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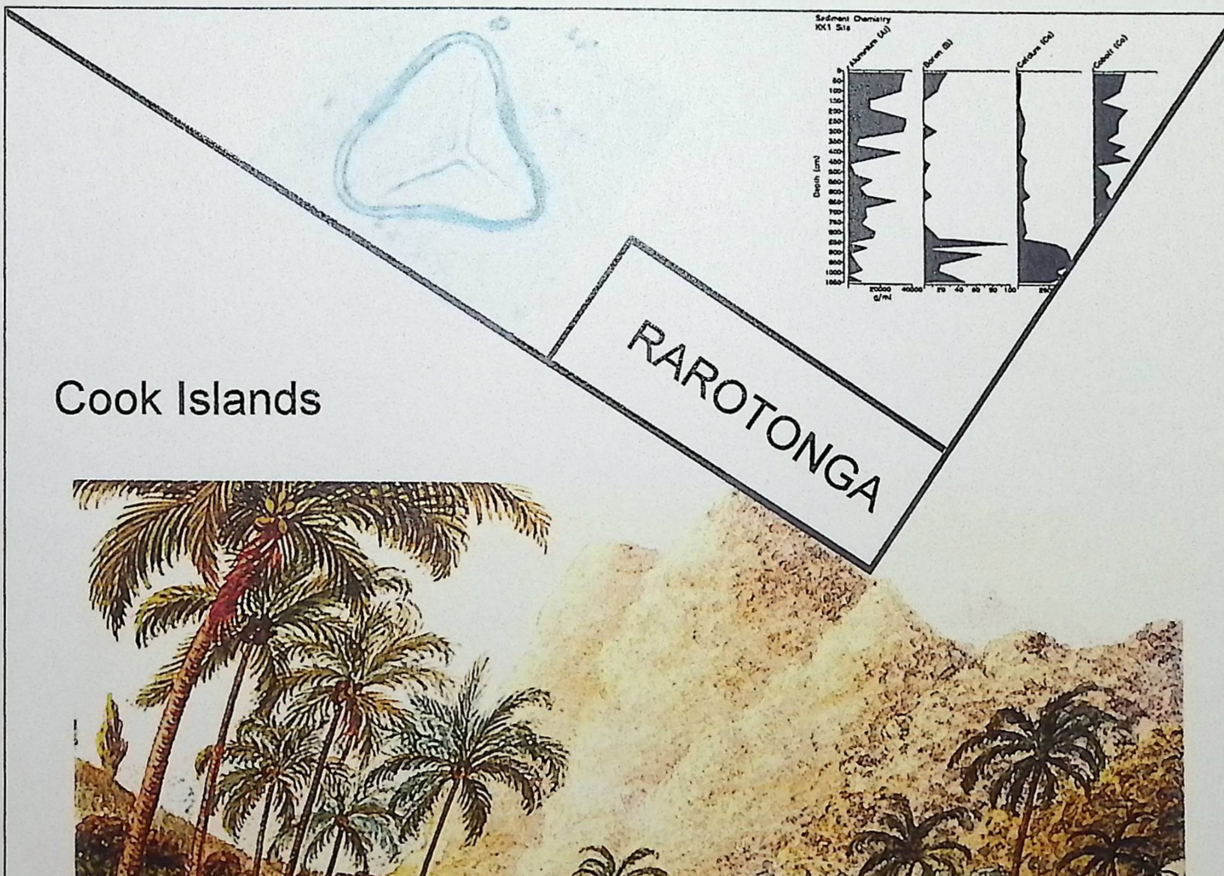

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1998

Publishers Preface:

Some years ago the publisher and the author met on an archaeological excavation near Leipzig in Germany and discussed some aspects of palaeo- and ethnobotany. Having a look on the exhaustive manuscript of the original thesis, we both decided to publish it, somewhat shortened in the type of the manuscript and with smaller letters, but principially without any revisions.
The manuscript is worth to be published because today we can understand the change caused by man on an island, which was discovered by Cook some hundred years ago.
The pollenprofiles give an impression of the vegetation today and yesterday and an analysis can lead to the understanding of changing biotopes and cultures, landscapes and vegetations.
This work is not only useful for botanists, for ethno- and archaeobotanists but also for ecologists, geologists and palynologists.
The title of the original manuscript was changed a bit and minor corrections were made, concerning the manuscript with all the footnotes, tables, figures and plates - but only in composition, not in any aspect of changing sentences or opinions.

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HUMAN SETTLEMENT, VEGETATION HISTORY AND LANDSCAPE CHANGE ON RAROTONGA, SOUTHERN COOK ISLANDS

by C. PETERS

Doctoral Thesis in Anthropology, University of Auckland

original manuscript title 1994:
„Human settlement and landscape change on Rarotonga, southern Cook Islands

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ABSTRACT

This thesis seeks to examine certain aspects of those changes which occurred in the landscape of Rarotonga during the period it has been occupied by humans. Because the exact date of human arrival is as yet uncertain, part of the problem has been to try to establish this by attempting to detect initial human interference with the landscape, in particular the vegetation.

A number of different approaches have been used in the investigation of these problems: swamp deposits were analysed by stratigraphic and palynological studies. Modern vegetation surveys and modern pollen rain studies provided a statement of the present landscape and comparisons for the fossil data and ethnographic and historical sources contributed information about the last two hundred years, and generated ideas and models for earlier periods and helped establish control over any changes to the landscape that were of more recent origin. Finally, archaeological evidence and oral tradition, where available, establish as far as possible what changes may have occurred in landscape usage and manipulation from first settlement to European contact. In addition, from late 1992, a series of techniques were brought to bear on the swamp sediments, in order to clarify questions raised by the pollen evidence. These include X-ray analysis, chemical analysis and particle-size analysis.

The early Holocene rising sea-level could have caused lake formation at Karekare before 8137 BP. Accruing sediment and local hydrology reduced the depth of the lake, consequently forming a marsh, though other factors may also have been involved. Falling sea-level could have been a vital factor too. With the formation of a marsh from 4,500 BP, there followed what is interpreted as a hydrosere beginning with swamp ferns, then some swamp forest, finally being replaced by drier elements after 3000 BP. Factors such as truncation, shrinkage and compaction due to cultivation and drainage by colonizing people between 2700 and 800 BP brought the sequence to an end.

A four phase model based on biogeographic theories is proposed for landscape change on Rarotonga, starting with the island before humans arrived, then with the first Polynesian settlement and later developments therefrom (up to European contact), then the arrival of Europeans and finally the late twentieth century. Wider implications for Pacific Islands emerging from this thesis are discussed under the following headings: extinction, problems with other sites, plant distribution history, sea-level change and climatic change, dating of human arrival and the influence of the environment on settlement history.

It could well be that whilst some extinctions are related to initial colonization of islands and later expansion therefrom, others may be associated with the economic, religious and social changes brought about by missionaries, merchants and colonial authorities. It is suggested here that whilst early Polynesian settlers no doubt altered their landscapes, it is not necessary to invoke quite as much alteration by them as is sometimes inferred. It is proposed that early Polynesian colonists adapted their economy to the landscape and did not attempt to impose a totally alien system on the local ecology of newly settled islands. Some plants were discovered to have existed on Rarotonga before humans arrived, others formerly had different distributions than today. Oral tradition (see Chapter 6) and missionary records show that breadfruit trees and plantains were grown in the lower-lying areas because they are better adapted to the warmer, drier conditions, whilst the taro and mountain plantains were grown further up the valleys, where reliable all-the-year-around supplies of freshwater were available.

Clark *et al.* (1978) and Clark and Lingle (1979) proposed that sea-levels in the mid-Pacific Ocean (Zone 5) rose from the end of the last glaciation to reach a mid-Holocene highstand of between 1 and 2 metres about 5000 years ago. Later studies have produced evidence supporting that hypothesis, though with the highstand being a little later in date than theorised. The swampland data from Rarotonga could well confirm the idea of a mid-Holocene highstand, followed by a fall to present levels. In Karekare Swamp, the freshwater lens, resting on the ocean's saltwater, could have risen causing, or at least facilitating, a transition from a lake to a marsh. The lowering sea-level from 5-4000 BP may have affected the water table in Karekare Swamp, leading to drier conditions and allowing plants to colonize its surface.

Human arrival on Rarotonga, at least in the area of Karekare Swamp, postdates 2730 BP and antedates 791 BP From lake sites on _tiu and Mangaia, where such factors have not been a problem, mid-first millennium AD dates have been obtained. These dates relate to pollen and sediment changes interpreted as being the result of gardening and clearance activities. They could be considered as minimum dates for initial colonization, because settlement may have taken place on other parts of these islands first and/or gardening activities may have assumed a lesser role in the initial stages of settlement. Such dating would not be incompatible with Karekare Swamp. The first colonization of Rarotonga would have involved the ecotones between valley, freshwater stream, coastal plain, lagoon and reef passage. Thence, expansion (between arrival and European contact) would have continued up the valleys and along the terraces, over which the *Ara Metua* passes (though leaving contested and sacred areas free of interference, following the prime agricultural land. Other advantages of these areas would have been greater protection against cyclonic winds and floods, and droughts such as occur on the lower and more coastal parts of the plain. Perhaps these could be considerations for other high islands. Any early settlement before 1500-2000 BP, if it existed, may have had to have been influenced by higher sea-levels, because except for a stretch of land between Avarua and Ng_Tangi`ia, the lowland plain may well have been inaccessible due to submergence.

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Firstly, I would like to thank the Cook Islands Government and the landowners of Karekare Swamp for their kind permission to undertake this research, and for their interest and encouragement....*meitaki ma`ata* !

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CHAPTER 1 INTRODUCTION

1.1 Aims

This thesis seeks to examine certain aspects of those changes which occurred in the landscape of Rarotonga during the period it has been occupied by humans. It explores how these changes have affected human settlement and the degree to which humans have had some part in them. This involves an investigation into what the environment of Rarotonga would have been like before human arrival and what effects colonization by Polynesians and later developments in their culture had, especially in terms of the vegetation. The effects of the later European influences and more recent changes also need consideration.

Because the exact date of human arrival is as yet uncertain, part of the problem has been to try to establish this by attempting to detect initial human interference with the landscape, in particular the vegetation. In pondering what human effects would have been, due attention had to be paid to natural changes and their relative contributions over the period covered: the last 8,000 years.

Other important issues were the past distribution histories of plant species (to find out among other things what plants were introduced by people), pre-human palaeoecology (in order to help distinguish natural from human-induced change), climatic and sea-level history, and the effects of local ecology on human settlement history.

The taphonomic model provided by Spriggs' work on Aneityum (Groube 1975; Spriggs 1981; 1986)[1], bolstered by investigations on Lakeba (Hughes *et al.* 1979), suggested that early sites belonging to an initial colonization phase might be obscured by later deposition of sediment, itself the product of erosion caused by human activity (Sutton *et al.* **in press**). On high islands, it has been suggested, the ratio of the height of the mountainous interior to the width of the coastal plain should provide a general idea of how much later deposition would have buried colonization-age sites, especially if precipitation is great (Sutton *et al.* **in press**), though this would not work for all cases[2].

Rarotonga was chosen because of its key location in the southern Cook Islands. As such it lies between West and East Polynesia on the likely course of west to east colonization, with the nearest neighbouring islands to West Polynesia being colonized first (Biggs 1972; Irwin 1992). The current late dating for initial colonization of 800 to 1000 AD could be too young, due to the same factors as for Aneityum and Lakeba. Some dating from West Polynesia and from French Polynesia and the Hawai`i Islands, on either side of the southern Cook Islands along the suspected migration route, also suggest there should be sites earlier than those found up to now.

Given the lack of convincing archaeological evidence for the period before 800 to 1000 AD (Allen and Steadman 1990; Ellison 1993; Kirch 1986b; Kirch *et al.* 1992; Walter 1990), palynological investigations were at this time thought to offer greater opportunities for defining the period of primary colonization. The object of the first stage of fieldwork was to locate polliniferous deposits securely extending back to before initial colonization[3].

A number of different approaches have been used in the investigation of these problems.

Firstly, examination of swamp deposits was undertaken from a stratigraphic and palynological point of view. Modern vegetation surveys and modern pollen rain studies were used to assess the present state of the landscape and provide comparisons for the fossil[4] data.

Secondly, ethnographic and historical sources were consulted to provide information about the last two hundred years, and to generate ideas and models for earlier periods. Such sources help to establish control over any changes to the landscape that are of more recent origin.

Thirdly, archaeological evidence and oral tradition[5], where available, were used to establish as far as possible what changes may have occurred in landscape usage and alteration prior to European contact.

In addition, from late 1992, a series of techniques were brought to bear on the swamp sediments, in order to clarify questions raised by the pollen evidence, such as X-ray analysis, chemical analysis and particle-size analysis.

This thesis is divided into ten chapters. The first chapter deals with the background information about Rarotonga, placing it in its cultural and natural historical context. The second chapter poses questions about the status of the modern day vegetation and how it has come to be what it is, while also providing comparative modern pollen data.

---

1. Similar views have since been expressed for the New Zealand situation (Chester 1986; Sutton 1987).
2. On Lakeba, for example, the soils of the coastal plain appear to have been created by the emergence of marine sediments such as calcareous sand and mangrove deposits within the last 2-4000 years (Best 1984, p.30). Also, in New Zealand, Jones (1991) argues in his study of the Rangitaiki plains, that natural alluviation and significant volcanic activity have been so great that human impact has been slight in comparison.
3. Rock shelters had not been investigated on Rarotonga until 1991, when Chikamori discovered 3 m of cultural deposits, as yet undated, 6 m a.s.l. in the Avana Valley (cf. Sutton *et al.* **in press**).
4. The term *fossil* is used in this thesis in preference to *sub-fossil* because the strict meaning of the word refers to the object's having been buried, not its chemical replacement. The addition of the prefix `sub' to the word, as is sometimes used, is thus superfluous (Geikie 1903, p.825).
5. `Tradition' is used in this thesis as meaning `culture and custom recorded in ethnographic literature and oral tradition, which probably originated before European contact'.

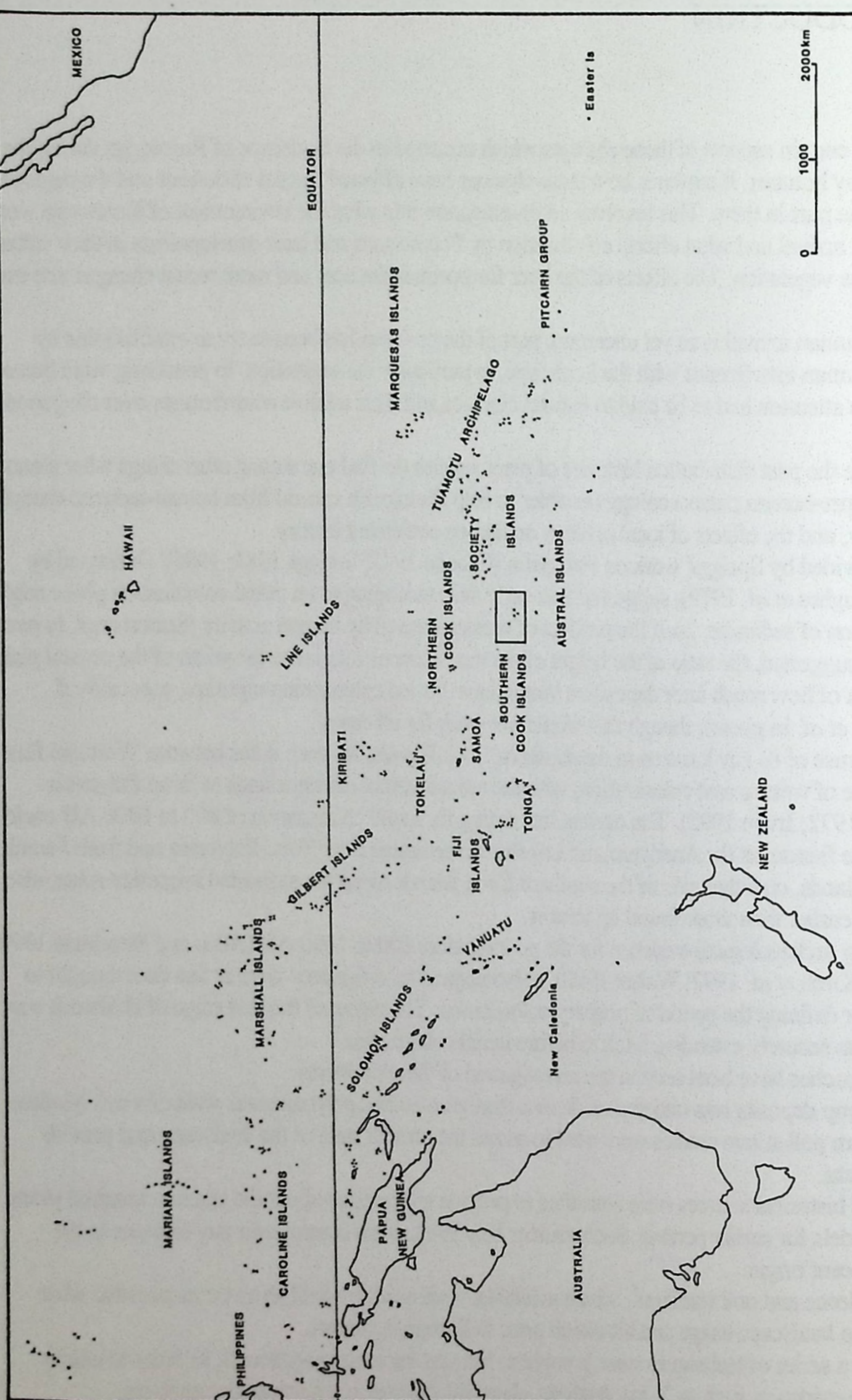

Figure 1.1 Location Map of the Cook Islands in the Pacific Ocean.

The third chapter is a statement of the current climate and status of opinion and research from a number of disciplines relevant to this thesis in Polynesia. The fourth chapter narrows the research area to the southern Cook Islands. The fifth chapter outlines the aims and techniques used in the fieldwork. The sixth chapter analyses the historical and ethnographic evidence (including data collected by the author on Rarotonga) for landscape change following human settlement. This is investigated further by the seventh chapter on lithostratigraphy and the eighth on biostratigraphy. The ninth chapter draws all the evidence together in a discussion of the major issues. Finally, the tenth chapter is a summary of the main conclusions reached.

1.2 Location

Rarotonga[6] is the principal (and largest) island of the Cook Islands. This political grouping of islands is composed of the northern and the southern Cook Islands (Figure 1.1). Stretched out over approximately 2 million square kilometres of the Pacific Ocean, they are located between 9 degrees South in latitude and the Tropic of Capricorn, and between 167 degrees and 155 degrees West in longitude. The land area of the Cook Islands is only 240 square kilometres. The southern group is about 3-4 degrees south of the northern group.

Rarotonga is located at 21°12′S in latitude and 159°46′W in longitude. The distances to some of the other islands of the southern group are: Atiu, 187 km; Ma`uke, 241 km; Miti`aro, 229 km; Mangaia, 177 km; Aitutaki, 141 nautical miles (Figure 1.2). The current population of the Cook Islands is about 17,200 residents. Rarotonga is the most populous island with 9,281, followed by Aitutaki with 2,400 (though Mangaia is the second largest island), Mangaia with 1,270, and Atiu with 1,040. All the others have populations less than 1,000 down to Palmerston with 50 residents. Takutea and Suwarrow are National Parks and not inhabited.

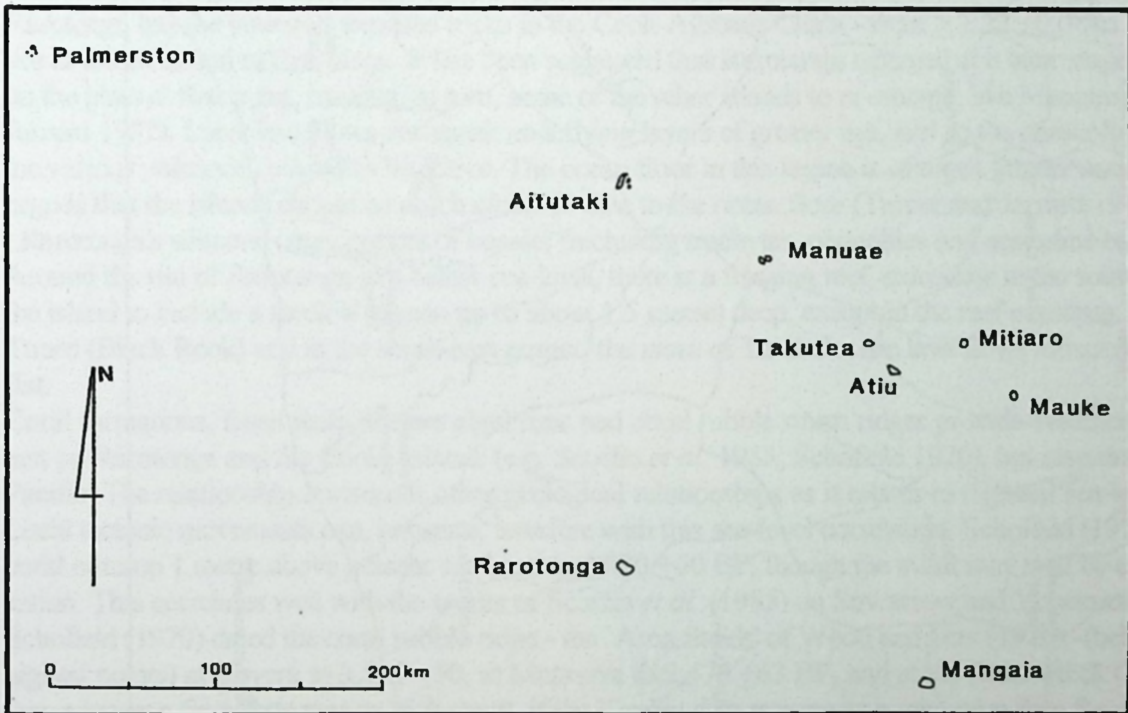

Figure 1.2 Location Map of Rarotonga in the southern Cook Islands.

