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PHOENIX ISLANDS

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Articles submitted for publication in the Atoll Research Bulletin should be original papers in a format similar to that found in recent issues of the Bulletin. First drafts of manuscripts should be double-spaced and can be sent to any of the editors. After the manuscript has been reviewed and accepted, the author will be provided with a page format which will be used to prepare a single-spaced copy of the manuscript.

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PREFACE

Atoll Research Bulletin, Special Issue – the Phoenix Islands Protected Area

This special edition of ARB, on the Phoenix Islands, summarizes the early science that set in motion a landmark initiative that has today become the Phoenix Islands Protected Area, the world's largest World Heritage Site and second largest marine protected area. The Phoenix Islands are an archipelago of remote coral islands and atolls in the very center of the Central Pacific, one of the three island groups of the Republic of Kiribati. As such they represent one third of Kiribati's land and sea area, though their isolation and the small size of the islands have meant they have never been permanently settled, setting the stage for what they have become today, one of the few archipelagos on the planet with low levels of local human threats.

The story has been one that shows how science works in tandem with policy and meeting societal goals in first expressing, then realizing, a grand dream in conservation. Through the initial expeditions that generated the findings reported here, a process of dialogue was established – between researchers and government, between peoples of different cultures, and between countries in the Pacific. The dialogue focused on the broader goals and values of natural heritage – what do unspoiled parts of the planet mean to local culture, to a national government, and to the international community? Through the early dialogue within Kiribati it became clear that the key value of the early science was to reveal the beauty of the underwater reefs in the Phoenix islands and be used as a communication tool in establishing the early phases of discussions within and between different arms of government, in presenting the reefs to the public through video, and to the world through publications such as National Geographic magazine.

Unfortunately for the Phoenix Islands, but perhaps fortunately for our understanding of conservation science, the process of establishing PIPA and the early coral reef surveys in the Phoenix Islands coincided with the signature symbol of coral reefs today – as the canary in the coalmine for global climate change impacts. The studies reported here document the reef community structure prior to a major coral bleaching event in late 2002 to early 2003. Even in this day of globalization, this bleaching event would have passed un-noticed if it weren't for the early expeditions to the Phoenix Islands. Despite fears that the bleaching event may have permanently damaged Phoenix Islands reefs, we fortunately now know that 6 years following that bleaching event the resilience and recovery potential of these otherwise unimpacted reefs was intact enough for rapid recovery – providing a baseline for understanding how reefs impacted by local threats have been undermined in populated parts of the planet. Of great importance to conservation management, this can provide targets for rebuilding the resilience of ecosystems to cope with future climate change and human population growth.

From these initial steps focused on coral reef ecology, PIPA science has now developed with the drafting of a 10-year research strategy that looks at continued exploration in the deep waters and seamounts that make up over 90% of PIPA's ocean area, cutting edge research on connectivity of marine communities including the coral reefs and tuna resources that are so important to island ecosystems and economies, serving as a global reference site for climate change impacts where there are no conflicting local human impacts that undermine the resistance and resilience of nature, and as a model for studying the dynamics of human use and interactions with the environment, especially on populated islands such as in the rest of Kiribati.

In getting to this point there are some key people in the early generation of the science we would like to thank, without whom the first steps would never have been made. In particular it was Cat Holloway and Rob Barrel of Nai'a Expeditions who saw the potential for spectacular scuba diving who convinced a variety of their friends, including Greg Stone and Kandy Kendall, a primary funder of the first visit in 2000, that the islands needed to be visited by a marine science and conservation expedition. The initial dialogue within Kiribati, and the vision for what PIPA has become found support in three people we would also like to acknowledge – Kaburoro Ruaia, Tetabo Nakara an Martin Tofinga – their leadership fostered the initial idea of PIPA and how to present it to both the government and the country as part of Kiribati's heritage and that of the world. And the vision and leadership of the President of Kiribati, Anote Tong, made it possible for firm support to grow at all levels of government in carrying PIPA from an idea to an institution.

As a fledgling protected area, PIPA now depends on the able contributions of many more people, in the protected area office, the official Management Committee and the public sector in Kiribati supported by the office of the Minister for Lands and Agriculture Development, Amberoti Nikora. The initial leadership by the New England Aquarium and Conservation International has grown into broader support not just in science, but in institutional structures and sustainable financing through an Endowment Fund, the PIPA Trust, that will finance the operations of PIPA and contribute to Kiribati's national economy. Finally, in gaining World Heritage status in 2008, PIPA also benefitted from broader international collaborations and support, and in particular the establishment of Sister Site agreement in 2010 with the Papahaunomokeakea National Marine Monument in Hawai'i.

It is our pleasure to have worked together from the beginnings of PIPA to the iconic protected area it is today, and to have worked with all of these initiatives and partners in realizing our dream. We are happy to present this set of papers from the early science of PIPA and to acknowledge the many members of the first expeditions for their contribution to what is now the world's largest World Heritage Site.

April 2011

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BASELINE MARINE BIOLOGICAL SURVEYS OF THE PHOENIX ISLANDS, JULY 2000

BY

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ABSTRACT

Rapid assessment surveys were conducted during a 21-day marine biological expedition to the Phoenix Islands, Republic of Kiribati, from 29 June to 11 July 2000. This study includes new data on the biological diversity and abundance of the region and research and management recommendations. We conducted surveys and over 300 research SCUBA dives among the remote Phoenix Islands: Nikumaroro (Gardner), McKean, Manra (Sydney), Kanton (Aba-Riringa), Enderbury, Orona (Hull) and Rawaki (Phoenix), only excluding Birnie Island due to time limitations.

Corals, benthic and mobile invertebrates, fishes, algae, sea turtles, sea birds, and marine mammals were surveyed at each site. Deep-sea life was sampled during seven deployments of an autonomous digital video camera system to 1,000 m depth at Kanton, Manra, and Orona. Coral reef and fish communities were surveyed using rapid assessment methods, small benthic fishes were collected using rotenone as a stunning agent, marine algae were collected by hand primarily during SCUBA dives, and a deep-drop collecting net was deployed to sample deep-sea animals.

The reefs show evidence of the extreme isolation of these islands, pounded on three sides by the large ocean swells of the Pacific with only a narrow protected side to the west providing protection for anchorage. Coral species diversity of the islands was moderately high. While lacking in some corals dominant in other major reef areas, the reefs have interesting species assemblages, with prolific growth of some species normally subdominant in other reef areas. The reefs were in an excellent state of health, at the time of these surveys free from the bleaching that has plagued reefs in other parts of the Pacific recently and with no evidence of any coral diseases. Our data include new distribution records for species of algae, coral and fishes.

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Fish communities were abundant and diverse and included pelagic fishes such as tuna and oceanic mackerels. Significant populations of grey reef, whitetip reef, and blacktip reef sharks were also observed indicating a healthy coral reef ecosystem. Reef macropredators (trevally, Napoleon wrasse) were also abundant. The deep-sea camera recorded images of deep-water sharks including six-gilled and Pacific sleeper sharks. Marine mammal sightings include bottlenose dolphins, Pacific spinner dolphins, beaked whales (*Mesoplodon* spp.), and unidentified whales. Sea birds observed on Rawaki, McKean, Enderbury, and Orona Islands included tens of thousands of nesting spectacled terns (grey-backed), sooty terns, white fairy-terns, brown noddies, blue-grey noddies, masked boobies, brown boobies, red-footed boobies, red-tailed tropic birds, great frigate birds and lesser frigate birds. Green sea turtle nesting sites were identified on Nikumaroro, McKean and Phoenix Islands. The observations on Rawaki Island are the first confirmed green turtle nestings for that island.

INTRODUCTION

This multidisciplinary scientific expedition to the Phoenix Islands was part of the Primal Ocean Project, which documents ecologically healthy regions of the ocean that resemble prehuman, or preexploitation, conditions. The program documents key aspects of the marine environments at uninhabited and undisturbed locations. For this study, we surveyed some of the most remote coral atoll islands in the Pacific Ocean. The Phoenix Islands (Figure 1), which are part of the Republic of Kiribati, are rarely visited and our expedition provided the first comprehensive, systematic survey of the reefs and adjacent marine biomes. We used a combination of methods to identify and quantify the abundance and distribution of marine mammals, the diversity and condition of the coral reefs and coral fish, and the distribution and diversity of marine algae. We also recorded observations of seabirds and turtles throughout the expedition. This paper provides a summary of the results for the year-2000 expedition, and recommendations for follow-up research and conservation management.

The Phoenix Islands are in the eastern Kiribati Group of Micronesia at approximately 4 degrees latitude south of the equator and 175 degrees west longitude, 1,850 miles southwest of Honolulu, Hawaii, 3,250 miles northwest of Sydney, Australia, and 1,000 miles northeast of Suva, Fiji. (Figure 1). They first found fame as the finest sperm whaling grounds of the South Sea whale fishery in the early 1800s (Towsend, 1935) and were featured in the famous tale, *Moby Dick*, as the location of the final confrontation between Captain Ahab and the white whale (Melville, 1851). The islands were entirely uninhabited until the late 1800s when British and American governments discreetly fought to claim control of the group by installing entrepreneurs to plant coconuts and establish guano mines. Coconut planters came and quickly went from a few of the islands and they were again uninhabited until 1938.

In 1937, British delegates surveyed the Phoenix Islands as potential places to resettle Gilbertese and Ellice Islanders as an escape from their overpopulated (and overmined) homelands. Upon seeing Gardner Island and its thick coverage of buka trees for the first time, the Gilbertese villagers immediately recognized the place from their dreams and myths: this was Nikumaroro, the legendary home of the fierce and powerful

Polynesian goddess of ocean navigation, *Nei Manganibuka*. Hence, the current correct name for Gardner Island is Nikumaroro. In 1938, modest colonization of Nikumaroro, Orona and Manra Islands began idealistically and passionately, largely as a result of the untouched beauty of the atolls and the incredible abundance of fish the settlers and surveyors found (Bevington, 1937). Apparently, blacktip sharks gathered in dozens around their ankles as they waded along the shore. Turtles, lobsters, crabs and large pelagic fishes were easily caught and the lagoons teemed with a common type of mullet and triggerfish. However, fresh water was difficult to catch and gather from wells and many families opted to leave in the 1940s; by the 1960s, the settlement scheme was entirely abandoned. Only Kanton Island has any inhabitants now, fewer than 50 people.

Previous research on these islands included a visit by the research vessel Bushnell in 1939 that resulted in a taxonomic collection of fishes (Shultz, 1943), studies on seabird (Clapp, 1964), turtles (Balazs, 1982) and the corals from McKean island in the early 1970s (Dana, 1975). It was not until 1972-73 that detailed marine surveys were conducted, of a comprehensive study of Kanton Atoll (Smith and Henderson 1978), including work on lagoon circulation and biogeochemistry (Smith and Jokiel 1978), coral taxonomy and biogeography (Maragos and Jokiel, 1978) and lagoon and leeward reef coral distributions and assemblages (Jokiel and Maragos, 1978). In additon to these primarily scientific interests, others have been attracted to the Phoenix Islands: the Waikiki Aquarium of Hawaii collected baby black tip sharks from Kanton in the 1980s and the TIGHAR expedition searching for Amelia Earhart's plane wreckage in 1997, dived the island of Nikumaroro (Holloway, 1999).

We chose these islands for our study because of their isolation, their long history of being uninhabited and the opportunity to provide biological information for the purpose of management and conservation.

METHODS

The 120' M/V NAI'A departed Fiji on June 24, 2000 and after a five-day crossing arrived at the Phoenix Islands on June 29, 2000. We began our survey with Nikumaroro Island, followed by McKean, Kanton, Enderbury, Enderbury, Manra, and Orona Islands and then returned again to Nikumaroro for the final two days of the expedition (Fig. 1). Birnie Island was excluded due to travel and time constraints. We spent between one and two days at each island and transited between islands at night. Upon arrival, we sought a station on the leeward side of each island from which skiffs could be launched safely. Next, we made three or four dives each day seeking maximum diversity of underwater habitats ranging from the shallow surf zone to depths of 140 feet. Most of our time was spent on the leeward sides of the islands due to wind and swell making operations difficult on the windward sides. Landings at each island were made to search for turtle nests and to assess the populations of seabirds. We departed the Phoenix Islands for Fiji on Tuesday, July 11, 2000. Specific methods for each area of research are described below:

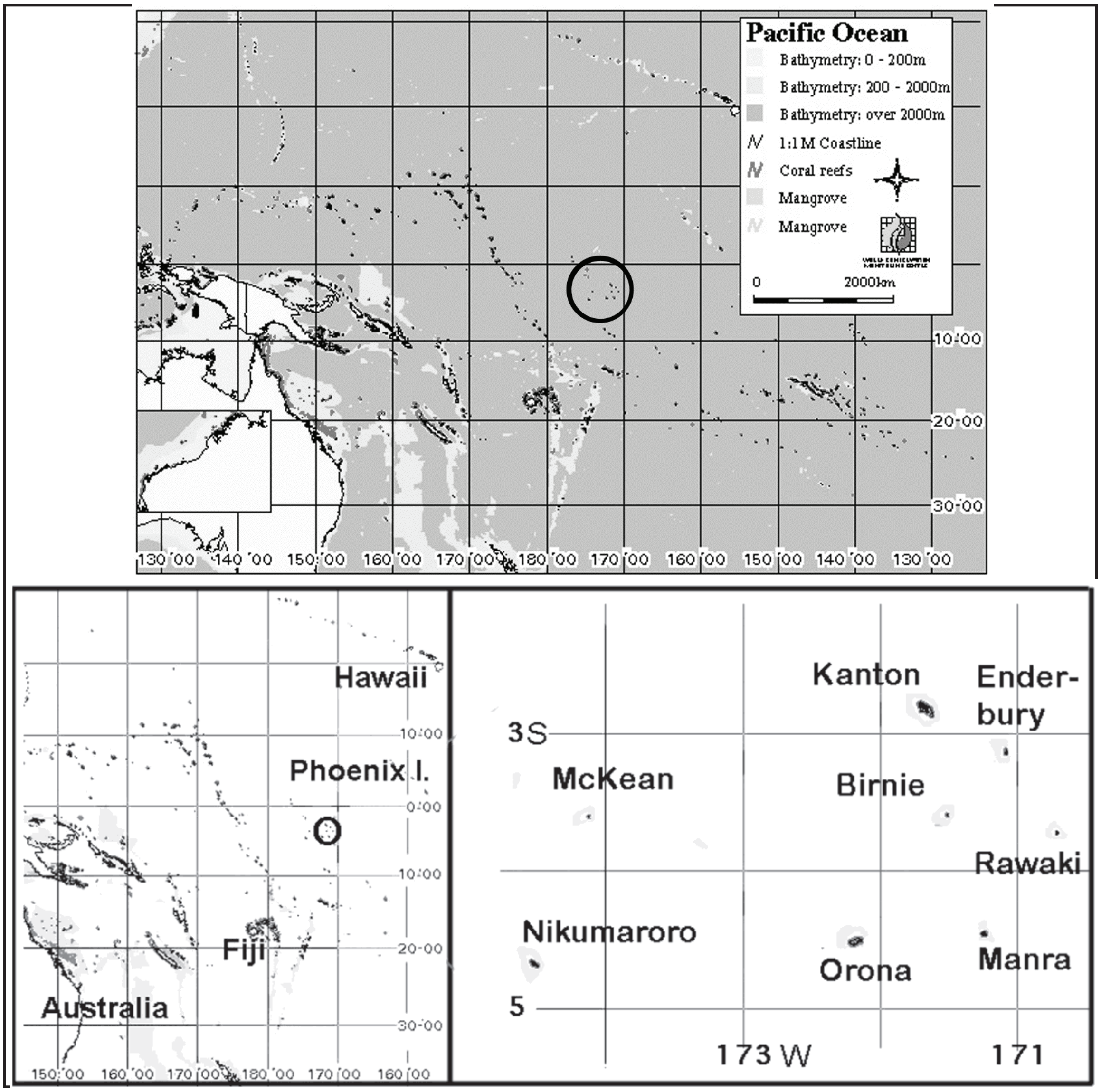

Figure 1. Left. The location of the Phoenix Islands in the Pacific Ocean. Right. The Phoenix Islands, showing all eight islands in the Republic of Kiribati.

Corals and Benthic Cover

Three methods were used for rapid surveying of reefs for coral diversity and condition, as well as benthic cover. Rapid assessment methods were chosen in order to cover as much area as possible during the several dives in each study area.

Coral Species Diversity - timed surveys. Coral species were identified at each site by recording new coral species observed in 2.5 minute intervals during each dive, giving information on species diversity, as well as community structure. Identification was done using Veron (1986). Small fragments of unidentified corals were collected, bleached for two days in domestic bleach, then dried and sealed in airtight plastic bags for transportation. Preliminary identifications were made at the Australian Institute of Marine Science (Doug Fenner) and the Museum of Northern Queensland (Dr. Carden Wallace).

Coral and benthic cover - video transects. Video records of the benthos using a fixed camera-to-subject distance provided reliable images for scoring benthic cover of major algal and benthic invertebrate groups, many of the latter to genus or species level. Sample quadrats were selected during playback of the material. The video tape of benthic cover was stopped at four-second intervals, sampling five fixed points on the screen, with 100 points defining a single "transect". As far as possible, five transects were analyzed for each site, though some sites had fewer transects due to the low video-time recorded.

Coral condition. The incidence of coral stress indicators (i.e., bleaching, epiphytism, partial mortality, seastar predation) was also noted for each site. These were recorded in repeated 10-minute samples during each dive.

Benthic Invertebrates

Important benthic invertebrate resource species were sampled in ten-minute intervals during dives. The identity (at species level where possible) and number of individuals were recorded for the following invertebrate groups: sea cucumbers, lobsters, clams and crown-of-thorns seastars.

Fishes

Fish populations were studied using four different methods designed to sample: a) abundance of large predatory fishes, b) abundance of ecologically important fish families, c) diversity of representative ornamental fishes, and d) diversity and taxonomy of small cryptic fishes. The first two methods consisted of identifying and counting fish in situ.
In the first method, 18 selected species of large predatory fishes were counted during all dives (Table 1). The second method counted fishes at the family level, selecting families common to coral reefs and with important ecological roles (Table 2). The third method assessed relative diversity of representative ornamental reef fish families. Species counts were taken for the following three groups: butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and clown fishes (Pomacentridae; Amphiprioninae).
In the fourth method, small benthic fishes were collected with rotenone, an organic fish toxicant. The only previous systematic fish collections made in this region were in 1939 during the *U.S.S. Bushnell* expedition (Shultz, 1943). Most of those collections were made with nets and traps because SCUBA technology was not yet available. Due to the fishing method used in collecting fishes, these collections focused on larger benthic and pelagic species. The small cryptic fish fauna that lives on the bottom and in crevices was not sampled as extensively; thus it was decided a significant contribution could be made by collecting the smaller cryptic fishes using SCUBA gear and hand-catching.

Collections were made at various depths. Sites were selected that contained a rubble bottom, which would provide suitable habitat for the target species, and had currents and structure likely to retain the rotenone. Rotenone was mixed on board the NAI'A into a paste with seawater to a consistency that would allow fine cloud dispersion; the paste was transported underwater in a plastic bag. Once on site, the rotenone bag was opened and mixed with seawater by scooping an amount sufficient to create a consistency

Table 1. Large fish species counted at each site for relative fish abundance

Scientific Name	Common Name
TUNA AND PELAGICS	
Gymnosarda unicolor	Dogtooth Tuna
Euthynnus affinis	Mackerel Tuna
Scomberoides lysan	Double-spotted Queenfish
Elegatis bipinnulata	Rainbow Runner
JACKS	
Caranx sexfasciatus	Bigeye Trevally
Caranx melampygus	Bluefin Trevally
Caranx lugubris	Black Trevally
REEF PREDATORS	
Sphyraena qenie	Chevron Barracuda
Cheilinus undulatus	Napoleon Wrasse
Epinephelus fuscoguttatus	Flowery Cod
Plectropomus laevis	Footballer Trout
Aprion virescens	Green Jobfish
Lutjanus bohar	Red Bass
Macolor macularis	Midnight Seaperch
SHARKS AND RAYS	
Carcharhinus melanopterus	Blacktip Reef Shark
Carcharhinus amblyrhynchos	Grey Reef Shark
Triaenodon obesus	Whitetip Reef Shark
Manta birostris/alfredi (complex)	Manta Ray

Table 2. Common fish families surveyed for abundance at each site.

Family	Common name
Serranidae	Groupers
	Fairy Basslets
Lutjanidae	Snappers
Scaridae	Parrotfishes
Acanthuridae	Surgeonfishes Unicornfishes
Balistidae	Triggerfishes

reminescent of heavy cream. This solution was then released out of the bag onto the rubble substrate where it primarily settled, depending on currents and surge. The mixture would envelop an area of substrate that was on average 4 m^2. Sometimes, depending on current and surge, the rotenone would be lifted into the water column and interact with those fishes. After 2-4 minutes, the effects of the rotenone would irritate the fish out of their burrows and eventually incapacitate them, at which point they were collected in small plastic jars. The majority of fish specimens were collected in a catatonic state in the immediate vicinity of the substrate. Due to the loose and extremely porous nature of the rubble, researchers would often dig down into rubble to a depth of 0.5 m on average to retrieve samples. Specimens were picked up and placed in clear plastic jars with screw-on lids. Specimens were fixed when back on board in 10% neutral buffered formalin (NBF) then transferred to 10% NBF-soaked gauze prior to transport. Thirty-five percent of the collections were photographed prior to fixing.

While in the field, the specimens were generally identified by personal familiarity or using references (Schultz, 1943; Randall et al., 1990; Myers, 1991). Definitive analysis of all specimens is being conducted at the ichthyology departments of the Museum of Comparative Zoology at Harvard University, Cambridge, MA, USA and the National Museum of Natural History at the Smithsonian Institiue, Washington, DC, USA. The expertise of some of the world authorities on particular fish families has been enlisted; among those are the Royal Ontario Museum (Ottawa), Natural History Museum (London), and J.B.L. Smith Institute of Ichthyology (South Africa).

All specimens will have their ultimate disposition at either the National Museum of Natural History, Smithsonian Institution or the Museum of Comparative Zoology, Harvard University, depending on their contribution to an already existing comprehensive collection for that species or family. All information and data concerning these specimens will be made available to the Kiribati Government and for scientific requests, following standard museum procedures.

Algae

Marine algae were collected by SCUBA diving, reef walking and snorkeling. Collections were stored and logged at the end of each day according to habitat and water depth, temperature and visibility, and then preserved in 5% formaldehyde in seawater. Specimens were catalogued by phyla on board the research vessel and then delivered to Professor Robin South of the Marine Studies Programme (USP) of the University of the South Pacific, Suva, Fiji for final analysis, including sorting, microscopic examination and preparation as slides and whole mounted specimens. For large specimens, herbarium or liquid-preserved specimens will be prepared and, where necessary, anatomical sections were retained on microscope slides. Photomicrograph records are stored at the USP laboratory. All species were analyzed and housed in the Phycological Herbarium, the University of the South Pacific Herbarium in Suva, Fiji. A list of recorded species has been compiled and a formal record of the collection is being published separately by South et al. (2001).

Marine Mammals

Sighting watches were kept from the bridge of the NAI'A during most daytime transits. Observer height-of-eye was 6 meters above waterline, and normally two observers, one on each side of the vessel, scanned the waters in an arc from the bow to 90 degrees on each side. For each marine mammal sighting the following information was recorded: date, time, species, number of animals, behaviors, latitude and longitude, distance at first sighting, distance when abeam of NAI'A, water depth, weather conditions (sea state, cloud cover, wind), observers, and comments.

Turtles and Birds

Turtles and birds were counted opportunistically throughout the cruise. Each island was surveyed for turtle-nesting sites by walking the beaches and from boats.

Deep-Sea Camera Survey

The National Geographic Society provided a deep-sea digital video camera ("rope-cam") for use on this expedition. The camera had an operating depth of up to 2,000 meters and had an automatic recording system with a preset on-off schedule once it reached depth. The camera was lowered over the side with bait to attract animals and was then recovered using block and tackle and a tow skiff. A single deployment took up to seven hours. The camera's operating program had the camera switched on for two minutes and then off, or "sleeping," for 13 minutes. The "sleeping" periods allowed the deep-sea animals time to return after usually being frightened away by the bright lights on the apparatus. There were seven camera deployments, each resulting in one hour of recorded bottom time. A full description of the methods can be found in Stone et al. (1998).

Deepwater Net Tow

In addition to the deep camera system there was one deployment of a deepwater net to a depth of 1000 meters. The net was a four mm mesh with a square frame that measured one metre square. The sample of deepwater fishes and other organisms was analyzed along with the shallow-water fish collections.

The above methods cover a range of spatial and temporal scales of measurement, and application at site and island-specific levels. Table 3 gives a summary of how they were collected, and their reporting in the results section.

GENERAL RESULTS

Thirteen days of surveys were completed in the Phoenix Islands, with nine days of ocean crossings (Table 4). Forty-two research SCUBA dives were completed at 29 survey locations within the island group, nearly 75% of which were at leeward locations due to inaccessibility of rougher waters on the windward sites (Table 5). Additional spot-checks were conducted, for example in the lagoon at Orona, but without detailed collection of data so are not shown in the table.

Results are presented in two formats. First, for those data that can be summarized for the entire expedition, we present summary information below. This includes fish collections, marine mammal sightings, algae, and deep-camera results. Following this, island-specific results are presented for coral and fish assemblages, bird populations and turtle sightings.

Table 3. Tabulation of methods, scales of observation and reporting

Method	Observations	Spatial scale	Results
Fish collection/ Deepwater Net Tow	Collection.	Tallied by site and aggregated by island	Overall
Algae	Collection.	Tallied by site and aggregated by island	Overall
Marine Mammals	Above-water observation and counts.	From vessel during crossings and at islands, from diving skiffs.	Overall
Deep-Sea Camera Survey	Video record.	Spot deployment at 7 locations off 4 islands	Overall
Corals and Benthic Cover	Underwater observations, quantitative.	Individual-site records from marked locations around each island	Island-specific
Benthic Invertebrates	Underwater observations, quantitative.	Individual-site records from marked locations around each island	Island-specific
Fishes	Underwater observations, quantitative.	Individual-site records from marked locations around each island	Island-specific
Turtles	Above-water and underwater counts for turtles, beach walks for nests	Individual-site records and total counts by island.	Island-specific
Birds	Beach and island walks to count nests and birds.	Total counts by island.	Island-specific

Table 4. Itinerary of Expedition.

Date	Locations
June 25 to 29, 2000	Ocean crossing – Fiji to Phoenix Islands
June 29 and 30, 2000	Nikumaroro (Gardner) Island
July 1, 2000	McKean Island
July 2, 3,and 4, 2000	Kanton (Aba-Riringa) Island
July 5, 2000	Enderbury (Enderbury) Island
July 6, 2000	Phoenix Island
July 7, 2000	Manra (Sydney) Island
July 8 and 9, 2000	Orona (Hull) Island
July 10 and 11, 2000	Nikumaroro (Gardner) Island
July 12 to 15, 2000	Ocean crossing – Phoenix to Fiji

Table 5. Number of sites sampled at each island in the major reef types in the Phoenix islands – leeward, windward, lagoon and channel.

Island	Leeward	Windward	Lagoon	Channel	Total
Enderbury	3	1			4
Kanton	5	1	1	1	8
Manra	2	1			3
McKean	2				2
Nikumaroro	4	2			6
Orona	2	1			3
Rawaki	3				3
Total	21	6	1	1	29

Fish Collection

Fishes were collected at all islands during the expedition. Eighteen collections were made with rotenone, five were live or incidental collections and one was made with a deep-drop net to 1000 m. Fifteen collections were on the protected leeward sides of the islands, five were made on the exposed windward side, and three were made inside lagoons. Further details of collections are in Tables 6-7 and the content of each collection is listed within each island's description.

Table 6. Number of fish collections, fish species and fish specimens at each island.

Island	Collections	Species	Specimens
Nikumaroro	5	31	96
McKean	2	20	43
Kanton	7	31	80
Enderbury	3	18	54
Enderbury	1	11	31
Manra	2	20	71
Orona	4	32	79

Table 7. Characteristics of fish collections by depth and substrate (depth in meters).

Depth range	# Collections	Substrate	# Collections
< 5	1	Sand (fine sediment)	3
6-10	8	Rubble	11
11-15	6	Sand/Rubble mix	5
16-20	2	Water column	3
21-25	4	Coral top	2
26-30	1	Other	1
31-50	1		
> 50	1		
Totals	24		25*

* one collection included specimens caught at two locations.

Twenty eight families and 85 species are currently represented in the collection. The Pomacentridae, with eight species, are the most diverse family, while 10 other families have just one species. The most often collected species was *Chromis acares* (Midget chromis: Pomacentridae) from 13 of 24 collections, while 34 species were sampled only once.

The team was provided with a species list compiled by the Kiribati Ministry of Natural Resource Development's Fisheries Division. It is currently comprised of 393 species with a scientific name, common name and Kiribati indigenous name listed for each one. Presently this report is able to add 37 additional species (Table 8). Of those 37 species it is believed that two represent zoogeographic range extensions (see Table 60). Some of the species listed as additions in Table 8 are quite common at most collection

Table 8. Additions to Kiribati Ministry of Natural Resource fish species list.

Family	Genus/species	Common name
Moringuidae (Spaghetti Eels)	*Moringua ferruginea*	Rusty spaghetti eel
Muraenidae (Moray Eels)	*Gymnothorax chilospilus*	(none)
	Gymnothorax buroensis	Buro moray
	Uropterygius supraforatus	(none)
Congridae (Conger and Garden Eels)	*Conger cinereus cinereus*	Moustache conger
Cyclothonidae	*Cyclothone pallida*	(none)
	Cyclothone alba	(none)
Ophidiidae (Cusk Eels)	*Brotula multibarbata*	Reef cusk eel
Bythitidae (Livebearing Brotulids)	*Dinematichthys iluocoeteoides*	Yellow pygmy brotula
Antennariidae (Frogfishes)	*Antennarius nummifer*	Spotfin frogfish
Exocoetidae (Flying fishes)	*Cheilopogon suttoni*	Sutton's flyingfish
Scorpaenidae (Scorpionfishes)	*Scorpaenodes guamensis*	Guam scorpionfish
	Scorpaenodes hirsutus	Hairy scorpionfish
	Taenianotus triacanthus	Leaf fish
	Pterois antennata	Spotfin lionfish
Serranidae (Fairy Basslets and Groupers)	*Suttonia lineata*	(none)
Grammistidae	*Pseudogramma polyacanthum*	(none)
Pseudochromidae (Dottybacks)	*Pseudoplesiops revellei*	Revelle's basslet
Cirrhitidae (Hawkfishes)	*Cirrhitops hubbardi*	(none)
	Paracirrhites nisus	(none)
	Paracirrhites xanthus	(none)
Apogonidae (Cardinalfishes)	*Gymnapogon urospilotus*	Lachner's cardinalfish
Pomacanthidae (Angel fishes)	*Centropyge flavicauda*	White-tail angel fish
	Centropyge flavissima	Lemonpeel angel fish
Pomacentridae (Damselfishes)	*Chrysiptera brownriggii*	Surge damselfish
	Plectroglyphidodon johnstonianus	Johnston damselfish
Tripterygiidae (Tripletails)	*Enneapterygius tutuilae*	(none)
	Enneapterygius nigricauda	(none)
Gobiidae (Gobies)	*Amblygobius phalaena*	Brown-barred goby
	Callogobius plumatus	Feather goby
	Callogobius sclateri	Pacific flap-headed goby
	Paragobiodon modestus	Warthead goby
	Priolepis nocturna	(none)
Acanthuridae (Surgeon and Unicornfishes	*Acanthurus nigricans*	White cheek surgeonfish
	Acanthurus nigrofuscus	Brown surgeonfish
	Zebrasoma scopas	Brown tang
	Zebrasoma veliferum	Sailfin tang

sites. *Cyclothone alba* and *C. pallida*, the two species of fish that were collected in the one deep water net tow, share the distinction with their close relation *Vinciguerria* as the genera that have the greatest abundance of individuals of any verterbrate genus in the world (Nelson, 1994). The cyclothonids occur in virtually all marine waters including Antarctica.

The number of specimens remaining to be identified is considerable. Table 9 outlines the task by illustrating the progress to date on more than 400 of those fishes. An additional 350 (primarily labrid and anthiid) specimens have only been grossly classified to family level. The collection methods focused the effort on interstitial fishes. Consequently, the majority of the specimens collected are species that do not achieve a size that facilitates classification using strong visual characteristics.

Table 9. Unidentified fishes collected during expedition.

Family	Genus (if known)	Species or description	Collection #	Status of inquiry
Synodontidae	*Synodus*	sp.1	10	pending
Antennariidae	*Histrio*	'xtreme small'	11	pending
Bythitidae	*Dinemichthys*	'yellow'	10,16,18,20	pending
Holocentridae	*Myripristis*	sp.1	7	pending
Holocentridae	*Sargocentron*	sp.1	5,18,20	pending
Scorpaenidae	(scorpaenid)	sp.1	5,16,18,21	pending
Scorpaenidae	*Scorpaenodes*	sp.1	4,6,10	pending
Scorpaenidae	*Scorpaenopsis*	sp.1	10	pending
Scorpaenidae	*Scorpaenopsis*	sp.A	16,22	pending
Scorpaenidae	*Sebastapistes*	sp.1	22	pending
Caracanthidae	*Caracanthus*	sp.1	18	pending
Serranidae	*Cephalopholis*	sp	1	pending
Apogonidae	*Apogon*	sp.1	4,8,10,20,22	pending
Apogonidae	*Apogon*	sp.2	10	pending
Tripterygiidae	*Enneapterygius*	sp.1	22	pending
Tripterygiidae	*Helcogramma*	sp.1	8	pending
Acanthuridae	*Naso*	sp.1	21	pending

Additionally: the Labridae portion of the collection (approximately 75 specimens) has not been examined; the Anthiinae (approximately 200 specimens) analysis is commencing; 12 other families have not yet received any cataloguing.

Algae Collection

A total of 69 taxa of subtidal benthic marine algae, including nine new records (Rhodophyceae) for Micronesia, were collected and identified (Table 10). The collections were made from Nikumaroro, McKean, Kanton, Enderbury, Enderbury, Manra, and Orona islands. These samples included seven Cyanophyceae, 29 Rhodophyceae, five Phaeophyceae and 28 Chlorophyceae. Together with previous studies (Doty, 1954; Degener and Gillaspy, 1955; Degener and Degener, 1959; Dawson, 1959), this brings to 107 the total number of species reported from these islands. The flora is representative of that of neighboring areas of Micronesia, although one species, *Cladophora boodleoides*, is reported only for the second time from the South Pacific Ocean. For a complete report of these specimens see South et al. (2001).

Table 10. Marine Algae Collected. Each ✓ represents a specimen. Two or more ✓ represents more than one sample of same species. Sites: A/B: Nikumaroro. C: McKean. D: Kanton. E: Enderbury. F: Enderbury. G: Manra. H: Orona. Confirmed = ✓

Species	A/B	C	D	E	F	G	H
Antithamnionella elegans (Berthold) Price & John					✓		
Asparagopsis taxiformis (Delile) Trevisan						✓	
Avrainvillea sp.			✓				
Blennothrix lyngbyacea (Kützing) Anagnostidies Komárek					✓		
Bryopsis pennata Lamouroux			✓✓				
Bryopsis sp.			✓				
Caulerpa cupressoides (Vahl) C. Agardh				✓✓✓	✓		
Caulerpa serrulata (Forsskal) J. Agardh				✓			✓
Ceramium flaccidum (Kützing) Ardissone			✓				
Ceramium sp.		✓	✓				
Cladophora liebetruthii Grunow					✓		
Codium arabicum Kützing							✓
Coralline algae				✓			
Crouania attenuata (C. Agardh) J. Agardh			✓				
Cyanophyta	✓✓✓	✓	✓✓	✓			
Dasya sp.						✓	
Dictyopteris repens (Okamura) Børgesen			✓	✓✓			
Dictyosphaeria cavernosa (Forsskål) Børgesen		✓		✓✓✓			
				✓			
Dictyosphaeria versluysii Weber van Bosse					✓✓		
Dictyosphaeria sp.				✓			
Galaxaura filamentosa Chou			✓				
Gelidiopsis intricata (C. Agardh) Vickers					✓		
Gelidiopsis sp.				✓			
Griffithsia heteromorpha Kützing					✓		
Halimeda copiosa Goreau & Graham			✓	✓			
Halimeda cuneata Hering					✓		
Halimeda cylindracea Decaisne						✓	✓
Halimeda macroloba Decaisne							✓
Halimeda micronesica Yamada		✓					
Halimeda taenicola Taylor					✓		
Halimeda sp.		✓✓	✓✓	✓✓✓		✓	✓
Herposiphonia dendroidea Hollenberg					✓		
Hypnea sp.	✓			✓✓			
Hypoglossum caloglossoides Wynne & Kraft					✓		
Jania micrarthrodia Lamouroux					✓		
Jania sp.				✓			
Lithothamnion proliferum Foslie						✓	
Neomeris annulata Dickie			✓✓✓	✓			✓✓
Polysiphonia sp.		✓					
Porolithon sp.		✓				✓	
Rhipilia geppii Taylor					✓		
Rhipilia orientalis Gepp & Gepp					✓		
Rhipilia sp.	✓✓	✓	✓	✓			
Rhipiliopsis sp.				✓			
Spermothamnion sp.				✓			
Turbinaria ornata (Turner) J. Agardh							✓
Turf algal assemblage	✓✓✓						✓
Valonia aegagropila C. Agardh				✓✓			
Not algae				✓		✓	✓

Deep-Sea Video Survey

Ropecam deployments were successful and documented several deep-sea sharks around the islands. Sharks repeatedly ate all the bait on the camera system and violent encounters were evidenced by bending and actually biting off the bait pole. On the last deployment, the bait pole was bitten off and the outer camera port was missing, causing flooding of the camera housing. Due to this damage, there were no further deployments. Either the port failed due to structural problems or a shark may have shaken the entire camera system and banged it against some rocks. Table 11 lists the types of animals seen during deployments.

Table 11. Deep-sea ropecam results

Date	Island	Position	Depth (m)	Comments
7-02-00	Nikumaroro	04^o 48.6' S 171^o 43.7' W	1,000	Camera out of focus
7-03-00	Kanton	02^o 47.8' S 171^o 44.1'W	1,000	Six-gill shark (Hexanchus sp.) and cat shark images (Scyliorhinoidei)
7-04-00	Kanton	02^o 48.2' S 171^o 44.1 W	1,200	Camera malfunction: ran continuously
7-05-00	Enderbury	03^o 07.4' S 171^o 06.6'W	1,100	Eels, sergestid shrimp
7-07-00	Manra	04^o 28.0' S 171^o 16.1' W	1,000	Pacific sleeper shark (Somiosinae)
7-08-00	Manra	04^o 29.3' S 171^o 13.4' W	1,100	Sergestid shrimp, unidentified fish, six-gill and unidentified Somniosinae sharks
7-09-00	Manra	04^o 29.2' S 172^o 13.4'W	1,300	Camera retrieved with missing lens port; camera destroyed by water damage; remaining system OK

Cetacean Sightings

Surprisingly few cetaceans were seen during the marine mammal watches which covered over 1,500 nautical miles of ocean as well as cruise tracks in between the islands. Odontocetes were the most common suborder observed and bottlenose dolphins (*Tursiops truncatus*) the most common species. Most notable was the lack of any identified large whales, such as sperm whales (*Physeter macrocephalus*) or any mystecetes. All cetacean sightings are listed in Table 12.

ISLAND RESULTS

This section lists results by island, covery underwater and terrestrial survey results. In total, 42 dives group dives totaling approximately 400 man-dives and 10 shore-visits were carried out.

Nikumaroro (Gardner) Island

Site Descriptions. Nikumaroro was the first and last island on the trip itinerary, with 12 dives made on four days, at eight unique sites (seven leeward and one windward, Table 13). The lee of the island consisted of only the farthest western portion of the island, the remaining north, south and eastern sides being pounded by heavy surf and exposed to storms and swell from the east and south. The return visit on July 10 and 11 was done to verify data collected during the initial familiarization and training dives.

All survey sites had a consistent topography characteristic of oceanic atolls. A sloping consolidated platform extended from the wave zone down to between 10 and 15 meters depth, below which the bottom sloped steeply in some places forming a vertical wall. The shallow platform varied from flat to a spur and groove formation, often with very deep-cut grooves and bowls with vertical walls. In shallow water, the substrate tended to be hard and consolidated, giving way to large amounts of rubble forming the majority of the steep slope in deeper water fed from rubble generated in shallow water, and transported downwards in the grooves. The deeper slopes were not sampled with video transects as extensively as slopes < 20 m deep due to diving safety constraints.

Table 12. Marine Mammal Sightings.

Date	**Position**	**Species**	**#**	**Comments**
6-24-00	17° 03.7'S 178° 15.0'W	*Tursiops truncatus*	5	Bow-riding
6-29-00	05° 34.7'S 173° 59.0'W	*Tursiops truncatus*	2	Bow-riding
7-1-00	03° 03.7'S 173° 36.0'W	Unidentified Whale	1	Blow seen only (sperm?)
7-2-00	02° 49.0'S 171° 43.0'W	*Tursiops truncatus*	10	Bow-riding
7-2-00	02° 49.0'S 171° 43.0'W	Dolphin species	?	Divers heard dolphins during night dive
7-3-00	02° 49.0'S 171° 43.0'W	Dolphin species	?	Divers heard dolphins during night dive
7-4-00	02° 49.0'S 171° 42.0'W	*Tursiops truncatus*	4	Jumping
7-5-00	03° 07.0'S 171° 05.0'W	*Tursiops truncatus*	50+	Bow-riding and porpoising
7-8-00	04° 29.9'S 172° 13.1'W	*Mesoplodon* spp.	1	Surfaced once 20m from boat
7-10-00	04° 41.6'S 174° 30.0'W	*Tursiops truncatus* (20) *Stenella longirostrus* (10)	30	Mixed school bow-riding and jumping
7-11-00	04° 43.2'S 174° 34.5'W	Unidentified whale	1	Blow seen
7-11-00	10° 57.6'S 178° 22.1'W	Unidentified whale	1	Blow seen 200m from boat (humpback?)

