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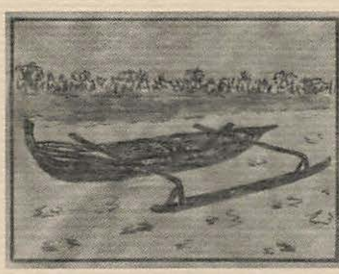
Sailing Routes of Old Polynesia
The prehistoric discovery, settlement and abandonment of the Phoenix Islands

ANNE DI PIAZZA
ERIK PEARTHREE



Bishop Museum Bulletin in Anthropology 11

Bishop Museum Press
Honolulu

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Bishop Museum Bulletin in Anthropology 11

SAILING ROUTES OF OLD POLYNESIA

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Bishop Museum Bulletin in Anthropology II

Bishop Museum Press
Honolulu, 2004

Published by
Bishop Museum Press
1525 Bernice Street
Honolulu, Hawai'i 96817-2704, USA

ISBN 1-58178-031-1
ISSN 0893-3111

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Preface

Flora For Thérèse and Learco,
Joyce and Edwin,
from their migrating children

"It looks like a canoe of old" said the old man. The few people assembled on the lagoon shore of Kanton island agreed and murmured: *"the kiaro*[1] *are wooden boxes, the nylon lashings are not right and it is so high above the water, but it must be safe and strong to have come from Hawai'i"*. Although Ka' Imi Ku'a was obviously not like their outrigger voyaging canoes, or baurua, she was still identified as a vaka or canoe. As soon as the people were over their surprise at finding such a canoe in their waters, voyaging protocol came into play. The canoe had to be properly moored and the sailors fed in the maneaba, or communal meeting house. Only hours later would the old man risk questions about the clouds seen, the fish encountered and the star course followed from Hawai'i... in other words, the song for the Phoenix Islands. Unfamiliar with navigating by chants, we demonstrated our portable GPS receiver. Later that night, when it was time for us to depart, he shook his head and thanked us for having let him hear our "electronic song". Touched by the hospitality of the I-Kiribati people, we realized how fortunate we were to be working in these Pacific Islands.

Several colleagues -or perhaps we should call them dear friends- have been generous enough to instill in us their grand passion for the Pacific world. There have been many of them, but we would especially like to thank José Garanger and Ben Finney, who each launched one of us on our respective voyages of discovery from the safe haven of the university, and who over the years have continued to be our mentors. John Sinton, Alan Ziegler, Jean-Denis Vigne and Hubert Forestier commented on specific topics. Their careful science has hopefully prevented us from making too many errors, any that remain are ours alone. We would also like to dedicate this work to the 12 families who made up the population of Kanton. Their welcome, their smiles and their curiosity, after the long days at sea and on land, gave us great pleasure. This project was funded by CNRS (Centre National de Recherche Scientifique) through the laboratory

CREDO (Centre de Recherche et de Documentation sur l'Océanie) in Marseille, whose members have the freedom to concentrate entirely on their research. Without this institution, nor the support of the "Division des Sciences Sociales et de l'Archéologie du Ministère des Affaires Etrangères" in Paris, Ka 'Imi Ku'a would have stayed in Hilo bay.

Introduction

THERE ARE AT LEAST TWENTY-FIVE[2] ISLANDS SCATTERED throughout Oceania with archaeological remains but which were unoccupied at the time of European discovery. These islands have come to be called the mystery islands by archaeologists (Bellwood 1987; Kirch 1988). The majority of them are atolls and their greatest concentration is found along the equator, in the Line and Phoenix archipelagoes, part of the Republic of Kiribati. Brief reports on the archaeology of the northern Lines have been published (Emory 1934 a, 1939; Finney 1958; A. Sinoto 1973; Anderson *et al.* 2000; Di Piazza and Pearthree 2001 a,b; Pearthree and Di Piazza 2003), but the Phoenix have remained unknown, except for brief notes in Bryan (1942) and a manuscript by Gordon MacGregor[3]. We rediscovered this document, which also contains a report by H. Bigelow, in a folder marked "Tokelau" in the archives of the Bishop Museum in Honolulu. It consisted of several versions of an unpublished paper, annotated by Emory, covering MacGregor's brief visits to Hull and Sydney islands in 1933, as well as Bigelow's 1939 visit to Sydney.

This manuscript was the inspiration for our 1997 expedition to the Phoenix Islands, an archipelago of eight[4] mystery islands situated just south of the equator, 540 nautical miles north of Samoa and 1,600 nm south of Hawai'i[5]. European names were applied to all these islands at the time of discovery and still appear on some charts. Four of them are now known by their modern I-Kiribati[6] names. Thus Sydney Island is now called Manra, Hull is Orona, Canton is Aba Riringa or Kanton and Gardner is Nikumaroro. Phoenix, Enderbury, Birnie and McKean have retained their colonial names. In this report, old names will be used to refer to work accomplished before 1979 (the year of Kiribati independence), and the I-Kiribati name thereafter.

Atolls in general have been less studied by archaeologists than high islands. This was due both to the opinion that high islands would have been settled first and that archaeological materials would not be preserved on atolls due to storm disturbance. This view has been changing since Janet Davidson's work on Nukuoro and a number of recent studies have demonstrated the antiquity of atoll settlement. They have also shown the difficulty of identifying early sites where continuous occupation has disturbed the archaeological record (Davidson

1971; Leach and Ward 1981; Dye 1987; Best 1988). We felt that a study on the Phoenix, the last archaeologically unknown archipelago in Oceania, offered certain advantages. It lies outside the hurricane belt, therefore any remains should have suffered minimal storm damage. Its prehistoric abandonment led us to suspect good site preservation and evidence of ecosystem recovery. It thus should offer a close analogue to the world discovered by ancient navigators.

Our research in the Phoenix Islands contributes to an understanding of atoll archaeology in general and to the phenomenon of mystery island settlement in particular. We use a cultural ecological approach to address questions such as; how were these islands discovered, what was the economic base for their successful settlement and what could have caused these settlers to move on? For the most part, anthropologists of the 20th century have responded to these questions by affirming that these islands were occupied by marooned sailors who were unable to survive on dry, barren and tiny atolls, or that at best, they were simply resting places for people on their way to high islands. Abandonment is thus assumed to be due to scarcity of resources, drought or isolation. However we show that these first settlers were exceptional navigators, by recognizing that these atolls were sanctuaries for ground nesting seabirds, finally by examining the type and density of their archaeological remains, these mystery islands are seen to have been inhabited by members of an Ancestral East Polynesian society, building temples or shrines (marae), trading stone artifacts, tending gardens and holding first fruits ceremonies. Neither famine, drought, nor war, need be invoked as the ultimate case of abandonment. Instead emigration becomes a voluntary and deliberate strategy.

The project combined research in archaeology with experimental voyaging and island ecology. For the experimental voyages, we built a Polynesian sailing canoe named Ka ʻImi Kuʻa and sailed her from Hawaiʻi to six of the Phoenix islands, and then to Kiritimati (Christmas island), in the Lines. We studied how a double canoe performed in different conditions both on the open ocean and during inter-island passages. On land, we recorded environmental data, mapped surface archaeological sites and excavated occupation deposits. These data are integrated into two computer simulations. One that investigates the age structure of a forest harvested to produce canoes, and another that looks at how human population growth leads to depletion of gathered resources and increasing reliance on agriculture.

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The book has been divided in three parts reflecting the cultural history of the Phoenix Islands: discovery (chapters 1 to 3), settlement (chapters 4 to 6) and abandonment (chapter 7).

Chapter 1 documents the design and construction of Ka' Imi Ku'a, based on John Webber's draft of a Tahitian tipairua. Sailing this double canoe allowed us to better understand the capability of prehistoric vessels to sail against, across, and with the trade winds. Since we had the unexpected good fortune to sail during the 1997 El Niño event, we were obligated to retrace the route of prehistoric expansion into Polynesia, sailing 1,000 nm eastward in only 12 days. These experiences led to a model which helps comprehend the maritime world of a Phoenix islander. A world characterized by the ease of two-way contact with islands to the south (Tokelau and Samoa), and by the relative isolation from their homeland far upwind in central East Polynesia.

Chapter 2 reviews our observations on an important aspect of voyaging: land finding using seabird behavior. It is well known that noddies and white terns are reliable land indicators up to 20 nm away from an island. Our data indicate that brown and masked boobies, as well as frigate birds, may be trustworthy up to 100 nm. Breeding populations of these species have been extirpated throughout Oceania, except on unoccupied islands, like the Phoenix. At the time of first discovery, navigators could thus have used the avifauna to find land at much greater distances than is possible today.

Chapter 3 details the characteristics of an ideal voyaging canoe, based both on our experience and a review of some early accounts. The size and shape of this vessel allows us to estimate the amount of timber it would have required. We further go on to investigate the dynamics of a Phoenix Island forest exploited to build and maintain a fleet of such canoes over time. This simulation puts voyaging within the realm of a day to day economy and gives some clues about how changes in the age structure of a forest might be reflected in canoe building technology.

Chapter 4 enumerates the resources offered by Enderbury, Kanton, Phoenix, Manra and Orona in order to understand how they patterned prehistoric use or settlement. Observations on vegetation, fresh water, reef passes, agricultural productivity and fauna, particularly seabirds, were made during the 1997 El Niño year, a relatively rainy period. They contrast with earlier accounts which emphasized the dry and barren appearance of these islands.

Chapter 5 reports the archaeological surface features discovered, including those reported by MacGregor, Bigelow and Bryan. We postulate that Manra and Orona supported sizeable populations, who from time to time visited Enderbury to tend dry gardens and hunt seabirds and turtles, and who occasionally went to Phoenix, Kanton and probably Birnie to replenish in protein.

Chapter 6 is dedicated to subsurface features, primarily a trash pit and workshop on Manra, and a large communal oven on Orona. These excavations provide evidence of a prosperous community dating to the 13th century, who worked or reworked imported basalt for tools, manufactured pearl shell fishhooks, and respected ritual obligations centered around their ancestral gods and food offerings.

Chapter 7 presents a paleo-economic optimization model investigating interactions between human populations, seabird biomass and agricultural productivity. The inhabitants of Manra and Orona seem to have known a relative abundance of food, "mining" resources that offered the best returns: ground nesting seabirds. Once the dominant seabirds, shearwaters and terns had declined significantly, they would have relied more and more on agricultural crops at home and seabirds from neighboring islands, up to the point when abandonment or emigration became the best of all strategies.

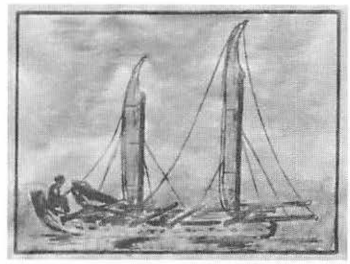
Our knowledge of the prehistory of the Phoenix Islands is limited to the modest observations of MacGregor, Bigelow, Bryan and ourselves. All other Polynesian archipelagoes have benefited from more excavations. The work reported here shows that these mystery islands are no less interesting, just that it will require more sailor-archaeologists to build a comparable cultural history to that of the rest of Polynesia.

PART I

DISCOVERY PROCESS

"HOW SHALL WE ACCOUNT FOR *this nation spreading itself so far over this vast ocean? We find them from New Zealand to the South, to these islands to the North and from Easter Island to the [New] Hebrides*" (Captain James Cook cited in Beaglehole 1967:279). The process of discovery of the hundreds of remote islands in the Pacific continues to astonish. How were these early voyagers able to make the sea into their ally? The first part of this book suggests that the discoverers of the Phoenix were likely to have been tuna fishermen following a route downwind from their home in central East Polynesia; that the canoes involved, perhaps outriggers which combined maneuverability, light weight and safety, were probably of middle size; that atoll dwellers were no doubt active participants in this exploration of the Pacific; and that brown boobies and frigate birds helped in the discovery of the Phoenix and probably other archipelagoes.

CHAPTER 1



Toward A "Sea of Islands"

Experimental voyaging and the discovery of the Phoenix archipelago

> "*In these Proes or Pahee's as they call them from all accounts we can learn, these people sail in those seas from Island to Island for several hundred Leagues, the Sun serving them for a compass by day and the Moon and Stars by night. When this comes to be prov'd we shall be no longer at a loss to know how the Islands lying in those Seas came to be people'd, for if the inhabitants of Uleitea [Ra'iatea] have been at Islands laying 2 or 300 Leagues to the westward of them it cannot be doubted but that the inhabitants of those western Islands may have been at others as far to westward of them and so we may trace them from Island to Island quite to the East Indias*" (Cook 1955:154).

Debates about the settlement of Oceania began during the first European contact, in the 1500's, and will no doubt continue. There are many levels of uncertainty, for most of us are neither islanders nor navigators. As Levison *et al.* pointed out: "*Early islanders may have perceived the Pacific as a sea of islands. To continental man it is often envisaged as an empty expanse of ocean... If one believes that island-studded seas are the norm and has not had experience of the empty ocean wastes, then one may well sail forth with confidence*" (Levison *et al.* 1973:62). Navigators from the central Caroline Islands such as Puluwat, picture their canoes to be stationary while the distant islands and seas flow toward and past them (Gladwin 1970:181). Europeans, on the other hand, envision their vessels moving away from the land and refuge, toward the dangers of the open sea. It was not until we had sailed a canoe through Hawai'i, and later the Phoenix Islands that we began to view the ocean as a safe and friendly place. The wind and waves of the open sea are little hazard to a well handled and well lashed canoe. The greatest danger comes when approaching a reef encircled island.

Our voyage was inspired by 35 years of experimental archaeology in Polynesia, pioneered by Ben Finney (1994 a). In 1966, Finney and some of his students started documenting the performance characteristics of Nālehia, a 40 foot long fiberglass replica of a double hulled Hawaiian sailing canoe (Finney 1967:147). Ten years later, Finney and the Polynesian Voyaging Society, successfully sailed the ancient migration route between Tahiti and Hawai'i, using traditional non-instrument navigation methods aboard a deep sea double canoe, Hōkūle'a (Finney 1979; 1994 a). Many more voyages were accomplished, both by Hōkūle'a and other canoes which have followed in her wake (Finney 1999). These passages throughout Polynesia have demonstrated how a traditionally navigated canoe was well adapted for deliberate voyaging and land finding.

Inspired by these successful experiments, and in homage to the ancient navigators, when we needed a vessel to conduct archaeological research in the Phoenix Islands, which lack transport of any kind, we decided on a double canoe. We named her Ka 'Imi Ku'a, "the search for red feathers", in reference to a Marquesan legend about 'Aka, a cultural hero who sailed through East Polynesia at least as far as Rarotonga in the Cook Islands, eventually returning home with the coveted red feathers of the ku'a, probably the lorikeet, *Vini kuhlii*[7]. By naming our canoe in honor of 'Aka and his descendents, Papa Teiki of Taipivai in the Marquesas and his granddaughter Imi Ku'a, we evoke the spirit which animated the sailors of the past.

Design and construction of Ka 'Imi Ku'a

Given the lack of an archaeological specimen of a voyaging canoe, Ka 'Imi Ku'a was based primarily on the drawing of a tipairua or double canoe, entitled: "*A canoe of a chief of Otaheite*" by John Webber, conserved at the British Museum (Add. MS n°15515; Haddon and Hornell 1975:fig.87). Sketched during Cook's last visit to Tahiti, it is the most detailed depiction of an early deep sea canoe known to the authors. Detailed enough to permit Ka 'Imi Ku'a to inherit her narrow projecting forefoot, horizontal planked "nose" or ihu, and raised transom stern, as well as the placement of her deck and foremast (Fig. 1.1, Plate 1). The elongated stern and ihu, both terminated by tiki on the drawing, signify the rank of the chief and owner of the vessel. Not well suited to the open sea, and inappropriate to our status, these features were shortened on Ka 'Imi Ku'a, enhancing her fishing canoe aspect contra a more majestic appearance.

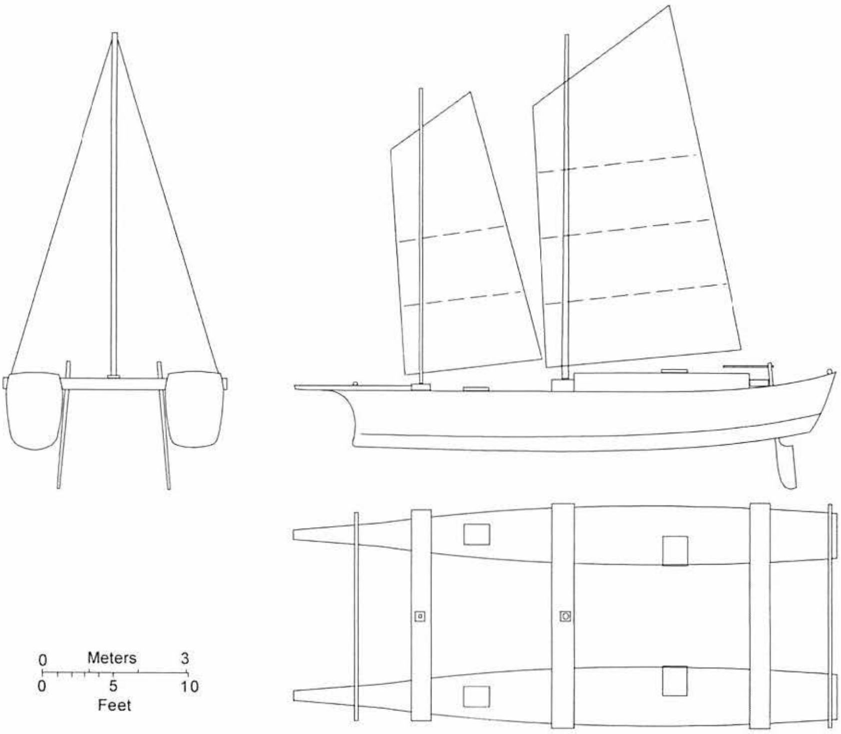


Fig. 1.1: Lines drawing of Ka 'Imi Ku'a
Length overall: 11.2 m; length on water line: 9.4 m; breadth overall: 4.5 m; breadth keel to keel: 3.4 m; draft: 0.35 m.

1. Ka 'Imi Ku'a moored in the lagoon of Kiritimati island

Design features that could not be ascertained from Webber's drawing, such as the shape of the bottoms, the sail rig and the steering system, were incorporated from other sources. Artists of the 18th century conventionally represented Tahitian canoes in the water or on the beach, hiding their bottoms. It is not until the work of Admiral Pâris in the early 19th century, that the first technical drawings of sailing canoes appear, whose bottoms range from semi-circular to a rounded V (Pâris 1843:pl. 123, 124; Haddon and Hornell 1975:fig.78). Ka 'Imi Ku'a has a round bottom which, because it sits higher in the water than a V bottom, makes her less prone to touch the reef, although it detracts somewhat from her windward performance. Reconstruction of the traditional sail rig is even more difficult than the hull. By the time Pâris made his scaled drawings, European sails had already supplanted the Tahitian spritsail. The best illustrations of double canoes under sail are two pencil sketches of tipairua by Webber (after Dodd 1972:136,139), one is the frontispiece to this chapter. Her two masts are fitted with the peculiar Tahitian spritsail, described by Banks as "*bordered all round with a frame of wood*" (Banks cited in Haddon and Hornell 1975:121). Ka 'Imi Ku'a's masts, positioned like those in the drawing, carry European lugsails. These can be easily lowered and reefed unlike Tahitian spritsails, which according to Banks, had "*no contrivance for reefing or furling, so that in case of bad weather [they] must be entirely cut away*" (*ibid.*). Banks may have been overstating their dangers, but his comment inclined us to adopt the more familiar lugsails. Early drawings give too little assistance to reconstruct the Tahitian steering method. Thus, Ka 'Imi Ku'a used quarter rudders, borrowed from those of Micronesia and Indonesia, which pivot against a cleat and are controlled by a tiller (Horridge 1987; Haddon and Hornell 1975).

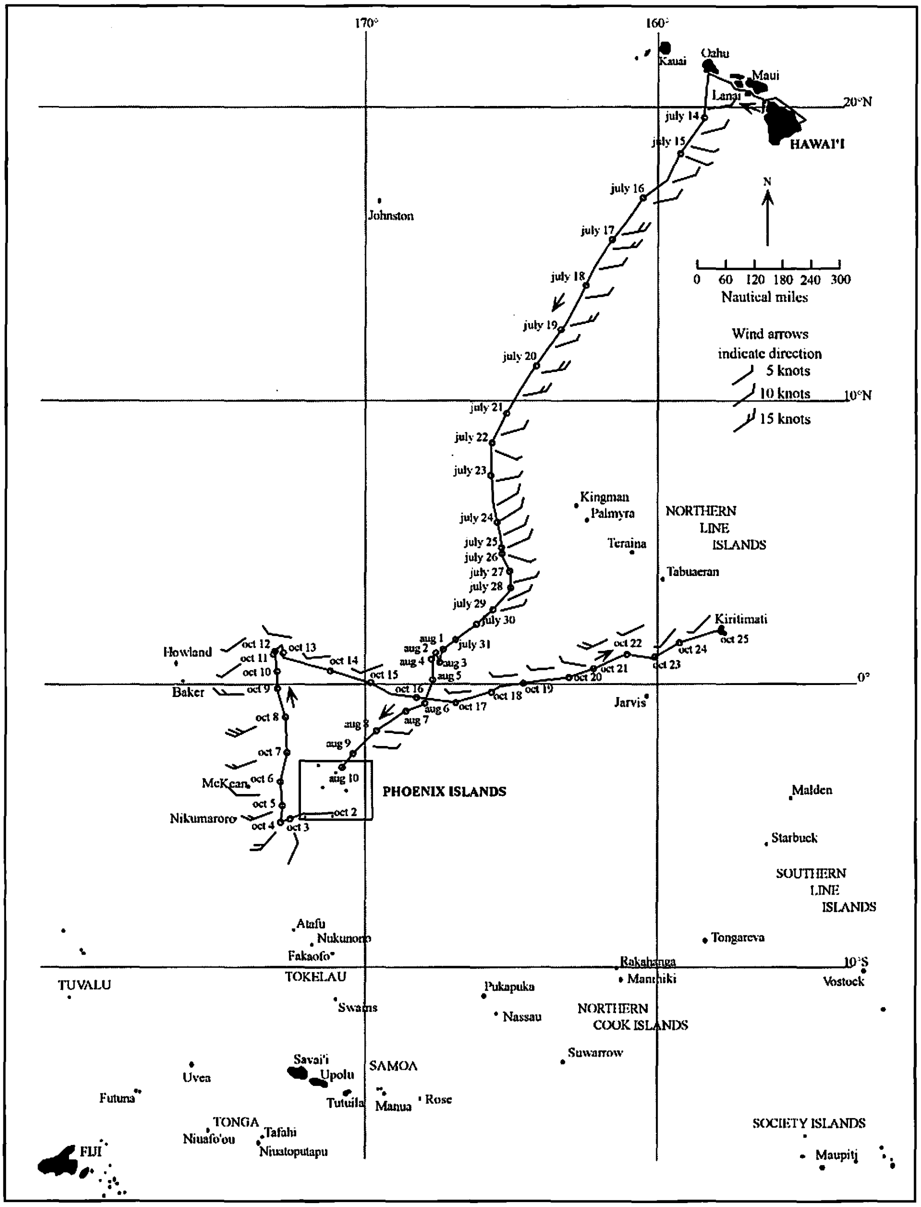
Because our proposed voyage from Hawai'i through the Phoenix Islands and onward to the Gilberts would take us far from hope of assistance, questions of safety and reliability were of great concern. Therefore Ka 'Imi Ku'a was built with decked over hulls and cabins to keep her from swamping in high seas, an accident that has twice befallen Hōkūle'a, and which Finney notes would likely be fatal at sea (Finney 1994 a:298). She also uses strong plywood boxbeams for her 3 main 'iako, while retaining the traditional wooden poles at bow and stern.

Voyaging and performance of Ka 'Imi Ku'a

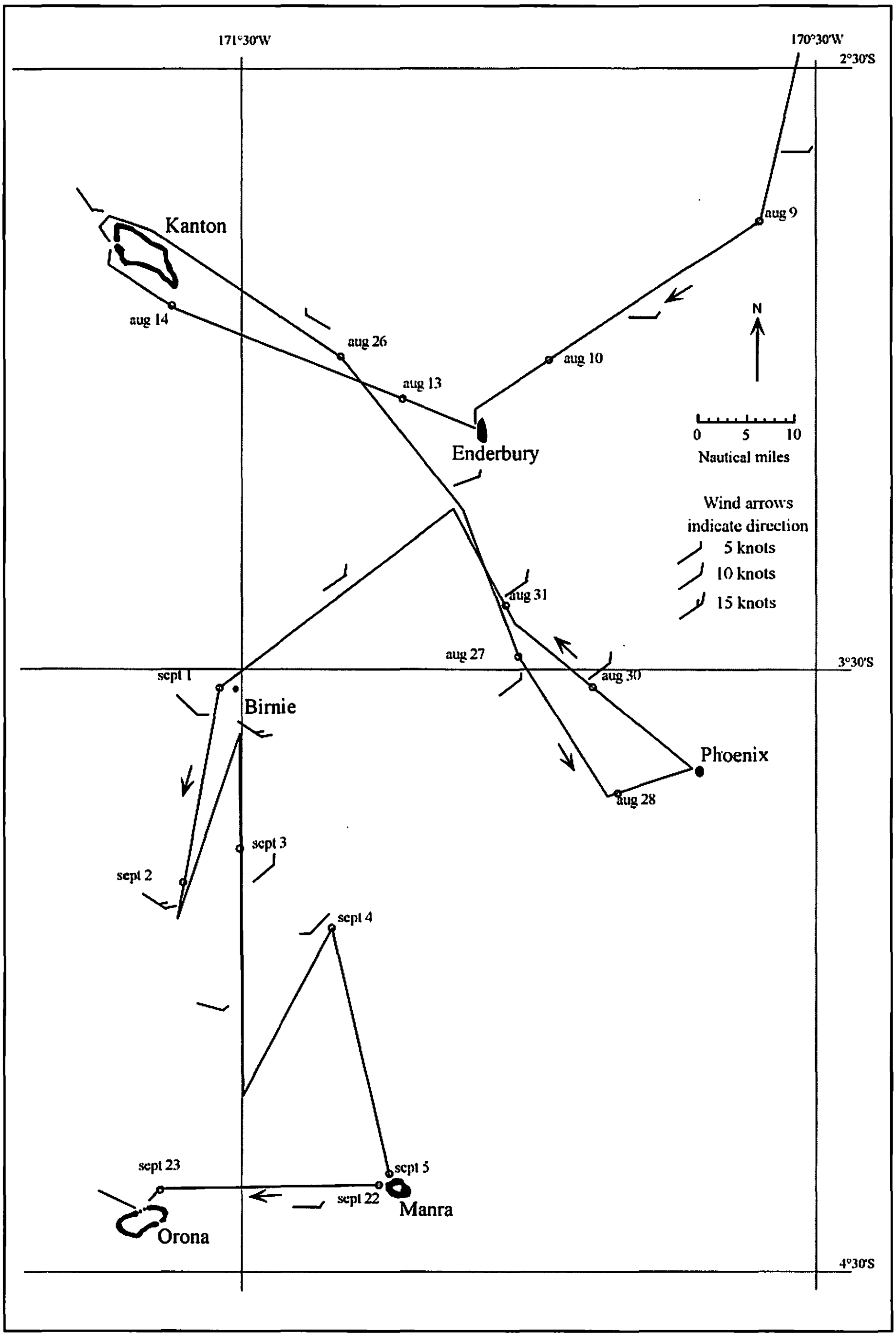
Ka 'Imi Ku'a was launched in Hilo bay on a typically rainy day, a blessing according to local tradition. Almost 3 weeks were spent making sea trials and learning to sail a round bottomed canoe to windward, while we waited for moderate trade winds to begin her shakedown voyage to Oahu, across the rough waters of the Alenuihaha channel. During this time, we experimented with various shapes and sizes of sail on her two masts. She was tried as a gaff schooner, a jib-headed schooner and a gaff ketch among other variations. In terms of balance and performance, the best combination turned out to be two lugsails, which closely approximate the area and aerodynamic force (centers of effort) of a traditional Tahitian spritsail rig. With her heavy wooden hulls, probably similar in weight to traditional canoes, Ka 'Imi Ku'a was able to surf on steep seas. She may even have been beached on a coral island, surfing across a fringing reef, had she been handled by a crew of muscular Polynesians. But with just two anthropologists on board, Ka 'Imi Ku'a often felt the lack of man power and was only landed in protected bays. As we will see in chapter 3, voyaging canoes from atolls would probably have been much lighter and handier outriggers. Ka 'Imi Ku'a's weight did however contribute to stability, making her resistant to capsize as well as decreasing her leeway.

Two more weeks of trials in Hawai'i with stops at Kawaihai, Maui, Lanai and Oahu gave us enough confidence to set off for central Polynesia in early July 1997, just as the first hurricane of the season was passing north of Oahu. As prudent navigators of the past would have done, we initially headed slightly into the trades to maintain our windward position, giving us the option to either return to Hawai'i or continue on to the northern Lines, if necessary. On the third day, 250 nm southwest of Honolulu, we turned downwind toward the Phoenix archipelago in brisk northeast trades to hurry across the hurricane tracks. At about 7°N, Ka 'Imi Ku'a entered the doldrums with alternating calms, rain squalls and light winds that shifted around the compass. We noted with some surprise that it was possible to travel slowly, about 30 miles a day, in any direction by sailing from rain cloud to rain cloud, each of which generated its own local winds. In the doldrums a navigator could replenish with rainwater and abundant tuna migrating along current lines and schooling below drifting debris.

Within the Phoenix group which extends north to south across the wind, navigation is relatively easy. The six eastern islands, all visited by Ka 'Imi Ku'a, form a close knit group almost like a giant atoll[8]. Inter-island passages typically took 1 or 2 nights, although we tacked for 4 days to make the 50 miles to windward from Birnie to Manra. In the past, with a smaller canoe or a stronger crew, it would have been faster to paddle this route, or one could simply wait for more favorable winds. As the season progressed, a series of low pressure troughs crossed the tropical South Pacific. At the latitude of the Phoenix, each trough interrupted the southeast trade winds, which were replaced by winds which backed around the compass from north to northwest, southwest and south, before the southeast trades resumed. These fairly predictable local wind shifts occurred over periods of 2 to 3 days. We took careful notice of the first of these lows, which passed over Kanton in mid-August. When it appeared that another system was beginning, we took our chance and rode the northerlies for 75 miles to Phoenix island. A voyage that in normal weather is directly against the southeast trades. These lows increased in strength until October 3, when we were one day west of Orona, and the El Niño westerlies settled in, accompanied by gale force winds. For the next 22 days Ka 'Imi Ku'a sailed in these winds, becoming the first experimental canoe to voyage in such conditions. Our objective was Tarawa in the Gilbert archipelago, about 970 nm "downwind" to the west, but after 10 days tacking hard to windward and gaining less than 100 miles, the canoe, her rigging and her crew were all severely stressed. When it became clear that no island could be reached to westward, we turned downwind to the east, reaching Kiritimati in the northern Lines 12 days and 1,000 nm later. During the 30 days these westerlies prevailed, a canoe could have sailed about 3,000 nm



Map 1.1: Ka'Imi Ku'a's passages from Hawai'i to Enderbury and Orona to Kiritimati in 1997



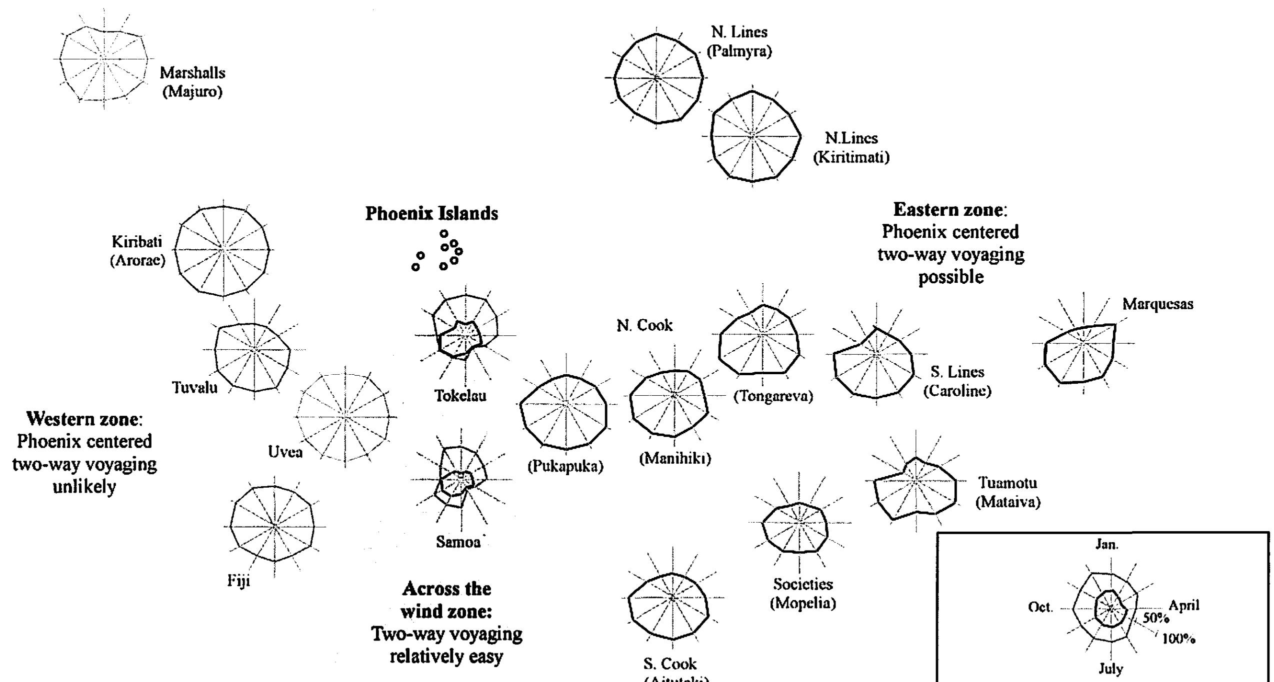
Map 1.2: Ka'Imi Ku'a's passages through the Phoenix archipelago in 1997

eastward. Such El Niño westerlies would have offered good opportunities for ancient navigators to make long eastward passages, such as those that resulted in the settlement of Easter Island and the probable discovery of South America, as well as facilitating long distance post-settlement interaction (Finney 1994 b; Irwin 1992:100).