1.3 Topography (Figure 1.3)

Rarotonga consists of a mountainous interior, dissected by stream valleys and gulches, and a coastal plain, surrounded by continuous reef flats and a discontinuous lagoon. On the leeward side to the west the mountains are lower and more level, and on the eastern and southern windward sides the mountains are higher and peaked. The highest mountain is Te Manga at 653 m a.s.l.. The valleys on the western and southern sides tend to be very constricted, whereas those on the eastern and northern sides are broader and much more open with extensive alluvial soils.

The coastal plain is tilted towards the landward side. On the eastern side this is at its most extreme as there is a high (4-5 m a.s.l.) storm ridge of coral rubble and sand, whereas elsewhere there is only a low ridge up to 2 metres composed mainly of well-sorted coral sand (Richmond 1990; 1992).

In the immediate vicinity of Karekare swamp, from which the main pollen cores were taken, there is a small mountain, Oro`enga, with 3 small ridges radiating out from it. The two nearest stream valleys, the Tupapa valley and the Matavera Valley, exit on to the coastal plain on either side of this mountain.

---

[6] Cook Islands Maori orthography follows Rangi Moeka'a in Simiona (n.d.), McCormack (1990), McCormack and Künzle (1990; 1991) and Biggs (pers. comm. 1993). `Maori' is taken to mean `Cook Islands Maori' except where otherwise stated.

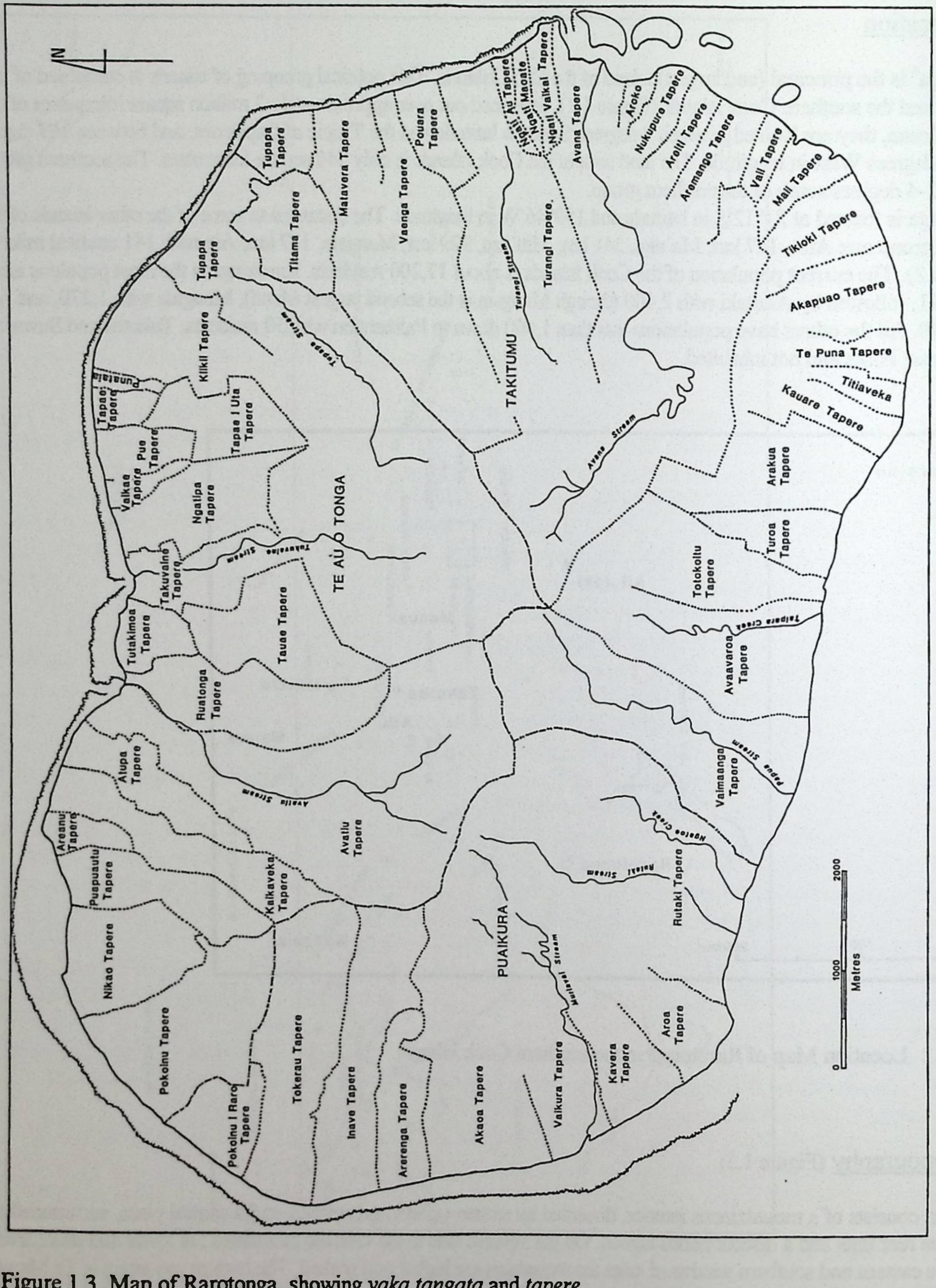

Figure 1.3 Map of Rarotonga, showing *vaka tangata* and *tapere*.

1.4 Geology

1.4.1 *Cook-Austral Chain*

Rarotonga forms part of the Cook-Australs Chain (Turner and Jarrard 1982). Although politically separate, the southern Cook Islands and the Austral (or `Tubuai') Islands are geologically related.

The group has been thought to have been formed due to the Pacific Plate passing westward over a `hot-spot' under the Earth's crust. This produced Avarau (Palmerston) at the older end and Marotiri (Îlots de Bass) at the other (Turner and Jarrard 1982). The `hotspot' would have caused volcanic activity which led to a crater rising out of the sea. This then weathered producing soil. The underwater volcanic slopes attracted coral where the shallow water meets its sides. This is the typical `high island'.

A low island is where the crater starts to sink and the coral reef grows upwards to keep pace with the subsidence. At times, this leads to the formation of an extensive shallow lagoon. An atoll is where the crater is completely submerged, but the coral reef has continued to keep pace with rising water. In the centre of the ring of coral reef is a lagoon, often deep, and on the reef flats banks of coral rubble and sand form *motu*[7] or lagoon islets.

Finally, there are the makatea islands, which are formed when a low island or atoll re-emerges out of the ocean. This exposes cliffs of fossil coral reef (the `makatea') surrounding a volcanic hill or mountain in the centre. Freshwater swamps develop at the junction of the volcanic hill and the coral cliffs, where drainage through the karst formations in the cliffs is sluggish (Marshall 1930).

In the southern Cook Islands, Rarotonga is a high island; Aitutaki is a low island; Avarau (Palmerston), Manuae/Te au o tu and Takutea are atolls; Atiu, u`aro, Ma`uke and Mangaia are makatea islands (Wood and Hay 1970).

1.4.2 *Rarotonga*

Rarotonga has the youngest exposed rocks in the Cook-Australs Chain - from $\geq$ 2.27 $\pm$0.08 to 1.10 $\pm$0.04 Ma, though it lies at the older end of that range. It has been suggested that Rarotonga emerged at a later stage, imposing a great weight on the plate at that point, causing, in turn, some of the other islands to re-emerge, like Mangaia and Ma`uke (Turner and Jarrard 1982). Later lava flows can mask underlying layers of greater age, and so the chronology may only reflect when the various volcanoes ceased to be active. The ocean floor in this region is of much greater antiquity, and it has been argued that the islands should be much closer in date to the ocean floor (Turner and Jarrard 1982).

Rarotonga's volcanic core consists of basalts (including trachytes, phonolites and nepheline basalts) and breccias. Around the rim of Rarotonga just below sea-level, there is a fringing reef, extending in the south-east and southern part of the island to include a shallow lagoon up to about 1.5 metres deep, except in the reef passages. In the north-west corner, Tuoro (Black Rock) and in the south-east corner, the *motu* of Ta`akoka are lava flows intrusive into the area of the reef flat.

Coral formations, fossil reefs, former algal rims and coral rubble storm ridges provide evidence of former sea-levels, not just on Rarotonga and the Cooks Islands (e.g. Scoffin *et al.* 1985; Schofield 1970), but also throughout the tropical Pacific. The relationship transcends other geological relationships as it relates to regional sea-levels and biological activity. Local tectonic movements can, however, interfere with this sea-level correlation. Schofield (1970) dated a raised fossil coral outcrop 1 metre above present sea-level to 2,030 $\pm$60 BP, though the event may well be earlier due to recrystallisation. This correlates well with the works of Scoffin *et al.* (1985) on Suwarrow and Yonekura *et al.* (1988) on Mangaia. Schofield (1970) dated the coral rubble ridge - the `Aroa Sands' of Wood and Hay (1970) -(below the A-horizon at the highest points) at Kavera to 3,510 $\pm$50, at Matavera to 2,470 $\pm$63 BP, and at the Black Rock (Tuoro) to 1,235 $\pm$57. This may suggest a fairly late marine high stand, if the Kavera date represents a minimum date for when the ridge stabilised. The coral element of the geology on Rarotonga is represented by some apparently remnant areas of makatea, and a modern active reef, which is continuous around the island apart from 6 reef passages. Former reefs relating to times of lower sea-level no doubt exist at various levels under the sea. The makatea is found on either side of Ngatangi`ia Passage (the coastal plain on the northern side and the *motu*, Motutapu, on the southern side) on the south-east side of Rarotonga, and by the Meterological Office at Nikao, on the north-west side. Schofield (1970) dated these to the Last Interglacial.

1.5 Soil

The soils of Rarotonga were first investigated by Grange and Fox (1953). This was improved upon and elaborated by Leslie (1980) - see Figures 1.4 and 1.5. Leslie's classification divided the soils into those of the coastal margin and those of the interior uplands. The coastal margin consists of 8 general types based on formation processes: estuarine margins, beach ridges, poorly drained depressions, moderately drained depressions, younger flood plains, older flood plains, terraces and fans. The interior uplands consist of 2 general types of soil: hilly land soils and steep and very steep land soils.

The soil of the estuarine margins (Koromiri Soils - Km) comprises muds and sands derived from basaltic alluvium and reworked coral particles. It is poorly drained, saline, carbonatic, subject to tidal flooding and significantly disturbed by crabs.

The soils of the beach ridges (Muri Soils - Mu; Muri Soils, stony phase - Mut) are based on reworked coral sands and have a weak profile development. These are drought-prone carbonatic soils with a low nutrient content. The stony phase

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7 Cook Islands Maori words are explained in the Glossary (see Appendix A.1).

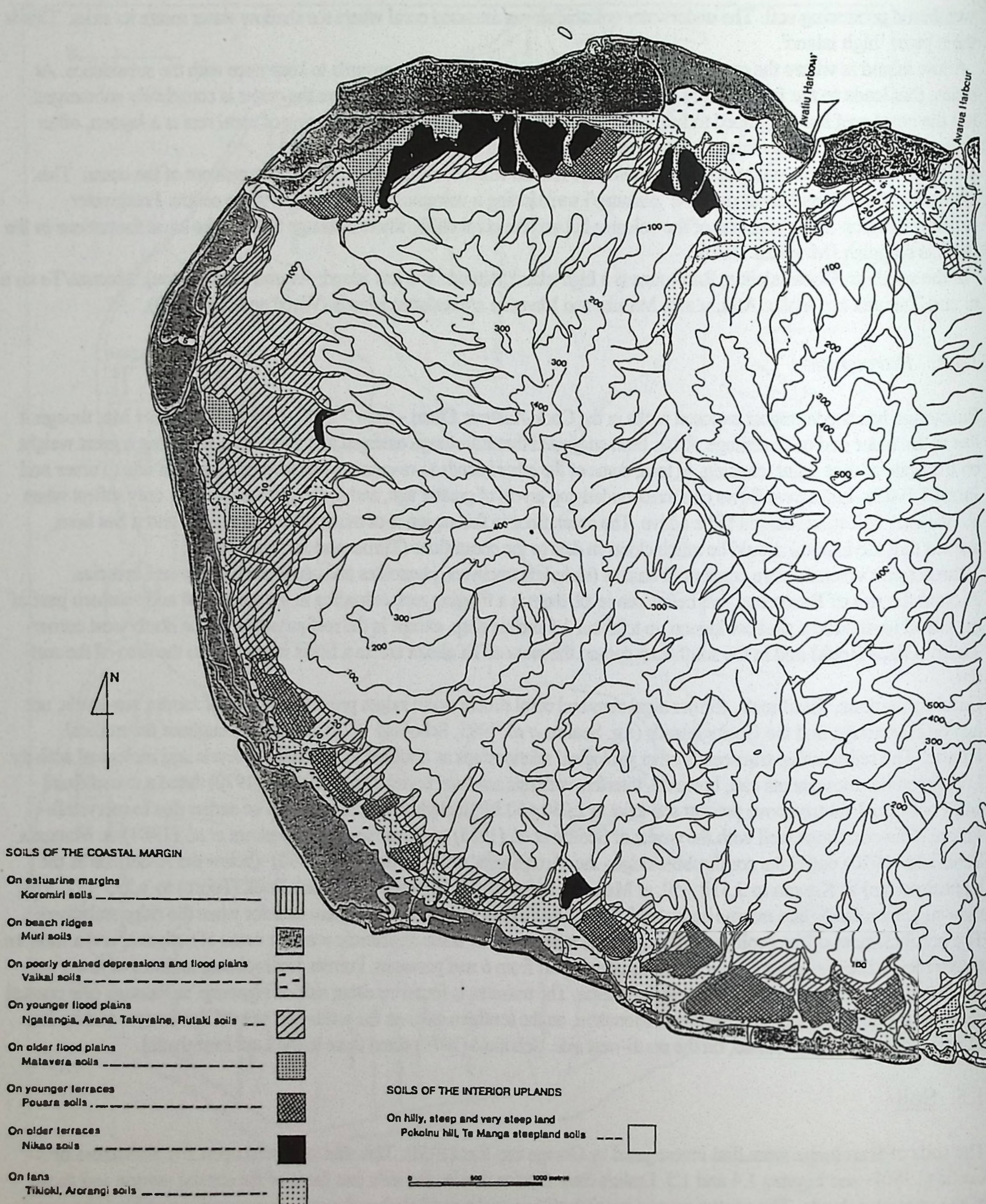

Figure 1.4 Map of the Western side of Rarotonga, showing contours and soils.

soils have lost much of their fine fraction and continually receive fresh coral detritus so that their profiles are even more weakly developed and coarse textured.

The soils of the poorly drained depressions (Vaikai Soils - Vk; Vaikai Soils, mottled variant - Vkm) are derived from moderately pre-argillised basaltic alluvium with a small contribution of coral fragments. These soils are poorly drained, kaolinitic, heavy in texture, sticky in consistency and poorly aerated. They have neutral to slightly alkaline pH, high

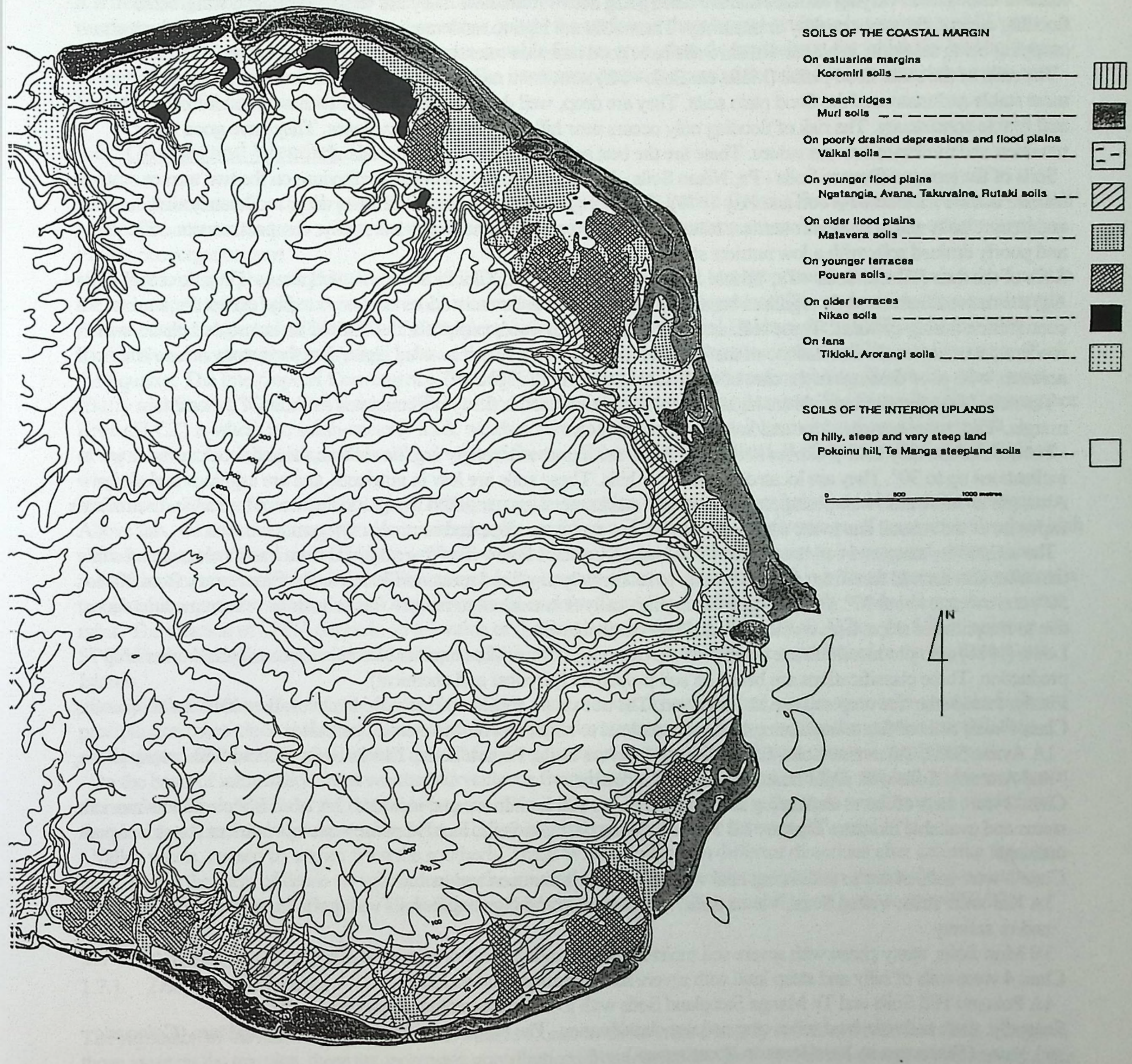

Figure 1.5 Map of the Eastern side of Rarotonga, showing contours and soils.

exchangeable cation, phosphorus and potassium values, though low values for total carbon, nitrogen and absorbed sulphate.

The soils of moderately drained depressions (Ngatangiia Soils - Nt) consist of moderately pre-argillised fine basaltic alluvium and coral sand over coral sand. They do not experience the long periods of flooding that Vaikai soils do, and the coral sand component ensures better drainage. Adequate, though low nutrient levels exist for plant growth (high amounts for shallow rooting crops), though flooding limits the range of plants that can be grown.

The soils of the younger flood plains (Avana Soils - Av; Takuvaine Soils - Tv; Rutaki Soils - Ru) are derived from basaltic alluvium of varying textures and are undergoing active formation. They are well drained, and while some flooding occurs, the water rapidly drains away. These soils are high to moderate in nutrients, the only real limitation to cropping being stoniness in places. Rutaki Soils have good moisture retention and are montmorillonitic.

The soils of the older flood plains (Matavera Soils - Mt) stem from moderately argillised basaltic alluvium, and the most stable and mature of the flood plain soils. They are deep, well drained, well aerated with a well matured structure and friable consistency. The risk of flooding only occurs near hill margins during cyclones. They have good water retention and moderate nutrient values. These are the best soils for gardening on the island.

Soils of the terraces (Pouara Soils - Pa; Nikao Soils - Ni) are developed on basaltic alluvium on the two terrace systems formed in the Pleistocene (Wood and Hay 1970). The younger terrace (Pouara Soils) has deep, moderately well drained and mature soils with a moderate nutrient status. The older terrace (Nikao Soils) has sticky, compact, montmorillonitic and poorly drained soils with a low nutrient status.

Soils of the fans (Tikioki Soils - Tk; Tikioki Soils, stony phase - Tkt; Tikioki Soils, mottled phase - Tkm; Arorangi Soils - Ag) are derived from strongly argillised basaltic gravels. Active colluviation does not occur today, except for a minor contribution during cyclones. These soils are moderately well drained, except for the Tikioki Soils, mottled phase, with moderate nutrient levels. Limitations of the Tikioki Soils (stony phase and mottled phase) are their stony nature and poor aeration, with poor drainage in the case of the Tikioki Soils (mottled phase).

The soils of the interior uplands are highly complex and were not as finely differentiated as those of the coastal margin. They have extreme slope and low nutrient limitations.

The soils of the hilly land (Pokoinu Hill Soils - PkH) are based on strongly argillised basic volcanic rocks with slope inclinations up to 30°. They are located on the lower hills. These soils are low in nutrients, and are argillous and stony. Attempts at cultivation with pineapple, dryland taro and kumara have resulted in significant loss of topsoil and sometimes exposure of the subsoil due to the combination of severe cyclones, slope and removal of vegetation cover.

The soils of the steep and very steep land (Te Manga Steepland Soils - TmS) are derived from basic volcanic rocks or the colluvium derived therefrom and are weakly to moderately argillised montmorillonitic soils. Slopes vary from 30° to 50°, and average about 37°. Profiles range from practically non-existent to mature. These soils have extreme limitations due to steepness of slope, high erosion risk and low nutrient levels.

Leslie (1980) also produced soil use classifications: for tree and tree-like crops and for subsistence dryland tuber crop production. These classifications are based on soil properties (physical and chemical).

Firstly, there is the tree crop soil use classification. The tree crops considered included bananas, breadfruits and coconuts.

Class 1 were soils of flat to undulating land with minimal to slight soil limitations and included:

1A Avana Soils, Takuvaine Soils, Rutaki Soils, Matavera Soils, Pouara Soils, Tikioki Soils, Tikioki Soils, stony phase, and Arorangi Soils with slight limitations of nutrient status.

