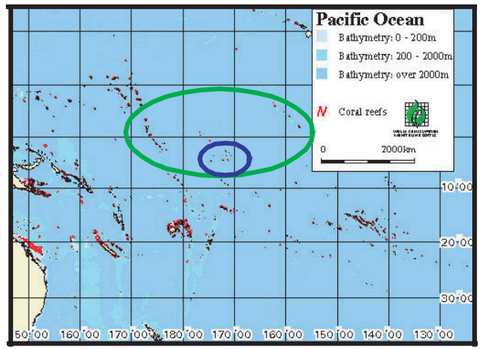


The Phoenix Islands are the central island group of the Republic of Kiribati, which covers over 5.5 million square kilometres of the central Pacific Ocean (in green). Kiribati has a population of 90,000 people of Micronesian origin, and comprises three island groups - the Gilbert Islands or Tungaru Group to the west, the Line Islands (including Kiritimati Island) to the east, and the Phoenix Islands in the center (in blue). The Phoenix Group includes ten islands with two submerged reef systems and is one of the remotest island groups in the Pacific, almost 1,000 kilometers from other islands to the north, south, east and west.

Primal Ocean Project Technical Report: NEAq-03-02
New England Aquarium
Boston, Massachusetts
USA

New England Aquarium

BERMUDA UNDERWATER EXPLORATION INSTITUTE

CONSERVATION INTERNATIONAL

CORDIO East Africa

PHOENIX ISLANDS

Summary of Marine and Terrestrial Assessments Conducted in the Republic of Kiribati, June 5 - July 10, 2002

New England Aquarium

Editors:
David Obura
and Gregory S. Stone

Phoenix Islands

Summary of Marine and Terrestrial Assessments Conducted in the Republic of Kiribati, June 5-July 10, 2002

Editors:

David Obura and Gregory S. Stone

Contributors:
Mary Jane Adams, Jerry Allen, Steven Bailey, Rob Barrel, Cat Holloway, Alistair Hutt, Sangeeta Mangubhai, Paul Nielson, Austen Yoshinaga

Primal Ocean Project Technical Report: NEAQ-03-02

Contacts:
New England Aquarium
Central Wharf, Boston, MA 02110, USA
Tel: (617) 973-5229; Fax: (617) 973-0242
dobura@cordio.info, gstone@neaq.org

New England Aquarium

Bermuda Underwater Exploration Institute

Conservation International

CORDIO East Africa

EXECUTIVE SUMMARY

Coral reef, deep ocean and terrestrial surveys were conducted during 25 days of field work in the Phoenix Islands, Republic of Kiribati, with additional surveys of marine mammals during the 9 days of passage to and from Fiji. This study builds on an earlier survey conducted in 2000. Islands visited in 2002 included Nikumaroro, Manra, Kanton, Enderbury, Orona, Birnie and Phoenix, leaving out McKean which was surveyed in 2000. This report summarizes the results of the expedition, with detailed results being prepared for individual components for separate publication.

Coral reefs were surveyed with a variety of methods that documented reef structure, benthic community structure, coral, invertebrate and reef fish diversity and abundance, shark and large-fish populations, and megafauna abundance. Taxonomic collections were made of corals, invertebrates and fishes, and genetic tissue banking samples were collected of deep-water fauna, reef fishes and dolphins. Marine mammal surveys were conducted on ocean crossings, and deep-water surveys were conducted using a 'drop-cam', an ROV (remotely-operated vehicle) and plankton tows. Island flora, birds and introduced species were surveyed.

The Phoenix Islands exhibit classic remote island and atoll characteristics, including steep reef drop-offs, relatively low species diversity coupled with endemicity, unusual species assemblages, high fish abundance, harsh island habitats and vegetation, and large seabird nesting colonies. Preliminary assessments of the coral fauna indicate range extensions of 2 species from the Eastern Pacific (*Pocillopora inflata, Pavona gigantea*) and at least one undescribed species. The total known fish fauna of the Phoenix Islands now stands at 518 species, including 217 new species records from the current expedition. We predict that at least 576 reef fish species, over 50 more than currently listed, can be expected to occur at the Phoenix Islands. A new species of damselfish, *Chrysiptera albata*, was collected in 42-50m depth at Nikumaroro Island. Other potential undescribed species were found in the genera *Myripristis* (Holocentridae), *Eviota* (Gobiidae), and *Trimma* (Gobiidae). High turtle nesting frequency is confirmed for the islands. The waters surrounding the Phoenix Islands were surprisingly devoid of large marine mammals, with few sightings of dolphins and none of large whales. Seabirds are the most notable terrestrial fauna, with the islands (particularly Phoenix I.) hosting significant breeding populations of boobies, frigatebirds, tropicbirds, noddies and terns, and some winter migrants.

The islands have a sparse and simple vegetation cover, with no open freshwater, and groundwater on only the larger islands. Significantly, mangroves are totally absent from the island group. The islands show the typical legacy of temporary and sporadic human use and settlement over several hundreds of years, with significant species introductions, both of plants (*e.g.* coconuts) and animals (*e.g.* rats, rabbits), and remnants of guano mining. None of the islands have hosted long term human settlements due to the paucity of terrestrial and freshwater resources.