In total Ka 'Imi Ku'a spent 68 days at sea, including a 28 day passage from Oahu to the Phoenix, across and down the wind, 17 days of passages within the Phoenix group (including 5 days downwind, 6 across the wind and 6 to windward) and finally a 23 day passage from Orona to Kiritimati, with 10 days tacking hard to windward in a vain attempt to sail west and 13 days running downwind to the east (Maps 1.1, 1.2). This experience, along with the accurate position fixes and the measurement of current speed permitted by the use of GPS (Global Positioning System), allowed calculation of performance on all points of sail. In light trades in a protected bay, Ka 'Imi Ku'a was able to sail 75° off the wind, but in the open sea her best average performance over 24 hour periods was 80°. Lewis noted similar windward ability for Micronesian canoes, as did Finney for Nālehia, a 12.7 m long Hawaiian double canoe (Lewis 1975:270; Finney 1977:1281). At these headings Ka 'Imi Ku'a could theoretically tack 12 to 17 miles a day to windward when sailing at speeds of 3 and 4 knots, equivalent to a velocity made good (VMG)[9] of 0.54 and 0.72 knots. Her best measured performance was more modest, 0.44 knots VMG in winds around force 4-5, decreasing to 0.2 knots VMG at about force 6-7 due to waves and surface drift. B. Finney reported a somewhat more modest performance for Nālehia, about 0.1 to 0.07 knots VMG (Finney 1977:fig.4). Ka 'Imi Ku'a's top speed is about 6 knots, but she averages 3.2 to 4 knots over 24 hour periods on a beam reach or a run (90° to about 160° off the wind). These relatively low speeds can in part be attributed to the prudence of her two person crew, who reefed her sails at night, but also to her small size, in particular her short waterline length (9.4 m).

The maritime world of a Phoenix navigator

Beyond these performance data is the experimental archaeologist and his attempts to reconstruct the voyaging routes of the past, by making strategic use of the winds. The long days at sea, studying weather charts and plotting courses, allowed us to visualize the changing accessibility of islands. On our mental map, islands would recede or draw closer as the possibility of holding their course changed with the shifting winds. For example, as the westerlies continued to blow throughout early October, the possibility of attaining Tarawa in the Gilbert archipelago became impossibly remote and the northern Lines entered our world.



Each ray is one month whose length records all winds (100%).

Distance of black line from center represents the % of favorable winds for sailing toward the Phoenix from the indicated island.

Distance of grey line from center represents the % of favorable winds for sailing away from the Phoenix Islands.

Map 1.3: Ease of two-way voyaging centered on the Phoenix Islands, based on average weather conditions during the last one hundred years.

Monthly percentage of favorable winds plotted for two-way voyages between the Phoenix group and each surrounding archipelago. Ease of voyaging for each month along a course between the Phoenix and the indicated island is calculated from the product of favorable winds encountered from the Pilot Chart of the South Pacific Ocean (Defense Mapping Agency 1990) and the Routing Chart of the South Pacific (Hydrographer of the Navy 1991). Favorable winds are those which allow a canoe to sail the course without tacking.

We developed a simple model to formalize these ideas, linking prevailing winds to sailing performance, which could be applied anywhere in the trade wind zone, although we will discuss it from the point of view of navigators from the Phoenix Islands. With this archipelago at the center, the sea would be divided into three sectors or zones, one east (usually upwind with respect to the trades), one west (usually downwind) and one across the wind to the north and south (Map 1.3). The eastern sector is 160° wide or 80° either side of the prevailing wind, reflecting the windward capability (or limits) of a canoe. Even the nearest islands in this sector, such as the northern Cooks, lie impossibly far away upwind, as long as the trades are blowing. The second zone lies roughly across the wind and spans the 20° angle within which it would be possible to reach another land and still return to the Phoenix, again based on the windward capability of a canoe. Across the wind is the fastest point of sail, bringing all islands within this zone "closer" to the Phoenix. To the north lies empty ocean for almost 2,000 nm, of little interest to sailors. The south is more appealing with two nearby archipelagoes, Tokelau and Samoa. The western or downwind sector mirrors the eastern one. It is 160° wide, 80° either side of a course directly downwind. Once a canoe enters this zone, it has crossed the point of no return, at least during the trades. It could easily have reached Tuvalu or the Gilbert group in Kiribati which form a wide screen downwind, but would have great difficulty sailing home against the trades.

This model represents the world from the Phoenix Islands during prevailing trades, but as Finney has pointed out, "*the southeast trade winds... do not prevail always and everywhere*" (Finney 1985:11). Navigators would be strategically exploiting both the annual and the less frequent El Niño westerlies to expand their world eastward (Finney *et al.* 1989). The annual westerlies might be more precisely described as winds that accompany a series of low pressure troughs that sweep across the subtropical Pacific from west to east, interrupting the tradewinds (Finney 1994 b:7-8). Individual weather systems could have been used by navigators from the Phoenix Islands to reach nearby archipelagoes in the eastern sector, such as the northern Cooks. Successive troughs may even have carried navigators further eastward by stages. But only prolonged El Niño westerlies would have been sufficient for longer voyages. Canoes at sea, surprised by such westerlies, may have had little choice but to sail eastward, since days of gale force winds may accompany their onset and would have obliged any undecked canoe to run downwind. However far east one went, it would have been relatively easy to retrace the voyage when the trades resumed. In contrast, a two-way voyage into the western sector is never as certain, because of the difficulty of predicting the arrival of the westerlies. The wait could be long (several months) and a navigator would be wise to choose a friendly island, one whose inhabitants would be willing to feed stranded sailors.

The archaeological record for the Phoenix has evidence of both across and down the wind inter-archipelago voyages (Di Piazza and Pearthree 2001 a). The across the wind link was with Samoa, perhaps via Tokelau, as indicated by imported basalt artifacts. The down the wind route was sailed by the original settlers, who probably came from central East Polynesia, as evidenced by their marae architecture and pearl shell fishhooks. These explorers would have been sailing into their own western sector, and found the uninhabited Phoenix Islands a congenial place to live, because of their pristine food resources. In light of our model, and accepting Irwin's premise that settlement is likely to be preceded by two way voyages of discovery (Irwin 1992:60-61), we can infer that navigators from East Polynesia would have had long waits in the Phoenix before returning home. This would have given exploratory parties the chance to inventory resources and perhaps find the other nearby islands. Had they returned home using an El Niño westerly, and assuming that the event was preceded by months of rainy weather as it was in 1997, they would likely have carried a favorable opinion, having seen the Phoenix at their wettest. From the model we can also learn that the across the wind route to the Samoan basalt quarries would have been possible throughout the year, and would have required only short stopovers.

Original settlers: a review of earlier hypotheses

Previous authors have presented other scenarios for settlement, emphasizing different navigational aspects, which we will apply specifically to the Phoenix archipelago. Andrew Sharp argues for colonization by one way or accidental voyages, although he allows purposeful voyaging up to a limit of about 300 nm (Sharp 1963:105). Thus, Tokelau would have been the most likely source for the Phoenix settlement, since the archipelago lies well within this distance. Levison *et al*, who tested the drift aspect of Sharp's theory, showed the unlikelihood of drift from anywhere, except Jarvis or Malden in the central Lines, and concluded that the Phoenix were probably settled by purposeful navigation (Levison *et al.* 1973:36, 52-53). Irwin hypothesized that the exploration of the Pacific was systematic and followed a general directional trend of exploration which for safety, led navigators first against the prevailing winds, and only later across and down the wind (Irwin 1992:42-63). Thus, depending on which of his 3 phases relate to the discovery of the Phoenix, they could have been found sailing upwind from Tuvalu, across the wind from Tokelau or downwind from the northern Cooks or beyond in central East Polynesia. Irwin's specific mention of the Phoenix is apropos their accessibility, defined as the target angle divided by the distance from the nearest inhabited island. In that case, the target angle from Atafu (Tokelau) in West Polynesia to the "island block" formed by the 6 eastern Phoenix is about 23° and the reverse (from Manra, the closest of the Phoenix Islands, to the Tokelau island block) is 26°, making these groups easily inter-accessible instead of isolated as suggested by Irwin (1992:fig. 67). But since archaeology indicates settlement from East Polynesia, accessibility between the Phoenix and various possible eastern homelands is more important. Lewis noted that most recorded inter-island voyages had target angles[10] of 11° to 18°, and that 7.5° "*might represent something like the limits of navigational feasibility*" (Lewis 1975:163-164, 224-232, 231). Given this, it appears that the most likely source for Phoenix settlement are the northern Cooks (9.5-16°), the northern Lines (8.5°) or the southern Cooks (7.5°-8°) (Table 1.1).

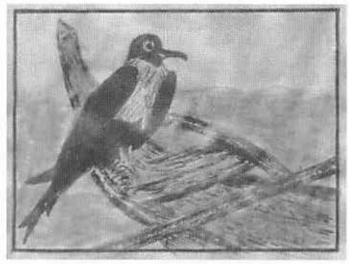
These models help us understand the maritime world of the Phoenix islanders, although they give a somewhat deterministic picture. One must not forget that these people had participated in the greatest maritime migration in prehistory as attested by the fact that all the far flung islands in East Polynesia were once settled, no matter how inaccessible (with the possible exception of the northwest Hawaiian atolls). This indicates attitudes and confidence that may have allowed navigators to transcend the windward ability of their canoes and to ride the stormy westerlies. These models perhaps reflect more on the "highways" used for regular inter-island exchange, than they do on the "paths" taken by lucky fishermen following tuna and homing birds.

Target angle to the Phoenix island block from:	Angle (°)	Angle (°)	Target angle from Manra or Kanton to:
Pukapuka (N. Cooks)	16	5	Pukapuka-Nassau
Tongareva (N. Cooks)	9.5	3.5	Tongareva
Kiritimati (N. Lines)	8.5	19	Kiritimati-Teraina
Starbuck (Central Lines)	7.5	3	Starbuck
Vostok (Southern Lines)	7	7.5	Flint-Caroline
Palmerston (S. Cooks)	8	10.5	Palmerston-Aitutaki
Aitutaki (S. Cooks)	7.5	10.5	Aitutaki-Palmerston
Manuae (Societies)	6.5	7	Manuae-Tupai
Hawai'i	4	15	Niihau-Hawai'i

Table 1.1: Inter-archipelago accessibility between the Phoenix island block and various possible homelands in East Polynesia, using a 20 nm expanded landfall radius.

Target angles are calculated using the closest island in the Phoenix archipelago to possible homelands; Manra for central East Polynesia and Kanton for Hawai'i.

CHAPTER 2



"Birds are the Navigator's Very Best Friends"

Birds as land and fish indicators

> *"He fills out the sail, taking in the sheet.*
> *He sees the black tern and the booby*
> *And the snowy white fairy tern.*
> *He knows he is close to shore.*
> *Of the several techniques a Carolinian navigator has for "expanding" his target, the most effective depends on his knowledge of birds. Birds provide just one of the "screens" that the navigator uses to deflect him inward to his destination, or to catch him should he overshoot it"*
> (Brower 1983:128).

In 1816 Otto von Kotzebue narrowly missed discovering the Phoenix Islands, although he guessed their presence from "*a great quantity of sea-birds, which after sun-set flew to the south... we could not doubt, from the great number of birds, that we were near many uninhabited islands and rocks, and if time had permitted, I should have followed the direction of the birds to the S.W. ; but, as it was, the current took us every day from 33 to 45 miles to the N.W*". At the time the vessel was around 3°14'34" S and 168°25'33" W, some 150 miles northeast of Phoenix island. Four days later, at 1°17'46" N and 177°5' W, the crew came "*among sea-birds, one land-bird, but could see no land, even from the mast-head; which made us conclude that it lay very low*". Kotzebue was again correct as Howland island lay just over the horizon, about 30 miles to the southeast (Kotzebue 1821:vol. 1, 169, 170). Not only did he postulate a good direction for the land, but he did so over distances significantly farther than has been allowed in current discussions of oceanic navigation (Gladwin 1970:196-199; Lewis 1975:162-173). Teeta Tatua of Kuria, a gilbertese navigator and one of Lewis' instructors, summarized the situation this way: "*Birds are the navigator's very best friends... Birds are very useful up to twice the sight range of an island from a canoe... The sight range of land is about ten miles and that of the birds twenty. The birds which are most significant are terns and noddies*" (cited by Lewis *op. cit.*:162). Hipour of Puluwat atoll, who steered Lewis to the Marianas, added that boobies, although uncommon in Micronesian waters, are the most favored of all bird guides. They display interest in any sailing vessel and are encountered further offshore than white terns and noddies, about 30 miles off (Lewis *op. cit.*:167). But confidence should not be placed on isolated sightings. As Gladwin notes, the navigator "*is not concerned with how far out he might conceivably see a given species of bird. Instead he wants to know how far out he can rely on seeing that same bird any time he needs it*" (Gladwin 1970:196).

To test how good birds actually were at indicating land, we identified, counted and plotted the position (with a GPS) of all birds while sailing on Ka 'Imi Ku'a. In contrast to Lewis' study, which took place on several settled island groups in the western Pacific (Carolines, Tonga, New Guinea, etc.) where birds have been heavily depleted by humans, our observations in central Polynesia relate to archipelagoes that are unoccupied (Phoenix Islands except Kanton) or recently reoccupied (Northern Line Islands). They attest to a wider bird screen. The fact that most seabird species no longer breed on occupied archipelagoes probably explains the discrepancy between Kotzebue's account and observations in Micronesia, but more importantly, it supports the hypotheses that at the time of discovery, the target angle of all islands would have been much wider because of their pristine avifauna. Today the Phoenix Islands, a refuge for millions of breeding seabirds, offer the best analog to the world encountered by ancient navigators during their expansion into the Pacific.

Observing seabirds

All observations were made with unaided eyes, although some identifications were confirmed with binoculars during the first few days. The distance we were able to identify birds to species is about 0.3 nm during clear weather.

This method contains numerous biases:

- Watch acuity: our acuity of observation varied. As Lewis (*op. cit.*:172) pointed out: "*The number of birds logged by a man casually on watch will bear absolutely no relation to the number picked out and identified by keen-eyed* *islanders, who search for them hour after hour with absolute concentration, as their destination draws near"*.

- Misidentifications: several taxa of seabirds, particularly petrels and shearwaters are notoriously difficult to identify. A careful effort was made to separate birds within this family based on size, flight behavior and plumage. There are probably some misidentifications among more than 1,900 observations, but likely not enough to skew our interpretations. We could not distinguish between different species of storm petrels, so we combined the two genera *Nesofregetta* and *Oceanodroma*. The white-naped petrel was provisionally identified just once.

- Feeding habits: differences in frequency are not only related to distances from land, but also to local factors such as upwellings, current lines, drift objects, weather conditions, as well as cultural activities such as fishing.

- Curiosity of birds: boobies for example, are conspicuous and display great interest in any sailing vessel. Therefore, they are likely to be counted. Petrels and shearwaters on the other hand, are not.

All birds sighted were seabirds, except for some ruddy turnstones observed at sea near Orona (Table 2.1). Sooty tern, shearwaters and boobies account for 94% of all birds between Hawai'i and Enderbury (Fig. 2.1). Between Orona and Kiritimati the pattern is very similar. Sooty terns, Christmas shearwaters and boobies represent 80% of all birds, and black-naped terns an additional 8%. Within the Phoenix archipelago, land based seabirds (common fairy terns, black and brown noddies) make up 26% of all birds, whereas they are negligible (less than 1%) in the open sea. But even there the most numerous species are still boobies and sooty terns, which add up to 67%. A more detailed analysis allows some useful insights about expanded target landfall, that is the distance and direction certain species may reliably indicate land (Fig. 2.2).

Frigatebirds

Flocks of 5 to 7 frigatebirds (*Fregata minor*) were always encountered within 90 miles of land. Gatty (1943:36) suggested that they were useful, but over shorter distances. He noted that when six or more frigatebirds are seen, land should be within 75 miles. Only 2 lone individuals were observed far at sea (about 350 miles from land) on the crossing from Hawai'i to Enderbury. In contrast, 19 frigates were seen close to land in the Phoenix group. The majority of these birds are presumed to be "*nonmigratory residents that do not wander far from their breeding islands*" (Harrison 1990:145). Frigates may also be used to indicate the direction to land, at least in the morning hours. We have frequently observed low flying frigatebirds travelling directly away from atolls at sunrise, when the thermals they

Taxon*	Common name*	Useful distance to land	Notes on behavior
Puffinus pacificus	Wedge-tailed shearwater	Found at any distance	Pelagic
Puffinus nativitatis	Christmas shearwater	Found at any distance	Pelagic
Puffinus lherminieri	Audubon's shearwater	Found at any distance	Pelagic
Pterodroma cervicalis (?)	White-naped petrel	Found at any distance	Pelagic
Pterodroma alba	Phoenix petrel	Found at any distance	May be useful at night near breeding colonies
Nesofregetta/ Oceanodroma	Storm petrel	?	Pelagic, uncommon
Phaeton lepturus	White-tailed tropicbird	Found at any distance	Solitary
Phaeton rubricauda	Red-tailed tropicbird	Found at any distance	Solitary
Sula dactylatra	Masked booby	<100 miles if 2 or 3 individuals<30 miles if in large groups	Visits boats, easily seen, indicates land up to 100 miles
Sula leucogaster	Brown booby	<25 miles if in groups>5	Visits boats, indicates land up to 25 miles
Sula sula	Red-footed booby	Found at any distance in groups up to 4	Visits boats, easily seen
Fregata minor	Frigatebird	75-90 miles if 5-7 individuals	Flies high when returning to island, difficult to see
Arenaria interpres	Ruddy turnstone	?	Shore bird, may be observed at sea
Sterna bergii	Great crested tern	Up to 300 miles	Usually on lagoons, but migratory
Sterna sumatrana	Black-naped tern	Up to 200 miles	Usually close to land
Sterna lunata	Spectacled tern	Found at any distance	Pelagic
Sterna fuscata	Sooty tern	Found at any distance	Pelagic
Anous stolidus	Brown noddy	20-30 miles	Homing bird, short daily range
Anous minutus	Black noddy	20-30 miles	Homing bird, short daily range
Gygis alba	Common fairy tern	20-30 miles	Homing bird, short daily range

Table 2.1: Value of seabirds for navigators.

(*Pratt et al. 1987)

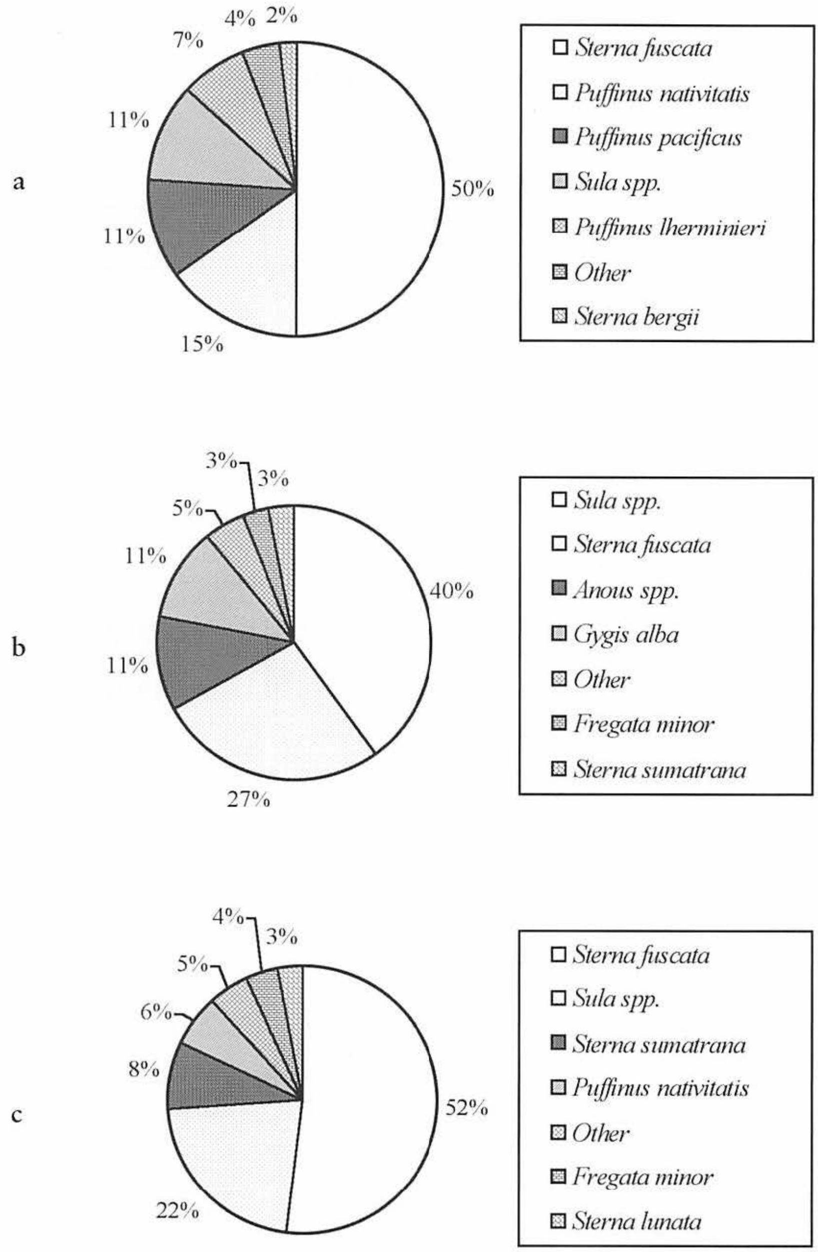


Fig. 2.1: Relative frequencies of birds encountered during Ka ‘Imi Ku‘a’s passages from Hawai‘i to Enderbury (a), from Orona to Kiritimati (b), and within the Phoenix group (c)

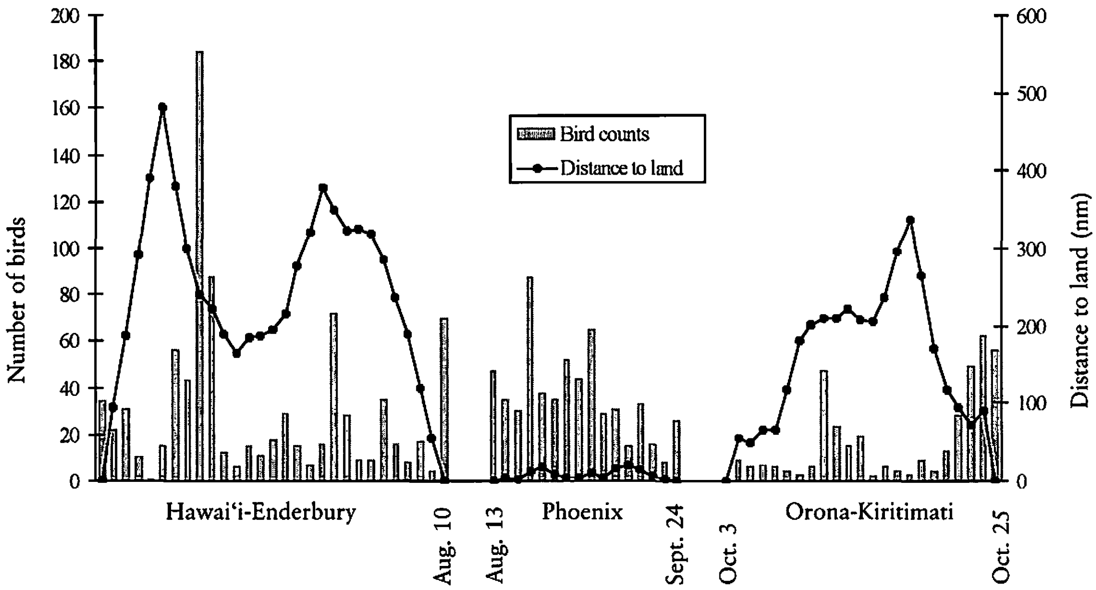


Fig. 2.2: Daily bird totals and distance to nearest land
Half of the bird observations were made within 70 miles of land

use for soaring high are absent. Gillett has suggested that they may fly too high to be visible when returning to their home island in the evening (1987:table n°7). Frigates were usually observed capturing their own food on the surface of the sea and only occasionally harassing boobies or shearwaters for food. This suggests that our bird data were collected during a period of food abundance. According to Harrison, theft occurs mostly during periods of food stress (*op. cit.*:147).

Boobies

Ninety-nine boobies (11% of all birds) were counted between Hawai'i and Enderbury, 269 (50%) within the Phoenix archipelago and 84 (25%) between Orona and Kiritimati (Plate 2). They are pelagic feeders. Isolated adults of all three species, flocks of up to 6 immature individuals, as well as smaller groups of up to 4 adult red-footed boobies, were encountered as far as 378 nm from land. Immature and non-breeding adults are more pelagic than breeders, who must forage close to their nesting islands. On Hōkūle'a's first voyage to Tahiti in 1976 immature boobies were sighted by a Tahitian crew member, some 400 to


2. Booby visiting Ka 'Imi Ku'a, 270 nm from Enderbury, south of the doldrums, on the equator.

500 nm away from the nearest island (Finney, *pers. com.*). Brown boobies and masked boobies appear to be good land indicators. Brown boobies occurred in groups of 5 or more within 25 nm of land, while masked boobies were seen in smaller groups (2-3 individuals) at around 100 nm, and as large groups (>13) less than 30 nm from land[11]. These ground nesting species are rare on inhabited loci and would probably have been more numerous in the past. Boobies generally visited Ka 'Imi Ku'a and would escort her for several hours, benefiting from small flying fish disturbed by the bow wave. These boobies were usually associated with mixed feeding groups of terns and shearwaters.

Tropicbirds

Tropicbirds were rarely observed at sea, although red-tailed tropicbirds are common breeders in the Phoenix Islands. Six of them (1% of all birds) were seen between Hawai'i and Enderbury, 2 (<1%) within the Phoenix group and 6 (2%) between Orona and Kiritimati. Nearly always lone individuals, they were observed at all distances from land. Thus they do not seem to be of great use for navigators. While attracted to Ka 'Imi Ku'a and her school of fish, they never remained long.

Terns

Laridae comprises two groups of species, those generally encountered close to land and those which are truly pelagic. The first group consists of the three species of noddies and the common fairy tern. The second group includes four species in the genus *Sterna*. Only 2 noddies were encountered, when approaching Enderbury, out of a total of 881 birds between Hawai'i and the Phoenix, and 5 out of 382 birds between Orona and Kiritimati. In contrast, 43 brown and 27 black noddies (11% of all birds), mostly in flocks, were seen within the Phoenix group, less than 20 miles from land. The blue-grey noddy, breeding on Phoenix island and possibly on Enderbury, was never observed at sea. Common fairy terns behave like the brown and black noddies, but are even rarer. Two individuals were sighted hundreds of miles from land during the voyage and 70 within the Phoenix archipelago as far as 20 nm from an island. These data corroborate Lewis' statement. Indeed, noddies and white terns "*are consistent land guides to double the sight-range of atolls, or 20 miles offshore*", but isolated birds may be found at any distance (Lewis *op. cit.*:170). According to navigators from Nikunau, in the Gilberts, the lower wing of a white tern points toward land when flying high. The three species of pelagic terns: sooty terns, spectacled terns and great crested terns are widely dispersed on the ocean. As Harrison (*op. cit.*:178) states, sooty terns "*are among the most pelagic of seabirds*". Four hundred and seventy four terns (51% of all birds) were counted between Hawai'i and Enderbury, 239 (51%) from Orona to Kiritimati and 209 (27%) within the Phoenix archipelago. Navigators from Nikunau say that tamed black-naped terns may look for their master if he has gone missing at sea.

Petrels and shearwaters

The family name of petrels and shearwaters, Procellariidae, is derived from the latin procella or storm (Harrison op. cit.:121). They are well named, being the first birds to visit Ka 'Imi Ku'a after squalls had passed. The great majority of them, 290 individuals belonging to 5 species (33% of all birds), were observed between Hawai'i and Enderbury. Wedge-tailed shearwaters and Christmas shearwaters dominate. Only 21 procellarids (3%) were counted within the Phoenix group, and 32 (8%) between Orona and Kiritimati. This pattern underlines their pelagic nature. Harrison writes (*op. cit.*:124): "*most shearwaters and petrels spend many years at sea before breeding and thus at any one time much of any population is observed only at sea. They do not make their first landfall until they reach about five years of age and first breed several years later*". These counts also indicate a very uneven distribution. Abundant in the first part of the voyage, shearwaters were rare thereafter. This may be the outcome of human disturbance in the past. Immature procellarids are highly prized for food throughout Polynesia. Feather hunting, rats and the widespread destruction of WWII have severely depleted populations on most islands, including those on Kanton and Enderbury. Large populations are only found on the most isolated islands today, such as Phoenix island and McKean, or the Northwest Hawaiian Islands (Garnett 1983; Harrison *op. cit.*:123).

In summary, it appears that noddies and white terns, which are able to breed on islands with human populations, indicate land up to about 20 miles (Table

2.1). Masked boobies, as well as frigate birds, which only nest on unoccupied islands, seem to be useful up to 100 miles or so when in flocks. These distances considerably expand the target to aim for. The discovery of the Phoenix may indeed owe a lot to these two species. Some of the Procellariidae may also be more trustworthy for land finding than previously recognized. Large numbers of Phoenix petrels, probably breeding birds, were seen flying away from Phoenix island right after dusk, presumably to return to their burrows the next night.

Birds as fish indicators

The ocean is not a uniform space. Particularly in the tropics, marine resources tend to be patchy, with large regions of low productivity and small concentrated areas of higher productivity, especially in upwelling zones, where seabirds congregate to feed (Harrison *op. cit.*; Wiens 1962). These gatherings are good indicators of the presence of schools of fish, particularly tuna, greatly appreciated by navigators. One of the best fishermen on Kiritimati told us that such feeding flocks were not only sought after for fishing, but for birds too, a delicacy still hunted with sticks from canoes.

To further investigate the nature of seabird distribution, we plotted our daily observations by latitude for the North to South part of the voyage, from Hawai'i to Enderbury[12] (Fig. 2.3). Peaks of seabirds are illustrated by boobies, sooty terns and shearwaters. The three species of boobies gather at different latitudes, an indication of the location of their favorite prey (Fig. 2.3a). Peaks of sooty terns and procellarids occurred within the same zone (Fig. 2.3b). They probably feed on similar food. There is a latitudinal shift in species within the genus *Puffinus*. The northern population is dominated by two species, the wedge-tailed shearwater and the Audubon's shearwater (88% of all procellarids), the southern by the Christmas shearwater (91%) (Fig. 2.3c). The boundary, about 4.5°N on July 25-26 1997, was the northern edge of the equatorial countercurrent, probably defining a zone of upwelling with abundant tuna. Within the Phoenix and just west of the Line Islands, tuna and pelagic birds were concentrated into two narrow bands, between 1.66 and 1.8° S (about 60 to 80 miles north of Kanton and Enderbury) and around 1.5° N (between Tabuaeran and Teraina). Due to the southward shift in winds and currents during the austral summer, these schools may occasionally swing even closer to land, making them more accessible to fishermen. These seabirds certainly live up to their billing as friends to sailors, helping to expand landfalls, indicating the presence of schools of fish and giving important clues about changing currents.