Class 2 were soils of flat to undulating land with moderate soil limitations and included: 2A Muri Soils with low nutrient status and available moisture capacity 2B Nikao Soils and Tikioki Soils, mottled phase with low nutrient status and poor drainage

Class 3 were soils of flat to undulating land with severe soil limitations and included:

3A Koromiri Soils, Vaikai Soils, Vaikai Soils, mottled phase and Ngatangiia soils with poor drainage, high water table and/or salinity

3B Muri Soils, stony phase with severe soil moisture deficit and/or shallow or very shallow soil depth

Class 4 were soils of hilly and steep land with severe soil limitations and included:

4A Pokoinu Hill Soils and Te Manga Steepland Soils with low nutrient status, slope and erosion risk

Secondly, there is the dryland tuber crop soil use classification. The crops considered included dryland taro (*Colocasia* sp.), yams (*Dioscorea* sp.) and kumara (*Ipomoea* sp.).

Class 1 were soils of flat to undulating land with minimal to slight soil limitations, and included:

1A Takuvaine Soils, Rutaki Soils, Matavera Soils and Pouara Soils with slight limitations

Class 2 were soils of flat to undulating land with moderate soil limitations and included:

2A Vaikai Soils, mottled phase and Tikioki Soils, mottled phase with poor drainage

2B Tikioki Soils, Ngatangiia Soils and Arorangi Soils with medium to low nutrient status

2C Muri Soils with a seasonal moisture deficit

Class 3 were soils of flat to undulating land with severe soil limitations and included:

3A Nikao Soils with very low nutrient status and drainage

3B Muri Soils, stony phase with severe soil moisture deficiency and/or very shallow depth

3C Avana Soils and Tikioki Soils, stony phase with limitations of stoniness

3D Koromiri Soils and Vaikai Soils with a high water table, poor drainage and/or salinity

Class 4 were soils of hilly and steep land with severe soil limitations and included:
4A Pokoinu Hill Soils and Te Manga Steepland Soils with severe erosion risk and/or low nutrient status
It is interesting to note that the areas with the best soils were the flood plains, the younger terrace and the fans: in other words the valleys and either side of the *Ara metua*, where the surface archaeological evidence is concentrated (Trotter 1974). Also, one should note that more areas are suitable for tree crops than dryland tubers, for which the best soils are all among the areas also suitable for tree crops. The interior mountainous core of the island is considered the worst area for cultivation for both tree crops and dryland tubers.

1.6 Climate and Weather

Four main factors influence the general circulation in the tropical south Pacific Ocean (Thompson 1986): the sub-tropical high pressure zone; the trade winds; the equatorial doldrum belt and the intertropical convergence zone; and the south Pacific convergence zone.

The first is a high pressure belt, centred on 25 - 30°S, across the Pacific. A semi-permanent anticyclone is to be found in the eastern part of the belt, and in the west, there are eastward migrating anticyclones. The trade winds blow consistently from the east along a broad belt north of the high pressure belt. The Equatorial Doldrum Belt (EDB) of the western Pacific Ocean is characterised by light perennial winds, high rainfall with much seasonal variability and lies within 5° of the Equator. The Intertropical Convergence Zone (ITCZ) is where northern and southern hemisphere trade winds meet (Barry and Chorley 1982). It is a region of cloud and drizzle due to the rising air currents. The South Pacific Convergence Zone (SPCZ) is where the south-easterly trade winds converge with the equatorial winds from the east. It is north of the southern Cook Islands, and south and west of Samoa, Tahiti and Easter island. It is an area of cloud and cyclonic wind shear.

In the area of the trade winds (Thompson 1986), strong temperature inversions occur between 1200 and 2500 metres. Above this, westerly winds are prevalent, with dry descending air. This prevents the formation of convective clouds at high altitudes, because clouds are unlikely to infiltrate the inversion. Showers are therefore not to be expected, except where mountains are encountered such as on Rarotonga. In the austral summer when the EDB is in its most southerly position, a trough of low pressure forms from Northern Australia and the Coral Sea, leading to westerly winds bearing the monsoon rains. The location of SPCZ depends on the value of the Southern Oscillation Index (SOI). When the SOI is negative, the SPCZ lies north and east of its mean position, and this means that dry conditions are experienced in the southern Cook Islands.

Precipitation is in the form of rain (Thompson 1986), with rare occurrences of hail, and is seasonally variable; higher precipitation takes place in the austral summer. The higher elevations on Rarotonga receive the greatest rainfall, the southern part of the island between Aro`a and Muri is the wettest part and the north-east corner is the driest part.

On the basis of information from weather surveillance from 1969 to 1986 (Thompson 1986), tropical cyclones occur in the southern Cook Islands at the rate of 1.4 a year. The southern Cook Islands lie in the trade wind zone, so winds from the east blow for over 50 per cent of the time. The most frequent directions are between 80° and 140°.

Valley winds, caused by eddies from the southerly Trade Winds, spill out in different directions after crossing the mountains. It is in the form of dense air which crosses the mountain ridges at high velocity and then slumps down on to the plain, where it spreads out. Easterly Trade Winds would counteract any valley winds (Ngari pers. comm. 6/08/92).

1.7 Flora and Vegetation[8]

1.7.1 *The Pacific Islands*

The vegetation of the mid-ocean islands of the Pacific Ocean owes its origins largely to Island South-east Asia, though in those areas on the margins, there are increasing contributions from Australia, North and South America respectively (Van Balgooy 1971). There is a gradient of decreasing diversity as one moves from east to west and major groups reach abrupt limits along this gradient (Briggs 1987). However, a large number of endemics occur at familial, generic, specific and sub-specific levels, so although ultimate origins may be found elsewhere, the vegetation represents local adaptation rather than simply a depauperate version of the Malesian region with some mixing at the peripheries. The migration of vegetation across the Pacific Ocean has a considerably greater time depth than that of humans, though there is as yet little evidence as to its nature prior to the late Pleistocene. One of the few studies undertaken was that of Cranwell (1962; 1964) on Tertiary deposits from Rapa (Iti), in the Austral Islands, and even this was limited in its extent. The central Pacific Ocean has a very different environment from South-east Asia: greater oceanicity, less precipitation, smaller landmasses (further

8 For Latin, Maori and English names of organisms, see Glossary in Appendix A.2.

apart) and less diversity of landforms, soil types and climatic zones in other words, much harsher environments, especially those out of the tropical zone, such as Rapa (Iti) and Rapa Nui (Easter Island).

Three major boundaries affect biotic distributions in the Pacific Ocean. Firstly, Wallace's Line or Huxley's Line (Briggs 1987) separate Sahulland (Australia and New Guinea) and Sundaland (the western part of Island South-east Asia), two large continuous landmasses during times of low sea-level, but flooded and divided when sea-level is high. Secondly, the boundary between Sahulland and the open ocean. Thirdly, the Andesite Line forms an important distributional boundary (Figure 1.6): i.e., it divides andesitic volcanics from basaltic volcanics, where the Indo-Australian and Philippine plates have met at sometime, if not the present, the Pacific Plate to their east. To the west of the Line, landmasses are larger and closer together and are composed more of continental rocks, whereas to the east, they become smaller, further apart and composed simply of basaltic and coralline rocks.

A sorting process selected and selects for those plant categories meeting the criteria for dispersion (Carlquist 1967): these categories are thus better represented than they are in the source area of Malesia. Pteridophytes and angiosperms are the best colonizers. Gymnosperms, due to their heavy seeds and lack of fruit, rapidly decline after leaving Sahulland and failed entirely to cross the Andesite Line until they were artificially conveyed over in the nineteenth century (Van Balgooy 1971). The light spores of Pteridophytes are easily transported by wind and water. Those angiosperms producing edible fruit attractive to birds or bats, or seeds that can in some way attach themselves to birds or bats are transported by such means, and other angiosperms have adapted to water transport (Carlquist 1965; 1967).

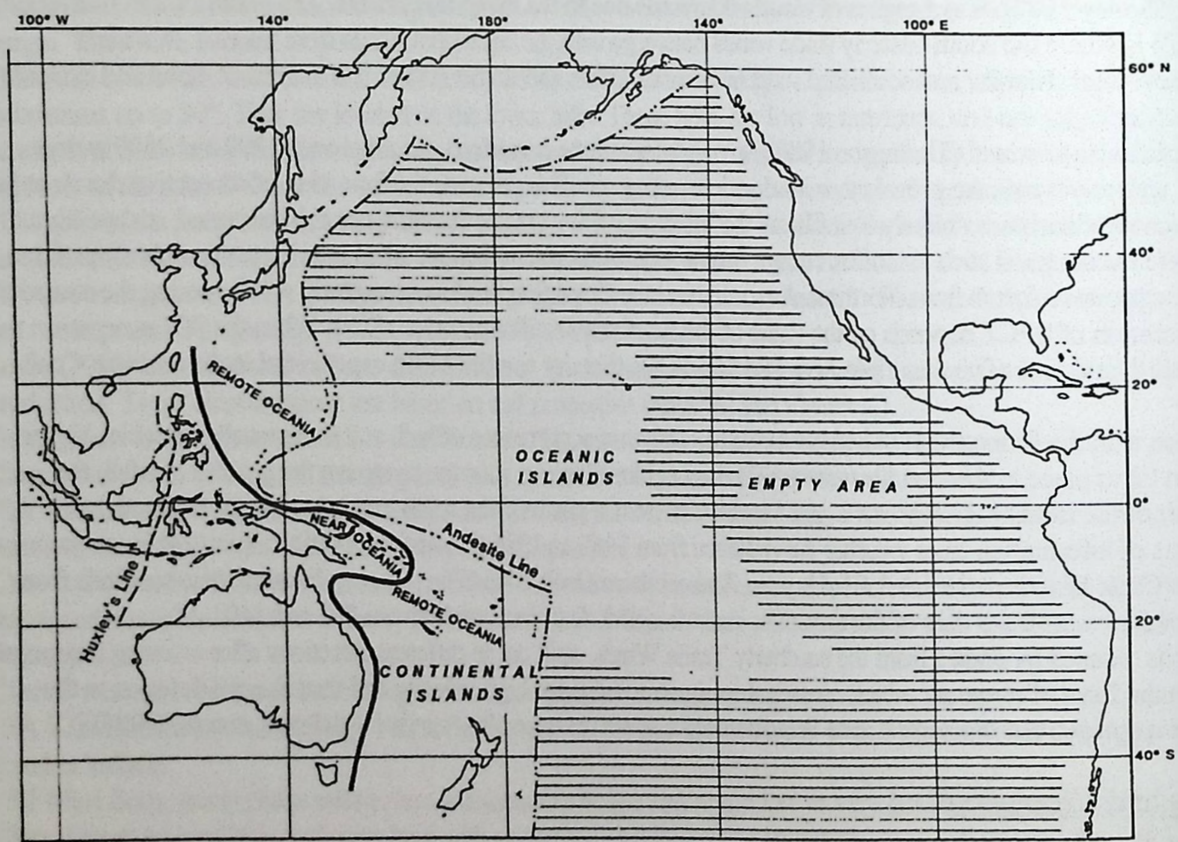

Figure 1. The Pacific basin and some biogeographic divisions in relation to Near and Remote Oceania.

Figure 1.6 The Pacific basin and some biogeographic divisions in relation to Near and Remote Oceania [*After Green (1991), fig.1, p.492*].

Founder-effect would have caused some of the variation between islands. Also, there is the consideration of later hybridisation between closely related species or subspecies. Adaptive radiation of one plant in a new island may lead to different varieties of that plant occupying separate niches. This leads to the potential for hybridisation at the junction of these niches, and thus creates the opportunity for greater genetic variation. This assists plant adaptation to changing circumstances in a restricted ecological situation.

Adaptive radiation has led to a number of pioneering plant groups of a normally shrubby or herbaceous type that have managed to traverse the oceans, for example members of the Compositae, developing into trees in the absence of their competitors on the continents (Carlquist 1965).

Vegetation groups into a number of zones: Alpine, Cloud Forest, Rain Forest, Slope Forest and Coastal Forest, as well as Swamplands, Fernlands and Savannahs (e.g., Merlin 1985; Sykes 1983).

1.7.2 *Rarotonga*

Rarotonga has 73 tree and shrub species, which have been suggested as being possibly or probably present before European contact (Cheeseman 1903; McCormack 1990; Sykes 1983; Wilder 1931). Some of these, like the breadfruit (*Artocarpus altilis*) and the paper mulberry (*Broussonetia papyrifera*)[9], were Polynesian introductions (Merlin 1985). Many species have been introduced since European contact, and these are largely confined to the lowlands (Sykes 1983). Some have had a limited success on higher ground such as the tree maniota (*Cecropia palmata*) and the guava (*Psidium guajava*).
For zonation, see Chapter 2.

1.3 Animals

1.8.1 *The Pacific Islands*

Similar factors to those described for the plants influence animal distributions. The Wallace Line generally separates placental from marsupial mammals, though a few exceptional placental mammals have crossed it. Marsupials were unable to colonize further than mainland Sahulland (at low sea-level) until transported by humans (Bellwood 1985: 14-15). Bats colonized right the way through to the Andesite Line and beyond. In central East Polynesia, there is only one bat (or `flying fox'), *Pteropus tonganus*.

Reptiles were able to cross beyond the Andesite Line, though this only includes gekkonids and scincids (Gibbons 1985; Crombie and Steadman 1986). Few amphibians colonized beyond Sahulland, and none passed the Andesite Line (Gibbons 1985). True freshwater fish hardly occur beyond the Wallace Line, except for New Zealand (Briggs 1987).

Successful colonists across these boundaries include birds, spiders, insects and small species of terrestrial molluscs (Briggs 1987). Land crabs are also very successful colonizers (Burggren and McMahon 1988), including the large Coconut Crab (*Birgus latro*). Birds are able to fly, and the others could survive on floating vegetation or be transported over by attaching themselves to birds or bats.

Sea birds are well-dispersed. Land birds vary in their readiness to cross barriers. Some will not even cross breaks in forest canopy, whilst others will migrate over kilometres of ocean (Diamond 1969; 1984b). The Reef Heron (*Egretta sacra*), which is a bird of marsh, swamp, dry fields and the coastal reef flats, and which is an all year round breeder, is thus well-adapted to colonization. It has a distribution right across the Pacific Ocean as far as the Marquesas Islands (Holyoak 1980).

One other group of birds are the migratory birds, which include the long-tailed cuckoo (*Urodynamis taitensis*) and various sorts of wading birds like plovers, such as the lesser golden plover (*Pluvialis dominica*) and the grey plover (*Pluvialis squatarola*) and sandpipers, such as the wandering tattler (*Heteroscelus incanus*) and the bristle-thighed curlew (*Numenius tahitiensis*)[10]. These birds do not nest in the central Pacific, but are either in transit from a summer in the northern temperate zone to a summer in the southern temperate zone and *vice versa* or they over-winter from the southern temperate zone, where they breed and nest.

There is evidence that some seabirds, like frigate birds for instance, do migrate from East to West and back (Watling 1982). Some birds, like the boobies, frigate birds and some terns, only breed on those islands which have little or no human settlement (Holyoak 1980; McCormack and Künzle 1990), whilst others, like the herald petrel (*Pterodroma heraldica*), nest where there are high mountains. Other seabirds have greater tolerance such as the noddies, the white tern (*Gygis alba*) and the tropic birds.

Land birds of prey, represented by the Falconiformes, were only able to disperse naturally as far as Samoa and Tonga. A harrier has been introduced to Tahiti since European contact by humans (Bruner 1972). Elsewhere, in central East Polynesia, there are still no such birds.

Successful colonists are represented by Columbiformes, including *Ducula pacifica*, and a number of fruit doves and ground doves, by Rallidae, Alcedinidae, Apodidae, Psittacidae, Sturnidae, *Anas superciliosa*, Sylviidae, Monarchidae and *Egretta sacra*.

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9 Nomenclature follows Sykes (1983).

10 Nomenclature for birds mentioned in the text follows McCormack and Künzle (1991), and failing that, Holyoak (1980). For extinct species, Steadman (1989b) is used.

1.8.2 *Rarotonga*

Rarotonga has at present 4 species of land bird, which pre-date human colonization: the *'i'oi* or rarotongan starling (*Aplonis cinerascens*), the *rupe* or pacific pigeon (*Ducula pacifica*), the *kukupa* or Cook Islands fruit dove (*Ptilinopus rarotongensis*) and the *kakerori* or rarotonga flycatcher (*Pomarea dimidiata*). The starling and the flycatcher are endemic to Rarotonga, the fruit dove is endemic to the southern Cook Islands and the pigeon is merely indigenous. A fifth, the *mokora rere-vao* or grey duck (*Anas superciliosa*), died out earlier this century (McCormack and Künzle 1991). The *Manu kura* or Red Lorikeet (*Vini kuhlii*) is recorded in oral tradition (Nightingale 1835; Savage 1962), and its feathers were used in headdresses collected by missionaries and collectors in the nineteenth century (Buck 1944). *karavia* or long-tailed cuckoos (*Eudynamis taitensis*) migrate to Rarotonga from New Zealand and over-winter there. A few birds, probably juveniles, even spend the summer in Rarotonga (Holyoak 1980; McCormack and Künzle 1990).

The Polynesians introduced the domestic fowl (*Gallus gallus*), and it subsequently established a feral population in the mountains (Holyoak 1980). European contact brought the *manu kavamani* or mynah bird (*Acridotheres tristis*) in 1906. It was introduced to control pests by the government, hence its Maori name (McCormack and Künzle 1990). It has since achieved high numbers in the lowlands. Only a small number are to be found at higher altitudes.

1.9 Historical Background

1.9.1 *Polynesia*

Oral tradition in the islands of the south Pacific records eastward movement of people, with the later exceptions of Hawaii to the north, New Zealand to the south and the Polynesian outliers in Melanesia (Kirch and Yen 1982) off the main direction of colonization. West Polynesian traditions record their westerly ancestral land as *Pulotu* and East Polynesian traditions record theirs as *Hawaiki* or variants thereof (Burrows 1938; Smith, S.P. 1921).

Cultural divergence began to appear after Polynesia was settled (Burrows 1938; Smith, S.P. 1898; 1921). The divisions among the island groups of East Polynesia, for example, occurred as a result of arguments between the various lineages of *Hawaiki*, who then went off to found colonies on new islands (Tara`are 1898). Later, there are examples of attempts to extend control over larger territories by some chiefs (Tara`are 1899). Multiple colonization took place, according to oral tradition, stretching out even into times separated by many generations from the original settlement, for example on Rarotonga (Tara`are 1899; 1917; More-Taunga-O-Te-Tini 1910) and Mangaia (Buck 1934).

The period of European contact began in the sixteenth century with the Spanish, and to a lesser extent Portuguese, exploration of the Pacific Ocean in their search for a short and trouble-free route to the Indies (Spate 1979). This included explorers such as Magellan, Mendaña and de Quiros. At least in the extant contemporary literature, there does not seem to be much evidence for contacts with Polynesian islands, except for the Marquesas Islands and possibly the northern Cook Islands or the northern Tuamotu Islands. However, the Spanish may have kept such information secret (Langdon 1975; Salmond 1991). The Dutch followed in the seventeenth and early eighteenth centuries with explorers such as Tasman, Le Maire, Schouten, and Roggeveen. Then, from the late eighteenth century onwards, English and French explorers like Wallis, Bougainville and Cook explored the rest (Howe 1984).

The next phase of contact involved traders, whalers, beachcombers and missionaries, whose visits were more frequent and longer. This phase appears to have led to much economic, political and social change. In Samoa and the islands of central East Polynesia, (apart from a brief episode in the 1770's on Tahiti with a Spanish Catholic mission - Corney 1913-19) the missionary organisation was the London Missionary Society (LMS), which began its work in Tahiti in 1797 and thence spread out to the other islands. The first long-term Catholic missions started with the Picpus fathers on Mangareva in 1837 and Tahiti in 1841 (Howe 1984: 121). In the southern Cook Islands, the LMS was only challenged by the Marist (Catholic) mission and other denominational missions in the latter part of the nineteenth century (Lovett 1899). The missionaries passed on not only religious beliefs, but also European arts, crafts, customs and laws. They were politically active too (Howe 1984). Merchants, whalers and beachcombers were also agents of the transmission of European technology and economic practices (Howe 1984; Martin 1817).

Imperialist expansion by the European states in Polynesia started with the British in New Zealand in 1840 and the French in Tahiti in 1844 and ended with New Zealand in the Cook Islands in 1901. This meant the seizure of political and military control, and the imposition of new laws, customs and economic practises. Sahlins suggests that unlike the previous contacts which led to the incorporation of European ideas into traditional culture, this latter form of contact was perceived by indigenous people as more of an attempt to replace indigenous culture with European culture (Sahlins 1992).

In the latter part of the twentieth century, varying degrees of self-determination have come about in Polynesia. For example, the Cook Islands became a self-governing dependency of New Zealand in 1965 (Gilson 1980) and Western Samoa became independent in 1971 (Howe 1984).

1.9.2 *The Southern Cook Islands*

The southern Cook Islands present an interesting case, because of their location between East and West Polynesia. Cook mentions the presence of some Ra`iateans on Atiu who had apparently drifted there by accident a number of years previously and did not wish to return (Beaglehole 1967). Such records in the literature have helped to generate ideas about so-called `drift voyaging' (for example, Sharp 1963). However, Walter (1990) has evidence from Ma`uke, at least for the earlier stages of settlement, for trade in pearl shell and basalt for adzes. This has received some support from the work of Allen and Schubel (1990) on Aitutaki. There are well-established traditions in Atiu of extensive pre-European contacts with the Societies, especially with Tahiti (e.g. Buck 1944; Marsters pers. comm. 1992). Rarotongan oral traditions narrated by Tara`are (1898; 1899; 1917) show extensive links around the Polynesian world, including `Amoa (Samoa), `Iva (Marquesas or Ra`iatea?), `Avaiki Tautau (New Zealand) and especially, Ta`iti (Tahiti). Some of this is confirmed by references in Savage (1962).

Tangi`ia and Karika, two chiefs who came to Rarotonga at a time when it was already settled, appear to be responsible for the political and administrative structure of the island up until European contact according to Tara`are (1899; 1917), Nicholas (1892) and Te Aia (1893).

