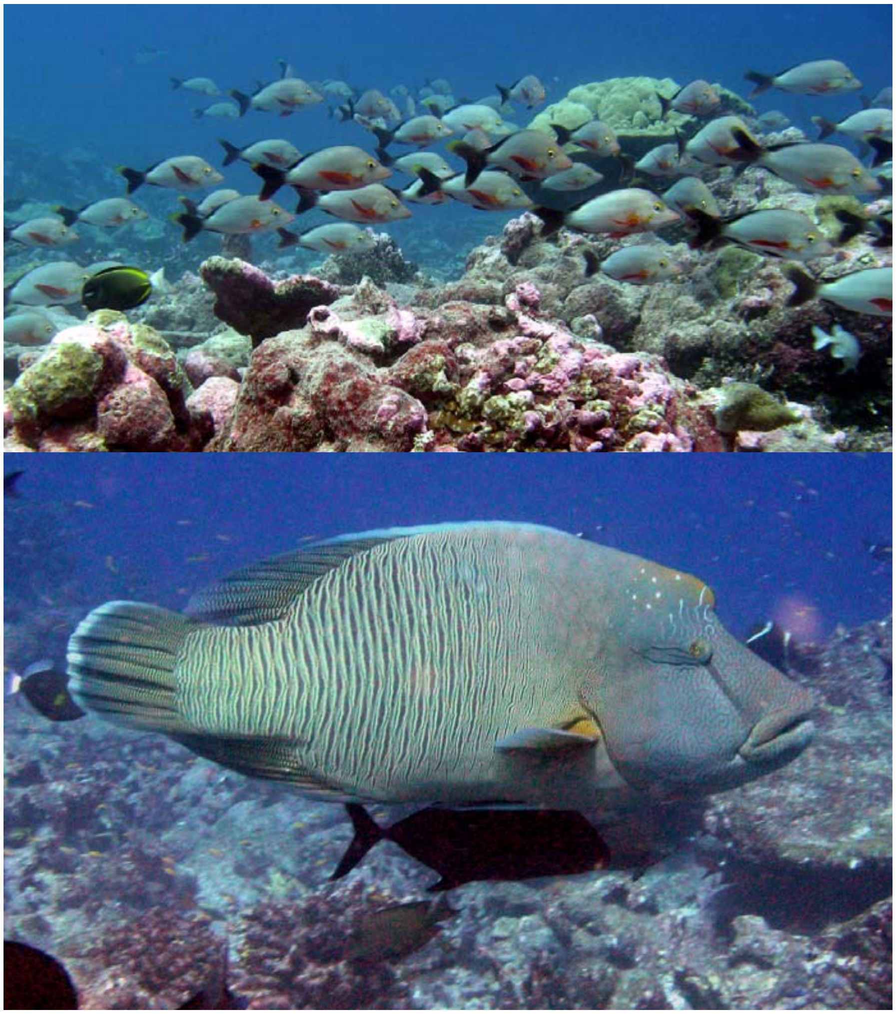


Photo: Paddle tail snapper at Orona (top), Humphead wrass at Nikumamoro (Bottom)

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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