Table 13. Dive and survey sites at Nikumaroro Island.

Date	Time	Name	Lat. (S)	Long. (W)	Exposure
29-Jun-00	8:00 am	Landing	04°40.54	174°32.59	Leeward
29-Jun-00	11:20 am	NAI'A Point	04°39.15	174°32.86	Leeward
29-Jun-00	2:45 pm	Amelia's Lost Causeway	04°40.27	174°32.85	Leeward
29-Jun-00	5:15 pm	Norwich City	04°39.61	174°32.94	Leeward
30-Jun-00	7:55 am	North Beach	04°39.10	174°32.53	Leeward
30-Jun-00	11:50 am	SW Corner	04°40.87	174°32.41	Leeward
30-Jun-00	3:20 pm	Windward Wing	04°39.00	174°32.68	Windward
10-Jul-00	10:45 am	Kandy Jar	04°39.30	174°32.88	Leeward
10-Jul-00	1:40 pm	NAI'A Point	04°39.13	174°32.85	Leeward
10-Jul-00	4:40 pm	Landing	04°40.53	174°32.59	Leeward
11-Jul-00	7:05 am	Landing	04°40.53	174°32.59	Leeward
11-Jul-00	9:45 am	Landing	04°40.52	174°32.59	Leeward

Bottom Cover: Coral cover tended to be higher on the shallow platform and decreased on the steep deeper slope giving way to rubble and *Halimeda*. Video transects were recorded at four sites, one windward and three leeward sites (Fig. 2).

Leeward sites had 25-40% coral cover, in some places exceeding 75% on the shallow platforms. Coralline algae, *Halimeda* and rubble were the three other dominant cover categories. Coralline algae tended to dominate in shallower water, associated with good coral growth, while *Halimeda* and rubble dominated the deeper, unconsolidated slopes. Rocky spurs along the deeper wall tended to have higher coral cover with algal turf and coralline algae, with soft corals (gorgonians) becoming more abundant at 30 m and deeper.

The windward site had a very distinct crest at 15 m depth from the shallow platform to the steeply sloping reef edge. Both platform and slope were smoother and less accidented than the leeward slopes. Coral cover on the platform was estimated at 70% and the lower cover on the slope was 30%, comparable to the leeward sides. The steep slope was dominated by *Halimeda* with plates of *Porites*. In contrast to the leeward side, very little loose rubble was found with the majority of bare surfaces covered by encrusting coralline algae in shallow water. At depth large coraline rocks were jammed together to form a relatively stable, steep incline.

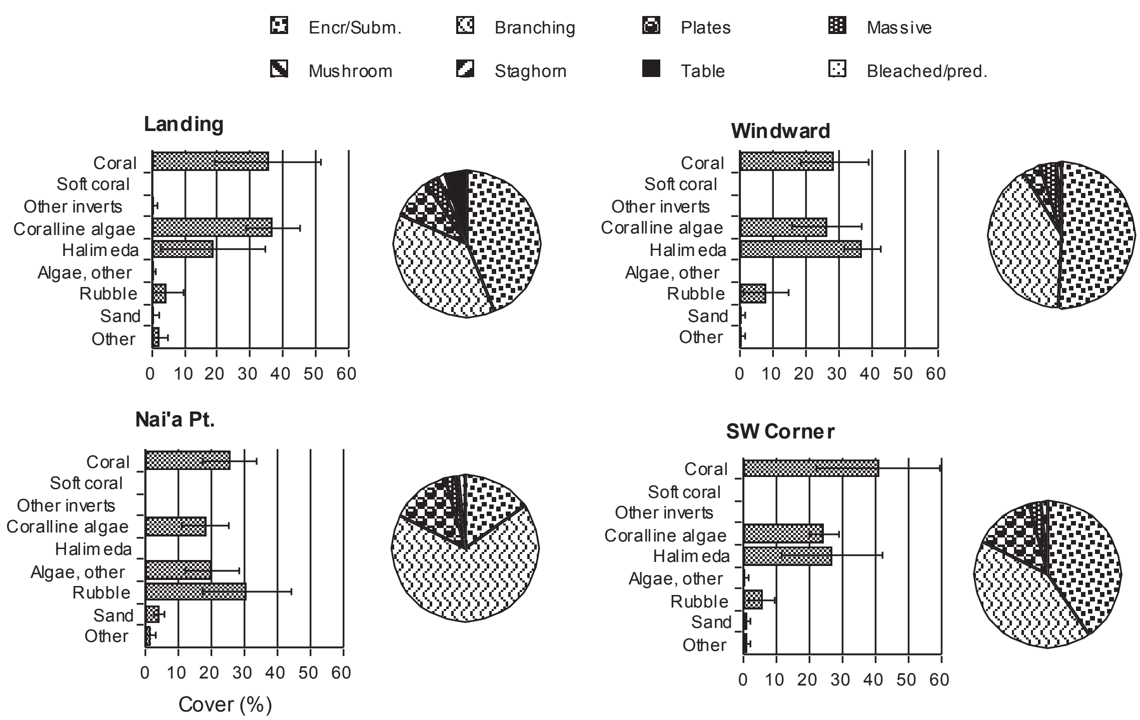

Figure 2. Benthic cover (bar charts) and relative abundance of coral growth forms (pie charts) at Nikumaroro Island. The bar charts show the mean and standard deviation of bottom cover in percentages. The pie charts show the proportion of the total coral cover contributed by the growth forms listed in the legend.

Corals. At the four sites sampled by video transect (Fig. 2), encrusting/submassive and branching corals were the most common growth forms, dominated by *Pocillopora*, *Pavona* and a variety of faviids. Plating corals were third, mostly at deeper depths (*Porites lutea*) or as minor components of the shallow coral fauna (*Echinopora*, *Echinophyllia*, *Montipora*). Leeward sites had very characteristic open-branching and submassive corals revealing the influence of water energy by the amount of fresh rubble. At the windward site, branches were more robust and closely packed, with less fresh rubble and greater substrate cementation by coralline algae.

Five dive sites were sampled for coral species, yielding 61 species. The 10 most frequently observed species are listed in Table 14 and were common to both leeward and windward sites. *Pocillopora* colonies showed the highest rates of partial and full bleaching (Table 15). *Porites* and *Fungia* showed low levels of any threat while *Acropora* was rare and seldom observed. On average, seven coral colonies with evidence of poor condition were observed in each 10 minute sample.

Table 14. The 10 most abundant coral species at Nikumaroro Island.

Family	Species
Acroporidae	*Montipora efflorescens*
Agariciidae	*Pavona minuta, Pavona varians*
Faviidae	*Echinopora lamellosa, Favia rotumana, Favia stelligera, Favites pentagona, Leptastrea purpurea*
Pectiniidae	*Oxypora lacera*
Pocilloporidae	*Pocillopora verrucosa*

Table 15. Frequency of coral threats observed at Nikumaroro Island. Number indicates the number of corals observed with each condition during 10-minute samples in each dive. Four coral genera were sampled for four categories of threat – algal growth, partial bleaching, full bleaching and seastar predation.

Site	NAI'A Pt. 1	NAI'A Pt. 2	Landing	Windward	SW corner	Average
Number of samples	5	4	5	5	4	4.6
Acropora						
Algal Growth	0	0	0	0	0	0
Fungia						
Bleached	0	0	0	1	0	0.2
Partly Bleached	0	0	0	0	1	0.2
Pocillopora						
Algal Growth	2	0	0	0	0	0.4
Bleached	1	1	1	3	4	2
Partly Bleached	3	1	2	10	0	3.2
Starfish Predation	1	0	0	0	0	0.2
Porites						
Bleached	0	0	1	0	0	0.2
Partly Bleached	0	0	1	1	0	0.4
Starfish Predation	1	0	0	0	0	0.2
TOTAL	8	5	2	15	5	7

Invertebrates. Clams in the genus *Tridacna* were the most frequent key invertebrate (Table 16) with no sightings of any sea cucumbers or *Acanthaster planci* (crown-of–thorns seastars) during the surveys. One *A. planci* was observed during a break in the survey schedule at 24m at North Beach. The low abundance of invertebrates was particularly striking, especially in view of the unexploited nature of the reefs.

Table 16. Number of key invertebrates observed at Nikumaroro Island, in replicate 10-minute samples.

Site	Landing	Nai'a Pt.	SW corner	Windward
Number of samples	5	5	4	5
Sea cucumbers				
Bohadschia argus	0	0	0	0
Holothuria atra	0	0	0	0
Holothuria leucospilota	0	0	0	0
Lobster	0	0	0	0
Clams (*Tridacna* sp.)	5	1	1	2
Acanthaster planci	0	0	0	0

Fishes. Large indicator predatory fishes were abundant at all sites at Nikumaroro (Table 17). Of the tuna and pelagics, rainbow runners were the most abundant, and dogtooth tuna were observed on every dive. Bigeye jacks were the most abundant of the carangids, forming large schools aggregated with barracuda on the windward site and at Nai'a Point. Chevron barracuda were present in large schools at two sites and large Napoleon wrasses were seen on all but one dive. Red bass were ubiquitous and highly curious, often circling within 30 cm of divers. Sharks were common and also highly curious at all sites, dominated by blacktip reef and grey reef sharks. They would usually approach divers directly, circle around a few times, then swim off only to return. Mildly aggressive behavior was observed occasionally, but never any escalation to strong aggression. One manta ray was recorded during surveys.

Of the ecologically important fish families, triggerfishes (invertivores) and surgeonfishes (herbivores) were ubiquitous and common at all sites (Table 18) in loose schools that would often break up as individual fish swam away. Snappers and parrotfishes were also common but their greater mobility often resulted in their not being counted during samples. Groupers were patchily distributed and not recorded at half of the sites sampled.

Nikumaroro had a high species richness of butterfly fishes and angel fishes (21 and 7 respectively, Table 19) recorded over 11 dives.

Sea Birds. There were no large aggregations of birds observed on this island indicating there may not have been any significant nesting occurring at the time of the survey. Species observed flying near the island included, 200-300 mostly sub-adult brown boobies (*Sula leucogaster)*, 50-70 great frigate birds (*Fregata minor*) of both sexes, 40-50 sooty (*Sterna fuscata*) or spectacled (*Sterna lunata*) terns, 20 masked boobies (*Sula dactylatra*), 20-30 brown noddies (*Anous stolidus*), and several little white fairy-terns (*Gygis microrhyncha*).

Table 17. Numbers of large indicator fish species at Nikumaroro Island.

Scientific Name	Common Name	Amelia LC	Land-ing	NAI'A Pt. (1)	NAI'A Pt. (2)	North Beach	SW Corner	Windward (1)	Windward (2)
TUNA AND PELAGICS									
Gymnosarda unicolor	Dogtooth Tuna	5	2	2	4	2	1	3	7
Euthynnus affinis	Mackerel Tuna	0	0	3	0	4	0	0	7
Scomberoides lysan	Double-spotted Queenfish	6	8	0	3	3	0	15	2
Elegatis bipinnulata	Rainbow Runner	11	0	10	20	22	6	20	8
JACKS									
Caranx sexfasciatus	Bigeye Trevally	30	50	200	50	30	0	50	100
Caranx melampygus	Bluefin Trevally	50	10	12	20	12	8	20	26
Caranx lugubris	Black Trevally	16	20	20	10	15	6	40	20
REEF PREDATORS									
Sphyraena qenie	Chevron Barracuda	1	0	2	2	250	0	300	300
Cheilinus undulatus	Napoleon Wrasse	4	2	4	6	2	1	6	0
Epinephelus fuscoguttatus	Flowery Cod	1	0	3		0	0	2	1
Plectropomus laevis	Footballer Trout	0	0	0	0	0	0	0	1
Aprion virescens	Green Jobfish	1	2	2	1	1	0	1	1
Lutjanus bohar	Red Bass	12	0	30	10	30	7	30	10
Macolor macularis	Midnight Seaperch	9	0	2	0	7	6	25	12
SHARKS AND RAYS									
Carcharhinus melanopterus	Blacktip Reef Shark	8	4	2	20	4	0	12	1
Carcharhinus amblyrhynchos	Grey Reef Shark	8	14	8	30	5	3	6	16
Triaenodon obesus	Whitetip Reef Shark	0	1	3	7	1	0	3	5
Manta birostris/alfredi	Manta Ray	0	1	0	0	0	0	0	0

Table 18. Average abundance of key fish families in 10-minute samples at Nikumaroro Island.

Site	Amelia's LC	Kandy Jar	Landing (1)	Sites (2)	NAI'A Point	North Beach	Norwich City	Windward
Epinephelinae (Groupers)	0	0	2.5	0	3.5	3	0	1
Lujanidae (Snappers)	31	60	40.5	18	60.5	0	18.5	29.3
Scaridae (Parrotfishes)	0	11	14.5	10	6.5	0	4.5	5.3
Acanthuridae (Surgeon and unicornfishes)	23	30	18	33	21	21	31	34.3
Balistidae (Triggerfishes)	12	6	19	6	10.5	8	10	20

Table 19. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at Nikumaroro Island.

Family	#	Species
Chaetodontidae (Butterfly fish)	21	*Chaetodon auriga, C. bennetti, C. ephippium, C. kleinii, C. lunula, C. meyeri, C. ornatissimus, C. punctatofasciatus, C. quadrimaculatus, C. reticulatus, C. semeiom, C. trifascialis, C. lunulatus, C. ulietensis, C. vagabundus* *Forcipiger flavissimus, F. longirostris* *Heniochus acuminatus, H. chrysostomus, H. monoceros, H. varius.*
Pomacanthidae(Angel fish)	9	*Apolemichthys arcuatus, A. griffisi* *Centropyge bicolor,C. flavicauda, C. flavissimus, C. loriculus, C. multifasciatus, C. nigriocellus, Pygoplites diacanthus*
Amphiprioninae (Anemone fish)	2	*Amphiprion chrysopterus, A. periderion*

Marine Turtles. Fifteen to 20 green sea turtle (*Chelonia mydas agassizi*) tracks were identified on the southwestern beach of this island (the only beach that researchers had time to survey). The tracks were fresh and may have represented nesting behavior within the past month. During the 11 dives on Nikumaroro, a total of one hawksbill (*Eretmochelys imbricata bissa*) and 12 green turtles were observed in situ.

Marine Mammals. A mixed group of bottlenose and spinner dolphins was oberved one mile to the east of Nikumaroro. The group swam in the bow wave of the vessel and both genera were photographed swimming within two meters of each other.

McKean Island

Site Descriptions. McKean was the second island on the trip itinerary with only two dives conducted on a single day, both on the leeward side (Table 20).

Table 20. Dive and survey sites at McKean Island.

Date	Time	Name	Lat. (S)	Long. (W)	Exposure
1-Jul-00	9:00 am	Guano Hut	03°35.86	174°07.69	Leeward
1-Jul-00	11:45 am	Rush Hour	03°35.52	174°07.65	Leeward

The lee (west) of the island appeared to have underwater shelves extending north and south. The first dive was on the southern shelf and slope, while the second dive was along the northern end of the lee side off the beach. The bottom topography was similar to that seen at Nikumaroro, except that the crest of the deep slope was closer to 20-24m, and the shallower slope was a more complex system of coral bommies and rocky patches surrounded by sand and rubble. The shallowest sections formed a steep solid wall, with “bowls” as observed at Nikumaroro. Visibility was lower and temperatures slightly cooler, suggesting upwelling and mixing of deeper water on this smaller island.

Bottom Cover. Coral cover was low at McKean, average 20%, with higher abundance of algae (mainly turf and incipient fleshy algae), rubble, and some coralline algae (Fig. 3). Very little *Halimeda* was observed while carpeting soft corals (*Sinularia*, *Lobophytum*) occupied 10% of the bottom. The greater abundance of algal turf was clear compared to Nikumaroro. Upwelling of nutrient-rich water may be a cause as well as fertilization from the guano deposited over hundreds of years by nesting sea birds on the island.

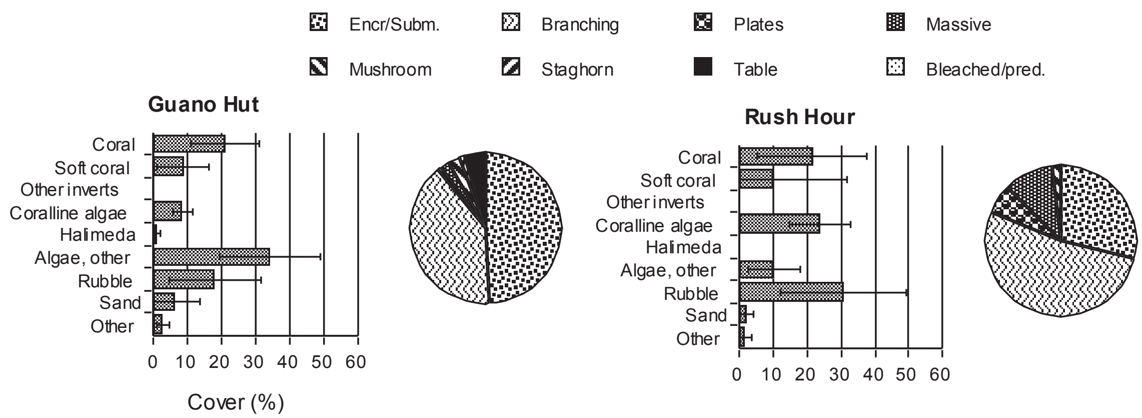

Figure 3. Benthic cover and relative abundance of coral growth forms at McKean Island.

Corals. As at Nikumaroro, branching and encrusting/submassive growth forms predominated, followed by massive corals in third place, due to the bommies that provided significant topography to the site (Fig. 3). Only one site (Guano Hut) was sampled for coral species, yielding a low number of 19 species. The coral fauna at the second site (Rush Hour) was apparently more diverse, however the coral fauna at this small island appears more depauperate than at the larger island of Nikumaroro. Very little evidence of coral stress was observed, with only one partially bleached *Fungia* recorded (Table 21).

Invertebrates. Sea cucumbers were found at only very low densities though giant clams (Tridacnids) were common at the second site, with an average of 23 recorded in a 10-minute sample (Table 22).

Fishes. The population of large predatory fishes at McKean was essentially similar to that of Nikumaroro, though with fewer schooling jacks and some missing species (Table 23), either because they were not there or because the low number of dives missed some of the rarer species. The shark population at Guano Hut was noticeably more active and aggressive than so far observed with rapid circling and aggregation by grey reef sharks at the start and throughout the dive.

Surveys for key fish families noted the low presence of herbivores at Guano Hut and high abundance of triggerfishes (Table 24). Though not recorded in the surveys, large parrotfishes were observed feeding in shallow waters < 15 m. The species diversity of butterfly fishes and angel fishes was significantly lower than at Nikumaroro (Table 25). As for corals, it is not possible to say explicitly whether smaller island area or lower sampling effort contribute to this low diversity of fishes.

Table 21. Frequency of coral threats observed at McKean Island. Number indicates the number of corals observed with each condition during 10 minute samples in each dive. Four coral genera were sampled for four categories of threat: algal growth, partial bleaching, full bleaching and seastar predation.

Site	Guano Hut	Rush Hour	Average
Number of samples	4	4	4
Acropora			
Algal Growth	0	0	0
Fungia			
Bleached	0	0	0
Partly Bleached	1	0	0.5
Pocillopora			
Algal Growth	0	0	0
Bleached	0	0	0
Partly Bleached	0	0	0
Seastar Predation	0	0	0
Porites			
Bleached	0	0	0
Partly Bleached	0	0	0
Seastar Predation	0	0	0
TOTAL	1	0	0.5

Table 22. Number of key invertebrates observed at McKean Island, in replicate 10-minute samples.

Site	Guano Hut	Rush Hour
Number of samples	4	5
Sea cucumbers		
Bohadschia argus	0	0
Holothuria atra	0	0
Holothuria leucospilota	2	0
Lobster	0	0
Clams (*Tridacna* sp.)	1	23
Acanthaster planci	0	0

Sea Birds. Large aggregations of birds were nesting on this island. Nearly the entire island was surveyed, allowing us to assess the bird populations with some certainty. Bird nesting sites were found throughout this island, with the large aggregations estimated at 2,000-4,000 spectacled or sooty terns, 2,000- 3,000 small white fairy-terns, 5,000-10,000 brown boobies, 10,000-20,000 great frigate birds, 1,000-2,000 brown noddies, and 5,000-10,000 masked boobies. Also present in lesser undetermined numbers were red-footed boobies (*Sula sula*). Probable petrel burrows were also observed, but no birds were seen. Several unidentified shorebirds, probably migrants, were also seen.

Marine Turtles. Due to the relatively small size of this island, researchers surveyed all sandy beach edges. Two recent green sea turtle tracks and nests were

Table 23. Numbers of large indicator fish species at McKean Island.

Scientific Name	Common Name	Guano Hut	Rushhour
TUNA AND PELAGICS			
Gymnosarda unicolor	Dogtooth Tuna	1	3
Euthynnus affinis	Mackerel Tuna	0	6
Scomberoides lysan	Double-spotted Queenfish	4	5
Elegatis bipinnulata	Rainbow Runner	15	12
JACKS			
Caranx sexfasciatus	Bigeye Trevally	0	0
Caranx melampygus	Bluefin Trevally	24	16
Caranx lugubris	Black Trevally	10	17
REEF PREDATORS			
Sphyraena qenie	Chevron Barracuda	0	0
Cheilinus undulatus	Napoleon Wrasse	3	6
Epinephelus fuscoguttatus	Flowery Cod	2	4
Plectropomus laevis	Footballer Trout	0	0
Aprion virescens	Green Jobfish	2	4
Lutjanus bohar	Red Bass	20	25
Macolor macularis	Midnight Seaperch	0	0
SHARKS AND RAYS			
Carcharhinus melanopterus	Blacktip Reef Shark	2	2
Carcharihinus amblyrhynchos	Grey Reef Shark	20	9
Triaenodon obesus	Whitetip Reef Shark	1	2
Manta birostris/alfredi	Manta Ray	0	0

Table 24. Average abundance of key fish families in 10-minute samples at McKean Island.

Site	Guano Hut	Rush Hour
Epinephelinae (Groupers)	4	6
Lujanidae (Snappers)	40	18
Scaridae (Parrotfishes)	0	0
Acanthuridae (Surgeon and Unicornfishes)	0	14
Balistidae (Triggerfishes)	23	12

Table 25. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at McKean Island.

Family	#	Species
Butterfly fishes	7	*Chaetodon auriga, C. ephippium, C. lunula, C. meyeri, C. ornatissimus, C. quadrimaculatus* *Forcipiger flavissimus*
Angel fishes	4	*Apolemichthys arcuatus* *Centropyge flavissimus, C. loriculus* *Pomacanthus imperator*
Anemone fish	1	*Amphiprion chrysopterus*

identified on the southern beach of this island. The tracks were fresh and may have represented nesting behavior within the past month. During three SCUBA surveys, a total of two green turtles and one hawksbill turtle were observed in situ.

Marine Mammals. There were no marine mammals observed at McKean.

Kanton (Aba-Riringa) Island

Site Descriptions. Kanton was the third and largest island on the trip itinerary and the first with a large lagoon. Twelve dives were made on nine unique sites (Table 26), of which four were on the leeward side, one windward, and two in the lagoon. As the largest island of the Phoenix group, and in the form of a true atoll with a large lagoon, Kanton had the largest variety of habitats to be surveyed. The lee of the island was the largest so far visited but, as with Nikumaroro, this only comprised the farthest western portion of the island. The lagoon of Kanton measured over 10 x 4 kilometers in length and width with the only opening at the leeward side through a channel artificially widened by blasting.

Table 26. Dive and survey sites at Kanton Island.

Date	Time	Name	Latitude	Longitude	Exposure
2-Jul-00	9:55 am	British Gas	02°49.20	171°43.15	Leeward
2-Jul-00	1:50 pm	Satellite Beach	02°47.47	171°43.81	Leeward
2-Jul-00	4:30 pm	President Taylor	02°49.03	171°43.15	Leeward
2-Jul-00	6:20 pm	British Gas	02°49.20	171°43.15	Leeward
3-Jul-00	7:50 am	Weird Eddie	02°48.86	171°43.34	Channel
3-Jul-00	11:50 am	Six Sticks	02°48.39	171°43.51	Leeward
3-Jul-00	2:45 pm	Coral Castles	02°48.22	171°42.61	Lagoon
3-Jul-00	6:45 pm	Six Sticks	02°48.37	171°43.50	Leeward
4-Jul-00	7:50 am	Nai'a Fly'a	02°48.91	171°43.24	Channel
4-Jul-00	12:10 pm	Steep To	02°50.32	171°42.47	Windward
4-Jul-00	3:00 pm	House of Cards	02°47.53	171°42.29	Lagoon
4-Jul-00	6:45 pm	Six Sticks	02°48.36	171°43.49	Leeward

The leeward sites showed a more highly developed reef community structure than at the islands visited so far with a broader shallow slope at 10-20 meters and greater development of a coral community. In 0 - 10 m of water the bottom was mostly made up of a solid wall and rock platform cut by deep surge channels. From 20 m and deeper the reef sloped steeply, as in previous islands visited, with a high proportion of rubble and large boulders.

At its entrance, the lagoon experiences very high tidal flows with extensive coral gardens extending a radius of approximately 2 km from the channel. Starting at about 4 km inside of the channel, the lagoon is crossed by four north-south reef ledges (Pacific Islands Pilot 1984, Jokiel and Maragos 1978) that reduce water flow and suppress coral growth. Surveys were restricted to the coral gardens zone which was characterized by highly developed *Acropora* tables and staghorn thickets growing over a sandy bottom with dunes and rocky spires.

Bottom cover. Coral communities were more highly developed on the Kanton reefs than at previous islands surveyed. The high end of coral development was represented by Satellite Beach with > 50% coral cover and approaching 100% on a 10 m scale of small patch reefs (Fig. 4). British Gas and Six Sticks represented the more average conditions with 30-40% coral cover and relatively high abundance of rubble, sand and turf and fleshy algae. Coralline algae and *Halimeda* were less abundant than at previous islands. Coral Castles in the lagoon, dominated by large tabular and staghorn *Acropora* colonies covering sandy and rocky substrates, had the highest coral cover of all sites on the expedition at > 80%. In the lagoon, coralline and other algae were only present underneath the canopy cover of coral colonies making identification on the video difficult.

Vertical and steep slopes also had more highly developed coral communities than seen at the previous islands. At Steep To, for example, on the windward side, the shallow slope was developed into a wall with deep canyons and caves supporting abundant and diverse coral and invertebrate growth. At Satellite Beach, the deeper steep slope had strong growth of small and medium-size corals on the rubble bottom, giving a high coral cover and diversity.

Corals. The coral community was morphologically more diverse at the Kanton outer sites (Fig. 4), generally dominated by the same branching and encrusting/ submassive corals as found previously (**Table 27**) . At Six Sticks there was a significant presence of massive and staghorn corals in the genera *Leptastrea/Favia* and *Acropora*,

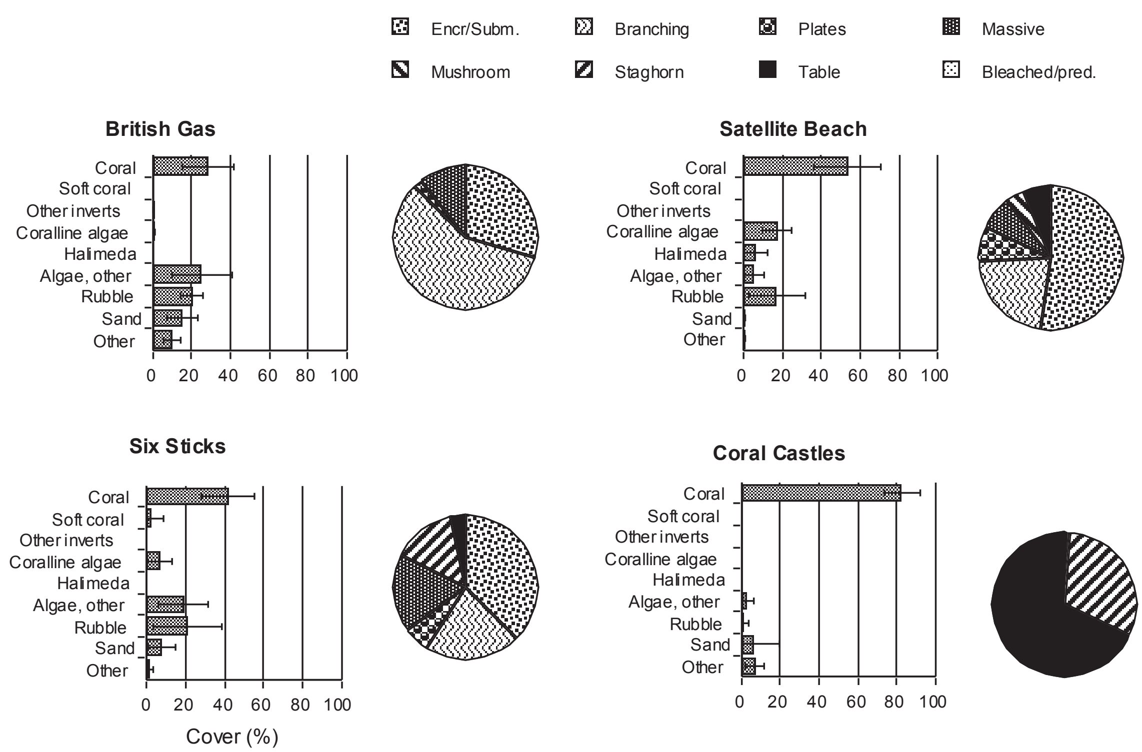

Figure 4. Benthic cover and relative abundance of coral growth forms at Kanton Island. See Figure 2 for legend.

Table 27. The 10 most abundant coral species at Kanton Island.

Family	Coral species
Acroporidae	*Acropora cytherea, Montipora efflorescens*
Agariciidae	*Pavona varians, Pavona explanulata*
Faviidae	*Leptastrea purpurea, Favia stelligera, Echinopora lamellosa*
Fungiidae	*Halomitra pileus*
Milleporidae	*Millepora platyphylla*
Pocilloporidae	*Pocillopora verrucosa*

respectively. The dominance of *Acropora* in the lagoon at Coral Castles is clearly shown by the dominance of table and staghorn morphologies. The lagoon sites surveyed are among the most highly developed *Acropora* communities we have seen anywhere in the world.

Six sites were sampled for coral species presence, yielding 73 species. Kanton had the highest single-site and island-wide number of coral species of all the islands, with 76% of all coral species recorded. Further evidence of the health of coral communities at Kanton was the near absence of signs of threat to corals, with only algal overgrowth recorded for two coral colonies in the four sites surveyed (Table 28).

Table 28. Frequency of coral threats observed at Kanton Island. See caption to Table 15 for details.

	Satellite Beach	British Gas	Six Sticks	Steep To	Average
Number of samples	5	3	3	3	3.5
Acropora					
Algal Growth	0	1	0	0	0.25
Fungia					
Bleached	0	0	0	0	0
Partly Bleached	0	0	0	0	0
Pocillopora					
Algal Growth	1	0	0	0	0.25
Bleached	0	0	0	0	0
Partly Bleached	0	0	0	0	0
Seastar Predation	0	0	0	0	0
Porites					
Bleached	0	0	0	0	0
Partly Bleached	0	0	0	0	0
Seastar Predation	0	0	0	0	0
TOTAL	1	1	0	0	0.5

Invertebrates. As at Nikumaroro, invertebrates were noticeably absent with only a few giant clams (genus *Tridacna*) noted on fore reef slopes,and a lobster in the complex canyons and caves at Steep To (Table 29).

Fishes. The general fish fauna at Kanton was similar to that at previous islands, with regular occurrence of dogtooth tuna, barracuda, red bass and sharks at all sites. Exceptionally abundant fish populations were recorded around the channel leading into the lagoon at the sites NAI'A Fly'a, President Taylor and Weird Eddie (Table 30,

Table 31). Schooling trevally were present in massive schools, congregating there with 1,000s-strong schools of parrot fish on the turn of the tides. Intense spawning activity was noted of the parrot fish, *Hipposcarus longiceps*, at the mouth of the channel on the new moon at the onset of the ebbing tide. A large school of snapper was recorded on the fore reef at the site British Gas (Table 31), consisting largely of *Lutjanus gibbus*, commonly seen throughout the islands. Manta rays were observed in the area of the channel mouth and patrolling the reef margin to the north.

Table 29. Number of key invertebrates observed at Kanton Island, in replicate 10-minute samples.

Site	**British Gas**	**Satellite Beach**	**Six Sticks**	**Steep To**
Number of samples	3	5	3	3
Sea cucumbers				
Bohadschia argus	0	0	0	0
Holothuria atra	0	0	0	0
Holothuria leucospilota	0	0	0	0
Lobster	0	0	0	1
Clams (*Tridacna* sp.)	0	2	1	1
Acanthaster planci	0	1	0	0

Table 30. Numbers of large indicator fish species at Kanton Island.

Scientific Name	Common Name	British Gas	NAI'A Fly'a	Satellite Beach	Weird Eddie
TUNA AND PELAGICS					
Gymnosarda unicolor	Dogtooth Tuna	0	7	4	6
Euthynnus affinis	Mackerel Tuna	0	0	0	0
Scomberoides lysan	Double-spotted Queenfish	1	0	0	11
Elegatis bipinnulata	Rainbow Runner	20	14	8	18
JACKS					
Caranx sexfasciatus	Bigeye Trevally	0	1000	0	700
Caranx melampygus	Bluefin Trevally	19	25	57	25
Caranx lugubris	Black Trevally	7	20	7	50
REEF PREDATORS					
Sphyraena qenie	Chevron Barracuda	10	16	1	100
Cheilinus undulatus	Napoleon Wrasse	9	7	7	4
Epinephelus fuscoguttatus	Flowery Cod	2	2	7	2
Plectropomus laevis	Footballer Trout	0	0	0	0
Aprion virescens	Green Jobfish	1	2	0	0
Lutjanus bohar	Red Bass	20	17	40	35
Macolor macularis	Midnight Seaperch	0	0	0	0
SHARKS AND RAYS					
Carcharhinus melanopterus	Blacktip Reef Shark	0	0	0	0
Carcharhinus amblyrhynchos	Grey Reef Shark	5	5	13	2
Triaenodon obesus	Whitetip Reef Shark	1	4	2	2
Manta birostris/alfredi	Manta Ray	0	2	0	2

Table 31. Average abundance of key fish families in 10-minute samples at Kanton Island.

Site	British Gas	President Taylor	Satellite Beach	Weird Eddie
Groupers	2	4	3	8
Snappers	1,000	110	65	11
Parrotfishes	7	800	18	8
Surgeonfishes	21	18	12	18
Triggerfishes	7	5	3	16

Despite its larger size, Kanton had a lower diversity of buttefly fishes and angel fishes than Nikumaroro (15 compared to 21, and five compared to seven, respectively, Table 32). This may, however, be due to repeat sampling at Nikumaroro at the end of the trip when more closely targeted observation for absent species may have yielded better survey results.

Table 32. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at Kanton Island.

Family	#	Species
Butterfly fishes	15	*Chaetodon bennetti, C. ephippium, C. kleinii, C. lunula, C. meyeri, C. ornatissimus, C. quadrimaculatus, C. trifascialis, C. lunulatus, C. ulietensis, C. vagabundus* *Forcipiger flavissimus* *Heniochus acuminatus, H. singularis, H. varius*
Angel fishes	5	*Apolemichthys griffisi* *Centropyge flavissimus, C. loriculus, C. multifasciatus* *Pomacanthus imperator*
Amphiprioninae (Anemone fishes)	2	*Amphiprion chrysopterus, A. periderion*

Sea Birds. More than 20,000 brown noddies were seen returning to land at dusk and continued to be heard returning after dark. A small undetermined number of spectacled or sooty terns, as well as small white fairy-terns, were also seen from the water.

Marine Turtles. No beach surveys for nesting sites were conducted at this island. During nine SCUBA surveys, a total of one hawksbill and 34 green turtles were observed in situ.

Marine Mammals. Bottlenose dolphins were observed five times along the southwestern side of the island; two sightings occurred during night dives. All sightings consisted of groups of 10 – 15 individuals.

Enderbury Island

Site Descriptions. Enderbury was the fourth island on the trip itinerary with four dives made on a single day at four unique sites (one windward, three leeward, Table 33). Similar to McKean Island, Enderbury is a small island with no lagoon, a small west-facing leeward side, and rocky platforms extending north and south from the leeward edge. The Southern Ocean site was the most windward facing point surveyed so far on the expedition at the extreme southeastern point of the island and facing straight into the south and easterly wind and swells.

Table 33. Dive and survey sites at Enderbury Island.

Date	Time	Name	Lat. (S)	Long. (W)	Exposure
5-Jul-00	7:45 am	Southern Ocean	03°08.79	171°04.51	Windward
5-Jul-00	12:15 pm	Obs Spot	03°08.45	171°05.71	Leeward
5-Jul-00	3:45 pm	Shark Village	03°06.22	171°05.44	Leeward
5-Jul-00	7:00 pm	Bird Beach	03°07.29	171°05.74	Leeward

The survey sites were similar to locations surveyed on previous islands. The leeward site was even more dramatic in its depth profile, with a sharp reef edge at about 15m. Above this was a gently sloping platform dominated by rubble (Fig. 5), to an extent not seen before on the trip. The rubble bottom was interrupted in places by the underlying rocky substrate, increasingly at shallow depths. The deeper slope was steep, almost entirely composed of large rubble pieces jammed together. The influence of ocean swell and wave-induced breakage of corals was clear in the amount of old and fresh rubble, with strong transport of the rubble down the reef slope.

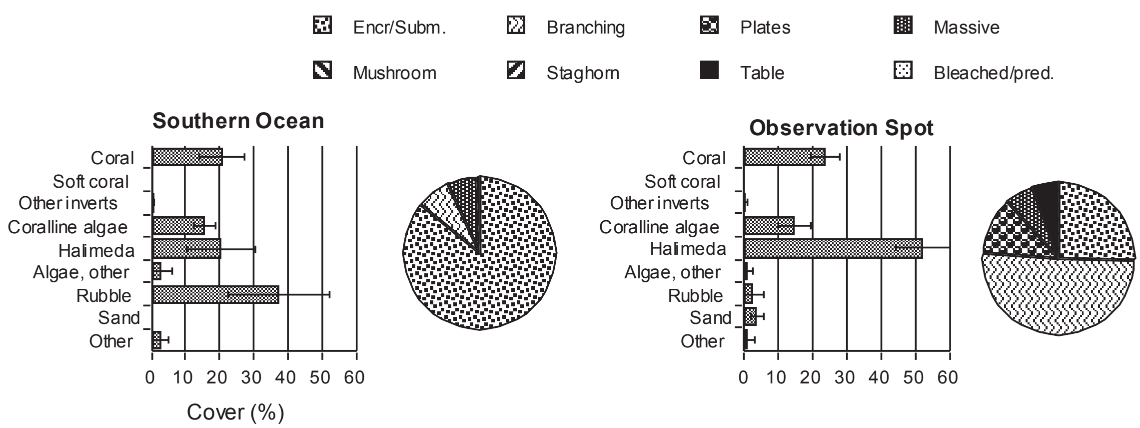

Figure 5. Benthic cover and relative abundance of coral growth forms at Enderbury Island. See Figure 2 for legend.

Bottom Cover. Both leeward and windward slopes were dominated by coral rubble (Figure 5), clearly produced by breakage from the existing corals, and, from observation on the beach and the island, from the rock that makes up the island. Algal cover on the rubble and rock surfaces was predominantly coralline algae and *Halimeda*. There was little evidence of soft coral and other invertebrates, perhaps due to the highly mobile rubble.

Corals. Coral cover at both survey sites was relatively low, at 20-25%, and clearly contributed to the abundant rubble. The dominance of encrusting/submassive corals at the windward site attests to the continual breakage of branching and plating forms. Few large coral colonies and many small ones were seen, indicating frequent breakage preventing growth to large size. Coral diversity was moderate, with 47 species recorded from 2 dives. Species in the genus *Pavona* were particularly abundant (Table 34), often found in areas of high physical disturbance and opportunistic growth. Coral condition and threats were not surveyed as at previous sites but little stress was seen and the only major influence noted was physical breakage, as mentioned above.

Table 34. The 10 most abundant coral species at Enderbury Island.

Family	Coral species
Agariciidae	*Pavona clavus, P. maldivensis, P. minuta, P. varians*
Faviidae	*Favia stelligera, Leptastrea purpurea, Favites pentagona*
Fungiidae	*Halomitra pileus*
Pocilloporidae	*Pocillopora verrucosa*
Poritidae	*Porites lutea*

Invertebrates. Invertebrate surveys were not conducted due to injury to the collector. Observations recorded the presence of *Tridacna* clams in moderate numbers (see previous results), three species of holothurian including *Bohadschia argus*, and the seastar *Linkia* spp.

Fishes. Overall, the fish populations at Enderbury had a larger component of pelagic species than the other islands and fewer coral reef species. In terms of the large fishes, more rainbow runner and black trevally were recorded than previously (Table 35). Most noticeably, the abundance of sharks, particularly grey reef sharks, at the windward point was significantly larger than previously seen at other islands. Red bass was also present in larger numbers. Triggerfishes were more abundant than previously noted with large numbers of the planktivorous black and blue durgons, *Odonus niger* and *Melichthys niger*, respectively (Table 36).

The populations of butterfly fishes, angel fishes and anemone fishes at Enderbury were noticeably less diverse than all the other islands, including McKean, with only three butterfly species seen (Table 37).