The first recorded European visits to the southern Cook Islands after Cook in 1777, were the *Bounty* in 1789 to Rarotonga (possibly mentioned in oral tradition), and then the *Endeavour* (not Captain Cook's *Endeavour*), followed by the merchant Philip Goodenough, who, in about 1813, came looking for sandalwood on Rarotonga (Maretu 1911a; 1911b). Finally, the LMS missionary, John Williams, arrived in Nga Pu Toru (Atiu, Miti`aro and Ma`uke) in 1821 to convert the inhabitants to Christianity.

Tahitian preachers trained by the LMS were landed on Rarotonga in 1823 to convert the population and prepare the ground for white missionaries who came in 1827.

The missionaries not only converted Rarotonga to Christianity, but introduced a number of plants and animals, and a variety of European cultural influences and technology. The visits of traders helped to reinforce some of these cultural and technological influences. Economic change meant that goods, such as cotton and coffee, began to be produced *en masse* for trade (Gill, W. 1856; Gilson 1980; Moss 1889). Sometimes the traders, such as Henderson and Macfarlane and `Bully' Hayes would indulge in acts of aggression, manipulation and exploitation in order to achieve their ends, even more radically changing the lives of Cook Islanders (Moss 1889; Scott 1991).

The missionaries also brought diseases against which Cook Islanders had little resistance, and many died. Rarotonga is one of the best documented cases of population decline due to European-introduced diseases in the Pacific Islands (McArthur 1967). Williams (1838) estimated the population of Rarotonga to have been between 6000 and 7000 people when he first visited in 1827. It is difficult to assess the accuracy of this statement, except to say that with a stated potential error of 1000, it can only be taken as a rough guide. Gill (1856) mentions that from an estimated 4000 people, the population dropped to 3,300 during the course of the 1830's. From the 1840's more accurate information becomes available as the missionaries, and then later the colonial authorities, kept proper records. By the end of the nineteenth century, the population decline was levelling off, and the population steadily rose up again through the course of the twentieth century (Gilson 1980).

The Cook Islands were annexed as a British Colony under the jurisdiction of New Zealand in 1901. A land court, modelled on that of New Zealand, was set up in order to individualise land so that it would become easier to rent it out to European traders and planters[11]. This is clearly evidenced by the writings of the then Resident Commissioner, Colonel Gudgeon (see quotes in Scott 1991: 90). The colonial government tried to effect a greater move towards a capitalist economy and persuade Cook Islanders to cultivate more land, far more intensively (Gilson 1980; Scott 1991). Some of the landscape that can be seen today may well be attributable to the changes made in this period.

In 1965, the Cook Islands became a self-governing dependency of New Zealand (Gilson 1980; Scott 1991). Since then, there have been the competing factors of increasing outside influences, especially economic and social ones, and increasing interest in promoting and reviving traditional culture. These later changes too have exerted an influence on the landscape.

1.10 Ethnographic Background

1.10.1 *Polynesia*

The Pacific Islands, from Island South-east Asia and Taiwan in the west, to the Hawaiian Islands, New Zealand and Easter Island in the east, were colonized by Austronesian-speaking people, and speakers of various other languages (once collectively known as `Papuan', though now thought to be too diverse to be grouped as a language family) in some areas

[11] Land in the Cook Islands was not allowed to be sold to non-Cook Islanders (Crocombe, R.G. 1961).

in and to the west of the Solomon Islands (Bellwood 1985). Austronesia divides up into a number of regions the most easterly of which is Polynesia. Polynesia forms an area roughly in the shape of a triangle, except for a number of small westerly outliers (Bellwood 1987). The Polynesian Triangle extends from New Zealand to Easter Island to the Hawaiian Islands.

Physically, Polynesians are genetically related to South-east Asian populations, with Melanesia having more complex origins (Hill and Serjeantson 1989). The genetic and osteological evidence from Houghton (1980), Hill and Serjeantson (1989) and Matisoo-Smith (1990) indicates that Polynesia was genetically fairly homogenous, although there is some clustering among regions therein, indicating regions with greater genetic interaction. It is often suggested that the distancing of the different groups is due to an initial period of close contact, followed by lessening contact until a state of limited or no contact was reached, as recorded at European arrival. Polynesian cultures have closely related languages, descended from a common theoretically reconstructed ancestor, Proto-Polynesian (PPN) (Clark 1979) Their settlements prior to European contact were rarely nucleated and they lived in scattered dwellings usually close to their food gardens. Social organisation was based, albeit weakly in some cases, on a kinship system. Inheritance was ambilineal, though preferentially patrilineal. An efficient and well-developed maritime technology had enabled them to locate and settle their islands (Irwin 1990; 1991; 1992). They cultivated plants and kept domesticated animals, and introduced new species sometimes deliberately and sometimes inadvertently. Cultivated plants included yams (*Dioscorea* spp.), taro (*Colocasia esculenta*), breadfruit (*Artocarpus altilis*), and bananas (*Musa* spp.); domesticated animals were represented by dogs, pigs and domestic fowls. Clothing was made from bark cloth, cordage and leaves.

Polynesian culture is distinguished more by its homogeneity than by large internal differences that occur elsewhere in Austronesia, say, within the region of Melanesia, where diversity is emphasized. This being said, some broad divisions of Polynesia have been suggested. The main one is that between West and East Polynesia (Jennings 1979; Bellwood 1987) - originally `Central-Marginal Polynesia' as defined by Burrows (1938). West Polynesia consists of Tonga, Samoa, the Wallis Islands, and the Polynesian Outliers (speaking Samoic languages). East Polynesia consists of the Cook Islands, except Pukapuka, the Society Islands, the Tuamotu (or `Paumotu') Archipelago, the Austral (or `Tubuai') Islands, the Marquesas Islands, the Gambier Islands, East Island, the Hawaiian Islands and New Zealand. Among the main differences apart from linguist considerations were an emphasis on godhouses in West Polynesia instead of the court, platform and uprights of *marae* in East Polynesia, and one-piece shell fishhooks, and tanged adzes and food-pounders, which occurred only in East Polynesia.

Within East Polynesia, the central area consisting of the southern Cook Islands, the Society Islands, the Tuamotu Archipelago, the Marquesas Islands, and the Austral Islands have much closer cultural links with each other than do the outlying parts of East Polynesia. The outlying parts or `Marginal Polynesia' have stronger cultural differences that mark themselves from each other and from the central area.

1.10.2 *Rarotonga*

Rarotonga is linguistically part of Cook Islands Maori, which is spoken throughout the southern Cook Islands, except Palmerston, which was settled later by the English-speaking Marsters family in the nineteenth century. Rarotonga has its own dialect, which nowadays is used as the standard version of Cook Islands Maori. New Zealand Maori is a close relative together with Tahitian (Biggs in press).

As far as genetic evidence is concerned, it suggests that the Cook Islands, the Society Islands and the Marquesas Islands were in contact to a degree significant enough for them to form a close genetic unit (Matisoo-Smith 1990). West Polynesia appears to be more distinct genetically, though the Cook Islands, especially the northern group, are more intermediate and have some similarities with West Polynesia. Indeed, Katayama working on physical features such as cephalic index and finger whorls has shown that the Cook Islanders have strong links with West Polynesia (Katayama 1987).

Religion consisted of a number of gods found elsewhere in East Polynesia, though the cult of Tangaroa was especially important (Buck 1944). Local gods also existed. The gods expressed their wishes through atavars such as lizards or birds or through the *ta`unga* or priests. Religious ceremonial took place on the *marae*, which consisted of a courtyard with a platform (*atarau*) or platforms, stone uprights and *unu* or sacred wooden carved boards. The *koutu* were a more specialised ceremonial monument for the installation of chiefs.

Chiefs had a number of religious functions, like the setting up of *ra`ui* or sacred prohibitions on the use of certain resources either to prevent famine or to build up that resource for some community occasion or project.

The main crops grown by Rarotongans were bananas, mountain plantains, coconuts, taro, atoll taro, giant taro, Polynesian arrowroot, yams, breadfruit, and Tahitian chestnut. Both Williams (1838) and Buzacott (Sunderland and Buzacott 1866) confirm that the kumara or sweet potato was introduced by themselves, though Hather and Kirch (1991) have found the carbonised remains of kumara on the neighbouring island of Mangaia in an archaeological context between dates of 988-1155 AD and 1409-1440 AD and Captain Bligh mentions it on the neighbouring island of Aitutaki in 1792

(Oliver 1988). Pigs, domestic fowls and possibly dogs were the domestic animals kept (Buck 1944; Williams 1838). Rats were found in abundance (Williams 1838), but were apparently not eaten anywhere in the southern Cook Islands, except Mangaia (Buck 1944).

Many wild plants were used on Rarotonga as well as will be discussed in Chapter 6 (6.3).

Rarotonga was traditionally divided up into the three tribal areas (*vaka*) of Te-Au-O-Tonga, Takitumu, and Puaikura as recorded ethnographically since European contact (Crocombe, R.G. 1961). These were further divided into *tapere*. When the missionaries arrived they created the *oire* or villages, as settlement was not nucleated up to that time. The head of a *vaka* was an *ariki*, and the *ngati* or lineages occupying the *tapere* were headed by either a *mata`iapo* or a *rangatira* (Crocombe, R.G. 1961).

1.11 Résumé

Rarotonga has now been placed in its context from the point of view of location, topography, geology, soils, climate, flora and fauna, history and ethnography in order that the reader may better comprehend the problems discussed. The basic aims of the thesis have also been set out, and in the next three chapters the major issues are presented in detail, beginning with the status of the vegetation.

CHAPTER 2 MODERN VEGETATION SURVEY

2.1 Aims

In the first part of this chapter, an assessment of the present day vegetation of Rarotonga was undertaken to establish why it exhibits such a disjointed nature. The assessment was also required to pose informed questions on the details of its composition and distribution. Suspicions were that human beings had much to do with its modern structure and, to a certain extent, its composition.

The second part of this chapter deals with modern pollen rain studies from the vegetation plots in order to provide comparative material with the fossil samples from the swamp cores. This makes allowance for the dichotomy that often exists between the actual vegetation structure in a given area and its representation in the pollen rain of that same area.

Sykes (1983) divided the vegetation of Rarotonga into three broad zones: the coastal, the lowland and the upland zones. Merlin (1985) subdivided the upland zone by means of dendrogram analysis in to three basic plant associations: the *Homalium* montane forest, the *Fagraea-Fitchia* ridge forest and the *Metrosideros* cloud forest.

For the purpose of this analysis, the vegetation has been divided into six zones, five have a `natural' appearance (1-3, and 5) and one (4) has a distinctly anthropogenic aspect. The other five, too, may well have some varying degrees of human disturbance or influence attached to them. The first of these is the Cloud Forest (Merlin 1985), which veers towards open woodland and contains plant types associated with temperate climes, as well as some more catholic species such as *Weinmannia samoensis* and *Fagraea berteriana*. This occurs usually from 400m (though from as low as 200m in some places) to 653m a.s.l. (Sykes 1983) on very thin volcanic soils (Te Manga Steepland Soils - Leslie 1980) and rock with extreme limitations due to steepness, high erosion risk and low nutrient levels. It is quite exposed to strong wind, and steep inclines create potential problems of subsidence.

Secondly, the Slope Forest from 50m to 400m (Merlin's *Homalium* montane forest and *Fagraea-Fitchia* ridge forest) is the most diverse and the most dense vegetation type. The most common trees here are *Homalium acuminatum*, *Canthium barbatum* and *Fitchia speciosa*. The substrate is Te Manga Steepland Soils (Leslie 1980); a volcanic moderately argillised montmorillonitic soil, or Pokoinu Hill Soils (Leslie 1980) with argillous and stony soils on the lower slopes, both of which are well drained because of the slope, although this is not as severe as in the Cloud Forest. At the back of the valleys, including tributary valleys, there are local concentrations of *Inocarpus edulis* and, occasional *Alocasia macrorrhiza*.

In stream beds, especially in constricted valleys, there is a fairly low diversity flora (Philipson 1971) - mainly *Hibiscus tiliaceus* and *Angiopteris longifolia*: two pioneer species (Philipson 1971; Sykes 1983). The ground is covered in boulders, pebbles and gravel, with some sand and soil (stonier phases of the younger flood plains - Leslie 1980). This irregular and ill-sorted medium is also subjected to flash-flooding during the hurricane season.

Thirdly, on some lower ridges, there are *Dicranopteris linearis* fernlands (Sykes 1983), containing mostly *D. linearis* with occasional small shrubs. Some Cloud Forest elements occur here (Merlin 1985): for example, *Metrosideros collina* and *Mussaenda raiateensis*, though these are only of small shrub size. The substrate is Pokoinu Hill Soils (Leslie 1980).

In the fourth zone, cultivation and housing are not significantly demarcated: in cultivated parts of the zone, there are traditional crop plants, like taro and breadfruit, more recently introduced cultigens, such as cassava and oranges, a few indigenous plants and many exotic weeds; on the house plots, there are hedge and border plants like *Codiaeum* and *Crinum asiaticum*. Exotic ornamentals abound in the gardens, together with a number of putative Polynesian introductions, such as *Cordyline terminalis*, and indigenous plants, like *Barringtonia asiatica*. Some crops may also occur in the gardens. In this zone, there are abandoned house sites and strictly cultivation plots. Where these are covered by herbaceous regrowth, adventive wayside weeds and weeds of cultivation are the most common, whereas arborescent pioneers are almost exclusively represented by *Hibiscus tiliaceus*.

The substrate in this zone comprises five different types: terrace soils (Pouara Soils and Nikao Soils - Leslie 1980), developed on basaltic alluvium; younger and older flood plains (Avana Soils; Takuvaine Soils; Rutaki Soils and Matavera Soils - Leslie 1980), also based on alluvium; fans (Tikioki Soils; Tikioki Soils, stony phase; Tikioki Soils, mottled phase and Arorangi Soils), based on strongly argillised basaltic gravels; swamps (Vaikai Soils and Vaikai Soils, mottled variant - Leslie 1980), based on moderately pre-argillised basaltic alluvium with a small contribution of coral fragments; and coastal sands and gravels (Muri Soils and Muri Soils, stony phase - Leslie 1980). Although this zone mostly does not respect these edaphic boundaries, some of the indigenous plant elements in this zone do. For instance, *Hernandia nymphaeifolia* does not appear off the coastal sands and gravels, and *Homalium acuminatum* does not occur on the sand substrate.

Fifthly, the coastal zone (Sykes 1983) has patchy and discontinuous drought resistant woodland, growing on the coastal sands and gravel mentioned above and those of estuarine margins (Koromiri soils - Leslie 1980). These are formed on basaltic alluvium and reworked coral particles. The *motu* across the lagoon from Muri, in the south-east, are the least disjointed parts of this zone. The vegetation is highly variable with different species achieving only localised dominance, though *Hernandia nymphaeifolia* trees are invariably a significant part of it, and *Barringtonia asiatica* are dominant trees except on the *motu*. Stretching from zone edge to the lagoon are a number of shrubs, like *Scaevola taccada* and *Argusia argentea*, and vines like *Ipomoea pes-caprae* and *Wedelia biflora*. This occurs on the coastal sands and gravels only, which are arid, alkaline, salty and low in nutrients. Their location means they are highly exposed to disturbance from winds, storms and flooding.

Vegetation surveys were undertaken to investigate the relative composition of the different plant species in these zones. Because pollen samples were taken from within each of these vegetation survey plots, they provide models for comparison with the former vegetation represented by pollen cores.

2.2 Methodology

A technique employing plots permitted comparison of modern pollen samples with fossil ones. Plot size was large to handle the diversity, especially of the uplands. Rectangles tackled the nature of the topography for forest, such as on upland ridges and the linearity of the coastal forest; squares simplified estimation of small herbaceous plot percentages.

Basal area was used to measure abundance because cover, frequency and density measurements would have been too time-consuming (Greig-Smith 1964). Cover methods, because they measure the vertical projection of trees, can involve different levels of vegetation or in the case of *top cover* just the highest level: both, but particularly the former, are laborious and impractical given the precipitous topography and time restrictions of the project. These problems occur with, for example, point quadrats, the Braun-Blanquet technique (cover methods), and plotless sampling (a frequency and density method). Plots were preferred to the point-centred quarter, `variable-radius' and transect procedures also due to these problems. Classification and ordination methods like principal components analysis (pca) and factor analysis, were not justified by the limited data that could be collected (*cf.* Arriaga *et al.* 1988; Greig-Smith 1964). The fact that some plots had no species in common would, in any case, have produced `arch' effects if pca had been used (Greig-Smith 1964: 261).

The method follows Greig-Smith (1964). Plots were selected subjectively for representative plots of vegetation types to avoid problems associated with difficult terrain in the mountains and the patchy nature of vegetation types on the lowlands. Herbaceous plots were 4 m^2, and arborescent plots were ideally 50 m by 10 m, though in practice, they were altered to deal with local conditions. Herbaceous plots were surveyed as estimates for each individual species' percentage cover of the plot. Arborescent plots surveys measured the circumference of all tree and shrub trunks at breast height (1.5 m). Only where they were greater than 0.15 m in diameter were they noted and a further calculation made of the basal area in square metres for each tree trunk. The totals for each species were added up. The portion of the basal area each species took up was then calculated as a percentage of the total area of tree trunk for the plot. Where relevant, slope was also measured.

Complete coverage of all the zones was achieved by selecting plots from each of the 5 zones identified above. Extra plots were taken from the following zones. Zone 6 has two plots (a,c) because this zone is highly variable. A second plot

(d) was selected for zone 2 because it is at the meeting of this zone with zone 4, and is under more human influence. Zone 4 has four plots (b,f,g,j) to reflect different types of human influenced vegetation, which is of major importance to this thesis.

The collection of moss, leaf litter and soil samples from the vegetation plots was surveyed for evidence of the modern pollen rain. These have the advantage over pollen traps that they tend to represent longer timescales in the same way sediment samples do. Pollen traps can give more seasonal information, though shortage of fieldwork time and funding precluded this. The collection of voucher specimens for identifications was undertaken.

2.3 Results

2.3.1 The vegetation plots[12] by zone[13] in a series of tables follows (for the raw data consult Appendix A.9):

With the vegetation of each zone now described in terms of an estimate of canopy cover, the pollen rain studies from the same vegetation plots are presented in order to assess how representative the fossil samples are likely to be of past vegetation.

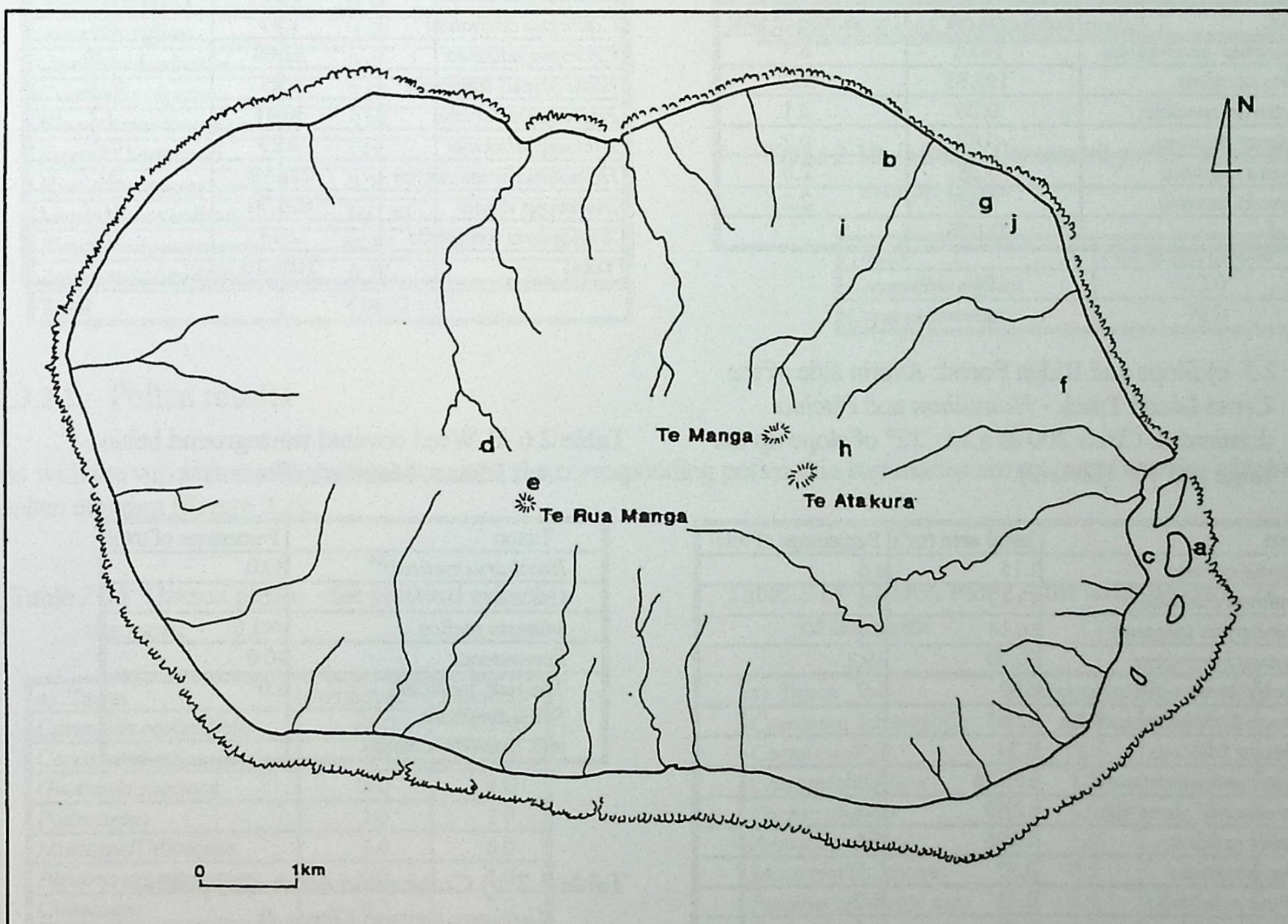

Figure 2.1 Location Map of the Vegetation Plots.