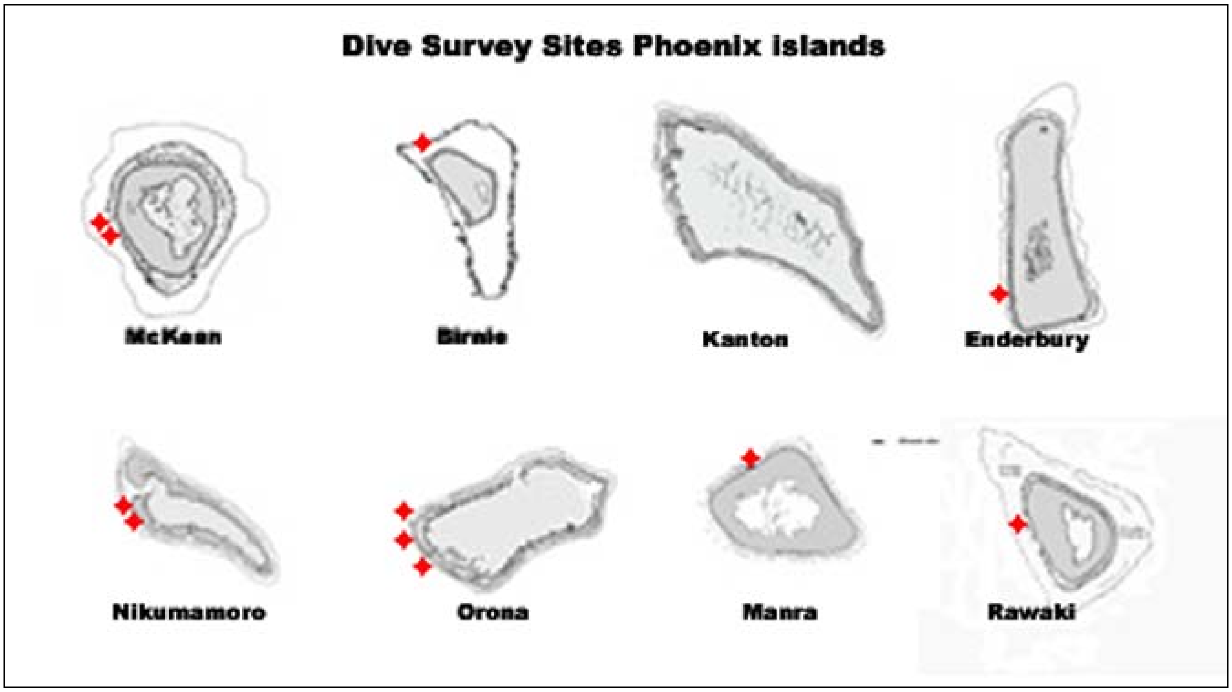

Figure 1. Composite map of Phoenix Islands dive sites (indicated in red)

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.

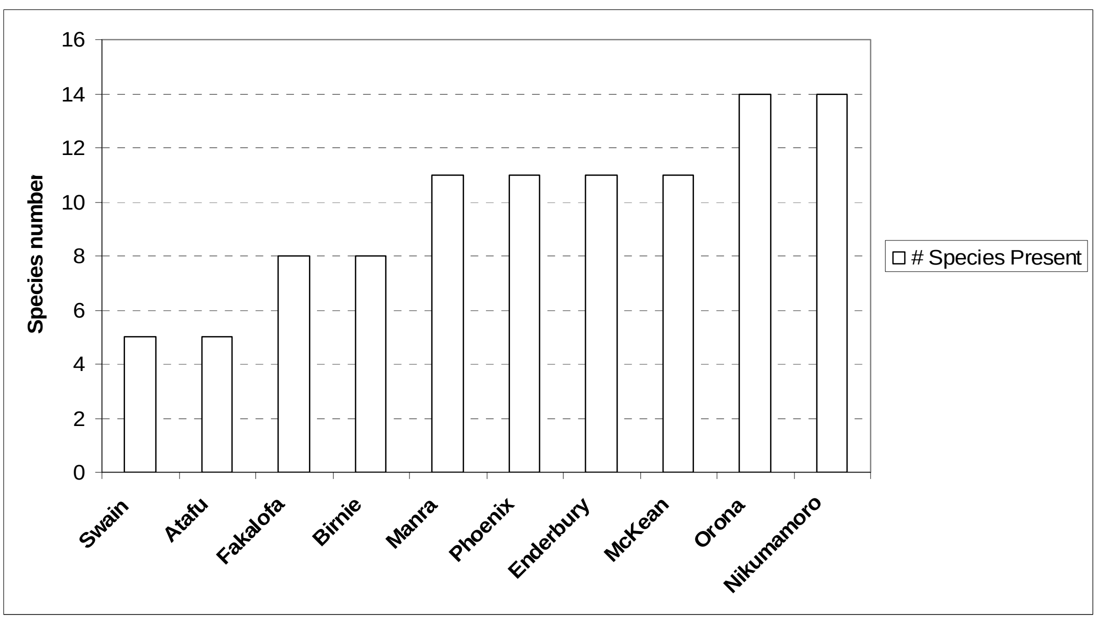

Figure 2. Species present in rapid survey counts, 30 minute swims for each island

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.