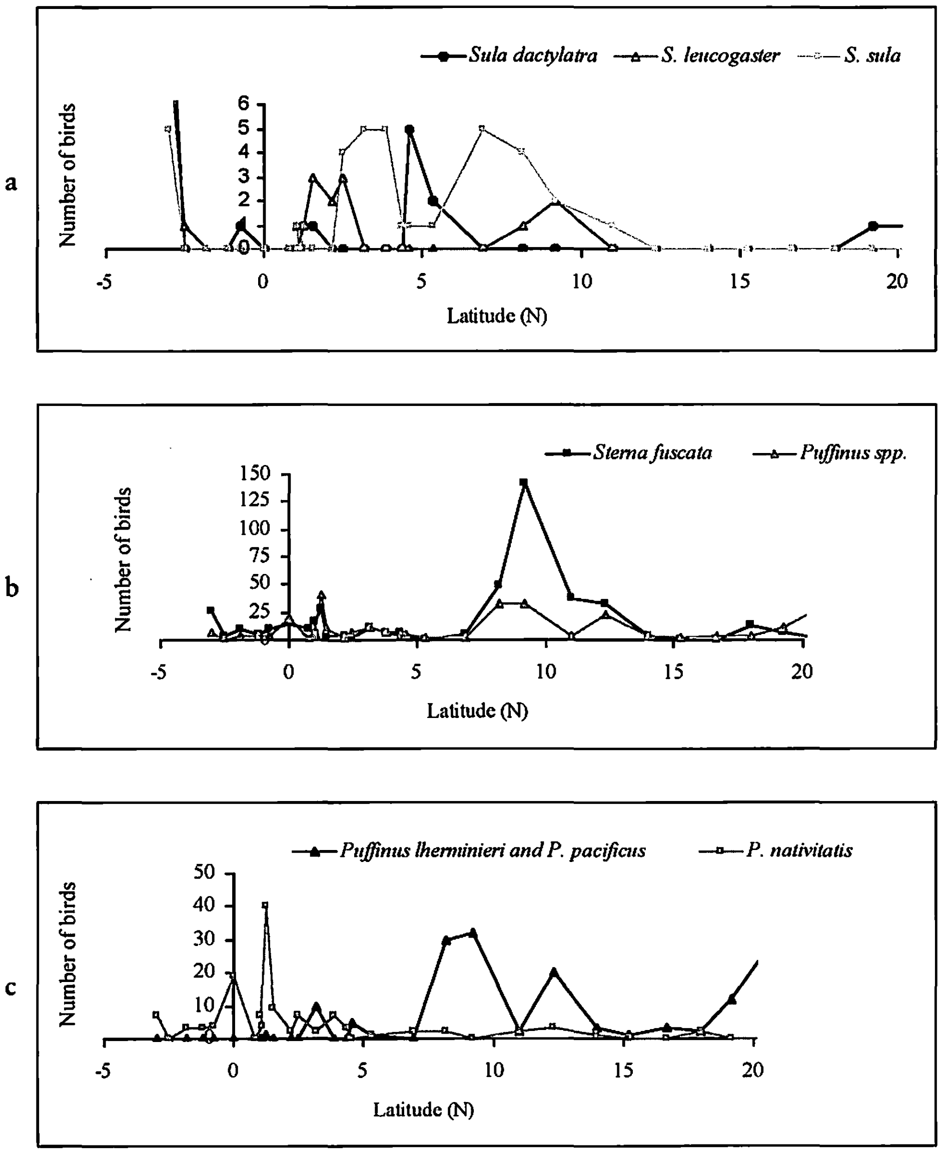
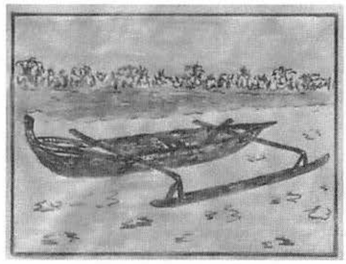


Fig. 2.3: Species change by latitude (Hawai'i-Enderbury)

a) Comparison of 3 species of Sulids. Peaks probably indicate relative abundance of favored prey for each species. b) *Sterna fuscata* compared to 3 species of *Puffinus*. Both taxa seem to feed on the same food. c) Distribution of 3 species of *Puffinus*. Latitudinal shift in dominant species occurred between 2.5 and 4.5°N, the northern edge of the equatorial countercurrent.

CHAPTER 3



Discovery, Voyaging and Experimental Canoes

Toward an outrigger of old

> *"Today conditions are so changed by long-continued contact with what is termed "white civilization", represented by explorers, missionaries, whalers, traders and globe-trotters, that the maritime activities of the past are represented in shadowy, vague, and uncertain outlines. An immense amount of labor became [and still is] necessary before a true appreciation could be attained of the characteristics and details of the sea-going craft of the islands as they existed when Magellan, de Quiros, Schouten, Tasman, Cook, Bougainville, and the rest of the great galaxy of early Pacific navigators sailed among the archipelagoes "* (Haddon and Hornell 1975:3).

Ka 'Imi Ku'a proved to be a handy vessel on ocean passages, as well as for observing birds from her raised deck, but unsuited to the reef landings of the Phoenix Islands. This experimental vessel was well adapted to long distance voyaging even in rough seas but proved to be too large to land through surf, too heavy to be dragged up the beach and too high sided to be paddled any distance. In the Phoenix Islands she was able to land solely on the island of Kanton, due to the presence of a reef pass. On the other islands only modern steel anchors and mooring lines saved her from shipwreck. This experience led us to question the suitability of double canoes like Ka 'Imi Ku'a for voyages to the majority of islands in Oceania which lack protected landings. But this question makes sense only if Ka 'Imi Ku'a handles quite similarly to the model she is based on: a Tahitian tipairua.

Ka 'Imi Ku'a: a construction between tradition and modernity

Details of design such as size, form and weight are the aspects that most influence the behavior of a boat. Ka 'Imi Ku'a has round bottom hulls and fore and aft rocker like the originals, although her hulls are some 30 cm longer and 15-20 cm wider on the waterline than Pâris' canoe. Her construction followed a quasi traditional pattern. First, the bottom was adzed smooth and planed. The bow and cutwater were shaped out of solid timber. The side planks were attached to the bottom and held by temporary braces. Instead of adzed planks, breadfruit sap and coconut fiber, milled timber and epoxy glue were used. After the shell was completed, the internal framing was inserted. Then the lashing cleats, decks and cabins were installed. As a final step, her timbers were coated with a layer of fiberglass to guard against marine borers. These untraditional materials saved effort hollowing out log underbodies, braiding kilograms or kilometers of coconut fiber line for the lashings, drilling and caulking the hundreds of holes and constant bailing at sea, but should have little or no effect on hydrodynamic performance.

With her massive timber construction, Ka 'Imi Ku'a is probably no lighter than traditional dugouts with built up wash strakes. Her hull bottoms are of solid timber, 1.5 inches (38 mm) thick. The topsides are 5/8 inch (16 mm) plywood framed with 2 by 4 (38 by 89 mm) and 2 by 6 (38 by 140 mm) timbers. There is about 2,600 kg of timber in the canoe, about 35% is plywood. Each hull weighs about 1150 kg (2,500 lbs.)[13]. The deck, rigging and crossbeams weigh an additional 700 kg (1,500 lbs.). The complete weight of the empty boat is around 3000 kg (6,500 lbs.).

As far as performance goes, the bigger size of Ka 'Imi Ku'a should lead to slightly greater average speed at sea than the Pâris canoe, if all other variables such as sail area, rig efficiency and load were comparable. Ka 'Imi Ku'a has Micronesian quarter rudders rather than steering paddles and dacron lugsails in place of the original pandanus mat spritsails. She also has epoxy glued joints that are certainly stronger than planks sewn with coconut sennit. The implication of these departures from the original are that Ka 'Imi Ku'a is probably both more maneuverable and tougher than the ancient tipairua and that these canoes would have been at even more of a disadvantage landing in difficult conditions.

Discovery versus settlement canoes

Returning to the question adressed above, might it be that Tahitian tipairua in particular and large doubles in general were not used for voyages to islands with difficult landings? In fact, the model Ka 'Imi Ku'a is based on is just one of many types of canoes used in ancient Tahiti. Wallis, the first European to observe Tahitian canoes, noted three sorts. Small 2-6 man dugouts for reef fishing, larger plank-built canoes, either rigged as doubles with two masts or outriggers with one mast in the middle. *"With these vessels they sail far beyond the sight of land, probably to other islands... The third sort were intended principally for pleasure and show: they are very large, but have no sail..."* (Wallis cited in Hawkesworth 1789:195-196). William Ellis, a missionary living in Tahiti in the early 1800's made numerous canoe voyages. He wrote that it was the large solidly built va'a motu or outriggers that were principally used for distant voyages. He also noted that tipairua 9-12 meters long were used for travelling (Ellis 1972: 117; Haddon and Hornell 1975:131). The term motu is interesting since its primary meaning refers to atolls or islets that usually lack protected landings. If our earliest and best descriptions of voyaging canoes come from Wallis and Ellis, the best illustrations of such vessels are those of Webber from 1777 and Pâris from 1827. Pâris depicted both single and double canoes from 8.5 - 11 m and noted that the largest was a two masted va'a motu for long distance voyaging. From these sources about the Societies, the archipelago for which we have the best documentation within Polynesia, we can deduce that voyaging canoes could be either single, double or could be two singles rigged together, that they had either one or two masts and that they varied from about 9 to 12 meters long. With such a wide range of types and sizes of voyaging canoes, it seems likely that different canoes were adapted to different conditions. And from the experience of Ka 'Imi Ku'a, it appears that voyages to the many islands that lack protected beaches would have been made in canoes light enough to have been carried or dragged over the reef by their crews. In the case of voyages of discovery, where conditions of landing would have been unknown, and where no assistance could be expected from ashore, single canoes would be more appropriate. Additional support for outriggers as voyaging canoes is that in the case of a capsize, they can be righted and sailed away with relative ease and without assistance, unlike double canoes which would be lost (Ellis 1972:120; Wilson 1799:401, 402 cited in Haddon and Hornell 1975:121). In contrast, double canoes with their greater cargo capacity seem more adapted to voyages of settlement, particularly to islands already known to have good landings. To put it another way, each type of voyage would have had its particular canoe. If as Durrans (1979: 155-156) wrote *"large sailing double canoes... have come to be the key colonizing vehicles in Polynesia"*, we can go one step further in suggesting that middle sized outriggers are the canoe of discovery.

A virtual voyaging canoe for the Phoenix Islands: an alternative to Ka 'Imi Ku'a

If indeed discovery canoes were lightweight outriggers, seafaring must have been far less expensive -in terms of timber and labour- than previously thought. A dynamic model, investigating the response of a native forest to the construction and maintenance of a fleet of canoes over time, supports this hypothesis. To run the simulation, we used parameters based on the forest of the Phoenix Islands and on canoes of neighboring atolls.

What would it require to build an 11 m long outrigger or a fleet of such canoes, in terms of available timber species and volume, in the Phoenix Islands? Among the 16 species most commonly used for canoe construction on atolls (Emory 1975; Whistler 1988), 9 are widespread throughout the archipelago, except on Birnie, Phoenix and McKean which have no trees at all, and probably never had (Garnett 1983) (Table 3.1). The timber resources at present are probably much

Botanical taxa	Canoe parts	Status in the Phoenix archipelago
Artocarpus altilis	Hull/planks/caulking	Modern introduction on Kanton and Nikumaroro
*Cocos nucifera**	Lashings/iako	Prehistoric introduction, common
*Cordia subcordata**	Hull/planks	Indigenous, common
Ficus tinctoria	Lashings/float	Modern introduction on Kanton
*Guettarda speciosa**	Hull/planks/iako/spars	Indigenous, common
Hibiscus tiliaceus	Lashings/float/spars	Modern introduction on Kanton
Inocarpus edulis	Hull/planks/iako/spars	Drift wood, common
*Morinda citrifolia**	Float connectives/iako/spars	Indigenous, common
Pandanus spp.	Sails/iako/spars	Indigenous (?), common
*Pemphis acidula**	Connectives	Indigenous, common
Pipturus argenteus	Lashings	Unknown
Pisonia grandis	Float	Indigenous, common
Suriana maritima	Connectives/caulking	Indigenous, common
Terminalia sp.	Hull/planks/iako/spars	Naturalized on Manra and Nikumaroro
Thespesia populnea	Planks/spars	Unknown
*Tournefortia argentea**	Planks/floats	Indigenous, common

Table 3.1: Possible canoe trees from the forests of the Phoenix Islands
The category Indigenous includes taxa widely naturalized. Archaeologically known taxa are indicated by an asterisk (*)

smaller than they were as recently as the turn of the 20th century century, when much of the native forest was cleared to plant coconuts. But even today there are a relatively large number of potential canoes either as standing timber in the forests, or lying on the beach as drift logs.

On the neighboring inhabited atolls of Tuvalu, Tokelau and the northern Cook Islands, canoe hulls are made of one or more dugout sections of Polynesian rosewood (*Cordia subcordata*) - although kamani or tamanu (*Calophyllum inophyllum*), breadfruit (*Artocarpus altilis*) or beach heliotrope (*Tournefortia argentea*) may be substituted - with raised sides and end covers (Haddon and Hornell 1975; Neyret 1974). Their size appears to be a compromise between available timber, labor input and safety for off-shore sailing. Their breadth, limited by tree diameter, is usually 0.5-0.6 m, up to a maximum of about 0.7 m. Their depth, about 0.7-0.9 m, allows them to be paddled. Their length, from 8 to 11 m, appears to be set by conditions of landing. The estimated timber volume to build such a canoe is about 2 m^3 for one hull[14]. It is the quantity used in the simulation to build one virtual canoe.

Our virtual forest consists of 1 ha. of trees from species suitable for building canoes. The tree population is subdivided into 4 age classes: seedlings (0-1 year), young trees (1-25 years) and two classes of mature trees (25-50 years and 50-100 year). As trees age, they progress from class to class until either cut for canoes or until they die of old age at 100 years. Seedlings sprout in any surface[15] not occupied by living trees. At the start[16], the forest consists of 1 ha of seedlings.

The 2 m^3 of wood to build our canoe would require harvesting 13 trees, 0.23 m in diameter from the 25-50 year age class or 1.7 trees, 0.5 m in diameter from the 50-100 age class[17] (Table 3.2). Various rates of cutting lead to a dynamic population of canoes, where "natality" is the rate of production and "mortality" is derived from the lifetime of a vessel, about 10 years (Ridgell *et al.* 1994:195).

	Trees aged 25-50 years	Trees aged 50-100 years
Trunk diam. at base	0.23 m	0.50 m
Trunk diam. at crown	0.115 m	0.25 m
Trunk height	6.45 m	10.65 m
Crown diam.	5.5 m	9 m
Crown area/tree (surf.)	24 m^2	64 m^2
Timber vol/tree	0.156 m^3	1.2 m^3
Nb of trees/ha	416.66	156.25

Table 3.2: Tree values used for the model
Data modified after Boyce (1995:52)

Forest dynamics and production of canoes

The simulation is divided into three strategies of forest exploitation, and runs over 1,800 years[18]. During strategy I, only 50-100 year old trees are harvested. In strategy II, equivalent volumes of timber from age classes 25-50 and 50-100 are exploited. In strategy III, only age class 25-50 is used. Within each phase, trees are cut at three rates: 1/2 canoe hull per year (1m^3 of timber), 1 canoe hull per year (2 m^3), and the maximum sustainable number of hulls per year[19].

At the two lower rates of exploitation, all three strategies give populations of 5 and 10 canoes (Fig. 3.1). At the highest rate of exploitation, canoe populations are maximized by using only large trees (strategy I). Using smaller trees leads to a decrease in the sustainable populations and an even larger decrease in potential canoes (standing trees) (Table 3.3). These different harvesting strategies, which affect the age structure of the forest, may have influenced traditions of canoe building. Strategy I would represent the dugout tradition of using large trees, while strategy III would represent canoes constructed with narrow planks from small trees. Today, both traditions are still known on low islands (Di Piazza and Pearthree

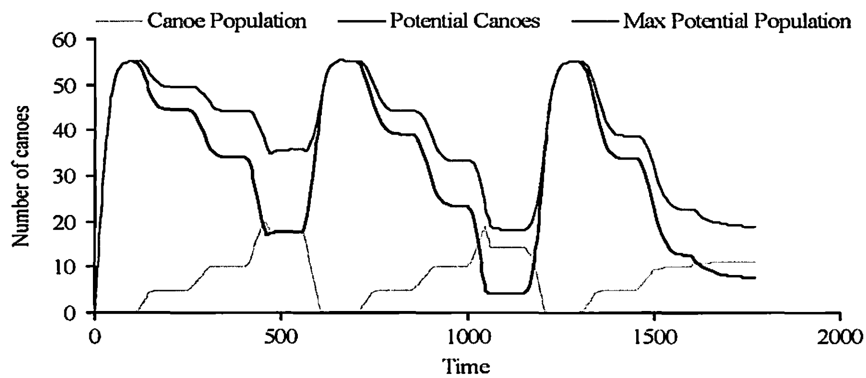


Fig. 3.1: Canoe population through time under three different harvesting strategies and three rates of exploitation

	Strategy I	Strategy II	Strategy III
Canoes built per year	1.8	1.4	1.1
Maximum sustainable population	18.2	14.2	11.2
Potential canoes (standing timber)	17.6	4.1	7.8
Maximum potential canoes	35.8	18.3	19.0

Table 3.3: Canoe populations under three harvesting strategies at maximum sustainable yield

Maximum potential number of canoes is the maximum sustainable population plus all available standing timber

2001c). On the relatively sparsely settled atolls of Tuvalu and Tokelau, canoes are built as dugouts, while in the more densely settled islands of the Gilberts and Carolines, canoes are made from planks. Labor input in both traditions is quite different. It is far less laborious to carve a dugout than to assemble many planks with fiber lashings. Planks must be dubbed to thickness and the joining surfaces have to be cut to match perfectly. Lashing holes must be bored, sennit installed and caulked. The lashings themselves are a constant source of maintenance, as is the bailing of water that continually leaks through the joints and holes. Plank built canoes also require regular rebuilding, every three months if they are in daily use (Lewis 1975:272). These points suggest that where large enough trees are available, canoes would tend to be dugouts, rather than plank built.

If our 11 m long virtual canoes carry 8 passengers, then a population of some 80 to 140 people would be able to evacuate their island using only their regular fleet, although many more canoes would be potentially available in the form of standing trees. These potential canoes are a kind of insurance against catastrophic events, such as prolonged droughts, typhoons, etc.

This simulation demonstrates that to sustain such a fleet of "discovery" canoes is neither outrageously expensive, nor necessarily damaging to the forest. More importantly, it puts atoll dwellers on an even footing with their high island neighbors, as far as being navigators, discoverers, traders and fishermen. Indeed, these "discovery canoes" were not specialized voyaging craft, but ones whose day to day employment would have been offshore fishing, especially trolling for tuna. To our knowledge, all the long distance voyages undertaken in Micronesia or Polynesia since the mid 1800's, were made in outrigger fishing canoes. Examples come from the Carolines and Marshalls (Lewis 1975), the Gilberts (Grimble 1924), Tikopia (Firth 1936), Anuta (Yen and Gordon 1973), Taumako, Santa Cruz (Davenport 1964) and even the Phoenix Islands (MacGregor n.d.; Bryan 1942:62). It may well be that the discovery of islands owes much to sailors seeking tuna fishing grounds. Trolling for tuna often calls for sailing out of sight of land, where the requirements for navigation and boat management are equivalent to those of long distance voyages (Gladwin 1970; Gillett 1987; Johannes 1981; Di Piazza and Pearthree 2001 c). And the widespread myth of Maui, pulling islands from the depths of the sea with his tapu fishhook, might be a metaphorical reference to this synergy between fishing and voyaging. Original sources, experimental voyaging and simulation suggest that quite different discoverers and canoes from those envisaged in the current orthodoxy can be proposed. Fishermen with low cost outriggers might well have been key elements to the discovery process of the Pacific. This "democratization" of voyaging opens new perspectives in regard to the number of offshore canoes active at any one time throughout Oceania, and thus makes the rapid colonization of East Polynesia more understandable.

PART II

SETTLEMENT PROCESS

THE QUALIFIER "MYSTERIOUS", still applied to the many islands occupied by the ancient Polynesians and then abandoned, reveals that even today they remain something of a historical puzzle. However, the fact that there are so many of them, at least 25 (footnote 1 in introduction), suggests that their occupation (and abandonment) reflects a colonization strategy carried out by skillful navigators and not "accidental occupations" by shipwrecked sailors. This observation helped us to change perspective. Rather than ask how people could have survived on such tiny, isolated islands, a question that directs one's thinking toward failed settlement and which emphasizes environmental constraints, a more interesting approach is: people chose to settle these islands, what did they find and what was their mode of existence? Marae, raised rectangular platforms, wet and dry agricultural pits, stepping stone trails, etc. give some answers. These remains testify to a population who built monuments, who were engaged in religious practices, who planted gardens, hunted seabirds and made long trading voyages, all activities consistent with ancestral Polynesian culture.

CHAPTER 4

Land of Abundance, Land of Misery

The environment of the Phoenix Islands

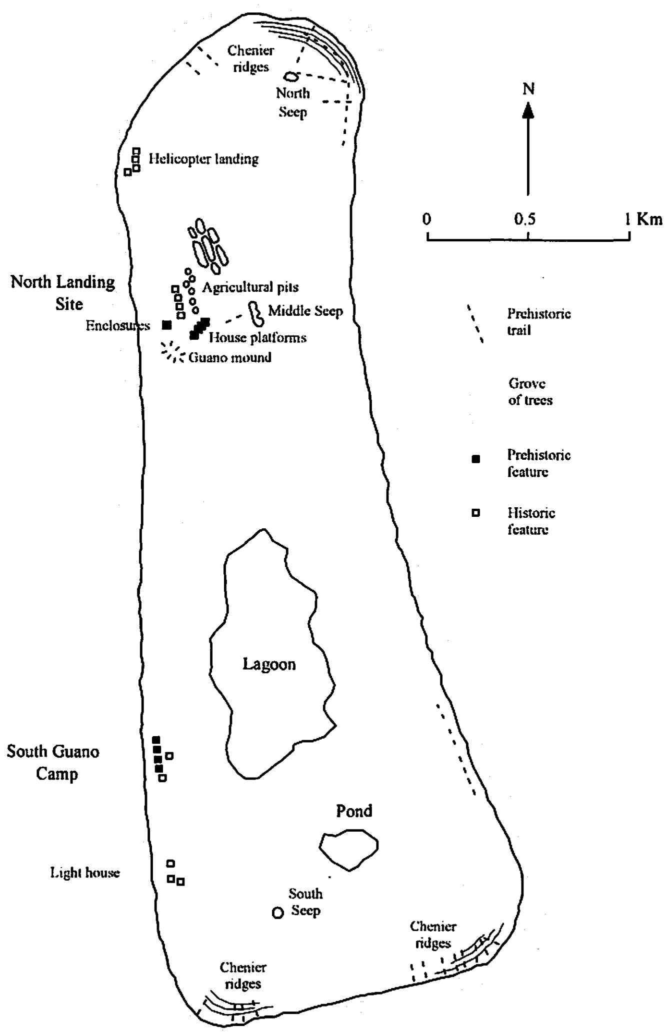
> "*This southernmost atoll [Sydney], possesses thick vegetation, a deep lagoon, and a brackish pond which might have been used for drinking water. Purslane grows on the island but no coconuts were reported growing there until planted for commercial purposes in 1905. For any earlier population, the food supply must have come almost entirely from the sea and lagoon...One may hazard a guess that the limited food supply was a major reason for the population of the island not remaining permanently*" (MacGregor n.d.:5).

> "*I consider that this island [Sydney] is suitable for permanent settlement... The soil is probably even better suited for the cultivation of native food bearing trees and plants [than that of Hull island]... Fish are plentiful off the reefs, but there are none in the lagoon. The native delegates considered the well water to be definitively good and above the standard of the average Gilbertese village well... I consider that at least 400 Gilbertese can be sent to Sydney island immediately and that the numbers can be gradually increased to 900 or more*" (Maude 1938:16-17).

These two accounts of the same atoll are somewhat contradictory. For Harry Maude, who in the 1930's was the administrative officer and native lands commissioner of the Gilbert and Ellice Islands colony, four of the islands of the archipelago (Sydney, Hull, Gardner and Canton) offered good opportunities to relocate the "excess" population of the southern Gilberts and northern Ellice (Maude 1968:315-342). For MacGregor, Sydney, like the rest of the archipelago, could not support the needs of a population over the long term. Is this dialectic between richness and poverty of atolls necessarily contradictory? The fact that both authors, in their turn, saw these lands as either inhospitable or welcoming, attests not only to fluctuations in rainfall, patterned by climatic events, such as El Niño, but also to their different backgrounds. Maude had lived for a long time on the atolls of the Gilberts, while MacGregor was more familiar with high islands.

When we visited five of the islands of the Phoenix group during a rainy period, the 1997 El Niño year, we were struck by their diversity: the luxuriance of the vegetation and extensive groves of coconuts on Manra and Orona, the barren aspect of Enderbury, Phoenix and Birnie, the rich lagoons connected to the sea on Orona and Kanton, the absence of fish in the landlocked brackish ponds on Enderbury, Birnie, Phoenix and Manra, and finally by their variation in land areas with tiny Phoenix, as well as Birnie (and McKean, although not visited by us), covering 0.8 and 0.6 km^2, medium sized Manra, Orona, Enderbury (3.9 to 5.1 km^2) and much larger Kanton (9.1 km^2).

While it is difficult to reconstruct the environment that greeted the first discoverers, a good place to begin is to investigate their environment today. All of these islands have been abandoned twice, the first time prior to European discovery, the second time in the early 20th century, after having been exploited for guano or copra (Bryan 1942; Garnett 1983). Each time, nature had a chance to recuperate. Therefore their environments, while far from pristine, have some resemblance to those of earlier times, and will be discussed in light of what they could have offered their first inhabitants. The eight islands of the Phoenix group form a relatively compact archipelago, which spans only 240 nautical miles east to west and 110 miles north to south, consisting of 3 atolls and 5 slightly elevated table reef islands. Inter-island distances are short and vary from 37 to 130 nm, a few hours to 2 days apart by canoe with favorable winds. The six eastern islands lie roughly across the wind from each other, facilitating two-way voyaging. Located between 2°48' and 4°45'S and 170°45' and 174°37'W, they lie outside the latitude of the main hurricane belt, in "*the usually scanty, but highly erratic, rainfall zone. Only the southern tier of three atolls, Gardner, Hull and Sydney, are far enough south to receive enough rainfall (averaging just over 1000 mm/year) to have the luxuriance of vegetation often expected on a coral atoll*" (Mueller-Dombois and Fosberg 1998:318). The indigenous atoll trees (*Cordia, Pisonia, Tournefortia*), shrubs (*Morinda, Pemphis, Scaevola, Sida, Suriana*), graminoids (*Cyperus*, *Lepturus*) and low-growing herbs (*Boerhavia*, *Ipomoea*, *Portulaca*, *Sesuvium*, *Triumfetta*) are flourishing, and tend to form monotypic communities on drier atolls such as Kanton and Enderbury and mixed communities on less arid islands such as Orona and Manra. Soils are calcareous with limited accumulations of organic matter, fertilized by nitrogenous and phosphatic bird manure. Taken together, how are the constraints of rainfall, island size and agricultural potential reflected in the richness of archaeological features on Manra, Orona and Enderbury and their scarcity on Phoenix and Kanton?



Map 4.1: Archaeological sites on Enderbury island

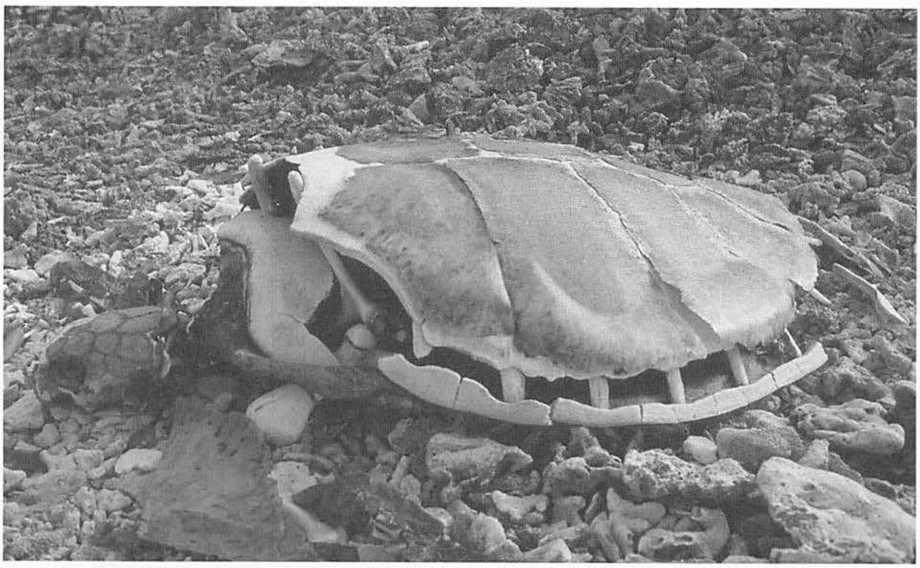
Enderbury island, a windy grassland

Enderbury was discovered and named in 1823 by Captain J.J. Coffin of the British whale ship "Transit". The name is a misspelling of Enderby, a famous whaling merchant (Bryan 1942:50). Enderbury is a slightly elevated table reef up to 7 m high, covering about 5.1 km^2, roughly rectangular in shape (about 4.8 km long and 1.6 km broad) with a narrow fringing reef (50 to 200 m wide) and good offshore fishing (Map 4.1) (Garnett 1983:212-225). A raised berm or rubble ridge surrounds the island, higher on the east, north, and south sides, and lowest on the west side, away from the prevailing winds. Exposed bedrock in the interior of the island averages about 1.3 to 1.5 m above sea level (Garnett *op. cit.*:216).

The barren eastern or windward side of Enderbury supports only a few salt resistant shrubs. The protected western or leeward side has more extensive deposits of sandy soil, sustains the densest vegetation and is the only part of the island that has any agricultural potential. This coast also offers the best inshore fishing, the only two reef passes suitable for canoe landing, accessible beaches for turtle nesting (and hunting), as well as the only groves of trees (*Cordia subcordata* and *Tournefortia argentea*) which would have been useful for building houses or canoes. The only source of plant food today are two coconut trees planted

3. Middle seep on Enderbury island, with *Tournefortia* grove in the background.

on the western rim at the American missile tracking station, occupied from 1970 to 1979. Since that time, these trees have matured and vigorous sprouts were noted around them, as well as at the South Guano and Lighthouse camp sites. In contrast, the palms planted at the 3 small seeps, along the inland edge of the western rim, numbered 60 and 31 in 1924 and 1938 respectively, are now dead (Bryan *op. cit.*:50). Besides the scattered groves of trees, the dominant vegetation types are mixed *Lepturus pilgerianus* and *L. repens* grassland with *Portulaca australis, P. lutea* and *P. oleracea, Sida fallax* and *Triumfetta procumbens* in the interior and *Scaevola taccada* along the coast, parasitized by *Cassytha filiformis* (Plate 3).



4. Green turtle skeleton, among chenier ridges on Enderbury island.

The most important resources to prehistoric settlers would have been nesting seabirds and turtles. Enderbury is still one of the most important green turtle (*Chelonia mydas*) nesting sites in the central Pacific (Plate 4). Eleven species of seabirds were observed breeding in 1997 (Table 4.2), including large colonies of sooty terns and lesser frigates, but no procellarids, perhaps due to the large numbers of *Rattus exulans*. These birds left a legacy in the rich guano deposits which were largely removed in the 1860's and 70's, about 100,000 tons in all (Garnett *op. cit*:217). The most extensive guano mining was carried out at the north and south ends of the island leaving the western rim, where the archaeological potential is greatest, relatively undisturbed.

	Salinity (ppt)	Phosphate (ml/L)	Calcium hardness (mg/L = ppm)	Ph
Enderbury (middle seep)	1	0	100	8.2 - 8.4
Enderbury (lagoon)	38	0.2	9400	8.2
Enderbury (southern pond)	12	0.3	120	8.2
Kanton (pond, near Pyramid point)	38	0	420	8.3
Kanton (SW crack)	3	1.2	480	8.2
Kanton (crack near SE pond)	8	0	190	8.3
Kanton (well near village)	0	-	-	-
Phoenix (well, near lagoon)	27	0.4	1500	7.2
Manra (lagoon)	0	0.15	-	-
Manra (swamp)	0	0.4	250	6.4
Manra (SE pond)	3	-	-	-
Orona (Cyrtosperma pit)	0	0.8	400	7.4 - 7.6

Table 4.1: Salinity and chemistry of various water sources on Enderbury, Kanton, Phoenix, Manra and Orona

Kanton island, a sanctuary for birds and marine life

Kanton was discovered "several times" by American whalers who were able to find safe anchorage there in the early 1800's. Numerous names, such as Mary, Swallow, and Mary Balcout attest these discoveries (Bryan *op. cit.*:46). Kanton, the northernmost island of the archipelago, is a large atoll 14.5 km broad on its long axis (northwest - southeast) with a total land area of some 9 to 10 km^2 (Garnett *op. cit.*:194). The interior of the island is generally 2 to 3.6 m high. The beach berm varies from 3 to more than 5 m high (Garnett *op. cit.*:189-190). The narrow land rim (from 100 to 500 m wide) surrounds a large lagoon.