The most significant finding of the expedition, with relevance to the long term viability of the island ecosystems, relates to the impact of recent fishing and the depletion of sharks, and to a lesser extent tuna. Shark fishing has occurred from two sources. First, a government resettlement scheme placed 200 people on Orona, starting in early 2001, to harvest island resources, particularly copra from coconut plantations, and sharkfin. Second, for a period of about 9 months in 2001, a foreign fishing boat was allowed to harvest sharkfin by longlining around the islands Kanton, Orona, Manra and Phoenix. As a result of this fishing, the frequency of blacktip reef shark (*Carcharhinus melanopterus*) sightings decreased from 64% of sites in 2000 to 16% in 2002. Shark densities at fished islands were significantly lower than at those that were not fished (0.05±0.1 per 150m^2 compared to 1.2±1.2 per 150m^2 respectively, T test, $p<0.001$). This demonstrates the extreme vulnerability of small-island populations to extraction lasting only a few months, and should serve as an indicator of the vulnerability of the entire island group to growing human resource use and threats.

ACKNOWLEDGEMENTS

We would sincerely like to thank the Government of Kiribati for approving a permit for the expedition, and in both years providing an observer to participate in the expeditions. We thank the Honorable Minister of Natural Resources and Development Tetabo Nakara for his time, support and interest in this project. We thank Tukabu Teroroko, Permanent Secretary for Natural Resource Development, and Maruia Kamatie, Acting Deputy Secretary, Ministry of Natural Resources Development, for help in arranging this expedition and for advice and counsel. We are also grateful to Mr. Ekati Tokarake and the residents of Kanton and Orona islands for welcoming us so warmly to their communities and showing us the islands. We thank Kandy Kendall for the original support, inspiration and vision to help launch this project in the year 2000 with the first expedition. We thank the trustees and staff of the Bermuda Underwater Exploration Institute for support and cooperation on this project and for a shared vision of stewardship and exploration of the oceans. We thank the National Geographic Society, the New England Aquarium, the Oak Foundation, Coral Reef Degradation in the Indian Ocean, NAI'A Cruises, New Zealand Department of Conservation, and Conservation International for support and cooperation. We thank MARES-DACOR© for the generous donation of diving gear which was invaluable during the 1000 SCUBA dives we logged. We thank the National Geographic photographers, Paul Nicklen and Joe Stancampiano, who accompanied us on this trip for their companionship, good humor, expertise in repairing equipment and terrific photographs. We thank New England Aquarium President Ed Toomey for his enthusiastic support of this research. This project would not have been possible without the help of many people including Bill Allen, Leslie Harroun, Kent Kobersteen, Kathy Moran, Peter Miller, Heather Tausig, Cynthia Nichols, Catherine Fox, Lisa Spalding, Bruce Thayer, Vicki Hutt, Tim Werner and Scott Baker.

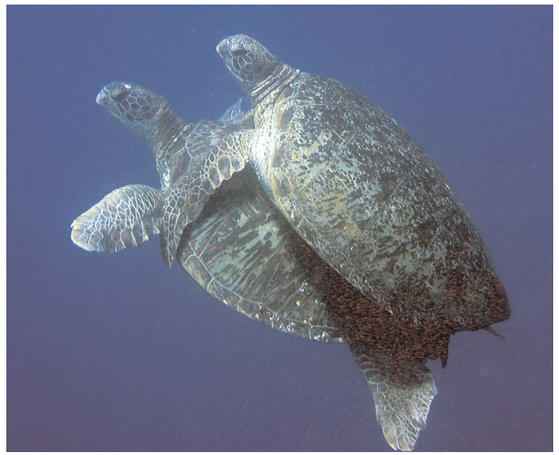
Photography by David Obura, Cat Holloway and Gregory Stone.

TABLE OF CONTENTS

INTRODUCTION

The Phoenix Islands are in the central island group of the Republic of Kiribati, with the Gilbert Islands or Tungaru Group to the west, and the Line Islands to the east. The Phoenix Group (174.8° W to 170.1° E Longitude and 2° to 8°S Latitude) comprises eight islands with two submerged reef systems. Two outlying islands north of the equator, Baker and Howland, are United States dependencies. Located over one thousand nautical miles north of Fiji, these are among the remotest islands in the South Pacific. All but 2 of the islands are currently uninhabited, though human settlements and use of the islands have been sporadic for over 150 years. The islands are therefore expected to be free of the degrading influence of fishing and coastal development and resemble near-pristine ocean conditions.

The scientific literature on the Phoenix Islands is limited (Lovell *et al*. 2000, Stone *et al.* 2001), and is primarily derived from survey expeditions during the last century and assessments related to military use and decommissioning of the islands following the Second World War (Degener and Gillaspy 1955, Degener and Degener 1959), the Smithsonian Institution's Pacific programme and the first collection of fish from the island group in 1939 (Schultz 1943) and limited marine assessments of Kanton Atoll in the 1970s and 80s (Maragos and Jokiel 1978, Jokiel and Maragos 1978, Maragos and Jokiel 1986). The first full account of the marine environments of the whole archipelago was compiled by the Phoenix Islands Expedition of the New England Aquarium in 2000 (Box 1; Stone *et al*. 2001, in review, South *et al*. 2002). Terrestrial and seabird studies were conducted extensively in the 1960s and 70s by the Smithsonian Institution and reported in the Atoll Research Bulletin (Clap 1964). More recently, The International Group for Historic Aircraft Recovery (TIGHAR) has conducted a number of expeditions to Nikumaroro Island searching for Amelia Earhart's plane wreckage hypothesized to have crashed there in 1937, resulting in some terrestrial and marine



Green turtles (*Chelonia mydas*) mating at Enderbury Island.

records (Holloway 1999, King *et al*. 2001). A report on economic options for the Phoenix Islands has been prepared by the Phoenix Islands Expedition (Mangubhai 2002) outlining the potential benefits and threats to the islands' biota from different types of resource use and development.