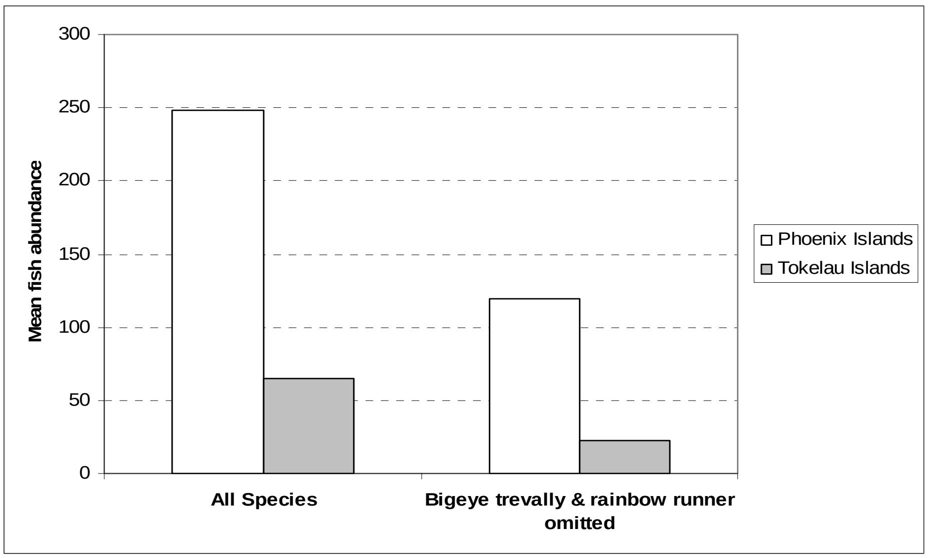

Figure 3. Comparison of Tokelau and Phoenix Island mean indicator fish abundance, 30 minute swims

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.

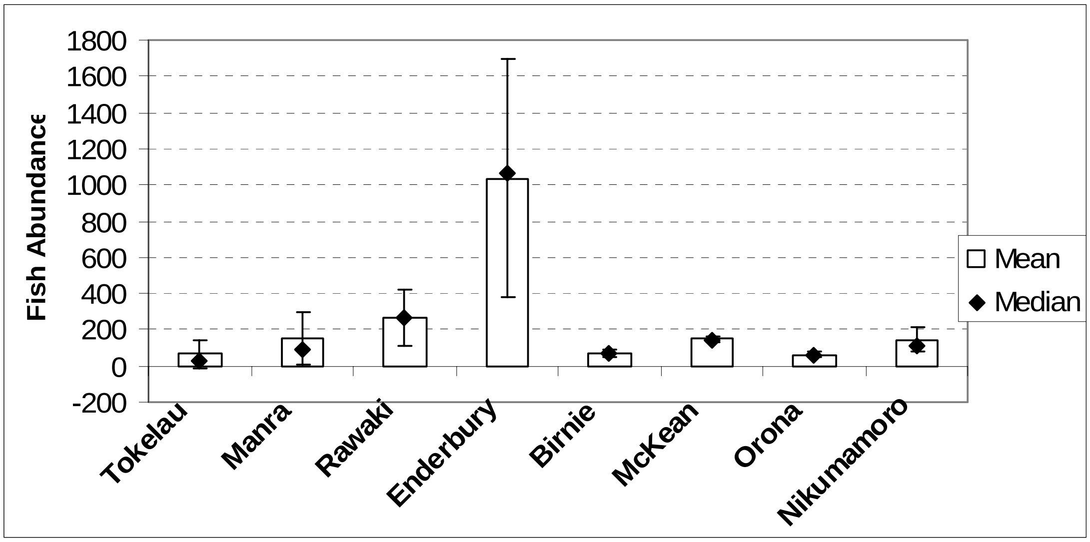

Figure 4. Comparison of Tokelau and individual Phoenix Island indicator fish abundance, all species (plus or minus SE), 30 minute swims

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.