12 0.15 (circumference in m)=0.1795 (basal area in m^2)

13 The location of vegetation plots is marked on Figure 2.1.

Table 2.1 a) Oneroa plot 1. - the seaward side of the *motu*(*Zone 5*)

Taxon	basal area (m^2)	Percentage of total
Casuarina equisetifolia	383.85	77.1
Cocos nucifera	2.46	0.5
Guettarda speciosa	62.87	12.6
Hernandia nymphaeifolia	46.50	9.3
Leguminosae sp.	0.41	0.1
Morinda citrifolia	0.38	0.1
Scaevola taccada	1.53	0.3
Total	498.00	

Table 2.2 b) Regeneration plot near Ariana Bungalows, Tupapa (*Zone 4*).

Taxon	basal area (m^2)	Percentage of total
Ceiba pentandra	32.47	14.0
Hibiscus tiliaceus	163.33	70.4
Syzygium sp.	35.36	15.3
Hibiscus rosa-sinensis	0.68	0.3
Total	231.84	

Table 2.3 c) Oneroa Plot 2. - the landward side of the *motu* (*Zone 5*)

Taxon	basal area (m^2)	Percentage of total
Casuarina equisetifolia	14.01	6.3
Cocos nucifera	195.81	88.3
Guettarda speciosa	0.26	0.1
Hibiscus tiliaceus	0.47	0.2
Argusia argentea	6.38	2.8
Scaevola taccada	4.83	2.2
Total	221.76	

Table 2.4 d) *Inocarpus* dominated Forest at the top of the Avatiu Valley. 14° of slope up the ridge, and 18° of slope on either side of the ridge (*Zone 2*).

Taxon	basal area (m^2)	Percentage of total
Bischofia javanica	5.90	0.5
Canthium barbatum	1.47	0.1
Cecropia palmata	32.68	2.9
Elaeocarpus tonganus	0.23	0.02
Fagraea berteriana	30.41	2.7
Hibiscus tiliaceus	0.29	0.02
Homalium acuminatum	228.99	20.7
Inocarpus edulis	805.70	72.7
Angiopteris longifolia	2.43	0.2
Total	1108.10	

Table 2.5 e) Slope and Ridge Forest: Avatiu side of the Cross-Island Track - *Homalium* and *Fitchia* dominated. *Circa* 200 m a.s.l.. 22° of slope up the ridge and 30° (*Zone 2*).

Taxon	basal area (m^2)	Percentage of total
Alstonia costata	2.15	0.6
Canthium barbatum	13.13	3.6
Elaeocarpus tonganus	16.14	4.4
Fagraea berteriana	70.30	19.2
Glochidion ramiflorum	6.81	1.9
Hernandia moerenhoutiana	12.63	3.4
Hibiscus tiliaceus	3.24	0.9
Homalium acuminatum	195.28	53.3
Weinmannia samoensis	12.65	3.5
Fitchia speciosa	19.96	5.4
Ixora bracteata	2.37	0.6
Meryta paucifolia	2.71	0.7
Pittosporum rarotongense	3.89	1.1
Xylosma suaveolens	4.64	1.3
Angiopteris longifolia	0.36	0.1
Total	366.26	

Table 2.6 f) Weed covered wasteground behind Ara Metua, Matavera (*Zone 4*)

Taxon	Percentage of total
Bracharia muticali[14]	80.0
Grass 2.	8.0
Mimosa pudica	<<1.0
Spermacoce	10.0
The rest, including *Stachyterphata* and *Vernonia cinerea*	1.0

Table 2.7 g) *Commelina* dominated patch - Karekare swamp (*Zone 4*)

Taxon	Percentage of total
Commelina diffusa	99.9
4 Others, including *Eclipta prostrata* ?	0.1 or perhaps less

14 Grass 1.

2.3.2 Pollen Rain Study

This study was undertaken to interpret the fossil data. The fossil record will have been biased by various means over time (see the Taphonomy section - 8.3). Two of these biases are the differential pollen output of separate plant species and their means of pollen dispersal. By carrying out a modern pollen rain survey, one can allow for these two factors. Such studies used in connection with fossil assemblages are well documented: for example, Moore and Webb (1978) and Southern (1986). In this study, moss samples were used instead of pollen traps because of limited time available to carry out field research on Rarotonga. Moss samples are also advantageous in that they are more likely to reveal the trend rather than the quirks of a season or year, though pollen traps allow for a more controlled timescale.

Table 2.8 h) Cloud Forest - ridge on Old Te Manga Track. *Circa* 440m a.s.l.. 22° of slope up the ridge and 50° of slope down from the ridge top. The other side of the ridge top was not surveyed as it was a sheer drop. *Zone 1*.

Taxon	basal area (m^2)	Percentage of total
Alstonia costata	0.32	0.1
Ascarina diffusa	3.49	0.8
Canthium barbatum	0.46	0.1
Cecropia palmata	2.58	0.6
Elaeocarpus tonganus	5.83	1.4
Fagraea berteriana	151.81	36.6
Homalium acuminatum	0.26	0.1
Metrosideros collina	160.38	38.7
Weinmannia samoensis	88.82	21.4
Angiopteris longifolia	0.77	0.2
Total	414.72	

Table 2.9 i) *Dicranopteris* dominated fernland ridge on the side of Tupapa Valley (*Zone 3*)

Taxon	Percentage of total
Melastoma dichotoma	5.0
Dicranopteris linearis	94.0
Nephrolepsis hirsutula	1.0
The rest (*Paspalum orbiculare*, *Ipomoea littoralis*, *Elephantopus mollis*)	<1.0

Table 2.10 j) Sedge dominated patch - Karekare swamp (*Zone 4*)

Taxon	Percentage of total
Commelina diffusa	22.0
Cyperus javanicus	78.0

2.3.2.1 Pollen results

As with the vegetation composition estimates, the corresponding pollen rain summaries are set out in a series of tables and a pollen diagram (Figure 2.2):

Table 2.11 Oneroa plot 1. - the seaward side of the *motu*

a) Taxon	Percentage	Numbers
Casuarina equisetifolia	88.0	177.0
Cocos nucifera	2.5	5.0
Guettarda speciosa	2.0	4.0
Podocarpus	1.0	2.0
Moraceae/Urticaceae	3.0	6.0
Pipturus argenteus sim.	0.5	1.0
Gramineae	0.5	1.0
Monolete Spores	2.5	5.0
Total		**201.0**

Table 2.12 Regeneration plot near Ariana Bungalows, Tupapa.

b) Taxon	Percentage	Numbers
Moraceae/Urticaceae	31.0	5.0
Gramineae	12.0	2.0
Monolete Spores	56.0	9.0
Total		**16.0**

Table 2.13 Oneroa Plot 2. - the landward side of the *motu*

c) Taxon	Percentage	Numbers
Casuarina equisetifolia	71.0	145.0
Cocos nucifera	18.5	38.0
Guettarda speciosa	1.5	3.0
Pisonia grandis	0.5	1.0
Argusia argentea	1.0	2.0
Moraceae/Urticaceae	0.5	1.0
Pipturus argenteus sim.	0.5	1.0
Compositae	1.5	3.0
Gramineae	3.5	7.0
Monolete Spores	1.5	3.0
Total		**204.0**

Table 2.14 *Inocarpus* dominated Forest at the top of the Avatiu Valley

d) Taxon	Percentage	Numbers
Bischofia javanica	1.0	2.0
Cocos nucifera	0.5	1.0
Elaeocarpus tonganus	2.5	5.0
Homalium acuminatum	6.5	14.0
Inocarpus edulis	76.0	168.0
Fitchia speciosa	0.5	1.0
Macropiper latifolia	4.0	9.0
Compositae	4.0	9.0
Gramineae	3.0	6.0
Tetrad	0.5	1.0
Davallia	1.0	2.0
Monolete Spores	0.5	1.0
Nephrolepis	0.5	1.0
Trilete Spores	0.5	1.0
Total		**221.0**

Table 2.15 Slope and Ridge Forest: Avatiu side of the Cross Island Track - *Homalium* and *Fitchia* dominated

e) Taxon	Percentage	Numbers
Elaeocarpus tonganus	20.5	41.0
Fagraea berteriana	0.5	1.0
Homalium acuminatum	4.0	8.0
Inocarpus edulis sim.	18.5	37.0
Weinmannia samoensis	3.0	6.0
Ixora bracteata	1.5	3.0
Macropiper latifolia	1.0	2.0
Moraceae/Urticaceae	2.0	4.0
Compositae	1.5	3.0
Gramineae	3.5	7.0
Davallia	23.0	46.0
Monolete Spores	10.0	20.0
Nephrolepis	5.0	10.0
Trilete Spores	6.0	12.0
Total		**200.0**

Table 2.16 Weed covered wasteground behind *Ara Metua*, Matavera

f) Taxon	Percentage	Numbers
Cocos nucifera	2.0	1.0
Inocarpus edulis sim.	7.5	4.0
Podocarpus	2.0	1.0
Moraceae/Urticaceae	2.0	1.0
Pipturus argenteus sim.	7.5	4.0
Compositae	4.0	2.0
Gramineae	36.5	19.0
Ipomoea batatas	29.0	15.0
Monolete Spores	4.0	2.0
Trilete Spores	6.0	3.0
Total		**52.0**

Table 2.17 *Commelina* dominated patch - Karekare swamp

g) Taxon	Percentage	Numbers
Cocos nucifera	3.0	6.0
Inocarpus edulis sim.	3.0	6.0
Moraceae/Urticaceae	1.5	3.0
Pandanus	0.5	1.0
Commelinaceae	78.5	168.0
Gramineae	1.5	3.0
Monolete Spores	8.0	17.0
Total		**204.0**

Table 2.18 Cloud Forest - ridge just above 400m on Old Te Manga Track

h) Taxon	Percentage	Numbers
Alstonia costata	0.5	1.0
Ascarina diffusa	0.5	1.0
Canthium barbatum	0.5	1.0
Casuarina equisetifolia	0.5	1.0
Elaeocarpus tonganus	0.5	1.0
Homalium acuminatum	0.5	1.0
Moraceae/Urticaceae	1.0	2.0
Gramineae	2.0	4.0
Davallia	13.5	28.0
Monolete Spores	17.0	35.0
Nephrolepis	4.0	8.0
Trilete Spores	56.0	117.0
Total		**200.0**

Table 2.19 *Dicranopteris* dominated fernland ridge on side of Tupapa Valley

i) Taxon	Percentage	Numbers
Casuarina equisetifolia	0.5	1.0
Melastoma dichotoma	0.5	1.0
Dicranopteris linearis	98.0	208.0
Monolete Spores	1.0	2.0
Total		212.0

Table 2.20 Sedge dominated patch - Karekare swamp

j) Taxon	Percentage	Numbers
Cocos nucifera	24.0	16.0
Inocarpus edulis sim.	4.5	3.0
Macropiper	1.5	1.0
Moraceae/Urticaceae	3.0	2.0
Pandanus	1.5	1.0
Compositae	4.5	3.0
Gramineae	7.5	5.0
Paspalum	1.5	1.0
Monolete Spores	34.5	23.0
Trilete Spores	9.0	6.0
Cyperaceae	7.5	5.0
Total		**66.0**

With these results, it is now possible to evaluate more precisely how the modern rain relates to its corresponding vegetation types.

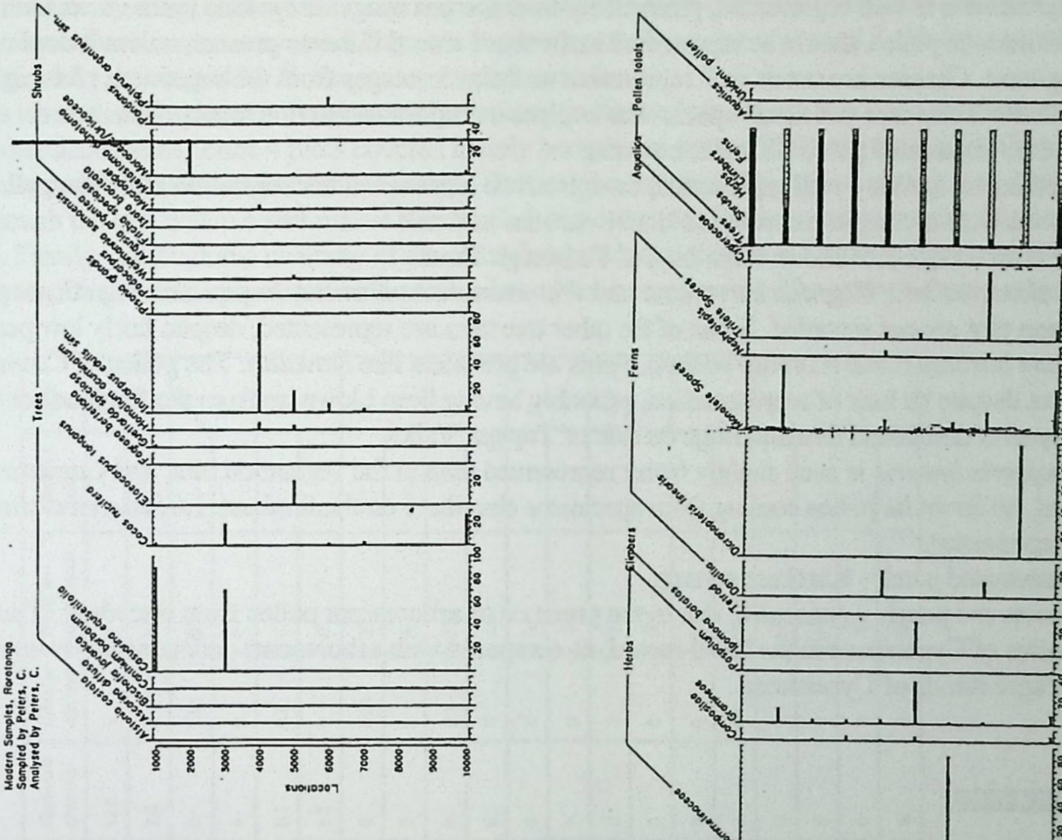

Figure 2.2 Modern Samples Pollen Diagram

see larger scale diagram on Appendices II, B.1

2.4 Comments on pollen rain/vegetation plot correlation

The various plots each highlight a different kind of bias in the modern pollen rain samples, and the comments are designed to highlight this.

a) Oneroa plot 1. - the seaward side of the *motu*
Casuarina equisetifolia is well represented, even better than its trunk space suggests. *Cocos nucifera* is slightly better represented too. However, *Guettarda speciosa* is very much under-represented and *Hernandia nymphaeifolia* is not represented at all.

b) Regeneration plot near Ariana Bungalows, Tupapa.
Hibiscus tiliaceus, despite 70.45 % of the trunk space, is not recorded at all from the pollen record. In fact, none of the trees noted on the ground are found as pollen. Weedy pollen is predominant, with grasses, ferns and the Moraceae/Urticaceae.

c) Oneroa Plot 2. - the landward side of the *motu*
Casuarina equisetifolia is well over-represented, and *Cocos nucifera* well under-represented. *Hibiscus tiliaceus* is again unrecorded. *Guettarda speciosa* and *Argusia argentea* in the vegetation plot occur in the pollen rain too. *Pisonia grandis* from outside the plot and a number of weedy taxa are found in the pollen rain.

d) *Inocarpus* dominated Forest at the top of the Avatiu Valley
Inocarpus edulis is over-represented, though it is also the largest single component of the trunk space. *Homalium acuminatum* is well under-represented, and some species simply are not represented like *Fagraea berteriana* and *Hibiscus tiliaceus*. *Fitchia speciosa* and a number of weedy taxa are represented in the pollen rain despite not being a significant component of the trunk space.

e) Slope and Ridge Forest: Avatiu side of the Cross Island Track - *Homalium* and *Fitchia* dominated
Homalium acuminatum and *Fagraea berteriana* are seriously under-represented in the pollen rain. *Elaeocarpus tonganus* and *Inocarpus edulis* are over-represented, despite *Inocarpus edulis* being unrepresented in the vegetation plot. *Canthium barbatum* is not represented at all, which is significant (see Chapter 8 and Chapter 9). Many of the

others are recorded despite their low frequencies, such as *Weinmannia samoensis*. Some weedy taxa are recorded at relatively high percentages.

f) Weed covered wasteground behind *Ara Metua*, Matavera
Ipomoea batatas is well represented, presumably from the last usage of the field before it was left fallow. This suggests that the pollen should be represented in the fossil record if it was present, unless it does not preserve well in the long-term. Grasses are not as well represented as the percentages from the vegetation plot might have suggested. The pollen of some tree and shrub species has become incorporated into the local pollen record.

g) *Commelina* dominated patch - Karekare swamp
Commelinaceae are very well represented, though a little less than in the vegetation plot. The pollen of some arborescent taxa are again recorded, no doubt via wind and rain.

h) Cloud Forest - ridge just above 400m on Old Te Manga Track
Metrosideros collina, *Fagraea berteriana* and *Weinmannia samoensis*, despite their significant presence in the vegetation plot are not recorded. Some of the other tree taxa are represented, despite fairly low percentages, like *Canthium barbatum* and *Alstonia costata*. Ferns are prevalent like *Davallia*. The pollen of *Casuarina equisetifolia* is present despite its lack of representation, probably having been blown up from the fernlands or the coast.

i) *Dicranopteris* dominated fernland ridge on side of Tupapa Valley
Dicranopteris linearis is even slightly better represented than in the vegetation plot, and *Casuarina equisetifolia* is recorded, no doubt its pollen coming from specimens elsewhere on the fernland. *Melastoma dichotoma* is a little under-represented.

j) Sedge dominated patch - Karekare swamp
Cyperaceae are poorly represented, due to the presence of arborescent pollen from elsewhere. Thus, the low frequencies of Cyperaceae in the fossil record, as compared with arborescent pollen, need not imply the swamp had only meagre stands of Cyperaceae.

2.5 <u>Conclusion</u>

A number of different types of vegetation were investigated, and their composition assessed in terms of basal area or ground cover, as appropriate. Plots were taken from all five zones indicated in section 2.1 above. It should be noted that the Zone 1 (cloud forest) and the Zone 2 plots (the slope forest and *Inocarpus*-dominated forest) were quite diverse in comparison to the other vegetation plots, and contained an overwhelming preponderance of species which occurred before European contact. The coastal forest plots (Zone 5) are not greatly affected by exotic species, though it should be remembered that the coastal forest is now very limited in extent. The investigation of Zone 4 (the cultivation and housing zone) revealed a regeneration plot, dominated by pioneer species and exotic species (albeit woody ones), and other plots of primarily herbaceous vegetation with a high proportion of exotic species.

Three of the main problems for the purpose of this thesis are to find out why these vegetation types occur in Zone 4, why they are located where they are (in the lowlands) and how far back into the past can they be traced. In addition, this raises the problem of why the coastal forest is so restricted in distribution, and is this connected with the appearance of the above more open or scrubby vegetation types. These factors may all be related to human influences. Conversely, the mainte-nance of apparent indigenous forest in the inland should be investigated. If, for example, humans were involved in the clearance of the lowlands, including the coast, why did the inland forest remain largely undisturbed (*cf.* Sykes 1983; Merlin 1985) ? One other question concerns the former extent of the inland forests and the coastal forest, and whether another (and now vanished) vegetation type once existed in between. This includes the issue of the origin of the fernlands. In this respect, it should be noted that the species found in the fernlands, including *Dicranopteris linearis*, can all be found in the inland forests (author's observation 1990 and 1992), especially where there are breaks in the canopy cover.

As for correlation with the pollen data, many problems arise with the comparison of fossil pollen with that from modern samples. Some taxonomic factors such as patterns of decay and preservation do not affect modern samples as much, whilst climatic factors affecting dispersal such as humidity and windiness may have altered. Also, the location and circumstances of the modern plots are in most of the cases very different from the fossil sites: the fossil sites are from a swamp that was once a lake.

Herbaceous plants, having been effectively excluded from measurement in the forest plots, were consistently present in the pollen results, though percentages were low (see Tables 2.21 and 2.22). Arboreal pollen occurred in herbaceous plots which reveals that species with wind-blown pollen in nearby woodland can still be represented. *Casuarina equisetifolia* and *Cocos nucifera*, particularly the former, are represented a fair distance from where they are actually present. Other trees, being subject to insect pollination, are either underrepresented or more or less correctly so, except *Elaeocarpus* *tonganus* and *Inocarpus edulis*. This may be due to their small light pollen being easily transported by wind and rain, or perhaps the flowers produce large amounts of pollen.

Zone 1 is unlikely to be well represented in any lowland pollen diagram as its main pollen types are not even well represented locally, and if any thing is likely to be represented it would be from the herbaceous taxa. In Zone 2, forest dominated by either *Homalium acuminatum* and *Fagraea berteriana* or *H. acuminatum* and *I. edulis* is most likely to be represented by pollen tables dominated by *E. tonganus*, *I. edulis* and ferns.