The Primal Oceans initiative of the New England Aquarium (USA) has as its goal to study and conserve parts of the oceans, such as the Phoenix group, that are as yet untouched by human activities and in their 'primal' state. Together with NAI'A Cruises, this is the second expedition organized to the Phoenix Islands. The goal of the more extensive second expedition was to deepen knowledge of the marine environments in this 'primal area', and in particular to anticipate growing threats from local and global threats such as fishing and climate change. The expedition was organized through consultations with the Ministry of Natural Resources Development of the Government of Kiribati, in order to provide the government with information useful for management of the islands and safeguarding the valuable marine heritage of the nation.

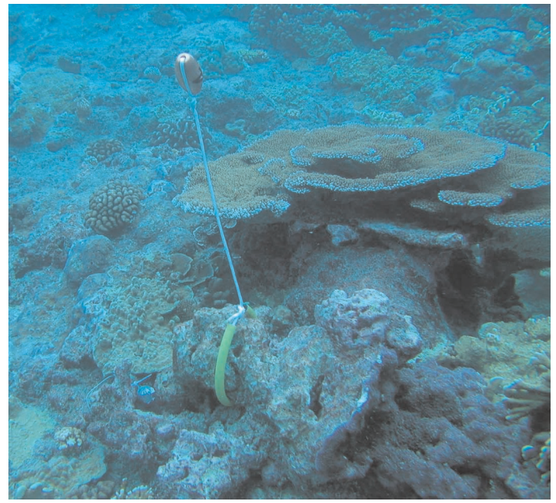
Box 1. Major findings and recommendations of the first Phoenix Islands Expedition, 2000 (Stone *et al.* 2001).

The reefs show classic features of small remote atoll islands, including:

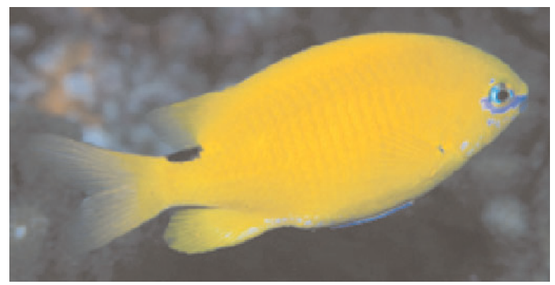
- extreme exposure to surf and storms on three-quarters of the island perimeters;
- endemicity of marine fauna and unusual species assemblages of reef organisms (algae, corals and fishes);
- relatively low species diversity but high abundances of normally minor species;
- almost negligible evidence of threats, including crown-of-thorns seastars and coral bleaching, and total absence of fishing impacts – in stark contrast to other reefs in Kiribati and tropical countries accessible to human populations, large predators, particularly sharks, trevally, tuna and humphead maori wrasse were abundant;
- marine mammal populations were surprisingly low;
- green sea turtles were abundant in the waters, with evidence of nesting on most islands;
- deep-sea surveys recorded the first distribution records of sixgill (*Somniosus pacificus*) and Pacific sleeper (*Hexanchus griseus*) sharks for this part of the Pacific;
- seabirds were abundant throughout the islands, with extensive nesting colonies.

Recommendations included comprehensive proposals for developing a far-sighted strategy for conservation and research of the island group with the objective of ensuring the integrity of the island ecosystems and the values they can provide to Kiribati and its people in a sustainable future. Further studies to document the resources and biodiversity and quantify their potential for sustainable use were proposed as a foundation, with the development of innovative management and financing strategies and evaluation of fishing and ecotourism potential and limits.

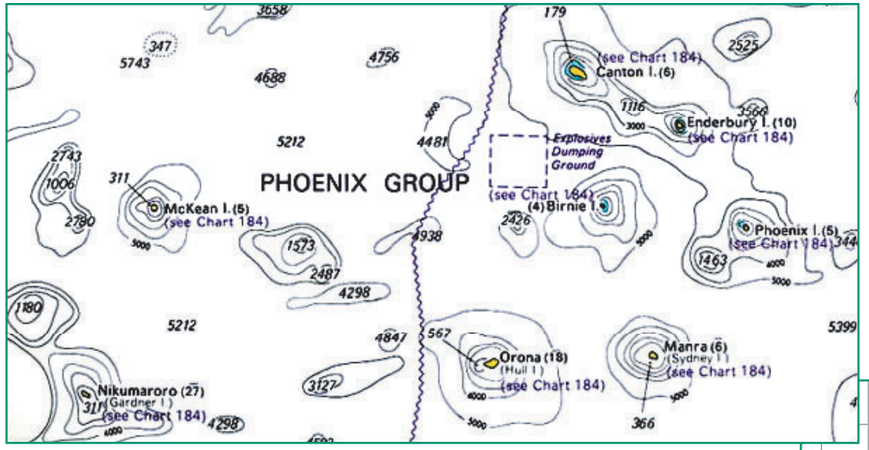
The expedition embarked from Lautoka, Fiji, on 5 June, 2002, and returned on 10 July, 2002 (Figure 1). Nine days were spent on ocean passage, with 25 days in the islands for island and reef surveys (Table 1). The expedition comprised 10 scientists, 2 photographers from the National Geographic Society, 1 Kiribati Government representative and 13 crew.