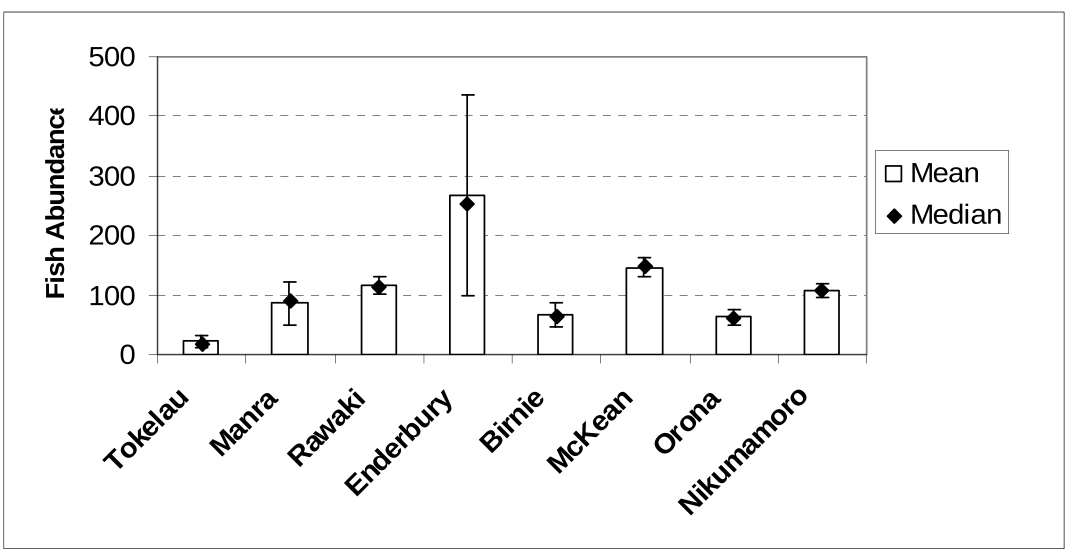

Figure 5. Comparison of Tokelau and individual Phoenix Islands indicator fish abundance with bigeye trevally and rainbow runner omitted from the analysis (plus or minus SE), 30 minute swims

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.

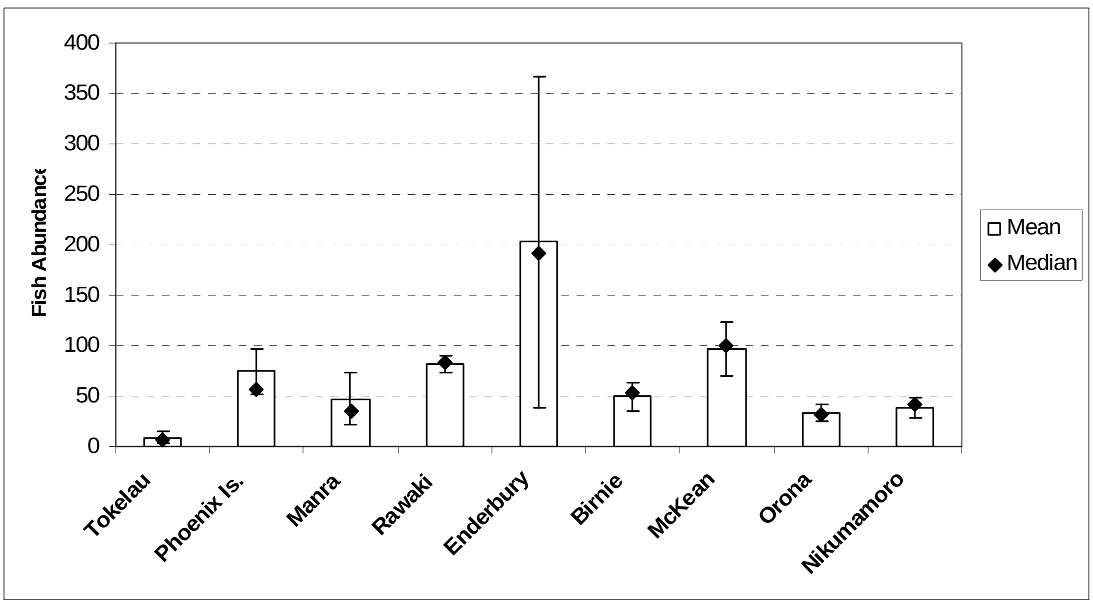

Figure 6. Mean abundance of twin spot snapper (plus or minus SE), Island group means and individual island means, 30 minute swims

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.