The entire rim, except on the west side, is rocky with extensive areas of bare coral rubble dominated by dense *Scaevola* thickets, with small patches of *Tournefortia*, *Cordia* and *Pemphis*. Numerous wells have been dug along the western side. We also recorded two sources of brackish water, one near the southeast point, the other along the southwestern lagoon beach (Table 4.1). The western or leeward side of the island is relatively wide, mostly covered with sandy soil, and supports small natural forests of *Cordia subcordata, Guettarda speciosa* and *Pisonia*

Family – Species	Phoenix	Enderbury	Manra	Orona	Kanton
PROCELLARIIDAE					
Wedge-tailed shearwater *(Puffinus pacificus)*	B	V	-	V	B
Christmas shearwater *(Puffinus nativitatis)*	B	V	-	-	B
Audubon's shearwater *(Puffinus lherminieri)*	B	V	-	-	B - *V*
Bulwer's petrel *(Bulweria bulwerii)*	V - *B*	-	-	-	-
Phoenix petrel *(Pterodroma alba)*	B	-	-	V	B - *V*
HYDROBATIDAE					
White-throated storm petrel (Nesofregetta albigularis)	B	V	-	-	-
PHAETHONTIDAE					
White-tailed tropicbird (Phaethon lepturus)	-	-	b	b	V
Red-tailed tropicbird (Phaethon rubricauda)	B	B	b	*b*	B
SULIDAE					
Masked booby (Sula dactylatra)	B	B	V	V	B
Brown booby (Sula leucogaster)	B	B	V	V	B - *V*
Red-footed booby (Sula sula)	B	B	-	B	B
FREGATIDAE					
Great frigate bird (Fregata minor)	B	B	B - *V*	B	B
Lesser frigate bird (Fregata ariel)	B	B	V	V	V
ANATIDAE					
Mallard (Anas platyrhynchos)	-	-	-	-	V
Pintail duck (Anas acuta) -	V	-	-	-	
Shoveler (Anas clypeata) -	-	-	-	V	
LARIDAE					
Grey-backed tern (Sterna lunata)	B	B	-	-	B
Sooty tern (Sterna fuscata)	B	B	B	B	B
Brown noddy (Anous stolidus)	B	B	B	B	B
Black noddy (Anous minutus)	B	B	b	B	B
Blue-grey noddy (Procelsterna cerulea)	B	b - *V*	-	V	b
White tern (Gygis alba)	B	B	B	B	B
Total of breeding species	17-18	11-12	4-7	6-8	14-15

Table 4.2: Inventory and breeding status of seabirds on the Phoenix Islands
Breeding (B), possibly breeding (b) and visitor or migrant (V)
Where Garnett (1983) differs from us, his observations are in italics

grandis, as well as groves of recently introduced species (*Casuarina equisetifolia*, *Cocos nucifera*, *Coccoloba uvifera*, *Hibiscus tiliaceus*, *Terminalia samoensis*). Hatheway reported that *Cordia* covered an area of 3.4 ha, *Tournefortia* 12.1 ha, *Scaevola* 71.2 ha, *Suriana* and *Sesuvium* 99.1 ha and *Portulaca* 230.5 ha (Hatheway 1955). Luomala recorded 58 species of plants, but many of these were ephemeral exotics around the various military installations (Luomala 1951:170). This leeward coast offers easy canoe access to the ocean, and the best reef fishing. Prior to WWII, there were four passes, two are still open, including a dredged ship channel. Tides moving in and out of these passes, along with the diatom-rich water from the shallow (2 m) eastern part of the lagoon, promote extensive reef growth in the deeper (10-15 m) waters of the western half. There, fish and pearl shell are flourishing. Pilot whales are common off the lee shore and occasionally within the lagoon. These marine and avian resources would have been attractive to prehistoric voyagers, although archaeological features are practically non-existent. In recent years, as many as 14 species of seabirds have bred on the island (Table 4.2) (Murphy *et al.* 1954). As far as plant subsistence, only the western side of the island seems to have agricultural potential. There, *Cyrtosperma*, banana and taro are produced in pit gardens, while breadfruit, pandanus and sugarcane have been planted around the modern village, located where the water table is highest, just below the ground level. The water was perfectly fresh in 1997, although it is not used for drinking due to fear of possible PCB contamination. Kanton has never been a copra plantation and only recently have coconuts been planted in any numbers. They seem to grow well, particularly on the leeward coast, due to the extensive freshwater lens. The relatively lush aspect of the leeward part of the island today is in stark contrast to its barren appearance as shown in photographs from 1930's (Bryan *op. cit.*: facing page 56). Since 1938, the efforts of Pacific islanders working for Pan American Airways and I-Kiribati settlers 40 years later have transformed the western half of the island into a garden.

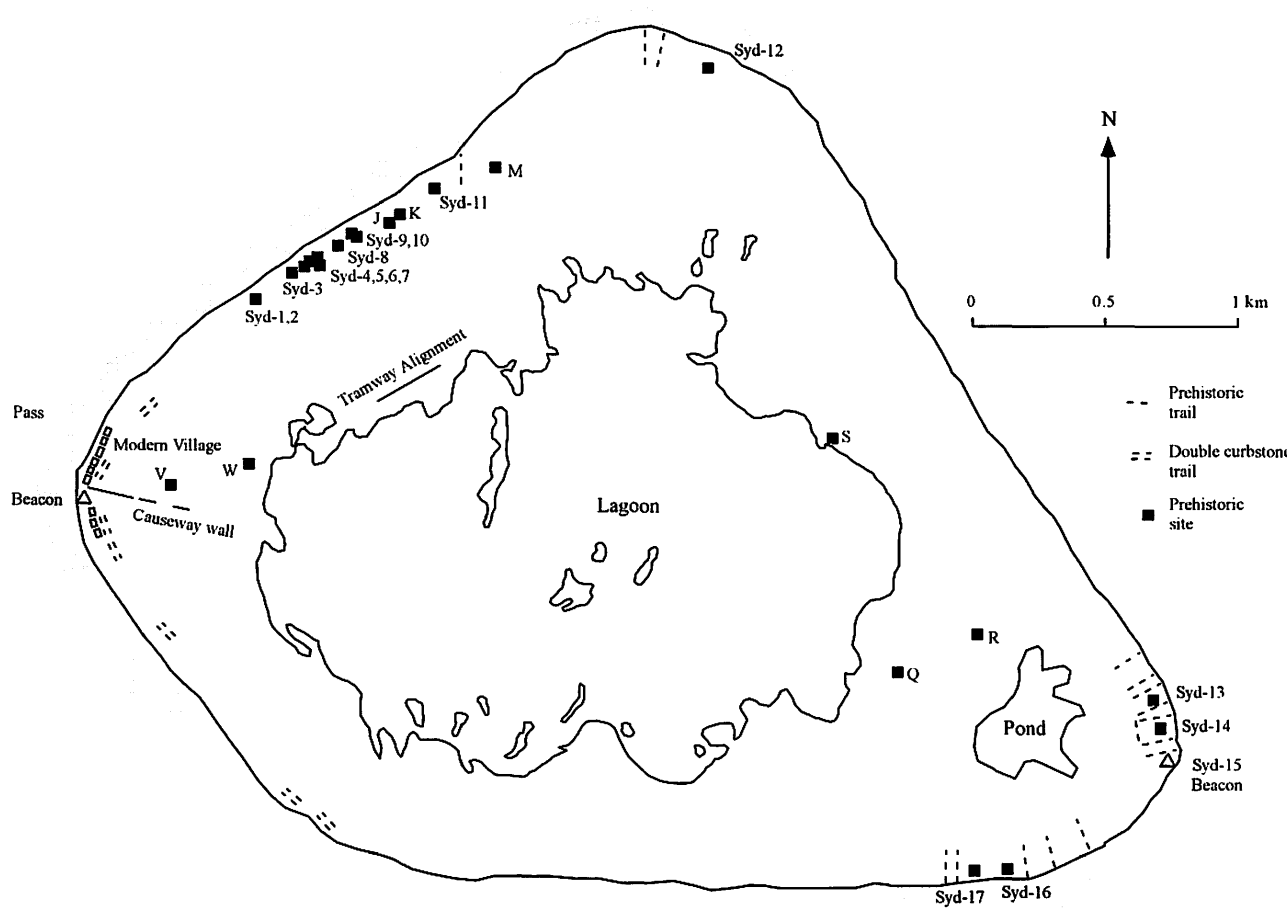
Phoenix, the last bird island

Phoenix island was probably discovered by Captain Moore of the American whale ship "Phoenix" in 1794, although other vessels of that name were cruising in the area in the early 1800's (Bryan *op. cit.*:54). Phoenix, one of the smallest islands in the group, has a total land area of 0.74 km^2, and stands about 2.5 to 4 m above sea level (Garnett *op. cit.*:226-237). A salt lake occupies the interior. A narrow fringing reef (30 to 100 m wide) surrounds the island except for a canoe pass on the protected southwest side. Phoenix is an ideal landmark or resting place, midway along the route between Enderbury and Manra, although its lack of freshwater probably precluded settlement. Indeed, no prehistoric remains were found. The flora consists of only 6 species of vascular plants, forming a grassland dominated by *Lepturus* and *Sida*. No trees are present. Phoenix is the only rat-and cat-free island in the archipelago and supports the richest (18 species) and densest populations of breeding seabirds, estimated at 346,000 individuals, about 5,000 birds per ha (Table 4.2) (Garnett *op. cit.*:231-232). Although 200 years of European visitors and 9 years of phosphate mining indicate that the environment is not pristine, its avifauna may not be too different from that which greeted the first prehistoric voyagers. Phoenix is one of the best examples in the entire tropical Pacific of the abundance of food that would have been available on any island at the time of first discovery.

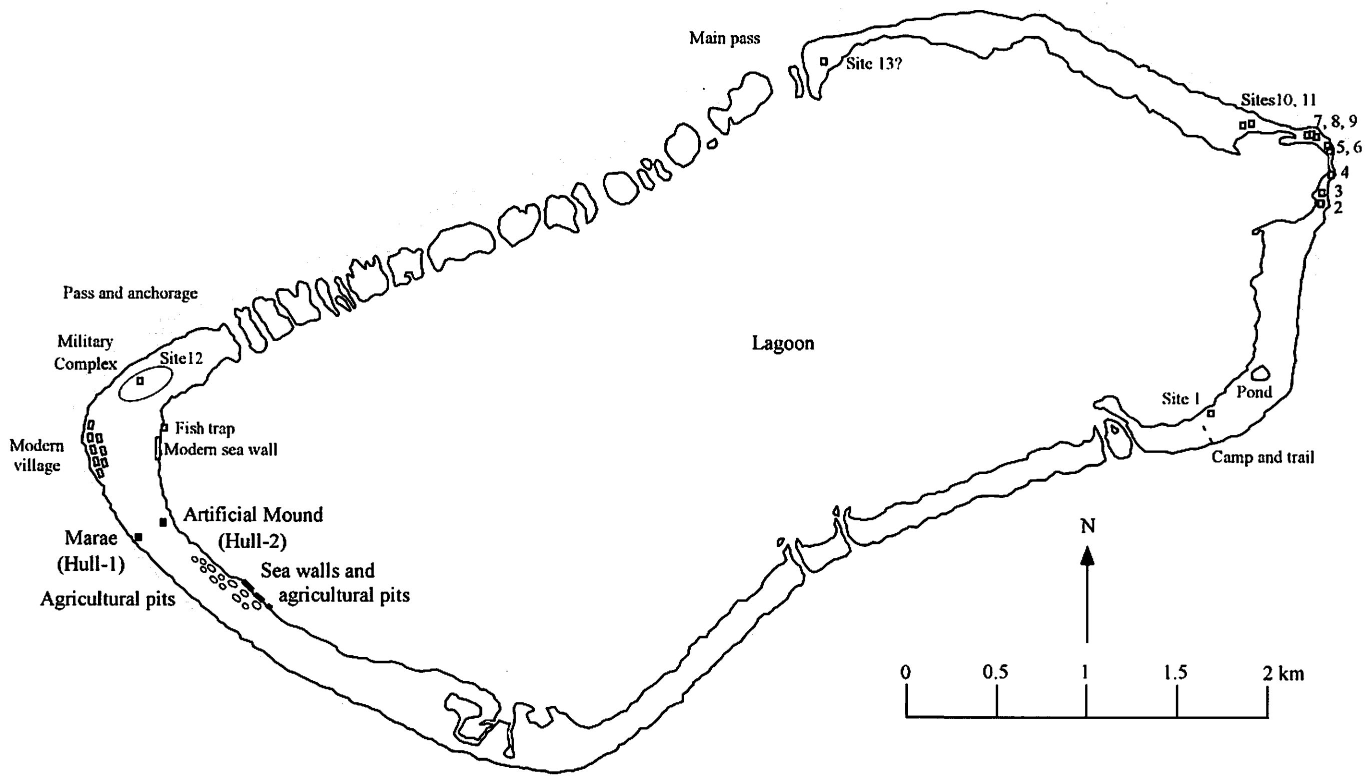
Manra, a forested island

The island was discovered by Captain Emment (of the whaler Sydney Packet) and named Sydney in 1823 (Bryan *op. cit.*:61; Garnett *op. cit.*:262). It is shaped like a triangle, about 3.2 km long and 2.8 km broad, with a roughly circular land-locked lagoon, about 6 m deep (Map 4.2). It is surrounded by a fringing reef 50 m wide and has a total land area of 4.36 km^2. The beach berm reaches almost 6 m high along the west coast. The interior averages 1.6 to 3 m above sea level (Bryan *op. cit.*:61; Garnett *op. cit.*:262-264).

The windward side of the island has extensive areas with parallel ridges of weathered coral rubble formed during storm events, bordered by dense groves of *Scaevola* with scattered *Tournefortia* trees. The leeward or northwest shore offers a protected reef and the only canoe pass, deep sandy soil supporting some 150 ha of thick forest dominated by coconuts, pandanus up to 10 m high, *Morinda*, *Pemphis* and tall *Cordia* trees as well as the densest concentration of archaeological features. The southern part of the island is more open, with patches of mixed *Guettarda*, *Tournefortia* and *Cordia* forest. Early settlers would have found good agricultural potential on the leeward side, but limited reef resources. The lagoon offers no food, at least not today. It has been reported to be hypersaline, although the surface layer was fresh in 1997 and several feet higher than previously reported (Table 4.1). The islets shown on earlier maps by MacGregor (n.d.) and Bryan (*op. cit*:59) were under water and the shoreline vegetation was submerged. Dozens of spoiled noddy eggs were being washed ashore. Green turtle nests are common but seabirds are rare today, only 4 species were breeding in 1997, 3 or 4 more are possible breeders (Table 4.2). The paucity of birds today may be due to both large populations of rats (*Rattus exulans, R. rattus*) and feral cats, as well as extirpations by humans in the past.



Map 4.2: Archaeological sites on Manra island



Map 4.3: Archaeological sites on Orona island

- ■ Sites recorded in 1997
- ◘ Sites reported by MacGregor (n.d.)

Orona, a wet atoll with forest and lagoon

Orona is a roughly rectangular atoll (about 8.3 km long and 4.6 km wide), cut by numerous passes on its northwest side, completely surrounded by a fringing reef, 80 to 250 m wide (Map 4.3). The lagoon is 15 to 20 m deep and contains well developed patch reefs. The total land area is about 3.9 km^2 concentrated on the southwestern islet which attains a width of 800 m (Garnett *op. cit*:275-281).

The windward side of the island, probably too narrow to support a freshwater lens, is relatively barren with patches of bare coral rubble, grass and scrub land. The northwestern side of the atoll, protected from the southeast trades, offers relatively easy access to the ocean through two canoe passes, as well as sheltered fishing on the fringing reef. The southwestern islet at the leeward end of the lagoon captures sediments transported by the trades, forming relatively deep deposits, allowing development of a dense forest, and favoring prehistoric settlement. Most archaeological features are concentrated there, although other sites are reported from the east coast. Today, Orona is primarily a coconut grove, with an under story of *Pandanus*, *Morinda*, *Guettarda*, *Cordia* and *Tournefortia*. Small numbers of coconuts were noted at the time Orona was officially discovered by Captain Wilkes in 1840, although a Frenchman and eleven Tahitians were living on the island at the time. This is the only reported population of *Cocos* in the Phoenix archipelago that may predate European discovery. In any case, the earliest prehistoric inhabitants would have settled an island dominated by *Pisonia* forest, "*the only really natural forest in the Phoenix group*" (Mueller Dombois and Fosberg *op. cit*:320). It is likely too that these settlers would have found several fresh to brackish ponds, present today along the southern part of the islet. These may have been full of milkfish, as noted by Ellis in 1887 (Ellis 1936). The first people would certainly have profited from the rich lagoon and abundant avifauna. Even today, the island has large populations of green turtles, tridacna, carangid fish and at least six species of breeding seabirds, although only sooty terns are abundant (Garnett *op. cit.*:282). Another resource would have been the rich agricultural soils that form under *Pisonia* forest. These soils store phosphate in a thick humus layer that persists for many years after the forest - and the birds that donate the phosphate have disappeared (Wiens 1962:347).

Evidence of the productivity of Orona comes from its 50 years as a copra plantation - some 20,000 coconuts were set out in 1887 by Albert Ellis and his brother (Bryan *op. cit.*:65) - and the settlement of several hundred I-Kiribati islanders (530 by 1947) from 1938 to 1963, the year when the island was evacuated by the British government (Garnett *op. cit.*:285). Although the official reason for abandonment was drought, our informants evoked homesickness, isolation and lack of communication. They told us too that their parents salted the wells to ensure that colonial officers would send them back home to the Gilberts! When Maude investigated the possible colonization of the Phoenix group, he estimated that if all available land was used, the island could support no less than 1,200 people (Maude 1938:16).

Islands in perspective

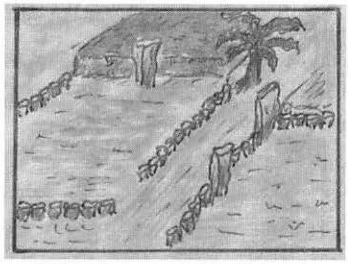
Dryness, remoteness and or smallness are three recurring attributes given to explain why these islands in particular and the "mystery islands" in general did not support settlement (Terrell 1986; Bellwood 1987; Kirch 1988; Irwin 1992), although these points have been somewhat overstated, leading to what we called the "paradigm of the mystery islands" (Di Piazza and Pearthree 2001 b). Apropos dryness, the lack of rainfall usually associated with the group is based on weather data from Kanton, the driest island but the only one with an airport and weather station. The three southern atolls receive about twice as much rainfall, and support lush forests. As for isolation, it should be thought of in two ways, between archipelagoes and within the group. The closest archipelago, Tokelau, lies only 180 nm to the south of Manra and Orona, an easy two-day voyage across the trade winds. Samoa is about three days further south, on the same heading. The next closest islands are the 6 scattered northern Cooks, about 350 nm to the southeast, but a much more difficult voyage into the wind (see chapter 1). Within the group, except for Gardner and McKean which lie downwind, the islands form a tight cluster oriented across the wind, an easy sailing sector. Therefore, since the inter-island distances are short and the direction is easy, it is reasonable to think of them as being in close contact which each other. Taking this idea one step further, we may speculate, as did Irwin (1992:179), that this cluster of six islands functioned as a unit, as a single large atoll composed of 6 islets, with a total land area of about 23 km^2. This is relatively large in the scale of atolls, and taken together would be capable of supporting some 247 people under Williamson and Sabath's model[20] for the Marshall Islands, although none of the four predicted populations exceed their minimum threshold of 100 for permanent settlement (Williamson and Sabath 1982, 1984) (Table 4.3). Limited land area of each island coupled with relatively low rainfall would appear to be serious obstacles to long term occupation. However, the recent resettlement indicates otherwise. Today Kanton is inhabited by 12 families, about 100 people in all, relying primarily on local resources while exporting large quantities of dried fish. Further indication of the productive capacity of these islands is the success of the commercial copra plantations on Manra, which exported 50 tons annually (Garnett *op. cit.*:270). A better analog than the Marshalls (to estimate the population of the Phoenix) may be found in the southern Gilberts which, at roughly the same latitude, have similar rainfall fluctuations and agricultural potential. There, the average population density is 150 per km^2 (Geddes *et al.* 1982:2). Using this figure, Manra and Orona would support 517 and 463 people respectively, not very different from their actual populations in the 1950's.

The intensity of human settlement can also be read through the composition of avifauna. In this regard, three classes of islands can be distinguished. The first class is constituted of Manra and Orona in the south, which once supported intensive settlement, in prehistory as well as in recent times. Here only relict populations of tree nesting birds (between 4 and 8 species), primarily Laridae, are found. Procellariidae, vulnerable to introduced mammals, have disappeared. The second class comprises Phoenix and even drier Kanton[21] where 14 and 18 species breed respectively (or did until recently), including up to 5 procellarids; a species richness that tends to prove a lack of disturbance in the past. The third class, made up of Enderbury, is between these extremes. Birds are abundant and about 11 species breed, although there are no procellarids among them. Archaeological features are present but do not indicate intensive settlement.

Island	Area (km^2)	Area (sq. mi.)	Rainfall (mm)	Mesophytic Index	Population (Estimate)*
Enderbury	5.1	1.57	600	942	33
Orona	3.9	1.2	1,200	1440	63
Manra	4.36	1.34	1,000	1340	57
Kanton	9.1	2.8	700	1960	94
Birnie	0.6	0.18	800	144	0
Phoenix	0.8	0.23	700	161	0
Total	23.86	7.32			247

Table 4.3: Estimated human populations for the Phoenix Islands
*(after Williamson and Sabath (1982, 1984)

CHAPTER 5



Different Uses for Different Islands

Strategies of temporary settlement developed by skillful navigators

"... *Our present knowledge reveals that structures of the Phoenix complex alone closely parallel* marae *of the eastern Polynesian Islands. Nothing of their type is found in Tonga or Fiji. The conclusion which first comes to mind upon comparison of the Phoenix with the eastern* marae *is that the Phoenix stone structures were built by people from eastern Polynesia... The Sydney* marae*, Sites A and B [Syd-1 and Syd-2], agree in general with the simple Tahitian* marae" (MacGregor n.d.:3-4).

The richness of the archaeological record of Manra and Orona, as well as the widespread evidence of wet and dry agriculture on Orona and Enderbury respectively, demonstrate the successful adaptation of the Phoenix islanders, at least for some time. The most common surface features recorded are marae[22], raised rectangular platforms, pavements, stepping stone trails and agricultural pits. The paucity of prehistoric features on Phoenix, Birnie and Kanton, only 35-40 nm away, denotes not so much marooned navigators, but minimal use of these lands. These contrasting patterns on closely spaced islands confirm that the mystery islands should not be treated as a single phenomenon, but rather as nodes in regional interaction spheres. Inhabitants have settled the wetter or bigger lands and utilized the complementary resources offered by adjacent territories (Di Piazza and Pearthree 2001 b).

Mystery islands have been discussed by various authors (MacGregor n.d.; Terrell 1986; Bellwood 1987; Kirch 1988; Irwin 1992; Weisler 1995, 1996; Anderson *et al.* 2000). What is remarkable about these studies is that researchers have focused on the abandonment process, speculating about settlement extinction and framing their interpretations in terms of isolation, resource scarcity or catastrophic events (drought, famine, etc.). But it is clear that occupation, however temporary or intermittent, indicates a settlement strategy developed by islanders who were capable at any time of migrating to other lands, using the navigational knowledge and technology that got them there in the first place. The domestication of the sea has endowed these islanders with a great adaptive faculty, allowing them to settle and exploit virtually all the scattered islands in the Pacific for a longer or shorter time, although not long enough in the case of the mystery islands to still be populated when re-discovered by Westerners.

The Phoenix Islands began to appear on European maps in the early 1800's. Most of them were found by whalers, hunting along the 'line' or equator (Bryan 1942; Maude 1968). The whalers apparently made scant use of these islands, probably due to the lack of coconuts and fresh water. Later on, between about 1860 and 1880, they became bases for guano exploitation. Guano was primarily gathered on the drier table reef islands of McKean, Enderbury and Phoenix, and to a lesser extent on Manra and Kanton. Numerous stone structures, tramway foundations and boat landings, remain from this period. Giant piles of guano are still waiting to be loaded. Between 1886 and 1932, most and perhaps all of the islands were planted in coconuts. Five years later England, then the United States, landed small occupation parties on Kanton and Enderbury which soon thereafter led to a division of the archipelago; the US managing the northern islands, England taking the southern ones and transferring settlers from the Gilbert and Ellice Islands (Maude 1968; Garnett 1983). During WWII Kanton was turned into a military airbase. Operations continued until 1967, under Pan American Airlines and later NASA. From 1970 to 1979, Orona, Enderbury, Manra and Kanton were used as bases for observation of satellites. These different historical uses have left archaeological remains throughout the archipelago and led to some disturbance of earlier prehistoric sites, although not as severely as on most continuously inhabited islands.

Enderbury, a land of dry agriculture

The only notes on possible prehistoric features in the literature come from E.H. Bryan, who visited Enderbury in 1924 and 1938 (Bryan 1942). During his first visit, he noted stone structures at the South Guano Camp (Map 4.1) and concluded that: "*Although some (of the ruins) rest on platforms similar to such as Polynesians build, they are obviously the remains of the "village" built by the guano diggers... it is possible that these platforms of Polynesian type...were ancient marae utilized by the laborers*" (Bryan cited in MacGregor n.d.). During his second visit, he re-inspected these structures, and concluded that the "walls" were modern, omitting mention of the previously recorded platforms. And there the matter rested.

We surveyed the entire coast of Enderbury as far inland as the crest of the beach berm. Additional north to south and west to east transects were made intersecting the two northern freshwater ponds or seeps, the lagoon and the groves of trees. Due to the open terrain, virtually all of the island was inspected.

Historical sites are mostly related to guano extraction. Thousands of tons of guano were removed between 1860 and 1877. Bryan (*op. cit.*:51) gives figures of as much as 100 to 150 tons loaded a day during the height of the industry. The most conspicuous sites such as the North Landing Site and the South Guano Camp date from this period. Later occupation left structures at the Lighthouse Camp in the 1930's and at the Helicopter Landing in the 1970's.

> The lighthouse camp site, situated near the southwest end of the island, consists of several concrete building foundations, a cistern, a collapsed wooden frame structure, and a stone lighthouse tower built between 1938 and 1941 by the American colonists.
>
> The Helicopter Landing, located on the west shore near the north end of the island comprises an aluminum helicopter landing platform and three concrete foundation pads which appear to have housed a generator and electronic equipment. Just to the north and northeast are several trenches bulldozed into piles of loose stones. Two antenna towers of creosoted wooden poles with aluminum tracks located near the south end of the island and at the middle of the SE shore are presumably related to this site. One bears a sign indicating it is the property of the US SAMTEC (Space and Missile Test Centre). This site appears to be a vestige of cold war military activity in the South Pacific.

Prehistoric features are clustered under or adjacent to the two guano camps along the leeward coast, while stepping stone trails are concentrated near the northern ponds, and along the southern shore of the island.

North Landing Site (End-1)

This is the main guano camp, situated just inland of the best small boat landing on the island, a narrow pass through the fringing reef. As indicated by piles of iron bolts lying on the sea bottom, there was once a wooden pier at this location.

The site is dominated by a large pile of guano, up to 10 m above sea level according to the US Govt. chart of 1943 and containing about 850 m^3. At its base, is a pile of iron tram rails. Extending north of the guano pile is a line of 9 rectangular building foundations bordered by two paved trails 1 m wide. In most cases the foundations consist of single outlines of stones with rock piers in the middle to support wooden beams. The three southern foundations are associated with fragments of machinery and rigging such as pieces of tram cars and wire rope. These are probably shops or barns for the guano operation. The other features appear to be a kitchen, habitation and storage structures. An iron stove, a bed frame, wooden floor beams, iron nails, and numerous bottles and crockery fragments were observed. One isolated feature, about 120 m east of the main complex is unique in that it had stone walls up to 135 cm high with 2 small niches and a serpentine entrance. A short tramway alignment can still be discerned near the camp. Several cut fragments of pearl shell were collected around the entrance of the kitchen. The cut pieces included the lateral margins of the shell presumably discarded during manufacture of trolling lures. The cut marks were made by saws and appear modern.

The prehistoric components consist of 10 possible habitation features, 2 rectangular enclosures, 2 low mounds and numerous probable agricultural pits.

Site End-1, habitation features. A complex of ten roughly rectangular to square paved areas are arranged in a northeast to southwest line, southeast of the historic features. They vary from about 5 x 5 m to 2.5 x 3 m. All these features are heavily disturbed, and are generally outlined by coral rock cobbles or small slabs. Their interiors are very roughly paved by a thin layer of coral beach pebbles. Two upright stones are located on one of these pavements and three additional uprights are dispersed along the complex. At the southeast end is a small fireplace consisting of three upright coral slabs (50 x 60 x 20 cm high) with small amounts of charcoal, fish and bird bones. The largest and best preserved pavement is divided into two areas indicated by different sizes of paving stones. The north portion is about 3 x 5 m and is filled with coarse pebbles 3-10 cm in diameter. The south portion is about 1.3 x 5 m and is paved with smaller flat pebbles to a thickness of about 5 cm, overlaying 15 cm of mixed coral rubble in a stained sandy matrix, then natural white sand and coral pebbles. No cultural material was recovered.

The prehistoric age of this complex is indicated by the weathering of the paving stones when compared to the adjacent historic guano camp as well as the lack of historic artifacts.

Site End-1, enclosures. Two rectangular enclosures are located within a dense grove of *Cordia* trees near the south end of the North Landing site, about 50 m seaward of the habitation complex (Fig. 5.1). The southern enclosure, the larger of the two, is 5.8 x 4.6 m. The walls are faced with upright beachrock slabs, set closely side by side, except for a portion of the seaward wall. This latter is constructed of smaller slabs stacked flat, faced on both sides, and in-filled with coral rubble to a height of 70 cm, forming a flat upper surface. Where the walls consist of upright slabs, much of the sand fill has disappeared. A section of the south wall about 1.3 m wide is entirely missing. This may have been an entrance.
The northern enclosure is 4.1 x 3.4 m. It is mostly constructed of flat stacked slabs, except for the east wall and part of the south wall which are faced with upright slabs. The flat upper portions of the walls are 0.75 m high. There is an entrance 0.9 m wide in the north wall. This feature is the better preserved of the two, probably because the stacked slab walls are more stable.
The eastern walls of these two enclosures are in perfect alignment with each other (10-12° to the west of true north) and parallel to the coast. They are slightly thicker (about 80 cm) than the other walls (about 60 cm). Natural beach sand as well as small amounts of iron and bottle glass fragments were noted within and around these enclosures. Shovel tests indicated no subsurface features. Neither iron nails, nor fragments of wooden timbers were present, in contrast to the historic features on the island. The architecture is unlike any of the European buildings. These appear to be the best preserved prehistoric structures on the island, probably because of their location, hidden in a dense *Cordia* grove.

Site End-1, mounds. Two linear mounds are located about 30 m north of the guano camp. The eastern feature is about 1.5 x 7 m x 0.15 m high. It is partially outlined by upright slabs and filled with coral rubble and sand. The surface is heavily disturbed, apparently by deliberate digging. No artifacts were observed. The western feature is about 1.6 x 8 m x 0.2 m high. Constructed in the same manner as the former, it has slabs along the margins and a fill of cobbles and sand. Fragments of iron and glass bottles are scattered around. These structures

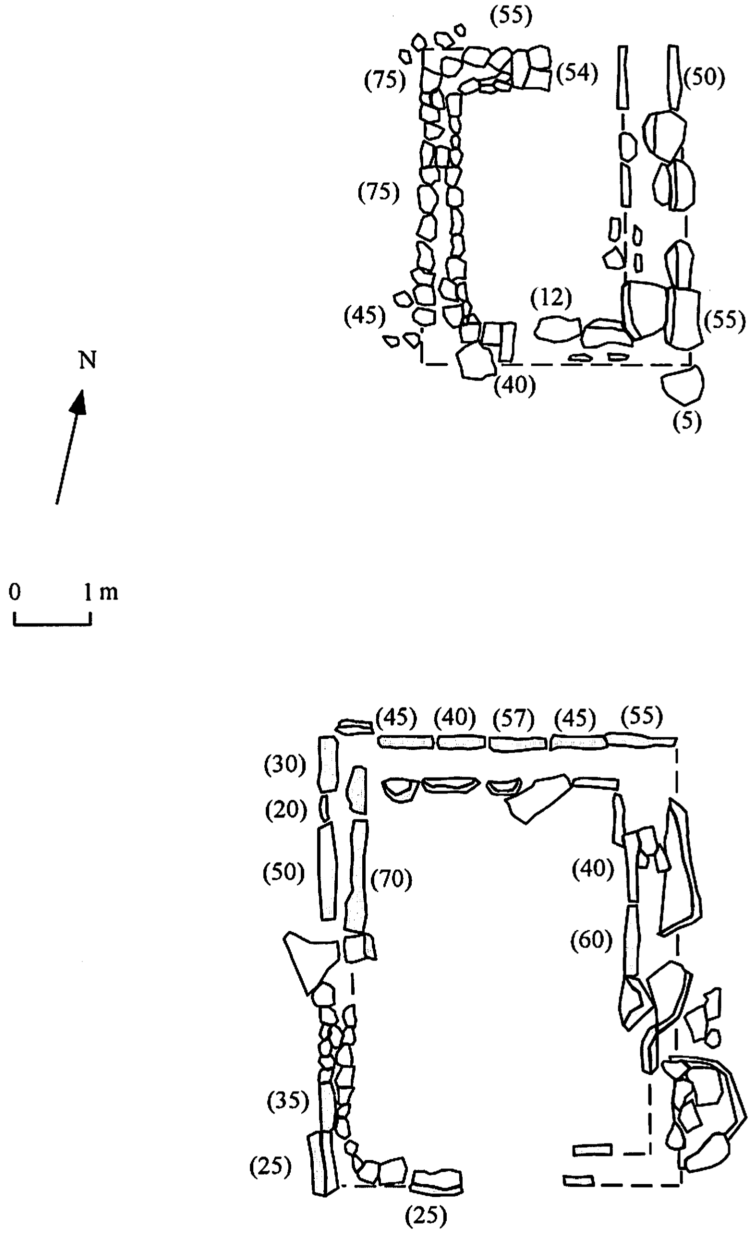
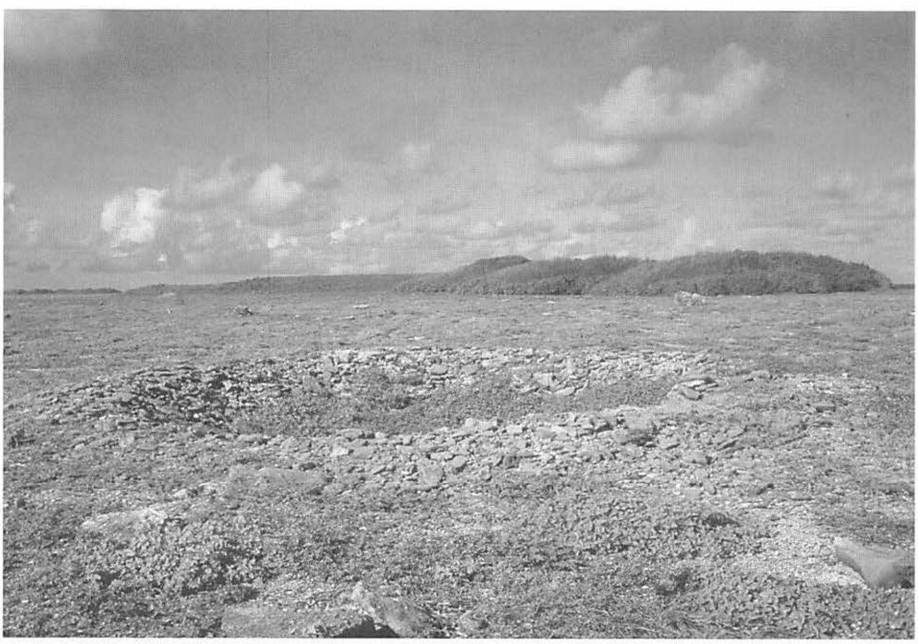


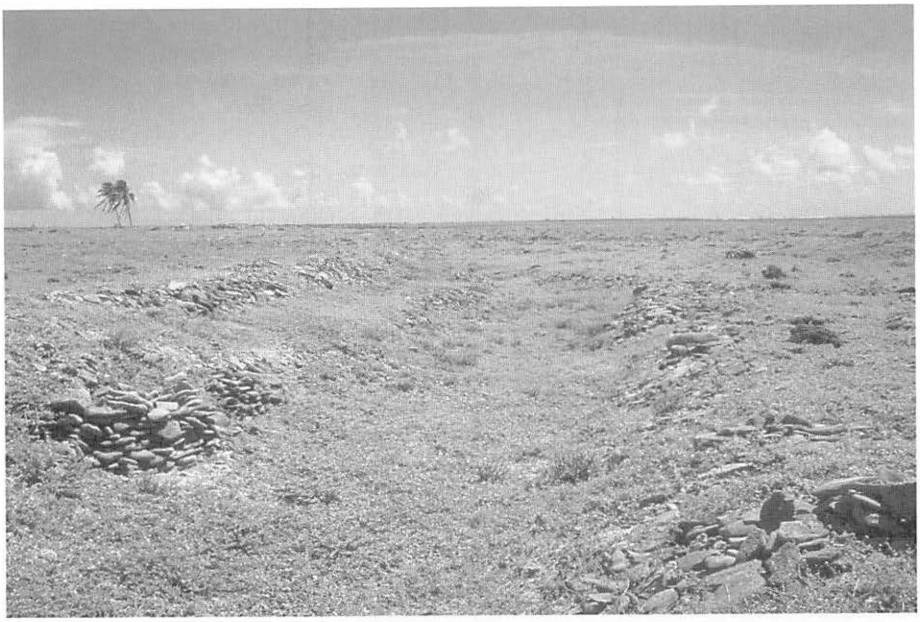
Fig. 5.1: Enclosures at the North Landing Site
Slabs set on edge in grey, heights in (cm)

may be remnants of prehistoric raised rectangular platforms. Their alignment, NW-SE and E-W respectively, as well as construction are different from the nearby historic features. Their state of preservation is poor.