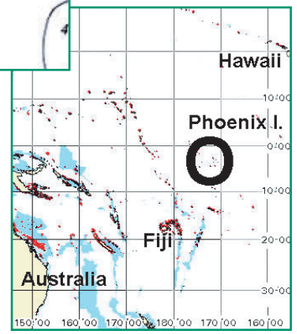


Temperature loggers deployed in the Phoenix Islands.



Stegastes aureus





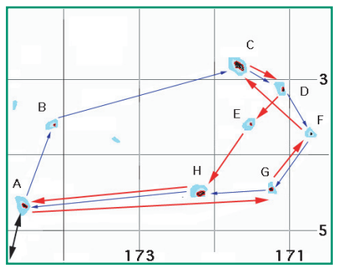
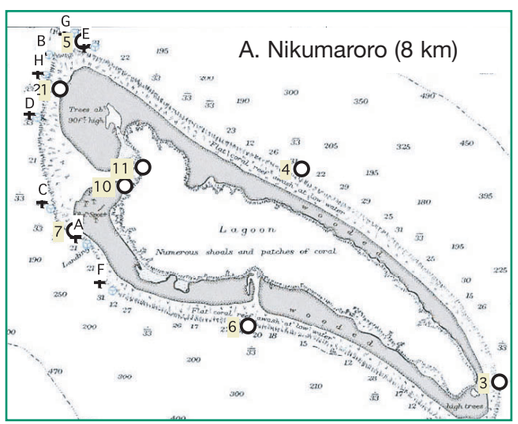
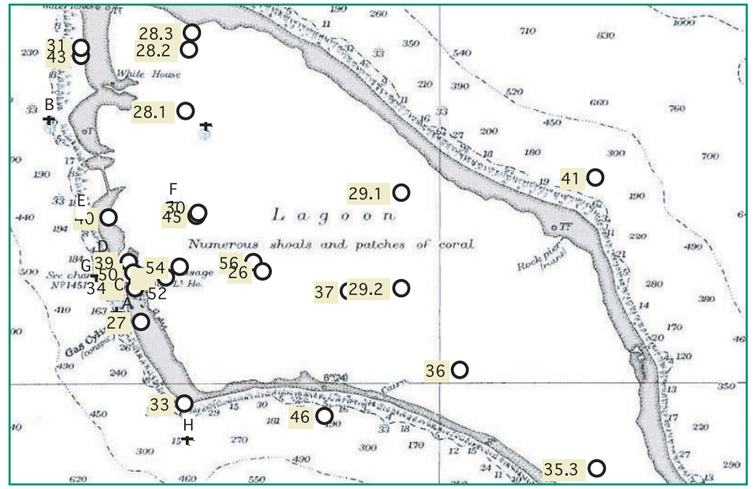


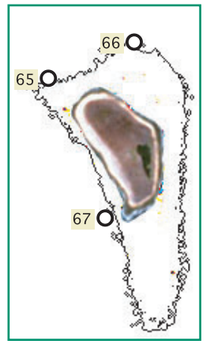
Figure 1. The main map (above), locator map (right) and itinerary (below right) show the geographic spread of the islands and the expedition routes in 2002 (thick red lines) and 2000 (thin blue lines), and the entry and exit point to the group at Nikumaroro, from Fiji.

On this and the facing page, individual island maps are named (with letter-codes corresponding to the itinerary map). The approximate east-west width of each island (in kilometers) is given in parentheses. Survey sites are individually marked by GPS and coded: year 2000 sites by letters, 2002 sites by numbers (full details available from authors). *Map sources*: individual island maps scanned from British Admiralty charts, except for Birnie, which was adapted from a LandSat image and Reefbase/WCMC.

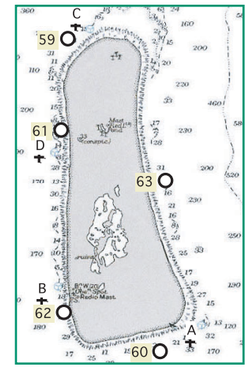


B. McKean
(1 km)

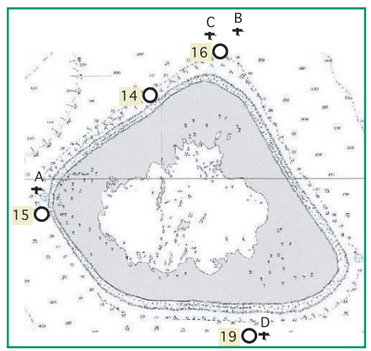




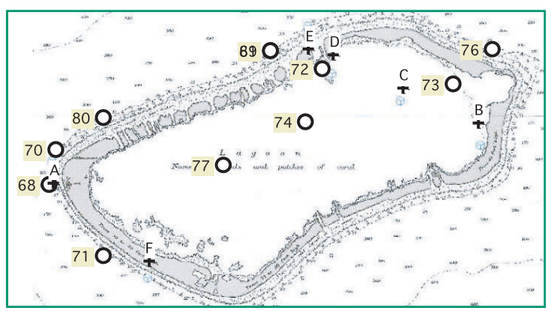
E. Birnie
(0.5) km)



G. Manra
(4 km)



H. Orona
(8 km)



MARINE SURVEY RESULTS

Coral Reef Survey Sites (*David Obura, Sangeeta Mangubhai*)

Geographic coordinates of all sample sites were recorded using handheld GPS, along with observations on wave exposure, visibility, and weather conditions. The location of permanent monitoring stations were further detailed with sketch maps.