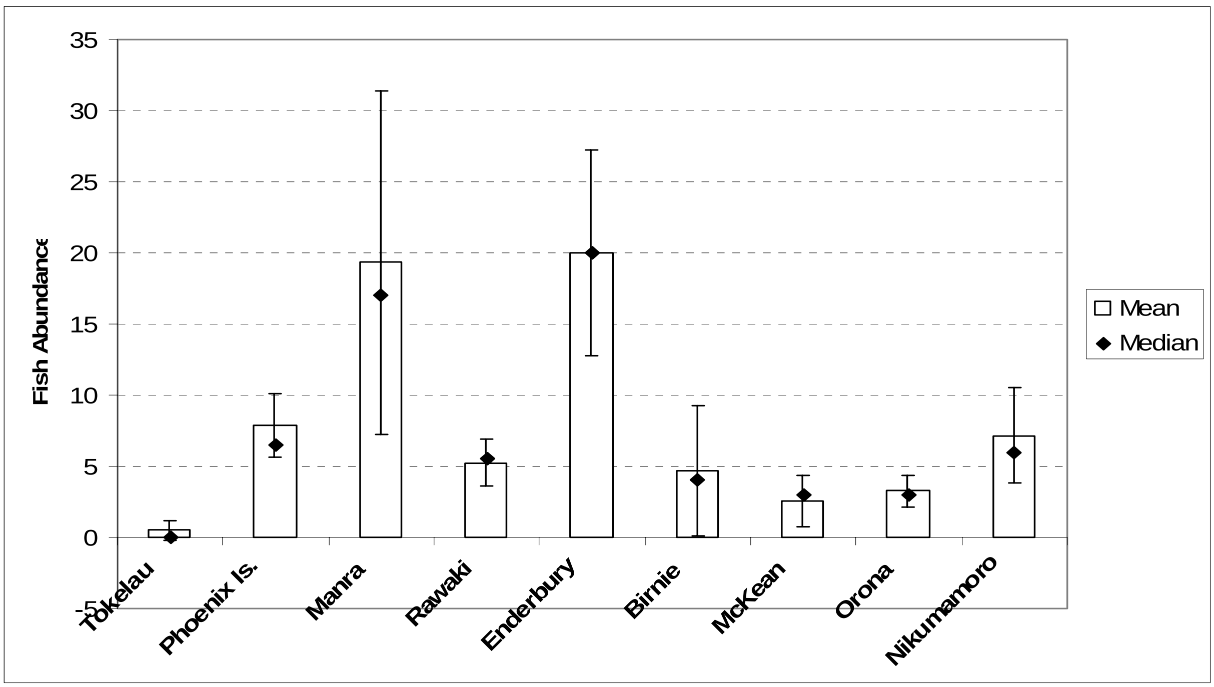

Figure 7. Mean abundance of combined shark species (plus or minus SE), Island group means and individual island means, 30 minute swims

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.