Site End-1, walled pits. Eleven small circular to oval pits (3 to 6 m in diameter) and seven larger rectangular or elongated pits (7-15 m wide and 30-60 m long), many with stone retaining walls, are located along the raised western rim of the island. Four of them are aligned roughly N-S and some 30-80 m east of the historic habitation complex features. At least 7 more are scattered as far as 150 m north and 100 m east of the complex. The retaining walls consist of stacked water-worn coral cobbles, with irregular faces (Plate 5; Map 4.1). The walls are quite steep, even vertical in places. Most of the pits are surrounded by raised rims of waste material, up to 1 m high, offering additional protection from the wind. The elongated pits are clustered some 350 m away to the NE, aligned at a right angle to the prevailing northeast trade winds (Plate 6). Trenches were excavated across two of the circular pits (3.8 and 9 m dia.) and shovel tests were made in others. In all cases, the surface layers consisted of aeolian sand deposits (about 30 cm thick). The original floors of the two circular pits were encountered at 82 cm and 130 cm below the natural ground surface. The floors were



5. Circular walled agricultural pit with mound of guano in the background (End-1)



6. Large oblong walled agricultural pit north of End-1, with helicopter landing site and palm trees in the background

flat and 3-5 cm thick, consisting of an organically stained silty sand in the smallest pit and a layer of coral pebbles in the larger one, overlying coral beach sand in both cases. The best evidence that these pits are prehistoric is that one of them was partially filled by guano workers for their tramway and therefore predates the historic period settlement[23].

The prehistoric components at the North Landing Site seem to form a small nucleated village of about 10 habitation features, used episodically by prehistoric agriculturalists. Short-term occupation is indicated by shallow cultural deposits, about 15 cm thick, lack of artifacts and scarcity of food remains. Carbonized plant tissues (parenchyma), possibly taro *(Colocasia esculenta)*, were identified in the small fireplace. Re-occupation is suggested by the numerous pit features and the high labor investment they exhibit. Such efforts would probably not have been undertaken if the island was not going to be re-used or re-occupied. We can thus hypothesize that this hamlet sheltered "itinerant" agriculturalists, who came to harvest dryland crops, such as bananas, yams, or Polynesian arrowroot and of course birds and turtles. Although architecturally these pit gardens are similar to those used today in the Gilbert, Caroline, Tuamotu or Tokelau islands for the cultivation of swamp taros and other crops, it is probable that on relatively dry

7. Left: Close up of prehistoric pavement (marae?) in the South Guano Camp on Enderbury island (End-2, feature I)

8. Below: Modern enclosure at South Guano Camp on Enderbury island (End-2, feature III)

Enderbury, they functioned more like the circular, walled and often sunken dry gardens of Easter Island, called manavai (Métraux 1940; Alkire 1965; Barrau 1961; Catala 1957; Thompson 1982). A good ethnographic analogue for End-1 would be the pit gardens on Nassau and Rakahanga, which are utilized occasionally by populations based on their respective home islands of Pukapuka and Manihiki (Hiroa 1932; Beaglehole and Beaglehole 1938).

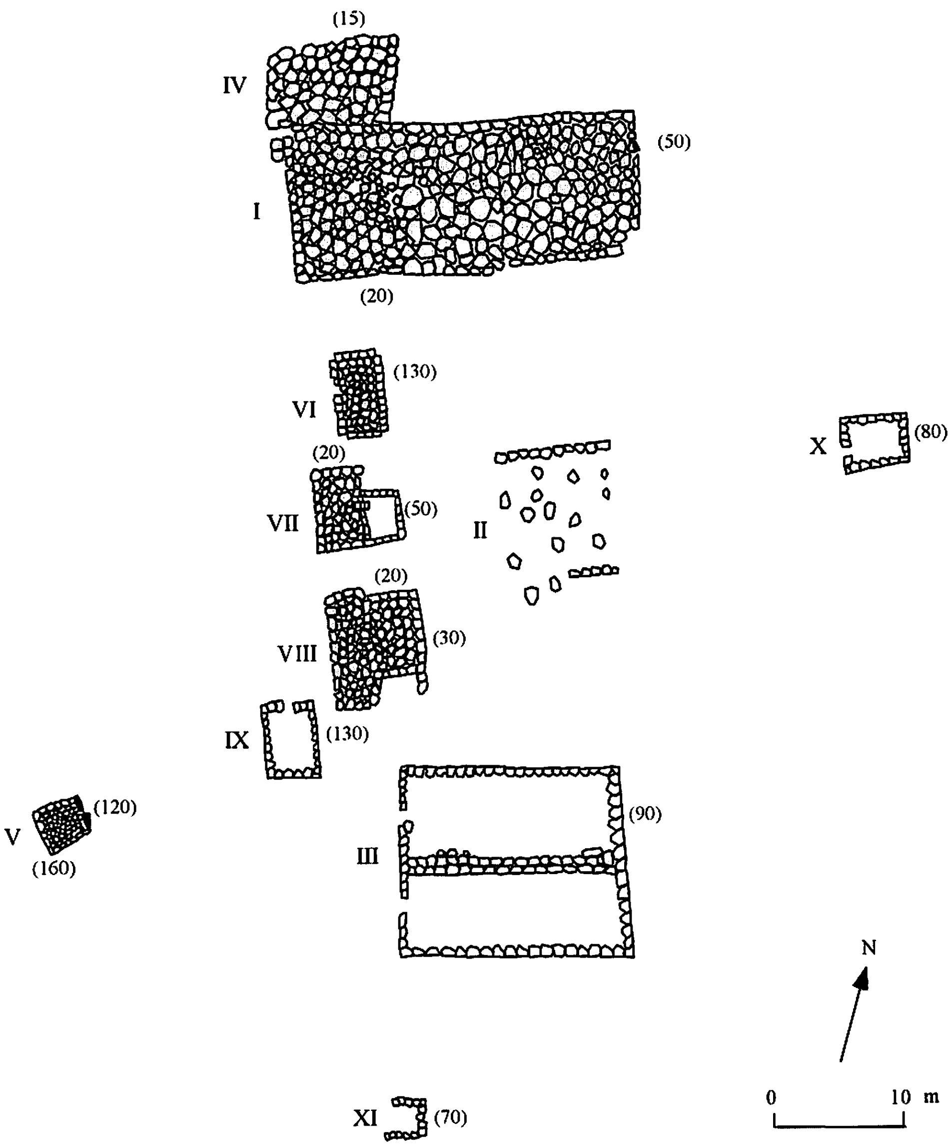


Fig. 5.2: Remains at the South Guano Camp
Grey slabs are remnants of prehistoric pavements, upright slabs in black, heights in (cm)

South Guano Camp site (End-2)

The second guano camp, situated on the west shoreline in the southern part of the island, faces a break in the reef, allowing relatively safe landing. Seven historic structures (features III, VI, VII, VIII, IX, X, XI), all constructed of coral and/or beachrock slabs stacked flat, faced on both sides (except features X and XI) have been recorded (Fig. 5.2). Four of them have been built on pre-existing pavements (features III, VI, VII, VIII), presumably prehistoric. The other early components consist of three more pavements (features I, II, IV) and one rectangular enclosure (feature V). This guano workers village, photographed by Bryan in 1924 or 1939, seems unchanged during the past 70 years as far as we can judge from the photos of features III, VII and IX (Bryan *op. cit.*: facing pg.72).

End-2, Pavements and enclosure. The largest feature (I) is a raised rectangular paving 12 x 27 m by about 0.2 m high, made of beachrock slabs (Plate 7). The upper surface and edges are regular with narrow joints between slabs. There is no foundation. The stones are bedded in the natural ground surface. One small leaning upright (about 50 cm high) is present along the narrow inland edge. Fragments of another slab, a possible upright, are scattered near the northeast corner. A smaller roughly rectangular pavement (IV) abuts feature I. It is 7 x 9.5 m and about 0.15 m high and constructed similarly. The north side appears to have been removed judging by its irregular edges in contrast to the rest of the feature. The seaward edges of the two features (I, IV) are not in alignment and the joint between the two indicates that feature IV was added to feature I.

Feature II consists of 2 parallel slab alignments (9 and 4 m long x 10 m apart) faced on their outer edges with a scatter of large slabs in between, which may be remnants of a paving.

Feature III is a large historic enclosure, 15 x 18 x 0.9 m high, with two entrances in the west wall (Plate 8). It is divided into two narrow rooms by an interior wall. The floor is the natural beach sand. There is a remnant of an older paving underneath the partition, about 0.7 m wide x 14 m long, with an intact section 1.5 x 2 m at its eastern end. A fragment of green bottle glass that appeared to have been unifacially flaked was recovered from the west wall.

Feature V is an enclosure about 3.8 m square x 1.6 m high with 1 m thick walls faced on both sides. The interior is filled with coral rubble. The northeast wall is partly faced with upright slabs up to 1.2 m high. An unusual architectural trait is the presence of several beachrock headers which span the distance between the interior and exterior faces. Its state of preservation and its unique building tradition suggest a prehistoric building.

Feature VI is a historic rectangular enclosure, 6.5 x 4 x 1.3 m high, with an opening on the west side built on a presumably prehistoric pavement, about 4 x 7 m. It consists of four freestanding walls not connected at the corners. It appears that the single stacked stone walls were built against a wooden superstructure. Clusters of iron barrel hoops are scattered around the enclosure, which was presumably used for water storage.

Feature VII is an old rectangular pavement, about 4 x 7 m, adjacent to a historic house foundation (4 x 3 x 0.5 m high), whose unpaved interior appears to have supported a wood-framed building. Two stone steps gave access to the house. The northern edge of feature VII is in alignment with the northern edge of feature II. Both features were probably components of a single pavement in the past.

Feature VIII is a presumably prehistoric rectangular pavement, about 7 x 8 m, with a historic house foundation (6.5 x 4 x 0.3 m high) built upon it. Stone steps lead up to the level of the foundation wall suggesting that it had a raised wooden floor above the pavement, evidence that the underlying pavement was not built by the guano workers. The western edges of features VIII and VII are in alignment with each other (as well as with the western edge of feature I) and possibly delineate a single prehistoric pavement.

Feature IX is a rectangular enclosure (4.2 x 6 x 1.3 m high), built of stacked slabs, partially collapsed with an entrance on the north side. This structure bears some resemblance in size and building tradition with some features (group A) found on McKean. They are characterized as rectangular or square, having "*three or four straight walls [of slabs stacked flat]... with sizes ranging from about five meters long to about 16 m long*" by Throssell and Specht (1989:19, 21), who note that "*evidence of the age and function of these structures is inconclusive*".

Feature X is a rectangular enclosure (4.5 x 5 x 0.8 m high) with an entrance on the west side. It is constructed of single stacked slabs faced only on the outside.

Feature XI is a low three sided enclosure (3 x 3 x 0.7 m at the highest). The lower quality of workmanship, irregular faces and collapsed walls, suggests a different and more recent history for this building.

A small concentration of *Tridacna* shells and a low windbreak wall were found about 12 to 15 m seaward of feature XI.

This historic guano workers village seems to have been superimposed on an important prehistoric ceremonial complex. Indeed it appears that much of the historic building material was borrowed from prehistoric features. The two large and fine rectangular pavements, made of large slabs with narrow joints and faced edges (features I + IV; features II + VII + VIII), which respectively cover areas about 390 and 380 m^2, seem to be remnants of courts of two adjacent marae, sharing the same E-W orientation and with their seaward edges in alignment, with possibly 2 uprights. This hypothesis was foreshadowed by Bryan, even if he later appears to have dismissed it. The lack of ahu, probably due to disturbance by the guano workers, does not allow further characterization of this East Polynesian architecture, although similar, but smaller raised beachrock pavements have been reported on Howland, Malden and Rarotonga islands (Emory 1934 a:6, 33-34; Duff 1974:28-34).

Additional prehistoric features on Enderbury are the numerous stepping stone trails.

> *Stepping stone trails.* Twenty segments of stepping stone trails were found. Nineteen are made of small weathered slabs of limestone conglomerate, spaced approximately 80 cm apart, and cross areas of sharp coral rock (Map 4.1). Sixteen of these extend from the second beach ridge toward the interior, along the north, southwestern and southeastern corners of the island where well developed ridges occur. Another parallels the ridges on the northeastern point. One runs between the latter and the north seep and the last one consists of a 40 m long section which lies between the middle fresh water pond and the North Landing Site. The twentieth trail, along the southeastern shore, is built of large and smooth slabs embedded in a sandy area. The great care spent on its construction and its location on a sand ridge are two traits that clearly distinguish it from the others. Undoubtedly its function is more ritual than utilitarian. This also seems to be confirmed by its position relative to the pavements or marae on the opposite coast. Some of the slabs of the common trails are so weathered that they break when stepped on. They are no doubt prehistoric in age. This was confirmed by the numerous small concentrations of fractured and highly weathered *Tridacna* shells noted along them, and the lack of historic debris. The seaward end of one trail is buried under the most recent beach ridge, and predates this important storm event.

These trails, facilitating foot travel, give access to interior ponds, and more generally to reefs and marine resources, such as fish, mollusks and turtles. Evidence of ceremonial and agricultural practices - the paved courts and pit gardens - has also been found. These features are the kinds of remains of day to day life one would expect, and not the vestiges of a hardscrabble existence of marooned navigators.

Kanton, the bird island

When the Whitney Expedition visited Canton in 1924, E.H. Bryan noted *"two small grave like platforms"* and one isolated upright slab. The two rectangular platforms were located along the northeastern portion of the island, parallel to the lagoon about 30 m inland and 30 m apart. They were 1.6 x 2 m x 0.3 m high and 2.2 x 3 m x 0.4 m high. Each had an upright slab (1 m high x 0.5 m wide x 0.15 m thick) near the center. Their walls consisted of two courses of flat stacked slabs. The isolated upright slab was standing in the open near the southeastern end of the island. It was about 0.9 m high and firmly planted in the ground. Seven or eight small slabs lay against its base (Bryan cited in MacGregor n.d.:23).

In 1997, these sites could not be re-located. They were probably bulldozed during the construction of a landing strip in WWII. Our survey was mostly concentrated on the forested western side of the island, near the lagoon passes, although a single transect around the entire atoll was made. The sole part of the island not inspected was the extreme southeastern tip. Only one site, dating to the late 1800's, was found. It is on the lagoon side of the northern rim and consists of a stone pier, guano scrapings and a scatter of historic debris in the adjacent *Cordia* grove growing on an outcrop of phosphate rock. This is apparently John T. Arundel's guano camp from 1885-1886 (Bryan *op. cit.*: 46; Garnett *op. cit*: 189).

Kanton supports, or did until recently, the largest and among the most diverse populations of seabirds in the Phoenix group[24] (Table 4.2), indicating minimal human disturbance prior to WWII (Murphy *et al.* 1954). This fact is in accordance with the low number of archaeological sites recorded, suggesting light settlement. It seems possible that dry Kanton functioned as a faunal reserve for the inhabitants of neighboring and more "luxuriant" islands, whose people travelled there to replenish in protein foods. In the ethnographical present, this pattern is known from uninhabited Pikelot, Gaferut, Olimarao, East and West Faiu, in the central Carolines, Bikar and Taongi in the northern Marshalls, and Fataka in the Solomons; in the past from Kiritimati in the Lines (Di Piazza and Pearthree 2001 b:158).

Phoenix, an island rarely visited

No archaeological site has ever been mentioned for Phoenix island which lacks a safe anchorage. Even beaching a canoe is often difficult due to high surf. We surveyed the entire beach crest and made a transect across the island and along the north side of the shallow lagoon. Due to the open terrain, virtually the entire surface was inspected. One possible agricultural pit, one small shelter, a well and a stone monument were found.

The excavated pit was encountered on the summit of a dune, about the three-quarters of the way between the eastern shore of the lagoon and the beach crest. The pit is oval, 19 x 5 m x 1.5-2 m deep. Its base consists of dark organic mud and is covered by water, at a higher level than the lagoon. This feature does not appear to be related to guano collection due to its location on a sandy substrate, unsuitable for phosphatic accumulation. It is possibly a pit garden.

The rectangular shelter, 2 x 1.9 m and 0.5 m high, is located about 50 m south-east of the lagoon. It is walled on three sides and open to the west. These walls are constructed of flat beachrock slabs, with irregular faces. Its good preservation suggests it is a historic windbreak.

The well is situated at the northwest edge of the lagoon. It consists of a shallow depression, 0.5 m in diameter, partially outlined by 6 beachrock slabs. This feature is probably recent due to the presence of an adjacent pile of mud which appears to be material removed from the pit.

The circular stacked stone monument, 3 m in diameter x 0.7 m high, is located near the southwestern side of the island, about 40 m from the beach ridge. It has a long wooden pole lying at its base. An adjacent segment of wall, partially collapsed, about 4 m long and 0.7 m high, lies a few meters south of it. These features are probably the remains of "the buildings, flagstaff and wharf" of the guano camp (Bryan 1942:55). The monument is the official observation spot reported in the Pacific Islands Pilot (1982) as a 30 foot (9 m) high marker.

On Phoenix, as on Kanton, the land bears slight archaeological and ecological signatures of human impact: scarce sites, abundant and diverse avifauna. Only one possible pit garden was recorded. It may be that voyagers, there to collect birds, attempted to test the agricultural potential of the island, without investing a lot of effort.

Manra, an island of religious monuments

Four expeditions have visited Manra. In 1889, the British Admiralty Survey reported "*ancient stone sites and an ancient fish pond*" (MacGregor n.d.). In 1924, H.E. Bryan observed rectangular stone platforms (Bryan 1942:61). In 1933, MacGregor and Stuart spent two days surveying the island on their return from the Solomon Islands expedition on the yacht Zaca. MacGregor recorded 23 sites but "*unfortunately in an accident on the reef at the end of the last day of* *the expedition, the records and photographs of nine sites (L-U) were lost"* (MacGregor *op. cit.*). In 1939, at MacGregor's request, Bigelow re-visited most of these sites, guided by Kima Jack Pedro, a Tokelauan from Swains island who had been a copra worker on Manra since 1905.

We surveyed the entire perimeter of the island, from the beach to the highest beach ridge (about 40 to 50 m inland), as well as the northwest side of the lagoon shore. In the extensive areas of parallel beach ridges (or chenier), especially around the north and east points, the survey was extended further inland due to lack of vegetation. Transects were made between the beach and the lagoon near the southwesternmost double curbstone trail segments, near the southeast beacon, the modern village and near sites Syd 1-3 (Map 4.2). Other attempts at penetrating inland were stopped by impenetrable *Scaevola* brush. We were able to identify all of MacGregor and Bigelow's sites, except for three isolated platforms (Sites J, K, Q), a "*small destroyed cairn (Site M)*", a cluster of graves (Site V), 5 mounds (Site W) and a platform and tower (Site R) (Table 5.1). Descriptions of these seven sites are taken from MacGregor's manuscript.

"Platform J stood about one quarter of a mile from sites H and I [Syd-9,10]... It is 12 feet long, 7 feet 6 inches wide, the erect wall slabs measuring 1 foot 8 to 1 foot 10 inches in height. The monolith of irregular shaped coral at the north end was 3 feet 4 inches high; the pointed one at the south end was 3 feet 10 inches high. The west or sea side of this structure was removed and the ground beneath excavated for a depth of 4 feet in search of burials, but no trace of bone or human possessions was discovered".

"Platform K, a badly crumbled, small shrine-like structure stood a short distance northeast of site J. The structure and size of site K - 6 feet long and 4 feet wide with walls 1 foot high - were approximately the same as the little shrine, site D [Syd-5]. It had two upright slabs side by side, on the north side... The western upright was triangular in shape, 1 foot 9 inches high...The eastern slab, roughly rectangular, was 2 feet 6 inches high...".

"Bigelow reports finding 13 ancient graves (Site V), well eroded by the elements. They were located south of the tramway a little distance from the modern village on the southwest point of the village. These graves were rectangular in shape, measuring 16 feet by 3 feet. They were marked by a low curbing, but had no head stones. This was in distinction to nearby modern graves, whose headstones were marked with names and the date 1905... Still further on, there were five low circular mounds of coral gravel (Site W), four of them in one line, and the fifth off the line a little. There was no indication of their origin or purpose".

MacGregor's nomenclature	Nomenclature Used here	Site type	Comments
A	Syd-1	Marae	Test excavation in 1997, numerous uprights*
B	Syd-2	Marae	Upright in front of ahu*
C	Syd-4	Raised rectangular platform	
D	Syd-5	Raised rectangular platform (disturbed)	Upright in front of seaward side*
-	Syd-3	Recent house, subsurface habitation deposit	Excavated in 1997
E	Syd-6	Raised rectangular platform	
F	Syd-7	Raised rectangular platform	Upright in front of seaward side
G	Syd-8	Raised rectangular platform	
H	Syd-9	Raised rectangular platform	Test excavation in 1997, upright at SW corner*
I	Syd-10	Raised rectangular platform	Excavated in 1997
J	-	Raised rectangular platform	Excavated by MacGregor, uprights at each end*
K	-	Raised rectangular platform	Small altar, with 2 uprights on northern end*
L	Syd-11	Raised rectangular platform	Upright at NW corner
M	-	Cairn	
N	Syd-12	Raised rectangular platform	Upright at NW corner
O	Syd-13	Cairn of coral slabs	
P	Syd-14	Raised rectangular platform	
Q	-	Pavement with uprights	Excavated by MacGregor, 7(?) uprights along inland side*
R	-	Tower and small platform	
-	Syd-15	Cairn	
S	-	6 piles of coral rocks	Fish traps (?)
T	Syd-17	Raised platform (?)	
U	Syd-16	Raised rectangular platform	Upright at SW corner
V	-	Burials	
W	-	5 mounds	

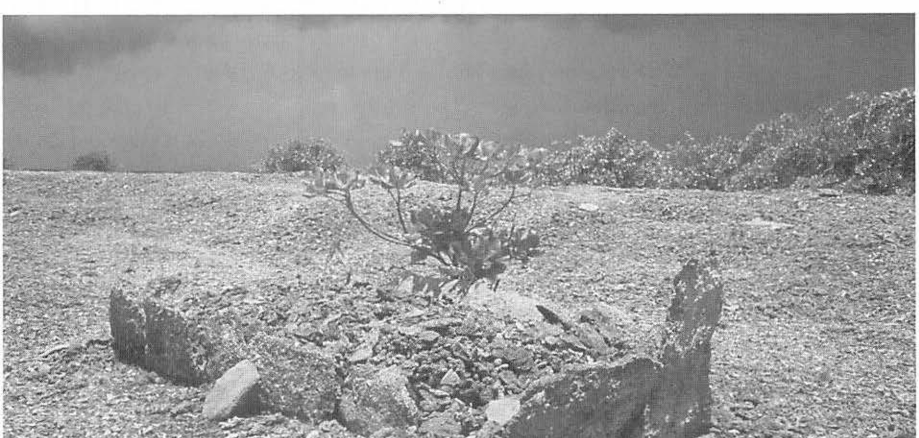
Table 5.1: Site types and nomenclature on Manra
*uprights from MacGregor (n.d.)

Site Q is situated not far from the east end of the lagoon and "*south of an old dock... It had a paving about 14 feet long and 3 or 4 feet wide made of limestone slabs laid on edge like thin cobblestones. This platform faced the lagoon and had along its back edge several (perhaps as many as seven) upright slabs ranging from 3 to 6 feet in height... Stuart's party from the Zaca... excavated beside the uprights but unearthed nothing of archaeological interest*".

Site R was "*about forty or fifty yards from the roadbed of an abandoned guano tramway, and some distance from the lagoon...Bigelow describes it as "a cylindrical tower of coral slabs, with a square platform in front. The cylinder is 3 feet in diameter, solid and 5 feet high. The platform in front is built up of slabs laid like bricks, and is 4 feet square and 8 inches to 1 foot high*".

9. Left: Stepping stone trail crossing cheniers on the southeast coast of Manra. Its seaward end is covered by the most recent chenier ridge

10. Below: Raised rectangular platform (Syd-16), with an upright in southwest corner, on Manra



There are three concentrations of prehistoric sites on the island. The most important one is situated along the protected western shore and consists of 2 marae (Syd-1 and 2), the prehistoric habitation deposit (Syd-3) and 11 raised rectangular platforms (Syd-4 through 11, J, K, M). This appears to be the main "village" or habitation area on the island. It offers the easiest sea access to the best inshore fishing locale and the widest reef flat. It is adjacent to what we infer to be the best agricultural zone, the densest forest extending for about 1.5 km NE from the modern village, and about 150-400 m inland from the sea. Other prehistoric features are clustered at the SE point, on the opposite end of the island. These are mainly stepping stone trails and cairns (Plate 9). They are probably associated with marine exploitation such as turtle hunting, but there are 2 or possibly 3 raised rectangular platforms (Syd-14, 16, 17?) which may have marked burials (Plate 10). The remaining features are at the northern point of the island, where two stepping stone trails and a single raised rectangular platform (Syd-12) were found.

The two marae (Syd-1, 2) have been significantly disturbed since MacGregor's and Bigelow's visits, so we used their notes and site map to reconstruct missing features, mostly facing slabs and uprights (Figs. 5.3, 5.4). Today, Syd-1 has the appearance of a flat topped rubble mound, but small test excavations identified the broken bases of numerous court edging slabs, some of the ahu facing slabs as well as the rectangular socket that once held a large court upright (Fig. 5.3).

> The ahu is situated along the inland side of the court. It is about 26 m long by 2.2 m wide and varies in height from 0.5 m to 0.7 m. The entire edge was faced with vertical slabs according to MacGregor (*op. cit.*). Its upper surface was leveled and paved with weathered cobbles and small slabs of beachrock. The platform was apparently subdivided into four sections, respectively 11, 8.7, 2.6 and 3.2 m long, by slabs on edge. Two of these partitions continue across the court, dividing it into three sections. The northeastern part (10.5 x 19.7 m) has a coarse paving of coral gravel and is partially outlined by court edging slabs set almost level with the ground. The two southwestern subdivisions (2.6 x 11 m and 3.2 x 11.5 m) are long, narrow and have been filled with about 15 cm of rubble. They are paved with 5 cm of fine coral pebbles to reach the level of the northeastern side. Presumably, they represent one or two later additions. Five uprights occurred in the larger court. Four of them were evenly spaced just in front of the ahu. The fifth one stood in the middle of the northeastern edge. Four uprights were arranged in a rectangle near the center of the ahu and eight more were incorporated into the ahu facings. One small one was located just outside of the southwestern corner of the court.

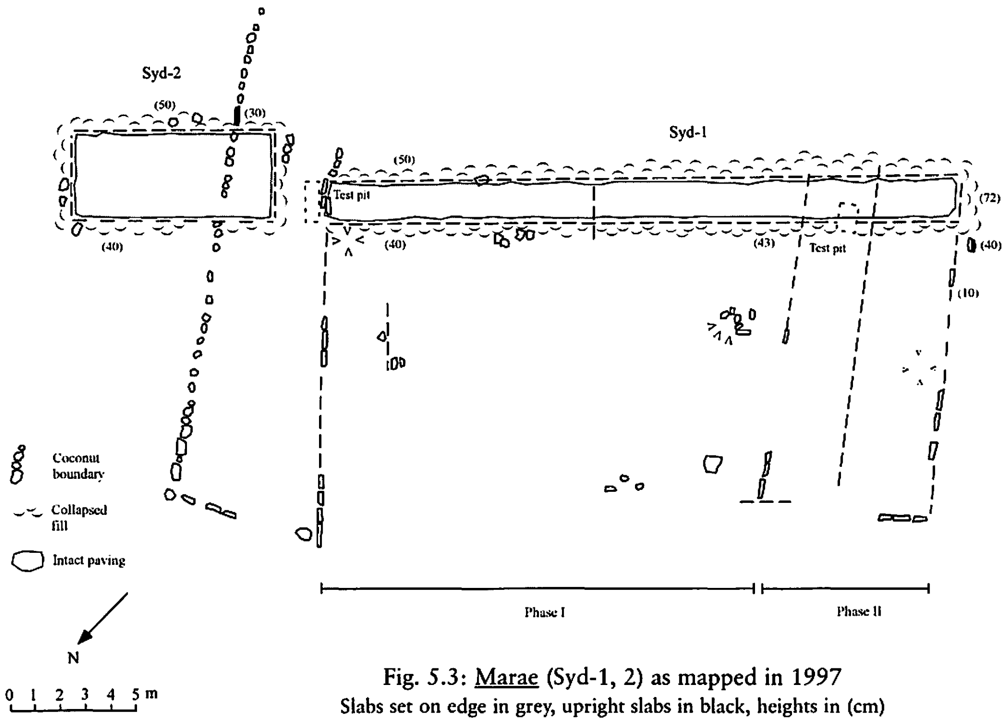


Fig. 5.3: Marae (Syd-1, 2) as mapped in 1997
Slabs set on edge in grey, upright slabs in black, heights in (cm)

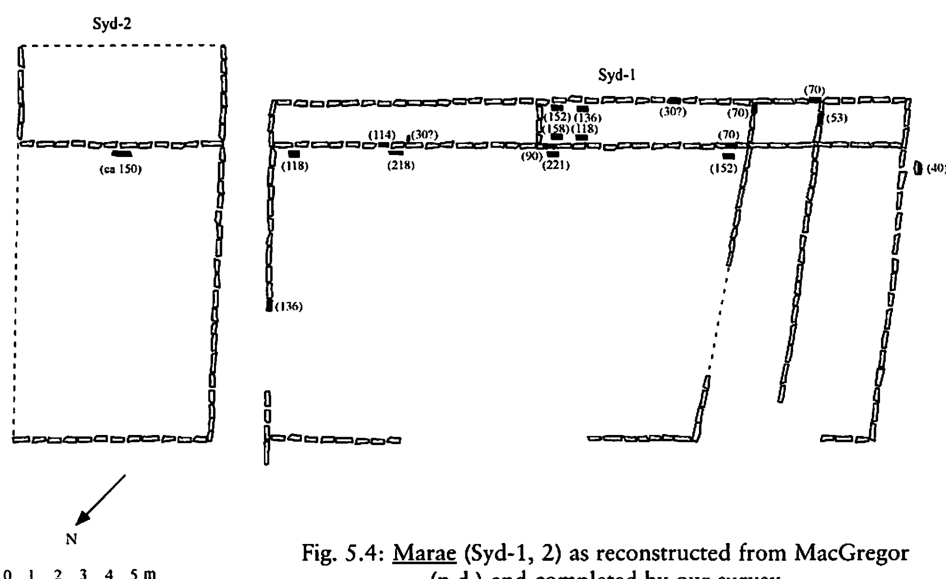


Fig. 5.4: Marae (Syd-1, 2) as reconstructed from MacGregor (n.d.) and completed by our survey
Upright slabs in black, heights in (cm)

A paved court curbed with limestone slabs on edge, an ahu faced with a single course of limestone slabs set on edge, and uprights along the front of the ahu as well as on the court, are a combination of traits commonly found on marae from the leeward Society Islands, as well as from the western and central Tuamotus and Malden island (Emory 1934 b, 1970:74, 76, 77). Three uprights along the front of the ahu, opposite three more on the court, is more specific to inland marae of the Societies, and is common throughout the Tuamotus. Two other characteristics of Syd-1, a court wider than it is long, an arrangement of upright slabs in the center of the ahu, forming a box or altar, are shared uniquely with the marae B and C at Site 1 on Malden (Emory a 1934:28-30). All these attributes are unlikely to be independent innovations. These architectural traits suggest relationships with the Societies and the Tuamotus, but more directly with Malden, some 970 nm to windward.