Sea Birds. Large aggregations of birds were nesting on this island including, in just one area, 10,000-15,000 great and lesser frigate birds and 30,000+ spectacled or sooty terns. In addition, smaller numbers of other birds were observed including masked and brown boobies, red-tailed tropic birds (*Phaethon rubricauda*), brown noddies, little white fairy-terns, and several shorebirds (one plover and one possible yellowlegs). Birds of all ages, of various species, were observed, as were eggs.

Marine Turtles. All beaches were carefully walked on this island, without evidence of turtle nesting. During three SCUBA surveys, a total of five green turtles were observed in situ.

Marine Mammals. No marine mammals were seen at Enderbury.

Table 35. Numbers of large indicator fish species at Enderbury Island.

Scientific Name	**Common Name**	**Obs. Spot**	**Shark Village**	**Southern Ocean**
TUNA AND PELAGICS				
Gymnosarda unicolor	Dogtooth Tuna	1	1	3
Euthynnus affinis	Mackerel Tuna	3	4	0
Scomberoides lysan	Double-spotted Queenfish	0	0	0
Elegatis bipinnulata	Rainbow Runner	30	46	18
JACKS				
Caranx sexfasciatus	Bigeye Trevally	0	0	0
Caranx melampygus	Bluefin Trevally	0	20	30
Caranx lugubris	Black Trevally	50	30	60
REEF PREDATORS				
Sphyraena qenie	Chevron Barracuda	0	20	0
Cheilinus undulatus	Napoleon Wrasse	0	2	2
Epinephelus fuscoguttatus	Flowery Cod	0	0	0
Plectropomus laevis	Footballer Trout	0	0	0
Aprion virescens	Green Jobfish	0	2	0
Lutjanus bohar	Red Bass	45	30	60
Macolor macularis	Midnight Seaperch	0	0	0
SHARKS AND RAYS				
Carcharhinus melanopterus	Blacktip Reef Shark	1	0	2
Carcharhinus amblyrhynchos	Grey Reef Shark	18	30	20
Triaenodon obesus	Whitetip Reef Shark	4	6	3
Manta birostris/alfredi	Manta Ray	0	0	0

Table 36. Average abundance of key fish families in 10-minute samples at Enderbury Island.

Site	Obs. Spot	Shark Village	Southern Ocean
Groupers	0	6	6
Snappers	29	18	0
Parrotfishes	3	8	0
Surgeonfishes	11	12	21
Triggerfishes	26	32	50

Table 37. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at Enderbury Island.

Family	#	Species
Butterfly fishes	3	*Chaetodon quadrimaculatus, C. punctatofasciatus, Forcipiger flavissimus.*
Angel fishes	4	*Apolemichthys griffisi Centropyge flavissimus, C. loriculus Pomacanthus imperator*
Amphiprioninae (Anemone fishes)	1	*Amphiprion chrysopterus*

Rawaki (Phoenix) Island

Site Descriptions. Rawaki Island was the fifth island on the trip itinerary with four dives made on one day, at three leeward sites (Table 38). Phoenix Island was slightly larger than Enderbury and McKean Islands, but with similar terrestrial habitats and more nearly circular. As with the others, the lee of the island comprised only the farthest western portion of the island with a long sandy beach bordered at the north and south by a rocky platform with heavy surf from the windward sides. The survey sites sloped gently from the beach margin, consisting of a sandy bottom with large coral bommies bearing high densities of coral heads. At 15-20m, the sandy bottom flowed into large and steep sandy canyons with the coral bommies coalescing into rocky and hard-substrate spurs, sloping steeply into deep water.

Table 38. Dive and survey sites at Rawaki Island.

Date	Time	Name	Lat. (S)	Long. (W)	Exposure
6-Jul-00	7:45 am	Stillwater	03°43.39	170°42.91	Leeward
6-Jul-00	10:45 am	Deepwater	03°43.18	170°43.00	Leeward
6-Jul-00	2:10 pm	Clearwater	03°43.60	170°42.79	Leeward
6-Jul-00	4:50 pm	Stillwater	03°43.39	170°42.91	Leeward

Bottom Cover. Excluding the sandy bottom between the coral bommies, the three dive sites at Rawaki Island had among the highest cover of live coral of all the fore-reef slopes visited comparable to Six Sticks at Kanton Island. The rocky platforms and spurs of Stillwater and Deepwater had coral cover of over 60% (Fig. 6) with coralline algae as the next dominant cover category in shallow water and rubble on the steep slopes in deeper water.

Corals. Unlike other sites, branching corals were not dominant at Rawaki Island with highest cover contributed by encrusting/submassive colonies at one site and plates at the other two (Fig. 6). Massive corals were also significant in abundance, reflecting the origin of the coral bommies that form the main reef substrate of the sites. Two sites were sampled for coral species yielding 38 species, a relatively low number compared to the other islands surveyed. The high abundance of massive corals recorded at Rawaki Island (Fig. 6) is reflected in the abundance of small and medium-sized massive colonies of 5 faviid species (Table 39).

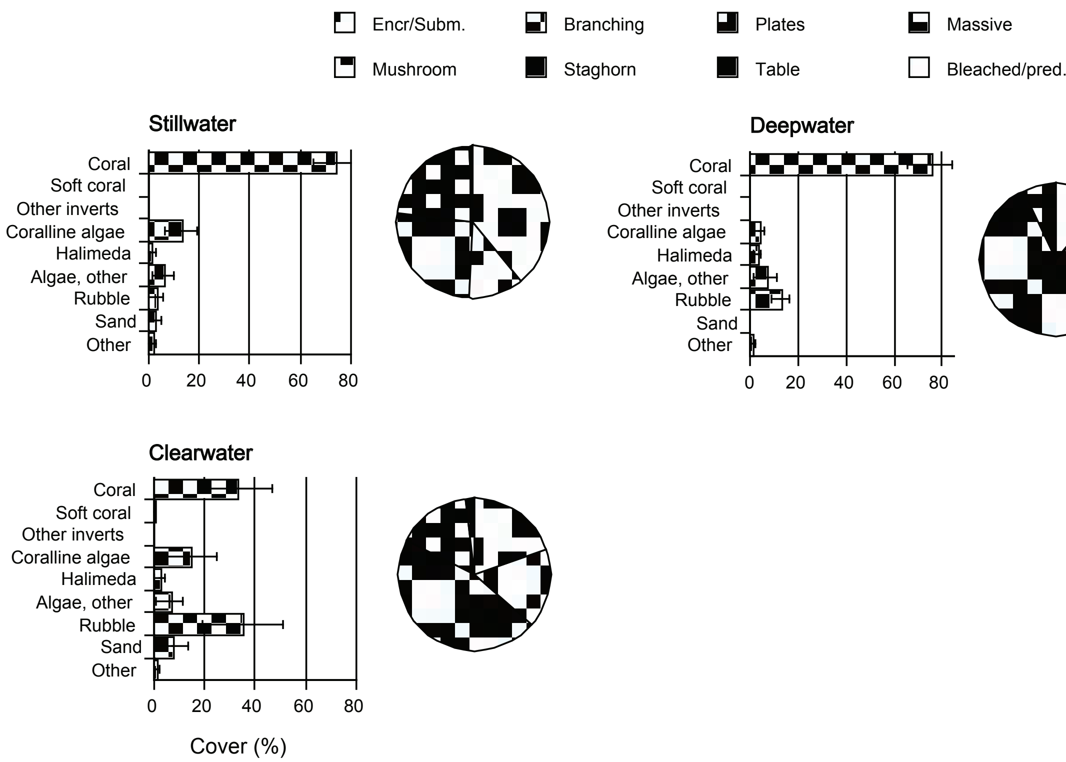

Figure 6. Benthic cover and relative abundance of coral growth forms at Rawaki Island. See Figure 2 for legend.

Table 39. The 10 most abundant coral species at Rawaki Island.

Family	Coral species
Acroporidae	*Acropora cytherea, Montipora efflorescens*
Faviidae	*Cyphastrea chalcidicum, Favia rotumana, Favia stelligera, Leptastrea purpurea, Montastrea annuligera*
Agariciidae	*Pavona varians*
Pocilloporidae	*Pocillopora eydouxi*
Poritidae	*Porites lutea*

Coral condition and threats were not quantified but little stress was seen. The only major influence noted was a high proportion of rubble in shallow water at Deepwater where surf refracted around the southern point causing breakage of corals. The elevation of coral heads on large bommies above the bottom likely has a large effect in reducing scouring damage by sand and rubble during storms.

Invertebrates. Invertebrate surveys were not conducted.

Fishes. Rawaki Island survey sites had a relatively low abundance of pelagic species, tuna, groupers and sharks. The dominant large fishes seen were the black trevally and red bass (Table 40). The dominance of large coral bommies at the sites were reminiscent of high-current patch reefs of mainstream Indo-Pacific reef systems potentially influencing the predatory fish fauna in a similar way towards an abundance of jacks and snappers as dominant predators. No data were recorded on the abundance of the key fish families.

Table 40. Numbers of large indicator fish species at Rawaki Island.

Scientific Name	Common Name	Rawaki	
		North West	South West
TUNA AND PELAGICS			
Gymnosarda unicolor	Dogtooth Tuna	1	0
Euthynnus affinis	Mackerel Tuna	0	0
Scomberoides lysan	Double-spotted Queenfish	0	0
Elegatis bipinnulata	Rainbow Runner	8	6
JACKS			
Caranx sexfasciatus	Bigeye Trevally	0	0
Caranx melampygus	Bluefin Trevally	6	9
Caranx lugubris	Black Trevally	20	40
REEF PREDATORS			
Sphyraena qenie	Chevron Barracuda	2	2
Cheilinus undulatus	Napoleon Wrasse	2	8
Epinephelus fuscoguttatus	Flowery Cod	0	0
Plectropomus laevis	Footballer Trout	0	0
Aprion virescens	Green Jobfish	1	3
Lutjanus bohar	Red Bass	50	50
Macolor macularis	Midnight Seaperch	0	0
SHARKS AND RAYS			
Carcharhinus melanopterus	Blacktip Reef Shark	0	0
Carcharhinus amblyrhynchos	Grey Reef Shark	2	4
Triaenodon obesus	Whitetip Reef Shark	3	2
Manta birostris/alfredi	Manta Ray	0	0

Rawaki Island had a representative assemblage of butterfly fishes (nine species compared to highs of 15 at Kanton and 21 at Nikumaroro where sampling was more intensive), and a full complement of angel fishes and anemone fishes (five and two species respectively, Table 41).

Table 41. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at Rawaki Island.

Family	#	Species
Butterfly fishes	9	*Chaetodon auriga, C. ephippium, C. lunula, C. meyeri, C. ornatissimus, C. ulietensis, C. unimaculatus, C. vagabundus Forcipiger flavissimus.*
Angel fishes	5	*Apolemichthys griffisi* *Centropyge flavissimus, C. loriculus, C. multifasciatus* *Pomacanthus imperator*
Amphiprionine (Anemone fishes)	2	*Amphiprion chrysopterus, A. periderion*

Sea Birds. The large numbers of birds nesting on this island created a strong guano odor that reached the boat offshore. Several spirals comprising 120 frigate birds each were seen over the water and the land. Tens of thousands of mostly great frigate birds were seen in one area, interspersed with occasional brown and masked boobies, as well as occasional red-footed boobies on their tall stick nests. Nests contained eggs or nestlings. A few juvenile lesser frigate birds were noted. The small area visited contained groups of mixed male-female great frigate birds as well as a group of 5000+ males; there was also a large area of same-age chicks alone. Present were a few little white fairy-terns on the wing and a few blue-grey noddies (*Procelsterna cerulea*) nesting. Also nesting were brown noddies with eggs and chicks. Two nesting red-tailed tropic birds were found in this area and one large juvenile. Several all-dark, unidentified petrels were found nesting under large rocks. Five shorebirds, probably migrants, were seen, of which three were whimbrels (*Numenius phaeopus*).

Marine Turtles. All beaches were carefully walked on this island and five green turtle nest sites were found. At the top of one nest a desiccated baby green sea turtle carcass was collected. During three SCUBA surveys, a total of three green turtles were observed in situ.

Marine Mammals. No marine mammals were seen at this island. (There were dozens of living rabbits observed on this island).

Manra (Sydney) Island

Site Descriptions. Manra was the sixth island visited on the expedition with four dives made at four unique sites. Two windward and twp leeward sites were visited; the first windward site (Northern Exposure) exposed to strong currents and refracted waves at the northern tip of the island and the second (Wild Side) on the southern tip of the island exposed to storms and swell from the south and east (Table 42).

Table 42. Dive and survey sites at Manra Island.

Date	Time	Name	Latitude	Longitude	Exposure
7-Jul-00	7:45 am	Harpoon Corner	04°27.15	171°15.93	Leeward
7-Jul-00	11:40 am	Northern Exposure	04°26.02	171°14.50	Windward
7-Jul-00	11:40 am	Northern Lee	04°26.05	171°14.70	Leeward
7-Jul-00	3:05 pm	Wild Side	04°27.64	171°13.42	Windward

The topography of the survey sites conformed to previous ones. The north windward point resembled closely the north windward sites at Nikumaroro (Windward Wing) with high cover of tightly packed branching and submassive corals, coralline algae and rubble on a shelf to about 15m, dropping sharply onto a rubble slope. The south windward slope resembled the similar site at Enderbury (Southern Ocean), with a shallow shelf dominated by the rubble of branching and plating corals broken by ocean swell and a sharp drop off onto a steep rubble wall. The leeward sites had the typical shallow shelf with a moderate cover of corals mixed with rubble and mixed algae turning into large coral bommies on a sandy bottom adjacent to a beach with a steep slope of rocky and rubble spurs between sand chutes.

Bottom Cover. The leeward sites showed typical coral communities for the Phoenix Islands with ≈ 30 % coral cover and 20 % coralline algae, followed by a mixture of fleshy algae, rubble and sand (Fig. 7). As with the other small, round islands, Manra had a beach on its leeward shore resulting in high supply of sand to the shallow subtidal platform, development of coral bommies, and steeply sloping sand chutes at 15-20m. The northern windward slope had a similar coral cover with comparable abundance of coralline algae and rubble indicating high levels of breakage by waves. The deep slope here was not as steep as most slopes so far encountered and was dominated by rubble tumbling down from the shallow platform above. The coral community at the southern windward site showed extreme influence of swell and storm damage with large expanses of recent partially living coral rubble, including many plates of the fast growing genus *Montipora* with coralline and turf algae on the dead parts of the rubble.

Corals. The coral communities at Manra were dominated by submassive and branching corals, typical of most survey sites (Fig. 7). The leeward site had a significant abundance of massive coral heads and the northern windward site had significant quantities of mushroom coral. Forty-three coral species were recorded in two dives with the abundance of submassive, massive and mushroom corals illustrated by the top 10 corals all being in the families Faviidae (massive/submassive) and Fungiidae (mushroom corals, Table 43).

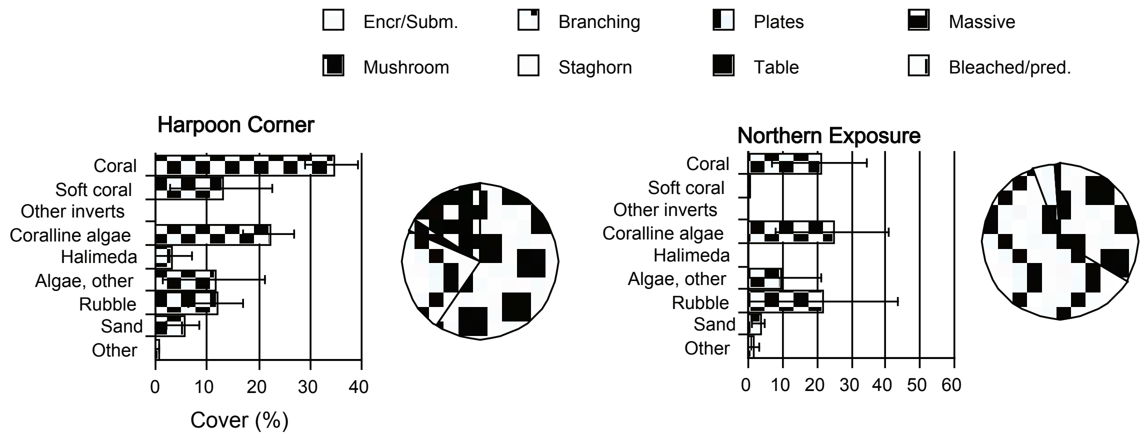

Figure 7. Benthic cover and relative abundance of coral growth forms at Manra Island. See Figure 2 for legend.

Table 43. The 10 most abundant coral species at Manra Island.

Family	Coral species
Faviidae	*Cyphastrea chalcidicum, Echinopora lamellosa, Favia rotumana, Favia stelligera, Favites pentagona*
Fungiidae	*Fungia danai, Fungia fungites, Fungia scutaria, Halomitra pileus, Herpolitha limax*

Fishes. Large predatory fishes were abundant at all survey sites in particular at or adjacent to the windward slopes (the Northern Lee site was around a point from Northern Exposure, which was not sampled for fishes). Northern Lee and Wild Side had high abundances of trevally, red bass and grey reef sharks, similar to populations encountered at the windward site at Nikumaroro and Enderbury (Table 44). Though not sampled quantitatively, Northern Exposure also had high abundances of sharks, trevally and barracuda.

The abundance of key fish families was moderate at the leeward sites surveyed in Manra with prominence of planktivorous triggerfishes(Table 45). The species diversity of butterfly fishes was high compared to those of other similar islands, reflecting the high diversity of coral species and complex topography of the coral bommy habitats. (Table 46)

Sea Birds. None noted.

Marine Turtles. All beaches were carefully walked on this island and 31 green turtle nest sites were found. During three SCUBA surveys, a total of 17 green turtles were observed in situ.

Marine Mammals. No marine mammals were seen at this island.

Table 44. Numbers of large indicator fish species at Manra Island.

Scientific Name	Common Name	Harpoon Corner	Northern Lee	Wild Side
TUNA AND PELAGICS				
Gymnosarda unicolor	Dogtooth Tuna	0	4	2
Euthynnus affinis	Mackerel Tuna	0	0	0
Scomberoides lysan	Double-spotted Queenfish	0	0	0
Elegatis bipinnulata	Rainbow Runner	20	6	20
JACKS				
Caranx sexfasciatus	Bigeye Trevally	0	0	50
Caranx melampygus	Bluefin Trevally	2	20	40
Caranx lugubris	Black Trevally	11	40	20
REEF PREDATORS				
Sphyraena qenie	Chevron Barracuda	200	100	10
Cheilinus undulatus	Napoleon Wrasse	2	4	4
Epinephelus fuscoguttatus	Flowery Cod	0	0	0
Plectropomus laevis	Footballer Trout	0	0	0
Aprion virescens	Green Jobfish	2	1	3
Lutjanus bohar	Red Bass	9	20	70
Macolor macularis	Midnight Seaperch	0	0	0
SHARKS AND RAYS				
Carcharhinus melanopterus	Blacktip Reef Shark	0	1	3
Carcharhinus amblyrhynchos	Grey Reef Shark	3	11	17
Triaenodon obesus	Whitetip Reef Shark	6	2	4
Manta birostris/alfredi	Manta Ray	0	0	0

Table 45. Average abundance of key fish families in 10-minute samples at Manra Island.

Site	Harpoon Corner	Northern Lee
Groupers	7	0
Snappers	7	8
Parrotfishes	2	6
Surgeonfishes	27	15
Triggerfishes	45	40

Table 46. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Pomacentridae; Amphiprioninae) species recorded at Manra Island.

Family	#	Species
Butterfly fishes	13	*Chaetodon bennetti, C. ephippium, C. meyeri, C. ornatissimus, C. quadrimaculatus, C. reticulatus, C. unimaculatus Forcipiger flavissimus, F. longirostris Heniochus acuminatus, H. monoceros, H. varius, H. singularis.*
Angel fishes	4	*Apolemichthys griffisi Centropyge flavissimus, C. loriculus Pomacanthus imperator*
Anemone fishes	2	*Amphiprion chrysopterus, A. periderion*

Orona (Hull) Island

Site Descriptions. Orona Island was the last island to be visited on the expedition before the final return to Nikumaroro. Seven dives and one snorkel survey (Lagoon Look 1) were conducted at six unique sites (Table 47). Orona is an atoll with a large lagoon second in size to Kanton but with several spill-overs and shallow channels allowing exchange between the lagoon and surrounding ocean. The lagoon was deep with 10 – 20 m basins dotted with shallow rubble patches on very fine white sand. Towards the main channel it had good development of bommies and rocky/rubble patches, with a low diversity of corals and high abundance of small *Tridacna* clams.

Table 47. Dive and survey sites at Orona Island.

Date	Time	Name	Lat. (S)	Long. (W)	Exposure
8-Jul-00	7:50 am	Algae Corner	04°30.58	172°13.56	Leeward
8-Jul-00	12:10 pm	Lagoon Look 1	04°30.37	172°08.32	Leeward
8-Jul-00	12:20 pm	Lagoon Look 2	04°29.83	172°09.31	Leeward
8-Jul-00	12:30 pm	Lagoon Look 3	04°29.49	172°10.15	Leeward
8-Jul-00	3:10 pm	Dolphin Ledge	04°28.90	172°10.45	Leeward
9-Jul-00	7:50 am	Aerials	04°32.05	172°12.39	Windward
9-Jul-00	11:00 am	Dolphin Ledge	04°28.89	172°10.45	Leeward
9-Jul-00	3:30 pm	Dolphin Ledge	04°28.89	172°10.45	Leeward

The outer reef sites were similar in topography to other sites visited, on windward and leeward sides, with two notable exceptions. Algae Corner on the western tip of the island did not have a deep wall or steep slope, the bottom deepening gradually from rocky and rubble patches as found in other sites to a rubble slope tailing off into deeper water. Dolphin Ledge, at the entrance to the lagoon channel on the north-western leeward shore was characterized by deep (3 - 5m vertical relief) and narrow surge channels in shallow water and leading into the lagoon giving way to a fine-rubble bottom steeply sloping at 15 – 20m into deep water. Unlike any other sites visited on the entire expedition Algae Corner and the shallow surge channels at Dolphin Ledge showed evidence of eutrophication, to be discussed below.

Bottom Cover. The survey sites at Orona Island had a number of unique characteristics in comparison to all the sites so far surveyed. Algae Corner showed evidence of high nutrient levels, currently and/or in the recent past by a high cover of filamentous wispy brown algae on all surfaces including rock, rubble, *Halimeda* and other algae (Fig. 8). Coral cover was extremely low at < 5%, though coral heads typical of a healthy reef were abundant though dead. Their varied appearance, levels of degradation and epiphytic algal covering suggested there was chronic mortality over an extended period of time. Nutrient enrichment was also apparent in the shallow surge channels at Dolphin Ledge at the entrance to the lagoon shown by the presence of small tufts of brown algae. This site also had a large iron anchor and chain extending from < 5 m down the slope and off the into the deep and evidence of shipwrecks on the beach. Iron enrichment causes characteristic "black turf" growths on remote atoll reefs, documented on Rose Reef and Tabuaeran in the

Line Islands (J. Maragos, pers. comm.), and this may have played a role in the degradation of Algae Corner. Additionally, we recorded observations by the residents of Orona in 2002, that there was a high incidence of ciguatera in fish from this site, probably related to eutrophication and algal growth.

The Aerials survey site was similar to other windward sites with large quantities of recent coral rubble, covered with coralline algae, and healthy coral populations though at a low cover of 20%. Dolphin Ledge had a very high proportion of fine, interlinked coral rubble on the bottom with many small living corals cemented onto this mobile substrate. Nevertheless, coral recruitment and growth were robust and diversity high.

At inner leeward lagoon sites, 10 coral species were identified typical of high-silt environments (e.g., *Favia* spp., *Cyphastrea chalcidium*, *Acropora lovelli*), growing loose on fine calcareous silt in aggregated patches with abundant *Tridacna* clams. Towards the center and windward side of the lagoon the sandy bottom became coarser with coral growth developing around dead bommies and small patch reefs. Coral diversity increased progressively towards the lagoon channel, with increasing presence of outer-reef species.

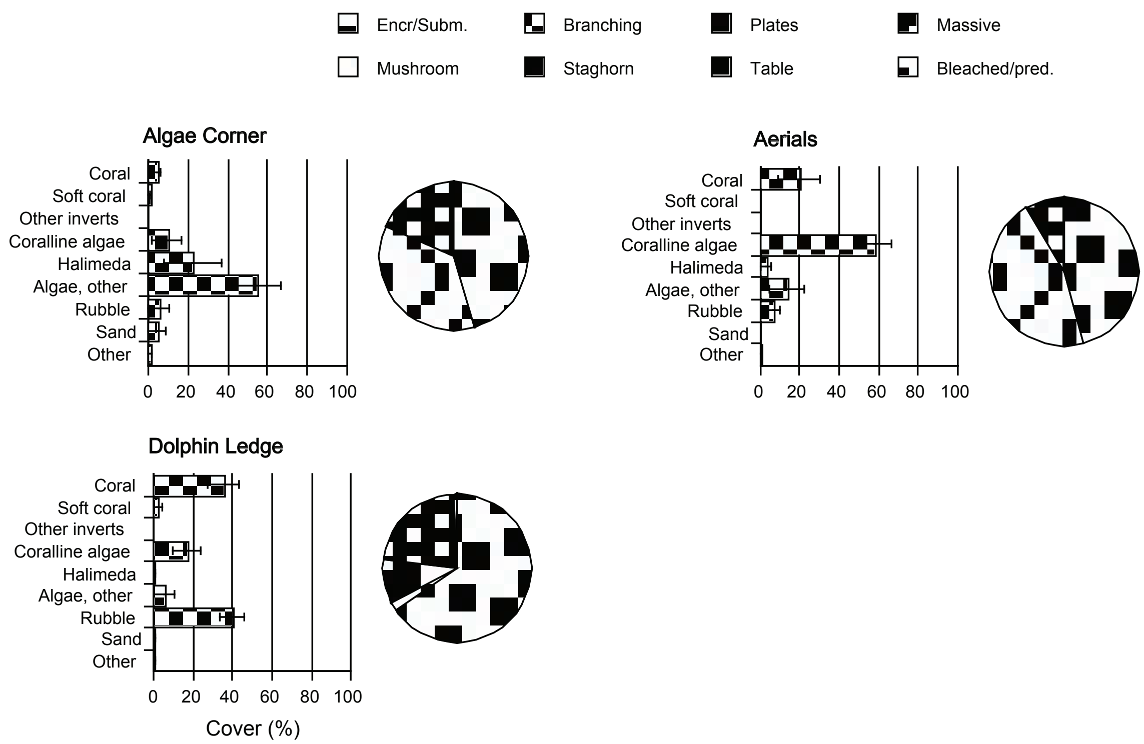

Figure 8. Benthic cover and relative abundance of coral growth forms at Manra Island. See Figure 2 for legend.

Corals. Coral species diversity was moderate at Orona with 49 species recorded from four dives. As at Manra, faviid species were particularly abundant (Table 48) along with the encrusting and submassive agariciids and *Montipora* plates. Threats to corals were reported for Dolphin Ledge, with overgrowth of *Pocillopora* colonies by algae as the main condition observed, linked to other signs of eutrophication (Table 49).

Table 48. The 10 most abundant coral species at Orona Island.

Family	Coral species
Faviidae	*Favia rotumana, Favia stelligera, Goniastrea edwardsi, Echinopora lamellosa, Leptastrea purpurea, Cyphastrea chalcidicum*
Agariciidae	*Pavona varians, Pavona clavus, Leptoseris mycetoseroides*
Acroporidae	*Montipora efflorescens*

Table 49. Frequency of coral threats observed at Orona Island. See caption to Table 15 for details.

Site	Dolphin Ledge
Number of samples	4
Acropora	
Algal Growth	0
Fungia	
Bleached	0
Partly Bleached	0
Pocillopora	
Algal Growth	6
Bleached	1
Partly Bleached	0
SeastarPredation	0
Porites	
Bleached	0
Partly Bleached	0
Seastar Predation	0
TOTAL	7

Invertebrates. Key invertebrate populations were sampled at Orona, at Dolphin Ledge, and in the lagoon. Dolphin Ledge had similar low densities of invertebrates as recorded at other outer reef sites (Table 50). The short survey conducted in the lagoon on a dense aggregate of corals and clams revealed very high densities of *Tridacna* sp. with numbers over 50 m^{-2} counted.

Table 50. Number of key invertebrates observed at Orona, in replicate 10-minute samples.

Site	Dolphin Ledge	Lagoon
Number of samples	4	1
Sea cucumbers	0	0
Bohadschia argus	0	0
Holothuria atra	0	0
Holothuria leucospilota	0	0
Lobster	0	0
Clams (*Tridacna* sp.)	1	523
Acanthaster planci	0	0

Fishes. The large fish fauna of Orona was typical of other sites visited though with generally lower tuna and pelagic fish numbers. Algae Corner had lower populations of schooling predators with large schools of barracuda, abundant red bass and abundant grey reef sharks at Aerials and Dolphin Ledge (Table 51). Herbivores were present in high abundance at Algae Corner, with larger numbers of parrotfishes than recorded before (Table 52). The diversity of butterfly fish species at Orona was relatively high reflecting the larger number of dives made and vibrant coral community. The diversity of angel fishes and anemone fishes was similar to most of the other islands, except for McKean and Enderbury (Table 53).

Table 51. Numbers of large indicator fish species at Orona.

Scientific Name	Common Name	Aerials	Algae Corner	Dolphin Ledge
TUNA AND PELAGICS				
Gymnosarda unicolor	Dogtooth Tuna	1	2	0
Euthynnus affinis	Mackerel Tuna	0	0	0
Scomberoides lysan	Double-spotted Queenfish	0	3	0
Elegatis bipinnulata	Rainbow Runner	2	2	7
JACKS				
Caranx sexfasciatus	Bigeye Trevally	0	0	0
Caranx melampygus	Bluefin Trevally	35	9	8
Caranx lugubris	Black Trevally	25	20	30
REEF PREDATORS				
Sphyraena qenie	Chevron Barracuda	100	0	200
Cheilinus undulatus	Napoleon Wrasse	3	3	4
Epinephelus fuscoguttatus	Flowery Cod	1	0	0
Plectropomus laevis	Footballer Trout	0	0	0
Aprion virescens	Green Jobfish	0	2	2
Lutjanus bohar	Red Bass	20	8	30
Macolor macularis	Midnight Seaperch	0	0	0
SHARKS AND RAYS				
Carcharhinus melanopterus	Blacktip Reef Shark	2	3	3
Carcharhinus amblyrhynchos	Grey Reef Shark	25	13	17
Triaenodon obesus	Whitetip Reef Shark	0	2	1
Manta birostris/alfredi	Manta Ray	0	0	0

Table 52. Average abundance of key fish families in 10-minute samples at Orona Island.

Site	Aerials	Algae Corner	Dolphin Ledge
Groupers	4	4	1
Snappers	0	100	12
Parrotfishes	3	75	4
Surgeonfishes	6	25	8
Triggerfishes	20	38	10

Table 53. Abundance and list of butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae) and anemone fishes (Amphrionae, Pomacentridae) species recorded at Orona Island.

Family	#	Species
Butterfly fishes	1 7	*Chaetodon auriga, C. ephippium, C. kleinii, C. lunula, C. meyeri, C. ornatissimu* *punctatofasciatus, C. quadrimaculatus, C. reticulatus, C. lunulatus, C. ulietensis,* *Forcipiger flavissimus, F. longirostris* *Heniochus acuminatus, H. chrysostomus, H. monoceros, H. varius*
Angel fishes	5	*Apolemichthys griffisi, Centropyge bicolor, C. flavicauda, C. flavissimus, C. lori*
Anemone fishes	2	*Amphiprion chrysopterus, A. periderion*

Sea Birds. In one area, tens of thousands of adult sooty terns were seen nesting beneath bushes with many chicks. No juvenile sooty terns were observed, however. A few frigate birds, little white fairy-terns, brown noddies, and an occasional brown booby and masked booby were seen.

Marine Turtles. Only a small portion of these beaches were surveyed and 12 probable green turtle nest sites were found. During six SCUBA surveys, a total of 13 green turtles were observed in situ.

Marine Mammals. No marine mammals were seen at this island

Island Results – Overall Synthesis

Bottom Cover. Taking all survey sites together, the dominant bottom cover was hard coral (36.0%) followed by coralline algae (18.0%), rubble (16.7%), turf and fleshy algae (11.6%) and *Halimeda* (10.4%). Other benthic categories had total covers of > 3%. The dominance of coral and coralline algae indicates healthy reef ecosystems dominated by calcifying organisms and active reef framework growth. The high abundance of rubble is testimony of the dramatic influence of wave energy from open ocean storms and swell. The level of exposure to storms is indicated by the dominance trends among benthic categories (Table 54):

1. Windward sites were characterized by coralline algae (which are more resistant to high wave energy than corals), rubble and *Halimeda* growth;
2. The single lagoon site surveyed had the highest cover of hard coral;
3. Leeward sites had higher abundances of hard and soft corals and turf and turf and fleshy algal cover.

A cluster analysis of mean benthic cover shows these relationships by grouping, in the top basal branch of the tree (Fig. 9) two subbranches of sites dominated by coralline algae and *Halimeda* on the one hand (Group 1, Table 55) and hard coral on the other (Group 2). The lower half of the tree contains a main group with nine sites with high cover of rubble (Group 4) and two outliers, of single sites with unusually high algae cover (Algae Corner) and sand (British Gas). The cluster analysis emphasizes the principal characteristics of coral reef sites in the Phoenix Islands where robust and dynamic growth of corals and coralline algae, indicating healthy reef growth, is offset by high levels of physical disturbance that produces rubble. This illustrates the dominant controlling force of water energy on the island reefs.

Table 54. Mean and standard error of benthic cover categories by exposure.

	Windward (17)		Lee (78)		Lagoon (5)		Comparison
Cover type	m	se	m	se	m	Se	
Coral	24.1	2.2	35.4	2.3	85.8	4.9	Lag > Lee > Wind
Soft coral	0.1	0.1	2.3	0.8	0.0	0.0	Lee > Wind/Lag
Turf/Fleshy Algae	6.0	2.1	13.4	2.0	2.9	1.5	Lee > Wind > Lag
Coralline Algae	29.6	4.0	16.7	1.3	0.0	0.0	Wind > Lee > Lag
Halimeda	17.3	4.0	9.5	1.8	0.0	0.0	Wind > Lee > Lag
Rubble	20.6	4.5	16.8	1.8	1.1	1.1	Wind/Lee > Lag
Sand	1.0	0.4	3.9	0.6	6.3	6.0	Lag/Lee > Wind
Other	1.3	0.5	1.8	0.3	4.0	0.7	Lag > Lee/Wind

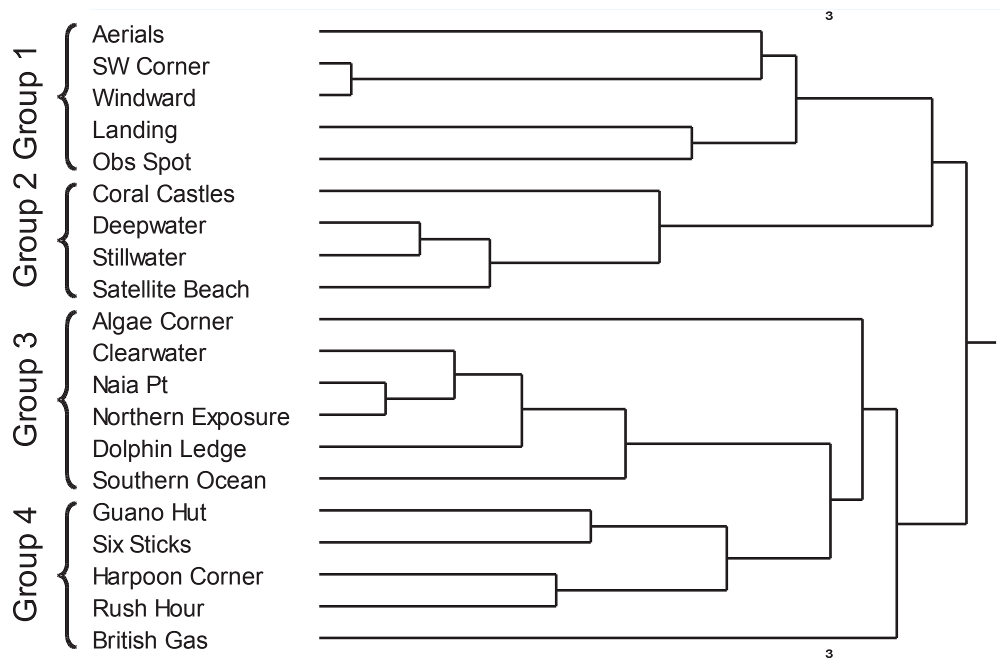

Figure 9. Cluster analysis of mean bottom cover. See table 55 for statistics on clusters.

Corals. The dominant growth form of corals throughout the islands was encrusting/submassive (38.8%) followed by branching (26.7%) and massive (14.8%, Table 56). The dominance of encrusting/submassive growth forms further emphasizes the importance of physical disturbance in the islands. Similarly, the breakdown of growth forms shows greater dominance of the resistant encrusting/submassive forms in windward sites (59.5%), its somewhat lower abundance at leeward sites and a corresponding increase in more delicate plate forms (17.4%), and the dominance of fragiles table and staghorn corals (70.7% and 18.6%, respectively) in protected lagoon sites.

Table 55. Cluster group statistics on benthic cover categories (means and standard deviation) for Figure 9. Sites included in each group are indicated.

Cluster	1		2		3		4		5	
# sites	5		4		1		9		1	
	m	Sd	m	sd	m	Sd	M	sd	m	sd
Coral	29.7	8.6	**71.9**	13.5	4.3		28.7	7.5	28.6	
Coral. algae	**32.0**	16.3	8.4	8.1	8.4		17.3	7.4	0.6	
Halimeda	**27.6**	18.7	2.5	2.7	19.6		3.0	6.6	0.0	
Algae-other	3.1	5.8	5.0	1.5	**59.2**		13.5	9.7	25.2	
Invertebrates	0.2	0.3	0.0	0.0	0.0		0.0	0.1	0.2	
Other	1.1	0.9	1.7	1.6	0.0		1.4	0.9	9.8	
Rubble	5.3	1.9	8.4	7.6	4.2		**27.8**	9.4	20.2	
Sand	1.1	1.5	2.1	2.9	4.3		4.1	2.9	**15.4**	
Soft coral	0.0	0.0	0.0	0.0	0.0		4.0	5.0	0.0	
Sites:	Aerials, Landing, Obs Spot, SW Corner, Windward		Coral Castles, Deep-water, Satellite Beach, Stillwater		Algae Corner		Clearwater, Dolphin Ledge, Guano Hut, Harpoon Corner, Naia Pt, Northern Exposure, Rush Hour, Six Sticks, Southern Ocean		British Gas	

Table 56. Percent contribution of coral morphologies (including dead and bleached/predated corals) in video transects by exposure.

	Wind	Lee	Lagoon	Overall
Encrusting/Submassive	59.5	38.8	1.2	38.8
Branching	32.7	27.7	0.6	26.7
Plates	1.6	17.4	-	14.8
Massive	4.9	11.6	-	10.2
Table	-	1.8	70.7	5.6
Staghorn	-	1.2	18.6	2.0
Mushroom	0.8	1.1	-	0.9
DeadCoral	-	0.1	8.6	0.5
Bleached/predation	0.2	0.1	-	0.1

Considering coral species diversity (Fig. 10), the larger islands of Nikumaroro, Kanton and Orona contributed more species than the smaller islands indicating the importance of the larger area of reef on these islands for support of biodiversity. This is consistent with classic island biogeography theory (MacArthur and Wilson 1967) wherein larger islands can support greater species and functional guild diversity.

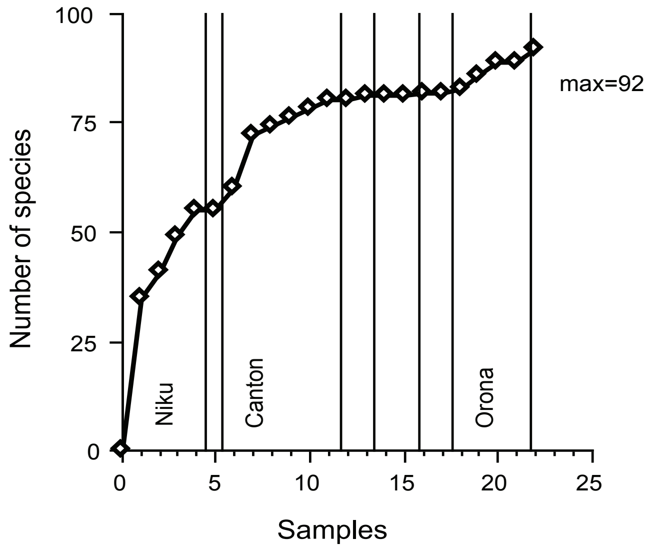

Figure 10. Coral species accumulation curve in successive sampling dives. Ninety-two coral species were recorded in 22 dives. The vertical lines indicate sampling of new islands with Nikumaroro, Kanton and Orona having the most samples and showing noticeable addition of new species at each new island.

In all, field identifications listed a tentative total of 99 coral species, from the timed species surveys, video transects, still photos and coral collection. Of these, 70 species were confirmed and definite identifications and 29 were at various stages of uncertainty (see Obura, this volume, for corrected numbers). These were collected in a total sampling time of 480 minutes (eight hours) spread over 22 dives. This, and individual island coral species richness, are tabulated with species numbers compiled for other islands and island groups in the South Pacific (Table 57).

The coral species diversity of individual sites appears to have been reasonably sampled in about six timed intervals (i.e.15 minutes) indicated by the flattening of most species accumulation curves at 4-6 intervals (Fig. 11). Nevertheless, sites at which longer surveys were possible from 11 to 16 intervals (i.e. 27 – 40 minutes) recorded continual increases in the species accumulation curves (i.e. Kanton – Satellite Beach and British Gas; Nikumaroro – Landing).