Zone 3 vegetation is relatively accurately represented by its local pollen sample though this does not guarantee a representation in more distant sites. Zone 4 plots covered mainly herbaceous taxa, and for the most part, the pollen results reflect this, albeit tempered by the influx of coconut pollen. The one plot dominated by arboreal taxa was dominated by herbaceous taxa, though the low pollen count makes this result dubious (eg. the local environment may have caused pollen to degrade rapidly). Finally, although the diversity of the coastal vegetation in the Zone 5 plots is obscured in the pollen results, the dominant types are well represented with some minor types being present. The overwhelming representation of

plot		*Alstonia costata*	*Ascarina diffusa*	*Bischofia javanica*	*Canthium barbatum*	*Casuarina equisetifolia*	*Cocos nucifera*	*Elaeocarpus tonganus*	*Fagraea berteriana*	*Guettarda speciosa*	*Hibiscus tiliaceus*	*Homalium acuminatum*	*Inocarpus edulis*	Zone
a	1%	0	0	0	0	77.1	0.5	0	0	12.6	0	0	0	5
	2%	0	0	0	0	88.0	2.5	0	0	2.0	0	0	0	
b	1%	0	0	0	0	0	0	0	0	0	70.4	0	0	4
	2%	0	0	0	0	0	0	0	0	0	0	0	0	
c	1%	0	0	0	0	6.3	88.3	0	0	0.1	0.2	0	0	5
	2%	0	0	0	0	71.0	18.5	0	0	1.5	0	0	0	
d	1%	0	0	0.5	0.1	0	0	0.02	2.7	0	0.02	20.7	72.7	2
	2%	0	0	1.0	0	0	0.5	2.5	0	0	0	6.5	76.0	
e	1%	0.6	0	0	3.6	0	0	4.4	19.2	0	0.9	53.3	0	2
	2%	0	0	0	0	0	0	20.5	0.5	0	0	4.0	0	
f	1%	0	0	0	0	0	0	0	0	0	0	0	0	4
	2%	0	0	0	0	0	2.0	0	0	0	0	0	0	
g	1%	0	0	0	0	0	0	0	0	0	0	0	0	4
	2%	0	0	0	0	0	3.0	0	0	0	0	0	0	
h	1%	0.1	0.8	0	0.1	0	0	1.4	36.6	0	0	0	0	1
	2%	0.5	0.5	0	0.5	0.5	0	0.5	0	0	0	0	0	
i	1%	0	0	0	0	0	0	0	0	0	0	0	0	3
	2%	0	0	0	0	0.5	0	0	0	0	0	0	0	
j	1%	0	0	0	0	0	0	0	0	0	0	0	0	4
	2%	0	0	0	0	0	24.0	0	0	0	0	0	0	

Table 2.21 Relationship between basal area (1%) and pollen rain (2%) for the main pollen types

plot		*Metrosideros collina*	*Weinmannia samoensis*	*Arguria argentea*	*Ixora bracteata*	*Melastoma dichotoma*	Commelinaceae	Cyperaceae	Gramineae	*Angiopteris longifolia*	*Dicranopteris linearis*	Zone
a	1%	0	0	0	0	0	0	0	0	0	0	5
	2%	0	0	0	0	0	0	0	0.5	0	0	
b	1%	0	0	0	0	0	0	0	0	0	0	4
	2%	0	0	0	0	0	0	0	12.0	0	0	
c	1%	0	0	2.8	0	0	0	0	0	0	0	5
	2%	0	0	1.0	0	0	0	0	3.5	0	0	
d	1%	0	0	0	0	0	0	0	0	0.2	0	2
	2%	0	0	0	0	0	0	0	3.0	0	0	
e	1%	0	3.4	0	0.6	0	0	0	0	0.1	0	2
	2%	0	3.0	0	1.5	0	0	0	3.5	0	0	
f	1%	0	0	0	0	0	0	0	88.0	0	0	4
	2%	0	0	0	0	0	0	0	36.5	0	0	
g	1%	0	0	0	0	0	78.5	0	0	0	0	4
	2%	0	0	0	0	0	99.9	0	1.5	0	0	
h	1%	38.7	21.4	0	0	0	0	0	2.0	0.2	0	1
	2%	0	0	0	0	0	0	0	0	0	0	
i	1%	0	0	0	0	5.0	0	0	0	0	94.0	3
	2%	0	0	0	0	0.5	0	0	0	0	98.0	
j	1%	0	0	0	0	0	0	78.0	0	0	0	4
	2%	0	0	0	0	0	0	7.5	7.5	0	0	

Table 2.22 Relationship between basal area (1%) and pollen rain (2%) for the main pollen types

Casuarina, even in the plot where it was physically present only as a minor component is noteworthy. If it were on the coral rubble beach ridge beside Karekare Swamp, one might expect some sort of representation for it.

Tables 2.21 and 2.22 reveal general trends of pollen presence, such as arboreal pollen occurring on patches of herbaceous growth, and the differing degree to which pollen represents its source plants, such as *Casuarina equisetifolia* always being overrepresented and *Homalium acuminatum* being consistently underrepresented. Section 2.4 amply demonstrates the potential error that can afflict crude comparisons between the fossil pollen data and the modern vegetation. Pollen percentages do not necessarily correspond exactly to percentages of species in the immediate area; in some cases, not at all. This information will be used in the interpre-tation of the fossil pollen data presented in Chapter 8 and Appendix A.4.

CHAPTER 3 CURRENT VIEWS AND RESEARCH IN POLYNESIA

This chapter presents the position attained by research into the archaeology, past environments and present environments of Polynesia, where relevant to the issues covered by this thesis.

3.1 Archaeology

Lapita is discussed to show its relevance to models of early settlement in East Polynesia, and because it covers the earlier settlement of Western Polynesia. The debate over chronology and order of settlement is presented as this thesis has a bearing on it. Issues concerned with the form, location and economy of the earliest settlements in East Polynesia, and later changes are raised with a view to later discussion on how they may relate to changing human-environment relations.

3.1.1 *The spread of Lapita*

Before 3500 BP, settlement in the Pacific Ocean was confined to large islands from the Solomon Islands westwards (Green 1991). In this region, whence the ancestors of the Polynesians were to come, there are settlement dates of about 30,000 to 50,000 years for Australia, Solomon Islands, New Guinea and the Bismarck Archipelago (Allen, Jim 1993; Kirch 1986a). Later, people with a material culture termed the Lapita Culture Complex migrated east into as yet uninhabited island groups (Golson 1971; Green 1979; Kirch 1984). `Culture complex' has been preferred to `culture' due to the temporal and geographic heterogeneity in both ceramic and non-ceramic elements (Green 1992). The Lapita Culture Complex stretched from the Bismarck Archipelago to West Polynesia, and is important in theories about the nature of early colonisation in the Pacific Islands.

Definitions of Lapita have varied from "a technological trait (i.e. dentate-stamped pottery) to a meaningful cultural unit based primarily on commonalities in its ceramic design system to a ceramic series which included both a design system, vessel shapes, and a plain ware component...to a full culture complex" (Green 1992: 11). The ceramic series is a crucial determining factor even in the last sense. Lapita material can occur without pottery (Spriggs 1991: 237-238), though non-ceramics have not gained the same level of analysis (Kirch 1988).

Lapita was a maritime society, which fished, kept certain domestic animals (pigs, dogs and domestic fowls), gardened and hunted, had distinctive artefacts such as pottery (sand-tempered, fired in an open fire, sometimes red-slipped and with dentate-stamped decoration), obsidian tools, stone adzes, bone tattooing chisels and shell fishhooks (Kirch and Hunt 1988). It must also have had an efficient voyaging technology (Irwin 1980; 1989; Irwin, Bickler and Quirke 1990). The increased distribution of the Polynesian rat is associated with Lapita colonization (Roberts 1991).

Lapita sites occur on former shore lines and in caves with 2-4 m of deposits from Vanuatu to West Polynesia, and often have evidence of extinct animals (Green 1992). They are usually shallow, but cover wide areas (at least ten are about 10,000 m^2 or more - Kirch 1987). The people lived in internally differentiated settlements up to village level, and had long distance exchange systems over vast areas (Kirch and Hunt 1988). Settlement types included caves, rockshelters, small hamlets and medium to large villages (Green 1992). Enright and Gosden (1992) suggest they had a maritime focus both in subsistence and external contacts. Island sequences like those from Lakeba (Best 1984), Tongatapu (Spennemann 1987) and northern Ha`apai (Shutler *et al.* 1994) portray this marked coastal distribution. Enright and Gosden (1992) imply that major vegetation changes, animal extinctions and erosion are associated with Lapita.

People bearing this cultural complex spread rapidly from the Bismarck Archipelago into the mid-Ocean island groups of Vanuatu, New Caledonia, Fiji, Tonga and Samoa by 3000 BP (Kirch and Hunt 1988). The Lapita Culture Complex has been equated with a significant migration of people across the Pacific Ocean (Green 1979), who were ancestors of the Polynesians and other Oceanic peoples. Any suggestion of settlement in East Polynesia in the period 3500 to 3000 BP would therefore need to consider this culture complex and how it colonized new areas. The Lapita Culture Complex gave rise to a series of regional successor pottery traditions throughout the area it occupied in addition to new areas settled after c. 3000 BP.

Various models have been proposed for Lapita colonization. The Strandlooper model, suggested by the coastal distribution of assemblages, stated that before the emergence of agricultural settlements, communities had an economy restricted largely to marine and lagoonal resources (Groube 1971). Clark and Terrell (1978) identify four main models: the Strandlooper model, the Supertramp model (*cf.* Diamond 1977), a Population Growth model and a Trader model. The Trader model (Green 1973; 1979), perhaps because trade items such as obsidian are more easily detectable, suggested that Lapita colonists were specialist traders with a highly developed maritime technology and a settlement pattern geared to long distance communication.

Irwin (1980) indicated that the models had flaws: the Population Growth model since people had expanded faster than required when population densities were low anyway; the ecological solutions to the Strandlooper model were deficient as it turned out that the Lapita economies had included agriculture; the Lapita economy's rapidity and continuity were not caused by ecological factors (Standlooper and Supertramp models) or trade (Trader model). Green (1982) investigated the variables on which the models in Clark and Terrell (1978) were based, selecting those variables from the individual models actually corresponding to archaeological evidence. He then presented a new model based on the new combination of variables, the Coloniser model, which listed the features that such a colonizing culture would have. Its distribution would be widespread, with cultural homogeneity, and would be of long duration; its rates of change would be affected by rapid dispersion, resistance to extinction or cultural replacement, and frequent interaction with neighbouring communities up to 600 km away; it would be caused by a generalised economy with both maritime and horticultural components, with effective colonisers, skilful voyagers, with rapid population growth and with an effective communication network.

Ancestral Polynesian Society is seen as having arisen out of the Eastern Lapita division comprising Fiji and West Polynesia, without needing to invoke later cultural influxes (Kirch 1984). Material evidence for a common ancestor of all Polynesian societies, like Polynesian Plain ware pottery and one-piece fishhooks, is, for example, manifested in the To`aga site, American Samoa (Kirch *et al.* 1990; 1993). In Polynesia, Polynesian Plain Ware (Green 1979) had replaced Lapita by about 2500 BP (Kirch 1984), and lasted till the early centuries AD in Western Polynesia (Irwin 1992), and the earliest archaeological levels in Eastern Polynesia (Bellwood 1987). This ware also forms part of the earliest cultural assemblage that is generally accepted as having occurred in East Polynesia, the `archaic' or `Early East Polynesian' assemblage (Walter 1990; 1993). Succeeding assemblages contain no pottery[15]. Walter (1990) has suggested that many of the variables in Green's Coloniser model (1982) are also valid for East Polynesian colonization (see below). Recently, more evidence from northern Ha`apai (Shutler *et al.* 1994) has filled in part of the gap between Tongatapu and Niuatoputapu as regards Lapita, and supports Green's idea of continual and deliberate dispersal of settlement to adjacent islands.

3.1.2 *The settlement of East Polynesia*

There has been much debate on how colonization happened. S.P. Smith (1921), using evidence of oral traditions to produce an account of `fleets' of canoes traversing the Pacific Ocean. Sharp (1963) questioned this view, and, drawing on evidence of historical `drift voyages', suggested no systematic or controlled discoveries took place. Levison *et al.* (1973) using computer simulations showed such haphazard voyaging could not have led to widespread settlement of the Pacific Islands, and experimental voyages have succeeded since (Babayan *et al.* 1987; Finney 1985; Finney *et al.* 1989; Lewis 1966; 1972). The computer simulations of Irwin, Bickler and Quirke (1990) later showed how directed voyages could have led to the settlement of the Pacific islands.

Till recently, the `orthodox view' (Irwin 1981) was that a `bottleneck' (`The Pause') in colonization, around Samoa (settled by 3000 BP[16] - Bellwood 1987; Jennings 1979), led to a consolidation in settlement before the advance into Eastern Polynesia 1000 years later. Sinoto (1968, 1970) proposed the first settled group in Eastern Polynesia was the Marquesas Islands (in 300 AD) with dates from his excavations at Hane, on Ua Huka, and Suggs'(1961) at Ha`atuatua, on Nuku Hiva. Sinoto (1970) suggested the Marquesas Islands became a secondary dispersal centre (joined later by the Society Islands) for the rest of Eastern Polynesia. Easter Island was settled first in 400 AD, the Hawaiian Islands in 750 AD and the Society Islands in 800 AD; the Cook Islands and New Zealand being settled from the Society Islands around 900-1000 AD. Secondary migrations from the Society Islands to the Hawaiian Islands and from the Marquesas Islands to New Zealand were allowed for.

Linguistics was deemed to verify this argument. Pawley (1966, 1967) and Green (1966) provided evidence that Tonga was the first part of Polynesia to be settled, and that the degree of separation was greater between Proto-Tongan (PTO) and Proto-Nuclear Polynesian (PNP) than between Proto-Samoan (PSM) and Proto-East Polynesian (PEP). A timescale was attached to the points of separation and divergence partly by calibration from archaeology (Green 1966; Clark 1979). Green (1981; 1985) later argued for a regional homeland including Fiji and West Polynesia. The idea of a Pause between Samoan settlement and the colonization of East Polynesia emerged (Pawley and Green 1973: 18-19), and was put at about 3000-2000 BP (Bellwood 1987).

Biggs (1972) suggested voyaging to the Marquesas Islands, by-passing all islands on the way, was implausible, and logically people colonize the closest islands without epic voyages. He criticised the A to B to C model of colonization too,

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15 Polynesians stopped boiling their food in bowls and emphasized earth-oven baking instead in which containers were made from natural fibres and wood (Leach, H. 1982). There is a lack of good quality clay on crossing the Andesite Line, except for Tonga and Easter Island - the line that separates islands in the Pacific Ocean with continental rocks and those with only recent volcanic and coral rocks (Claridge 1984; Leach, H. 1982).

16 Initially, there was also a proposal that there had been a long pause in migration between Tonga and Samoa Groube 1971), until the discovery of the submerged Mulifanu`a Ferry Berth site, a Lapita pottery site dating to 3000 BP (Jennings 1974; Green 1981).

ignoring possible return voyages and continued inter-island contacts: archaeologists were applying historical linguistic models of language subgroupings to archaeological sequences of different islands and island groupings far too liberally, and without examining enough of the problems (Biggs 1972; Clark 1979).

Further challenges came from archaeology: Irwin (1981) criticised the idea of the `pause', because it did not make sense given the rapid and continuous dispersal of the Lapita Culture Complex across Remote Oceania. He pointed out that a previous pause model (Groube 1971) had foundered when more information came to light. The `pause' was too inflexible a model in the context of a limited history of research: the risk of sampling error was too high.

Kirch (1986b), reviewing evidence accrued thus far, suggested settlement in Polynesia was older than usually thought. He indicated many features of the `Archaic East Polynesian Culture' of Sinoto (1970) did not occur in the earliest layer at Hane (Layer VII). The `archaic' assemblages did not closely match contemporary ones in Western Polynesia as would be expected if they were of the initial colonization phase. On the other hand, the assemblage of Layer VII at Hane included Polynesian Plain Ware, one-piece fishhooks, untanged adzes and a stone octopus-lure, which ties in with Western Polynesia to a greater extent. Pottery sherds were few and judged to be in a secondary context, which led to hopes that even earlier sites, rich in pottery, were yet to be found. Kirch (1986b) suggested that the `Archaic East Polynesian Culture' of Sinoto (1970; 1983) dated consistently to the period 700-1100 AD, including the Marquesas Islands, Society Islands, Hawaiian Islands and New Zealand, when he reviewed the dating evidence.

The radiocarbon dates from early sites, including those form the Marquesas Islands and the Hawaiian Islands, were reviewed. The possible range of the earliest dates from these sites included some much earlier dates than those usually accepted: Kirch suggested human colonization for the Marquesas Islands by the late first millennium BC, and for the Hawaiian Islands, 2-300 AD. The Society Islands were postulated to have undergone subsidence due to tectonic activity, because the Vaito`otia-Fa`ahia site on Huahine was below the water table (Kirch 1986b)[17]. The absence of sites earlier than 850 AD was due to the sites being submerged, and the absence of early dates from the Cook Islands, Austral Islands and other areas was due to lack of investigation, and masking by later sedimentation, itself a product of human activities.

Sutton too (1987; 1988) proposed that the possibility of settlement in New Zealand in the interval between 0 and 500 AD should be pursued actively. He suggested multiple colonization before *circa* 1500 BP had occurred. The proposition was later deposits could have overlaid the early sites, and palynological and geomorphological evidence could suggest earlier settlement. The evidence from Chester's study (1986) was seen as supporting this. She submitted that her pollen sequences from the Bay of Islands, New Zealand, showed human impact at around 1500-1400 BP, much earlier than previously expected, though there are problems with the dating of the Kaharoa Ash layer, which was present in the sediments and was used in the time *versus* depth calibration for the pollen core. The dates for the Kaharoa Ash were reviewed by Froggatt and Lowe (1990) who proposed a more recent date than that used by Chester (1986). Bulmer (1989) also argued earlier episodes of deforestation represented human interference with the environment.

Walter (1990) extended the range of Polynesian Plain Ware outlined by Kirch *et.al* (1988) by discovering this pottery at Anai`o, on Ma`uke, though the pottery was late in date (later in fact than its supposed loss in Tonga or Samoa). Walter thought the `archaic' assemblages represented an early phase of widespread contacts, as did Kirch (1986b), continuing from after the period of initial settlement until about the 13th to 14th centuries AD, when islands supposedly became more reliant on and protective of local resources, and long-distance contacts were no longer pursued. Only where islands were clumped together, with short distances between them, did inter-island contact continue. Walter (1990) identified the early part of the Anai`o assemblage and other early assemblages from the southern Cook Islands as fitting in with this assemblage and timescale.

Hunt and Holsen (1991) reviewed the radio-carbon sequence for the Hawaiian Islands, and suggested that humans may have been present as early as the first century AD., though there was still a potential for erroneous dates deriving from inbuilt age in charcoal samples.

However, radio-carbon sequences have been receiving strict scrutiny and criticism. In Southeast Asia, Spriggs' work undermined some of the early dates for agriculture, and brought about changes in the relationships suggested by the pattern of radiocarbon dates (Spriggs 1989). Spriggs (1990) reviewed the dating of Lapita sites, and found a broader definition of the Lapita culture allowed its beginnings to be dated from 3850-3450 BP. The spread of Lapita beyond the Bismarck Archipelago was placed at about 3200 BP and its spread to the eastern part of Lapita distribution, including West Polynesia, from about 3050-2950 BP onwards. This implied that the process of colonization had involved a series of pauses. In New Zealand, Anderson, applying Sprigg's ideas of `Chronometric Hygiene' to the dating sequence, proposed that the timescale of human settlement could be reduced from 1000 to 700 years ago (Anderson 1991: 792).

Irwin (1989, 1990) has suggested settlement was systematic and continuous, increasing in pace as it gathered momentum (Fig. 3.1). Improved technology and voyaging skills accumulated as greater experience was gained (Irwin 1989; Keegan

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17 New evidence from the `Opunohu Valley, Mo`orea, suggests a date of settlement by 650 A.D. (Lepofsky *et al.* 1992). A coconut from a partially domesticated variety of coconut tree was found preserved in valley alluvial deposits, and radio-carbon dated.

and Diamond 1987). Populations did not have to build up to a stage where excess inhabitants had to leave to find new lands: once enough surplus had accrued, people could afford to set up new colonies (Keegan and Diamond 1987). Using existing dates and the idea of systematic colonization, Irwin (1990) proposed a series of dates for the colonization of areas including undated ones. He estimated the discovery (and settlement) of Central-eastern Polynesia occurred between 3000 BP and 1500 BP; South America[18], Norfolk Island, the Kermadec Islands and New Zealand were reached by Polynesians by 1000 BP and the Chatham Islands by 500 BP. Some smaller islands with harsher conditions and further away from nearest neighbours were later deserted, because of the greater difficulties of existence. Alternatively, they may never have been settled on a permanent basis and may have only been used as an extra, possibly seasonal resource for people from elsewhere (Irwin 1991).

This debate continues with counter-challenges from Kirch, Flenley and Steadman (1991) regarding an early date in Mangaia, southern Cook Islands, and work being presently undertaken by Sutton, Flenley, Elliot and Striewski in Northland, New Zealand (Elliot 1992).

Finally, Spriggs and Anderson (1993) have employed `chronometric hygiene' in reassessing the C-14 chronology of East Polynesia. Their conclusion was there was no conclusive evidence of settlement in East Polynesia before AD 300-600, and this only in the Marquesas Islands where the evidence was still questionable. Anderson *et al.* (1994) suggest that the evidence in the Marquesas Islands that more reliable evidence favours a mid-first millennium AD date on the basis of the artefactual assemblages, the faunal evidence and stratigraphic indications of a short period of occupation. The radiocarbon chronology was not considered clear enough to settle the dating issues. Other than this, the colonization was dated to AD 600-950 in the central, northern and eastern archipelagoes, and AD 1000-1200 at most in New Zealand. The idea of a `pause' between the settlement of West Polynesia and East Polynesia was resurrected due to an apparent 1300-1600 year discrepancy between their respective settlement dates.

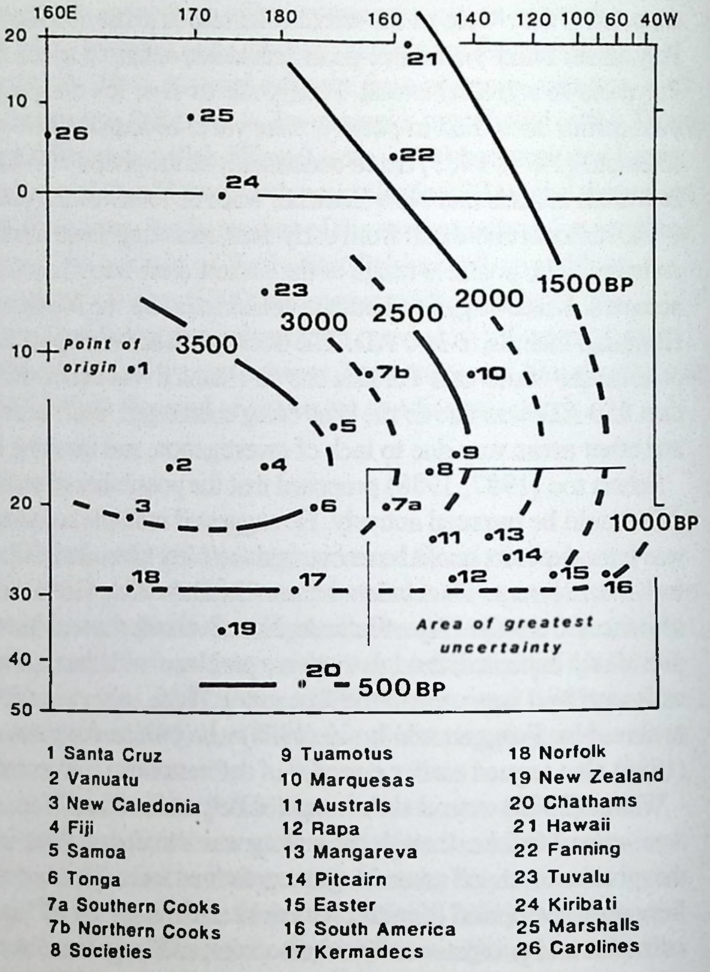

Figure 3.1 Diagram showing the chronology of settlement hypothesized by Irwin. *After Irwin (1990), fig.1. p. 91*

The earliest archaeological dates from the southern Cook Islands accepted by Spriggs and Anderson (1993) are AD 810-1170 (Allen and Steadman 1990) and AD 890-1240 (Bellwood 1978) both from Urei`a, Aitutaki. An accepted date (AD 780-1160) from Rakahanga in the northern Cook Islands taken by Chikamori (Spriggs and Anderson 1993) may be significant for the southern group because oral tradition states that Rakahanga, and its neighbouring island of Manihiki, were settled from Rarotonga (Buck 1932a).