Due to the relatively large number of raised rectangular platforms, no less than 16 (if we include Q and the ahu of Syd-1, 2), the following detailed comparisons are made using statistics rather than feature by feature descriptions. All these features share numerous attributes. They are rectangular in plan, have raised stone faced edges and have their interiors filled with coral rubble (Figs. 5.5, 5.6, 5.7). They also have a similar orientation with their long axes parallel to the beach. Some of these platforms have one or more upright stones that extend above their upper surface. The facing stones are arranged in two ways, either vertically with their butts set into the ground or laid flat and stacked up on each other in horizontal courses, like "bricks". These will be referred to as vertical or horizontal slabs. Vertical slabs appear to have been the preferred method. Thirteen platforms have all sides vertically faced, one has all sides faced horizontally (Syd-14) and the fifteenth has three sides faced with vertical slabs and one with horizontal slabs (Syd-12). Their upper surfaces are flat or nearly so, and consist of a paving of eroded slabs of coral rock placed inside the facing slabs (Syd-1, 2, 4-11, 16). In two cases only, the paved upper surface extends to the edge of the platform and covers the top edges of the facing stones (Syd-12, 14). Of the 16 platforms known, 5 are virtually intact (Syd-9, 11, 12, 14, 16), 3 are partially disturbed (Syd-7, 8, 10), 2 have had much of their fill eroded away (Syd-4, 5) and three have had their facing slabs removed (Syd-1, 2, 6). The remaining 3 are known only from MacGregor's manuscript (Syd-J, K, Q) and may not exist any more. Syd-17 is not included in these counts, although it too may have originally been a rectangular platform. Today, it consists of a roughly circular rubble pile with a scatter of relatively large slabs arranged around the base of the mound. It is about 1 m high and 6 m in diameter. The fill and the size of the slabs are similar to those used to build the raised rectangular platforms.

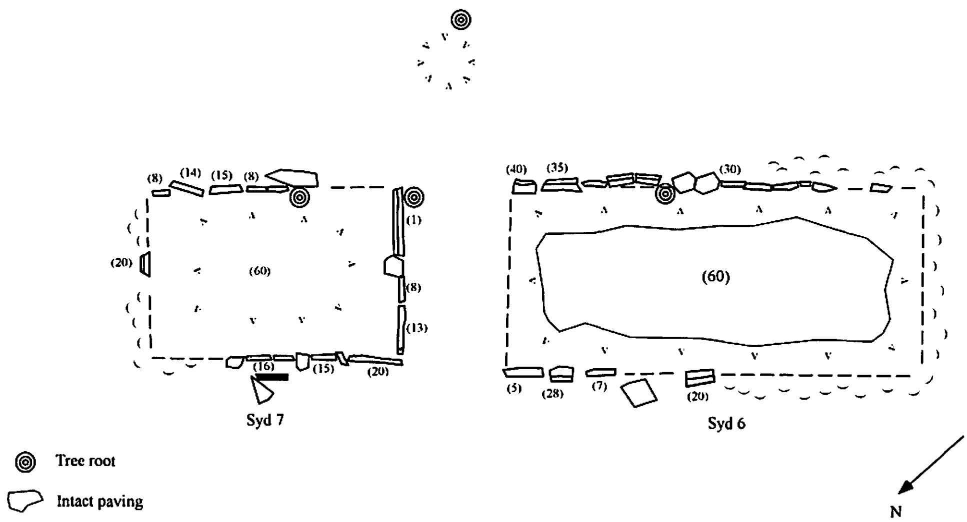


Fig. 5.5: Raised rectangular platforms (Syd-6, Syd-7)
Slabs set on edge in grey, associated uprights in black, heights in (cm)

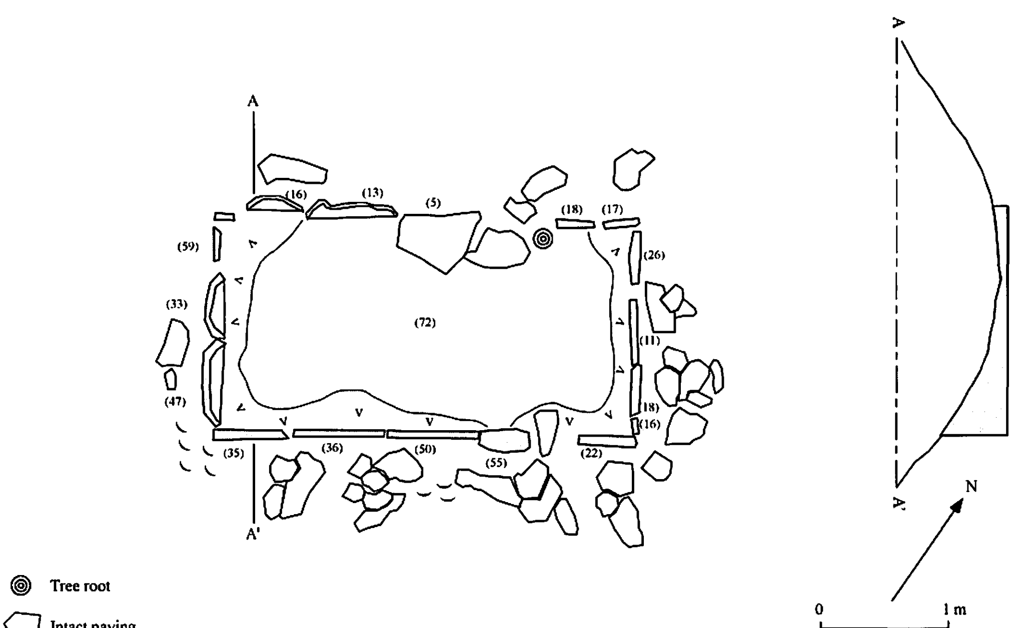


Fig. 5.6: Raised rectangular platforms (Syd-11) built on
a chenier ridge, with a schematic profile
Slabs set on edge in grey, heights in (cm)

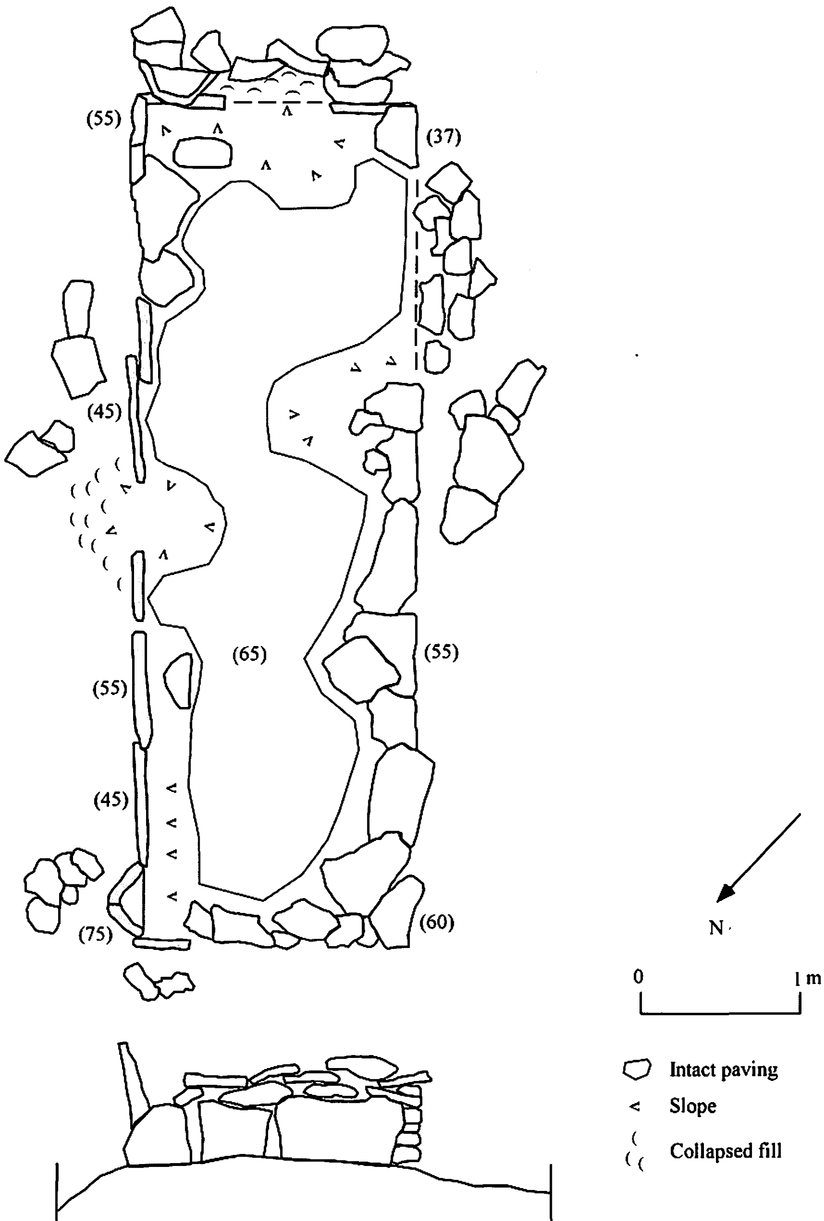


Fig. 5.7: Raised rectangular platforms (Syd-12), plan and side view
Slabs set on edge in grey, heights in (cm)

Site	Area (m^2)	Length (m)	Width (m)
Syd-1 marae	366.24	25.5	13.7
Syd-1 ahu	61.2	25.5	2.4
Syd-1 court	295.8	25.5	11.6
Syd-1 phase I	213.12	19.2	11.1
Syd-2 marae	140.35	16.32	8.6
Syd-2 ahu	36.12	8.6	4.2
Syd 4	14.52	4.4	3.3
Syd 5	1.7	1.42	1.2
Syd 6	30.7	8.3	3.7
Syd 7	17.5	5.0	3.5
Syd 8	4.16	2.6	1.6
Syd 9	7.0	2.8	2.5
Syd 10	10.3	4.5	2.3
Syd 11	6.17	3.43	1.8
Syd 12	9.55	5.37	1.78
Syd 14	5.67	3.5	1.62
Syd 16	5.5	3.53	1.56
J	8.1	3.6	2.25
K	2.16	1.8	1.2

Table 5.2: Length and width of raised rectangular platforms

Following an earlier study by Gerard (1978), we investigated the length to width ratios of these platforms (Table 5.2)[25]. There is a strong linear correlation that suggests the platforms as well as the marae were built to an architectural rule (Fig. 5.8). The equation for the regression line is $y = 0.498x + 0.28$, that is their length is about twice their width. The ahu of the Syd-1 marae diverges quite widely from our inferred rule with a length to width ratio of .09. Interestingly, at both Syd-1 and Syd-2, the combined courts and ahu have almost exactly the same rectangular relationship (.53 and .52), and the front edges of the courts

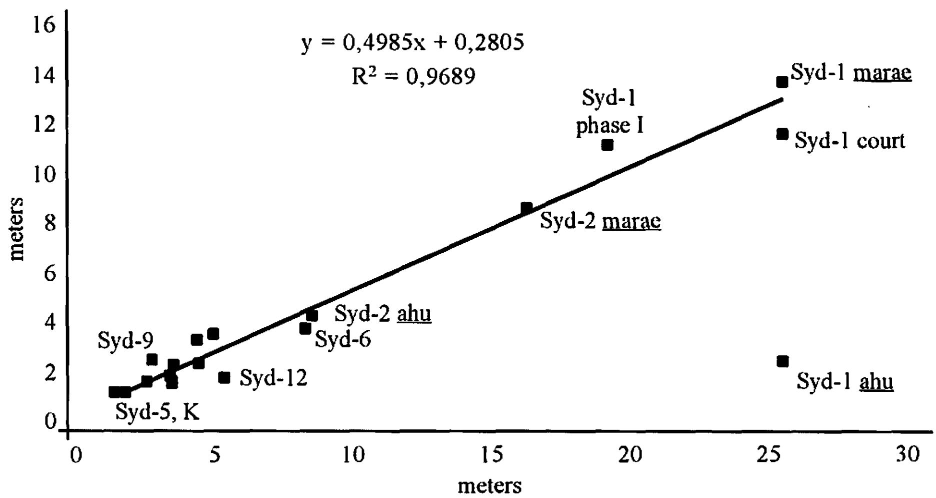


Fig. 5.8: Regression line and coefficient of correlation (R^2) between length and width of raised rectangular platforms and marae

Syd-1 ahu is the only outlier and was not used in the calculation

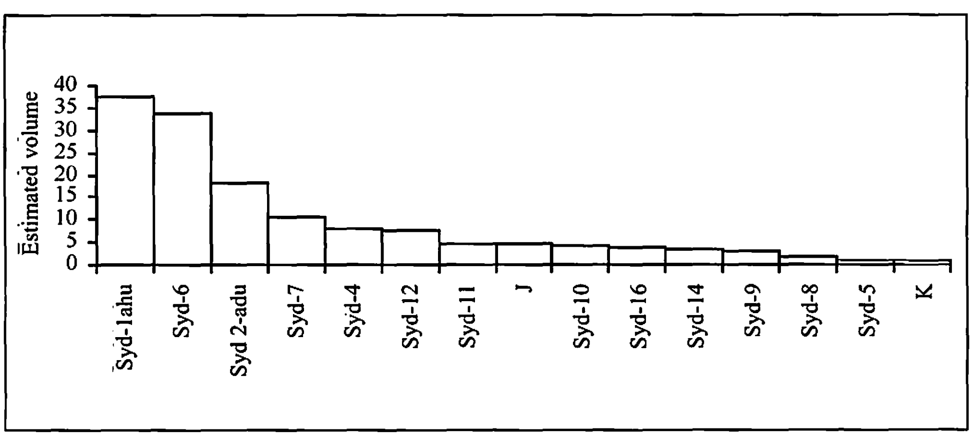
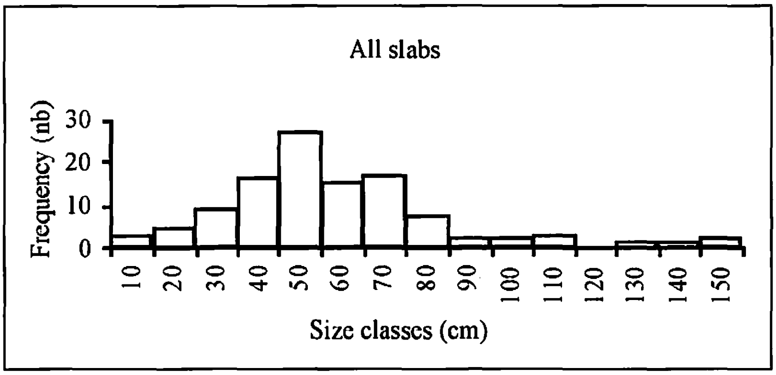
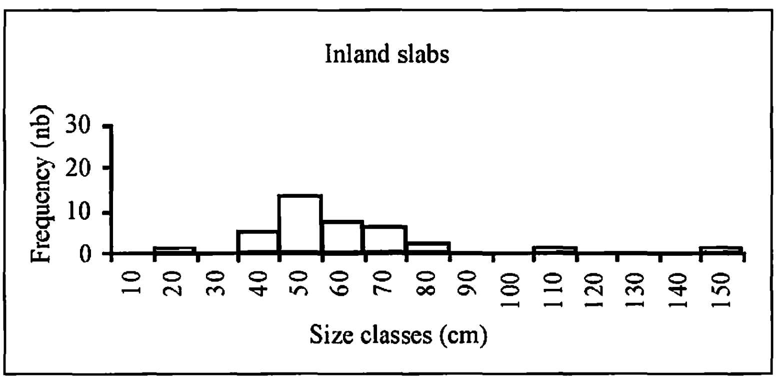


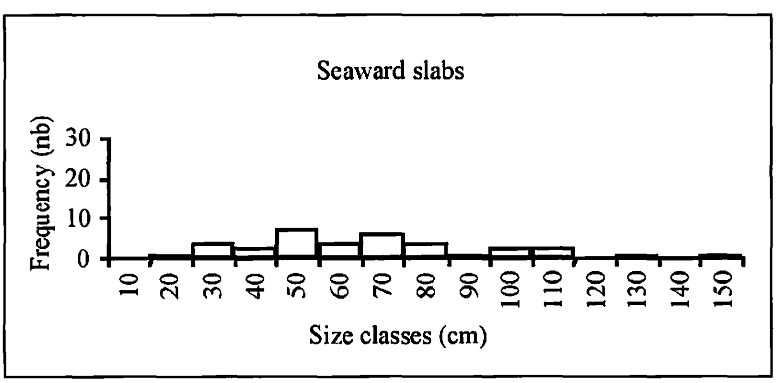
Fig. 5.9: Histogram of estimated volume (m^3) of raised rectangular platforms



Average: 56.78; Standard deviation: 26.78



Average: 55.42; Standard deviation: 15.68



Average: 65.70; Standard deviation: 30.07

Fig. 5.10: Width of upright facing slabs of raised rectangular platforms

and ahu are carefully aligned. We might speculate that there was some ritual requirement to bring these two adjacent marae into "balance" with each other (Fig. 5.4).

The computed volume of these platforms ranges from 37 to .6 m^3 and falls into two size classes (Fig. 5.9). Thirteen of the features have volumes less than 17 m^3, the other two are 33 and 37 m^3. A cubic meter of stone masonry weighs approximately 2 tons. Thus, platforms weigh between 1 and some 74 tons. Assuming that the main labor input is transportation of the stones and that a man can gather and carry about 2 tons per day, the biggest ahu at Syd-1 would represent about 37 man-days of labor, and the smallest about half a man-day. These figures, rough as they are, should be considered as a bare minimum, since the platforms are presumably foundations and may have supported perishable structures. Many of them are also faced with quarried slabs, requiring additional labor.

While recording platforms, we noted that the facing slabs on the seaward side appeared to be both larger and more regular in length than those on the other sides. After measurement, this impression was partly confirmed (Fig. 5.10). The average length of slabs is greater on the ocean side than on the landward side, although less regular, as shown by the higher standard deviation. We infer that the inhabitants were concerned that their monuments present a majestic appearance when viewed from the beach. This orientation is also true at sites Syd-1 and 2, which have their courts and principal uprights on the seaward side, and at platforms Syd-5, 7, 9, 11,12, 16 which have uprights either in front of or extending above their seaward faces (Table 5.1).

Four platforms have had subsurface testing. Two platforms (Q and J) were partially excavated by the Zaca Expedition in 1933 (see above). We dug a 0.5 by 2.7 m trench across much of platform Syd-10. The fill was resting on the undisturbed natural ground surface, except along the platform edge where a 30 cm wide by 20 cm deep trench had been cut to mount the facing slabs. No cultural material was recovered. A second trench dug between Syd-9 and Syd-10 revealed pig bones and one tiny basalt flake, without edge wear or retouch.

Osteological analyses were conducted by Jean-Denis Vigne[26]. He reported: "*There are there numerous bones of a pig aged 8-12 months, the cranial rostrum, the anterior portion of a rachis, from the occipital to the second thoracic inclusive, complete left and fore limbs. Two or three hundred indeterminate fragments seem to have come from the same skeleton and would appear to account for its missing parts. The other identified remains seem to be an accidental assemblage with no anatomical logic. These consists of less than 10 bones of young pigs, different from the individual above, but dead at more or less comparable ages, perhaps a tarsal of a small ruminant and 2 possible human bones, certainly not turtle. My general impression is that, mixed in with this ordinary garbage, is a*

11. Double curbstone trail segment on the northwest coast of Manra island

deposit of pieces of meat which evoke behavior seemingly sacrificial, in any case not profane". The mandible of the most complete pig gave a modern ^{14}C date of 40 ± 40 B.P. with intercepts at AD 1695-1725 and 1815-1920 (Beta 128287).

Although little can be said about the function of these raised rectangular platforms, their relatively large number testifies to their importance in prehistory. The lack of human bones, artifacts or food waste would seem to preclude their use as habitations or burials. The upright slabs associated with most of them (Table 5.1) suggest that they were commemorative monuments, perhaps built to honor a death or a deified ancestor. And rather than evoking despairing castaways, putting their fates in the hands of their gods, as Carlquist (1980) once speculated about the marae on two hawaiian mystery islands, another reading of these monuments would make their builders happy fishermen, involved in regular rituals and obligations.

Two different kinds of trails were discovered on Manra: stepping stone trails and sections of a double curbstone trail.

The stepping stone trails consist of single alignments of coral slabs spaced about 0.8 to 0.9 m apart. The slabs appear to have been selected for smooth surfaces, but weathering over the centuries has weakened their edges and left sharp projections. The trails lie at right angles to the beach and are clustered around the north point of the island and along the southern shore, in areas where chenier ridges are well developed. Concentrations of weathered fragments of *Tridacna* shell debitage were noted along several of these trails.

The double curbstone trail comprises two parallel alignments of waterworn beachrock slabs set on edge (Plate 11). Its width ranges from about 4.5 to 5.5 m. It was identified at numerous locations along the west and southwest sides of the island, where sections up to 100 m long were visible in thick forest. It lies between about 70 m to 150 m inland and appears to be continuous around perhaps 1/4 of the circumference of the island. It serves no obvious economic function, nor does it facilitate travel, since the surface both inside and outside is loose sand. Within the historic village, house platforms were built right across the trail, in some cases using slabs borrowed from it. In other places, coconut boundary alignments abutted the trail. Thus it predates the 1930's re-settlement and may be prehistoric. MacGregor (*op. cit.*) reported trail segments paralleling the coast between Syd-10 and site J and between sites K and Syd-11. These may be part of the double curbstone trail.

The stepping stone trails, which occur primarily on areas of sharp coral, facilitate access to the reef, thus to fishing grounds and turtle nesting areas. Along with coconut charcoal, fishhooks and bones from the Syd-3 excavations, the trails represent the only evidence of subsistence activities on Manra. The other surface finds, raised rectangular platforms and marae, seem to be related to religious or ceremonial purposes. Their monumental scale attests to their important role in the past. Even the double curbstone trail, which parallels the coast in sandy areas seems to have had a social, rather than utilitarian function. Similar paths have been reported from Hawai'i (Clark and Kirch 1983; Kirch 1985), Rarotonga (Bellwood 1978) and Wallis (Frimigacci *et al.* 1983) where they served for ritual processions of chiefs and priests. A comparable function may be inferred for the trail of Manra.

The historic features on Manra, which consist of house foundations, coconut allotment boundaries, stone lined wells and agricultural pits are located in and around the modern village. All appear to date to the resettlement program of 1939-1961, except the tramway roadbed along the lagoon shore and a beacon on the east point which belong to the guano mining period in the late 1800's.

Modern village. The village lies within 600 m of the western point of the island. The commonest features consist of traditional house foundations with low rectangular curbings of beachrock slabs set on edge, and interiors paved with beach pebbles. In some cases, wooden posts and horizontal beams are still standing. More often, post bases or post holes were present. In only a few cases were nails or imported material used. Modern portable artifacts such as iron pot supports, a copper tea kettle and vessels made out of airplane fragments, are scattered on some foundations. Several houses also have one or more water-worn exotic stones apparently for whetstones in their paving near the fire place. Fragments of similar metamorphic rocks, probably discarded oven stones, are dispersed all around. Several low stone walls divide the village. One, the longest and widest, extends inland toward the lagoon shore. It may have been a causeway or trail to the guano dock. A stacked stone beacon (2.2 m square by 1.3 m high), probably the monument noted by Bryan (1942:60), stands on the beach at the south end of the village.

A complex of European frame buildings lies along the beach, at the north end of the village. The largest, apparently the Administration Officer's quarters, had a sheet steel roof, a concrete floor and a wooden flagpole. Seaward of the pole is an upright concrete slab commemorating official visits with the names of ships, officers and colonial officials including H.E. Maude and the dates of their visits. Between the Administrative quarters and the beach is a rectangular house platform with a poured concrete pad and an adjacent paving of beachrock slabs up to 20 cm thick. Fifty meters to the northeast, is another wooden building, presumably for storage, with nails, pipe fittings and other hardware, as well as medicine bottles, an iron copra scale and a glass graduated cylinder. A large concrete cistern is located about 100 m north of the Administration quarters, and about 40 m from the beach. It is built half underground with an intact roof of cement asbestos tiles. According to a retired police officer on Kiritimati, this structure is occasionally maintained by the Kiribati government. In front of the cistern, a narrow boat passage has been blasted through the fringing reef, improving the landing. Five wells, lined and coped with stone were noted along the inland side of the village. Numerous pieces of a multi-engine airplane are scattered throughout this modern complex. It had three bladed aluminum propellers with two piece cast steel propeller hubs.

Coconut Boundaries. Much of the southwestern half of the island has been marked off into a rectangular grid of rock alignments, which vary from spaced cobbles to linear piles of rubble to proper walls. The corners are often marked by vertical slabs, sometimes with red painted numbers. In a few cases they abut pre-existing features, such as the double curbstone trail or the broad wall or causeway in the modern village. Several prehistoric sites, particularly Syd-1 and Syd-2, were partially dismantled to supply stone for these alignments (Fig. 5.3). This grid appears to be the boundaries of the allotments of coconut trees given to the I-Kiribati settlers beginning in 1938. "*Each man and woman has been given 50 coconut palms, to use as food or to make copra, and each child, two unplanted sections, each 150 feet square*" (Bryan *op. cit.*:62).

Agricultural Pits. Several excavated pits were noted in dense forest, between the lagoon and the village, as well as along the lagoon shore. They varied from rectangular (up to 3 x 4 m) to circular (about 4 m inside diameter) with raised berms and steeply sloping sides. No retaining walls were noted in any of them. Judging from the eroded berms, they appear to have been used during historic times, although that does not preclude them being more ancient. Similar pits, undoubtedly prehistoric, were described by Arundel, the manager of the guano enterprise, as "*a collection of deep holes perfectly round, about 6 feet deep and 8 feet in diameter...*" in the 1880's (cited in Ellis 1936:57).

Beacon, aluminum mast and guano tramway. On the eastern point of the island is a square stone platform (Syd-15) with sloping sides. It is 2.5 x 2.5 m x 2 m high. This "*beacon was built about 1916, for Capt. Allen, and is very similar to the beacon on the west point of Hull Island*" (MacGregor n.d.).
A tall aluminum pole supporting a foam and fiberglass sphere is located near the first chenier ridge on the northern point of the island. A plate identifies it as the property of the U.S. Space and Missile Test Center.
One section of an old guano tramway alignment could be recognized along the north west shore of the lagoon. It consists of a straight level section of fill, about 1.5 m wide, 20 cm high and 80 m long.

Orona, an island whose inhabitants feast on birds and turtles

On Orona, archaeological features were first discovered by Arthur F. Ellis in 1887. He noted: "*at the far northeast end of Hull Island, is an ancient burial ground with about a hundred marae 6 feet long and 4 feet high and a much smaller graveyard elsewhere*" (Ellis 1936:14). Due to the dimensions of these features, his use of the term marae may refer to raised rectangular platforms. E.H. Bryan with the Whitney Expedition of 1924, found "*the ruins of an ancient stone marae or Polynesian shrine and small shelters, made of blocks of coral sandstone*" at the extreme eastern point of the island. He also noted graves and platforms along the northern rim (Bryan 1942:64), one of which (Site 12) he excavated to a depth of 4 feet without "*unearthing any finds*". It was "*8 feet in length and 6 feet in width... faced with a single course of rough limestone slabs on edge and filled nearly to the top with large pieces of coral*" (Bryan cited in MacGregor *op. cit.*). The description and dimensions of this structure led MacGregor to conclude that it was a faced platform similar to others on Orona and Manra. In 1933, MacGregor revisited some of the sites reported by Ellis and Bryan at the eastern end of the island. He also reported other features, such as an isolated upright slab, and two circular alignments of uprights (Sites 1, 2, 13). Since we were unable to visit this complex, the following descriptions of Sites 1 through 13 are based on MacGregor's manuscript.

Isolated upright slab. An upright slab (Site 1), about 2 m high by 0.6 m broad was recorded about 25 m from the lagoon shore.

Rectangular platforms. Four to six rectangular platforms (2 at Site 4, 1 at Site 5, 1 at Site 12, and 2 more probable platforms at Sites 10 and 11) have been recorded. Three of these are fairly small, about 2 m long (Sites 10, 11) and 2.4 x 1.8 x m (Site 12). Two more are much larger, 5.2 x 2.6 x 1.1 m high at Site 5 and 9.4 x 4.7 x 1.4 m high at Site 4[27]. A second platform at Site 4 had been torn down prior to MacGregor's visit. All the platforms are faced with vertical slabs, except for the largest one (Site 4) and the inland sides of Site 5, which consist of horizontally stacked slabs.

Crescent Shaped Shelters. Seven or more crescent shaped shelters (3 at Site 3, 1 or more at Site 6, and 1 each at Sites 7, 8, 9) are mentioned by MacGregor. They are built of slabs stacked horizontally. Most are about 0.6 m high, but one is 1.45 m. They vary from about 1 to 2 m in length. As far as is known, all have their backs to windward, indicating use as windbreaks. Their proximity to the eastern shallows of the lagoon and to the most extensive offshore reef suggest that they may have functioned as fishing shelters.

Paved Trails. A "*double path of coral slabs*" was found on the lagoon side, below the two platforms of Site 4. Another trail, possibly prehistoric, was noted on the southeast shore opposite Site 1.

Circular Slab Alignments. Site 2 "*was an incomplete circle of slabs set in the ground at intervals of about 2 feet (0.6 m), and tilting out from the center of the circle.*" The interior was filled with "*heaped limestone slabs*". MacGregor excavated this feature without finding any trace of a burial. Site 13 "*was con-*

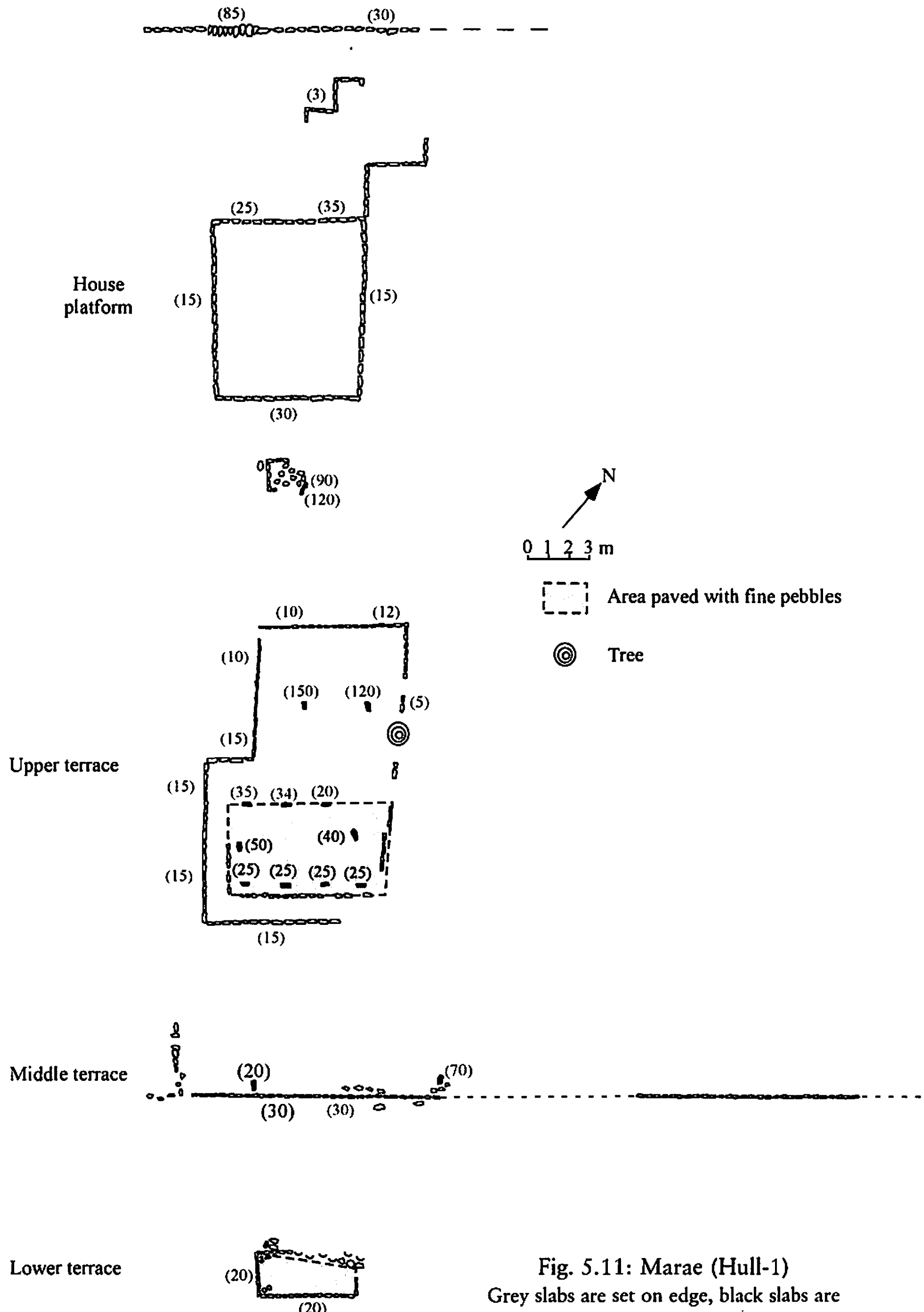


Fig. 5.11: Marae (Hull-1)
Grey slabs are set on edge, black slabs are uprights, heights in (cm)

12. Cut stone facing the middle terrace of marae on Orona island (Hull-1)

> *structed of slabs set on edge in a circular formation about 10 feet in diameter.*" Schultz, a member of the U.S. surveying expedition, excavated this feature in 1939 without result[28].