Sixty reef sites were sampled during the expedition, in 92 dives (Table 1), compared to 36 sites in year 2000. Thirty-one sites were monitored using rapid assessment techniques, 10 using permanent monitoring techniques, and temperature loggers were set at 5 of the latter (Table 2).

The majority of survey sites were leeward reefs (42%), due to better accessibility and proximity to the NAI'A's anchorage with even sampling of windward and lagoon sites (27%; Table 3, Plate 1).

Hobo Tidbit loggers (Onset Computer Corp, USA http://www.onsetcomp.com) were deployed for recording seawater temperature. These were placed at permanent monitoring stations (Table 2), and marked with underwater buoys <1m off the bottom. The loggers were set with a sampling frequency of 1 hr 36 min, giving a potential sampling time of 2168 days, or 5.94 years (the batteries last 5 years). Placement of loggers was selected to record conditions at the reef edge (15m) at multiple leeward sites, in shallow and deeper zones at one of these

Table 1. Islands visited during the second Phoenix Islands Expedition, showing sampling for coral reef, islands and birds, and deep sea samples.

Island	Start date	#days	#sites	#dives	Island/bird	Deep sea
Nikumaroro	10-Jun-02	6	10	19	Y	2
	4-Jul-02	2				
Manra	15-Jun-02	2	4	7	Y	1
Phoenix	17-Jun-02	1	3	3	Y	0
Kanton	18-Jun-02	9	24	40	Y	3
Enderbury	27-Jun-02	2	5	6	Y	0
Birnie	29-Jun-02	1	3	3	Y	0
Orona	30-Jun-02	4	11	14	Y	3
TOTAL		25	60	92		

Table 2. Rapid assessment and permanent monitoring sites established in the Phoenix Islands, 2002. Permanent sites at which temperature loggers were deployed marked by a number indicating the depth in meters of logger deployment.

Island	Site	Permanent	Rapid Assessment	Island	Site	Permanent	Rapid Assessment
Kanton	British Gas		X	Nikumaroro	Amelia's Lost Cswy	X(15)	
	Coral Castles	X (5)			Electra Landing		X
	Crash Landing		X		Nai'a Point		X
	Lagoon Pass A		X		Turtle Nest Beach		X
	Oasis		X		Windward Wing	X(15)	
	President Taylor		X	Manra	Harpoon Corner	X	X
	Roller Coaster		X		Northern Exposure		X
	Satellite Beach	X(5 15,37)	X		Northern Lee		X
	Six Sticks	X	X		Wild Side		X
	Steep To		X	Enderbury	Lone Palm	X	X
	Weird Eddie		X		Mystery Wreck		X
	Small Channels		X		Obs Spot		X
	The Far Side		X		Shark Village		X
					Southern Ocean		X
Orona	Aerials		X	Phoenix	Deepwater	X(15)	
	Algae Corner	X	X		Farwater		X
	Dolphin Ledge	X	X		Stillwater		X
	Small Channels		X	Birnie	Prognathus Point		X
	The Far Side		X		Puff Magic		X
					Rock 'n' Roll		X

Table 3. Number of sites by exposure by island, Phoenix Islands.

Island	Leeward	Windward	Channel	Lagoon	Total
Birnie	1	2			3
Enderbury	4	2			6
Kanton	15	4	2	19	40
Manra	5	2			7
Nikumaroro	7	10	1	1	19
Orona	5	4		5	14
Phoenix	2	1			3

(5 and 37m), windward reefs (Nikumaroro, Windward Wing) and a lagoon (Kanton, Table 2).

Water temperatures during the expedition was very stable at an average of 29.4°C, a maximum of over 30°C recorded only in shallows and when snorkeling, and a minimum of 26.7°C at Nikumaroro.

Coral Reef Community Structure (*David Obura*)

The community structure of Phoenix Islands reefs was sampled using visual assessment methods to define overall reef structure and habitats, with video transects collected at 10 permanent monitoring sites for detailed assessments and to detect long term trends. Visual assessments were done on multiple, approximately 10m², areas per reef zone, estimating cover of rubble, sand, coralline algae, turf, macroalgae, *Halimeda*, hard coral, soft coral, zooanthids/anemones and sponges. Fifteen-minute video transects were recorded at sites selected for permanent monitoring, restricted to the edge and platform reef zones, from 12-15m depth.

Results

Visual assessment and description of site profiles were done for 57 sites (Table 4), out of which 10 sites were selected for permanent monitoring stations. Typical reef structure comprised 4 zones, from deep to shallow (Figure 2), with 2 additional zones on islands with lagoons (Plate 2):

- **Reef slope** (Plate 2A) – between 60-85° slope, surveyed from 20 to 50m deep, and extending beyond the range of visibility to > 100 meters depth. Upper slopes tended to have high cover of rubble and *Halimeda*, some with up to 60-70% coral cover. Soft corals were common, dominated by leathery forms.
- **Reef edge** (Plate 2B) – transition between the steep slope and the near-horizontal shallow platform, about 12-20m deep.
- **Shallow platform** (Plate 2C) – from 12-20m at its deep edge, to the shallow surge zone at 5-6m. Depending on wave exposure, it can be covered with hard and soft coral growth with close to 100% cover in patches, or dominated by rubble and coralline algae on wave exposed slopes.
- **Surge zone** (Plate 2D) – extends from 4-6m to the surface, and typically cut into buttresses and surge channels with up to 3m vertical relief.