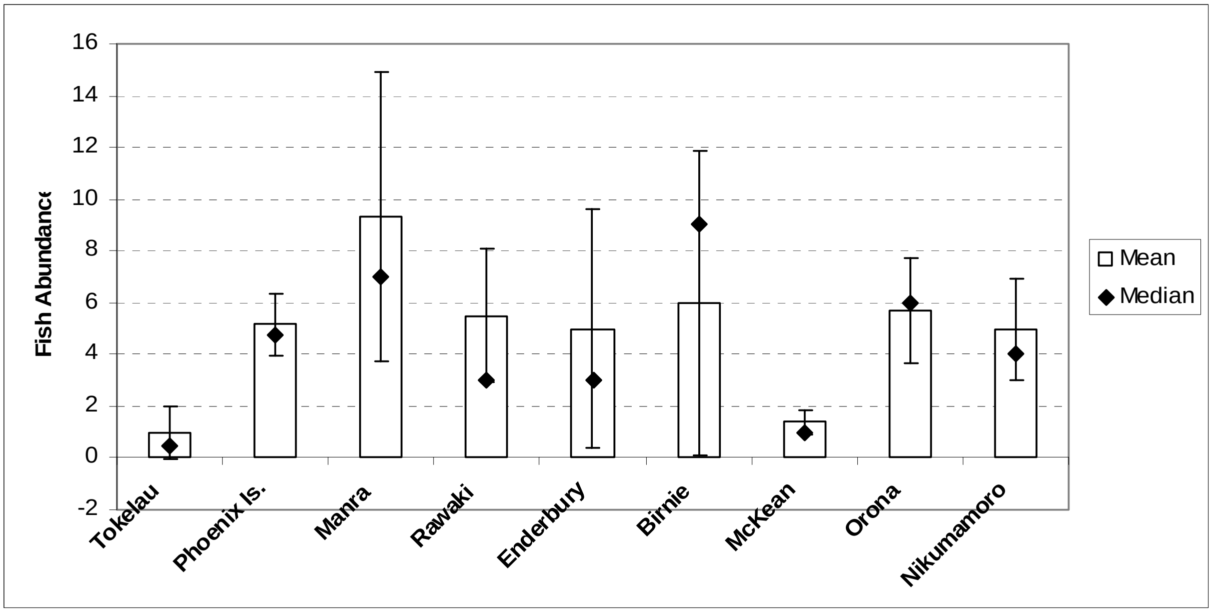

Figure 8. Mean abundance of napoleon wrass (plus or minus SE), Island group means and individual island means, 30 minute swims

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.

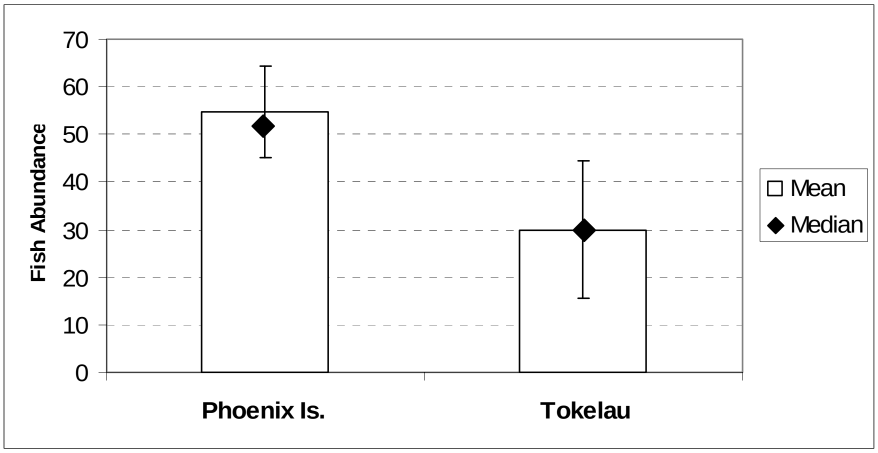

Figure 9. Mean fish abundance all families combined for island groups on 150m^2 transects

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.