In 1997, we restricted our survey to the western part of Orona, in order to stay close to the anchorage during unsettled weather. Our primary focus was the lagoon side, although several transects were made across the rim of the island and along the islets just east of the anchorage. The features observed were a marae, a short segment of a double curbstone trail, a large artificial mound (first reported by MacGregor), a possible habitation complex, seawalls and agricultural pits (Map 4.3).

The marae is situated south of the modern village, along the inland side of the beach crest (Fig. 5.11). Built on a slope, it comprises three faced terraces and numerous upright slabs.

> *Marae*. It consists of three natural ridges of coral rubble leveled and faced with slabs of beachrock.. The marae measures about 36 m front to rear and 15 m wide, although the middle terrace facing extends for an additional 60 m to the northeast, with gaps where stones have been removed.
>
> On the lower terrace is a rectangular enclosure faced on all sides with roughly

13. Uprights on upper terrace of marae on Orona island (Hull-1)

rectangular slabs. Its northern corner is buried by storm deposited rubble. There are larger flat slabs of coral rock, possibly fallen uprights, in both upslope corners (north and west) and the interior is filled and paved with fine coral pebbles. The middle terrace is located 10 m seaward and some 70 to 80 cm higher. It consists of a modified natural ridge of coral rubble. The downslope edge is faced with cut rectangular slabs about 30 cm high and filled with coral rubble (Plate 12). It has two uprights mounted just upslope from the facing. The upper terrace, situated on the highest rubble ridge, about 50 m inland from the ocean beach and about 3 m above sea level, is 9 m further upslope. It consists of a "notched" rectangular enclosure outlined with a low curb of cut slabs. At one end is a rectangular area paved with fine pebbles and partially outlined with curbstones, with a rectangular arrangement of uprights. This is probably the ahu. Further back are the two highest uprights, both somewhat anthropomorphic (wider at the top and with a concave notch in their upper edge). They face each other and may have supported a pole or offering stand. Twelve meters seaward of the marae enclosure is a raised rectangular house platform paved with

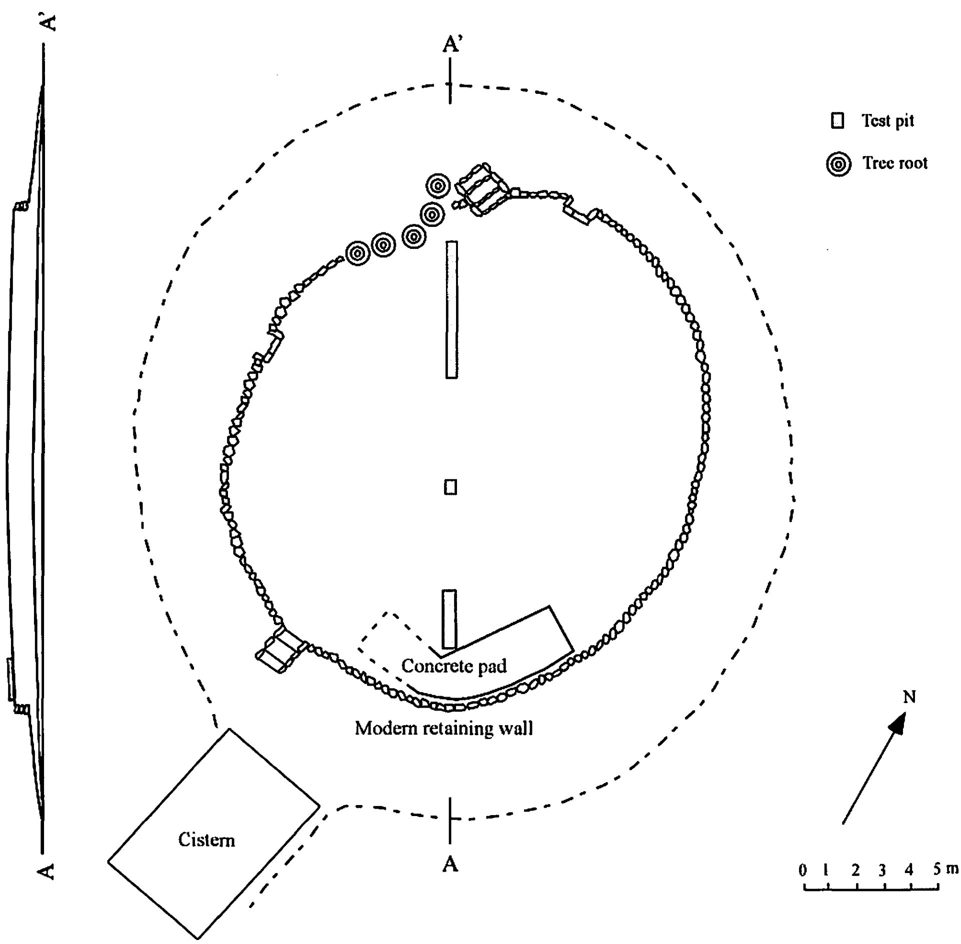


Fig. 5.12: Plan and profile of prehistoric artificial mound (Hull-2)

sand and irregular slabs of beach rock with remnants of wooden posts on its surface. The platform is faced with cut rectangular slabs of the same size (55 to 60 cm wide) as those used to face the middle terrace of the marae. The facing consists of 35 linear meters of slabs, the same amount which appears to be missing from the terrace. Between the marae and the modern house is a small rectangular area with paving similar to the house and two uprights, like those on the upper terrace (Plate 13).

The architecture of this marae shares certain traits with those on nearby Manra and Enderbury. They have rectangular courts. They appear to have been built over time, becoming larger and more complex. On Manra and Orona, there are uprights on both the court and the ahu, where they form a rectangular "box". Yet these marae exhibit notable differences. The courts vary from pebble pavements outlined with curbing to slab pavements without curbs. In plan view, they are either long and narrow or wide and short. Ahu may be rectangular pavements with uprights, or raised platforms either with or without uprights. These stylistic variations, which conform to a more general and widespread design tradition, are contemporaneous since the occupation of the archipelago is relatively short. This suggests, as Kolb has noted for Hawai'i, that the "*goal when constructing a new temple was to imitate, or at least incorporate, architectural elements of heiau [marae] built by successful rulers*"... resulting in "*something unique and unlike any previously built structure*" (Kolb 1992:14).

The area south and east of the marae revealed quite an unexpected richness of surface features. Some of them, such as a complex of agricultural pits, seawalls and a house platform. are testimonies of daily life; another, a large artificial mound of cooking debris (Fig. 5.12), attests to more specialized activities, presumably related to festive gatherings and an abundance of food, probably "first fruits" ceremonies.

Artificial Mound. "A large artificial mound stood at the west end of the island from which turtle and bird bones had been recovered"(MacGregor *op. cit*). This mound, located 60 m from the lagoon, is 25 m in diameter and today stands about 1.3 meters high. Its fill is a dark stained sand with coral oven stone fragments, bones and charcoal (see chapter 6). It covers an area of about 500 m^2, and has a volume of at least 200 m^3. Most of this dense concentration of cooking debris is contained within a modern circular retaining wall, about 18 m in diameter, constructed of 6 courses of flat slabs of water-worn coral rock, 40 to 50 cm high. The center of the mound extends about 20 cm above the wall. It has been disturbed during modern times by the construction of a European structure on its top, which was leveled and covered with a layer of sterile beach sand for the occasion, and by an adjacent concrete cistern. Numerous rotting wooden timbers and bits of furniture are scattered on the surface. Excavations revealed that the prehistoric fill continued for about 40 cm below the base of the wall.

Habitation Complex. A stone lined well (about 1 m deep x 1 m in diameter), a section of wall, a possible house platform and numerous scattered beachrock slabs lie to the northwest, within 100 m of the artificial mound. These features, poorly preserved, are the last testimony of what appears to be a prehistoric hamlet.

Seawall complex. Several sections of seawalls were noted along the western shore of the lagoon, beginning about 300 m south of the artificial mound and extending for about 700 m. They consist of retaining walls along the current shore line or parallel to it a few meters into the lagoon. The latter are in about 20 cm of water at mid-tide. The walls are about 0.6 to 0.8 m wide, 0.2 to 0.3 m high and up to 20 m long. They consist of weathered coral rock and coral heads stacked flat, sometimes naturally cemented into a solid mass. The lagoon shore has eroded landward, leaving corners of these retaining walls projecting into the water. These prehistoric features apparently served to protect a series of brackish ponds and walled agricultural pits a short distance inland.

Lagoon Agricultural Pit Complex. An extensive complex of shallow pits is located along the lagoon shore, starting about 200 m south of the artificial mound and continuing for about 700 m to the south. They vary from circular to oval. The largest were up to 30 m long, although the majority seemed to be about 15 m in diameter. Many pits had low (ca. 10 cm) spoil banks around their margins. Some of them, in particular the one nearest the lagoon, had short sections of stacked walls (up to 0.7 m high) protecting their edges. These pits are in a low lying area and many were filled with fresh or slightly brackish water. Others were dry and occupied by pure stands of *Pemphis acidula*. Their banks were covered with mixed stands of *Morinda citrifolia*, *Pisonia grandis*, sparse coconuts and thick mats of vines and *Pandanus sp.* further inland. In 1887, A. Ellis noted about 5 brackish ponds filled with very fat awa or milkfish (*Chanos sp.*) in this part of the island (Ellis 1936:2-3). It is likely that Ellis's ponds are part of this complex of prehistoric agricultural pits.

Double Curbstone Trail. A short section of a double curbstone alignment was noted in thick forest northeast of the modern village, about 70 to 100 meters inland from the sea. It consisted of two parallel rows of beachrock slabs set on edge, extending about 25-30 cm above the ground. The curbstones were aligned at 265° (true), with the two rows spaced 1.8 m apart.

Orona is without a doubt the island where the remains give the best picture of the different aspects of the life of the occupants. A festive life if one envisions the great quantities of food from turtles and birds suggested by the artificial mound, a religious life too, as testified by the marae and the numerous platforms and finally a life of work, as shown by seawalls and the extensive agricultural pit complex.

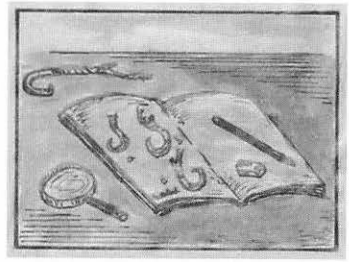
Most of the historic features are concentrated on the western side of the island, in the most productive area for growing coconuts. They consist of the modern village, boundaries of coconut allotments, agricultural pits and wells which date to the colonial resettlement program of 1939-1961. Other more recent remains are related to US missile testing in the 1970's.

> *Modern Village.* The village where the copra workers and later the Gilbertese settlers lived is located on the western tip of the island. Its components are numerous traditional Polynesian house platforms and a few European frame buildings. The house platforms are built of beachrock slabs set on edge, delineating a raised surface paved with beach pebbles. Some have remnants of thatched structures. On the lagoon shore opposite the village are a stone walled fish trap and a sea wall or quay with pieces of concrete blocks in it.
>
> *Coconut Boundaries.* A few stone alignments were noted in the areas of healthy coconut trees, near the modern village. Some of these alignments were low rubble walls, but most were rows of single stones laid flat. These alignments appeared to delimit roughly rectangular plots. In a few cases, their corners were marked by slabs on edge. According to Bryan, the coconut trees on Orona were *"apportioned among the settlers at the rate of about fifty bearing trees to each adult"* (Bryan 1942:65).
>
> *Inland Agricultural Pits and Well.* Two agricultural pits and a stone lined well were encountered inland, a few hundred meters northeast of the historic village. The pits were oblong in shape (about 5 x 7 m long and 1.0 to 1.8 m deep), and have retaining walls of beachrock slabs with spoil banks around their edges. These abandoned *Cyrtosperma* pits have been colonized by a luxuriant growth of *Cocos* and *Pandanus* trees. The good preservation of these features indicates that they were in use during the historic period, although they may be re-used prehistoric features.
>
> *Military complex (USAF SAMTEC).* Three helicopter landing pads of perforated steel sheets are located along the sea side of the northwestern rim of the island. About 5 ha around these features has been bulldozed (Garnett 1983:280) and recolonized by *Morinda*, *Guettarda* and *Pisonia*. Two tall wooden poles or masts, similar to the ones on Enderbury and Manra islands, were also noted along the north rim.

At this point, we see three contrasting strategies of occupation of these five islands. On Manra and Orona, surface features are diverse, abundant and are evidence of thriving populations. It seems highly unlikely that such archaeological richness would be present if the occupation of these islands was temporary or episodic. On Kanton and Phoenix, the lack of habitation sites or agricultural features and the scarcity of freshwater indicate short term use, limited to temporary visits. The inferred exploitation of these islands is for fishing and hunting the abundant faunal resources. On Enderbury, the number of archaeological sites is in between. There, inhabitants practised effective environmental management, as shown by dry agricultural features, but the limits imposed by that environment did not allow a large or permanent population. However, the monumental pavements or marae suggest that, from time to time, substantial numbers of people assembled on the island, perhaps for harvest ceremonies.

On the three inhabited islands, we find a recurrent settlement pattern with similar features in similar "niches". Habitations are located on the protected leeward sides, close to agricultural features and reef passes. Protected from storms, their settings coincide with the best soil development, forest growth and the biggest fresh water lenses. Marae are situated nearby, close to the ocean. Raised rectangular platforms, circular mounds and isolated upright slabs are found on the dry and barren windward shores of the islands, particularly among chenier ridges. Stepping stone trails occur primarily at right angles to the coast, in areas of sharp coral and cheniers, while more formal double curbstone trails are built in inhabited leeward sandy areas, and lie parallel to the coast. This cultural landscape was presumably built by one community, who inhabited forested Orona and Manra, sailed often to Enderbury to care for their gardens and voyaged occasionally to Kanton and Phoenix to collect birds, turtles, fish and pearl shell. High mobility and low human density are probably the two key factors allowing successful occupation of the Phoenix group.

CHAPTER 6



Occupation of Two Mystery Islands

Early East Polynesian settlement of Manra and Orona

"*Intensive archaeological studies on some of these [mystery] islands have opened up a fascinating chapter in prehistoric man's attempted "conquest of the Pacific". These studies not only provide evidence on the timing and extent of the past Polynesian migrations, they also yield clues as to the Polynesians' skills and abilities as island colonizers*" (Kirch 1988:28).

Of the Mystery Islands, Manra and Orona are among the most mysterious. Neither size, nor limited resources, nor isolation can reasonably explain why these atolls were abandoned prior to their re-discovery by Europeans. On the contrary, the numerous archaeological surface features, built by agriculturalists who participated in the East Polynesian tradition of monumental architecture, suggest that these islands supported a reasonably large population for a relatively long period of time.

Only subsurface archaeological study can provide a firm foundation in which to understand the process of settlement of the Phoenix archipelago. Excavations[29] of a trash pit and habitation deposit on Manra and a large cooking mound on Orona allowed us to address two issues currently debated by prehistorians: the chronology of colonization of East Polynesia and human cultural adaptation to the atoll environment. The results demonstrate that these two islands were neither occupied by "*castaways*" (Mac Gregor nd; Emory 1934 a) lost on their way to high islands, nor did they serve as simple stepping stones to sailors during the systematic colonisation of the rest of the Pacific (Irwin 1992).

They were the site of a veritable early settlement, whose people engaged in ceremonial practices and who specialized in hunting seabirds for meat and probably for feathers and eggs. These people also participated in exchange, both locally for pearl shell and long distance for high quality basalt and manufactured their fishhooks and stone tools from these imported materials.

Prehistoric trash pit and workshop

A survey along the leeward side of Manra revealed a concentration of 4 basalt flakes adjacent to a historic house platform and 6 m west of a prehistoric raised rectangular platform (Syd-4). Associated with the debitage was a pearl shell fishhook shank and a small cluster of turtle bones (Fig. 6.1). Initially a trench was opened along the edge of the house platform. It was then extended to include subsurface features, totaling 5.5 m^2.

The stratigraphy consisted of three layers (Fig. 6.2). Strata I (0-7 cm below surface) is a grey-stained sand mixed with numerous coral pebbles and *Strombus* shells. Strata II (7-40 cmbs) is a cohesive dark sandy loam, grading to light gray with depth, with abundant water worn pebbles and cobbles. Features recorded in this cultural layer are an earth oven, a thin charcoal lens and a round bottomed trash pit, which intrudes into Strata III. Cultural material includes imported pearl shell and basalt debitage, adze fragments and pearl shell fishhooks. Oven stones, charcoal and bird bones were also recovered. Strata III is sterile white beach sand with rare bird bones.

The earth oven was 23 cm deep. It consisted of two lenses of charcoal mixed with burnt coral oven stones separated by a thin layer of white sand, suggesting two episodes of use. The lower lens was lined with strips of charred coconut husk. The upper lens had a single *Strombus* shell in the center, with the opening turned upright and two pieces of *Tridacna* shell (0.14 kg total). The oven stones are mostly water-worn *Porites* coral (about 12 kg total).

The trash pit, 1.25 m in diameter, is partially outlined by flat beach rock slabs along the southwest edge, forming a rough pavement that possibly served as the floor of an atelier since the greatest concentration of artifacts was recovered among and underneath the stones.

The charcoal lens (at 25-30 cmbs) is almost at the bottom of the cultural layer. It presumably resulted from cleaning a nearby earth oven.

Two charcoal samples were collected as bulk feature fill, one from the lower portion of the earth oven (Beta-112419), the other from the charcoal lens (Beta-112420) (Fig. 6.2). Charcoal was identified and submitted samples consisted of single taxa, respectively *Cocos nucifera* (husk) and *Guettarda speciosa*. Both

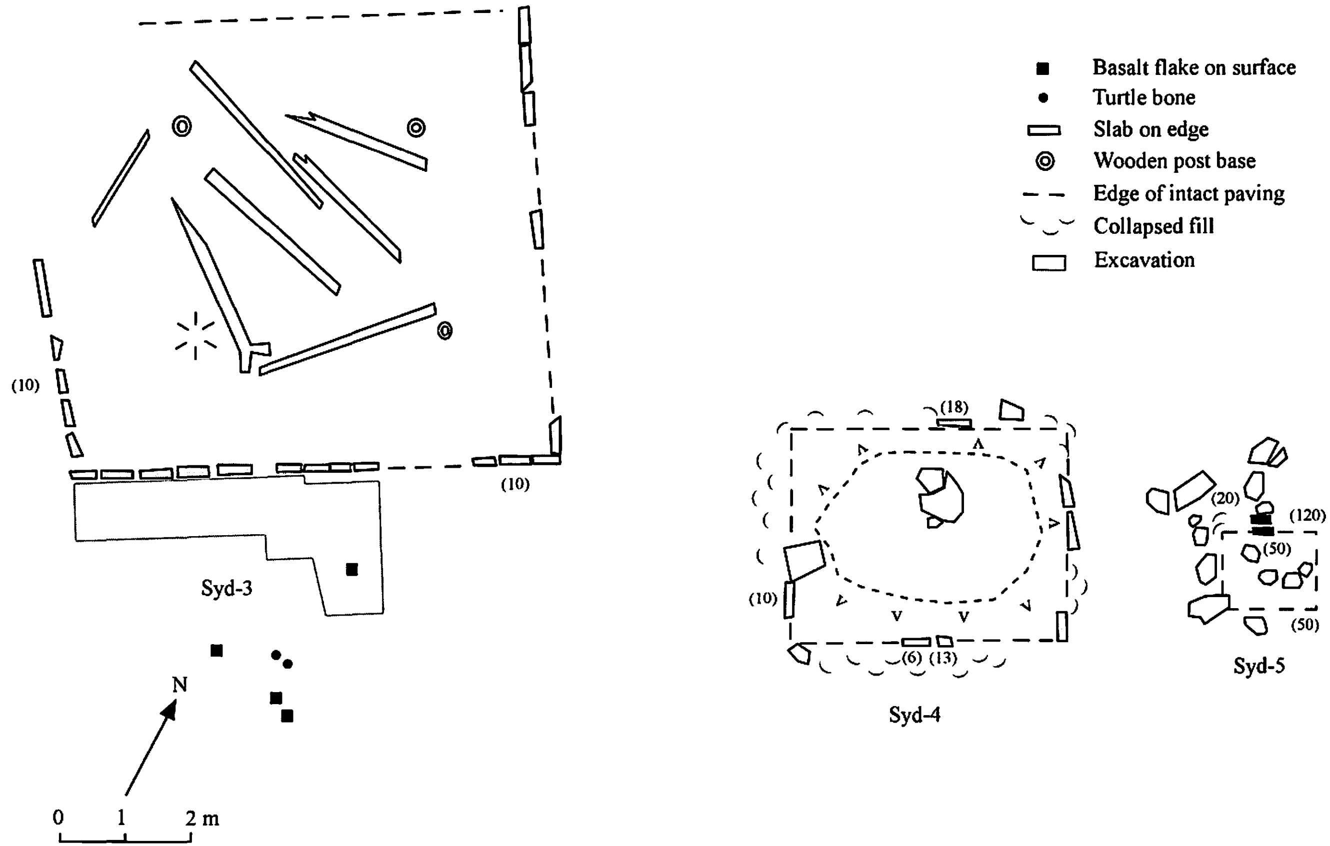


Fig. 6.1: Raised rectangular platforms, historical house floor (Syd-3) and location of excavation
Syd-5 is reconstructed after MacGregor (n. d.)

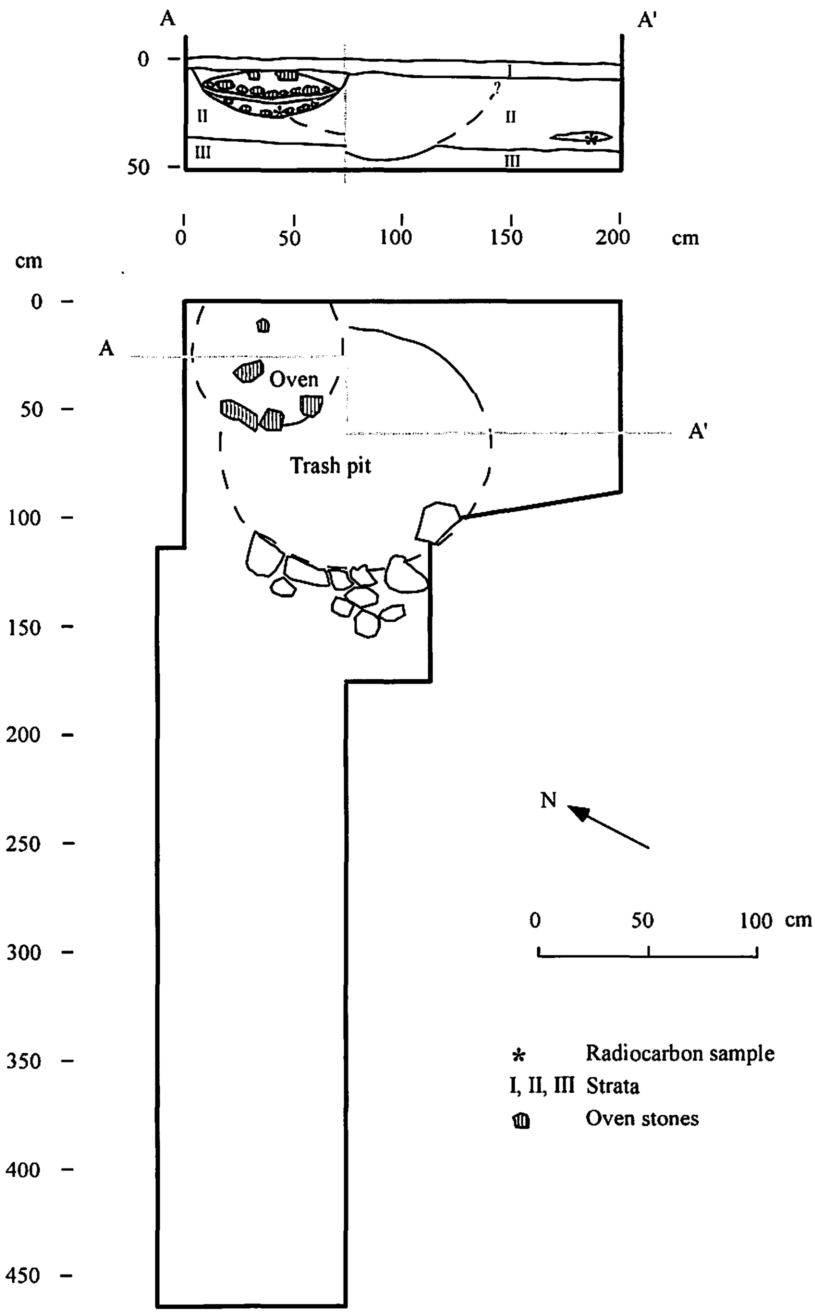


Fig. 6.2: Syd-3 Excavation plan and profile showing earth oven and trash pit

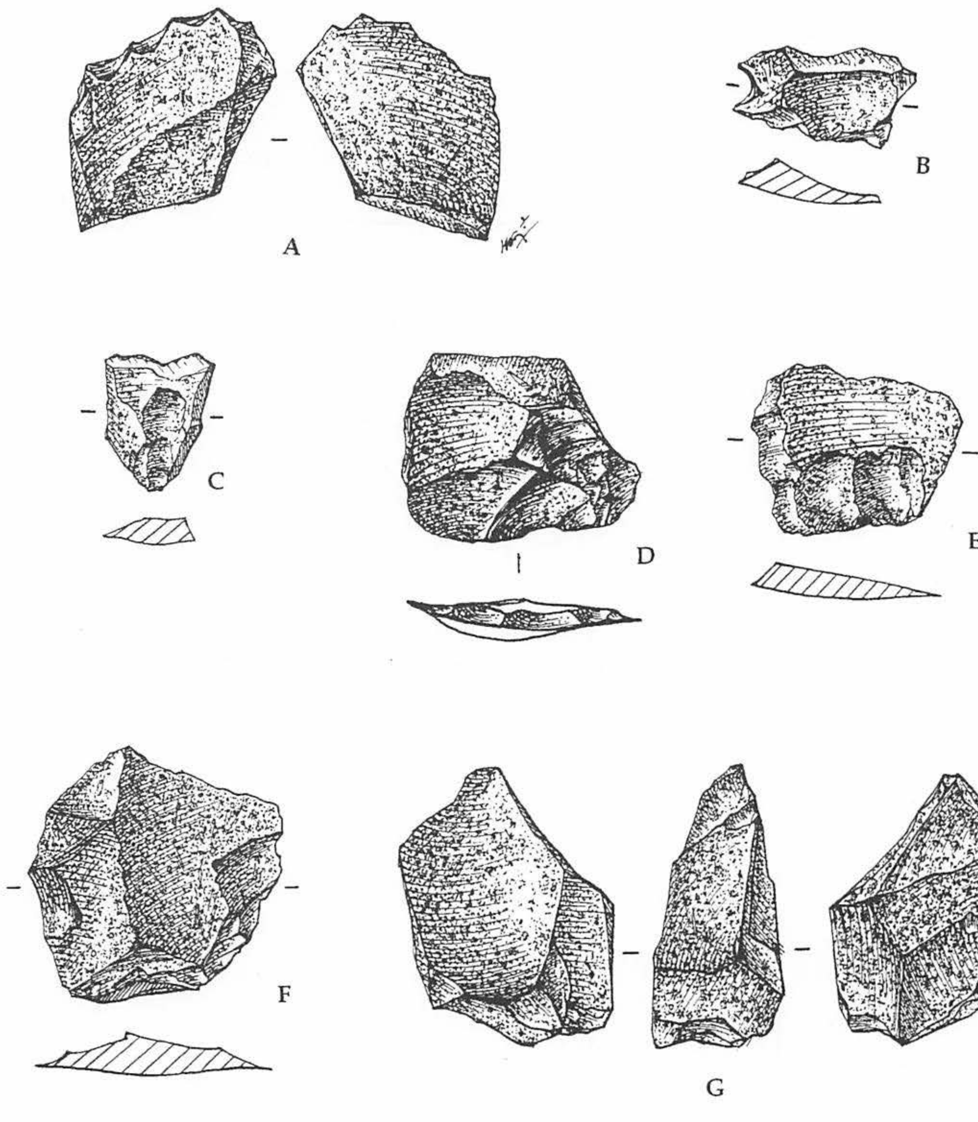


Fig. 6.3: Basalt flakes from Syd-3 (drawn by H. Forestier)
A: flake transversally denticulated, B: flake wider than it is long with a small clactonian notch on left side, C: flake with faint use wear on distal end, D and E: non retouched flakes, F: flake with retouch on left edge, G: core.

samples were given standard pre-treatment and Beta-112420 was given extended counting time. They dated to 10 ± 70 BP and 730 ± 80 BP. The results at 2 sigma are cal AD 1685 to 1740 and cal AD 1810 to 1930 (Beta-112419) and cal AD 1175 to 1405 (Beta-112420), with estimated C13/C12 ratios of -25 0/00 for both (Stuiver *et al.* 1993; Talma and Vogel 1993; Vogel *et al.* 1993). The oldest date suggests occupation of Manra no earlier than the beginning of the 13th century AD. The modern date from the earth oven associates this feature with the nearby curbed house floor.

Basalt flakes

A total of 122 basalt flakes were recovered; 4 on the surface, 73 in the cultural layer (Strata II), 44 in the trash pit and 1 in the fill adjacent to Syd-9. Their length varies from 3 to 71 mm, with an average of 13 mm, their width from 2.5 to 45 mm, with an average of 11.7 mm, and their thickness from 1 to 22 mm, with an average of 3.6 mm. Their heterogeneity and small size indicate that economy of material was of much concern to the islanders. The importation not only of stone adzes, but of the technology of knapping basalt, suggests close links with high islands. All flakes were analyzed by Hubert Forestier[30]. In commenting on the assemblage, he wrote: "*The raw material is a highly granular basalt. Traces of use wear and even retouch are therefore difficult to distinguish. Taking account of the form and thickness of the flakes, it is relatively certain that the reduction technique used was direct percussion with a hard hammer. More than half of the assemblage consists of simple flakes. We have however been able to identify 4 pieces with retouch on one edge, one additional piece which suggests a core, as well as flakes which clearly display the classic stigmata of hard rock, such as pronounced bulbs of percussion*" (Fig. 6.3).

Basalt cores

Two basalt cores, subtriangular in shape, were recovered in the cultural layer (Strata II). One had remnants of 3 ground surfaces, indicating that it had previously been an adze, probably quadrangular in cross section, which once broken was used as a flake core in the interest of economy of a "precious" material. The shape of the second core also suggests a reworked adze, but it is so heavily flaked that ground surfaces are lacking. These two basalt cores were analyzed by J. Sinton[31], using WD-XRF (wavelength-dispersive x-ray fluorescence), following procedures discussed in Sinton and Sinoto (1997). They were of identical material and came from the Tataga matau[32] quarry on Tutuila (Samoa) (Di Piazza and Pearthree 2001 a, Table 1). On hand inspection, the cores appear to be the same material as the flakes. The Tataga matau quarry lies directly south across the trade winds, in the two-way voyaging sector, some 580 nm away. While the movement of stone is evidence of interaction, it may have occurred via West Polynesian Tokelau, which lies along the route and may have served as a node or stepping stone for this across the wind exchange.

Fishhooks

Five broken pearl shell fishhooks were found. Four came from the cultural layer (strata II), the fifth was recovered from the surface. In all cases, the point was missing, thus they were probably broken at sea and discarded upon returning home. Three of these hooks had heads with reduced inner shanks and horizontal knobs. Heads were missing on the other two. The best preserved specimen had a length of 3.4 cm and a width of 2.4 cm. Similar fishhook heads, referred to as "type c" by Walter (1989:72) and "class 123" by Allen (1994:103-105) have been found at Anai'o, Ureia (AIT.10), Moturakau and Rakahanga in the Cooks, as well as at Vaito'otia and Maupiti in the Societies, at Hane, Hanamiai and Ha'atuatua in the Marquesas, at Ahu Naunau on Easter Island (a stone specimen), on Henderson, at Wairau Bar in New Zealand, at Kamaka (GK-1) on Mangareva, at Atiahara in the Australs and on Tabuaeran and Kiritimati in the Lines[33]. This fishhook head type, which is probably a diagnostic artifact of the "Archaic East Polynesian assemblage", indicates the close cultural links between Manra and other early East Polynesian sites (Pearthree and Di Piazza 2003).