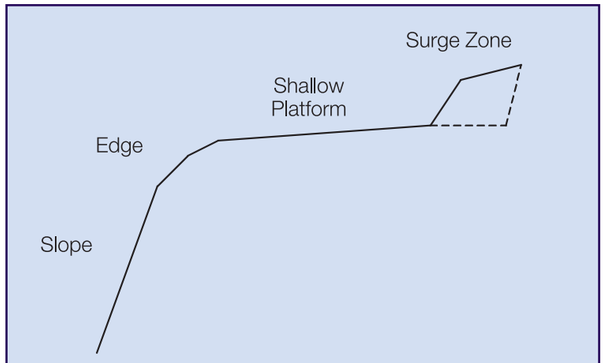


Figure 2. Profile typical of Phoenix Islands reefs.

Table 4. Number of sites sampled by visual assessment for each island, by exposure.

Island	Leeward	Windward	Lagoon	Channel
Birnie	1	2		
Edenbury	3	2		
Kanton	6	4	12	1
Manra	1	2		1
Nikumaroro	1	4	1	1
Orona	3	2	5	
Phoenix	1	1		
Total	16	17	18	3

On Nikumaroro, Orona and Kanton Islands two additional zones were recorded:

- **Channels** (Plate 2E) – shallow for Orona and Nikumaroro (<1m), and deep (10m) in Kanton.
- **Lagoons** (Plate 2F) – characterized by soft silty bottoms with raised rocky features on which grow corals, algae and encrusting invertebrates. Maximum depths recorded were 4m (Nikumaroro), 12m (Orona) and 26m (Kanton). Extensive relict pillars and ancient reef structures are common in Orona and Kanton lagoons, while Kanton lagoon has some 'line reef' structures that run approximately north-south, topped by sand and rubble.

The following observations on reef structure of the Phoenix islands were made:

- Benthic communities differ between leeward and windward sides, typically with high coral cover on On Nikumaroro, Orona and Kanton Islands two additional zones were recorded:
- **Channels** (Plate 2E) – shallow for Orona and Nikumaroro (<1m), and deep (10m) in Kanton.
- **Lagoons** (Plate 2F) – characterized by soft silty bottoms with raised rocky features on which grow corals, algae and encrusting invertebrates. Maximum depths recorded were 4m (Nikumaroro), 12m (Orona) and 26m (Kanton). Extensive relict pillars and ancient reef structures are common in Orona and Kanton lagoons, while Kanton lagoon has some 'line reef' structures that run approximately north-south, topped by sand and rubble.

The following observations on reef structure of the Phoenix islands were made:

- Benthic communities differ between leeward and windward sides, typically with high coral cover on leeward slopes. Windward slopes tend to have large areas with low coral cover and high rubble cover, and on the reef slopes *Halimeda*, due to wave disturbance
- Lagoon communities were highly differentiated between Kanton, Orona and Nikumaroro. Kanton had the most highly developed lagoon, with four zones, one of which harbours profuse growth of *Acropora* tables. Lagoon structure was similar to that reported in the 1980s by Maragos and Jokiel (Jokiel and Maragos 1978, Maragos and Jokiel 1978)
- Algae Corner, Orona was reported in 2000 to be the only eutrophied site in the archipelago (Stone *et al*. 2001), a situation which persisted in 2002. Additionally, we recorded observations by the residents of Orona, that there is a high incidence of ciguatera in fish from this site, probably related to eutrophication and algal growth.
- Minor coral bleaching was observed, primarily in the lagoons of Kanton and Orona, where pale colonies were common, mainly of the genera *Echinopora, Goniastrea* and small numbers of *Acropora*. Water temperatures were noticeably warmer compared to 2000, though at the time of surveys the NOAA SST hotspot webpage (http://www.osdpd.noaa.gov/PSB/EPS/SST) showed only the beginning of a hotspot around the Phoenix Islands (about 2 weeks old). The hotspot remained stationary for over 3 months into August; however, we were unable to obtain any reports of the status of corals at this time.
- Predation scars from Crown-of-Thorns (COTS) were observed, though only 4 COTs were sighted in the whole expedition, 3 of them on Nikumaroro.

Coral Species Diversity (*David Obura*)

A species list of Phoenix Islands corals was built up by visual observation underwater, aided by collection of skeletons and a photographic record (Plate 3). Identification, collection and photography were conducted systematically on 62 out of approximately 90 dives, with collecting and photography conducted on other dives whenever a new or interesting coral was found.

Results

One hundred and eighty-two coral skeletons were collected, covering 24 genera in 9 families of hard corals. The collection may cover some 70-80 species once identifications are verified. This compares to a sparser collection of 35 corals in 2000, which numbered 32 coral species. The photographic database comprises some 930 images. *In situ* visual identification of corals included some 14 families, 38 genera and 186 taxon records out of 1,171 observations. The number of species will drop from 186 due to several uncertainties in data collection, probably to around 120 to 130. This species number compares to 13 families, 36 genera and 93 species identified in 2000 (Stone *et al*. 2001). For Kanton alone, 31 genera and 85 species were recorded by Maragos and Jokiel (1978, 1986), compared to some 120 species in this expedition.