The Phoenix islands, located at the intersection of the equator and 180^{o} east and west fall outside of the sharp decline in biodiversity recorded for scleractinian corals in the Central and South Pacific (Veron and Stafford-Smith, 2000). While the low number of coral species, compared to those in American Samoa, Guam and the Marshall Islands is expected (Table 57), it is instructive to note that the low sampling time at individual islands (Table 57) and the increasing species accumulation curves (Figs. 10, 11) suggest significantly more coral species could be recorded with more intensive surveys at each island.

Due to the rapid survey nature of the study, firm species identifications were not possible for all coral species seen and a number are classified as uncertain and unidentified (Table 5). More intensive collection of coral skeletons will likely produce a larger number of uncertain specimens, unidentified species and unknown species. Several

Table 57. Coral species number reported for other South and Central Pacific islands and island groups, extracted from the references shown, compared with species richness for individual islands and the entire Phoenix group from this study. Data from this study are highlighted in bold, and sampling effort at each island in number of minutes dedicated to coral species surveys.

Island and Island groups	Species richness	Source
American Samoa	222	Lovell *et al.* 2000
Palmyra Atoll	168	Brainard et al. 2004
Guam	159	Lovell *et al.* 2000
Kingman Reef	155	Brainard et al. 2004
Marshall Islands	138	Lovell *et al.* 2000
Kiribati (Tarawa and Abaiang Atolls)	127	Lovell *et al.* 2000
Rose Atoll	111	Brainard et al. 2004
Phoenix Islands (480 min)	**96**	**This study**
Howland Island (US Phoenix Islands)	91	Brainard et al. 2004
Baker Island (US Phoenix Islands)	88	Brainard et al. 2004
Palmyra Atoll	82	Lovell *et al.* 2000
Kanton	82	Maragos and Jokiel 1978
Kiritimati Island (Line Islands)	82	Brainard et al. 2004
Tabuaeran Atoll (Line Islands)	77	Brainard et al. 2004
Kanton	77	Maragos and Jokiel
Kanton (130 min)	**73**	**This study**
Tabuaeran I. (Fanning I.)	71	Lovell *et al.* 2000
Nikumaroro (218 min)	**61**	**This study**
Main Hawaiian Islands	59	Brainard et al. 2004
Northwestern Hawaiian Islands	57	Brainard et al. 2004
Commonwealth of Northern Mariana Islands	53	Lovell *et al.* 2000
Hawaii	51	Lovell *et al.* 2000
Orona (80 min)	**49**	**This study**
Jarvis Island	49	Brainard et al. 2004
Enderbury (43 min)	**47**	**This study**
McKean (Phoenix Islands)	46	Lovell *et al.* 2000
Johnston Atoll	46	Brainard et al. 2004
Swains Island	44	Brainard et al. 2004
Manra (40 min)	**43**	**This study**
Wake Atoll	39	Lovell *et al.* 2000
Rawaki (40 min)	**38**	**This study**
Johnston Atoll	29	Lovell *et al.* 2000
McKean (20 min)	**19**	**This study**
Northern Hawaiian Islands	13	Lovell *et al.* 2000

species identified in the field were reclassified where reference specimens were available, suggesting that some of the uncollected species may be wrongly identified and could even be unknown or new species.

Threats to corals were quantified during surveys but were negligible compared to the influence of physical disturbance from waves. The most common evidence of coral stress was the presence of partially bleached colonies of *Pocillopora* spp. (*verrucosa*, *meandrina*, *eydouxi* and *damicornis*); however this was at low levels that can be considered normal for healthy coral communities. No evidence of a recent bleaching event was seen though it is possible that dead colonies from the worldwide bleaching event of 1997-98 could not be recognized due to their age and colonization by algae.

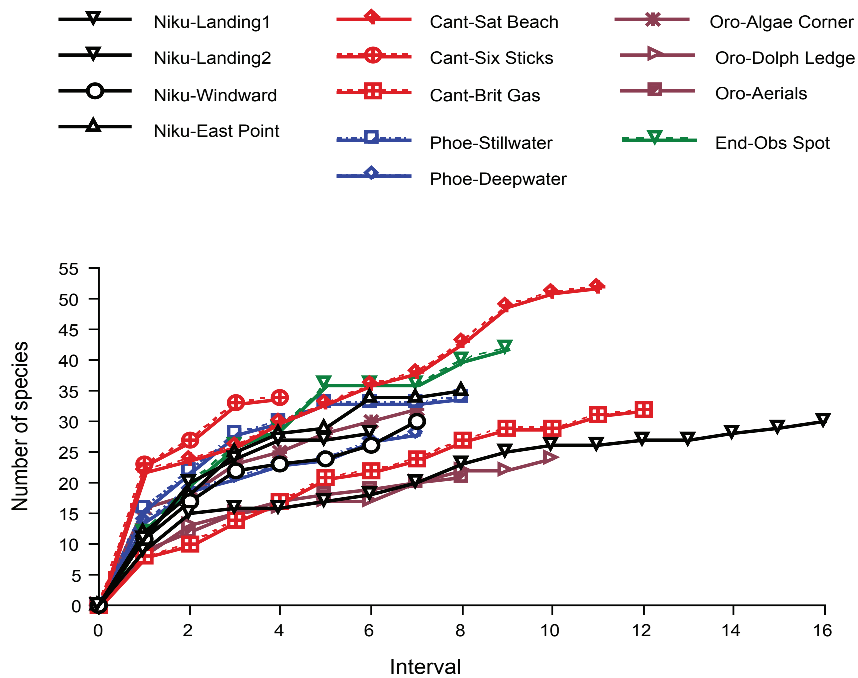

Figure 11. Coral species accumulation curves within dives at the sites shown. Intervals are 2.5 minutes, the curves show the number of new species seen in each interval over previous ones (see methods). The longest sample dive was 16 intervals (40 minutes) at Nikumaroro Landing.

The presence of harmful invertebrates was also noted with only one *Acanthaster planci* being observed during survey periods (with only four more counted during the expedition). The corallivorous snail *Drupella* was not noted and the only significant coral predator seen was the cushion star *Culcita*, though in low numbers and no impact on coral abundance.

Invertebrates. Mobile invertebrate densities were exceedingly low in the Phoenix Islands. Low numbers of holothurians were noted in the order of 1 – 5 per dive and often none during sampling intervals. Only one lobster was recorded during sampling and low numbers seen at other times during the expedition, including during night dives. As indicated above, invertebrates that potentially threaten corals were also low in abundance. Clams in the genus *Tridacna* were observed in low numbers at all survey sites with 1 – 5 being recorded in sampling intervals. *Tridacna squamosa* and *T. maxima* were observed but not *T. gigas*. Abundances were higher in sthe Orona lagoon but highly patchy and separated by large sandy expanses.

Reasons for the low abundance of invertebrates were not immediately clear. Further area-based transect surveys need to be done to obtain more accurate data as well as to differentiate between the three main influences that may explain the low abundances. These are: a) isolation of the Phoenix groups from source populations may reduce larval influx to levels below those needed to maintain abundant populations; b) the area of suitable habitat, e.g., of lagoon (only two islands have true lagoons) or shallow fore-reef, is relatively low and may hinder high rates of population growth; and c) predation by the large fish populations on larval, juvenile and/or adult invertebrate life stages may prevent accumulation and dense populations.

Fishes. Most of the survey sites had a diverse mix of reef and pelagic predatory fishes schooling in large numbers. Sites clustered into two main clusters with the largest comprising the two subgroups 1 and 2 (Table 58) characterized by variable numbers of most species, abundant bigeye and blue jacks in large mixed schools and moderate numbers of barracuda. The second main cluster was comprised of sites with massive abundances of individual species with rainbow runners and grey reef sharks superabundant in group 3 (all Enderbury sites and Nai'a Pt. On Nikumaroro), bigeye jacks in group 4 (the two Kanton channel-mouth sites) and a massive resident aggregation of barracuda at the Nikumaroro Windward site, sampled on two separate occasions.

Table 58. Abundance of large fish species in five clusters of sites (mean and standard error). Groups 1 and 2 contain the majority of sites, with variable numbers of fish species. Fish are listed by common names and preceded by their group code (see methods results for scientific names and groups in full).

Cluster	1		2		3		4		5	
N Rows	8		9		4		2		2	
	m	se	m	se	m	se	m	se	m	se
tun-Dogtooth	2.1	0.6	1.4	0.4	2.3	0.8	6.5	0.5	5	2
tun-Mackerel	1.1	0.8	0.4	0.4	1.8	1	0	0	3.5	3.5
tun-Queen	2	0.9	1.6	0.9	0.8	0.8	5.5	5.5	8.5	6.5
tun-Rainbow runn.	12.8	1.8	8.1	2.6	**28.5**	**6.4**	16	2	14	6
jac-Bigeye jack	35	24.5	8.9	6.1	12.5	12.5	**850**	**150**	75	25
jac-Blue jack	28.4	6.4	12.2	3.3	17.5	6.3	25	0	23	3
jac-Black jack	17.1	3.8	20.8	3.4	37.5	11.1	35	15	30	10
rf-Barracuda	3.3	1.5	94.7	33.7	5.5	4.9	58	42	**300**	**0**
rf-Napoleon wrasse	5.6	0.8	2.6	0.3	2.5	1.3	5.5	1.5	3	3
rf-Flower cod	2.4	0.8	0.1	0.1	0	0	2	0	1.5	0.5
rf-Footballer trout	0	0	0	0	0	0	0	0	0.5	0.5
rf-Jobfish	2	0.5	1.2	0.3	0.8	0.5	1	1	1	0
rf-Red Bass	33.4	6.8	19.3	5.2	36.3	10.7	26	9	20	10
rf-Seapearch	1.4	1.1	1.4	1	0	0	0	0	18.5	6.5
sha-Black Tip	2.1	0.9	1.9	0.6	5.8	4.8	0	0	6.5	5.5
sha-Grey Reef	10.5	2	10.3	2.6	**24.5**	**3.2**	3.5	1.5	11	5
sha-White Tip	1.9	0.4	1.8	0.6	5	0.9	3	1	4	1
sha-Manta	0	0	0.1	0.1	0	0	2	0	0	0
Sites:	British Gas, Satellite Bch., Wild Side, Guano Hut, Rush Hour, Nai'a Pt., Amelia's Landing, Deepwwater		Harpoon Crnr, Northern Lee, SW Corner, Landing, North Bch., Dolphin Ledge, Aerials, Algae Crnr, Stillwater		Obs. Spot, Shark Vill., Southern Exp., Nai'a Pt.		Weird Eddy, Nai'a Flya		Windward 1 and 2	

A dendrogram of the large predatory fishes (Fig. 12) indicates that there are two clusters of fish. The upper group is made up of the low-abundance species with the bigeye jack as the outlier due to its superabundance at some sites. The lower group comprises the more abundant and uniform species with barracuda as the outlier also due to superabundance at one site.

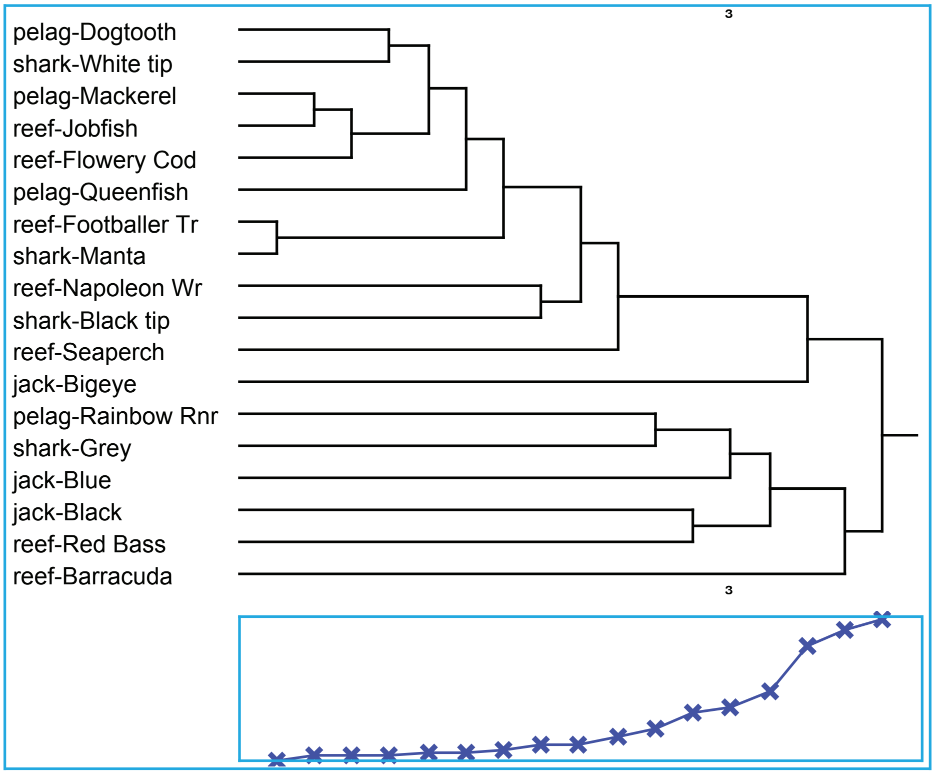

Figure 12. Cluster analysis of mean large fish abundance at each site. Two main groups are indicated as the two main forks of the base tree. Each group has outliers represented by Bigeye jack (above) and Barracuda (below).

Data on dominant fish family abundance indicates overall similarity among sites with 12 out of 22 sites grouped together with low-to-moderate abundances of all families (group 1, Table 59). The second cluster group is characterized by higher abundance of surgeonfishes, the predominant herbivorous finfish family observed on the reefs. All of these sites are leeward sites on Nikumaroro, protected from wave action. The three sites in group 3 were characterized by high abundances of all fish families and were characterized by high water flow (Southern Ocean), abundant herbivorous food (Algae Corner) and high topographic complexity (Harpoon Corner). The two outlier sites in "groups" 4 and 5 comprised two sites adjacent to the mouth of the lagoon on Kanton where parrotfishes and snappers were superabundant.

The species diversity of anemone fishes and scorpionfishes did not show any differences among the islands, principally due to the low species diversity within each group and their ubiquitous spread among islands. Similarly with butteflyfishes, though species diversity was higher (23 species) than with these groups, it is likely that differences in species number between islands was affected greatly by sampling effort and uncertainties in species recognition. Lower numbers of species were recorded on the smaller islands, however more systematic species surveys would need to be done to confirm this trend.

Table 59. Abundance of dominant fish families (mean and standard devaition) and cluster analysis grouping of sites.

Cluster	1		2		3		4		5	
N Rows	12		5		3		1		1	
	m	sd	m	sd	m	sd	m	sd	m	sd
Groupers	.	2.4	0.3	0.6	5.7	1.5	4.0		2.0	
Snappers	25.2	22.0	31.4	17.1	35.7	55.8	**110.0**		**1,000**	
Parrotfishes	5.9	5.7	6.2	4.5	25.7	42.7	800.0		7.0	
Surgeonfishes	13.0	6.3	**30.3**	**4.4**	24.3	3.1	18.0		21.0	
Triggerfishes	18.3	10.7	10.8	5.8	44.3	6.0	5.0		7.0	
Sites:	Satellite Bch. Weird Eddie, Obs Spot, Shark Village, Aerials, Dolphin Ledge, Guano Hut, Rush Hour, Landing, NAI'A Point, North Beach, Northern Lee		Amelia, Kandy Jar, Landing, Norwich City, Windward Wing		Southern Ocean, Algae Corner, Harpoon Corner		President Taylor		British Gas	

A number of fish species collected during this study qualify for species range extensions and new records for the Phoenix Islands (Table 60). At least two species had not been described in the Phoenix Islands group but were common, the hawkfishes *Paracirrhites nisus* and *P. xanthus*. They were particularly prominent, nestling in the branches of *Pocillopora* coral colonies and on other surfaces. The data on fish diversity was greatly increased through surveys in 2002, reported in Allen and Bailey (this volume).

Table 60. Fish species range extensions and new records for the Phoenix Islands (2000).

Family	Genus/species	Justification
RANGE EXTENSIONS		
Cirrhitidae (Hawkfishes)	*Paracirrhites nisus*	(Randall, pers. Com)
	Paracirrhites xanthus	Closest record is the Tuamotu Islands group(Randall, 1982-2000.)
NEW RECORDS		
Muraenidae (Moray Eels)	*Gymnothorax chilospilus*	recorded from the Society Islands (Randall, 1985)
Serranidae (Fairy Basslets and Groupers)	*Suttonia lineata*	recorded from the Hawaiian, Line and Society Islands, Fiji, Vanuatu and Guam (Randall, pers. Com.)
Gobiidae (Gobies)	*Priolepis nocturna*	reported from numerous sites in the west and the Marquesas Islands (Randall, 1985).

DISCUSSION

Prior to 2002 the Phoenix Islands were a diverse and healthy example of central Pacific atoll coral reef communities. The fact that these islands and lagoons have been excluded from long term human impacts makes them excellent examples of this habitat type in its near pristine state. For these reasons we believe it is of global significance and deserves further study and a management plan that will ensure the long-term health and sustainability of the ecosystem.

This is the first comprehensive marine biological survey of the Phoenix Islands and these results provide a foundation for understanding these ecosystems and cataloguing the fauna and flora of the region. These data are particularly valuable because all but one of the Phoenix Islands are completely uninhabited (Kanton has less than 50 people) and all are remote from major human settlements and near shore anthropogenic impacts. Phoenix Island reefs provide a model of what atoll reefs in this part of the Pacific Ocean are like with minimal human disturbance. These data are useful at both the regional and global level because they provide biological benchmarks for understanding change and for rebuilding reef systems elsewhere that have been degraded.

Coral reefs of the Phoenix Islands were notable for their moderate coral cover (20-40%) and evidence of high physical breakage by wave energy on the southern, eastern and northern shores of the islands. Fish populations were abundant with large schools of jacks, barracuda, snappers, surgeonfish, and parrotfish, and abundant sharks at locations featuring high currents and topographic complexity. Both coral and fish communities showed differentiation between windward, leeward and lagoon habitats. Invertebrate populations were notably low with low numbers of clams (*Tridacna* spp.), pearl oyster (*Trochus* spp.), holothurians (beche de mer) and lobster. This is potentially due to the isolation of the islands from larval sources, the minimal area available for lagoon-dependent species and high predation by fish on larval, juvenile and/or adult life stages.

Overall, coral reefs appeared in near-pristine condition with no evidence of human influence. This pilot expedition identified several “significant sites” based on ecological parameters which stood out as either providing unique or sensitive habitat, or unique species assemblages (Table 61).

These surveys were also valuable for identifying new species and providing an inventory of the biodiversity of this region. The occurrence of new coral and fish (Allen and Bailey 2003) species, reported in Obura (this volume) and Allen and Bailey (this volume) underscore the significance of these reef systems for biodiversity. Additionally, range extensions were recorded for a number of algae (South et al. 2001), coral and fish species. The surveys conducted on this expedition were for rapid assessment of biodiversity and effort at most islands amounted to only one day of diving. There is therefore a strong rationale for continuing inventories of marine life at all these islands. This is emphasized for corals by the increasing coral species accumulation curves (Figs. 10, 11) which suggest an additional 30% more species may be identified given more sampling effort (and see Obura, this volume). It is likely that other new species of coral and fishes remain to be discovered. We also did not survey Birnie Island at all and this site should be considered a priority for any future surveys.

Table 61. Significant sites

Dive Site/Island	Significant pattern	Importance
Coral Castles (Kanton lagoon)	Maximum coral cover, dominance of table and staghorn Acropora	Delicate climax community of low-energy reefs. High vulnerability to disturbance.
Satellite Beach (Kanton), Deepwater, Stillwater (Phoenix)	High coral cover, diverse coral communities	Biodiversity and ecological complexity
Algae Corner (Orona)	Lowest coral cover, highest algal cover – evidence of chronic stress from low water quality	Impact of lagoon and land-based factors on coral communities, vulnerability
Nikumaroro, Kanton, Orona Islands	Highest coral diversity due to large area effect	May contain key source and refuge sites for corals and other reef species during stressful events.
Orona and Kanton lagoons	Only true lagoons with coral and other communities	Rare habitats with extreme isolation from neighbouring island groups.
Kanton lagoon mouth and adjacent sites	Superabundant fish populations aggregate in and beside channel mouth, for feeding, spawning, etc.	Critical ecological role in feeding and reproduction, high vulnerability to destructive- and over-exploitation.
Windward Wing (Kanton)	Largest barracuda aggregations seen in islands	High vulnerability to fishing.
Enderbury	Largest aggregations of sharks, in particular grey reef sharks	Special circumstances enhancing shark populations?
Rawaki	Green turtle nesting sites	First record of Green Turtles nesting at this island.

With respect to fishes, at the time of writing there are two range extensions, three new records and many additions to the Kiribati Government's official fish list. It is possible that new species will be identified. For fishes, a high priority in the Phoenix Islands region is to add significantly to our knowledge of the cryptic fishes found in the coral rubble habitat. The expedition's intent was to focus primarily on the Blenniidae, Tripterygiidae and the Gobiidae, but the results reveal that at least 27 families of fish rely on, or have some association with, the thick layers of accumulated coral rubble substrate common on the leeward side of these islands. Further sampling is necessary to improve coverage of depth zones to include more shallow (< 3m) and deeper (50 – 300m) sites. For the latter, this may need Nitrox and Trimix diving gases for the 33 – 75m range and rebreathers for the 75 – 125m range. Further sampling of coral communities is also necessary as shown by the species accumulation curves (Figs. 10, 11) and coral species taxonomy is in a state of flux. Recent publication of additional references (Veron and Stafford-Smith 2000) is likely to improve greatly future coral taxonomic work at Phoenix Islands.

Sea birds, turtles and dolphins were found mostly near islands probably because their food, small fishes and coastal invertebrates, are also found there as opposed to the deep-water in-between islands. The expedition found turtle nests on Phoenix Island which had not been previously recognized as a nesting ground.

A very surprising result was the almost total lack of large whales, in particular sperm whales. The Phoenix Islands are located in the heart of the famous 19th century sperm-whaling ground. In these waters, whalers from North America came and hunted sperm whales in tremendous numbers in the 19th century (Townsend, 1935). Our data indicate that populations of sperm whales in the Phoenix Islands are negligible today, at least at the time of year we surveyed. These data are of concern and support the need for the currently proposed International Whaling Commission South Pacific Sanctuary, which would protect all large whales in the region.

Deep-water camera deployments and images provided the first data on deep-sea fauna for the Phoenix group. These are new sighting records for six-gilled sharks and help to build our understanding of their worldwide distribution. The Phoenix Islands are located in extremely deep ocean waters (> 5,000m) and our sampling program was relatively shallow (1,000m). It is likely that many new gains in our knowledge of the biodiversity of these waters will be gained from deep-sea sampling and imaging. The "ropecam" provided a low cost method for viewing animals in this biome but remotely operated vehicles and deep-sea submersibles will provide a more thorough method for surveying these regions (Stone et al., 2000).

We note that a previous management plan for the Phoenix Islands (Garnett, 1983) pertained only to the terrestrial ecosystems and did not include the marine aspects. Conservation and management of the marine ecosystems of this area can yield long-term benefits to Kiribati.

The coral reefs of this island group are of national, regional and global significance and provide a rare opportunity in the South Pacific for conservation and biodiversity research. The importance of protecting Kiribati's biodiversity has been highlighted by the government's signing of the Convention on Biological Diversity in 1994 and the recent drafting of the country's National Biodiversity Strategy and Action Plan in 2000. To date, the only management plan produced for nature conservation in the Line and Phoenix Islands by Garnett (1983) has a terrestrial focus and does not extend sufficiently to cover the marine environment.

CONCLUSIONS

Recommendations are split into two components, that outline opportunities for further research and the need to embed this in an integrated management framework that includes the whole island group.

Research

The findings of the scientific expedition to the Phoenix Islands, detailed in this report, provide a strong justification for the development and implementation of a more focused research strategy. This will be aimed at obtaining more substantial inventories of the species of flora and fauna in the island group as well as quantifying their marine resources. The information from more extensive research will provide invaluable data to the Kiribati Government on its marine resources and will provide the information required to make sound decisions about the conservation, management and wise use of these nationally significant reefs. The pristine state of the reefs and their global significance will be of great interest to the wider scientific community.

The following components are recommended for a future research strategy:

1. Birnie Island was not surveyed during the expedition due to time restraints and should be visited to complete our understanding of the habitat and diversity found in the Phoenix Island group.
2. More extensive and quantitative coral, invertebrate and reef-fish surveys should be conducted at each of the eight atolls to obtain baseline inventories and abundance estimates of the species of flora and fauna present. An annual monitoring program based on these baseline surveys should be designed and capacity developed within Kiribati institutions to implement this.
3. More comprehensive assessments of reef resources should be undertaken focusing on major food fish and invertebrate species.
4. Collections of relevant faunal groups (algae, corals, small fishes) should be expanded to improve taxonomic knowledge of the island group's flora and fauna.
5. Greater attention needs to be paid to windward and lagoon reefs to increase their sampling with respect to leeward reef sites.
6. A strategy for deep-water research around these islands should be developed, incorporating remotely operated vehicles (ROVs) as well as the "rope-cam" method used here.

Management Plan for Marine Conservation

The findings of the scientific expedition to the Phoenix Islands unequivocally support the recommendation for the establishment of a conservation and management plan for the Phoenix group that recognizes both the need to protect biodiversity and allows for the wise use of the marine resources in the area. A precedent for conservation management is provided in north Tarawa where the Kiribati government in collaboration with the South Pacific Regional Environment Programme (SPREP) has established the country's first Marine Protected Area.

An Integrated Coastal Area Management (ICAM) framework provides the most broad-based approach to marine biodiversity and resource conservation. This approach incorporates the following key concepts for management of a remote and near-pristine region such as the Phoenix Islands:

1. Managing threats to ecosystem health and function through management of resource use and human coastal populations;
2. Incorporating and integrating multiple objectives of management such as resource use and biodiversity protection;
3. Preservation of options for future decisions through an explicit multiobjective management framework.

As a complement to ICAM, management models that explicitly recognize the biodiversity, resource, cultural, historical, and potential tourism value of the individual islands and the island group are useful. These, such as the World Heritage Site (IUCN) and Biosphere Reserve (UNESCO-MAB) models, are internationally recognized and can provide significant leverage for funding and implementation by the Kiribati Government.

Full development of an Integrated Management Plan may take 5-10 years for which the Kiribati government may need external support, institutional capacity building, and a commitment to implementation that prevents short-term opportunistic uses of the islands that may be detrimental in the medium-to-long term.

The results presented in this report, together with our experience of marine ecosystem management and conservation in other parts of the world, indicate five key components for an integrated management framework for the Phoenix Islands:

1) Multiple-Use Management. This is appropriate for the larger islands, Kanton and Orona, where multiple marine (and terrestrial) habitats occur, and there is already some level of current human habitation and resource use. This spatial and utilization complexity requires a multiple-use framework that can follow a classic ICAM model as well as the Biosphere Reserve concept of the UNESCO Man and the Biosphere program. Our recommendations include:

a) The identification of representative windward, leeward and lagoon sites for complete protection, e.g., Satellite Beach, Coral Castles, comprising up to 50% of their total areas;
b) The identification of key vulnerable sites such as the lagoon mouths to protect spawning aggregations of fishes; and
c) For the remainder of the islands, establishment of management regulations for existing sites being used (for habitation, fishing, copra, etc.) based on sustainable use principles.

2) Fully Protected Marine-Terrestrial Sanctuaries. Marine Protected Areas (MPAs) are viewed by the tropical scientific and fisheries management community as the only fully effective tool for managing fish stocks in multispecies coral reef fisheries. MPAs address the critical features of fishery stock management that include brood-stock protection, minimum viable population size, habitat protection and enforcement. As the first component of an integrated plan for multiple-use management, a representative network of multiple protected sites is necessary to conservation management in the Phoenix Islands. The current existence of two fully protected areas, the terrestrial bird sanctuaries of McKean and Birnie Islands, provides a precedent for expansion of this concept to other islands and, in particular, for integration across terrestrial and marine environments. Additionally, as recognized by the World Heritage Site designation for which a site is under consideration in Kiribati (Christmas Island or Millenium Island), both biodiversity and cultural/historical features can be central features of a protected area.

Our results suggest the following islands as potential MPAs, in addition to the representative sites on Kanton and Orona mentioned in the section above. None of the following sites have any current exploitative uses while they all have current biodiversity value as well as potential tourism value through diving and visitation. Through full protection they may collectively have sufficient value for World Heritage Site protection:

a) McKean, Birnie – extend terrestrial bird sanctuary protection to cover the marine environment;
b) Nikumaroro – the cultural significance of Nikumaroro to the I-Kiribati people, and its potential archeological and historical importance as a possible site of Amelia Earhardt's plane crash, give it conservation value in addition to biodiversity reasons;
c) Phoenix – has potential for sanctuary status as it has the same characeristics as McKean and Birnie islands (i.e. bird populations, turtle nesting, marine habitats, unsuitability for human habitation), with additional importance of name for island group.

3) Preserving Future Options. The near-pristine nature of the Phoenix Islands group and their potential value for income generation through conservation advocates a strict application of the precautionary principal in the development of a management framework for the islands. This can be applied in two stages:

a) In the form of a provisional moratorium on all new activities pending development of the integrated management plan for the island group. This will prevent degradation by opportunistic and degrading activities while the management plan is being developed;
b) As a central component of the management plan, the reservation of significant areas of the island group based on the potential for future uses, not identifiable at present, that rely on a nondegraded and pristine habitat.

Based on components *1)* and *2)* above, this designation can be applied as follows:

a) To the remaining islands, Enderbury and Manra, this is analogous to ascribing them sanctuary status as in *2)* above but with flexibility for future uses that are not degrading;
b) On Kanton and Orona, to the additional sites not currently being used, but not in the 50% protection zones. This will effectively reserve options for future uses not conceived during the establishment of the Integrated Management Plan.

4) High Seas Issues. The high seas, or pelagic environment, are a critical link in the life cycles of coral reef organisms, as well as harboring species independent of reef environments. In Kiribati, the high seas of the EEZ are a highly significant resource for the country. With respect to the Phoenix Islands, the high seas contained within the boundaries of the island group are important in three areas relevant to conservation management of the islands and reefs:

a) Management of fisheries of reef-associated species such as sharks, jacks and mackerel;
b) Evaluation of the relevance of the Phoenix Islands for the South Pacific Whale Sanctuary. Few marine mammals were recorded in this study, potentially emphasizing the long-term effects of unrestricted utilization over a century ago;
c) The flow of ocean currents and eddies among the islands may have a critical role in the maintenance of reef populations and biodiversity through migration of fish, marine

mammals and turtles, and dispersal of larvae. Management of the Phoenix Islands high seas must incorporate this issue together with identifying needs for research in this area.

5) Financing And Economic Implications. The biological communities of the Phoenix Islands represent a significant part of the natural wealth of Kiribati and potentially an important income resource for the country. The trade-off of short-term and long-term benefits and costs of different ways of using this resource is critical to the conservation status and value of the islands as well as to the real benefits accrued to the people of Kiribati in this and future generations (Mangubhai 2002). Comparative analysis of financial and economic options, including resource extraction, tourism and conservation options, must be carried out during preliminary stages of establishing an integrated management plan in order to justify objectives of the plan and empower its enforcement.

The findings of this report, and our experience in other small-island marine ecosystems, strongly advocate a focus on biodiversity conservation and management. To provide immediate as well as long-term benefits to the people of Kiribati, conservation has to be backed up by innovative financing and investment through low-impact tourism (eco-tourism, dive tourism) and global investment in key-site biodiversity conservation. Key features for this type of financing would include:

a) Development of an integrated conservation management plan that meets international criteria through mechanisms such as World Heritage Sites, Biosphere Reserve and Integrated Coastal Area Management;
b) Promotion of the Phoenix Islands as near-pristine coral reefs for dive and visitor-based low-impact tourism (ecotourism) based on live-aboard dive boats and a small number of exclusive cottage-style resorts;
c) Promotion of the cultural and historical importance of the Phoenix Islands, for example, the I-Kiribati people, Amelia Earhardt's plane crash, 19th century whaling and the Second World War;
d) Improvement of appropriate infrastructure, which would include airstrip and marina facilities on Kanton, reservation of a small number of sites for ecotourist concessions, quality infrastructure for a limited population on Kanton to service government needs and a small scale, high quality tourism industry;
e) Fishery and resource-use regulations that are biologically sound and ban export-based extraction for consumption outside of the Phoenix group.

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CORAL REEF STRUCTURE AND ZONATION OF THE PHOENIX ISLANDS

BY

DAVID OBURA

ABSTRACT

The eight islands of the Phoenix Group in the Republic of Kiribati vary in size from 17.5 to 1.03 km across. Three major reef types are present in the islands: outer reef slopes, lagoon reefs and channel patch reefs. Channel reefs are negligible and limited to small patches. Lagoon reefs are well developed in Kanton and Orona, growing on relict reef structures and controlled by circulation of water in the lagoons. Outer reefs have the most vibrant growth of corals, with four depth zones clearly shown by reef geomorphology and coral communities: a) deep slopes below 20-25 m varying from 45-85^{o} slope, of rocky substrate and extensive rubble and sand chutes transporting material down the island slopes; b) reef edge varying between 15-20 m where the deep steep slope transitions into the flatter reef platform above. The reef edge tends to be the most vibrant area of coral growth with highest cover and diversity of corals; c) reef platform, from about 15 m to 5 m deep, comprising the broadest zonation band on the reefs and showing clear differentiation with exposure of the reef slope to wind and waves; and d) surge zone, generally from 5 m to the surface, dominated by surge channels and with coral growth limited by wave energy. On average almost 3/4 of the island perimeters show evidence of high exposure to waves and wind, generally comprising the northeast to southern-facing flanks of the islands. The remaining 1/4 were classified as leeward or sheltered shorelines, generally on west and northwest-facing flanks. The total reef area was calculated as 33.9 km^2, of which 24.0 km^2 is windward reef, 7.3 km^2 is leeward reef and 2.6 km^2 is lagoon reef (71, 22 and 8 %, respectively). Overall, the proportion of outer reefs in surge, platform, edge and deep slope zones was 15, 60, 10 and 15 % respectively. Kanton dominates the island group with 35% of all reef area and 55 % of lagoon coral reefs. The islands group roughly into 3 clusters: Kanton and Orona with the largest area of reefs and lagoons with healthy coral communities (55 % of reefs), Nikumaroro, Enderbury and Manra have intermediate outer reef areas (31 % of reefs) and Birnie, McKean and Rawaki have the smallest island size but proportionately larger reef platforms (14 % of reefs).

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INTRODUCTION

The Phoenix Islands are the central island group of the Republic of Kiribati, with the Gilbert Islands to the west, the Line Islands to the east, and in a line between Fiji and Hawaii (Fig. 1). The Kiribati Phoenix Group (174.8^{o} W to 170.1^{o} E Longitude and 2.5^{o} to 5^{o}S Latitude) comprises eight islands with two submerged reef systems spread over some 100,000 km^2 of ocean. Two outlying islands north of the equator, Baker and Howland, are United States dependencies and lie 300 km from the Phoenix Islands. The island group is among the remotest islands in the central Pacific, lying over 1,000 km from the Gilbert group to the west, 1,500 from the Line islands to the east and 500 km from the Tokelaus, the closest islands to the south.

Reflecting their isolation, the Phoenix Islands have received only scanty marine scientific attention, and much of it related to activities on the islands by British and United States companies and government agencies from the Second World War until the late 1970s. A research expedition in 1939 resulted in a taxonomic fish collection (Shultz 1943), which was followed by studies on seabird populations in the 1960s (Clapp, 1964), and a focused collection of corals from McKean island in the early 1970s (Dana, 1975). It was not until 1972-73 that detailed marine surveys were conducted, comprising a comprehensive study of Kanton Atoll (Smith and Henderson, 1978), including work on lagoon circulation and biogeochemistry (Smith and Jokiel, 1978), coral taxonomy and biogeography (Maragos and Jokiel, 1978) and lagoon and leeward reef coral distributions and assemblages (Jokiel and Maragos, 1978). These studies established a basic zonation for the lagoon environments of Kanton atoll.

In addition, apart from basic estimates from aerial photographs of reef area coverage on Kanton by Jokiel and Maragos (1978) there is no available information on the spatial dimensions of the islands and reef habitats. The purpose of this chapter is to present basic statistics and dimensions on the coral reefs of the Phoenix Islands, to support further work on the islands.

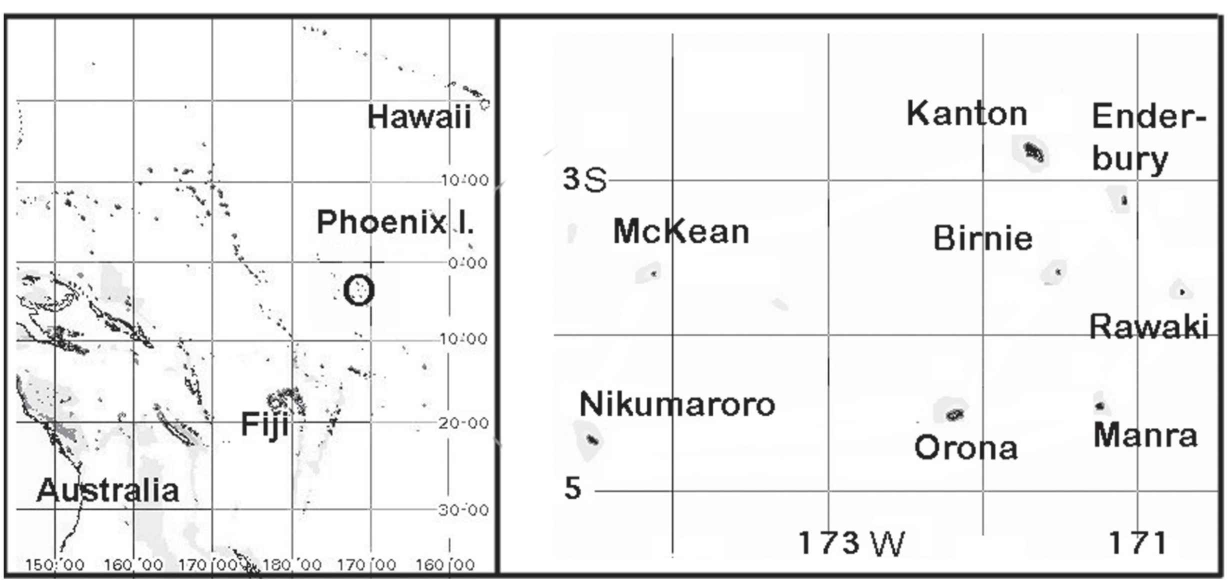

Figure 1. Location of the Phoenix Islands in the central Pacific (left), and map of the island group (right).

METHODS

Descriptions of the islands and reefs of the Phoenix Islands were derived from underwater observations and analysis of charts and maps of the islands.

Coral Reef Structure and Zonation

In situ observations of the coral reefs of the Phoenix Islands, including quantitative analysis of benthic community structure were used to characterize the principal habitats of the island reefs, and major zonation patterns with depth (Stone et al., 2001; Obura and Stone, 2003; Obura et al., this volume). These descriptions were also informed by the literature on coral reef structure and zonation, particularly of oceanic Pacific reefs and past work on Kanton atoll (Maragos and Jokiel, 1978; Jokiel and Maragos, 1978) and more broadly in the Line islands and remote central Pacific islands (Brainard et al., 2004).

Geographic coordinates of all sample sites were recorded using handheld GPS, along with observations on wave exposure, visibility, and weather conditions. Survey site locations are detailed in Appendix 1.

Coral Reef and Island Dimensions and Statistics

Statistics on island, lagoon and reef dimensions were derived from two primary sources used in conjunction with each other and geo-referenced on the GIS system at the Environment and Conservation Division (ECD) of the Ministry of Environment Lands and Agricultural Development in Tarawa, Kiribati. GIS shapefiles from the ECD were combined in Adobe Photoshop with images of charts of the Phoenix Islands (showing depth soundings and some contours) and satellite photographs (showing various coastline features and structures within Kanton lagoon). The composite island and reef images are shown here with study sites located using GPS coordinates. The following measures were estimated from the images:

- Maximum Length (km) – measured; longest axis of island.
- Lagoon Area (km^2) – measured; area of lagoon, excluding channels.
- Reef Perimeter (km) – measured; perimeter length of approximated 20 m depth contour, i.e. the reef edge (see section below). Windward and leeward reef perimeters were calculated based on observations on each island.
- Reef Width (m) – measured; shortest distance between the outer intertidal/wave zone indicated on charts and the approximate 20 m depth contour. Average of 10-13 samples around perimeter of each island. Since most reefs drop off steeply below 15-20 m (see results), the area of reef beyond 20 m is assumed to be negligible compared to that < 20 m.
- Reef Area (km^2) – calculated; reef perimeter multiplied by reef width.

CORAL REEF STRUCTURE AND ZONATION

To date 67 separate sites have been surveyed quantitatively or qualitatively in the Phoenix Islands, during the expeditions in 2000, 2002 and 2005 (Table 1). Due to accessibility restrictions, surveys have concentrated on leeward as compared to windward outer reefs, and a large concentration of survey sites in the large lagoon at Kanton (Table 2). Channel sites were only surveyed quantitatively on Kanton and Orona.

Table 1. Overall sampling of the Phoenix Islands by the New England Aquarium Phoenix Islands Expeditions in 2000, 2002 and 2005. Numbers shown are the total days and research dives in each year, and the number of survey sites by island in each year.

	Year			
	2000	**2002**	**2005**	**Combined**
Total sampling, each year				
# days	13	26	12	
# research dives (approx.)	376	736	117	
Number of sites, by island				
Birnie		3		3
Enderbury	4	5	4	5
Kanton	8	25	11	25
Manra	3	4	2	4
McKean	2			2
Nikumaroro	6	10	6	12
Orona	3	9	8	12
Rawaki	3	3	4	4
TOTAL	29	59	35	67

Table 2. Number of sites sampled in each major reef habitat.