However, Spriggs and Anderson (1993) challenge dates from lake and swamp sediments from the Cook Islands, the Society Islands and Easter Island as being contaminated. On Mangaia, the Lake Tiriara sequence was thought to be affected by leached CO^{-2}_3 from the makatea, because of the dichotomy between the later period of extinctions on such a small island and the apparently earlier period of deforestation and settlement by Polynesians. C_{14}-deficient carbonate rocks are known to be disruptive of limnic chronologies (MacDonald *et al.* 1991), though there is surprisingly little irregularity and much consistency about the swamp and lake chronologies from the southern Cook Islands (see Chapter 9) which may well meet criterion P from Spriggs and Anderson's (1993) list for acceptance of radiocarbon dates.

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18 South America was probably visited by Polynesians, hence the dispersal of the kumara across the Pacific, though they did not settle there (Irwin 1992, p.100).

Ellison (in press) has recently proposed a date of 2500 BP for the first human-induced deforestation episode on Mangaia. This was on the basis of a series of radiocarbon-dated swamp pollen sequences. Kirch and Ellison (1994), though not directly challenging the methodology of 'chronometric hygiene' (except to say that it was 'overzealously applied'- p.311), attempt to use the Mangaian data to demonstrate a case for an environmentally-constructed chronology of early colonization. This time a more cautious date of between 2450±80 and 1640±50 BP is suggested, though as pointed out in 9.3.2, this could well be an artefact of truncation. However, two other points made by Kirch and Ellison may well caution against too swift a dismissal of other aspects of the Mangaian evidence: firstly, the avifauna could have survived to the extent it did due to the impenetrability of the *makatea*; and secondly, that the consistency of the radiocarbon dates from the Mangaian cores contests the claim that they have been contaminated by calcium carbonate from the *makatea* (Spriggs and Anderson 1993: 211).

3.1.3 *Models of early settlement and economy*

The form of early settlement and economy is crucial in determining former human-environment relations. The first models of settlement form, location and economy conjectured that, because of an assumed short chronology (Buck 1944; Smith, S.P. 1898; 1921), there would have been no change since the initial settlement. Such change would have meant changes in human-environment relations too. With the onset of radiocarbon dating and the growth of archaeology, early sites seemed to be coastal, right from Lapita through to the colonization of East Polynesia (Bellwood 1979a). These early sites were found to involve a large amount of the remains of birds, bats and marine animals, including presently extinct or endangered species (Steadman 1989b).

Earlier models assumed that island sequences developed in isolation on the basis of the 'drift' voyaging ideas of Sharp (1963). Kirch (1984) advanced the view that, for example on high islands, small populations would have begun on the shoreline, dividing into senior and junior lineages till they occupied each valley section of the island, and then they would have spread up the valleys, exploiting the different resources located at separate points along that catena. This was then applied to the case of the Hawaiian Islands, where these valley sections, *ahupua'a*, had earlier and later sites located at the coast with progressively only later and later sites found further and further up the valleys (Cordy 1974; Green 1980; Kirch 1985).

Walter (1990) drawing on the evidence of the existing archaeological literature for the southern Cook Islands, showed that there seemed to be a correspondence between the early sites and reef passages too, because of the importance of marine resources and long-distance trade in the early economies. Basalt and pearlshell had been imported from at least the neighbouring islands of Rarotonga or Aitutaki. Imported pearlshell was also found at Tangata Tau rockshelter on Mangaia (Kirch *et al.* 1992). Allen and Schubel (1990) investigated a basalt quarry site on a *motu* of Aitutaki which was suggested as having some sort of involvement in such inter-island trade, though P.J. Sheppard (pers. comm. 1993) questions whether it can really be called a quarry. Recently however, Weisler *et al.* (1994) carried out XRF analysis on some suspected quarries on Mangaia, Aitutaki and Rarotonga as well as basalt adzes from a well-dated rockshelter on Mangaia. It was found that the source for the basalt adzes was a quarry on Mangaia 3 km away. The Lapita Culture Complex had also developed a network of long-distance trade in obsidian (especially from the Talasea source, New Britain), pottery and chert (Best 1987; Kirch 1988; Sheppard and Green 1991). This connects well with increasing evidence for return voyaging as a factor in the colonization of the Pacific Islands (Anderson and McFadgen 1990; Irwin 1990).

Walter (1990: 21-22) also proposed a ten point outline of Eastern Polynesian settlement, influenced by the earlier Coloniser model developed by Green (1982) for Lapita:

1) Eastern Polynesian colonization commenced soon after that of Western Polynesia as a result of the continuation of Lapita voyaging and colonization strategies.
2) Colonization followed a basic west to east orientation with the first Eastern Polynesian colonies established in the Northern or Southern Cook Islands.
3) By about 2500 BP most of the islands of central East Polynesia had been discovered and many of these settled.
4) Voyaging continued unabated, despite the decline in successful discovery voyages, until a point at which an effective communication system was in place.
5) As innovation in material culture and language appeared, they were spread throughout the communication network. There was no 'centre' (single or otherwise) within which these innovations developed.
6) Trade in raw materials also took place through the medium of the communication network.
7) This network would have incorporated distance decay factors so that islands closer together would have been in more regular contact. This resulted in the development of overlapping interaction spheres possibly marked linguistically as dialect chains or as isogloss ares. These, however, may not be marked archaeologically in a form that is amenable to study under the recent schemes of artefact trait comparisons (ie Duff 1959, Emory 1968, 1970, Bellwood 1970, Sinoto 1970).

8) At a point sometime after the 14th century the frequency of voyaging decreased, the network contracted to the point where some island became isolated and regular voyaging continued only in the most densely packed regions.
9) The decline in regular inter-island interaction would have accelerated and two major subgroups of PCE developed out of dialect areas focused on two spheres of major interaction which became increasingly isolated from one another. Smaller linguistic units such as `Tahitian' and `Cook Islands Maori', which in turn composed of several loosely defined dialects, also developed within these major subgroups through the same process of constriction. The use of imported materials would have fallen off at about the same time. This would have brought about a change in the material culture of those islands that had an increasingly limited access to specialist resources.
10) By the beginning of the 19th century, many islands were in a state of near total isolation. The individual island sequences had diverged and regionally specific adaptations in economic and political organisation were well established.

From his work in the southern Cook Islands, Walter (1990; 1991; 1993; in press) suggested that the initial pattern of nucleated coastal villages was replaced by scattered settlement over inland horticultural areas as kin-based groups began to be associated with specific land areas and it became important to be resident on the land claimed. Maritime links with other islands then waned and became less significant. This model in particular has influenced the development of the model proposed by the author in section 9.2.

Another view is once marine resources and bird stocks were reduced, greater attention was directed to agriculture, and control over land gradually became more important (Kirch 1984). A slightly different scenario has been mooted for Mangaia (Kirch *et al.* 1992). Here, it is suggested that people deforested the interior by practising swiddening, reducing the bird and bat population to refugia in the makatea, where they were then hunted out. Finally, the population turned to the swamp lands, between the other two zones, to plant taro, which became their main staple.

Initial settlement in inland valleys of the Hawaiian Islands, Tahiti, Mo`orea and Rarotonga seems not to appear until after about 1200 or even 1300 AD (Bellwood 1987; Kirch 1990). In some windward valleys of the Hawaiian Islands, there is some evidence of agricultural activity as early as 1000 AD, though large scale developments do not appear until 1400 AD (Allen, Jane 1991). The lack of early inland sites is seen as supporting the idea of coastal settlement being the first sort of settlement. This pattern is also evident from Fiji, where Lapita sites are all coastal, and the subsequent pottery sites are both coastal and inland until relatively late (Best 1984; Crosby 1988). On Tongatapu, all the early Lapita sites are in the form of coastal middens (Spennemann 1987). In Samoa, the only Lapita site found so far is coastal (Bellwood 1987).

Evidence for human presence, especially agricultural activity, is important in establishing a chronology of settlement. Another problem is whether earlier coastal settlement involved widespread clearance or did this occur later. The case of Mangaia having early inland settlement, if true, seems more an exception.

Rolett (1993) has identified four models for the colonization of the Marquesas Islands and East Polynesia in general: cultural continuity in isolation, innovation in isolation, interaction and cultural continuity and interaction and innovation. The first saw immigration from West Polynesia around 200 BC, with the Marquesas Islands and the Society Islands acting as "centres of diffusion", though thereafter the archipelagoes remained highly isolated with significant change only occurring 1000 years later (Suggs 1961). The second (Sinoto 1968; 1970; 1983) suggested that after settlement around 300 AD from West Polynesia, cultural change developed more rapidly into a cultural complex that Sinoto and McCoy (1975) have called the "Archaic East Polynesian" and Bellwood (1979b) the "Early East Polynesian". The Marquesas Islands remained in this model the main centre of dispersal in East Polynesia. The third model identified two-way voyaging and rapid exploration (Finney *et al.* 1989; Irwin 1990) as the process of colonization. Continued interaction with exchange systems and regular two-way voyaging hindered diversification (Walter 1990: 21-22). The final model (Kirch 1986) sees the East Polynesian homeland as a region (including the Society Islands and the Marquesas Islands) which was colonized as part of a continuous chain of settlement from West Polynesia. Cultural innovation occurred in this region firstly before the settlement of the more distant islands such as Hawai`i and Easter Island, and secondly after the settlement of such islands (*c.* 700-1100 AD).

3.1.4 *The Diversification of East Polynesian Culture*

Later periods (post 1400 AD) varied in social, political, economic, technological and religious relations. These later developments generally included higher populations, more internal island expansion and a growth in distinctive regional cultures. In many cases, there appears to be increased stratification in society. Divergence in material culture between East and West Polynesia is clear (Burrows 1938): some of this due to change in both areas since initial colonization of East Polynesia, and is best illustrated in the archaeology record (Bellwood 1987).

This is the period which received the first archaeological attention, because of the highly visible remains and connection with the more accessible, and interpretatively informative, immediate pre-European contact society. Emory undertook the first archaeological surveys in Polynesia: in the Hawaiian, Society and Tuamotu island groups (1928; 1933; 1934). He classified the forms of the *marae* in the Society and Tuamotu groups into types. Detailed areal excavations and settlement pattern studies to investigate the structural relationships were carried out later by Green (Green *et al.* 1967) and Descantes (1993) in the `Opunohu Valley on Mo`orea, by Green and Davidson (1974a; 1974b) and Jennings *et al.* (1980) in Western Samoa, by Kirch and Kelly in the Halawa Valley, on Moloka`i (1975), by McCoy on Easter Island (1976), by Green in the Makaha Valley, on O`ahu (1969; 1970), and Kirch *et al.* in the Anahulu Valley, on O`ahu (1992). These have assisted in the analysis and interpretation of sequences of settlement, economy and sociopolitical change on individual islands (for instance, Kirch 1985).

Kirch (1984) noted in some areas, powerful, more centralised chiefdoms arose, such as in Hawai`i and Tonga, whereas others had much less stratification and centralisation. In all areas, the society remained dominated by kin-relations, though weakening in Hawai`i as chiefs and their more immediate families sought to distance themselves genealogically from the commoners - though some of the later changes were due to European contact, and it is not clear how far these changes would have gone otherwise (Kirch 1984). These differences in societies were thought to have arisen from such factors, deduced from the archaeological record, as population increase, intensification of agriculture, environmental change (human-induced as well as natural), reduction in availability of resources and increasing warfare (Bahn and Flenley 1992; Kirch 1984).

This consolidation and internal intensification can be seen from recent studies in the Hawai`ian Islands which suggest that colonisation into the upper valleys took place from about 1200 AD with rapid expansion after 1400 AD (Allen, Jane 1991; Spear 1992; Williams, S.S. 1992). Earlier activity in these valleys may have occurred by 300 AD and colonisation by 700 AD, but S.S. Williams (1992) suggests that since a gap in data between these dates and later ones, there may be a problem of inbuilt age. Leeward areas were colonized from windward areas after 1200 AD as well (Allen, Jane 1992). In the saddle region, activities may have begun as early as 700 AD, though significant use occurred between 1300 and 1650 AD, the formalising of land tenure eventually leading to a decline in intensity of use (Streck 1992).

Kirch (1990) argued Hawaiian society reached a high degree of sociopolitical complexity by the late nineteenth century by forming larger political units, greater levels of energy extraction (by intensive productive technology), considerable functional specialisation (craft specialisation, artefact standardisation, nascent bureaucracy and warriors) and an evolved political hierarchy. Only three or four Polynesian societies could be said "in Sahlins' terms, to have pushed the limits of tribal society" (Kirch 1990: 312): Hawai`i, Tonga, the Society Islands and possibly Samoa.

Kirch (1984: 101-104, 120-122) applied an evolutionary model, based on models from population biology and evolutionary ecology, tempered by multifactorial approaches, to the processes occurring up to European contact. He proposed that populations began with relatively small founder groups, gradually dividing into different lineages, later subdividing till all the island was settled. These lineages contested resources and status, whilst populations rose, causing ecological disaster as competition led to over-exploitation of resources. This combined with warfare reduced the population (eg. tensions between dryland and wetland cultivation areas were one source of conflict - Kirch 1990), and the process began again. Demographic pressure was thus linked to inherent stresses in the formation and development of Ancestral Polynesian Society.

Bahn and Flenley (1992) have recently suggested a similar model (inspired by the Club of Rome's predictions for global environmental problems) for Easter Island, though more ecologically-based. Some archaeologists like Hommon (1986) and Stevenson (1986) argue population growth was the principal factor underlying cultural, social and economic (and resulting environmental) changes. Stevenson (1986) argued that the decline in ancestral shrines (*ahu*) on Easter Island and the related break down in community solidarity was due to high population densities and the consequent decline in availability of agricultural land.

Such views have not been generally accepted. Kirch (1984) was queried by Sutton and Molloy (1989), who felt that the application of a model based on colonizing animal populations to cultural beings was inappropriate. Algorithms developed since 1983 had suggested that differences in fertility rather than mortality (as Kirch had indicated) were more important, and that shifts in fertility were not dependent on population density. There were cultural restraints on fertility and mortality which had been ignored. Brewis *et al.* (1990) in a study based on New Zealand skeletal evidence have calculated a population growth rate of less than 1% a year, though indicating that the growth rate pattern tended to be more sigmoid than linear.

During this period, a number of islands lost their human populations altogether, so that by the time of European contact, they were empty of people. These `Mystery Islands', such as the Pitcairn, Necker, Nihoa, Raoul and Norfolk Island, have been found to contain structural and artefactual evidence and cultivated plants (Anderson 1980; Bellwood 1987; Emory 1928; Heyerdahl and Skjölsvold 1965; Specht 1984). It may be that the harshness of the environments of these islands, many being small and drought-prone, made survival unacceptably difficult (Bellwood 1987; Irwin 1991). Such islands were found to be too distant from neighbours if plotted out (Irwin 1990). Some uninhabited islands were utilised from time to time (and at some periods had been settled on a permanent basis) if they were close to a larger neighbouring island.

Examples of this are Nassau, near Pukapuka, in the northern Cook Islands (Bellwood 1987). Irwin (1992) noted that lack of accessibility is the common factor behind all the `Mystery Islands', and this could, thus, be the major factor. The reduction in voyaging after 1400 AD suggested by Walter (1990) would have thus diminished their viability as inhabitable islands.

Weisler (1994) found that Henderson Island, one of the `Mystery islands', had indications of voyaging contacts between Henderson Island, Pitcairn Island and Mangareva in the discovery of exchange items dating to before about 1400-1450 AD: imported pearlshell, volcanic oven stones, basalt adzes and flakes and volcanic glass. After this date, local items such as *Tridacna* shells for adzes and limestone cobbles for oven stones replaced the exotic materials. This lends support to the arguments of Irwin (1990) and Walter (1990) above.

The withdrawal from less accessible islands and the process of internal colonization of larger more accessible islands, being argued for, implies that the latter would have been increasingly subject to human pressure from perhaps 1000 AD, and especially after 1400 AD. Other arguments discussed suggest these human pressures derived from factors such as increasing hierarchies, intensification of agriculture and possibly population growth. These would be important considerations in any model for environmental change on Rarotonga.

3.2 Environmental Past

The debate surrounding past environments, including those before human settlement, are explored here to identify the range of potential questions and problems which will be addressed by the research presented in chapters 5 to 9.

Trends in the attitudes of European and European-inspired literature about the relationship of Pacific Islanders and their environments has often had much to do with philosophical and ideological change in Europe and those countries largely populated by people of European descent. Such trends can significantly influence the evidence that is available to researchers. Also, the history of thought in this subject presented here shows how the present debate emerged and what its basis was.

The first attitudes were influenced by the `Enlightenment' of the late eighteenth century, which included the view that humans had once lived in simple harmony and peace, and were at one with their environment. The European explorers at the time, especially Bougainville (1771), who for example named Tahiti, `*Île de Cythère*', interpreted the Pacific Islanders as having remained in this former state of innocence. The artists accompanying the expeditions of Captain Cook between 1769 and 1780 painted Pacific Island landscapes as if they resembled Classical Greek and Roman visions of divine and idyllic scenes (David *et al.* 1988; Joppien and Smith 1985a; 1985b; 1987a; 1987b; Smith, B. 1988).

The next group of Europeans to interpret human-environment relations were the missionaries who were more critical of the achievements of pre-Christian Pacific Islanders (e.g Sunderland and Buzacott 1866; Gill, W. 1856; Gill, W.W. 1876a). Missionaries frequently commented on the amount of waste land not taken up for agriculture (see 9.2), or on the destruction of resources during wars (Lovett 1899).

Merchants, whalers and beachcombers were also active in promoting visions of the Pacific Islands. For example, as early as 1864, Marsh (1864: 49) comments on the way in which Australian and New Zealand landscapes were being transformed at the time: `large tracts of virgin forest and natural meadow are rapidly passing under the control of civilized man'. Marsh feared that the sheer scale of activity might have long-term effects for the environment. These capitalist interests led to calls for colonial rule by the major imperialist powers in order to protect the financial interests of their own nationals operating in the Pacific Islands (e.g. Scott 1991 and Howe 1984). Colonial administrators attempted to improve management techniques and agricultural methods (Moss 1889; Scott 1991).

After the Second World War, accompanying the wave of independence sweeping the Pacific Ocean, there were waves of anti-colonialist sentiment (Ravuvu 1987; Ravuvu 1988; Nunn 1990b) and also anti-technological thought (Nunn 1990b). The former chastised European writings for being insensitive and imposing their cultural norms on the indigenous customs and values, and the latter revived some of the older ideas of a harmonious relationship between Pacific Islanders and their environments.

In this intellectual climate, researchers may have been inclined not to link Polynesian settlement and vegetation change. Selling's (1946-1948) palynological studies of upland bogs in the Hawaiian Islands linked environmental change there in with the climatic periodisation developed for Europe as extrapolated from Hawaiian pollen diagrams. Humans were not regarded as being responsible for the changes he saw as the Polynesian colonization of the islands was not considered to have any great time depth (Selling 1948: 127). Unfortunately, this work preceded the advent of radiocarbon dating, so no dates are available for these environmental changes.

In New Zealand, Raeside (1948) and Holloway (1954; 1964) argued that change in the form of colder, drier climates had caused matai (*Libocedrus bidwillii*) forest of South Island to be replaced by grassland in its uplands regions from about 750 years ago. Human interference was rejected on the basis that the South Island forests were unusually heterogenous and that significant climatic changes were suggested by the fact that warm-climate crops had once been grown in the South Island.

Yen (1961) suggested that a warmer climate prior to 1200 AD, such as mooted by Raeside and Holloway, could have permitted the introduction of the tropically adapted kumara to New Zealand, which was later adapted to winter storage when temperatures declined.

In the 1970's, general sequences for the Holocene in the Pacific were being worked out, which encouraged some authors to consider wider natural changes as having a greater influence on environmental change. Porter's (1975) study of the glacial chronology of Mauna Kea on Hawai`i, in the Hawaiian Islands dealt with the late Pleistocene and early Holocene periods, and successfully linked the chronology with that of mid-latitudes. Actual glaciation of the peak was considered to been short, and over by around 9000 BP. Flenley and Morley (1978) dated the end of glaciation on Mount Kinabalu, on Borneo, to a minimum of 9,186 $\pm$120 BP, suggesting that this represents a more general tropical Pacific trend. Indeed, Löffler (1972) has shown that the glacial sequence from the Highlands of New Guinea also matches the dating from mid-latitude sequences.

A renewal of cold temperatures on Mauna Kea (Porter 1975), though not extreme enough to produce snow banks, occurred within the last thousand years, because solifluction had taken place during the period that humans had quarried Mauna Kea for stone. This may be linked to a cold phase experienced elsewhere in mid to low latitudes in the latter part of the second millennium AD (Porter 1975; Roberts 1989).

Cores from the equatorial Pacific Ocean were analysed (Shackleton and Opdyke 1973) by means of Oxygen Isotope ratios and Palaeomagnetism. These revealed temperature changes over the late Pleistocene and Holocene periods, as well as periods beyond the timescale relevant here.