Additional observations on the coral fauna include:

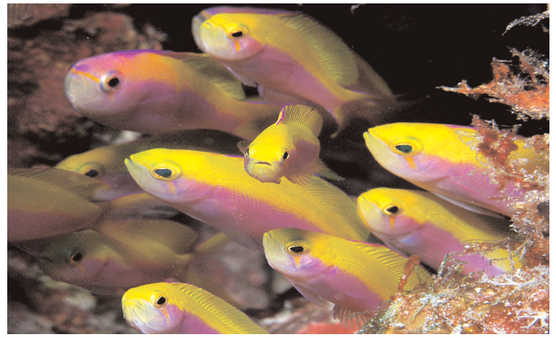
- Pocilloporidae – potentially, up to 12 distinct (though overlapping) growth forms of *Pocillopora* were identified, being most abundant and diverse at Nikumaroro and Manra. Similar diversity of forms was reported earlier (Jokiel and Maragos 1978), and improvements in taxonomy of the group (Veron 2000) may allow delineation of species from this expedition. Many of the records would represent significant range extensions, most notably from the Eastern Pacific (tentative identification of *P. inflata*) and a form only recorded from Madagascar (*P. fungiformis*) (Veron 2000), Plate 3C.
- An unidentified species of *Porites* from 2000 still remains unidentified.
- A number of new *Acropora* records were documented, and need to be confirmed. The *Acropora* communities of the Kanton lagoon (comprising tables and staghorn species) are exceptional in their physical development with stands of >80% cover covering hectares of lagoon floor, and dominated by *A. cytherea*, *A. hyacinthus*, *A. donei* and *A. irregularis*.
- *Pavona gigantea* – as with *Pocillopora inflata*, represents a range extension from the Eastern Pacific (Veron 2000).

Invertebrate Diversity and Abundance (Mary Jane Adams, Sangeeta Mangubhai)

The diversity of selected groups of motile invertebrates was catalogued through observation, photography and collecting. Emphasis was placed on molluscs, echinoderms and crustaceans. Collected specimens are lodged at the Natural History Museum of Los Angeles for identification and to add to their permanent collections. The primary method used was daytime visual observation, on SCUBA, of reef surfaces and searching under ledges, coral heads, rubble, macroalgae and sand and macroalgal stands, with photographic records when possible. Additional samples were collected during rotenone collections for fish (see Fish section), beach walking and night-lighting at the surface.

The abundance of important benthic invertebrate species was recorded using circular transects of 150m^2. The same sampling design and transects were used for fish abundance surveys (see later section). Sampling was conducted at two levels, for:

- rapid assessment, where two transects were under taken at each of 3 depth zones (steep slope, edge and shallow platform)



Pseudanthias bartlettorum

- permanent monitoring, where 6 transects were undertaken at 12-15m depth on the reef edge.

Invertebrate groups were chosen because of their importance as commercial or subsistence resources in Kiribati or the wider Pacific, or in the case of the crown-of-thorns and pincushion seastars, the potential impact on corals of elevated populations. The identity (where possible to species level), number and sizes of individuals were recorded.

Results

The motile invertebrate fauna of the Phoenix Islands was low in diversity, had a number of taxonomic gaps, and densities of large invertebrates were generally low (see Invertebrate Abundance). Echinoderms were the most diverse and prominent phylum sampled, though with low species richness, noticeable for all the major classes – seastars, sea cucumbers, brittle stars and sea urchins. Some species were abundant on all islands, such as the seastar *Linckia multifora* and in shallow waters, the urchin *Echinometra mathaei*. Two crown-of-thorns seastars, *Acanthaster planci*, and a small number of pincushion stars, *Culcita novaeguinea*, were seen, both of which are coral predators but with negligible impacts in the Phoenix Islands. The sea cucumbers *Bohadschia argus* and *Holothuria edulis* were present but rare on outer reefs, while *Holothuria atra* and *H. leucospilota* were common in lagoons. Brittle stars were common under dead coral and rubble, and in the bubble coral *Dictyosphaeria sp*. No basket stars or crinoids were seen by any member of the team. The collection of invertebrates is summarized in Table 5, and typical invertebrates are shown in Plate 4.

Mollusks were most strongly represented by bivalves and gastropods (snails). Nudibranch abundance and biodiversity was low, which may be attributable to a general paucity of sponges. No cephalopods were observed in 2002, though in 2000 they were seen during night dives.

Numerous small shrimp and crabs were collected from dead coral and algae, and nocturnally by light attraction at the surface. Rotenone used for fish collections also affected crustaceans and brittle stars and these were collected. Two goby-associated shrimp were observed at Kanton Island, *Alpheus djeddensis* and *A. rubromaculatus*. Two species of lobster were seen at Kanton Island. Numerous upside-down jellies, *Cassiopea andromeda*, were seen in Kanton and Orona lagoons, all less than about 3cm in diameter. No flatworms were observed.

Ten permanent monitoring sites were established, and 31 sites were monitored using rapid assessment techniques. General opportunistic searches were made at 32 of the sites surveyed. Sea cucumbers and mollusks had the highest numbers of species surveyed (Table 6). Densities of invertebrates were low at all sites (typically between 0 and 0.3 per 150m^2, with high values up to 4 per 150m^2), except at Orona lagoon, where *Tridacna spp.* clam densities could be as high as 10-15 per m^2, and a windward site at Orona (Mystery Wreck) where *Actinopyga sp.* was found at densities up to 21 per 150m^2. Orona lagoon also had high abundances of the sea cucumbers *Holothuria atra* and *H. edulis*.

Table 5. Summary of invertebrate collection. Over 250 sample containers were used,many containing multiple specimens.