	Outer reefs		Lagoon	Channel	
Island	Leeward	Windward			Total
Kanton	6	3	15	1	25
Orona	3	6	3		12
Nikumaroro	5	5	1	1	12
Enderbury	3	2			5
Manra	2	2			4
Rawaki	3	1			4
Birnie	1	2			3
McKean	2				2
Total	25	21	19	2	67

Outer Reefs

The outer reefs of the Phoenix Islands have a highly consistent topography, characteristic of oceanic atolls. A rocky consolidated bottom extends from the wave zone down to between 15-20 m depth. Below this the bottom slopes steeply, usually made of up compacted rubble and boulders, though in the steepest places being a solid wall, to depths of over 1000 m within several hundred meters horizontal distance. In some locations steep sand and rubble slopes predominate, the latter made up of loose broken coral (from both live and fossil reefs). The outer reefs are easily distinguished into 4 zones, present at most sites (Fig. 2):

Reef slope – deep slopes below 20-25 m and extending beyond visible depths, between 45-85° slope. This zone was surveyed quantitatively from 20 to 50m deep. Upper slopes tended to have high cover of rubble and *Halimeda*, and in some locations up to 60-70% coral cover. Soft corals were common, dominated by leathery forms. Rubble and sediment transport down the slopes was present in all locations.

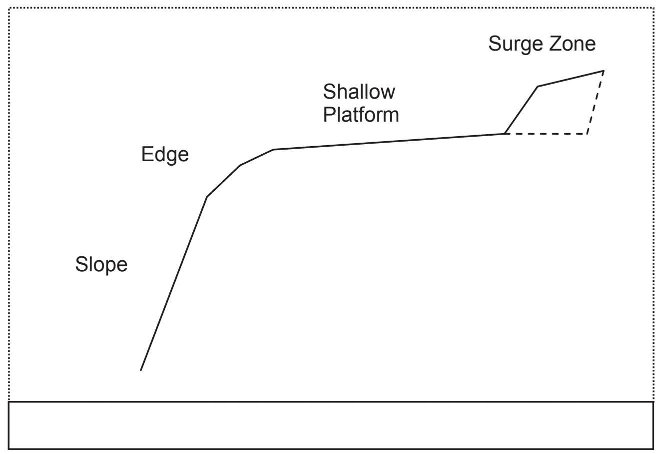

Figure 2. Profile typical of Phoenix Islands reefs

Reef edge – transition zone between the steep slope and the near-horizontal shallow platform above, the reef edge tended to occur between about 12-20m depth, variable by exposure level and island. In some locations the reef edge was a sharp transition, barely 10-15 m wide, in others there was no clear difference in slope between about 15-30 m on the slope and about 10 m in the shallows. In general, the edge had the highest cover and diversity of hard corals.

Platform – from the top of the reef edge at 12-20 m to the shallow zone dominated by wave surge at 5-6 m. This zone comprised the largest area coverage of coral reef, extending out 1 km at its widest (on Birnie) and averaging 200 m wide on most islands. In areas of low wave exposure, this zone is covered with hard and soft coral growth with close to 70-100% cover in patches; at highly exposed sites, this zone is dominated by rubble from continually breaking hard coral patches and coralline algae. In some locations the 'platform' is broken into a series of spur and groove formations, or with large bowl 'cut-outs' on highly exposed shores, or short cliffs of 5-10 m height.

Surge zone – from 5-6 m to the surface, this zone is typically cut into buttresses and surge channels with up to 3 m vertical relief, with low-relief coral and algae growth, and high cover of coralline algae. On sheltered slopes branching corals grow abundantly on buttresses and encrusting corals in the grooves where sand-movement allows. On windward slopes growth forms are restricted to encrusting/submassive forms, and very robust, low-relief branching colonies.

There were clear differences in the habitat, general topography and benthic cover of leeward and windward reefs, typically with higher coral cover on leeward slopes. Windward reefs tend to have large areas with low coral cover and high rubble cover, and on the reef slopes *Halimeda*.

Channels

Channels were only present on the three islands with lagoons – Nikumaroro, Orona and Kanton. They were shallow for Orona and Nikumaroro (< 1 m), and only navigable by small boat at high tide. The Kanton channel is 10 m deep through its center, due to blasting during the Second World War. In all cases the high current flow in the channels prevents the development of extensive coral reefs, with minor development of small patch reefs where substrate within the channels allows. The Kanton channel was dominated by a rubble bottom.

Lagoons

True lagoons are present at three islands – Nikumaroro, Orona and Kanton. They vary strongly from each other, and the individual characteristics are highlighted in the island descriptions below. In common, however, they are all highly restricted lagoons compared to most other atoll environments, having only 1 permanent outlet in the case of Nikumaroro and Kanton, and restricted shallow inlets on Orona. Maximum depths recorded during dives were 4 m (Nikumaroro), 16 m (Orona) and 26 m (Kanton). All three of the lagoons are characterized by soft silty bottoms of very fine carbonate material, with raised rocky features of varying heights, apparently remnants of reef growth and geological processes in the past. In Nikumaroro these were low-relief patches. In Kanton and Orona these could rise from the deepest bottoms to the surface, and were of varying pillar and patch-reef shapes. In Kanton they also come in the form of linear reef structures (see details below, and Jokiel and Maragos 1978, Maragos and Jokiel 1978). Any growth of corals, invertebrates and algae occurs on these hard substrate patches, or on rubble pieces on the sandy floors. Lagoon communities were highly differentiated between the islands. Kanton had the most highly developed lagoon, with four zones, one of which harboured profuse growth of *Acropora* tables at over 80% cover (though see Alling et al. this volume, Obura and Mangubhai, in review).

ISLAND DESCRIPTIONS AND DIMENSIONS

The Phoenix Islands are small compared to many of the islands and groups in the central and south Pacific, and only three of them have lagoon environments. The following island descriptions are listed in order of island area, with statistics being reported from Table 3.

Table 3. Island and reef dimensions for islands in the Phoenix group. See methods for details of each measure. Islands ordered by decreasing outer reef perimeter.

Island	Windward slopes (km^2)					Leeward slopes (km^2)					Total
	Total	surge	platform	edge	slope	Total	surge	platform	edge	slope	
Kanton	8.45	1.30	5.18	0.79	1.18	1.93	0.27	1.08	0.23	0.35	10.38
Orona	4.29	0.66	2.63	0.40	0.60	1.62	0.22	0.87	0.21	0.32	5.91
Enderbury	2.59	0.42	1.66	0.20	0.31	1.19	0.18	0.71	0.12	0.18	3.78
Nikumaroro	2.59	0.35	1.40	0.34	0.51	1.04	0.16	0.65	0.09	0.14	3.64
Manra	2.16	0.32	1.30	0.21	0.32	0.81	0.12	0.47	0.09	0.14	2.97
Birnie	2.49	0.43	1.74	0.13	0.19	0.16	0.01	0.05	0.04	0.05	2.64
McKean	0.84	0.12	0.50	0.09	0.13	0.43	0.07	0.27	0.04	0.06	1.27
Rawaki	0.58	0.09	0.36	0.05	0.07	0.17	0.03	0.11	0.01	0.02	0.74
Total	23.98	3.69	14.77	2.21	3.31	7.35	1.05	4.20	0.84	1.26	31.33
%		15.4	61.6	9.2	13.8		14.3	57.1	11.4	17.1	

Kanton Atoll (Aba-Riringa)

Kanton is the largest atoll in the Phoenix group (Fig. 3), with a maximum length of 17.5 km oriented on a northwest-southeast axis. The atoll reef perimeter of 51.0 km encloses a lagoon of approximately 56 km^2. The atoll has only one channel on the western side, a secondary channel further north on the western side having been blocked in the 1950s by construction. The channel was blasted and dredged to a depth of 10 m during the Second World War and drains a lagoon volume of approximately 186 x 10^6 m^3 (Smith and Henderson 1978). With an average depth calculated at 6.2 m (and maxima of > 26 m) and a tidal exchange of 0.7 m, approximately 11% of the lagoon volume changes on each tide, twice a day. Kanton's lagoon is highly complex, with 4 zones being identified by past workers (Jokiel and Maragos 1978) and confirmed during these surveys:

a) A Pass zone approximately 2 km radius from the channel, in which water exchange is high and extensive staghorn and tabular *Acropora* colonies predominated. The primary reef structures in this zone are relict pillars, bommies and patch reefs on which the current coral community grows in profusion, with sand channels in between becoming increasingly fine and silty with distance from the channel (sites K8-10, K15-16);

b) A Line Reef zone extending eastwards and taking up most of the central lagoon area. This zone is dominated by ancient reef structures that form a reticulate but predominantly north-south pattern in the lagoon and visible in remote sensing images. The reef tops reach up to just below low tide level making navigation in the lagoon hazardous. In between, depths have been recorded at > 26 m, with very fine silty muds on the bottom and murky water, apparently completely still and with minimal circulation. Coral growth is minimal, apparently limited by poor water chemistry (Jokiel and Maragos 1978; sites K5-7).

c) A Back Lagoon zone with small patch reefs on a sandy/silty bottom and coral communities characteristic of inner reef/high sediment areas, similarly limited as in the Line Reef zone. (sites 2-4).

d) An Altered zone, to the north of the Pass zone. This area was apparently affected by closure of the secondary channel and contains dead coral colonies and fine tables still in growth position, covered by very fine silt and algal turf (sites K12-14). It is not clear though if dead tables still in growth position at the time of these surveys (2000-2005) were killed from pass closure in the 1950s, or by some other more recent impact.

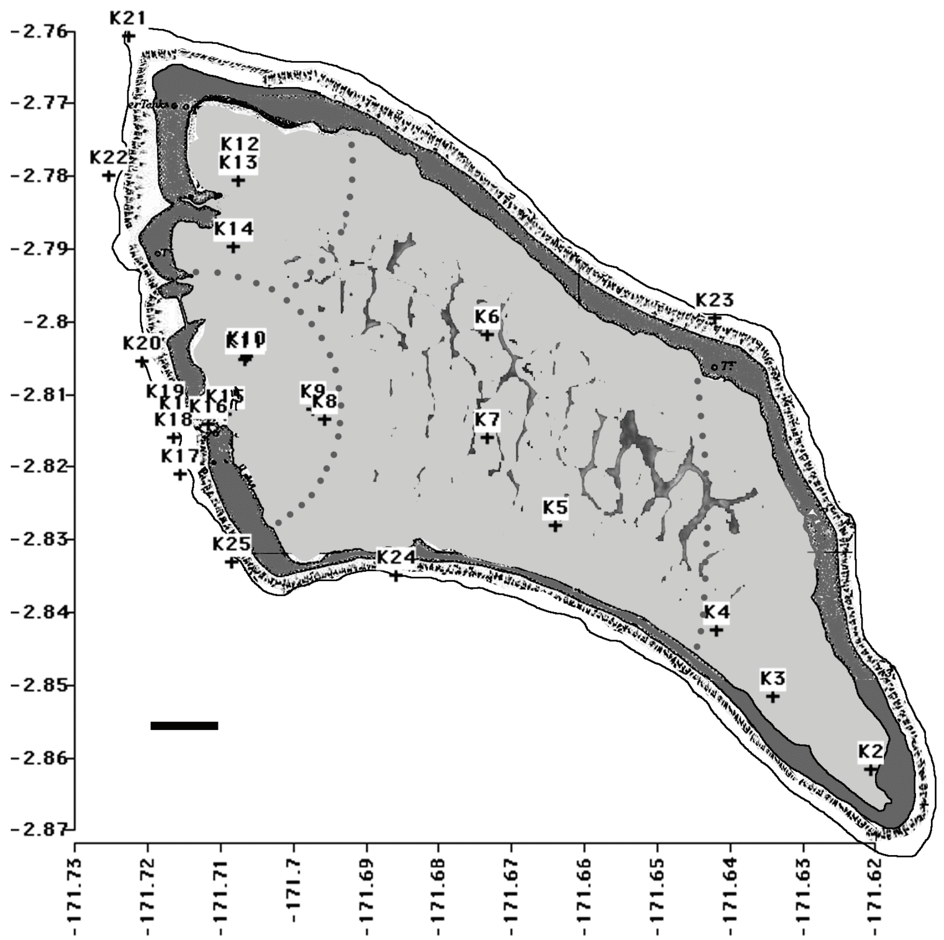

Figure 3. Kanton atoll. The map shows land features of the atoll (dark grey), the lagoon (light grey), intertidal reef (stippled area) and approximate location of the 15-20 m reef edge (continuous line). Survey sites are coded by numbers and marked by the crosses (Appendix I). The axes show degrees south and west in decimal format and the scale bar in all figures represents 1 km. In the Kanton map additional detail is shown of the line reef structures within the lagoon (adapted from satellite photographs) and the dotted circles within the lagoon show zones corresponding to Jokiel and Maragos 1978 (see text).

The outer reef area of Kanton is estimated at 10.38 km^2. The entire northeastern, eastern and southern flanks of the island (from sites K21 to K25) show windward exposed characteristics, slightly less than 4/5 of the island rim. The western flank is the only sheltered leeward face, over 1/5 of the island rim and the largest leeward shore of the island group. The subtidal reef width calculated for Kanton is typical for the island group, at 166 m. All shores have a steep drop-off starting uniformly at 15-20 m, broken only by the deep entrance to the channel.

Orona Atoll (Hull)

Orona is the second largest atoll (Fig. 4), with a maximum length of 9.9 km oriented on a northeast-southwest axis. The atoll reef perimeter of 30.8 km encloses a lagoon of approximately 22 km^2, with numerous inlets on the northern and southern side and is thus the leakiest of the atolls in the Phoenix Islands. Like Kanton, Orona's lagoon contains a variety of remnant knolls and pinnacles, though no line reef structures. Lagoon survey sites O2 and O3 were located on these structures, with maximum depths of 12-15 m being recorded with rubbly corals on broken up substrate at the base of the knolls, and soft sand substrates continuing down to deeper depths. The far east of the lagoon is very shallow and sheltered from the predominantly easterly winds and weather, and is dominated by fine sand. The west of the lagoon is deeper and rougher due to the fetch of the lagoon with patch reef structures. On both sandy and rocky substrates, dense patches of *Tridacna* (dominated by *T. squamosa*) clams littered the lagoon of Orona, with densities in patches at over 50 m^{-2}. These were generally of small to medium size, and were not seen in such aggregations in other islands of the group.

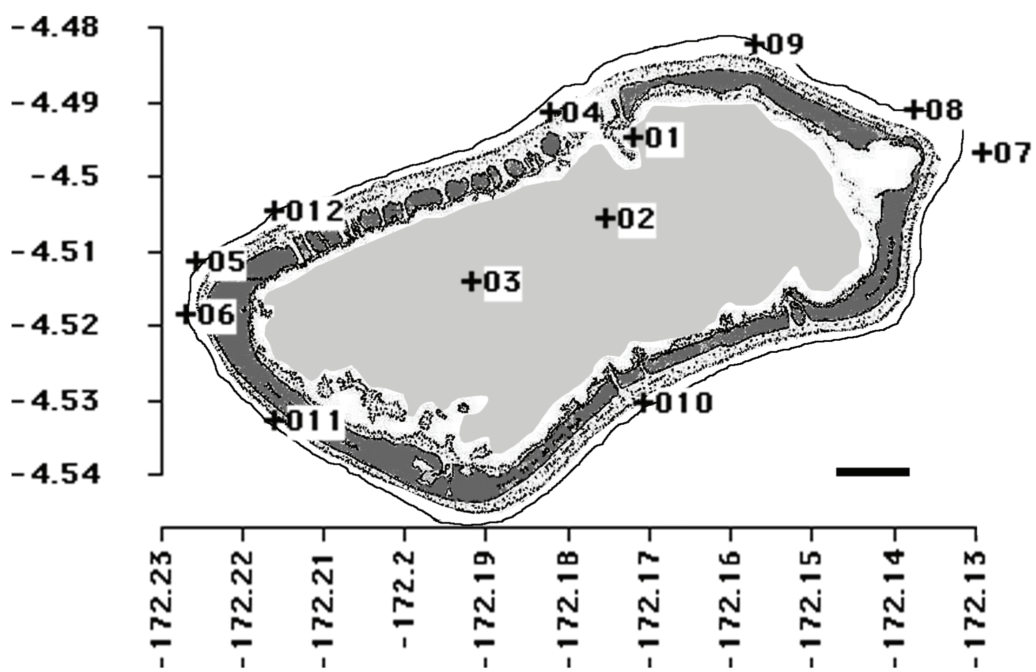

Figure 4. Orona atoll (Hull) in the Phoenix Islands. The map shows land features of the atoll (dark grey), the lagoon (light grey), intertidal reef (stippled area) and approximate location of the 15-20 m reef edge (continuous line). Survey sites are coded by numbers and marked by the crosses (Appendix I). The axes show degrees south and west in decimal format and the scale bar in all figures represents 1 km.

The outer reef area of Orona is estimated at 5.91 km^2. The entire northeastern, eastern, southern and southwestern flanks of the island (from sites O9 to O11) show windward exposed characteristics, approximately 2/3 of the island rim. The northwestern flank and western point (sites O4 to O6) are sheltered leeward locations, approximately

1/3 of the island rim. The subtidal reef width of Orona is 159 m, with steep drop-offs starting uniformly at 15-20 m. Orona is the only island to have an extensive shallow bank on its most windward point (survey sites O7 and O8), extending out about 500 m.

The western point (O6) is a unique site in the Phoenix Islands. It is strongly dominated by turf and fleshy algae (both brown algae and *Halimeda*) with < 5% coral cover even before recent human settlement in 2001, giving it the appropriate name ‘Algae Corner’. A large ship’s chain was located at the southern end of the study site potentially causing iron enrichment and suppression of coral and invertebrate growth, and the site appears subject to natural eutrophication from nutrient accumulation based on lagoon production, terrestrial vegetation and groundwater seepage (see Obura et al. this volume).

Nikumaroro Atoll (Gardner)

Nikumaroro is the smallest of the three atolls (Fig. 5) with a maximum length of 7.0 km and a similar shape and orientation to Kanton. The atoll rim perimeter of 21.6 km encloses a lagoon of approximately 6 km^2, with one inlet on the western side, and one on the southern side that is periodically open depending on weather and sedimentation conditions. It thus has the most restricted circulation of the lagoons in the Phoenix Islands, and the water within the lagoon is a milky colour with visibility less than 1 m.

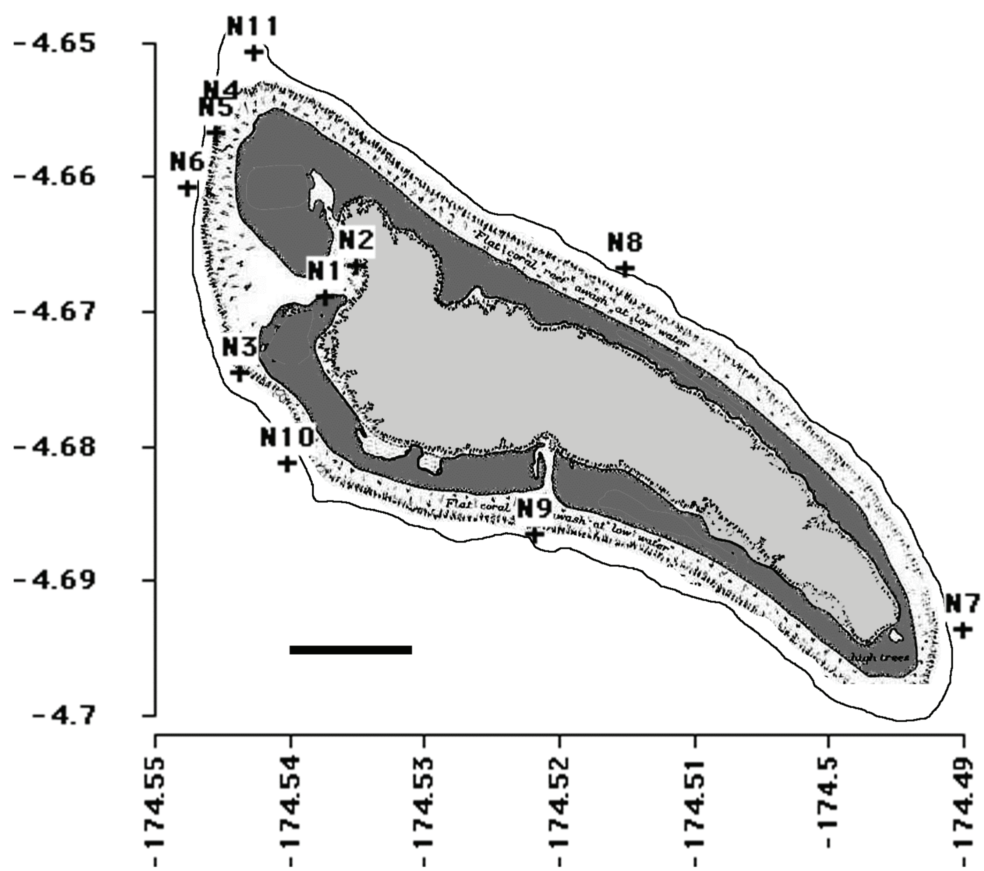

Figure 5. Nikumaroro atoll.

Lagoon survey sites N1 and N2 were located just inside the channel on the rubble bottom and an adjacent patch reef, and maximum depths in the lagoon are estimated at 3-4 m.

The outer reef area of Nikumaroro is estimated at 3.64 km^2, about the same size as Enderbury and only slightly larger than Manra. The entire northern to southwestern flanks of the island (from sites N11 to N10) show windward exposed characteristics, approximately 4/5 of the island rim. The western flank (north of site N10 to N4) is well sheltered. The intertidal reefs of Nikumaroro are relatively broad due to the wide intertidal reef shelf at the lagoon channel. The subtidal reef platform averages 151 m wide and is particularly narrow on the western shore where the reef drops from the intertidal rim to > 40 m within 50 m in some locations. The north/northwestern point is a typical feature of some of the islands (including Kanton, Phoenix, Birnie), where the platform extends out several 100s of meters from the reef crest and is swept by strong westerly currents and waves from the northeast shoreline, and sometimes strong southerly currents flowing up the leeward reef. These meet over the northern platform at the point creating swirling currents and a rip-current off the island, attracting large aggregations of barracuda, jacks and other schooling and pelagic predators.

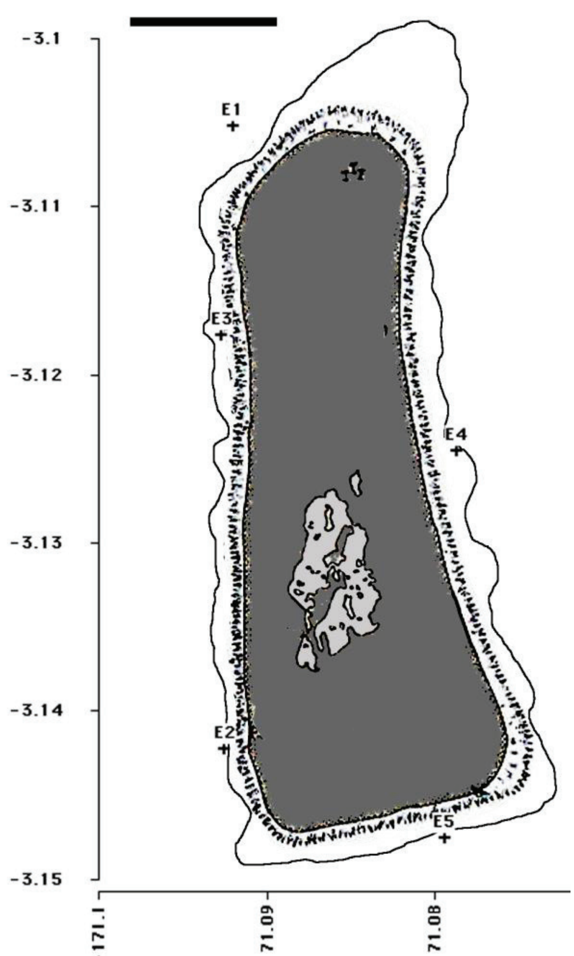

Figure 6. Enderbury Island.

Enderbury Island

Enderbury is the largest of the Phoenix Islands without a true lagoon, and is unique in being elongated north-south, measuring 4.6 km long (Fig. 6). As with the other small islands, it has a brackish pond in its center. The outer reef of Enderbury is estimated to have a perimeter of 16.3 km and area of 3.78 km^2, which is larger than the reef area of Nikumaroro. The northern to southwestern flanks of the island (incorporating sites E4 and E5) show windward exposed characteristics, just under 2/3 of the island rim. The western side is well sheltered by the long north-south axis of the island and makes up over 1/3 of the island rim, the longest leeward reef other than that of Kanton. The intertidal rim of Enderbury is narrow, while the subtidal reef width is 201 m with a platform sticking out to the northeast up to 700 m.

Manra Island (Hull)

Manra is the second largest of the Phoenix Islands (Fig. 7) without a marine lagoon, measuring 4.2 km across its widest axis (east-west), and like all islands smaller in size is nearly round in shape. The reef perimeter of 15.2 km is slightly shorter than Enderbury's. This island has the largest brackish lagoon, though the dense forest of trees and shrubs makes it difficult to access. The outer reef area of Manra is estimated at 2.97 km^2, slightly less than that of Enderbury due to the lack of an extended platform. The northeastern to southwestern flanks of the island (from site M3 almost to M2) show windward exposed characteristics, comprising 2/3 of the island rim. The northwestern

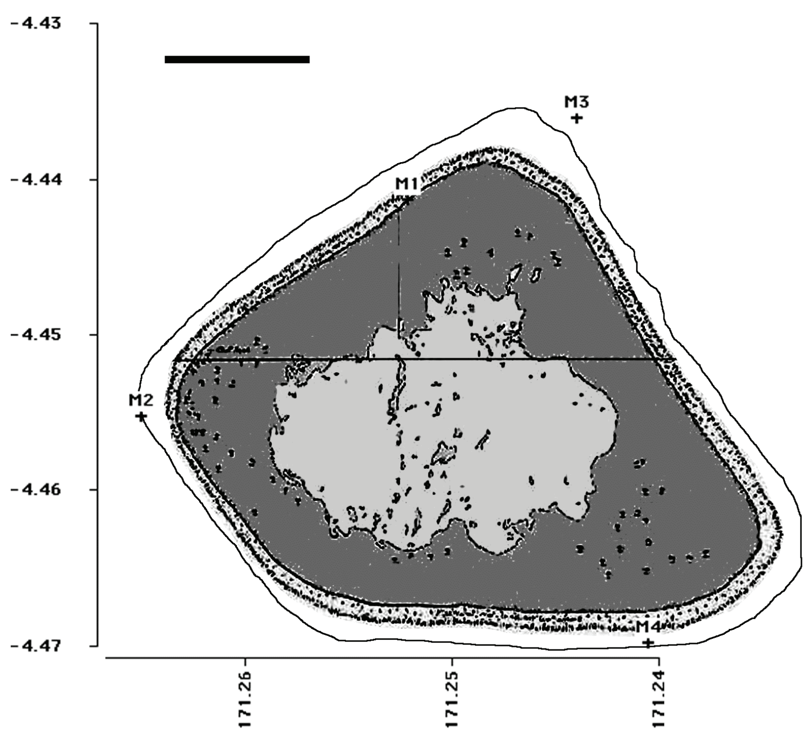

Figure 7. Manra Island.

side is the only sheltered flank of the island, about 1/3 of the island rim. The subtidal reef width is a relatively uniform 161 m wide. Manra is the smallest island with tree vegetation, including coconut trees and indigenous species.

Birnie Island

Birnie (Fig. 8) is the largest of the three smallest Phoenix Islands, in terms of reef area, though smallest in terms of island size. It is elongate, measuring 1.03 km along its longest axis. The reef perimeter of 8.12 km and area of 2.64 km^2 are high because of the long platform extending south (1.05 km, the longest in the island group) and north from the island. As with the other small islands, it has no lagoon, though the island does have a brackish pond in its center, and the entire northern to southern flanks of the island are exposed and windward. The western shore is more sheltered, though because of the island's small size there is no true leeward side. Because of the long subtidal reef extending south and exposed to wave energy, it is likely that > 4/5 of Birnie's reefs are 'windward' in nature, with only a small proportion to the west of the island being leeward. The subtidal reef averages 280 m wide, the widest among all the islands. This island was only visited once in 2002.

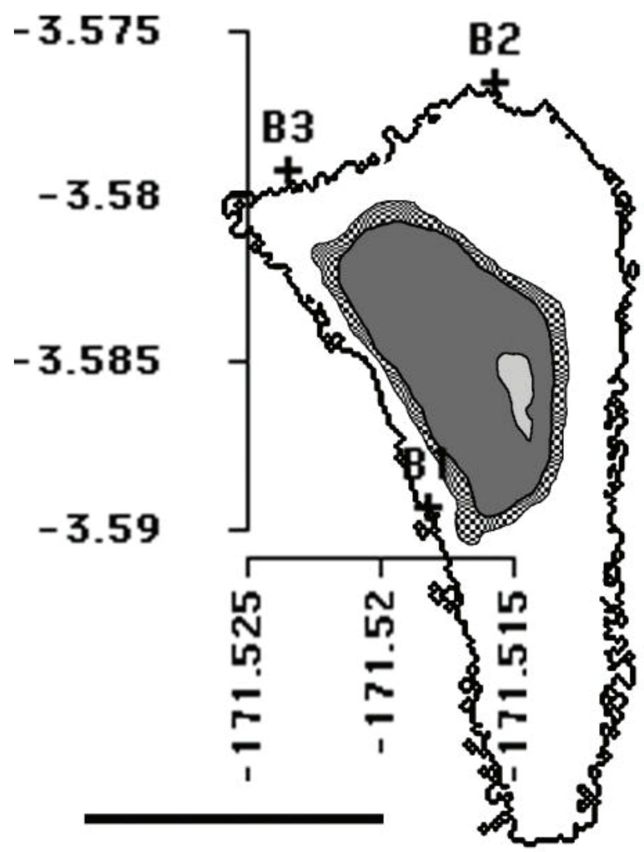

Figure 8. Birnie Island.

McKean Island

McKean (Fig. 9) is among the three smallest of the Phoenix Islands and is the most circular, measuring 1.07 km along its longest axis. The reef perimeter is 6.25 km and area is 1.27 km^2. As with the other small islands, it has no lagoon, though the island does have a brackish pond in its center. The entire northern to southwestern flanks of the island are expected to be windward in character (this zone has not been surveyed). The western side is more sheltered, though because of the island's small size there is likely to be no true leeward side. The subtidal reef width is 177 m. This is the least known island of the group, only being visited once in 2000.

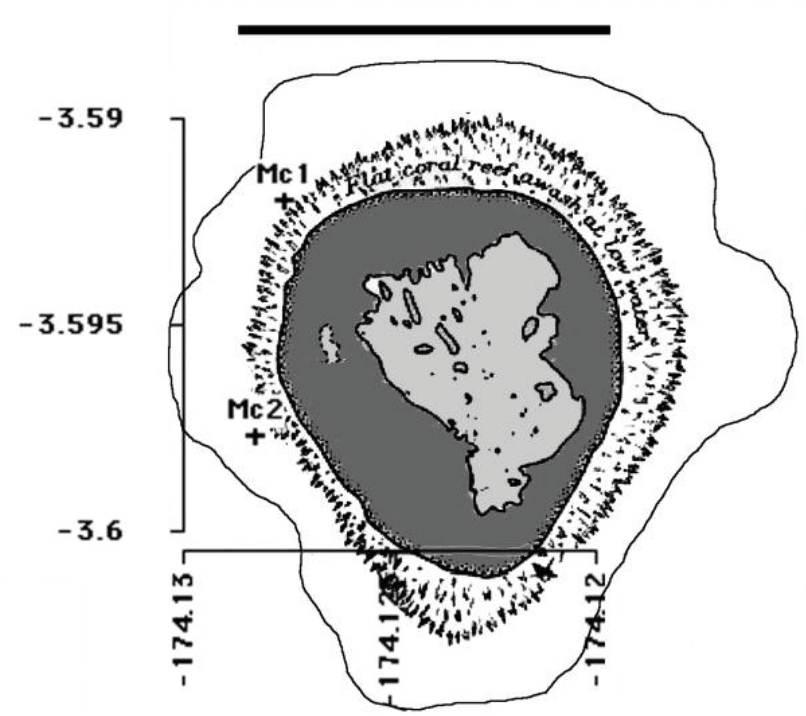

Figure 9. McKean Island.

Rawaki (Phoenix) island

Rawaki is among the three smallest of the Phoenix islands (Fig. 10), measuring 1.12 km along its longest axis. The atoll rim perimeter of 3.07 km, and area of 0.74 km^2 are the smallest of the entire group. As with the other small islands, it has no lagoon, though does have a brackish pond in its center. The entire northeastern to southeastern flanks of the island (incorporating site R4) show windward exposed characteristics, slightly more than 2/3 of the island rim. The western flank (sites R1 to R3) is sheltered, slightly less than 1/3 of the island rim. However because the subtidal reef width is relatively broad at 219 m due to an extension to the northeast and a broad eastern point, approximately 4/5 of Rawaki's reef area shows windward/exposed characteristics.

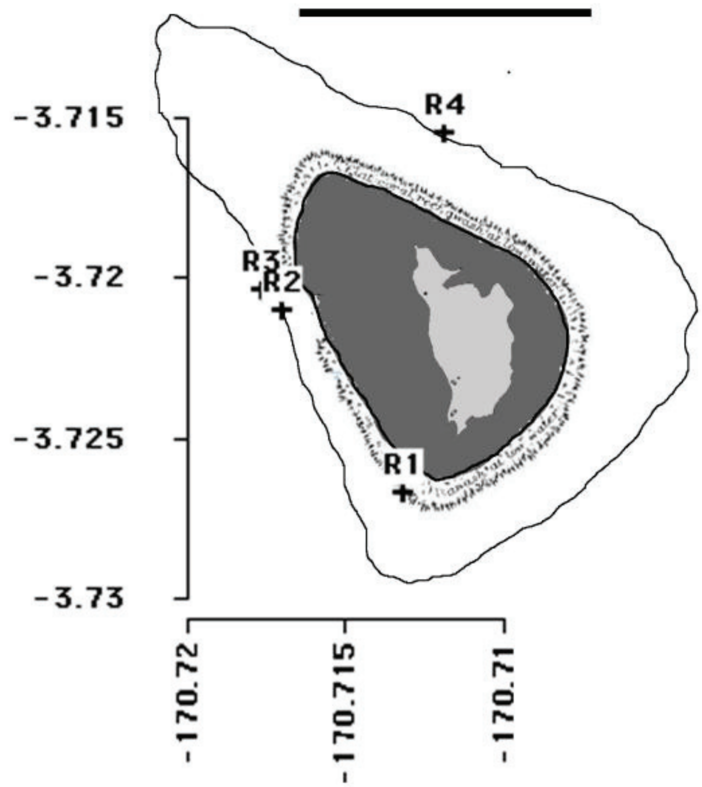

Figure 10. Rawaki Island.

DISCUSSION

Previous workers have noted the homogeneity of coral reefs of the Phoenix Islands, both zoogeographically (Maragos and Jokiel, 1978) and geo-morphologically (Jokiel and Maragos, 1978). These results are supported by observations reported here and in the accompanying chapters in this volume, with homogeneity within reef zones and of reef zones among islands. The methodology for obtaining area estimates here was based on overlaying data from charts, satellite images and existing GIS files. The values calculated vary to some degree from estimates for Kanton by Jokiel and Maragos (1978), who calculated a lagoon area of 49.6 km^2 and an atoll length of 17 km (compared to 56 km^2 and 17.5 km, respectively, measured here), but are close enough to be in agreement.

The islands in the Phoenix group vary incrementally in overall size, and thus in the dimensions and area of coral reefs (Table 3), with the exception of the lack of lagoon zones on all five of the smaller islands. A major goal of mapping was to specify the area of coral reef in each island/zone combination to facilitate study and management planning and zoning of the islands. The proportions of windward to leeward reefs (Table 3) enable a simple calculation of the area of windward and leeward reefs (Table 4). More problematic is estimation of coral reef habitats within the lagoons. Within the lagoons, coral growth was restricted to certain habitats, controlled by circulation (Jokiel and Maragos, 1978). Coral growth was abundant in the Pass Zone of Kanton lagoon,

Table 4. Reef area by major zone on each island (km2). Notes: a- reef area in Kanton lagoon Pass zone, calculated based on a half-circle of radius 2 km; b- reef area in remainder of Kan.

Island	Windward	Leeward	Lagoon	Total	%
Kanton	8.45	1.93	1.42(0.893[a], 0.53[b])	11.80	34.8
Orona	4.29	1.62	1.12	7.03	20.7
Enderbury	2.59	1.19		3.78	11.2
Nikumaroro	2.59	1.04	0.06	3.69	10.9
Manra	2.16	0.81		2.97	8.7
Birnie	2.49	0.16		2.64	7.8
McKean	0.84	0.43		1.27	3.7
Rawaki	0.58	0.17		0.74	2.2
Overall	23.98	7.35	2.60	33.93	

moderate on Orona and limited in all other lagoon zones on Kanton and in Nikumaroro. Jokiel and Maragos proposed an overall estimate of 5% of lagoon area to be suitable for coral growth. With improvements from the surveys conducted here, we postulate that coral reef may cover 25% of the Pass Zone on Kanton, 5 % of Orona's lagoon, and 1% of all other lagoon zones, giving first estimates for lagoon coral reef areas (Table 4).

Thus we estimate the Phoenix Islands have a combined coral reef area of 33.93 km^2 of which 23.98 km^2 is windward reef, 7.35 km^2 is leeward reef and 2.6 km^2 is lagoon reef (or 71, 22 and 8 %, respectively). Kanton dominates the island group with 35% of all reef area and 55 % of lagoon coral reefs, followed by Orona with 21 % of all reefs. Notably, the area of outer reef is higher on Enderbury than Nikumaroro. Interestingly, though Birnie is the smallest island in size, its reef area is only slightly less than Manra's due to the long shelf extending south. The wider and more extensive reef platforms on the smaller islands significantly increase their coral reef area. These broader reef platforms on the smaller islands are suggestive that they may have subsided further than the larger islands, with the islands representing a continuum of age and/or subsidence.

As a final calculation, the estimated reef area in each outer reef zone was calculated by island (Table 5). Thus the proportion of outer reefs in each of the reef zones is roughly similar between windward and leeward reefs, and in the percentages surge (15), platform (60), edge (10) and deep slope (15).

Overall, considering the various characteristics of island size and dimensions, orientation and reef area, the islands appear to cluster into three groups as follows:

1) the two largest islands with lagoons and extensive leeward reefs, Kanton and Orona (55% of all reefs);
2) three intermediate islands, Nikumaroro, Enderbury and Manra (31 % or reefs); and
3) the three smallest islands, Birnie, Rawaki and McKean (14 % of reefs).

Table 5. Area of outer reef slopes in the four main zones: surge zone, reef platform, reef edge and deep slope. The measured reef width to 20 m (Table 3) was assumed to include the reef edge (fixed at 20 m wide), the reef platform (80% of the remainder) and the surge zone (20% of the remainder), and the deep slope was fixed at 30 m wide.

Island	Windward slopes (km^2)					Leeward slopes (km^2)					Total
	Total	surge	platform	edge	slope	Total	surge	platform	edge	slope	
Kanton	8.45	1.30	5.18	0.79	1.18	1.93	0.27	1.08	0.23	0.35	10.38
Orona	4.29	0.66	2.63	0.40	0.60	1.62	0.22	0.87	0.21	0.32	5.91
Enderbury	2.59	0.42	1.66	0.20	0.31	1.19	0.18	0.71	0.12	0.18	3.78
Nikumaroro	2.59	0.35	1.40	0.34	0.51	1.04	0.16	0.65	0.09	0.14	3.64
Manra	2.16	0.32	1.30	0.21	0.32	0.81	0.12	0.47	0.09	0.14	2.97
Birnie	2.49	0.43	1.74	0.13	0.19	0.16	0.01	0.05	0.04	0.05	2.64
McKean	0.84	0.12	0.50	0.09	0.13	0.43	0.07	0.27	0.04	0.06	1.27
Rawaki	0.58	0.09	0.36	0.05	0.07	0.17	0.03	0.11	0.01	0.02	0.74
Total	23.98	3.69	14.77	2.21	3.31	7.35	1.05	4.20	0.84	1.26	31.33
%		15.4	61.6	9.2	13.8		14.3	57.1	11.4	17.1	

ACKNOWLEDGEMENTS

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APPENDIX I - SURVEY SITE DETAILS

The appendix shows the names, codes latitude/longitude and exposure type for each survey site shown in the maps. Also shown is the year(s) in which the each site was visited, and numerical site codes used in 2002 that correspond to sites listed in the fish distribution paper (Allen and Bailey, this volume).