Pearl shell debitage

Numerous pieces of worked pearl shell (*Pinctada margaritifera*), varying from tiny fragments a few mm long to quadrangular "tabs" or blanks up to several cm^2 in area, resulting from local manufacture of fishhooks, were found. *Pinctada* appears to be absent from Manra and this raw material was probably imported from Kanton, where it is relatively common, although Orona may also support a population. The only other shell tool recovered was a bitt fragment of a small pearl shell chisel. MacGregor reports a single *Tridacna* adze from Hull island and we found none during our extensive surveys even though the raw material was available throughout the archipelago. The rarity of shell tools, except for fishhooks, in the Phoenix is unusual vis a vis other atolls and underscores the importance of stone tools and long-distance exchange in the economy of these people.

Bird bones

A total of 384g of bones were recovered during excavation, mostly from the trash pit. All were bird bones except for a few small Elasmobranchii vertebrae and indeterminate fish bone fragments. This probably indicates a protein subsistence dominated by avian fauna, although it is possible that fish may be underrepresented in the trash pit for cultural reasons. The bird bones were examined briefly by Alan Ziegler[34], who noted: "*All the large birds appear to be Sulidae. Chicken, Phaeton, and Fregata are absent. The assemblage is dominated by smaller-medium sized bone, belonging to the genus Puffinus, recognizable by their curved humerus, followed by a fair amount of Laridae, represented by the genus Sterna, with maybe some noddies. Several curved toe bones, presumably of the Rallidae family, are the sole indication of land bird in the collection*"[35]. *Puffinus*, *Sterna* and *Sula*, the three dominant genera of this assemblage, all nest on the ground, although *Sula sula* can also nest in trees. All of these birds are easy prey for humans as well as commensal mammals (rats, dogs and pigs) and are thus the first birds likely to be extirpated following settlement (Harrison 1990; Steadman 1989, 1995). The fact that these sensitive taxa constituted the primary food remains in the cultural layer testifies that this site dates to near the beginning of settlement.

Archaeobotanical remains

The charcoal assemblage consists of 1,039 specimens (> 3 mm). The material from the earth oven is dominated by coconuts. Husk fibers make up 65% of the assemblage by weight, while endocarp is 38% by count. In the trash pit, *Guettarda speciosa* adds up to 75% by count. This shows two different but almost monospecific strategies of fuel collection. Four endemic species: Polynesian rosewood (*Cordia subcordata)*, beach heliotrope (*Tournefortia argentea)*, noni (*Morinda citrifolia*) and naupaka (*Scaevola sericea*) are present in low frequencies throughout both features. The absence of coconut, an easily gathered and widely used fuel, in the prehistoric trash pit and charcoal lens is remarkable. The simplest explanation is that it had not yet been introduced to Manra by the 13th century. However, its presence on Orona at this time period would tend to rule out such a hypothesis. More likely is that palms were not growing on this part of Manra at this early stage of settlement.

This excavation not only provides evidence for dating the migration that brought sailors so far north and west of their central East Polynesian homeland, but also yields clues about human adaptation on newly settled islands. Manra was home for several generations, as evidenced by the relatively rich and deep cultural deposit (about 30 cm thick). This equatorial atoll offered adequate timber for houses, canoes and firewood as well as millions of tasty seabirds. Procellariidae and the larger Laridae, the most easily gathered sources of protein, were extirpated long ago and have never returned. The evidence of basalt exchange demonstrates that Manra was far from isolated, but presumably in contact with Tataga matau, the closest quarry source, widely known within Polynesia (Best *et al.* 1992; Leach 1993). On the other hand, the particular fishhook head type shows shared cultural affinities with early East Polynesian sites.

Prehistoric cooking debris and festive activities

Excavation on Orona was concentrated on the large artificial mound (Hull-2) noted by MacGregor (Fig. 5.12). Two trenches (3.5 m long by 0.6 m wide, 1.5 m long by 0.6 m wide) and one square pit (0.6 by 0.6 m) were excavated to bisect the feature. Strata I consists of a layer of beach sand and water-worn beach pebbles, 13 to 15 cm thick. Stripping off this recent imported fill revealed a cluster of rusted iron fragments and fire cracked basalt oven stones, possibly reused ship ballast, adjacent to the concrete pad. Strata II is a homogeneous dark stained sand, containing abundant, angular fire cracked coral stones, 6 to 8 cm in diameter, with sparse fragments of charcoal and bones. Because the upper surface was leveled to build the modern house, it is impossible to estimate the original height of the mound, although this prehistoric cultural deposit averages about 90 cm thick today. No internal stratigraphy, nor features were encountered in this oven fill, except for two intrusive postholes from the historic house. Strata III is a natural sterile sandy gravel, undifferentiated from the surrounding ground surface. This layer was encountered about 15 to 20 cm higher in the center of the mound than at its edge, indicating that the cooking mound was built on a slight natural rise, adding to the grandeur of the site and perhaps reflecting an ostentatious presentation of food.

One radiocarbon sample was collected as bulk fill from strata II. Charcoal was identified and two taxa, coconut (*Cocos nucifera)* and noni (*Morinda citrifolia),* selected to minimize the chance of dating "old wood", were pooled for processing. The sample was given standard pre-treatment and extended counting time. It dated to 750 ± 70 BP (Beta-115211). The calibrated results at 2 sigma are cal AD 1175 to 1325 and cal AD 1340 to 1390 with an estimated C13/C12 ratio of

-25 0/00 (Stuiver *et al.* 1993; Talma and Vogel 1993; Vogel *et al.* 1993). Polynesians were thus feasting on Orona by the 13th century AD.

Additional charcoal identification, rendered difficult due to the small size and friability of the remains, revealed the presence of four species: coconut, noni, as well as the endemic beach heliotrope and *Pisonia grandis*. This limited range probably reflects cultural selection. Branches of *Pisonia* and noni have thick pith cavities and make poor fuel. They may have been chosen more for their culinary uses than for fuel. For example, in Kiribati, noni is sought for earth oven coverings because of the pleasant odor it gives to the food.

Bone preservation was poor. Bird, turtle and fish remains had been reduced to tiny bits and pieces, perhaps due to historical disturbance and compaction when leveling the mound. Identification, even to family level, was impossible.

Similar mounds, although dedicated specifically to turtles, have been found on Rakahanga and Tongareva in the northern Cook Islands. "*When Lamont visited the islet of Motu-unga, ...he participated in an adoption ceremony on a marae...on the day following the above ceremony, Lamont was conducted to another marae on the islet, where a turtle was cooked for him in a large fire prepared on an elevation of stones*" (Bellwood 1978:189 after Lamont 1867:182). This "elevation of stones" is the mound (TON.1) excavated by Bellwood. "*The layers consist mainly of dense concentrations of heat-shattered coral lumps with greater or lesser amounts of a matrix of loose black sandy soil and charcoal...The TON.1 oven mound does have quite deeply stratified deposits, but these go back to only A.D. 1600, and contain no cultural material apart from pieces of pearl shell, turtle bone, and the oven stones themselves*" (Bellwood, *op. cit.*:190, 197). He reported that a number of these turtle ovens existed on Tongareva and described two more of them (TON.3, TON.21). Situated near marae, they were about 20 m in diameter and ranged from 1 to 1.5 m in height. One such feature has also been reported by Te Rangi Hiroa from the site of Mua marae on Manihiki, as "*a large rounded earthen mound, resembling the turtle ovens of Tongareva*" (1932:209). Sacred turtle ovens or mounds have also been recorded for Mangareva, the Tuamotus and Tahiti. In Tahiti, as on Orona, turtles appear to have been cooked alongside fish and birds, in contrast to Tongareva, the Tuamotus and Mangareva where turtles seem to have been the sole offering (Emory 1947, 1975; Henry, T. 1928:164-186).

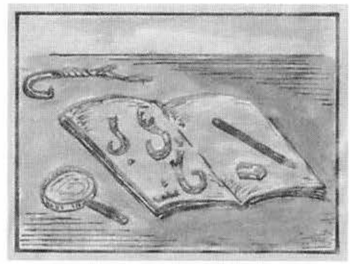
If the conventional idea of the life of an inhabitant of one of the mystery islands is that of someone oppressed by their environment and haunted by hunger, "*unable to sail to another island...*" (Carlquist 1980:387), then the evidence from these excavations allows one to think rather differently. The volume of oven fill from Orona testifies that there, a community developed an economy beyond scarcity and beyond the level of individual households, one that transcended simple subsistence, with people working together for religious ends. Perhaps they experienced a certain level of coercion in the interests of a political elite, but still they made their offerings with the expectation that the gods would continue to smile upon them. Orona and Manra provide examples of atolls where Polynesian colonisation was evidently quite successful, sometime around the 13th century.

PART III

ABANDONMENT PROCESS

THE DOMINANT PERCEPTION of most twentieth-century anthropologists toward the mystery islands has been to see them as fragile and vulnerable environments, milieu where humans have failed to find a niche. A consequence of this idea has been the implicit understanding that these islands were never key settings in the discovery and colonization of Oceania. But this was without taking account of the birds. Not only do they aid sailors to discover islands, but successful settlement depends on them for subsistence. Ground nesting seabirds, a low cost and easily gathered resource, initially permitted Polynesian voyagers to settle coral atolls in a condition of abundance. An abundance that seems to renew itself unceasingly. No matter how many nests were emptied, it seemed that new breeding pairs would always re-occupy them. In nature, the vast majority of these pelagic populations would not visit their breeding island, unless nest sites had become available. It may have taken a hundred years or more for the settlers to eat their way through these vast populations. Eventually a time came when even the nesting colonies would become silent, triggering the navigators to continue their odyssey.

CHAPTER 7



Abandonment as an Economic and Political Strategy

Optimal exploitation of mystery islands

> "*Uninhabited islands, especially, provided a sanctuary for birds, so that birds in great numbers became accepted in the Pacific by the explorers as the sign of an uninhabited island. In this we might find an explanation of why almost every uninhabited island in the Pacific gives signs of having been visited by the Polynesians*" (Dening 1963:114).

The term abandoned, commonly used apropos the mystery islands is somewhat equivocal. It is often implied to be a failure of the settlement process rather than a stage or a strategy of the process itself. Nothing in the archaeological record seems to evoke a time of crisis, as one would expect from the idea of abandonment. Neither famine, nor cyclone, nor drought, nor massive deforestation seems to have afflicted the prehistoric communities on Manra and Orona. On the contrary, it appears that the Phoenix islanders could have feasted on birds on every single island and could gather reef resources from the lagoons of Kanton, Orona and possibly Manra -where an early visitor reported prehistoric stone fish traps (Bryan 1942:61)- switching to agriculture as seabirds become overexploited. Vayda (1959:820) has reviewed a number of rare events, such as cyclones, hurricanes or drought, which have placed atoll populations at risk of human extinction, because of their effect on food production. But such natural disasters are rare in the latitude of the Phoenix islands, which lie between the northern and southern hurricane zone (Pacific Islands Pilot 1982). Kanton is even well known as a refuge for yachts during the southern hurricane season. Emory (1934 a:40) implicated drought in the disappearance of the marae builders on Malden. Certainly, the Phoenix lies across a steep precipitation gradient, varying from 432 mm a year on Kanton in the north to 2,500 mm on Gardner in the south (Wiens 1962:151; Maude 1968:324), but the situation there is no worse than in the Gilbert Islands, which have been occupied for 2,000 years (Di Piazza 1999). Moreover, even a severe drought on one of the northern Phoenix, need not preclude continued settlement in the south. Deforestation is another ecological disaster which has been evoked to explain abandonment of mystery islands. On Mangareva, a shortage of canoe timber was implicated in the breakdown of voyaging and led to the abandonment of Pitcairn and Henderson (Weisler 1996). In the Phoenix Islands *Guettarda, Tournefortia* and *Cordia*, three important canoe timbers, are common today and have been recorded archaeologically.

Lacking evidence to support any of the catastrophic scenarios, we propose an alternative hypothesis based on Anderson's paleo-economic optimization model for New Zealand prehistory (Anderson 1997). He argues that "... *Polynesian migration... may have been impelled by repeated discoveries, and thus expectations, of rich avifaunal colonies [cf. Groube's [1971] strandlooper model]... [and that their] rate of expansion was archaeologically instantaneous because optimal exploitation requires dispersal at low densities...*" (Anderson 1997:277-279). He was explaining the concentration of early sites in dry leeward areas followed by migration to areas more conducive to agriculture as cost-benefit ratios change. We believe this model can be applied to entire archipelagos where islands are abandoned as they are pushed below optimal levels of productivity. As long as "new" lands are available, abandonment becomes imminently strategic.

A Paleo-economic optimization model

All settlement requires management of the environment, an interplay between endemic resources (turtles, fish, mollusks and especially seabirds in the beginning), transported resources (*Pandanus*, coconuts perhaps *Cyrtosperma* and *Tacca*) and competitors (rats, sometimes pigs and dogs). Assuming that exploitation of resources "*occurs in order of perceived energy efficiency and desirability*" (Anderson *op. cit.*:276), the cost/benefit ratio favors gathering seabirds, mainly Procellariidae and Laridae above all other subsistence activities, as demonstrated by the dominance of these taxa among prehistoric faunal remains. Their naive behavior and their ground nesting habit, make them into easy prey.

To investigate the delicate balance between endemic and transported resources, we built a dynamic model, using Stella software, simulating the arrival of colonists who initially concentrate on ground nesting seabirds. Endemic resources prove sensitive to overexploitation, and settlers would have had to rely more and more on transported resources, switching to horticulture and its more demanding labor investment, to the point that reliance on cultivated crops - in an archipelago subject to large fluctuations in rainfall - has too high a ratio of costs to benefits. Primary settlement would not necessarily be in the richest or wettest location for crop growing. It is quite the opposite. Barren[36] and dry islands would have had a greater biomass of ground nesting seabirds than forested milieu, and thus be more attractive during the earliest phases of occupation.

The environment of the Phoenix Islands would have presented no surprises to arriving Polynesians, who were well accustomed to the ecological characteristics of low islands. Establishing gardens on such new lands would have been well within their experience, as would be the hazards of farming during ENSO events. The sensitivity of agricultural plants to drought contrasts with the greater independence of seabirds and fish. Procellariidae, for example make feeding circuits of hundreds of kilometers over several days from their nesting islands. Such a large catchment area makes them relatively insensitive to changes in their maritime environment such as upwellings or fish migrations. Laridae in general, and noddies in particular, feed above tuna schools within about 20 nm and are thus more responsive to local conditions (Grigg and Tanoue 1984).

Three simulations will be presented. The first is an estimated human carrying capacity based solely on harvesting populations of Procellariidae and Laridae. The entire surface of the island is dedicated to both families, who each occupy half of it. Each population consists of breeding pairs with their chicks and eggs, and non-breeding adults and juveniles at sea. Breeders of both families are those adults able to find a nesting site, that is 10 m^2 of unoccupied land. The liberation of a nesting spot, following the death of a breeder, allows a non-breeding adult of the same species to begin breeding. Procellariidae live a long time, up to 40-45 years, breed late, after their 7th year or so and lay one egg per year (Harrison 1984:120-142; Pettit *et al.* 1984:265-282; Fefer *et al.* 1984:9-76). When disturbance is minimal, 100% of them hatch and 85% of chicks survive to fledge. With the presence of man or rat, as many as half of the eggs do not hatch (Harrison *op. cit.*:131). Chicks are fat, weigh about 700 gm -against 400 gm for an adult- and furnish about 4,200 calories to a lucky hunter. Laridae live up to 30-35 years, breed after their 4th year and will often replace an egg (lost to nest disturbance) (Harrison *op. cit*:175-188; Pettit *op. cit*; Fefer *op. cit.*). From egg to chick, overall success is 80% (Harrison *op. cit*:186). Adults weigh 205 gm, represent some 1,230 calories, and are preferred over the much smaller chicks or eggs (50 gm and 300 calories). The Phoenix islanders feast preferentially on Procellariidae (70% of total subsistence), with 80% of that being chicks and 20%

adults. Laridae furnish the remaining 30%, in the proportion of 80% adults and 20% eggs. These initial proportions vary through time as a function of availability. The capture of an adult leads to the death of a chick. Each person eats 3,000 calories per day. During food shortages, calorie intake may descend to 1,500 per day, less than this leads to death.

The outcome of this simulation predicts the period of time during which a population could subsist on seabirds on a given size island. We should not take these numbers too literally, but they nevertheless give a useful estimate. It appears that a founding colony of 30 people, with a population growth rate of 1%, could rely on Procellariidae and Laridae for about 80 years on islands about 4 km^2 in area, the size of Orona and Manra; for about 40 years on smaller Phoenix and 140 years on Kanton. The population reaches respectively 65, 44 and 119 individuals. There is really no equilibrium possible between human and seabird populations the size of Orona and Manra. Even with a growth rate of 0, this community of 30 people will wipe out the birds in 150 years.

The second simulation includes agriculture and rainfall. Although the primary food resource is still seabirds, the settlers begin to plant coconuts as soon as they arrive, at a rate of 10 trees per year per person. *Cocos* is the only subsistence plant so far recovered archaeologically. Agricultural pits have been found, but *Cyrtosperma*, however important it is for rituals, is secondary to coconut and pandanus on most low islands and rarely attains the status of a staple. Coconut trees begin to produce after 10 years, continue for 80 years and occupy a surface area of about 200 m^2 each (Catala 1957). The planted area never exceeds half of the size of the island and is subtracted from seabird nesting territory. The Phoenix archipelago, which straddles a low rainfall zone, is subjected to wide fluctuations in agricultural productivity, patterned by ENSO events. El Niño and La Niña, the alternate dry and wet phases of the ENSO, are simulated arbitrarily over a 100 year period, which is then repeated through time. During each century, there is one strong and twelve lesser events, reducing the number of coconuts per tree to 30 and 45 respectively. During normal years, production averages 60 nuts per tree, or 36,000 calories (Catala *op. cit.*).

With agriculture, islands become more hospitable. On Kanton, Enderbury, Manra and Orona, the human population growing at 1% per year and experiencing deaths by starvation during droughts, is able to grow to several hundred people (Fig. 7.1). On Manra, the population reaches 217 after 200 years of settlement, and 385 a century later, during which time 143 people have died in 5 El Niño famines. On smaller Phoenix, the population crashes after just 90 years. On Kanton, starvation only comes after 343 years of peaceful life within a community of almost 900 Polynesians. Over the long run, the population on middle size islands (Enderbury, Manra, Orona) averages about 400 people, with lows

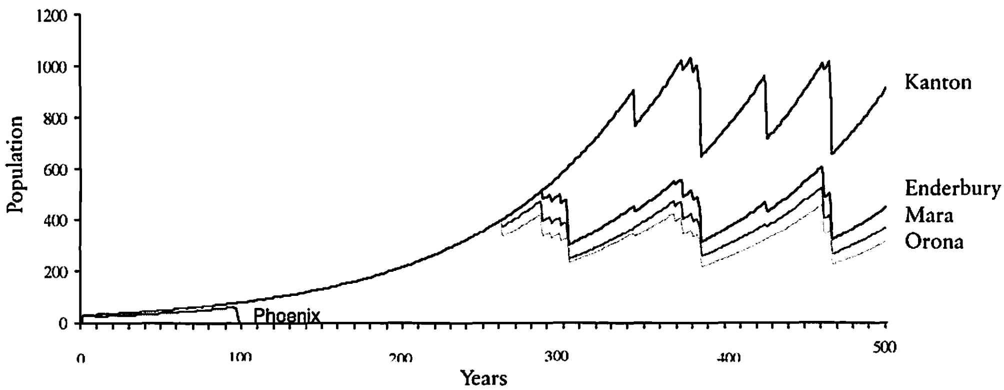


Fig. 7.1: Human population at 1% growth rate on five of the Phoenix Islands with seabirds and agriculture for subsistence

around 300 and peaks of 450-500. Of course, these are theoretical numbers, since other variables such as freshwater are not taken into account. To "eliminate" deaths from shortfalls, or more precisely, to delay them, a decrease in the growth rate is necessary. On Manra, slowing growth to 0.5 % and 0.4% is enough to avoid a lack of food or starvation for 465 and 630 years respectively.

To come closer to the archaeological findings, the third simulation allows the two communities living on islands the size of Manra and Orona to harvest not only their own birds and coconuts, but also to harvest birds on three neighboring islands the size of Kanton, Phoenix and Enderbury and to cultivate an area of 1 ha on the latter. In difficult times, when there are less than 3,000 calories per day, a share of food taken from the birds and coconuts on these other islands is apportioned among those hardest hit, while the growth rate decreases (from 1 to 0.1%) due to amenorrhea among the women (Fig. 7.2a).

The results show one way history could have played out on Manra and Orona with a rapid early growth fueled by abundant resources followed by a period of increasing scarcity (marked by declining birth rates during El Niño), but with overt starvation avoided by re-supply voyages to the northern islands to collect birds and coconuts. Eventually the growth rate would have been limited by permanent scarcity, a stage that the Phoenix Islands seem never to have reached. It appears that during the period of increasing scarcity, people were triggered to seek new horizons to continue their strategy of optimal exploitation. A closer look at seabird population dynamics suggests a possible triggering mechanism. From the very beginning of settlement, the inhabitants were already massively over-exploiting seabirds, yet they would have no way of knowing this. For several human generations the apparent seabird population, that is birds actually

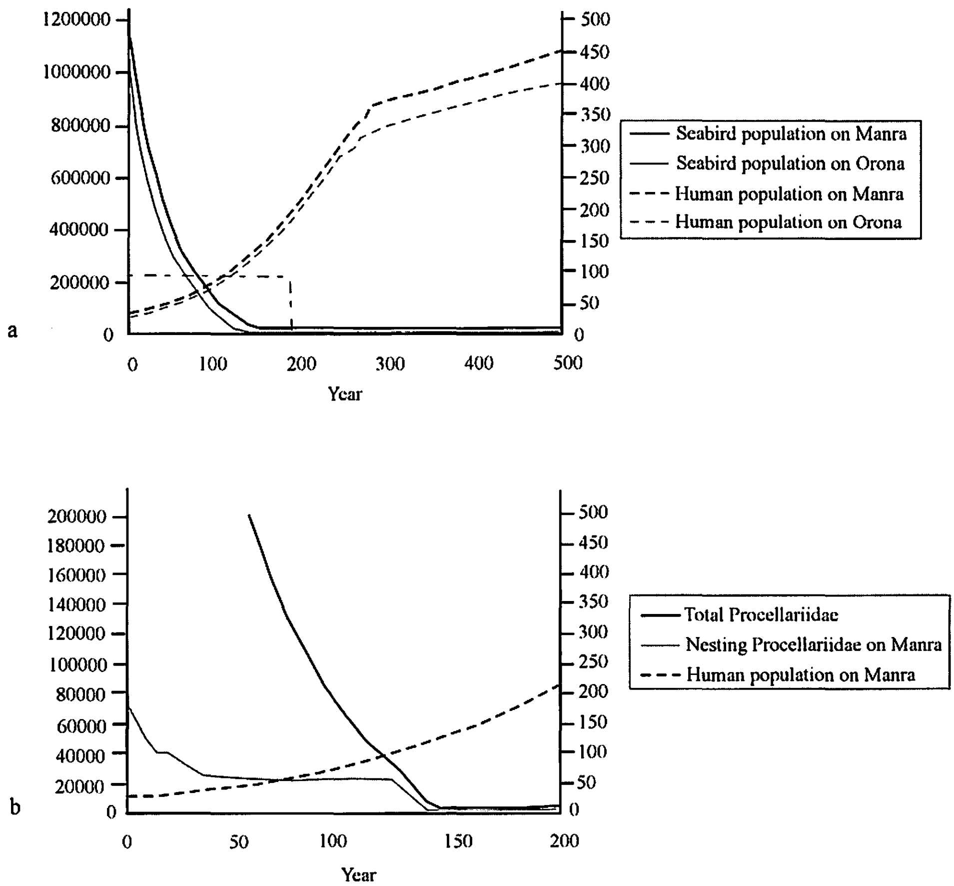


Fig. 7.2: Human and resident seabird populations on Manra and Orona
a) Human population at 1% growth rate decreasing to 0.1% during food shortages and using resources from neighbouring islands. Seabird populations include breeders and non-breeders of both Laridae and Procellariidae.
b) A case study showing nesting Procellariidae versus total population during 200 years of human predation. Laridae would exhibit essentially the same pattern.

nesting in any given year, would remain effectively stable as indicated by the plateau in Fig. 7.2 b. As chicks and breeding birds are harvested, they would be replaced by adults living at sea, the majority of a natural population, awaiting nesting space. This breeding strategy, common among pelagic seabirds, has two consequences for prehistoric humans. The first is that these populations are virtually impossible to manage, since the shrinking population is invisible to hunters on the island. The second is that by the time a decrease does become visible, it is already far too late and the population is on the verge of extirpation. In the Phoenix Islands, this would have signaled the end of abundance and the time to look beyond the horizon.

This paleo-economic approach helps to understand the process of settling new islands as well as the attraction of migrating onward to where there are new resources to exploit. For these islanders, abandonment or perhaps more appropriately emigration was part of their colonization strategy and was sometimes the price of continuing to live in abundance.

Concluding Comments

When canoes are cultural heroes...

It cannot be emphasized too much how central the context of navigation is to archaeology in Oceania. Previous prehistorians who proposed hypotheses about the abandonment of the mystery islands were not mistaken. One after another, they characterized these early settlers as marooned sailors or more recently as experienced navigators on their way to high islands. Throughout this present work, we have attempted to go further by showing how the domestication of the sea by these ancient navigators fostered the domestication of the entire Phoenix archipelago and even beyond.

Certainly to take to the sea in search for islands has its cost, but the rewards are years or generations of relatively easy living. This time of abundance is prolonged by exploiting the endemic *Pisonia* forest soil and its stored phosphate deposits for agriculture, long after bird population had crashed. But eventually, the last big pool of resource to be tapped was the open sea. It is the most expensive too, but an increasing expenditure in ocean fishing yields dividends in transportation and potentially in other lands to settle. Fishing canoe fleets are the guardians of low islands. When Pialug was asked how long he thought canoe technology would last on Satawal, he replied: "*For as long as the Satawalese people live on that tiny bit of land*" (Gillett 1987:44). Without a doubt, similar words could have been uttered by a sailor whose ancestors spoke the Phoenix branch of the East Polynesian dialect chain, though just where must remain unknown for now.

Endnotes

1. Kiaro is the I-Kiribati word for the wooden beams that link the canoe hull to the outrigger float. They are called kiako or 'iako in various Polynesian languages.

2. Archaeological remains have been found on 3 islands in the Pitcairn group (Pitcairn, Henderson and Ducie), 6 islands in the Lines (Caroline, Flint, Malden, Kiritimati, Tabuaeran, Teraina), 6 islands in the Phoenix (Manra, Orona, Enderbury, Kanton, Howland, McKean), 2 islands in the Cooks (Palmerston, Suwarrow), 1 island in the Tuamotus (Temoe), 1 south of Tokelau (Swains), 1 island in Samoa (Rose), 2 islands in Hawai'i (Nihoa, Necker), 1 island in New Caledonia (Walpole), and 2 islands north of New Zealand (Norfolk, Raoul).

3. This manuscript was cited in Emory (1934 a) but never published.

4. Howland and Baker, administered by the U.S., are sometimes included within the Phoenix group.

5. Distances at sea are given in nautical miles. One nautical mile is one minute of latitude and is equal to 1.15 statute miles or 1.85 km.

6. I-Kiribati refers to the people of Kiribati, the transliteration of "Gilberts", the European name for their home archipelago. The uninhabited Lines and Phoenix Islands were included in the Republic of Kiribati at independance in 1979.

7. This species still lives on Rimatara (Austral Islands), Teraina, Tabuaeran and Kiritimati (northern Lines). It has been extirpated from the Cook Islands (Steadman 1989:188, table 5) and presumably from other islands in between (Pratt *et al.* 1987:206-207).

8. The other two islands in the group, McKean and Nikumaroro lie well downwind and are somewhat isolated from each other.

9. VMG is the distance gained to windward multiplied by the boat speed, divided by the actual distance sailed (tacking). For example, a boat traveling 80° off the wind, must sail 20 miles for a gain of 3.6 miles. At 3 knots boat speed, this gives a VMG of 0.54 knots. VMG = 3.6 x 3/20.

10. The target angle is figured using the 20 nm flight radius of noddy terns on either side of the island.

11. These observations corroborate those from Gatty (1943:35,36) for *S. leucogaster*, but differ for *S. sula* and *S. dactylatra*. Gatty notes that six or more *S. leucogaster* denote land within 30 miles, and groups of 3 or more *S. sula* or *S. dactylatra* indicate land less than 75 miles away, while groups of 6 or more point to an island at less than 50 miles.

12. Observations over the latter parts of the voyage are not comparable due to proximity of islands (Enderbury-Orona) or small variation in latitude (4°S to 2°N) (Orona - Kiritimati).

13. The sailing weight with 2 people aboard and food and equipment was about 4,000 kg. It includes 500 kg of tools, archaeological and boat gear, 200 kg of water and 150 kg of food.

14. The required volume (2 m^3) is derived from a Tokelau canoe 11 x 0.5 x 0.9 m (after MacGregor 1937). It is calculated as 6 m of cylindrical tree trunks 0.6 m dia. plus a cone for the end pieces 6 m x 3 m long. Together they are carved into the 6 or 7 pieces that make up a typical canoe. It would have a surface of about 25 m^2 and if the planks were 3 cm thick at a specific gravity of 0.66, it would contain about 0.75 m^3 of timber and weigh about 250 kg. This is equivalent to about 38% effective timber utilization ($0.75m^3/2m^3$), therefore about 62% waste.

15. The surface occupied by one tree is derived by its crown diameter. Area per age class is the aggregate of all tree surfaces within the class.

16. The model is not sensitive to initial conditions and always comes to equilibrium within the lifetime of individual trees (100 years).

17. Using the smaller trees requires cutting 3 times as much forest area as using larger ones, 312 m^2 and 109 m^2 respectively.

18. This length of time allows the model to reach equilibrium between each change of rate. It does not reflect history of settlement. For example, Strategy I plays out over 600 years, the initial 50 years of seedling growth + 100 years to reach equilibrium, + 50 years at rate 1, + 100 years for equilibrium, + 50 years at rate 2, + 100 years...

19. These exploitation rates are equivalent to 53.33, 106.66, 191.99 m^2 of forest area per year for 50-100 year old trees and 153.85, 307.7, 344.62 m^2 per year for 25-50 year old trees.

20. From the relationship between land area and rainfall in the Marshall Islands, Williamson and Sabath derived a "mesophytic index " which they consider to be an approximate measure of carrying capacity. Plotting the mesophytic index against the population of each island, they derived a regression equation used to estimate the potential population for unsettled atolls.

21. Nikumaroro, Birnie and McKean, although not studied during this project, should fit respectively into the 3 classes, based on reported seabird diversity.

22. Marae, after Emory (1970:73) have: -a rectangular court indicated by a pavement, terrace, or curbs; -a platform or alignment of stone slabs along one end of the court, termed an ahu, or tuahu; and often -upright slabs on the court.

23. Similar prehistoric agricultural pits have been reported on Howland Island up to "*several hundred feet long and 15'deep*" (Ellis 1936:30).

24. The breeding status of the 4 procellarids on Kanton is uncertain today.

25. For a seriation of the Phoenix architectural sites, see Carson 1998.

26. CNRS, URA 1415, "Archéozoologie et Histoire des Sociétés", Muséum National d'Histoire Naturelle, Laboratoire d'Anatomie comparée, Paris.

27. Presumably this platform at Site 4 was the feature referred to as a "shrine or marae" by Bryan (1942:63-64).

28. The location of this site is equivocal. MacGregor places Site 13 near the large artificial mound on his map. We searched that area thoroughly and found nothing. Map 4.3 shows the site location as described in MacGregor's text.

29. Excavations totalled solely 11.5 m^2 due to limited time ashore caused by the stormy El Niño conditions. All cultural deposits were excavated stratigraphically and layers were dry-sieved through 1/8 inch mesh.

30. Hubert Forestier, Institut de Recherche pour le Développement, département d'Archéologie, Orléans.

31. Department of Geology and Geophysics, University of Hawai'i, Honolulu.

32. Within the extensive Tataga matau database, their closest match is to a sample collected from the base of Leafu waterfall, collected in 1993 by E. Pearthree.

33. Duff 1950:fig. 54.9; Suggs 1959:fig. 26n,i,j,l; Emory and Sinoto 1964:figs. 5e, 6e; Bellwood 1970:fig. 45; Sinoto 1967:fig. 7f, 1970:figs. 1c,j,l, 1983:fig. 3f; Sinoto, A. 1973:figs. 12,13; Sinoto and McCoy 1975:plate 3Ba,b; Walter 1989:fig. 2; Allen and Schubel 1990:fig. 6; Rolett 1998:figs. 7.7,7.9, 7.10; Skjølsvold 1994:fig. 87e; Eddowes 1999:fig. 9; Weisler and Green 2001:fig. 31.4c; Pearthree and Di Piazza 2003.

34. Alan Ziegler, *pers. com*, Kailua, Hawai'i

35. The collection was sent to D. Steadman for further studies. But "*the sad truth is that the bones arrived in the lab in simply a horrible condition. They are impossible to identify with any precision*" (Steadman 1998, *pers. com.*).

36. Dening (1963:122) reports that "*the Tikopians... kept Fataka cleared of coconuts because the fish and birds' eggs were so valuable to them that they did not want the island occupied by stray voyagers*".

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CONCLUDING COMMENTS

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