GROUP	COMMENTS
Opisthobranchs	Thirty-two specimens, including pleurobranchs, cephalaspideans, phyllidiids, aeolids and dorids. The dorids were all very small.
Bivalve and univalve mollusks	Collected from numerous locations.
Seastars	Samples of *Linkia multifora* collected from each island. Two specimens were noted to have mollusk parasites. Four other asteroid species collected.
Holothurians	Two specimens.
Brittle stars	Multiple samples of three species.
Sea urchins	Collections made of *Echinometra mathaei* and *Echinostrephus molaris*
Polychaetes	Collected from dead coral.

Similar to findings of the year 2000 expedition, densities of invertebrates were very low (with the exception of Orona Lagoon), and therefore not commercially viable for extraction. The density of giant clams in Orona lagoon is the highest observed by the expedition scientists, and is particularly unique. Giant clams are currently harvested by I-Kiribati (Kiribati citizens) settled on Orona, for food. While clam populations are healthy and abundant at this point in time, uncontrolled or unmanaged collection for food will result in significant depletion or loss of this unique feature of Orona and the Phoenix Islands.

Table 6. Species recorded in the Phoenix Islands during the 2000 and 2002 expeditions. n/a = species not included in target list in 2000.

Groups	Species	2000	2002	Groups	Species	2000	2002
Sea cucumbers	*Actinopyga sp.*		Y	Mollusks	*Tridacna squamosa*	Y	Y
	Bodhad schia argus	Y	Y		*Tridacna maxima*	Y	Y
	Holothuria atra	Y	Y		*Tridacna crocea*	Y	
	Holothuria leucospilota	Y			*Pinctada ma garitifera*	n/a	Y
	Holothuria edulis		Y		*Lambi* spp.	n/a	Y
	Holothurian sp. X		Y		*Trochu* spp.	n/a	Y
Seastars	*Acanthaste plancii*	Y		Lobster	*Panulirus* spp.	Y	Y
	Culcita novaeguinea	n/a	Y				

Fish Diversity (*Gerald Allen, Steve Bailey*)

Method

A list of fishes was compiled for 56 sites, involving 163 hours of SCUBA diving to a maximum depth of 57m. Additional observations were made at depths between 60-183m using a ROV and Dropcam. The visual survey was supplemented with targeted collections using procured with rotenone, quinaldine sulphate, and rubber-propelled, multi-prong spears, for archiving at the Museum of Comparative Zoology, Harvard University and the Western Australian Museum, Perth.

Results

The fish fauna of the Phoenix Islands consists mainly of species associated with coral reefs (Table 7, Plate 5). The most abundant families in terms of number of species collectively account for 320 species or about 62 percent of the total reef fauna. The total known fauna of the Phoenix Islands now stands at 518 species, consisting of the following: 192 species originally recorded by Schultz (1943), 100 species recorded by the year 2000 expedition (Stone *et al*. 2001), 9 species recorded in various generic revisions, and 217 new species from the current expedition. A formula for predicting the total reef fish fauna based on the number of species in six key indicator families (Allen, unpublished data) indicates that at least 576 species, over 50 more than currently listed, can be expected to occur at the Phoenix Islands.

Species numbers at visually sampled sites ranged from 17 to 165, with an average of 109. Leeward outer reefs contained the highest fish diversity with an average of 134.6 species per site. Other major habitats included windward outer reefs (123.7 per site), passages (113.5), and lagoon reefs (38.5 per site). Certain species were particularly common on Phoenix Islands reefs, occurring in much higher densities than at most localities in the Indo-Pacific region. These included various surgeonfishes

Table 7. Number of species (#) in the top ten fish families, Phoenix Islands.

FAMILY	COMMON NAME	#
Labridae	Wrasses	52
Serranidae	Groupers	39
Gobiidae	Gobies	38
Pomacentridae	Damselfishes	37
Acanthuridae	Surgeonfishes	32
Muraenidae	Moray Eels	31
Chaetodontidae	Butterflyfishes	27
Blenniidae	Blennies	22
Holocentridae	Squirrelfishes	21
Apogonidae	Cardinalfishes	18

Chrysiptera albata, a new species of damselfish discovered on the expedition.

(*Acanthurus guttatus, A. nigricans, A. triostegus*, *A. xanthopterus, Naso literatus,* and *Zebrasoma veliferum*) and parrotfishes (*Hipposcarus longiceps* and *Scarus ghobban*). All of these species were frequently sighted in extraordinarily large aggregations.

The giant humphead maori wrasse *Cheilinus undulatus* (Plate 5B), usually a good indicator of local fishing pressure, was seen in much greater numbers compared with other areas recently surveyed in the Indo-Pacific (Table 8).

A new species of damselfish, *Chrysiptera albata*, was collected in 42-50m depth at Nikumaroro Island (Allen and Bailey 2003). Other potential undescribed species were found in the genera *Myripristis* (Holocentridae), *Eviota* (Gobiidae), and *Trimma* (Gobiidae).

Fish Collection (*Steve Bailey, Jerry Allen*)

This project's primary objective was to add to the two existing collections of Phoenix Islands reef fish: Schultz's 1939 collection at the U.S. Natural History Museum, Smithsonian Institution and the New England Aquarium's 2000 collection at the Museum of Comparative Zoology, Harvard University. In addition, selected samples were collected to add to the collections of the Western Australian Museum, Perth, or specific specimens for ongoing research projects (Chlopsidae, false moray eels, for Ken Tighe Ph.D., USNM; and Holocentridae, squirrel and soldierfishes, for Ross Robertson, Australian