Code	Site Name	Exposure	Longitude (W)	Latitude (S)	2000	2002	2005	CODE 2002
	Birnie							
B1	Puff Magic	Lee	171°31.093'	3°35.363'		y		67
B2	Rock 'n' Roll	Wind	171°30.936'	3°34.597'		y		66
B3	Prognathus Point	Wind	171°31.404'	3°34.754'		y		65
	Enderbury							
E1	Shark Village	Lee	171°5.517'	3°6.312'	y	y	y	59
E2	Obs Spot	Lee	171°5.549'	3°8.539'	y	y	y	62
E3	Lone Palm	Lee	171°5.564'	3°7.06'	y	y	y	61,64
E4	Mystery Wreck	Wind	171°4.723'	3°7.469'		y		63
E5	Southern Ocean	Wind	171°4.761'	3°8.855'	y	y	y	60
	Kanton							
K1	Nai'a Fly'a	Cha	171°43.002'	2°48.821'	y	y	y	24,50
K2	Lagoon End	Lag	171°37.227'	2°51.697'		y		35a
K3	Back Reef A	Lag	171°38.031'	2°51.102'		y		35b
K4	Back Reef B	Lag	171°38.506'	2°50.558'		y		35c
K5	Line Reef B	Lag	171°39.837'	2°49.694'		y		36
K6	Line Reef A	Lag	171°40.395'	2°48.113'		y		29a
K7	Rocks & Pole	Lag	171°40.395'	2°48.966'		y	y	29b, 37
K8	Coral Castles	Lag	171°41.743'	2°48.814'		y		26,45,53,55
K9	Lagoon Pass Zone B	Lag	171°41.835'	2°48.729'		y		56
K10	Lagoon Pass Zone A	Lag	171°42.378'	2°48.289'		y	y	30
K11	Coral Castles	Lag	171°42.388'	2°48.314'	y	y	y	
K12	Degraded Zone C	Lag	171°42.432'	2°46.691'		y		28c
K13	Degraded Zone B	Lag	171°42.457'	2°46.84'		y		28b
K14	Degraded Zone A	Lag	171°42.491'	2°47.384'		y		28a
K15	Guano Alley	Lag	171°42.56'	2°48.77'		y	y	54,58
K16	Kanton Wharf	Lag	171°42.69'	2°48.86'		y		52
K17	British Gas	Lee	171°42.924'	2°49.263'	y	y		27
K18	President Taylor	Lee	171°42.987'	2°48.959'	y	y	y	34,38,47,48
K19	Weird Eddie	Lee	171°43.047'	2°48.723'	y	y	y	32,39
K20	Six Sticks	Lee	171°43.24'	2°48.337'	y	y	y	25,40,51
K21	Crash Landing	Lee	171°43.35'	2°45.639'		y	y	42
K22	Satellite Beach	Lee	171°43.51'	2°46.802'	y	y	y	43
K23	Rolly Coaster	Wind	171°38.523'	2°47.978'		y		31,41,43,44,49
K24	Oasis	Wind	171°41.149'	2°50.098'		y		46,57
K25	Steep To	Wind	171°42.511'	2°49.986'	y	y	y	33
	Manra							
M1	Northern Lee	Lee	171°15.128'	4°26.475'	y	y	y	14
M2	Harpoon Corner	Lee	171°15.901'	4°27.315'	y	y	y	15,17,18,20
M3	Northern Exposure	Wind	171°14.634'	4°26.164'	y	y		16
M4	Wild Side	Wind	171°14.431	4°28.186		y		19

Code	Site Name	Exposure	Longitude (W)	Latitude (S)	2000	2002	2005	CODE 2002
	McKean							
Mc1	Rush Hour	Lee	174°7.65'	3°35.52'	y			
Mc2	Guano Hut	Lee	174°7.69'	3°35.86'	y			
	Nikumaroro							
N1	Nikumaroro channel	Cha	174°32.238'	4°40.137'		y		10
N2	Nikumaroro lagoon	Lag	174°32.1'	4°40'.0		y		11
N3	Amelia's Lost Cswy	Lee	174°32.616'	4°40.477'	y	y	y	7,9,84
N4	Nai'a Point	Lee	174°32.697'	4°39.335'	y	y	y	1,83
N5	Kandy Jar	Lee	174°32.724'	4°39.409'	y	y		2
N6	Norwich City	Lee	174°32.847'	4°39.652'		y		87
N7	Ameriki	Wind	174°29.407'	4°41.619'		y		3
N8	Turtle Nest Beach	Wind	174°30.905'	4°40.008'		y	y	4,82,85
N9	Electra Landing	Wind	174°31.302'	4°41.19'		y	y	6
N10	SW Corner	Wind	174°32.41'	4°40.87'	y		y	
N11	Windward Wing	Wind	174°32.552'	4°39.048'	y	y	y	5,8,12,13,86
N12	Landing	Lee	174°32.59	04°40.54	y			
	Orona							
O1	Orona Lagoon A	Lag	172°10.302'	4°29.701'		y	y	72
O2	Orona Lagoon B	Lag	172°08.712	4°29.878		y		73
O3	Orona Lagoon C	Lag	172°10.509'	4°30.341'		y	y	74,78
O4	Orona Lagoon D	Lag	172°11.502'	4°30.86'		y		77
O5	Orona Lagoon E	Lag	172°09.31	4°29.83	y			
O6	Orona Lagoon F	Lag	172°10.15	4°29.49	y			
O7	Algae Corner	Lee	172°13.616'	4°31.112'	y	y	y	68,75,79
O8	Dolphin Ledge	Lee	172°10.932'	4°29.487'	y	y	y	69,81
O9	Small Channels	Lee	172°12.962'	4°30.285'		y		80
O10	Transition Reef	Lee	172°13.531'	4°30.683'		y		70
O11	Aerials	Wind	172°12.953'	4°31.961'	y	y		71
O12	Backdoor	Wind	172°10.243'	4°31.815'			y	
O13	Far Side	Wind	172°8.241'	4°29.468'		y	y	76
O14	Farther Side	Wind	172°7.738'	4°29.816'			y	
O15	North Side	Wind	172°9.422'	4°28.942'			y	
	Rawaki							
R1	Clearwater	Lee	170°42.79'	3°43.6'	y		y	
R1	Deepwater	Lee	170°43.054'	3°43.222'	y	y	y	23
R1	Farwater	Wind	170°42.711'	3°42.927'		y	y	22
R1	Stillwater	Lee	170°43.017'	3°43.26'	y	y	y	21

REEF FISHES OF THE PHOENIX ISLANDS, CENTRAL PACIFIC OCEAN

BY

GERALD ALLEN[1] AND STEVEN BAILEY[2]

ABSTRACT

Visual inventories and fish collections were conducted at the Phoenix Islands during June-July 2002. A list of fishes was compiled for 57 sites. The survey involved 163 hours of scuba diving to a maximum depth of 57 m. A total of 451 species were recorded, including 212 new records. The total known fish fauna of the Phoenix Islands now stands at 516 species. A formula for predicting the total reef fish fauna based on the number of species in six key indicator families indicates that at least 576 species can be expected to occur at this location. Wrasses (Labridae), groupers (Serranidae), gobies (Gobiidae), damselfishes (Pomacentridae), and surgeonfishes (Acanthuridae) were the most speciose families with 53, 40, 36, 36, and 32 species respectively. Species numbers at visually sampled sites during the survey ranged from 17 to 166, with an average of 110. Leeward outer reefs contained the highest diversity with an average of 135.5 species per site. Other major habitats included windward outer reefs (123.7 per site), passages (113.5), and lagoon reefs (38.5). The Napoleon Wrasse (*Cheilinus undulatus*) was extraordinarily abundant, providing excellent baseline information on the natural abundance of this species in the absence of fishing pressure.
Conservation recommendations include protection of certain large predatory fishes including the Napoleon Wrasse, Bumphead Parrotfish, and reef sharks.

INTRODUCTION

The primary goal of the fish survey was to provide a comprehensive inventory of reef fishes inhabiting the Phoenix Islands. This segment of the fauna includes fishes living on or near coral reefs down to the limit of safe sport diving or approximately 55 m depth. It therefore excludes most deepwater and offshore pelagic species such as flyingfishes, tunas, and billfishes. We did, however, record several species at depths between 60-183 m that were observed with the ROV and Dropcam.

Historical Background

The remote Phoenix Islands have attracted relatively little attention from ichthyologists. The first significant fish collections were made by Leonard Schultz from

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the United States National Museum, who visited the islands in 1939 during an extensive cruise aboard the US naval ship "Bushnell." The expedition departed San Diego on 1 April and terminated at Honolulu on 27 July after having made extensive fish collections at the Phoenix and Samoan islands. Approximately one month was spent at four islands in the Phoenix Group, including Kanton, McKean, Enderbury, and Hull (Orona). These collections, containing 184 species, were reported by Schultz (1943). A total of seven species, including *Echidna letucotaenia, Uropterygius cantonensis, Aporops bilinearis, Cirrhitops hubbardi, Kuhlia petit, Plectroglyphidodon phoenixenis,* and *Oplopomus diacanthus*, were described as new species from the Phoenix Islands in this publication.

The only other collections prior to the present expedition were obtained during a marine biological survey of the Phoenix Islands by the New England Aquarium and associates between 24 June and 15 July 2000. Collections were reported by Stone et al. (2001 and see Stone et al., this volume) and consisted of approximately 80 coral reef species, that were mainly identified by K.E. Hartel of the Museum of Comparative Zoology, Harvard University. In addition, underwater photographs of approximately 109 species were obtained by M.J. Adams. The combination of collected specimens, recorded observations, and photographic records accounted for a species total of 188 species, including 107 new records for the Phoenix Islands.

METHODS

The fish portion of this survey involved approximately 163 hours of scuba diving by G. Allen and S. Bailey to a maximum depth of 57 m. A comprehensive list of fishes was compiled for 57 sites (see Obura, this volume for site codes). The basic method consisted of underwater observations made during a single dive at each site with an average duration of about 65 minutes. The name of each observed species was recorded in pencil on a plastic sheet attached to a clipboard. The technique usually involved rapid descent to 30-55 m, then a slow, meandering ascent back to the shallows (Obura, this volume). The majority of time was spent in the 2-15 m depth zone, which consistently harbors the highest number of species. Each dive included a representative sample of all major bottom types and habitat situations.

Fishes were photographed underwater while scuba diving with a Nikon SLR camera in aluminum housing and a Nikonos. Photographs were obtained of approximately 130 species. We also utilized video images obtained with an ROV and Dropcam at depths between about 60-183 m. This equipment is described in Stone et al. 2000 and Stone et al. (this volume).

The visual survey was supplemented with occasional collections procured with rotenone, qiuinaldine-sulphate, and rubber-propelled, multi-prong spears. The purpose of the rotenone collections was to flush out small, crevice and sand-dwelling fishes (for example eels and tiny gobies) that are difficult to record with visual techniques. A total of 1853 specimens were collected, representing approximately 180 species. Most of these were deposited at the Museum of Comparative Zoology, Harvard University. A small collection (123 specimens) were also lodged at the Western Australian Museum, Perth.

RESULTS

A total of 451 species were recorded during the present expedition, including 212 new distribution records. Therefore, the total known fauna of the Phoenix Islands now stands at 516 species, in 217 genera and 67 families consisting of the following elements: 185 species originally recorded by Schultz (1943), 107 species recorded by the Primal Oceans Expedition 2000, 212 species from the current expedition, and 10 species recorded in various generic revisions (Jewett and Lachner, 1983; Randall, 1956 and 2000; Randall and Clements, 2001; Randall and Heemstra, 1991; Springer, 1967; Randall and Randall, 2001; Schwarzhans et al., 2005; Moller & Schwarzhans, 2008). Two of the species recorded by Schultz, *Plectropomus leopardus* and *Parapercis tetracanthus*, most likely represent misidentifications of *Plectropomus areolatus* and *Parapercis lata*. Consequently they do not appear on the overall checklist if Phoenix Islands reef fishes presented in Appendix I.

General Faunal Composition

The fish fauna of the Phoenix Islands consists mainly of species associated with coral reefs. The most abundant families in terms of number of species are wrasses (Labridae), groupers (Serranidae), gobies (Gobiidae), damselfishes (Pomacentridae), surgeonfishes (Acanthuridae), moray eels (Muraenidae), butterflyfishes (Chaetodontidae), blennies (Blenniidae), squirrelfishes (Holocentridae), and cardinalfishes (Apogonidae). These 10 families collectively account for 62 percent of the total reef fish fauna (Fig. 1).

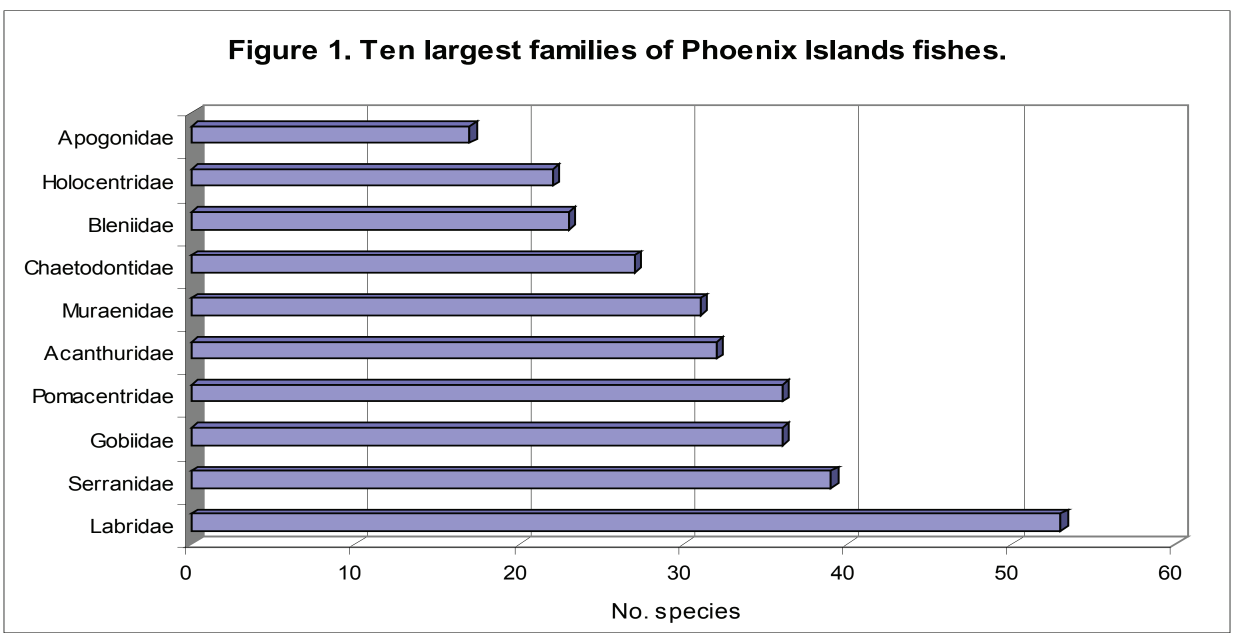

Figure 1. The ten largest families of Phoenix Islands fishes.

The relative abundance of Phoenix fish families is similar to other reef areas in the Indo-Pacific, although the ranking of individual families is variable depending on locality. The Phoenix rankings differ from those obtained on recent Conservation International surveys in the "Coral Triangle" (Indonesia, Philippines, and Papua; Allen, 2000; Allen, 2002a and b) most markedly in relation to the position of the Serranidae, Muraenidae, and Holocentridae. The Serranidae generally ranks about fifth at coral triangle localities, while Muraenidae and Holocentridae do not feature in the top 10 families (Allen, 2002). Muraenidae no doubt deserves a higher ranking in the coral triangle, but is difficult to visually survey due to the cryptic habits of most morays.

Fish Community Structure

The composition of local reef fish communities in the Indo-Pacific region is largely dependent on habitat variability and consequent availability of food and shelter. The relatively limited fauna of the Phoenix Islands compared to areas further to the west is primarily due to two factors: 1) the distance from the "coral triangle", which is generally acknowledged as the center of Indo-Pacific coral reef fish diversity, and 2) the relatively homogenous nature of the reef environment. Phoenix Island reefs are generally characterised by a lack of habitat diversity (Obura, this volume), and are consequently inhabited mainly by fishes typical of atoll seaward reefs, with the exception of the 26 lagoon species listed in Table 1. The few islands that contain substantial lagoons (Nikumaroro, Kanton,and Orona) possess relatively impoverished lagoon faunas due to poor circulation, extensive shallows, lack of reef structure, or combination of these factor

Similar to other reef areas in the Indo-Pacific, most fishes at the Phoenix Islands are benthic (or at least living near the bottom) diurnal carnivores (Table 2). A relatively small portion of the community is herbivorous, but this element is slightly higher than at recently sampled areas in the coral triangle. Certain herbivorous species were

Table 1. Fishes mainly found in lagoons at the Phoenix Islands.

Atherinidae	**Labridae**
Atherinosoma lacunosa	*Cymolutes praetextatus*
Mugilidae	*Halichoeres trimaculatus*
Neomyxus leuciscus	*Thalassoma trimaculatus*
Crenimugil crenilabis	**Callionymidae**
Liza vaigiensis	*Callionymus simplicornis*
Serranidae	**Gobiidae**
Epinephelus merra	*Amblygobius nocturnus*
Apogonidae	*Amblygobius phalaena*
Cheilodipterus quinquelineatus	*Ctenogobiops sp.*
Fowleria punctulata	*Eviota cometa*
Gerreidae	*Fusigobius neophytus*
Gerres argyreus	*Macrodontigobius wilburi*
Pomacentridae	*Oplopomus diacanthus*
Chromis viridis	*Oplopomus oplopomus*
Dascyllus aruanus	**Ptereleotridae**
Pomacentrus pavo	*Ptereleotris microlepis*
Stegastes nigricans	**Balistidae**
	Rhinecanthus aculeatus

Table 2. Percentage of species in major dietary categories at the Phoenix Islands compared to the average value for 4 locations (Calamianes Islands, Philippines; Komodo Islands, Indonesia; Togean/Banggai Islands, Indonesia; Raja Ampat Islands, Indonesia) in the coral triangle (data from Conservation International surveys).

Dietary category	Phoenix Islands	Coral Triangle
Carnivore	61.0 %	60.1 %
Omnivore	14.2 %	16.4 %
Planktivore	13.2 %	15.1 %
Herbivore	11.6 %	8.5 %

particularly common, occurring in much higher densities than at many localities in the Indo-Pacific region. These included various surgeonfishes (*Acanthurus guttatus, A. nigricans, A. triostegus, A. xanthopterus*, *Naso lituratus,* and *Zebrasoma veliferum*) and parrotfishes (*Hipposcarus longiceps* and *Scarus ghobban*), which were frequently sighted in extraordinarily large aggregations.

The number of species recorded at each site is indicated in Table 3. Totals ranged from 17 to 166, with an average of 110 per site**.** Outer reefs were the richest areas for fish diversity, with leeward reefs (135.5 species per site) containing more species than windward reefs (123.7 species). Lagoon reefs were relatively impoverished with 38.5 species per site. Although passages were surveyed on only two occasions, the average number of species was 113.5.

Table 3. Number of fish species recorded at each site.

Site	Species	Site	Species	Site	Species
1	137	25	126	50	126
2	135	26	37	52	71
3	120	27	158	54	102
4	103	28	17	55	57
5	103	29	17	62	142
6	107	30	72	63	116
7	133	31	155	64	156
8	98	32	155	65	120
11	31	33	138	66	132
14	108	34	155	67	161
15	140	36	17	68	161
17	112	37	18	69	116
18	134	38	166	71	138
19	110	39	129	72	50
20	126	40	71	73	33
21	154	41	140	74	46
22	117	42	150	76	124
23	150	43	155	77	34
24	125	46	142	80	144

The 10 richest sites for fishes are indicated in Table 4. The total species at a particular site is ultimately dependent on the availability of food and shelter and the diversity of substrata. Significantly, the most species (166) for a single dive was recorded in the vicinity of the President Taylor shipwreck at Kanton Island. Considering the relative habitat homogeneity at the Phoenix Islands, this site was relatively diverse. It is located next to the main passage leading into the lagoon, and therefore exposed to strong currents that support a wealth of plankton feeders. The site also incorporates an impressive dropoff, extensive rubble bottom, reasonable coral growth, and an extensive shallow reef top with additional shelter provided by the shipwreck.

Table 4. Ten richest fish sites.

Site No.	Location	Total fish spp.
38	President Taylor, Kanton I.	166
67	Puff Magic, Birnie I.	161
68	Algae Corner, Orona I.	161
27	British Gas, Kanton I.	158
64	Lone Palm, Enderbury I.	156
31	Satellite Beach, Kanton I.	155
32	Weird Eddie, Kanton I.	155
34	President Taylor, Kanton I.	155
43	Satellite Beach, Kanton I.	155
21	Stillwater, Phoenix I.	154

Coral Fish Diversity Index (CFDI)

Allen (1998) devised a convenient method for assessing and comparing overall reef fish diversity. The technique essentially involves an inventory of six key families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. The number of species in these families is totalled to obtain the Coral Fish Diversity Index (CFDI) for a single dive site, relatively restricted geographic areas (eg. Phoenix Islands) or countries and large regions (eg. western Pacific Ocean).

CFDI values can be used to make a reasonably accurate estimate of the total coral reef fish fauna of a particular locality by means of regression formulas. The latter were obtained after analysis of 35 Indo-Pacific locations for which reliable, comprehensive species lists exist. The data were first divided into two groups: those from relatively restricted localities (surrounding seas encompassing less than 2,000 km^2) and those from much larger areas (surrounding seas encompassing more than 50,000 km^2). Simple regression analysis revealed a highly significant difference ($P = 0.0001$) between these two groups. Therefore, the data were separated and subjected to additional analysis. The Macintosh program Statview was used to perform simple linear regression analyses on each data set in order to determine a predictor formula, using CFDI as the predictor variable (x) for estimating the independent variable (y) or total coral reef fish fauna. The resultant formulae were obtained: 1. total fauna of areas with surrounding seas encompassing more than 50,000 km^2 = 4.234(CFDI) - 114.446 (d.f = 15; $R^2 = 0.964$; P = 0.0001); 2. total fauna of areas with surrounding seas encompassing less than 2,000 km^2 = 3.39 (CFDI) - 20.595 (d.f = 18; $R^2 = 0.96$; P = 0.0001).

CFDI is useful for short term surveys such as the present one because it is capable of accurately predicting the overall faunal total. The main premise of the CFDI method is that short term surveys of only 3-4 weeks duration are sufficient to record nearly all members of the six indicator families due to their conspicuous nature. The CFDI for the Phoenix Islands is 176, composed of the following elements: Chaetodontidae (27), Pomacanthidae (13), Pomacentridae (36), Labridae (53), Scaridae (15), and Acanthuridae (32). The resultant predicted faunal total is 576 species, indicating that approximately 63 additional species of shallow reef fishes can be expected from the islands.

Zoogeographic Affinities And Comparison Of Faunal Totals

Table 5 presents the major zoogeographic categories for reef fishes of the Phoenix Islands. The largest segment of the fauna consists of species that are broadly distributed in the Indo-west and central Pacific region from East Africa to the islands of Oceania. This is not surprising as nearly all coral reef fishes have a pelagic larval stage of variable duration, depending on the species. Dispersal capabilities and length of larval life of a given species are usually reflected in its geographic distribution.

Table 5. Major Zoogeographic Categories for fishes of the Phoenix Islands.

General distribution	No. species	% of fauna
Indo-west and central Pacific	325	63.2
Western and central Pacific	94	18.3
Central Pacific	41	8.0
Indo-Pacific to the Americas	36	7.0
Circumtropical	12	2.3
Undetermined	6	1.2

Reef fish diversity is greatest in the Indonesian region, and there is a more or less predictable attenuation of the fauna as one travels away from this area (Table 6). The rate of attenuation is affected by both distance from the Indonesian center and latitude. Although the Society Islands lie much further to the east than the Phoenix Group, they are inhabited by more species because there is much greater habitat diversity associated with high islands.

Table 6. Comparison of total number of reef fishes for various locations in the western and central Pacific Ocean (adapted from Allen, 2002).

Location	Total species
Indonesia	2027
Papua New Guinea	1494
New Caledonia	1097
Marshall Islands	795
Phoenix Islands	516
Society Islands	560

Perhaps the most interesting segment of the Phoenix fauna is the group of species that are largely restricted to the central Pacific. Springer (1982) provided ample evidence for a discrete Pacific Plate province characterized by a high degree of endemism, particularly for shore fishes. Allen (in press) estimated that approximately 19 percent of the overall Pacific Plate fauna is endemic, based on an analysis of 17 common reef fish families. A list of species that are either Pacific Plate endemics or mainly distributed on the Plate is presented in Table 7.

Table 7. List of Phoenix Island fishes that are mainly confined to the Pacific Plate (see Springer, 1982).

Muraenidae	**Pomacentridae**
Anarchias leucotaenia	*Chrysiptera albata*
Anarchias leucurus	*Stegastes aureus*
	Labridae
Hemiramphidae	*Bodianus prognathus*
Hyporhamphus acutus	*Coris centralis*
Holocentridae	*Labropsis polynesica*
*Myripristi*s *earlei*	*Pseudocheilinus tetrataenia*
Serranidae	**Creediidae**
Epinephelus socialis	*Crystallodytes cookei*
Pseudanthias olivaceus	**Tripterygiidae**
Pseudochromidae	*Helcogramma hudsoni*
Pseudoplesiops revellei	**Bleniidae**
Cirrhitidae	*Cirripectes jenningsi*
Cirrhititops hubbardi	*Cirripectes variolosus*
Paracirrhitus nisus	*Entomacrodus cymatobiotus*
Paracirrhitus xanthus	*Entomacrodus sealei*
Kuhliidae	*Rhabdoblennius rhabdotrachelus*
Kuhlia petit	**Gobiidae**
Mullidae	*Ctenogobiops* sp.
Upeneus arge	*Priolepis ailina*
Chaetodontidae	**Acanthuridae**
Chaetodon declivus	*Acanthurus achilles*
Chaetodon quadrimaculatus	*Acanthurus nigroris*
Hemitaurichthys thompsoni	*Ctenochaetus flavicauda*
Pomacanthidae	*Ctenochaetus marginatus*
Apolemichthys xanthopunctatus	*Zebrasoma rostratum*
Centropyge multicolor	**Soleidae**
Centropyge nigriocella	*Aseraggodes melanostictus*

Endemism

Considering the broad dispersal capabilities via the pelagic larval stage of most reef fishes it is unlikely that any reef fish species are endemic to the Phoenix Group. The recently described damselfish (*Chrysiptera albata*) and goby (*Trimma squamicanta*) are currently known only from the Phoenix Islands. However, they can be expected at other areas in the central Pacific such as the Line Islands. The damselfish, which inhabits the steep outer reef on the windward side of Nikumaroro Island, has no doubt escaped attention due to its small size, drab coloration, and relatively deep-dwelling habits. It was collected for the first time on this expedition and forms part of a select group of 12 species that have highly restricted distributions on the Pacific Plate (Table 8).

Table 8. Phoenix Islands fishes with apparent restricted distributions.

Species	General Distribution
Myripristis earlei (Holocentridae)	Marquesas and Phoenix Islands
Paracirrhitus nisus (Cirrhitidae)	Tuamotus and Phoenix Islands
Kuhlia petit (Kuhliidae)	Marquesas and Phoneix Islands
Chaetodon declivis (Chaetodontidae)	Marquesas, Line Is., and Phoenix Is.
Apolemichthys xanthopunctatus (Pomacanthidae)	Gilbert, Phoenix, and Line Islands
Chrysiptera albata (Pomacentridae)	Nikumaroro Atoll
Bodianus prognathus (Labridae)	Line and Phoenix Islands
Coris centralis (Labridae)	Line and Phoenix Islands
Parapercis lata (Pinguipedidae)	Line and Phoenix Islands
Ctenogobiops sp. (Gobiidae)	Line and Phoenix Islands
Priolepis ailina (Gobiidae)	Society and Phoenix Islands
Trimma squamicana (Gobiidae)	Phoenix Islands

ROV Camera Results

The ROV camera was deployed at several outer reef sites providing an opportunity to extend our observations below the depths of conventional scuba diving to about 180 m. These investigations, unfortunately, were greatly hampered by persistent equipment malfunctions. Although our list (Table 9) of ROV species is very limited, at least two species, *Paracaesio xanthurus* and *Chaetodon declivus* were exclusively recorded with this method. The deep outer reef habitat was characterized by a steep slope with a mixture of rubble and soft sediment, with occasional ledges.

Table 9. Fishes recorded with the ROV camera at depths between 90 and 180 m.

Carcharinus amblyrhynchos (Carcharinidae)
Triaenodon obesus (Carcharhinidae)
Caranx lugubris (Carangidae)
Lutjanus bohar (Lutjanidae)
Paracaesio xanthurus (Lutjanidae)
Lethrinus olivaceus (Lethrinidae)
Chaetodon declivis (Chaetodontidae)
Forcipiger flavissimus (Chaetodontidae)
Heniochus acuminatus (Chaetodontidae)
Apolemichthys griffisi (Pomacanthidae)
Odonus niger (Balistidae)
Xanthichthys auromarginatus (Balistidae)

Unfortunately it was not possible to detect smaller species such as damselfishes and fairy basslets (*Pseudanthias*), due to the limitations of the wide angle lens. The most common larger species on the deep slope included *Triaenodon obesus, Caranx lugubris, Lutjanus bohar*, and *Odonus niger*. Although there is scant published information on the distribution of deep reef fishes, the work of Chave and Mundy (1994), dealing with the Hawaiian Archipelago and Johnston Island, showed that numerous species usually found on shallow coral reefs, are capable of penetrating considerable depths. For example, these authors recorded respective maximum depths of 275 m, 291 m, 128 m, and 161 m, for *C. amblyrhnchos, C. lugubris, F. flavissimus,* and *X. auromarginatus*, four of the same species seen on deep slopes at the Phoenix Islands.

New Species and Notable Range Extensions

Four new species were collected during the 2002 expedition, which have been recently described. The holocentrid *Myripristis earlei* Randall, Allen, and Robertson (2003) was first thought to be a color variant of *M. berndti*, but specimens collected during the expedition revealed distinctive differences. The species is also known from the Marquesas Islands. *Chrysiptera albata* Allen and Bailey (2002), a small pomacentrid that frequents the steep outer slopes of Nikumaroro Atoll at depths below 45 m, was collected on the last diving day of the expedition. We also collected two new gobiids that were subsequently described by Winterbottom (2004) as *Trimma sostra* and *T. squamicana*. The latter species is known only from the Phoenix Group, but *T. sostra* is also found at the Solomon Islands, Caroline Islands, Fiji, and the Gilbert and Ellice islands (Kiribati).

A total of 219 new records for the Phoenix Islands were recorded during the current expedition (Appendix I) Most of these are widespread species, whose occurrence at the Phoenix Islands was predictable. Nevertheless, several notable range extensions were recorded including species previously known from isolated outposts in the central Pacific such as the Line Islands, Society Islands, Tuamotus, and Marquesas (Table 8). Other notable extensions include those for the caesionid, *Ptereleotris lativittata* (Chagos to Palau), and the labrids *Halichoeres pallidus* (common in the Indonesian area, but rarely reported from the central Pacific), and *Labropsis polynesica* (Austral Islands, Society Islands, and Tuamotus).

Inter-island Comparisons

Although general diving conditions between the various islands were similar due to the relatively homogenous atoll environment, each island possessed distinctive faunal characteristics. In view of the brief nature of our visit, it is difficult to assess the validity of these differences. They may be real, or simply false impressions based on a limited number of dives. Nevertheless, it seems worthwhile to mention some of the most obvious faunal highlights or peculiarities of each island.

Nikumaroro Island. – Huge numbers of surgeonfishes were certainly one of the most impressive faunal features of the Phoenix Islands in general and some of the largest aggregations were witnessed at dive sites 1 and 2. Schooling species included *Acanthurus triostegus, A. guttatus, A. nigroris, A. xanthopterus*, and *Zebrasoma veliferum*. Nikumaroro was also the best location for sharks, including *Charcharhinus amblyrhynchos, C. melanopterus*, and *Triaenodon obesus*. As many as 15-20 sharks were seen on each dive. Other highlights included large schools of *Lutjanus fulvus* and an inordinate number of hawkfishes, which were generally abundant throughout the Phoenix Group.

Manra Island. – Manra was notable for its abundance of the surgeonfish *Acanthurus guttatus*, which formed large feeding shoals in shallow, wave-affected gutters. In addition, an extensive sand patch at dive site 18 yielded about 20 individuals of *Malacanthus brevirostris* as well as numerous *Coris centralis*. Other extraordinarily abundant fishes included *Kyphosus cinerascens* and *Mulloidichthys mimicus*.

Phoenix Island. – Plectognaths (triggerfishes, puffers, and allies) were generally abundant. The most puffers (*Arothron meleagris*) were seen at this island, including up to 15-20 fish in a single aggregation. There was also an abundance of the relatively rare *Xanthichthys* triggerfishes (*X. auromarginatus* and *X. caeruleolineatus*).

Kanton Island. – The relatively wide, deep passage and interconnected lagoon habitat were unique physical features associated with a number of fish species that were seen here and nowhere else in the Phoenix Islands: *Heteroconger haasi, Atherinomorus lacunosa, Doryhamphus dactyliophorus, Epinephelus socialis, Kuhlia petit, K, mugil, Gerres argyreus, Centropyge bicolor, Heniochus acuminatus, Chromis ternatensis, Amblygobius nocturnus, Ctenogobiops sp.,* and *Pleurosicya micheli*. In addition, the following species were sighted only on the outer reef at Kanton: *Belonoperca chabanaudi, Apogon taeniopterus, A. semiornatus, Fowleria punctulata, Chromis weberi, Halichoeres chrysus, H. pallidus, Hologymnosus doliatus, Ptereleotris evides,* and *Siganus argenteus*. Parrotfishes were generally more numerous at Kanton compared to the other islands. Especially notable in this regard were huge spawning aggregations of *Hipposcarus longiceps*, encountered on the outer reef at the entrance to the main passage. Spectacular early morning (during outgoing spring tides) spawning episodes were witnessed on two occasions. Also, with the exception of one sighting at Birnie Island, *Scarus altipinnis* was confined to Kanton, and present in large numbers. Other fishes with unusually high abundance included *Caranx lugubris, Chaetodon lunula* (a school of 70 individuals seen in the lagoon), and *C. trifascialis* (confined to the lagoon).

Birnie Island. – This small island was subject to strong surge, and consequently exhibited relatively low coral relief and a lower level of fish diversity. One notable observation was the presence of the normally deeper dwelling *Paracentropyge multifasciatus* and *Xanthichthys auromarginatus* in only 8-9 m depth. Conversely, *Myripristis woodsi*, usually found in less than 12 m, was seen as deep as 32 m. This soldierfish was exceptionally common. Other species that were seen in higher than usual numbers included *Epinephelus polyphekadion* and *Bodianus prognathus*.

Orona Island. – Large shoals of Bumphead Parrotfish (*Bulbometopon muricatus*), included up to 200 or more individuals. This impressive fish was seen on most dives at Orona, both in the lagoon and on outer reefs. Kanton and Nikumaroro were the only other locations where it was sighted, but only small groups were encountered. The lagoon at Orona was also notable for its population of juvenile Napoleon Wrasse (*Cheilinus undulatus*), with observations of as many as 20-25 per dive.

CONSERVATION RECOMMENDATIONS

The first author has dived extensively on reefs of the Indo-Pacific region over the past 35 years. This experience provides an excellent basis of comparison, which encompasses a huge variety of reefs from the coast of the Americas to East Africa. Although unremarkable with regards to total fish species, percentage of endemics, or habitat diversity, the Phoenix Group is certainly one of the best examples of a near-pristine atoll environment. Moreover, the islands seem to have escaped coral-bleaching episodes up until the event of late 2002 (see Alling et al, this volume, Obura and Mangubhai, in review). Therefore, there is excellent justification for establishing a conservation reserve that incorporates at least a portion of these islands. Nikumaroro seems especially well suited for this purpose. It is large enough to have a full range of atoll-associated habitats, and because it is uninhabited there is virtually no fishing pressure. The shark population is also healthy, compared to other places in the Phoenix Group where these animals have been recently decimated by foreign shark-fin fishing (Obura and Stone 2003).

Certainly consideration should be given to protecting the remaining shark populations. The apparent damage to shark stocks by foreign fishing vessels underlines their fragility. Intense fishing over a relatively short period can due considerable harm due to the territoriality of reef sharks, their slow growth rate, and low fecundity.

We also recommend that the government protects two of the largest reef fish species, the Napoleon Wrasse and Bumphead Parrotfish. This could conceivably be accomplished without sacrificing an important item in the local diet. Our limited observations at Kanton and Orona indicate that neither of these species was important in the artisanal fishery, especially since the closure of the settlement at Orona. The Napoleon Wrasse, in particular, is increasingly threatened across the Indo-Pacific, as a consequence of its high value in the live-fish trade associated with the restaurant industry in South-east Asia. Stocks of this fish are severely depleted over much of its range. As more easily accessed fishing grounds in the Philippines and Indonesia are being depleted, there is more pressure on outlying regions to supply the demand for this fish. The Phoenix Islands population of Napoleon Wrasse is exceptional compared to most other locations (Table 10). As many as 20-25 individuals were seen on each dive. The population could be quickly devastated if foreign or local ventures started fishing operations. This species is presently protected under Appendix II of CITES and although it is not necessarily threatened by extinction, it could easily vanish if the trade is not closely controlled.

Table 10. Frequency of Napoleon Wrasse (*Cheilinus undulatus*) for various locations in the Indo-Pacific previously surveyed by Conservation International.

Location	No. sites where seen	% of total sites	Approx. no. seen
Phoenix Islands 2002	47	83.92	412
Milne Bay, PNG – 2000	28	49.12	90
Milne Bay, PNG – 1997	28	52.83	85
Raja Ampat Islands – 2001	7	15.55	7
Togean/Banggai Islands – 1998	6	12.76	8
Weh Island, Sumatra – 1999	0	0.00	0
Calamianes Is., Philippines – 1998	3	7.89	5

Protection of the Bumphead Parrotfish would be focused at Orona Island, the only place it was common. This would obviously involve coordination of the local community, who could provide an opportunity for strict law enforcement. The lack of people at most localities in the Phoenix Group provides an opportunity for clandestine illegal poaching, an obstacle that needs to be considered in framing any conservation initiatives.

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Appendix I. List of the reef fishes of the Phoenix Islands.

This list includes all species of coral reef fishes known from the Phoenix Islands at 10 July 2002. The list is based on the following sources: 1) collections reported by Schultz (1943); 2) fishes collected, photographed, or observed during the Primal Oceans 2000 Expedition.; 3) observations and collections made during the current Expedition., and 4) a few species reported in recent literature such as the review of *Ctenochaetus* by Randall and Clements (2001). The family classification follows that of Eschmeyer (1998) except for the placement of Cirrhitidae. Genera and species are arranged alphabetically within each family.

Terms relating to relative abundance are as follows: *Abundant* **-** Common at most sites in a variety of habitats with up to several hundred individuals being routinely observed on each dive. *Common* **-** seen at the majority of sites in numbers that are relatively high in relation to other members of a particular family, especially if a large family is involved. *Moderately common* **-** not necessarily seen on most dives, but may be relatively common when the correct habitat conditions are encountered. *Occasional* **-** infrequently sighted and usually in small numbers, but may be relatively common in a very limited habitat. *Rare* **-** less than 10, often only one or two individuals seen on all dives. Species that lack abundance and site record information were not recorded during the 2002 survey. An asterisk (*) after the species citation indicates that it was photographed by G. Allen during the 2002 survey. Site records correspond to site numbers in Obura, this volume.

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
SPECIES	**SOURCE**	**ABUNDANCE**	**SITE RECORDS**
GINGLYMOSTOMATIDAE			
Nebrius ferrugineus (Lesson, 1830)	New record.	Rare, only one seen.	44
CARCHARHINIDAE			
Carcharhinus albimarginatus (Rüppell, 1837)	New record.	Rare.	One seen by Paul Nicklin at Enderbury Island.
C. amblyrhynchos (Bleeker, 1856)*	2000 Expedition.	Locally common.	1-8, 14, 15, 19, 21, 23, 31, 33, 42, 62, 63, 64-67, 69, 76
C. melanopterus (Quoy and Gaimard, 1824)*	Schultz, 1943; 2000 Expedition.	Locally common.	1-5, 7, 8, 10, 11, 15, 17, 19, 21, 27, 31, 38, 41, 43, 46, 63-67
Triaenodon obesus (Rüppell, 1835)*	Schultz, 1943; 2000 Expedition.	Locally common.	1, 2, 14, 17, 20-23, 33, 38, 41, 42, 46, 50, 62-68
DASYATIDAE			
Taeniura myeni Müller & Henle, 1841	New record.	Rare, only one seen.	21
MYLIOBATIDAE			
Aetobatis narinari (Euphrasen, 1790)	New record.	Rare, only one seen.	50
Manta birostris (Walbaum, 1792)*	2000 Expedition.	About 10 sighted.	4, 24, 34, 42, 50, 52, 68

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
MORINGUIDAE			
Moringua ferruginea (Bliss, 1883)	2000 Expedition.	Collected with rotenone.	17, 20, 61, 64, 79, 81
M. macrochir Bleeker, 1853	Schultz, 1943.	Collected with rotenone.	11
M. microchir Bleeker, 1853	Schultz, 1943.		
CHLOPSIDAE			
Kaupichthys atronasus Schultz, 1953	New record.	Collected with rotenone.	44
K. diodonatus (Schultz, 1953)	New record.	Collected with rotenone.	20. 44. 61. 64. 79
MURAENIDAE			
Anarchias cantonensis (Schultz, 1943)	Schultz, 1943.		
Anarchias. leucurus (Snyder, 1904)	Schultz, 1943.		
A. seychellensis (Smith, 1962)	New record.	Collected with rotenone.	20, 44, 61, 64, 79,
Echidna leucotaenia Schultz, 1943	Schultz, 1943; Enderbury I. is type locality.		
E. nebulosa (Thünberg, 1789)	Schultz, 1943.	Collected with rotenone.	10, 29
Enchelycore bayeri Schultz, 1953	New record.	Collected with rotenone.	20
E. pardalis (Schlegel, 1846)	Schultz, 1943.		
E. schismatorhynchus (Bleeker, 1853)	Schultz, 1943.	Collected with rotenone.	79
Gymnothorax atolli Pietschmann, 1835	New record.	Collected with rotenone.	20
G. buroensis (Bleeker, 1857)	Schultz, 1943.	Collected with rotenone.	61, 64
G. chilospilus (Bleeker, 1865)	2000 Expedition.		
G. fimbriatus (Bennett, 1831)	Schultz, 1943.		
G. flavimarginatus (Rüppell, 1828)*	Schultz, 1943; 2000 Expedition.	Occasional.	10, 20, 21, 33, 42, 46, 50, 62, 69
G. gracilicaudus (Jenkins, 1903)	Schultz, 1943.		
G. javanicus (Bleeker, 1865)*	Schultz, 1943; 2000 Expedition.	Occasional.	27, 30-32, 42, 50, 72, 80
G. margaritophorus Bleeker, 1864	Schultz, 1943.		
G. melatremus Schultz, 1953	New record.	Collected with rotenone.	34
G. meleagris (Shaw & Nodder, 1795)	2000 Expedition.	Rare, only 3 seen.	2, 8, 20
G. monostigmus (Regan, 1909)	Schultz, 1943.		
G. pictus (Ahl, 1789)	Schultz, 1943.	Locally common.	10, 52, 81
G. pseudothyrsoideus (Bleeker, 1852)	Schultz, 1943.		
G. ruepelliae (McClelland, 1845)	Schultz, 1943.		17
G. thyrsoideus (Richardson, 1844)	Schultz, 1943.		
G. undulatus (Lacepède, 1803)	New record.	Collected with rotenone.	79
G. zonipectus Seale, 1906	Schultz, 1943.	Collected with rotenone.	79
U. concolor Rüppell, 1837	New record.	Collected with rotenone.	64
U. fasciolatus (Regan, 1909)*	New record.	Collected with rotenone.	44, 64, 79
U. marmoratus (Lacepède, 1803)	Schultz, 1943.		
U. micropterus (Bleeker, 1852)	Schultz, 1943.		