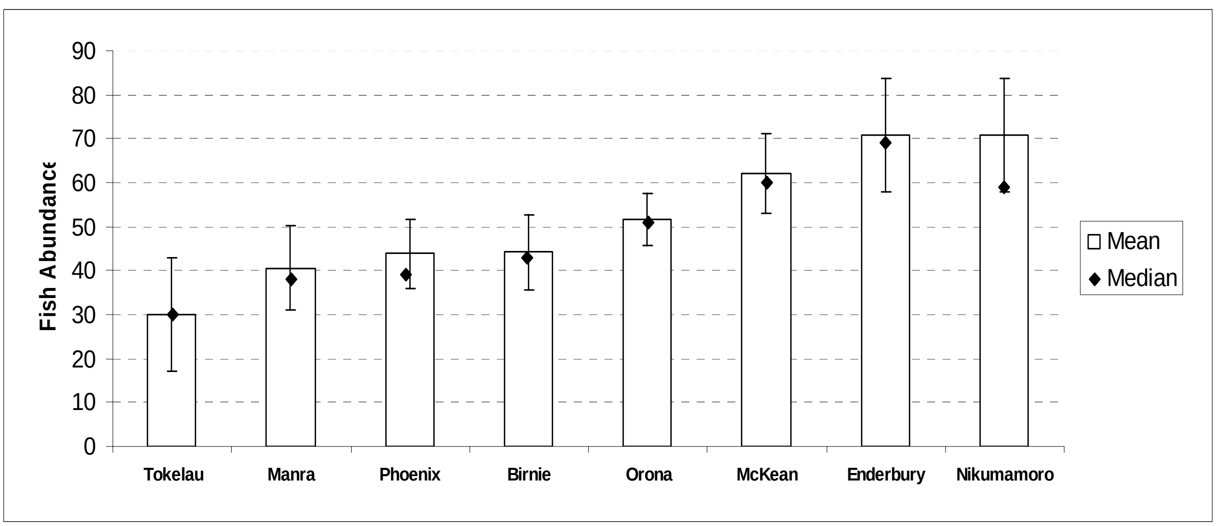

Figure 10. Mean fish abundance all families combined for Tokelau group and individual Phoenix Islands on 150m^2 transects

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.

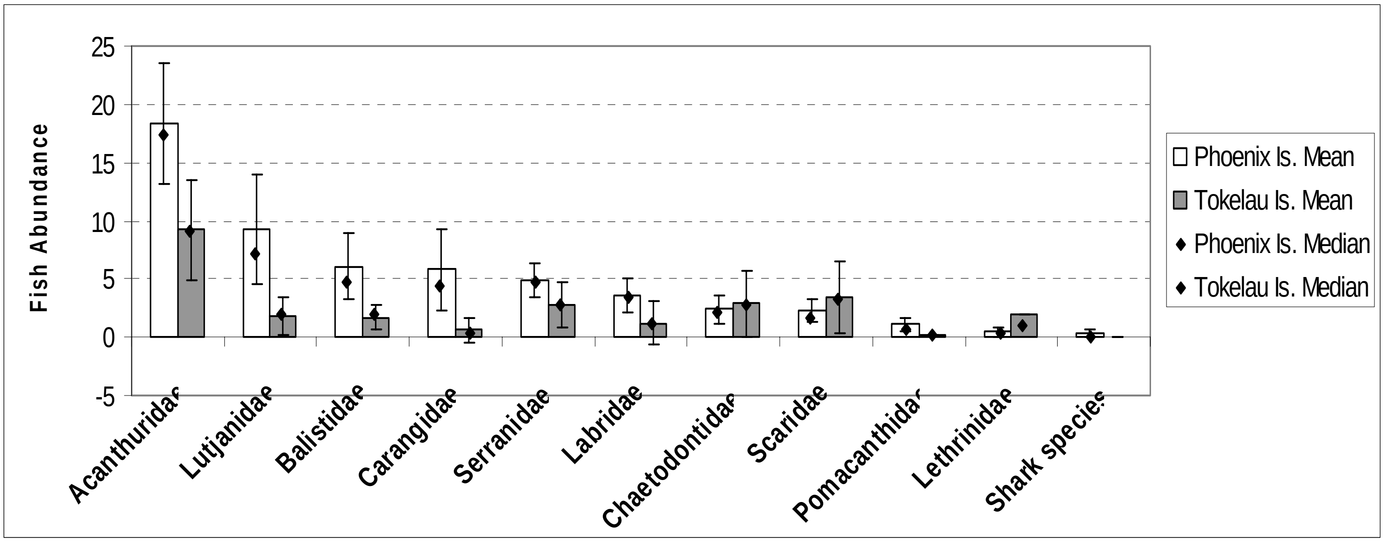

Figure 11 Abundance of key fish families for Phoenix and Tokelau Islands on 150m^2 transects**.**

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 252 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.

Acknowledgements

David Obura and Greg Stone provided recommendations on priority sites and methods prior to the survey which were greatly appreciated. Special thanks are due to the entire Bounty Bay crew and survey team for putting in all the extra effort which made it possible to tackle the marine survey work. Huub Van Buchen, the first mate of the *Bounty Bay,* delivered a sterling performance as our cook and contributed some valuable underwater photographs to the survey collection. Graham Wragg, captain of the *Bounty Bay* flawlessly put the boat where we wanted on every occasion, as well as fulfilling the role of the second survey diver. Ray Pierce, our survey leader, deserves credit for our result - his understanding and support for the marine work made it all possible. Thanks also to Jessica Kerr who did proof reading of this manuscript. Lastly a special thank you is due to our research vessel the *Bounty Bay* - she rose to all challenges and got us home.

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