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
U. supraforatus (Regan, 1909)	2000 Expedition.		
U. xanthopterus Bleeker, 1859	Schultz, 1943.		
OPHICHTHIDAE			
Callechelys marmoratus (Bleeker, 1853)	Schultz, 1943.		
C. melanotaenia Bleeker, 1864	Schultz, 1943.		
Leiuranus semicinctus (Lay and Bennett, 1839)	Schultz, 1943.		
Muraenichthys. macropterus Bleeker, 1857	Schultz, 1943.		
M. schultzei Bleeker, 1857	Schultz, 1943.		
Myrichthys colubrinus (Boddaert,1781)	Schultz, 1943.		
M. maculosus (Cuvier, 1817)	Schultz, 1943.	Collected with rotenone.	17
CONGRIDAE			
Conger cinereus Rüppell, 1828	2000 Expedition.		
Heteroconger haasi (Klausewitz & Eibl-Eibesfeldt, 1959)	New record.	Several seen on 3 occasions.	24, 30. 52
CHANDIDAE			
Chanos chanos (Forsskål, 1775)	New record.	Occasional.	8, 18, 24, 25, 27, 38, 39, 41-43, 46, 50, 52, 71
CLUPEIDAE			
Spratelloides delicatulus (Bennett, 1832)	Schultz, 1943.		
SYNODONTIDAE			
Saurida gracilis (Quoy & Gaimard, 1824)	2000 Expedition.		
Synodus jaculum Russell and Cressy, 1979	2000 Expedition.		
S. variegatus (Lacepède, 1803)	Schultz, 1943; 2000 Expedition.		
OPHIDIIDAE			
Brotula multbarbata Temminck & Schlegel, 1846	2000 Expedition.	Collected with rotenone.	20, 64
BYTHITIDAE			
Alionematichthys piger (Alcock, 1890)	Schultz, 1943 as *Dinematichthys iluocoeteoides*		
Diancistrus atollorum Schwarzhans, MØller, and Nielsen, 2005	2000 Expedition		
Diancistrus mennei Schwarzhans, MØller, and Nielsen, 2005	2000 Expedition	Collected with rotenone	17, 20, 44
ANTENNARIIDAE			
A. nummifer Cuvier, 1817	2000 Expedition.	Collected with rotenone.	61
ATHERINIDAE			
Atherinomorus lacunosa (Forster, 1801)	New record.	Common at one site in Canton lagoon.	35

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Hypoatherina ovalaua (Herre, 1935)	Schultz, 1943.		
MUGILIDAE			
Neomyxus leuciscus (Günther, 1871)	Schultz, 1943.	Locally common in lagoons.	10, 11, 81
Crenimugil crenilabis (Forsskål, 1775)	Schultz, 1943.	Locally common in lagoons.	11, 20, 54, 74
Liza vaigiensis (Quoy and Gaimard, 1825)	Schultz, 1943.	Locally common in lagoons.	11, 52, 54
BELONIDAE			
Ablennes hians (Valenciennes, 1846)	Schultz, 1943.		
Platybelone platyura (Bennett, 1832)	Schultz, 1943.	Occasional.	
HEMIRAMPHIDAE			
Hyporhamphus acutus (Günther, 1871)*	Schultz, 1943.		7, 8, 31, 34, 38, 80
ANOMALOPIDAE			
Photoblepharon palpebratus (Boddaert, 1781)	New record.	Observed on one night dive.	40
HOLOCENTRIDAE			
Myripristis adusta Bleeker, 1853*	Schultz, 1943; 2000 Expedition.	Common.	1-3, 7, 25, 27, 31-34, 38,-43, 46, 50, 68, 62, 71, 79, 80
M. amaena (Castelnau, 1873)	2000 Expedition.	Occasional.	18, 21, 27, 31-33, 38, 40, 43, 46, 50, 67
M. berndti Jordan and Evermann, 1902*	2000 Expedition.	Common	1-8, 14, 15, 17-23, 25, 27, 31-34, 38-43, 46, 50, 62-69, 71, 76, 79, 80
M. earlei Randall, Allen & Robertson, 2003*	New record.	Moderately common.	38, 39, 42, 43, 50, 62-64, 66-68
M. kuntee Valenciennes, 1831*	New record.	Occasional.	5, 25, 27, 31-34, 39, 40, 42, 46, 50, 63, 66, 67
M. pralinia Cuvier, 1829	New record.	Locally common, but usually seen at night.	6, 20, 31, 40, 46, 79
M. violacea Bleeker, 1851	Schultz, 1943.	Occasional.	27, 39, 40, 42, 50, 71, 72
M. vittata Valenciennes, 1831	New record.	Common below 25 m.	1-3, 6, 7, 14, 15, 18, 19, 21-23, 25, 27, 31-3438-43, 46, 62-67
M. woodsi Greenfield, 1974*	Schultz, 1943 as *M. murdjan*.	Moderately common.	4, 6, 18, 20, 21, 54, 62, 64, 66-68
Neoniphon argenteus (Valenciennes, 1831)	Schultz, 1943.		
N. opercularis (Valenciennes, 1831)	New record.	Occasional.	14, 17, 23, 25, 27, 29, 42, 46, 67, 71, 80
N. sammara (Forsskål, 1775)	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 7, 11, 22, 24, 25, 27, 30, 32, 25, 39, 40, 42, 43, 46, 50, 55, 63, 66-68, 73
Plectrypops lima (Valenciennes, 1831)	New record.	One collected with rotenone.	20
Sargocentron caudimaculatum (Rüppell, 1835)	2000 Expedition.	Common.	1, 2, 5, 7, 8, 15, 17-23, 25, 27, 32-34, 38-42, 62, 65, 67-69
S. diadema (Lacepède, 1801)	New record.		
S. iota Randall, 1998	New record.	Three specimens collected with rotenone.	31, 64
S. microstoma (Günther, 1859)	Schultz, 1943.	Rarely seen, but nocturnal.	40, 67
S. punctatissimum (Cuvier, 1829)	Schultz, 1943.	Collected with rotenone.	20

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
S. spiniferum (Forsskål, 1775)*	Schultz, 1943; 2000 Expedition.	Moderately common.	1-4, 7, 18, 19, 21, 24-27, 31-34, 38-43, 46, 50, 54, 55, 68, 69, 74, 80
S. tiere (Cuvier, 1829)*	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 4-8, 14, 15, 17-23, 25, 27, 31-34, 39-43, 46, 50, 62-65, 68, 69, 71, 76, 79
S. tiereoides (Bleeker, 1853)	2000 Expedition.	One collected with rotenone.	55
S. violaceum (Bleeker, 1853)	Schultz, 1943.		
AULOSTOMIDAE			
Aulostomus chinensis (Linnaeus, 1766)	Schultz, 1943.	Occasional.	1, 2, 24, 39, 50, 68, 71, 76
FISTULARIIDAE			
Fistularia commersoni Rüppell, 1835	Schultz, 1943.	Occasional.	7, 24, 25, 40, 46, 64, 69, 72, 74, 80
SYNGNATHIDAE			
Choeroichthys sculptus (Günther, 1870)	Schultz, 1943.		
Corythoichthys flavofasciatus (Rüppell, 1838)	New record.	Collected with rotenone.	11, 26
Doryrhamphus dactyliophorus (Bleeker, 1853)	New record.	Collected with rotenone.	34, 55
D. excisus Kaup 1856	New record.	Rare, only 2 seen.	26, 64
SCORPAENIDAE			
Dendrochirus biocellatus (Fowler, 1938)	New record.	One collected with rotenone.	44
Pterois antennata (Bloch, 1787)	2000 Expedition.	Rare	20, 42, 68
P. radiata Cuvier, 1829	Schultz, 1943.	Rare.	7, 20, 40, 52, 69, 79
Scorpaenodes guamensis (Quoy and Gaimard, 1824)	Schultz, 1943; 2000 Expedition.	Two collected with rotenone.	61, 79
S. hirsutus (Smith, 1957)	2000 Expedition.	Several collected with rotenone.	17, 20, 44, 61, 64
S. varipinnis Smith, 1957	New record.	Collected with rotenone.	38, 39, 61
Sebastapistes cyanostigma (Bleeker, 1856)	2000 Expedition.	Common.	5, 23, 25, 27, 41, 42, 50, 62-65, 69, 71
Taenianotus triacanthus Lacepède, 1802	Schultz, 1943; 2000 Expedition.		
CARACANTHIDAE			
Caracanthus maculatus (Gray, 1831)	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 5, 8, 14, 15, 21-23, 25, 27, 31, 32, 38, 41-43, 50, 62-69, 71, 76, 80
C. unipinna (Gray, 1831)	New record.	One collected with rotenone.	79
SERRANIDAE			
Aethaloperca rogaa (Forsskål, 1775)	New record.	Rare.	6, 34, 46
Anyperodon leucogrammicus (Valenciennes, 1828)*	Schultz, 1943.	Common.	1, 2, 5, 7, 14, 15, 18-25, 27, 28, 30-33, 38-43, 46, 50, 63-69, 71, 80
Aporops bilinearis Schultz, 1943	Schultz, 1943; 2000 Expedition.; Orona is type locality	Collected with rotenone.	17

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Belonoperca chabanaudi Fowler & Bean, 1930	New record.	Rare, only 3 seen.	25-46
Cephalopholis argus Bloch and Schneider, 1801*	Schultz, 1943; 2000 Expedition.	Common.	1-8, 14, 15, 18-25, 27, 31-34, 38-43, 46, 50, 52, 62-69, 71, 72, 74, 76, 77, 80, 81
C. leopardus (Lacepède, 1802)	Schultz, 1943; 2000 Expedition.	Common.	1-8, 11, 14, 15, 17-23, 25, 27, 31-34, 38-43, 46, 50, 52, 61-64, 66-69, 72, 79, 80
C. miniata (Forsskål, 1775)*	2000 Expedition.	Moderately common.	1-3, 5-8, 14, 15, 17-25, 27, 31-34, 38-43, 46, 50, 62-64, 66-69, 76, 80
C. sexmaculata (Rüppell, 1828)	New record.	Occasional.	6, 7, 42, 62, 67
C. sonnerati (Valenciennes, 1828)*	New record.	Occasional.	8, 21, 25, 34, 43, 62, 68
C. spiloparaea (Valenciennes, 1828)	New record.	Moderately common below 20 m.	4, 6, 18, 21, 23, 27, 32, 34, 38, 39, 41-43, 46, 52, 61, 67, 68, 71, 80
C. urodeta (Schneider, 1801)	Schultz, 1943; 2000 Expedition.	Common.	1-8, 11, 14, 15, 17-19, 21- 25, 27, 31, 33, 34, 38-43, 46, 50, 52, 61-69, 71, 76, 79, 80
Epinephelus fasciatus (Forsskål, 1775)*	2000 Expedition.	Occasional.	1-5, 7, 18, 21, 50, 68, 71
E. fuscoguttatus (Forsskål, 1775)*	New record.	Moderately common.	1, 2, 6, 7, 24-27, 30-34, 38, 39, 40, 42, 50, 52, 54, 68-69, 71, 72, 73, 76, 77, 80
E. hexagonatus (Bloch & Schneider, 1801)*	Schultz, 1943.	Moderately common.	1, 2, 4, 7, 14, 15, 17, 18, 20, 21, 27, 31, 34, 38, 43, 46, 64, 71, 76
E. howlandi (Günther, 1873)	New record.	Rare.	76, 79, 80
E. lanceolatus (Bloch, 1790)	New record.	Rare, only one seen.	One filmed at President Taylor shipwreck by R. Barrel.
E. macrospilos (Bleeker, 1855)	New record.	Occasional.	21, 39, 42, 43, 46, 52
E. melanostigma Schultz, 1953	2000 Expedition.	Occasional.	5, 10, 40, 41, 65, 69, 71
E. merra Bloch, 1793	Schultz, 1943.	Common in lagoons.	10, 11, 24, 26, 28-30, 35-37, 52, 72,-74, 77, 81
E. polyphekadion (Bleeker, 1849)*	New record.	Moderately common.	1, 2, 5, 31, 38-43, 46, 50, 52, 54, 55, 68, 69, 76, 80
E. socialis (Günther, 1873)*	Schultz, 1943.	Rare.	54
E. spilotoceps Schultz, 1953*	New record.	Occasional.	1-3, 5, 7, 8, 42, 43, 50, 69
E. tauvina s (Forsskål, 1775)	New record.	Rare.	21, 25, 31, 32
Gracila albomarginata (Fowler & Bean, 1930)*	New record.	Common.	1-4, 6, 7, 14, 15, 18, 19, 22, 23, 25, 27, 31-34, 38-43, 46, 50, 62-69, 71, 76, 80
Liopropoma mitratum Lubbock & Randall, 1978	New record.	Collected with rotenone.	31
L. susumi (Jordan & Seale, 1906)	New record.	Collected with rotenone.	44
Luzonichthys whitleyi (Smith, 1955)	Schultz, 1943.		6, 7, 14, 15, 18, 38, 39, 41, 46, 62, 65, 67-69
Plectranthias nanus Randall, 1980*	2000 Expedition.	Collected with rotenone.	27, 33, 34, 39, 44
Plectropomus areolatus Rüppell, 1830	Randall & Heemstra, 1991	Moderately common.	24, 25, 31-33, 38-43, 50, 54, 55, 68, 69, 71, 76, 80
Pseudanthias bartlettorum (Randall & Lubbock, 1981)*	2000 Expedition.	Abundant.	1-3, 5-8, 14, 15, 18-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 61-69, 71. 76, 80
P. cooperi (Regan, 1902)*	New record.	Rare, but moderately common at site 18.	18, 34, 38
P. dispar (Herre, 1955)	New record.	Occasional.	1, 21, 23, 25, 27, 31, 32, 34, 38, 39, 41-43, 46, 62-64
P. lori (Lubbock & Randall, 1976)	New record.	Rare, only one seen in 55 m.	68

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
P. olivaceus Randall & McCosker, 1982*	New record.	Occasional in 4-10 m on windward reefs.	3-5, 7, 8, 15, 19, 22, 27, 33, 41, 42, 46, 65, 66
P. pascalus (Jordan & Tanaka, 1927)*	New record.	Moderately common, usually below 20 m.	3, 4, 6, 14, 15, 19, 21-23, 25, 27, 32-34, 39, 41, 42, 46, 63, 65-69, 71, 76, 80
P. smithvanizi (Randall & Lubbock, 1981)*	New record.	Abundant below 30 m.	25, 32-34, 38, 39, 41, 46, 62-64, 71, 76, 80
Pseudogramma polyacanthum (Bleeker, 1856)	2000 Expedition.	Collected with rotenone.	
Suttonia lineata Gosline, 1960	2000 Expedition.		
Variola louti (Forsskål, 1775)	2000 Expedition	Occasional.	4, 18, 22, 24, 27, 32, 38, 46
PSEUDOCHROMIDAE			
Pseudoplesiops revellei Schultz, 1953	2000 Expedition.		
PLESIOPIDAE			
Plesiops corallicola Bleeker, 1853	Schultz, 1943.		
CIRRHITIDAE			
Cirrhitichthys oxycephalus (Bleeker, 1855)	2000 Expedition.	Moderately common.	1. 2. 7. 15, 17, 18, 20-24, 27, 31, 32, 34, 38, 39, 41-43, 50, 61-69, 71, 79, 80
Cirrhitops hubbardi (Schultz, 1943)*	Schultz, 1943; 2000 Expedition.; Enderbury I. is type locality.	Rare.	3. 4, 25, 41, 64, 65
Cirrhitus pinnulatus (Schneider, 1801)	Schultz, 1943.	Occasional.	3, 4, 21, 31, 43, 62, 76
Neocirrhites armatus Castelnau, 1873	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 14, 15, 21, 23, 25, 27, 31-34, 38, 41-43, 50, 62-69, 71, 76, 80
Paracirrhites arcatus (Cuvier, 1829)*	2000 Expedition.	Common.	1-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 50, 62-69, 71, 76, 79, 80
P. forsteri (Schneider, 1801)*	2000 Expedition.	Common.	1-3, 5-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 61. 63-69, 71, 76, 79, 80
P. hemistictus (Güntehr, 1874)*	Schultz, 1943; 2000 Expedition.	Moderately common.	1-8, 14, 15, 17-19, 21-23, 27, 31-34, 39, 41, 43, 46, 50, 62-69, 71
P. nisus Randall, 1963*	2000 Expedition.	Occasional.	1-3, 5, 8, 15, 17, 22, 25, 38, 65-67, 69, 76
P. xanthus Randall, 1963*	2000 Expedition.	Moderately common.	1-5, 8, 14, 15, 18-23, 25, 27, 31-33. 39, 41-43, 50, 62-69, 71, 76
KUHLIIDAE			
Kuhlia petiti Schultz, 1943*	Schultz, 1943; Orona I. is type locality.	Locally common at one site.	54
K. mugil (Forster, 1801)	Schultz, 1943 as *K. sandvicensis.*	Rare, one seen.	54
APOGONIDAE			
Apogon angustatus (Smith and Radcliffe, 1911)	2000 Expedition.	Occasional.	18, 31, 34, 40, 61, 79
A. crassiceps Garman, 1903	New record.	Collected with rotenone.	17, 20, 40, 44, 61, 79
A. doryssa (Jordan & Seale, 1906)	Schultz, 1943.	One collected with rotenone.	79
A. exostigma Jordan and Starks, 1906	2000 Expedition.	Occasional.	26, 55, 72

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
A. fraenatus Valenciennes, 1832	Schultz, 1943.		
A. kallopterus Bleeker, 1856	New record.	Occasional.	26, 40, 72, 79
A. novemfasciatus Cuvier, 1828	Schultz, 1943.		
A. savayensis Günther, 1871	Schultz, 1943, as *A. bandanensis*; 2000 Expedition. as *A. fuscus*.	Occasional. More common at night.	40, 55, 61
A. semiornatus Peters, 1876	New record.	One collected with rotenone.	38
A. taeniopterus (Bennett, 1835)	New record.	Moderately common at night.	40
Cercamia eremia (Allen, 1987)	New record.	Collected with rotenone.	39, 55
Cheilodipterus macrodon (Lacepède, 1802)	New record.	Rare.	
C. quinquelineatus Cuvier, 1828	Schultz, 1943; 2000 Expedition.	Moderately common in lagoons.	26, 36, 37, 52, 55, 67, 72-74, 77
Fowleria punctulata (Rüppell, 1838)	Schultz, 1943 as *F. isostigma*.	Collected with rotenone.	55
Gymnapogon urospilotus Lachner, 1953	2000 Expedition.		
Pseudamiops gracilicauda (Lachner, 1953)	New record.	Collected with rotenone.	20
MALACANTHIDAE			
Malacanthus brevirostris Guichenot, 1848	2000 Expedition.	Occasional.	15, 18, 20, 21, 23, 38, 52, 62, 67
M. latovittatus (Lacepède, 1801)	New record.	Rare.	8, 62
ECHENEIDAE			
Echeneis naucrates Linnaeus, 1758	New record.	Rare, only one seen.	66
CARANGIDAE			
Carangoides ferdau (Forsskål, 1775)*	New record.	Occasional.	4, 7, 31, 32, 39, 46, 52, 64, 67
C. orthogrammus (Jordan & Gilbert, 1881)*	New record.	Occasional.	3, 4, 7, 15, 17-20, 23, 24, 31, 38, 42, 54, 63
Caranx ignobilis (Forsskål, 1775)*	New record..	Occasional.	4, 6, 21-24, 27, 34, 42, 43, 46, 50, 52, 54, 63, 65, 66
C. lugubris Poey, 1861*	2000 Expedition.	Common to locally abundant.	1-4, 6-8, 14, 15, 17, 19-25, 27, 31-34, 38-43, 46, 5062-68, 80
C. melampygus Cuvier, 1833*	Schultz, 1943.	Common to locally abundant.	1-8, 10, 11, 14, 15, 17-28, 30-35, 38-43, 46, 50, 52, 54, 55, 62-69, 71, 72, 74, 76, 77, 80
C. sexfasciatus Quoy and Gaimard, 1825*	2000 Expedition.	Locally common.	3. 5. 7. 8, 14, 19, 21-24, 32-34, 50, 54
Elegatis bipinnulatus (Quoy and Gaimard, 1825)	Schultz, 1943.	Locally common.	3, 8, 17, 24, 32, 33, 63, 66, 68,76, 80
Gnathanodon speciosus (Forsskål, 1775)	New record.	rare	One seen in Kanton passage by C. Holloway
Scomberoides lysan (Forsskål, 1775)*	New record.	Occasional.	1, 2, 5, 6, 27, 31-34, 42, 54, 80
Selar crumenophthalmus (Bloch, 1793)	New record.	Rarely seen, but locally common.	18, 20, 62
Trachinotus baillonii (Lacepède, 1802)*	Schultz, 1943.	Common at 2 sites.	20, 54

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
LUTJANIDAE			
Aphareus furca (Lacepède, 1801)*	New record.	Common.	1-3, 6, 7, 14, 15, 18-25, 27, 31-34, 38-43, 46, 50, 55, 62-69, 71, 76, 80
Aprion virescens Valenciennes, 1830	New record.	Moderately common, but always in low numbers.	1, 2, 8, 14, 17, 18, 21-25, 32-34, 38, 43, 62, 63, 65, 66, 68-79
Lutjanus bohar (Forsskål, 1775)*	Schultz, 1943; 2000 Expedition.	Common.	1-8, 11, 14, 15, 17-25, 27, 28, 30-34, 38-43, 46, 50, 52, 54, 55, 62-69, 71, 72, 74, 76, 77, 80
L. fulvus (Schneider, 1801)*	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 4, 6-8, 10, 11, 15, 17-23, 35, 46, 52, 54, 71, 73, 76
L. gibbus (Forsskål, 1775)	Schultz, 1943.	Abundant.	1, 2, 6-8, 21-25, 27, 28, 30-43, 46, 50, 52, 54, 66-69, 71, 72-74, 76, 77, 80
L. kasmira (Forsskål, 1775)	2000 Expedition.	Moderately common.	14, 15, 17, 18, 19, 20-25, 35, 38, 40, 46, 52, 62, 64-67
L. monostigma (Cuvier, 1828)*	Schultz, 1943.	Moderately common.	1-8, 11, 14, 15, 17-25, 27, 28, 30-35, 38-43, 46, 50, 52, 54, 55, 62-69, 71, 72, 74, 76, 77, 80
Macolor macularis Fowler, 1931	2000 Expedition.	Occasional.	4, 6, 7
M. niger (Forsskål, 1775)	New record.	Occasional.	7, 20, 21, 23, 24, 40, 64-66, 68, 80
Paracaesio xanthurus (Bleeker, 1869)	New record.	Seen below 80 m with remote video.	
CAESIONIDAE			
Caesio teres Seale, 1906*	2000 Expedition.	Common.	1, 2, 5, 7, 8, 18-20, 24, 27, 31-34, 40, 41, 43, 46, 50, 54, 62, 64, 66, 67, 71
Pterocaesio lativittatus Carpenter, 1987*	New record.	Occasional, but locally common.	1, 2, 6, 14, 41, 46, 57, 66
P. tile (Cuvier, 1830)*	New record.	Locally abundant.	1-4, 6, 7, 14, 21-25, 28, 32-34, 39-42, 46, 65-67
GERREIDAE			
Gerres argyreus (Forster, 1801)	New record.	About 200 seen at one site.	52
LETHRINIDAE			
Gnathodentex aurolineatus (Lacepède, 1802)*	New record.	Moderately common.	7, 21, 23, 25, 27, 31, 33, 34, 39, 40, 42, 43, 46, 63-67
Lethrinus erythracanthus Valenciennes, 1830	New record.	Occasional.	5, 6, 17, 20, 21, 33, 38, 50, 63-69, 71, 76, 80
L. obsoletus (Forsskål, 1775)	Schultz, 1943.	Occasional.	5, 7, 11, 24, 30, 38, 39, 42, 43, 46, 55, 62, 74
L. olivaceus Valenciennes, 1830*	New record.	Moderately common.	1, 2, 5, 7, 14, 15, 17-24, 27, 31-33, 38, 42, 43, 50, 54, 63-69, 71, 72, 74, 76, 80
L. xanthochilus Klunzinger, 1870	New record.	Moderately common.	3, 6-8, 15, 24, 27, 31-34, 40, 43, 50, 52, 63, 64, 68, 76, 80
Monotaxis grandoculis (Forsskål, 1775)	New record.	Common.	1-2, 4-6, 7, 8, 15, 17-27, 30-35, 38-43, 46, 50, 54, 55, 62-64, 66-69, 71, 72-74, 76, 77, 80
MULLIDAE			
Mulloidichthys flavolineatus (Lacepède, 1802)	Schultz, 1943.	Occasional.	11, 15, 18, 23, 35, 52, 67
M. mimicus Randall & Guézé, 1980*	New record.	Occasional.	20, 23, 52, 66, 67
M. vanicolensis (Valenciennes, 1831)*	Schultz, 1943.	Occasional.	1, 2, 5, 17, 18, 20, 23, 27, 42, 64-67

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Parupeneus barberinus (Lacepède, 1801)	2000 Expedition.	Occasional.	11, 15, 24-26, 30, 31, 34, 38, 41, 42, 54, 68, 71, 72, 74, 77
P. cyclostomus (Lacepède, 1801)	New record.	Occasional.	15, 21-24, 39, 54
P. multifasciatus (Quoy & Gaimard, 1825)	New record.	Common.	1-8, 14, 15, 17-25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54. 55, 62-69, 71, 76, 80
P. rubrioculatus Randall & Myers, 2002*	Schultz, 1943.	Common.	1-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 62-66, 68-69, 71, 76, 80
Upeneus arge (Jordan & Evermann, 1902)	Schultz, 1943 as *U. taeniopterus*.		
PEMPHERIDAE			
Pempheris otaitensis Lesson, 1830 *	Schultz, 1943 as *P.oualensis.*	Moderately common.	4, 5, 14, 18-23, 27, 31, 40-43, 46, 62-65, 67-69
KYPHOSIDAE			
K. cinerascens (Forsskål, 1775)	New record.		1, 2, 4, 7, 8, 14, 15, 18, 19, 21, 23, 24, 27, 28, 31-34, 38, 39, 42, 43, 46, 50, 54, 62-64, 66-69, 71, 80
K. vaigiensis (Quoy & Gaimard, 1825)*	New record.		20, 21, 27, 31, 42, 50, 54, 62, 63,
CHAETODONTIDAE			
Chaetodon auriga Forsskål, 1775*	Schultz, 1943; 2000 Expedition.	Common.	1-5, 7, 8, 10, 11, 15, 17-43, 46, 50, 52, 54. 55, 63-69, 71, 72-74, 76, 77, 80
C. bennetti Cuvier, 1831	Schultz, 1943; 2000 Expedition.	Common.	3, 7, 14, 15, 19, 22-25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54, 62, 65-68, 72, 74, 76, 77, 80
C. citrinellus Cuvier, 1831	Schultz, 1943.	Occasional.	21, 23, 32, 34, 38, 54
C. declivus Randall, 1975	New record.	Seen below 80 m with remote video.	
C. ephippium Cuvier, 1831	Schultz, 1943; 2000 Expedition.	Common.	1-3, 5, 7, 8, 11, 14, 15, 17-28, 30-35, 37, 38, 39, 40-43, 50, 52, 54. 55, 64, 67-69, 71, 72-74, 77, 80
C. kleinii Bloch, 1790	2000 Expedition.	Moderately common.	15, 18, 19, 21-25, 30, 34, 38, 50, 62, 63, 80
C. lineolatus Cuvier, 1831	New record.	Rare, less than 10.	31, 32, 39, 74
C. lunula Lacepède, 1803*	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 5, 7, 8, 11, 14, 15, 17, 18, 20-25, 27, 30-34, 38, 39, 41-43, 46, 50, 54. 55, 62-69, 71, 72, 74, 76, 77, 80
C. lunulatus Quoy and Gaimard, 1824	2000 Expedition. as *C. trifasciatus*	Moderately common.	3, 7, 24, 25, 27, 30, 32-34, 38-43, 46, 55, 69, 71, 73, 74, 76, 77
C. meyeri Schneider, 1801	Schultz, 1943; 2000 Expedition.	Common.	1, 2, 6, 7, 14, 15, 18-25, 27, 30-34, 38-43, 46, 50, 62-69, 71, 76, 80
C. ornatissimus Cuvier, 1831*	Schultz, 1943; 2000 Expedition.	Common.	1-8, 14, 15, 17-23, 25, 27, 30-34, 38-43, 46, 50, 62-69, 76, 80
C. pelewensis Kner, 1867	2000 Expedition.	Occasional.	3, 4, 6, 18, 19, 25, 34, 41, 64, 67, 69, 71, 76, 80
C. punctatofasciatus Cuvier, 1831	Schultz, 1943; 2000 Expedition.		
C. quadrimaculatus Gray, 1831*	Schultz, 1943; 2000 Expedition.	Occasional.	1-5, 7, 8, 14, 15, 17-24, 32, 34, 38, 63-69, 71
C. reticulatus Cuvier, 1831*	2000 Expedition.	Occasional.	1-8, 15, 17-19, 22, 23, 65, 67-69, 71, 76, 80
C. semion Bleeker, 1855	2000 Expedition.	Rare, less than 10.	3, 11, 68, 69, 74, 77

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
C. trifascialis Quoy and Gaimard, 1824	Schultz, 1943; 2000 Expedition.	Generally scarce, but common at Kanton lagoon.	1, 2, 6, 7, 15, 23-27, 30-35, 38-43, 46, 50, 52, 54, 55, 73
C. ulietensis Cuvier, 1831*	2000 Expedition.	Common.	1-8, 11, 15, 17-25, 27, 30-34, 38-40, 42, 43, 46, 52, 54, 62-69, 71, 72-74, 77, 80
C. unimaculatus Bloch, 1787*	2000 Expedition.	Occasional.	3, 15, 19, 21-23, 39, 41, 65-67
C. vagabundus Linneaeus, 1758	2000 Expedition.	Occasional.	1, 2, 7, 24, 27, 32, 34, 38, 43, 50, 54, 68
Forcipiger flavissimus Jordan and McGregor, 1898	2000 Expedition.	Common.	1-8, 14, 15, 17-25, 27, 30-33, 38-43, 46, 50, 54. 55, 62-69, 71, 80
F. longirostris (Broussonet, 1782)*	2000 Expedition.	Occasional.	1, 2, 8, 15, 66
Hemitaurichthys thompsoni Fowler, 1923*	New record.	Locally common on steep dropoffs.	4, 6, 8, 14, 18, 19, 21-23, 32, 62, 68, 76
Heniochus acuminatus (Linnaeus, 1758)*	2000 Expedition.	Moderately common.	24, 25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54, 55
H. chrysostomus Cuvier, 1831*	2000 Expedition.	Moderately common.	23, 25, 27, 31-34, 38, 41-43, 46, 50, 54, 62, 64, 67-69, 71, 76, 80
H. monoceros Cuvier, 1831*	2000 Expedition.	Occasional.	1, 2, 5, 7, 15, 21, 25, 32, 34, 41-43, 67-69, 71, 80
H. varius (Cuvier, 1829)*	2000 Expedition.	Occasional.	1-3, 7, 23, 25, 31-34, 38, 39, 41-43, 50, 62, 68, 71, 80
POMACANTHIDAE			
Apolemichthys griffisi Carlson & Taylor, 1981)*	2000 Expedition.	Common.	1-8, 14, 15, 17-23, 25, 27, 32, 34, 38, 41, 43, 46, 62-69, 71, 76, 80
A. xanthopunctatus Burgess, 1974*	New record.	Occasional.	8, 15, 24, 27, 33, 34, 39, 42, 65
Centropyge bicolor (Bloch, 1798)	2000 Expedition.	Rare, only a few seen on one dive.	24
C. bispinosa (Günther, 1860)	2000 Expedition.		
C. flavicauda Fraser-Brunner, 1933	Schultz, 1943; 2000 Expedition.	Seen at only 2 sites, but locally common.	50, 62
C. flavissima (Cuvier, 1831)	2000 Expedition.	Abundant	1-5, 7, 8, 14, 15, 17-27, 30-34, 38, 39, 41-43, 46, 50, 54, 63-69, 71, 73, 76, 80
C. heraldi Woods & Schultz, 1953	New record.	Occasional, usually below 30 m.	6, 18, 34, 62, 71, 80
C. loricula (Günther, 1874)*	2000 Expedition.	Abundant.	1-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 61-69, 71, 76, 80
C. multicolour Randall & Wass, 1974	New record.	Rare, only 3 seen in 55 m.	68
C. nigriocella Schultz, 1953	2000 Expedition.		
Paracentropyge multifasciatus (Smith & Radcliffe, 1911)*	2000 Expedition.	Moderately common, usually below 20 m.	1, 2, 6, 7, 21, 23, 25, 27, 31, 38, 43, 46, 63, 65, 66-68, 71, 76, 80
Pomacanthus imperator (Bloch, 1787)*	2000 Expedition.	Occasional.	14, 15, 18-23, 27, 30-34, 38, 39, 41, 42, 50, 55, 62-67
Pygoplites diacanthus (Boddaert, 1772)*	2000 Expedition.	Rare.	6, 24, 25, 33, 43, 72
Abudefduf notatus (Day, 1869)*	New record.	Occasional.	10, 18, 20, 38, 52
A. septemfasciatus (Cuvier, 1830)*	Schultz, 1943.	Occasional in shallow surge zone.	10, 52, 54
A. sexfasciatus Lacepède, 1802	Schultz, 1943.		

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
A. sordidus (Forsskäl, 1775)*	Schultz, 1943.	Occasional in shallow surge zone.	21, 23, 52, 54, 68
Abudefduf vaigiensis (Quoy & Gaimard, 1825)*	New record.	Occasional on windward slopes.	3, 19, 21, 66, 67
Amphiprion chrysopterus Cuvier, 1830*	2000 Expedition.	Common.	1. 2, 5, 6, 14, 21, 23, 25, 27, 31-34, 38-40, 42, 43, 46, 62, 64-69, 76
A. perideraion Bleeker, 1855*	2000 Expedition.	Common only at Nikumaroro.	1, 6, 8
Chromis acares Randall & Swerdloff, 1973	2000 Expedition.	Abundant.	1-8, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 62-69, 71, 76, 79, 80
C. agilis Smith, 1960	New record.	Occasional.	1, 2, 4, 6, 7, 15, 17-23, 27, 39, 44, 62, 67, 69
C. alpha Randall, 1988*	New record.	Moderately common below 30 m.	4, 6, 7, 14, 18, 19, 21-23, 25, 27, 32-34, 41, 43, 63, 66, 76, 80
C. atripes Fowler & Bean, 1928*	New record.	Rare, about 5 seen.	67
C. caudalis Randall, 1987*	New record.	Abundant below 15 m.	1, 2, 6, 14, 21, 23, 25, 27, 31-34, 38-40, 42, 43, 46, 62-69, 71, 76, 80
C. lepidolepis Bleeker, 1877	New record.	Rare, only a few small groups seen.	18, 24
C. margaritifer Fowler, 1946	2000 Expedition.	Common above 15 m.	3-8, 15, 17-23, 25, 27, 31-34, 38-43, 50, 52, 54, 61-69, 71, 76, 79, 80
C. ternatensis (Bleeker, 1856)	New record.	Rare, only a few small groups seen.	24
C. vanderbilti (Fowler, 1941)	2000 Expedition.	Common.	3-8, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 62-69, 71, 76, 80
C. viridis (Cuvier, 1830)	Schultz, 1943.	Common in Kanton lagoon.	11, 24, 26, 29, 30, 35, 54, 55, 72-74, 77
C. weberi Fowler & Bean, 1928*	New record.	Rare, only one seen.	38, 54
C. xanthura (Bleeker, 1854)*	New record.	Common.	4-8, 14, 15, 17-25, 27, 31-34, 38-43, 46, 50, 54, 62-69, 71, 80
Chrysiptera albata Allen & Bailey, 2002*	New record.	Common at one site in 42-55 m.	85
C. brownriggii (Bennett, 1828)	Schultz, 1943; 2000 Expedition., as *C. leucopoma*.		1, 2, 4, 10, 14, 15, 17, 18, 21, , 27, 31-34, 38, 41, 43, 54, 62-64, 67, 68, 71, 76, 80
C. glauca (Cuvier, 1830)	Schultz, 1943.	Common in tide pools and shallow passages.	10, 11, 72, 81
Dascyllus aruanus (Linnaeus, 1758)*	Schultz, 1943.	Common around lagoon corals.	11, 24, 26, 30, 35-37, 52, 54, 55, 72-74, 77
D. auripinnis Randall & Randall, 2001*	Randall & Randall, 2001	Common.	1, 2, 4-8, 15, 17-25, 27, 31-34, 38-43, 46, 62-68, 71
Lepidozygus tapeinosoma (Bleeker, 1856)	Schultz, 1943; 2000 Expedition.	Abundant.	1-5, 8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 62-69, 71, 76, 80
Plectroglyphidodon dickii (Liénard, 1839)	Schultz, 1943; 2000 Expedition.	Common.	1-5, 7, 8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 62-69, 71, 80
P. imparipennis (Vaillant & Sauvage, 1875)	Schultz, 1943.	Moderately common in shallow surge zone.	1, 2, 4, 14, 15, 18, 21, 25, 27, 31, 32, 38, 41, 43, 62, 64, 67, 71, 76, 80

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
P. johnstonianus Fowler & Ball, 1924	2000 Expedition.	Common.	1-8, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 62-69, 71, 76, 80
P. leucozonus (Bleeker, 1859)	Schultz, 1943.	Occasional in shallow surge zone.	1, 2, 14, 18, 27, 31-34, 38, 41, 43, 52, 54, 63, 64, 80
P. phoenixensis (Schultz, 1943)	Schultz, 1943; Enderbury I. is type locality	Moderately common in shallow surge zone.	3, 4, 15, 17, 18, 21, 23, 27, 31, 41, 43, 54, 62-64, 66, 67, 69, 76, 80
Pomacentrus coelestis Jordan & Starks, 1901	New record.	Moderately common.	4, 5, 18, 19, 21, 23, 27, 41, 50, 52, 54, 62, 64, 67, 68, 71, 76
P. pavo (Bloch, 1878)*	Schultz, 1943; 2000 Expedition.	Common in lagoons.	10, 26, 28-31, 34, 36-38, 52, 54, 55, 63, 72-74, 77, 80
Stegastes albifasciatus (Schlegel and Müller, 1839)*	Schultz, 1943.	Occasional.	10, 11, 24, 26, 30, 52, 54, 67, 72
S. aureus (Fowler, 1927)*	Schultz, 1943; 2000 Expedition.	Moderately common just below surge zone.	1-5, 7, 8, 14, 15, 17-23, 25, 27, 31-34, 38, 41-43, 46, 50, 62-64, 66-69, 71, 76, 80
S. fasciolatus (Ogilby, 1889)	New record.	Moderately common just below surge zone.	1, 2, 4, 7, 8, 14, 15, 17, 18, 20-23, 25, 27, 31-34, 38, 41, 43, 54, 62-65, 67-69, 71, 76, 80
S. nigricans (Lacepède, 1802)*	Schultz, 1943.	Moderately common in lagoons.	11, 24, 26, 30, 37, 54, 55, 72-74, 77
LABRIDAE			
Anampses caeruleopunctatus Rüppell, 1828	Schultz, 1943.	Occasional.	1, 2, 5, 8, 15, 34, 38, 39, 41, 43, 62, 64, 67, 68, 71, 76
A. melanurus Bleeker, 1857	New record.	Rare, only a few seen.	18, 38, 46, 63, 66
A. meleagrides Valenciennes, 1839*	New record.	Occasional.	21-23, 25, 34, 38, 39, 47, 65, 67, 71, 80
A. twistii Bleeker, 1857	New record.	Moderately common.	1-3, 5, 6, 8, 14, 18, 19, 21-23, 25, 27, 32, 38, 41, 42, 46, 50, 64-69, 71, 76, 80
Bodianus anthioides (Bennett, 1831)*	New record.	Rare, only one seen.	80
B. axillaris (Bennett, 1831)*	2000 Expedition.	Occasional.	7, 18, 22-25, 33, 34, 42, 46, 66-68
B. diana (Lacepède, 1802)*	New record.	Occasional.	1, 2, 6, 7, 25, 27, 31-34, 38, 41, 42, 46, 50, 62-65
B. loxozonus (Snyder, 1908)*	New record.	Rare.	8, 14, 15, 18, 20, 41, 68
B. prognathus Lobel, 1981*	New record.	Generally rare, but several seen at Birnie and Enderbury.	64-68, 76
Cheilinus oxycephalus Bleeker, 1853*	New record.	Occasional.	19, 33, 39, 46, 65, 68, 71, 80
C. undulatus Rüppell, 1835*	Schultz, 1943.	Common.	1-3, 5, 7, 8, 14, 15, 17-25, 27, 30-34, 38-43, 46, 50, 52, 54, 55, 63-69, 71, 72-74, 76, 77, 80
Cirrhilabrus exquistius Smith, 1957	New record.	Occasional, but locally common.	4, 5, 23, 24, 33, 38, 50, 52, 54, 62, 71, 76
Coris aygula Lacepède, 1801*	Schultz, 1943; 2000 Expedition.	Occasional.	4, 18-25, 27, 33, 34, 50, 54, 62, 67-69, 71, 80
Coris centralis Randall, 1999*	New record.	Occasional.	18, 21, 23-25, 27, 31-34, 38, 39, 41-43, 46, 66-68, 71
C. gaimardi (Quoy & Gaimard, 1824)	New record.	Moderately common.	1-7, 14, 15, 17-25, 27, 31-34, 38, 41-43, 46, 50, 54, 62-69, 71, 76, 80
Cymolutes praetextatus (Quoy & Gaimard, 1834)	Schultz, 1943.	Rare, only seen at one site by S. Bailey	52

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Epibulus insidiator (Pallas, 1770)	Schultz, 1943.	Moderately common.	24, 25, 30-34, 38, 39, 41-43, 46, 50, 54, 55, 62, 68, 69, 71, 72-74, 76, 77, 80
Gomphosus varius Lacepède, 1801*	Schultz, 1943.	Common.	1-8, 14, 15, 17-25, 27, 30-34, 38, 39, 41-43, 46, 50, 54, 55, 62-69, 71, 72, 74, 76, 80
Halichoeres chrysus Randall, 1981	New record.	Rare.	24, 27, 42
H. hortulanus (Lacepède, 1802)	Schultz, 1943; 2000 Expedition.	Common.	1-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 52, 54, 62-69, 71, 76, 80
H. margaritaceus (Valenciennes, 1839)	Schultz, 1943.	Occasional.	15, 21, 67
H. melasmopomus Randall, 1980*	2000 Expedition.	Moderately common.	3, 4, 6, 14, 15, 19, 21-23, 25, 27, 32-34, 38, 39, 41-43, 46, 62-69, 71, 76, 80
H. ornatissimus (Garrett, 1863)	2000 Expedition.	Common.	1-8, 14, 15, 17-19, 21-25, 27, 31-34, 38, 39, 41-43, 46, 50, 52, 54, 62-69, 71, 76, 80
H. pallidus Kuiter & Randall, 1994*	New record.	Rare, about 8 seen below 40 m.	38, 46
H. trimaculatus (Quoy & Gaimard, 1834)	Schultz, 1943.	Occasional, mainly in lagoons.	11, 18, 21, 23, 24, 26, 29, 30, 36, 37, 52, 54, 55, 67, 68, 72-74, 77
Hemigymnus fasciatus Bloch, 1792	2000 Expedition.	Moderately common.	1-7, 14, 15, 17-19, 21-25, 27, 30-34, 39, 42, 43, 46, 62, 64-69, 71, 76, 80
H. melapterus (Bloch, 1791)	New record.	Occasional.	32. 50, 52, 72-74, 76, 77
Hologymnosus doliatus (Lacepède, 1801)	New record.	Rare.	27, 50
Labroides bicolor Fowler & Bean, 1928	New record.	Moderately common.	4, 6, 14, 18, 20-25, 30-34, 38, 39, 43, 46, 50, 62, 65-69, 71, 72, 76, 77, 79, 80
L. dimidiatus (Valenciennes, 1839)*	Schultz, 1943; 2000 Expedition.	Moderately common.	3-8, 14, 15, 17, 18, 20-25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54, 55, 62-69, 71, 72, 76, 80
L. rubrolabiatus Randall, 1958	2000 Expedition.	Common.	1-8, 14, 15, 17-25, 27, 31-34, 39, 41-43, 46, 50, 54, 62-69, 71, 76, 80
Labropsis polynesica Randall, 1981	New record..	Rare, one male seen.	64
L. xanthonota Randall, 1981	New record.	Moderately common.	1-3, 5, 14, 18, 21-25, 27, 32-34, 38, 39, 41-43, 46, 65-69, 71, 76, 80
Macropharyngodon meleagris (Valenciennes, 1839)	Schultz, 1943.	Moderately common.	1, 2, 4, 14, 15, 19, 21-25, 31, 34, 38, 41-43, 54, 62, 63, 65, 67-69, 71, 76, 80
Novaculichthys taeniourus (Lacepède, 1802)	Schultz, 1943; 2000 Expedition.	Occasional.	4, 15, 18, 24, 27, 30, 38, 42, 54, 67, 76, 80
Oxycheilinus arenatus (Valenciennes, 1840)*	New record.	Rare, only one seen.	21
O. unifasciatus (Streets, 1877)*	2000 Expedition.	Moderately common.	1-4, 6-8, 14, 15, 17-23, 25, 27, 31, 33, 34, 41-43, 46, 62, 63, 65-69, 71, 76, 80
Pseudocheilinus evanidus Jordan & Evermann, 1903	New record.	Rare.	24, 41

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
P. hexataenia (Bleeker, 1857)	Randall, 1999	Moderately common.	1-3, 7, 14, 21-25, 27, 31-34, 38, 39, 41-43, 46, 55, 63-69, 71, 76, 79, 80
P. ocellatus Randall, 1999*	New record.	Occasional, usually below 40 m.	14, 25, 68, 76, 79
P. octotaenia Jenkins, 1900	2000 Expedition.	Common.	3, 4, 6, 7, 14, 15, 17-20, 22, 23, 25, 27, 31-34, 38, 39, 41-43, 46, 62-69, 71, 76, 79, 80
P. tetrataenia Schultz, 1969	New record.	Occasional.	15, 17, 18, 42, 66, 76
Pseudodax moluccensis (Valenciennes,1839)	New record.	Occasional.	6, 15, 17-19, 21, 23, 25, 31, 34, 38, 42, 43, 66-68
Stethojulis bandanensis (Bleeker, 1851)	Schultz, 1943.	Occasional.	21, 34, 36, 54, 64, 67, 68, 71,
S. strigiventer (Bennett, 1833)	Randall, 2000		
Thalassoma amblycephalum (Bleeker, 1856)	Schultz, 1943.	Common.	1, 2, 4, 15, 17-21, 23-25, 27, 31-33, 38, 39, 41-43, 46, 50, 52, 54, 62-65, 67-69, 71, 72, 74, 76, 80
T. hardwicke (Bennett, 1828)	Schultz, 1943.	Rare, except Orona lagoon.	30, 72, 73, 74
T. lunare (Linnaeus,1758)*	New record.	Occasional.	11, 24, 26, 30, 50, 52, 54, 55, 66-68, 72
T. lutescens (Lay & Bennett, 1839)*	Schultz, 1943.	Rare, less than 10 seen.	33, 65, 67
T. purpureum (Forsskål, 1775)	Schultz, 1943.	Moderately common in shallow surge zone.	1, 3, 7, 18, 20, 21, 25, 27, 31, 32, 41, 43, 46, 54, 62, 63, 66-68, 80
T. quinquevittatum (Lay & Bennett, 1839)	New record.	Common.	1-4, 6-8, 14, 15, 17-23, 25, 27, 31-34, 38, 41, 43, 46, 50, 54, 62-69, 71, 72, 74, 76, 80
T. trilobatum (Lacepède 1801)	New record.	Occasional in shallow surge zone.	27, 31, 32, 41, 43, 62, 64, 67, 68
Wetmorella nigropinnata (Seale, 1900)	New record.	Three specimens collected with rotenone.	44
SCARIDAE			
Bulbometopon muricatum (Valenciennes, 1840)*	New record.	Generally rare, but common at Orona.	33, 68, 69, 71, 72, 74, 76, 80
Calotomus carolinus (Valenciennes, 1839)	New record.	Occasional.	3-6. 15, 19, 23, 62, 64, 65, 69, 76, 80
Cetoscarus bicolor (Rüppell, 1828)*	Schultz, 1943.	Occasional.	8, 30, 71, 80
Chlorurus frontalis Valenciennes, 1839	New record.	Rare, only 5 seen.	80
C. microrhinos (Bleeker, 1854)*	Schultz, 1943.	Common.	1-8, 14, 15, 17-25, 27, 28, 30-34, 38-43, 46, 50, 54, 62-64, 66-69, 71, 72, 74, 76, 80
C. sordidus (Forsskål, 1775)	2000 Expedition.	Common.	3, 5, 7, 24, 25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54, 55, 67, 68, 71, 76, 80
Hipposcarus longiceps (Bleeker, 1862)*	2000 Expedition.	Abundant in passage at Kanton.	3, 8, 24-27, 30-34, 39, 42, 43, 46, 50, 52, 54, 55, 67, 68, 71, 73, 74, 76, 77, 80
Leptoscarus vaigiensis (Quoy & Gaimard, 1824)	Schultz, 1943.		
Scarus altipinnis (Steindachner, 1879)*	New record.	Common at Kanton.	24, 30-34, 38, 39, 41, 43, 50, 52, 54, 67
S. frenatus Lacepède, 1802	Schultz, 1943.	Moderately common.	3, 14, 15, 18, 21, 24, 25, 30, 32-34, 38, 39, 42, 43, 46, 54, 62, 64, 66-68, 71, 76, 80

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
S. ghobban Forsskål, 1775	Schultz, 1943.	Common.	1-7, 24-28, 30-32, 34, 37-39, 42, 43, 50, 52, 54, 55, 68, 69, 71-74, 76, 77, 80
S. oviceps Valenciennes, 1839	New record.	Moderately common.	7, 24, 25, 27, 30-34, 38, 39, 41-43, 46, 50, 54, 55, 71, 74, 76
S. psittacus Forsskål, 1775	Schultz, 1943.	Occasional.	3, 11, 24, 54, 55
S. rubroviolaceus Bleeker, 1849	New record.	Moderately common.	1-8, 14, 15, 17-25, 27, 30-34, 38, 39, 41-43, 46, 50, 52. 54, 62-69, 71, 76, 80
S. tricolor Bleeker, 1847*	New record.	Moderately common.	1-3, 6, 7, 14, 15, 17-24, 27, 31-34, 38, 41-43, 46, 62-69, 71, 76, 80
PINGUIPEDIDAE			
Parapercis lata Randall & McCosker, 2002*	Schultz, 1943 and 2000 Expedition. as *P. tetracanthus.*	Occasional.	23, 24, 27, 32, 38, 41, 50, 62, 64
Parapercis millepunctata (Günther, 1860)*	2000 Expedition.	Occasional.	25, 38, 41, 54, 67
P. schauinslandi (Steindachner, 1900)	New record.	Occasional.	24, 38, 41, 43
CREEDIIDAE			
Chalixodytes tauensis Schultz, 1943	New record.	Collected with rotenone.	17
Crystallodytes cookei Fowler, 1923	Schultz, 1943.		
TRIPTERYGIIDAE			
Enneapterygius minutus (Günther, 1877)	2000 Expedition.		
E. nigricauda Fricke, 1997	2000 Expedition.	Collected with rotenone.	6
E. tutuilae Jordan & Seale, 1906	2000 Expedition.	Collected with rotenone.	17, 20, 44, 61, 64, 79
Helcogramma capidatum Rosenblatt, 1960	2000 Expedition.	Collected with rotenone.	17, 20, 44
H. chica Rosenblatt, 1960	2000 Expedition.		
H. hudsoni (Jordan & Seale, 1906)	Schultz, 1943.		
BLENNIIDAE			
Aspidontus taeniatus Quoy & Gaimard, 1834	New record.	Occasional.	46, 64, 66, 67, 69
Blenniella caudolineata (Günther, 1877)*	New record.	Collected with rotenone.	10
B. gibbifrons (Quoy & Gaimard, 1824)	Schultz, 1943; 2000 Expedition.		
B. paula (Bryan & Herre, 1903)*	Schultz, 1943.	Collected with rotenone.	10, 81
Cirripectes auritus Carlson, 1981	2000 Expedition.		
C. jenningsi Schultz, 1943	2000 Expedition.		
C. polyzona (Bleeker, 1868)	Schultz, 1943.	Rare, only one seen.	38
C. quagga (Fowler & Ball, 1924)	2000 Expedition.		
C. variolosus (Valenciennes, 1836)	Schultz, 1943; 2000 Expedition.	Common.	1-4, 8, 14, 15, 18, 20, 21, 23-25, 27, 28, 32-34, 38, 39, 41-43, 62, 64-67, 69, 71, 76, 79, 80
Ecsenius midas Starck, 1969	2000 Expedition.		

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Entomacrodus caudofasciatus (Regan, 1909)*	Springer, 1967		
E. cymatobiotus Schultz & Chapman, 1960	Springer, 1967		
E. sealei Byan & Herre, 1903	Springer, 1967		
E. striatus (Quoy and Gaimard, 1836)	Schultz, 1943.		
E. thalassinus (Jordan & Seale, 1906)	Schultz, 1943.		
Exallias brevis (Kner, 1868)	New record.	Rare, only a few seen.	5, 27, 62
Istiblennius edentulus Bloch and Schneider, 1801*	Schultz, 1943.	Common in intertidal.	10, 81
I. lineatus (Valenciennes, 1836)*	Schultz, 1943.	Common in intertidal.	10, 81
Petroscirtes xestus Jordan & Seale, 1906	Schultz, 1943 as *P. mitratus*		
Plagiotremus rhinorhynchus (Bleeker, 1852)	2000 Expedition.	Rare, only two seen and one collected.	32, 79
P. tapeinosoma (Bleeker, 1857)	2000 Expedition.		
Rhabdoblennius rhabdotrachelus (Fowler & Ball, 1934)	Schultz, 1943.		
R. snowi (Fowler, 1928)	New record.	Common in intertidal.	10, 81
CALLIONYMIDAE			
Callionymus simplicornis Valenciennes, 1837	New record.	Collected with quinaldine.	29, 36
Synchiropus morrisoni Schultz, 1960	New record.	Rare, only one seen.	38
GOBIIDAE			
Amblygobius nocturnus (Herre, 1945)	New record.	Moderately common in Kanton lagoon.	26, 29, 36
A. phalaena (Valenciennes, 1837)	Schultz, 1943; 2000 Expedition.	Occasional.	26, 28, 29, 35-37, 52, 72-74, 77
Asterropteryx semipunctatus Rüppell, 1830	New record.	Occcasional in lagoons.	11, 26, 37, 52
Bathygobius coalitus (Bennett, 1832)*	New record.	Collected with rotenone.	81
B. cotticeps (Steindachner, 1880)	New record.	Collected with rotenone.	10
Cabillus tongarevae (Fower, 1927)	Schultz, 1943.		
Callogobius hasselti (Bleeker, 1851)?	New record.	Collected with rotenone.	17
C. plumatus (Smith, 1959)	2000 Expedition.	Collected with rotenone.	64
C. sclateri (Steindachner, 1880)	2000 Expedition.	Collected with rotenone.	17, 44, 61, 64
Ctenogobiops sp.	2000 Expedition.		24, 26, 37, 52
Eviota cometa Jewett & Lachner, 1983	Jewett & Lachner, 1983	Common in lagoon at Kanton & Orona.	29, 36, 37, 55, 72-74, 77
E. latifascata Jewett & Lachner, 1983	New record.	Common; collected with rotenone.	17, 20, 31, 44, 61, 64
E. prasites Jordan & Seale, 1906	Schultz, 1943.		
E. sp. 1	New record.	Collected with rotenone.	17, 20, 79

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
E. sp. 2*	New record.	Collected with rotenone.	17, 20, 31, 55, 61, 79
E. zonura Jordan & Seale, 1906	Schultz, 1943.	Collected with rotenone.	6, 81
Fusigobius neophytus (Günther, 1877)	Schultz, 1943.	Rare in lagoons.	30, 74
Gnatholepis anjerensis Bleeker, 1851	Schultz, 1943.		
G. cauerensis Bleeker, 1853	2000 Expedition.	Common on fines sand bottoms.	11, 15, 18, 24-26, 28-31, 38, 40, 46, 52, 54, 55, 61, 62, 64, 67, 68, 72-74, 77, 79
Gobiopsis exigua Lachner & McKinney, 1983*	New record.	Collected with rotenone.	61
Lotilia gracillosa Klausewitz, 1960	New record.	One photgraphed by M.J. Adams	43
Macrodontogobius wilburi Herre, 1936	Schultz, 1943.	Occasional in lagoons.	26, 29, 72, 73
Oplopomus diacanthus Schultz, 1943	Kanton I. is type locality	Occasional in lagoons.	11, 29, 37
Oplopomus oplopomus Valenciennes, 1837	New record.	Occasional in lagoons.	29, 37, 72
Oxyurichthys papuensis (Valenciennes, 1837)	Schultz, 1943.		
Paragobiodon modestus (Regan, 1908)	Schultz, 1943; 2000 Expedition.		
Pleurosicya micheli Fourmanoir, 1971*	New record.	Collected with rotenone.	55
Priolepis ailina Winterbottom & Burridge, 1993*	New record.	Collected with rotenone.	64
P. cincta (Regan, 1908)	Schultz, 1943.		17
P. nocturna (Smith, 1957)	Schultz, 1943.		
P. semidoliatus (Valenciennes, 1837)	Schultz, 1943.	One specimen collected with rotenone.	81
Sueviota sp.*	New record.	Collected with rotenone.	20, 39, 55, 61, 79
Trimma sostra Winterbottom, 2004	New record.	Collected with rotenone.	32, 34, 38, 39, 41, 44, 76
Trimma squamicana Winterbottom, 2004*	New record.	Collected with rotenone.	6, 17, 20, 27, 32, 34, 38, 39, 41, 44, 55, 61, 64, 79
Trimmatom eviotops (Schultz, 1945)*	New record.	Collected with rotenone.	20
Valenciennea strigata (Broussonet, 1782)	New record.	Occasional.	15, 21, 23, 52, 62
PTERELEOTRIDAE			
Nemateleotris decora Randall & Allen, 1973*	New record.	Rare, one seen in 42 m.	46
Ptereleotris evides (Jordan & Hubbs, 1925)	New record.	Rare, only 3 seen on one dive	33
P. heteroptera (Bleeker, 1855) 18 m	New record.	Rare, only 2 seen.	62
P. microlepis Bleeker, 1856	Schultz, 1943.	Occasional.	26, 73, 74
P. zebra (Fowler, 1938)	New record.	Occasional.	4, 15, 27, 52, 68
EPHIPPIDAE			
Platax orbicularis (Forsskål, 1775)*	New record.	Rare, only 2 seen.	63
P. teira (Forsskål, 1775)	New record.	Rare,less than 10 seen.	25, 30, 65

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
SIGANIDAE			
Siganus argentatus (Quoy & Gaimard, 1925)	New record.	Occasional.	25, 27, 33
ZANCLIDAE			
Zanclus cornutus Linnaeus, 1758	2000 Expedition.	Common.	1-8, 14, 15, 17-25, 27, 30-34, 38-43, 46, 50, 54, 55, 62, 64-69, 71, 76, 80
ACANTHURIDAE			
Acanthurus achilles Shaw, 1803*	Schultz, 1943.	Common.	1-4, 6, 7, 15, 17-23, 25, 32-34, 38, 41, 62-64, 66-69, 71, 72, 76, 80
A. blochi Valenciennes, 1835*	New record.	Occasional.	5, 18, 24, 28, 30, 34, 38, 52, 68, 74
A. guttatus Bloch & Schneider, 1801	Schultz, 1943; 2000 Expedition.	Common.	1, 2, , 4, 6, 7, 15, 18, 20, 21, 27, 31, 38, 43, 54, 62-65, 67, 68, 71, 80
A. leucocheilus Herre, 1927*	New record.	Occasional.	21, 30-32, 34, 38, 41-43, 46, 50, 54, 55, 62-64
A. lineatus (Linnaeus, 1758)*	Schultz, 1943; 2000 Expedition.	Common.	1-4, 6-8, 14, 15, 17-25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 62-64, 66-69, 71, 80
A. maculiceps (Ahl, 1923)	New record.	Rare, only 5 seen.	23, 41
A. mata (Cuvier, 1829)	New record.	Occasional.	1, 2, 15, 46
A. nigricans (Linnaeus, 1758)	Schultz, 1943; 2000 Expedition.	Common.	1-5, 7, 8, 14, 15, 17-25, 27, 30-34, 38, 39, 41-43, 46, 50, 54, 62-69, 71, 74, 76, 80
A. nigricaudus Duncker & Mohr, 1929	New record.	Moderately common.	1, 2, 7, 15, 18, 20-22, 24-27, 30-33, 41, 43, 46, 50, 52, 55, 67, 68, 71, 76, 80
A. nigrofuscus (Forsskål, 1775)	2000 Expedition.	Occasional.	7, 27, 31, 34, 67, 68, 76, 80
A. nigroris Valenciennes, 1835*	Randall, 1956;	Moderately common.	1, 2, 4, 6, 7, 15, 17, 19-21, 23-25, 27, 30, 31, 34, 38, 39, 41-43, 50, 67, 68, 71, 76, 80
A. nubilus (Fowler & Bean, 1929)*	New record.	Rare, only one seen.	23
A. olivaceus Bloch and Schneider, 1801	2000 Expedition.	Moderately common.	5, 7, 15, 17-25, 27, 30, 32-34, 38, 50, 52, 54, 62, 67-69, 71, 76, 80
A. pyroferus Kittlitz, 1834*	New record.	Occasional.	14, 15, 19, 21, 68
A. thompsoni (Fowler, 1923)	New record.	Moderately common.	3, 4, 6, 7, 14, 15, 8, 19, 21-23, 25, 27, 32, 38, 39, 41, 43, 46, 62-69, 76, 80
A. triostegus (Linnaeus, 1758)*	Schultz, 1943; 2000 Expedition.	Abundant	1-7, 14, 15, 17-21, 23-27, 31-34, 36, 38; 40, 42, 43, 46, 50, 52, 67-69, 71, 80, 81
A. xanthopterus Valenciennes, 1835*	New record.	Abundant	1, 2, 4-7, 10, 11, 15, 20-28, 30-35, 38-43, 46, 50, 52, 54, 55, 62-69, 71, 72-74, 76, 77, 80
C. cyanocheilus Randall & Clements, 2001*	Schultz, 1943; 2000 Expedition.	Common.	3-8, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 55, 62-69, 71, 76, 80
C. flavicauda Fowler, 1938*	New record.	Moderately common.	1, 2, 5, 6, 8, 14, 15, 18-23, 25, 27, 31-34, 38-43, 46, 62-69, 71, 76, 80
C. marginatus (Valenciennes, 1835)*	2000 Expedition.; Randall & Clements, 2001	Abundant	1-8, 14, 15, 17-25, 27, 30-34, 38-43, 46, 50, 54, 62-69, 71, 76, 80
C. striatus (Quoy & Gaimard, 1825)	Randall & Clements, 2001	Occasional.	1, 2, 24, 25, 27, 30-35, 38, 39, 41-43, 46, 50, 52, 54, 55, 68, 69, 71, 72

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Naso annulatus (Quoy & Gaimard, 1825)	New record.	Rare, only one seen.	24
N. brevirostris (Valenciennes, 1835)	New record.	Occasional.	5, 8, 24, 25, 30-34, 38, 39, 41-43, 46, 50, 63, 65, 66, 71, 80
N. caesius Randall & Bell, 1992*	New record.	Rare, one photographed.	67
N. hexacanthus (Bleeker, 1855)	New record.	Occasional.	1-3, 5, 6, 14, 15, 19, 23, 32, 40, 42, 64, 65, 67
N. lituratus (Bloch & Schneider, 1801)	New record.	Common.	1-8, 14, 15, 17, 18, 20, 22, 23, 25, 27, 30-34, 38, 39, 41-43, 46, 50, 52, 54, 55, 63, 64, 66-69, 71, 76, 80
N. unicornis (Forsskål, 1775)	New record.	Rare, less than 10 seen.	7
N. vlamingii Valenciennes, 1835*	2000 Expedition.	Common.	1, 2, 5, 6, 14, 15, 19, 22-25, 27, 31, 32, 34, 38, 40, 43, 46, 62-65, 67, 69, 71
Paracanthurus hepatus (Linnaeus, 1766)	New record.	Occasional.	7, 42, 68, 80
Zebrasoma rostratum Günther, 1875*	New record.	Moderately common.	1-8, 14, 15, 17, 19, 20, 22, 31, 32, 43, 46, 64-66, 69, 76, 80
Z. scopas Cuvier, 1829	2000 Expedition.	Common.	1-8, 14, 15, 17-22; 24, 25, 27, 30-34, 38-43, 46, 50, 54, 55, 62-69, 71, 76, 80
Z. veliferum Bloch, 1797	Schultz, 1943.	Common.	1, 2, 7, 24-27, 30, 31, 33, 34, 38-43, 46, 54, 55, 68, 69, 71, 72-74, 76, 77, 80
SPHYRAENIDAE			
Sphyraena acutipinnis Day, 1876*	New record.	Occasional large schools.	27, 40, 43, 69
S. barracuda (Walbaum, 1792)	Schultz, 1943.	Moderately common.	1, 2, 3, 7, 14, 15, 21, 23, 24, 26, 31, 32, 40, 41, 65-68, 71, 76, 80
S. qenie Klunzinger, 1870	New record.	Occasional large schools.	
SCOMBRIDAE			
Euthynnus affinis (Cantor, 1849)	2000 Expedition.		
Gymnosarda unicolor (Rüppell, 1838)	New record.	Rare, only a few seen.	1-3, 40, 41, 50
Thunnus albacares (Bonnaterre, 1788)	New record.	Rare, only one seen.	57
BOTHIDAE			
Bothus mancus Broussonet, 1782	Schultz, 1943.	Rare, but cryptic.	43, 52, 76
B. pantherinus (Rüppell, 1830)	Schultz, 1943.		
SOLEIDAE			
Aseraggodes melanostictus (Peters, 1876)	New record.	Collected with rotenone.	31
A, whitakeri Woods, 1966	New record.	Collected with rotenone.	64
SAMARIDAE			
Samariscus triocellatus Woods, 1966	2000 Expedition.	Collected with rotenone.	20, 62
BALISTIDAE			
Balistapus undulatus (Park, 1797)	Schultz, 1943; 2000 Expedition.	Common.	1-8, 14, 15, 17-27, 30-34, 38, 39, 41-43, 46, 50, 55, 62, 64-69, 71, 76, 79, 80
Balistoides viridescens (Bloch & Schneider, 1801)	New record.	Occasional.	1-5, 22-24, 31-34, 38, 41-43, 50, 63-69, 76, 80
Melichthys niger (Bloch, 1786)	New record.	Common.	1-8, 14, 15, 17-23, 27, 31-34, 38, 41-43, 46, 50, 62-69, 71, 76, 80
M. vidua (Solander, 1844)	New record.	Common.	1-8, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 62-69, 71, 76, 80

SPECIES	SOURCE	ABUNDANCE	SITE RECORDS
Odonus niger (Rüppell, 1837)	New record.	Moderately common, but locally abundant.	4, 14, 15, 18, 21, 23, 33, 34, 38, 41-43, 46, 62-68
Pseudobalistes flavimarginatus (Rüppell, 1829)	New record.	Occasional.	1-3, 6, 7, 14, 17, 20-24, 29-31, 33, 34, 36, 38, 41, 42, 50, 52, 54, 55, 63, 67, 68, 69, 73, 74, 77
Rhinecanthus aculeatus (Linnaeus, 1758)	Schultz, 1943.	Occasional in lagoons.	11, 26, 29, 36, 37, 52, 54, 72, 74
R. rectangulus (Bloch & Schneider, 1801)	Schultz, 1943.	Occasional in shallow surge zone.	1, 2, 6, 14, 15, 17, 18, 21, 24, 25, 27, 31, 32, 34, 38, 43, 50, 54, 62, 64, 66-69, 71, 76
Sufflamen bursa (Bloch & Schneider, 1801)	2000 Expedition.	Common.	1-7, 14, 15, 17-23, 25, 27, 31-34, 38, 39, 41-43, 46, 50, 54, 62-69, 71, 76, 80
S. chrysoptera (Bloch & Schneider, 1801)	New record.	Moderately common.	1, 15, 18, 21, 24, 25, 27, 31, 32, 38, 43, 52, 54, 62-64, 67, 68, 69
Xanthichthys auromarginatus (Bennett, 1831):	New record.	Occasional, usually below 15 m.	15, 19, 22, 23, 38, 46, 62, 64-67
X. caeruleolineatus Randall, Matsuura, & Zama, 1978*	New record.	Rare, usually below 30 m.	22, 64
MONACANTHIDAE			
Aluterus scriptus (Osbeck, 1765)	New record.	Occasional.	6, 7, 24, 31, 32, 41, 50, 64, 68
Amanses scopas (Cuvier, 1829)	New record.	Occasional.	5, 7, 8, 32, 33, 41, 46, 67
Cantherines dumerilii (Hollard, 1854)	New record.	Moderately common.	3-5, 8, 15, 21, 22, 27, 30-34, 38, 39, 42, 43, 50, 62, 64-67, 71
C. pardalis (Rüppell, 1837)	New record.	Rare, less than 10 seen.	1, 22, 63, 66
OSTRACIIDAE			
Ostracion meleagris Shaw, 1796	2000 Expedition.	Occasional.	1-3, 6, 14, 15, 17-21, 23, 27, 33, 39, 43, 62, 64-68, 76
TETRAODONTIDAE			
Arothron hispidus (Linnaeus, 1758)*	New record.	Rare, less than 10 seen.	2, 6, 29, 37, 66
A. meleagris (Lacepède, 1798)*	2000 Expedition.	Occasional, but common at site 22.	14, 21-23, 62, 64, 65, 67
A. nigropunctatus (Bloch and Schneider, 1801)	2000 Expedition.		
Canthigaster amboinensis (Bleeker, 1865)	New record.	Occasional.	3, 15, 21, 25, 62, 64, 67
C. janthinopera (Bleeker, 1855)	New record.	Occasional.	14, 17, 18, 20, 31, 43, 67
C. solandri (Richardson, 1844)	Schultz, 1943; 2000 Expedition.		
DIODONTIDAE			
Diodon holocanthus Linnaeus, 1758*	New record.	Occasional.	22, 23, 27, 64, 65, 67-69
D. hystrix Linnaeus, 1758	New record.	Occasional.	21, 32, 50, 66, 69

SEA TURTLES OF THE PHOENIX ISLANDS, 2000-2002

BY

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INTRODUCTION

Balazs (1973) has written the only recent report on marine turtles of the Phoenix Islands, summarizing a small literature from observations in the 19th and 20th Century, his own observations on a 7-day trip to Kanton atoll in 1973 and anecdotal information from residents on Kanton Island. At that time only green turtles (listed as *Chelonia* sp.) were confirmed to be present in the Phoenix Islands with additional reports of a turtle "with distinct ridges on the carapace" which Balazs did not venture to name. Balazs notes that reviews at the time did not list the Phoenix Islands within the distribution records of turtles across the Pacific.

Balasz summarized that marine turtles were seen commonly throughout the year in the Phoenix Islands, listed for various different islands by different references and observers including Enderbury, Orona, Manra, Nikumaroro, Birnie. He cited no reported turtle activity on Rawaki (Phoenix) and McKean. Nesting was noted to occur throughout the year with a peak of nesting in October and November and particularly high nesting activity was noted for November 1972 on Kanton. He documented old and new turtle tracks and nest pits and observed two females digging nests on one site on Kanton. In a week on Kanton, he identified four areas around the outer perimeter of the atoll rim between 0.5 to 2.2 km in length where nesting was concentrated. Not all apparently suitable beaches showed nesting activity tentatively related to surface alteration and construction during the Second World War. Suitable beaches had moderate-to-steep slopes and vegetation on the beach top (*Portulaca*, *Lepturus*, *Boerhavia* and *Scaevola*) under which nests were dug. No nesting activity was noted for beaches facing the lagoon.

With respect to marine turtles, our objectives were to document turtle activity on the beaches and in the water and identify any clearly significant islands, locations or habitats in which turtles might be concentrated. In addition, we were particularly keen to document the presence of turtles on Rawaki and McKean and species other than the green turtle (*Chelonia mydas*).

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METHODS

Observations were made on land and in the sea. Beach surveys for evidence of nest pits and tracks were conducted by walking along the beaches and by observation from small boats on the way to and from dives. The number of nest pits and tracks at each location was counted. For the small islands, the entire island perimeter was covered while on the larger islands spot-surveys were made. From boats, tracks were counted in pairs with a pair of tracks counting for one nest. On land, individual nest pits were counted attempting not to count “attempted nests” as real ones by observing the tracks to and from each pit and counting only one pit as evidence of a nest.

In the sea all turtle sightings were recorded while at the surface and in the water, by all divers. Each day the sightings were verified to exclude likely double counts where multiple divers might have recorded the same individual. Records were collected during 42 SCUBA dives in 2000 and 87 in 2002 (with 6-10 divers in the water on each dive). Observations were made in May of 2000 and June of 2002.

RESULTS

Turtles were observed at all islands visited both in 2000 and 2002 (Table 1). Green turtles (*Chelonia mydas*) outnumbered hawksbill turtles (*Eretmochyles imbricata*) by a factor of 20. The total number of turtles seen in 2000 and 2002 were, respectively, 86 and 65 green turtles and 3 and 5 hawksbill turtles over 11 and 21 days. Corrected for the amount of observation time at each island in 2002, on average 2.0 green turtles and 0.1 hawksbill turtles were observed per dive, respectively. The maximum number of turtles observed during a single dive was 6 at the northern tip of Manra Island.

Table 1. Number of turtles seen per dive.

Island	# of samples		Green turtles			Hawksbill turtles		
	2000	2002	2000	2002		2000	2002	
			m	m	sd	m	m	sd
Manra	3	5	5.7	2.0	2.9	-	0.2	0.5
Birnie	0	3	-	1.7	1.5	-	-	-
Enderbury	3	7	1.7	1.0	1.4	-	-	-
Phoenix	3	3	1.0	0.7	0.9	-	0.3	0.7
Nikumaroro	11	10	1.1	0.7	1.0	0.1	0.2	0.4
Kanton	9	32	3.8	0.9	1.1	0.1	-	-
Orona	6	8	2.2	0.8	0.7	-	0.1	0.4
McKean	3	0	0.7	-		0.3	-	
Total	38	68	2.0	1.0	1.5	0.1	0.1	0.3

Comparison of green turtle abundance between 2000 and 2002 showed lower numbers in 2002 at all islands with a significant difference at the two largest, and the only populated, islands Kanton and Orona (Fig. 1). Mating green turtles (Fig. 2) were observed at Nikumaroro, Manra and Enderbury in 2002. In the latter case one male was successfully mating with the female while another was attempting to dislodge him.

Most islands showed signs of turtle nesting (Table 2) shown by old depressions in the sand, without recent tracks, and recent tracks with fresh nest depressions. All tracks observed appeared to be green sea turtle tracks determined by distinctive opposite flipper marks. Enderbury had the highest density of old nests concentrated at the top of the leeward beach.

During the 2002 survey, several green turtle shells were observed on the beach near the settlement village on Orona. Otherwise, little evidence of mortality was seen of turtles.

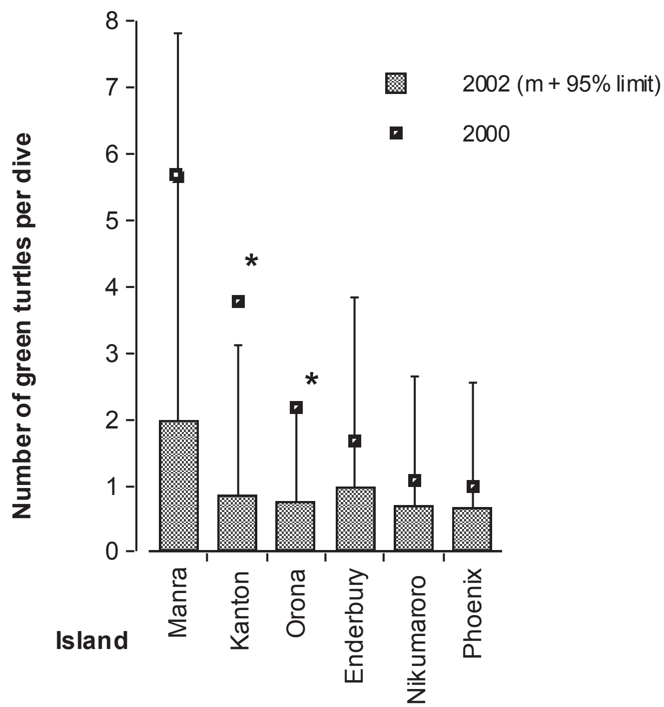

Figure 1. Comparison of 2000 and 2002 abundance of green turtle in the Phoenix Islands. Error bar shows the 95% upper confidence limit for 2002. For Kanton and Orona, the density documented in 2000 was significantly higher than that recorded in 2002, shown by the asterisks. Islands are ordered by decreasing green turtle abundance in 2000.

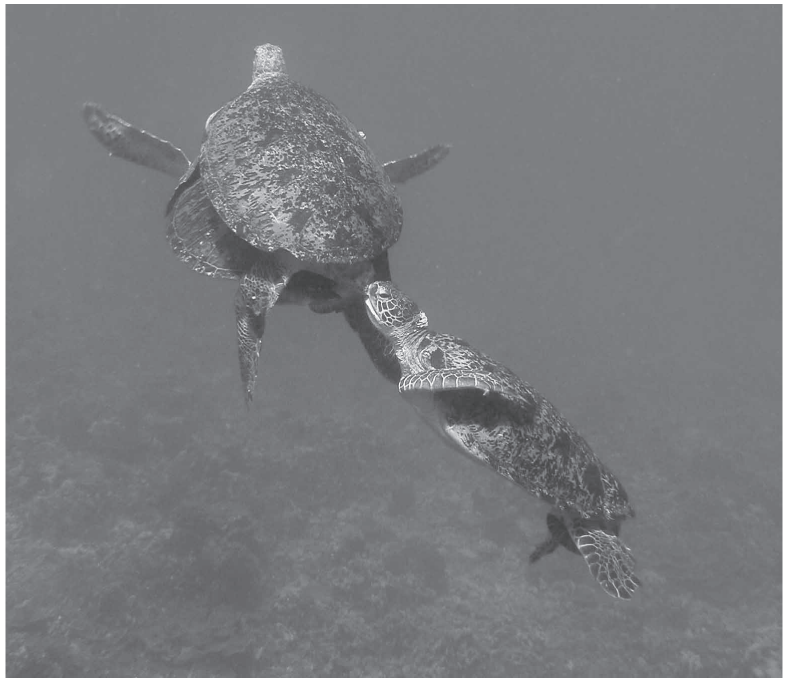

Figure 2. Green turtles mating at Enderbury, in 2002.

Table 2. Number of turtle nests observed on beaches of the Phoenix Islands in 2002. Separate counts are given for old nests (without tracks) and recent nests with tracks in the sand. All turtle tracks appeared to be those of green sea (*Chelonia mydas*) turtles. Surveys were done of all beaches on the small islands (Birnie, Phoenix, Enderbury), but not on the larger islands (Manra, Nikumaroro, Orona, Kanton).

Island	Old nests	New nests	Total
Enderbury	160		160
Nikumaroro	41	18	69
Kanton	30	5	35
Orona		8	8
Phoenix		6	6
Birnie	2	3	5
Manra		2	2
TOTALS	233	34	267

DISCUSSION

This paper confirms the presence of green turtles at all islands in the Phoenix Group, both feeding and nesting. Though hawksbill turtles were not seen on all islands it is likely that they do occur on all of them. Similarly, nesting activity of green turtles was seen on all islands. No evidence was seen of a third turtle species matching Balazs (1973) description "with ridges on its carapace."

The most significant locations for turtles were Manra for abundance of turtles in the water, but Enderbury, Nikumaroro and Kanton for nesting activity. As noted by Balazs, nesting activity was patchy with dense concentrations in some locations and long stretches of apparently suitable beach without nests immediately adjacent. The lack of significant human activity on most of the islands precludes artificial alteration to the habitat as being a reason for this, as was the case on Kanton (Balazs 1973).

The most striking result documented here is the significant decline in turtle populations from 2000 to 2002. This was most evident on Kanton and Orona where the abundances recorded in 2000 were above the 95% confidence limits of the more quantitative samples in 2002. Marked declines were also noted for Manra and Enderbury, and less so for Nikumaroro and Rawaki islands. Birnie and McKean were only visited in one year so no comparison was possible.

Potential causes of the decline in turtle abundances include capture on the populated islands and bycatch by offshore commercial fisheries. Kanton and Orona Islands were the only islands in the group to have any resident human populations in the period covered by the surveys. Kanton has an administrative population of ≈30 people who undertake subsistence fishing for local needs. The population is serviced by a supply ship every 3-4 months enabling minor trade in durable marine products occurs, including dried sharkfin and possibly also turtle shells. The Phoenix Islands Kakai (settlement) Scheme (PIKS) had placed about 140 villagers on Orona Island from 2001 to 2003 to harvest marine resources such as sharkfin and reef fish, and coconuts. Harvest of sea turtles for their meat and shells was also likely evidenced by the turtle shells seen near the village. In conversation with villagers it was learned that an unknown number of turtles are caught on long lines and eaten.

Second, a commercial shark fishing vessel passed through the Phoenix Islands en route between Hawaii, Kiritimati Island and American Samoa, spending about 6 months in the islands in 2001. According to reports from residents of Kanton and Orona, the boat fished at Kanton, Orona, Enderbury and Manra Islands. These are the four islands that showed the most significant decline of sea turtles (Fig. 1). Since 2001 other boats have been reported visiting Kanton and longline fishing for tuna is licensed from 12 km out from the islands. The depredation of sea turtles by longlining and other hook-based fisheries is well documented in the Pacific (Ovetz, 2005) and it is very likely that both targeted and bycatch of turtles occurs sporadically around the Phoenix Islands.

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