Based largely on Wardle's (1973) study of glacial advance and retreat and its implications for general New Zealand climate change, Leach and Leach (1979) proposed a `climatic optimum' between around 900 and 1500 AD allowed the cultivation of kumara and gourds in the Wairarapa, which was subsequently abandoned when the climate deteriorated. Burrows and Greenland (1979) show many climatic changes during the period 1100-1900 AD, though their temperature values record a maximum amplitude of $\pm$0.7 °C from 1100 to 1600 AD and $\pm$0.5 °C from 1600 to 1900 AD based on speleothems (Ibid: 363). This need not present too much of a problem for Leach and Leach's view, because speleothems are notoriously conservative (cave environments tend to be buffered against short term temperature changes outside their microenvironment - Evans 1978: 4). Green and Burrows (1979: 363) themselves warn that the speleothem temperatures are only taken at face value.

However, a view that Polynesian colonization was the major contributor to environmental change began to emerge as the dominant view during the course of the 1960's and 1970's. Cumberland (1962) thought that the deforestation of New Zealand was wrought by means of `*Brandwirtschaft*' practised by the Maori. Molloy *et al.* (1963) produced radiocarbon dating evidence from fossil wood and charcoal samples to demonstrate that the New Zealand savannahs, especially the tussock-lands of the South Island, were woodlands at the time of Polynesian settlement. On Easter Island, McCoy (1976) claimed that the landscape had `deteriorated.....following over-exploitation and misuse by man' on the basis that with a population of 7, 000 people (estimated from settlement surveys), Easter Islanders would have been forced to overexploit their resources. Flenley and King (1984) later investigated the pollen record finding evidence for the decline of woodland species, which they interpreted as the result of Polynesian clearance activities. Kirch's (1975; 1976) study of economic practices and their ecological effects in the Wallis Islands challenged the idea that indigenous Polynesian economies were based on sound conservation practices.

A key variable in the change in thought was the study of settlement patterns in archaeology (Kirch 1982). This focused attention on local environments and their relationship with human settlement. Local erosion at Makaha (Green 1969; 1970) and Halawa (Kirch and Kelly 1975), and dwindling woodland at Lapakahi (Tuggle and Griffin 1973) were interpreted as evidence of human mismanagement of the environment.

By the 1980's, the Environmental Degradation view had become orthodoxy:

> In certain academic as well as popular circles, the thesis has arisen that prehistoric Oceanic peoples avidly practised a `conservation ethic' towards their island habitats, and that major ecological changes did not occur until after the advent of Europeans. Recent evidence shows this view to be false, and one suspects that the true scale of prehistoric human impact on the Pacific Islands is not yet fully grasped.... [Kirch 1984: 123].

In New Zealand, McGlone and Topping (1977) noted forest decline from their pollen studies in the Tongariro National Park, North Island. Holloway (1954) had previously suggested that the forest fires of pre-European times were of such a scale that it was unlikely to have been the work solely of human beings. However, McGlone (1983) presented pollen diagrams from both the North and South Islands, showing a decline in forest taxa between around 800 and 500 BP, and argued that Polynesian settlers were responsible.

Grant (1985) countered these assertions with sedimentological studies. The total deposition of sediment in successive erosion periods in the last *circa* 1,000 years in New Zealand had decreased, despite the presence of humans. Grant proposed that the erosion periods, though declining in severity, were caused by increased northerly air flow and atmospheric warming, which led to an increased storminess and more floods, which in turn had caused greater deposition of sediment relative to non-erosion periods. Grant (1985) and McFadgen (1985) also linked these events to coastal sand dune sequences.

Spriggs (1981) influential study on Aneityum, in Vanuatu, proposed the idea that first settlers had gardened the hillsides, due to the swampiness of the valleys and coastal plain. This could have led to erosion which led to alluvial and colluvial progradation of the coastal plain, as well as causing it to be drier and richer in nutrients. Pollen diagrams were used as evidence that the landscape became more open from after 2890 $\pm$60 years ago due to deforestation by humans, which in turn released the topsoil (Spriggs 1986; Hope and Spriggs 1982). Some contribution to the progradation was allowed for from tectonic uplift, though this alternative has been very much down-played (Nunn 1990a).

Coastal progradation has been interpreted as caused by human activities, even if only as a contributing factor such as at To`aga on Ofu, in American Samoa (Kirch *et al.* 1990). Interference with dune systems in the Manawatu, New Zealand, has been mooted (Flenley pers. comm. 1990), though this has not been accepted by all workers (McFadgen 1985, 1989; Shepherd, M. pers. comm. 1990).

Pollen work on Easter Island showed declining values for woodland taxa during the last 1000 years (Flenley and King 1984), including the pollen of an endemic palm tree that no longer exists (Dransfield *et al.* 1984). It was suggested that over-use of resources due to increasing population, monument-building, and warfare led to deforestation. More recently, Bahn and Flenley (1992) even suggest that, bar a few relict trees on the crater rims, over-hanging the sea, every tree was cut down by the time of European contact.

Kirch developed the notion of `transported landscapes' in Polynesia, whereby humans modified new environments by introducing new organisms and landscape concepts from their original homelands (Kirch 1982; Kirch 1983). Some organisms were conveyed to new islands by accident rather than design, for example the weed *Ludwigia octivalvis* and the land mollusc, *Lamellidea pusilla*. Parts of the landscape would be converted into cultivations: for example, valley bottoms would be used for irrigated terracing, and forest would be cleared for shifting cultivation (Kirch 1982; Kirch 1983).

According to Kirch, agriculture in Oceania comprised two systems: pondfields for the cultivation of taro (*Colocasia esculenta*) and atoll taro (*Cyrtosperma chamissonis*) primarily, and swidden systems (`slash-and-burn') involving plants such as kumara (*Ipomoea batatas*), yams (*Dioscorea* spp.) and plantains/bananas (*Musa* spp.) (Kirch 1982; Kirch 1983; Yen 1973). Kirch (1982; 1983) argues that lowlands were conceived of in terms of agricultural systems, and that Polynesian settlers transformed natural lowlands into this preconceived model wherever they went.

Another theory promoted by Kirch (1982; 1984) was evolutionary theory. Populations on newly settled islands would rise exponentially until they out-stretched their resources, the population would crash, over-compensating, by means of famine and war, and thereafter, this pattern would continue, the population naturally adjusting itself according to the limits of the available resources. This process would have led to constant depletion of soils and indigenous biota.

The case of Tikopia (Kirch and Yen 1982) was an attempt to integrate ethnography, ethnobotany, archaeology and geomorphology in order to examine human-environment relations. Humans were again implicated in environmental degradation and overpopulation, with accompanying warfare, leading to exile for some of the people.

At Barbers Point on O`ahu, in the Hawaiian Islands, Christensen and Kirch analysed the terrestrial molluscan fauna from archaeological and palaeontological sites, and extrapolated from the results an impression of the type of vegetation changes that would have been concomitant with the molluscan ones (Christensen and Kirch 1981; Kirch 1984). Their view was that the fauna was suggestive of dry, open woodland and grassland before human arrival, and that this was cleared for cultivations subsequently. A later study by B. Davis (Kirch 1984: 148) confirms this. Erosional events have been detected from sites elsewhere in the Hawaiian Islands, associated with burn layers and extinct land molluscs (Kirch and Kelly 1975; Green 1970; 1980; Yen *et al.* 1972).

Southern's (1986) palynological study of swamps from Viti Levu and a lake from Taveuni, Fiji, detected a reduction in forest taxa and a rise in grasses. In one case, Bonatoa Bog (possibly two, with the less precise information from Melimeli swamp), this took place after 4380 $\pm$180 BP and before 2290 $\pm$75 BP. If sedimentation was constant, this looks like a date of around 3029 BP - consistent with the archaeological date of initial Lapita settlement (3200-3300 BP) - though the rise in grasses which starts before the other pollen changes dates to 3473 BP. However, these two sites are not in the *talasiga* or savannah of the western part of Viti Levu. Southern believed that the *talasiga* may have been partly natural, with later extension due to human intervention, much of it possibly being created as late as European contact since a very high proportion of the species contained therein are European introductions.

Chester (1986) suggested that humans were responsible for clearance in the Bay of Islands, by burning woodland in open areas for cultivation, using evidence from pollen diagrams. This was taken up by Sutton (1987) who suggested that the deforestation episodes over large areas between 0 and 500 AD., associated with a continuous charcoal record, silt influx and certain indicator species (for clearance) like bracken and various grasses, dating earlier than the present archaeo-logical record could be indicative of human presence. Bulmer (1989) also suggested that these deforestation episodes could imply earlier human settlement.

Enright and Osborne (1988) criticised these ideas on the basis that natural events could cause similar effects, and there was no archaeological evidence for earlier settlement, though they conceded that such evidence may just not have been found. The onus was on archaeologists to prove such a case. Grant (1988; 1989) challenged these views as well. He stated that natural change normally affected large areas, and that periods of burning had occurred over the last 8,000 years and earlier. Instead, he proposed that climatic change with periods of increased storminess, higher temperatures and flooding were responsible for the greater levels of erosion and alluviation.

Nunn (1991) denied that human influence was so crucial in New Zealand in the period when settlement was generally accepted to have occurred on the basis that it was an abrupt occurrence after a long period from the time of initial settlement, and that it coincided with the Little Climatic Optimum when conditions might be expected to have been drier and vegetation, therefore, more susceptible to fire. Nunn's (1991) paper, also challenging the orthodoxy of human primacy amongst agents of environmental change in the Pacific Islands, draws a comparison with a study in the northern Amazon Basin where evidence for large fires since 6260 BP was found, and the authors proposed that humans were responsible, even though evidence of human occupation only dated to 3750 BP. The conclusion had been based on assumptions about human behaviour rather than solid material evidence.

3.2.1 *Sea Level Change*

Sea level change is important not only in altering land area and coast line, but can also affect the moisture regime of islands (Enright and Gosden 1992). This presents a major natural source of environmental change in the past.

At the end of the last glaciation, glaciers melted and the resulting meltwaters affected relative sea level even at great distances from the glaciers. This is not only due to increased water volume but also to loading of the sea floor by the same meltwater, causing it to depress (e.g. Walcott 1972).

Clark *et al.* (1978) and Peltier *et al.* (1978) created a worldwide model dividing the world into regions where certain defined sequences of past relative sea level were to be expected. The model was based on the concept of the earth being a viscoelastic sphere, altered by northern hemisphere glaciers melting and ocean basins consequently filling up. Observed sea level was considered in terms of the difference between the ocean floor and the ocean surface, the latter being at constant gravitational potential. Clark and Lingle (1979) revised the model by taking the effects of the melting of the Antarctic glaciers into account.

At the height of the Last Glacial, sea level at least in the south-west Pacific was about 120 metres below the present level (Nunn 1991), and then meltwaters from the distant glaciers began to fill up the Pacific Ocean. In terms of Polynesia, the area falls within Zone V (Clark *et al.* 1978; Clark and Lingle 1979; Peltier *et al.* 1978). Islands in this area are suggested as having experienced slight mid-Holocene emergence. A peak in this emergence should have been in the order of up to 2 metres above current sea level around 5000 years ago. Nakada (1986) added the qualification that for islands with a radius larger than 10 km, the relative sea level is almost independent of the upper mantle rheology, whereas islands with a radius less than 10 km simply fall in line with the global isostatic adjustment. This latter group includes the Cook Islands.

Support for this model of mid-Holocene emergence proposed for Zone V comes from a number of studies, though there is some suggestion that it could have been a little later in date than predicted. On Enewetak, in the Marshall Islands, Buddemeier *et al.* (1975) record the highest sea level as being over 1 metre between 3 and 2000 BP. Schofield (1977) suggests higher than present sea levels attained during the last 4000 years, with a high stand at 2760 BP reaching +2.4 m. From Fiji, Nunn (1990a) has dated the Holocene sea level maximum, which he put at 1-2 metres above present, to between 3 and 2000 BP. Nunn (1991) has data from Western Samoa placing this episode at about 1000 BP with the high stand being at about 1 metre. In the Tuamotu Islands, Pirazzoli and Montaggioni (1988) dated the sea level maximum (0.8 m above present) to between 5500 and 1,200 BP. For French Polynesia in general, the same authors dated the sea level maximum (around 1 metre above present) to between 2000 and 1,500 BP. Problems were encountered with atolls because the sea level maximum probably transgressed their highest points, thus leaving no physical legacy. The mid-Holocene high stand is placed at 0.8 m about 3450 BP on Mopelia, in the Society Islands (Guilcher *et al.* 1969). Stoddart *et al.* (1985) place this high stand at 1.8 m, 3410 years ago on Mangaia, which has been revised to 1.7 m between 4000 and 3400 BP by Yonekura *et al.* (1988).

Yonekura *et al.* (1988) have suggested on the basis of the results of dating that the timing of the hypothesised mid-Holocene high stand was a little later than estimated by Clark *et al.* (1978) and Clark and Lingle (1979). Schofield (1970) claims dates for the Aroa Sands of between 3500 and 1200 BP, but these have been disputed by Yonekura *et al.* (1988), as most of the corals dated were not in growth position and thus likely to be secondary in character. Yonekura *et al.*

(1988) also suggest that no convincing evidence exists for a higher sea level on Rarotonga or Aitutaki. However, Schofield (1970) does have some evidence in a primary context on Rarotonga: a raised fossil coral outcrop at Avarua, 1 metre a.s.l. dated to 2,030 ±60 BP, though recrystallisation may mean the date should be placed earlier.

Tectonic movements can complicate sea level data by means of uplift or subsidence. In the south Pacific Ocean, tectonism is particularly important along the plate boundaries by the following island arcs: Solomon Islands-Vanuatu and Tonga- Kermadec-New Zealand (Nunn 1991). In the eastern Pacific Ocean away from the plate margins, tectonism has not been as significant factor, being controlled by `hotspot' effects (see Introduction 1.4.1) and subsidence is generally more common. Over the kind of timescale in question, however, these effects are not too much of a complicating problem.

Green argued that models of a higher sea-level stand during the Holocene could be significant for archaeology (Green and Richards 1975; Green 1979). Lapita sites were found in situations from which the sea had recently withdrawn, such as marine terraces and raised coral platforms. Though the general trend was eustatic fluctuation, a few situations could be explained in terms of tectonism (Green 1979).

Kirch and Hunt (1988) proposed a model of tectonic change with islands to the west of the Andesite Line experiencing uplift whilst those to the east underwent subsidence, such as Huahine, where a water-logged site was investigated by Sinoto (Sinoto and McCoy 1975). This helped to explain the lack of Lapita sites to the east of the Line that have come to light compared to the west.

Clark (1989) points out that frequently archaeologists have attributed the visible effects of the mid-Holocene highstand in sea level to local tectonism. Clark lists the mounting evidence from Southeast Asia to central Polynesia for this late drop in sea-level, and argues that a hypothesis suggesting regional uplift is severely weakened by such widespread concurrence. Also islands unaffected by tectonism still show signs of a higher sea level. The only island east of the Andesite Line to have possible evidence of subduction is `Upolu, so that only rare local effects can confound the situation, such as at Huahine. Even in Fiji, where there has been tectonic activity in more recent Holocene times, once the tectonism is allowed for and compared with stable areas of Fiji, a mid-Holocene highstand is still apparent (Nunn 1990a).

3.2.2 *Extinctions*

The mechanisms and timing of extinction are important in assigning cause. The research into extinction is critically reviewed, and alternative explanations proposed.

In New Zealand, the fact of the extinction of a number of creatures had long been recognised both in the Maori oral tradition and in the Pakeha writings of the 19th century (Davidson 1984: 5). Indeed, much skeletal evidence came to light of a spectacular sort: bones of large ratites, the moa, attracted a great deal of attention, some of it scholarly. The size of these birds no doubt meant that an awareness of the extinctions issue in the archaeological debate came well in advance of anywhere else in Polynesia. Duff's periodisation of New Zealand archaeology included a `Moa-hunter Period' (1956).

The size of the moa ranged from that of a bushturkey to a little over 3 metres tall (Anderson 1989b; Cassels 1984). Climatic change and human induced factors such as deforestation and hunting have been suggested as causes of extinction (Anderson 1989a; 1989b; Davidson 1984; Millener 1981). Eleven species of moa and 21 other bird species have been ascribed to pre-European human induced extinction, whereas 9 species are known to have become extinct since European arrival (Gill and Martinson 1991). Not only birds, but other animals were found to have been affected (Davidson 1984). Exploitation even affected shellfish in some areas (Anderson 1981).

Kirch and Yen (1982) noted the presence of an extinct megapode, declining numbers of turtle, fish and shellfish, and the eradication of certain large types of shellfish from archaeological deposits on Tikopia, a Polynesian Outlier.

Olson and James (1982) collated evidence that twice as many endemic species existed in the Hawaiian Islands as is recorded in the historic literature when fossil birds are taken into consideration. Three percent of nonpasserine birds survived into the historic period, 62% of passerines, and only one raptorial bird out of six originally existing. The finding of some of the extinct species' remains on archaeological sites confirms the contemporaneity of Polynesian settlement and these extinct birds and the fact that the birds were hunted (Olson and James 1984; Olson and James 1982). This does not, however, necessarily imply extinction before European contact. One must again remember the limited nature of the documentation for the first century, and especially the first decades, of European contact.

Kirch (1982) proposes that clearance of lowland forest and hunting would have been the major causes of faunal extinctions in the Hawaiian Islands. Christensen and Kirch's (1981) work on the terrestrial mollusc fauna from Barber's Point, O`ahu, indicated that there had formerly been open-canopy dry-forest and grassland. Some species cease to appear (extinction?) and exotic introductions, including those introduced during the period of European contact, materialise all in the top layer. It is difficult to establish from this what occurred prior to European contact and what thereafter. One interpretation from Christensen and Kirch (1981) might be that grasslands were already an important component of the lowland vegetation before human arrival, and thus, the intensity of cultivation rather than clearance should be the crucial factor in the elimination of endemic species of molluscs.

Steadman and Olson (1985) analysed bird bones from an archaeological site on Henderson Island in the Pitcairn group. Twelve species of bird were identified, 3 of which do not occur on Henderson island today, and 2 of which visit but do not breed there today. They argued that modern distribution patterns can give rise to erroneous views of the relationships and evolutionary history of organisms, and that the distributions of many species and genera today are not necessarily their full natural distribution. Diversity of many islands would have been much greater than at present. A second study (Schubel and Steadman 1989) with a larger sample of bones revealed the former presence of a *Gallicolumba* species, the most easterly representative of the genus so far discovered.

However, they assume that midden deposits (Sinoto 1983) faithfully represent the surrounding fauna, because the island appears to be so distant from others. An alternative explanation is that Henderson Island was visited by humans on a temporary basis[19] (rather than permanently settled), and these bird remains represent the consumption of remaining supplies from the inward journey, before the collection of new supplies for the outward journey. The archaeological sites (*cf.* Schubel and Steadman 1989; Sinoto 1983) could represent a series of temporary occupations. In such a case, the bird bones could represent birds from other islands. Voyaging experiments using traditional technology show that large distances on the map are relatively short in terms of voyaging time (Babayan *et al.* 1987; Finney *et al.* 1989; Lewis 1966).

Diamond and Case (1986) reviewing animal extinctions, especially on islands, re-iterated the view that human expansion has been responsible for the disappearance of many species during the course of the Holocene, and much of it before European expansion. This was taken up in more depth by Keegan and Diamond (1987), and analysed in terms of biogeographical theory.

Steadman's (1986) investigation of caves from Mangaia, in the southern Cook Islands, produced the bones of two extinct species of rail, which he suggests were made extinct by Polynesian settlers. As he points out, rails need little area, elevation or habitat diversity to survive. By comparison with the case histories of Laysan and Wake islands, they are vulnerable to human presence. In the absence of documentation from the period of European contact, it is not possible to confirm his suggestion that pre-European contact Polynesians were responsible for the demise of these rails.

This was expanded upon by Kirch *et al.* (1991; 1992), who advanced the idea that Mangaia's central volcanic interior was once forested, and that through swiddening activities, this was reduced in a matter of centuries to fernland. The indigenous and endemic fauna persisted in refugia in the makatea, until finally hunted out there. Steadman's analyses (Kirch *et al.* 1991; Kirch *et al.* 1992; Steadman and Kirch 1990) demonstrate the former presence of a number of sea and land birds and that they were hunted (because they were found in archaeological deposits). Their replacement by domesticated animals as the major animal food, however, might be interpreted as economic change rather than as total extinction as proposed in Steadman and Kirch (1990) and Kirch *et al.* (1991; 1992).

Olson (1986) analysed the information from the manuscript of Andrew Bloxham, who visited Ma`uke briefly in 1825 aboard HMS *Blonde*, and made a few notes on the biota. A "mysterious starling" collected by him still exists in the British Museum, and is a valid species, now extinct. A fruit dove, *Ptilinopus rarotongensis* cf. *goodwini* mentioned is probably extinct, and a petrel and a hawk are also mentioned, but are less probable.

Hawks may well have been more widely distributed. At the present time, they are restricted to West Polynesia (Watling 1982), though in the past, they were also found in the Hawaiian Islands before the advent of humans (Olson and James 1982). If identified by Bloxham correctly, Norway rats were already on Ma`uke in 1825 and this may have accelerated avian decline. Olson (1986) suggests that other birds would once have been present on the basis of comparisons with other islands, but had been destroyed by Polynesians prior to European contact. He further suggested that the remaining extinctions were just part of the continuum. One might wonder whether such extinctions would not have been assigned to the pre-European past if HMS *Blonde* had not passed by, and bones of these birds were found in archaeological deposits[20].

More evidence of avian extinction comes from the Marquesas Islands in the form of 2 species of parrot and 1 species of rail (Steadman 1987; Steadman and Zarriello 1987). These were found on pre-European archaeological sites.

Postulating that the distribution of many bird genera was once more extensive than today, Steadman (1989a) illustrated his view by describing a new species of starling (*Aplonis*) from Huahine, mentioning that another species from Ra`iatea was painted by Georg Forster in 1774 on Captain Cook's second voyage and yet another once existed on Ma`uke (Olson 1986), and by pointing out that an extant species still exists on Rarotonga.

Steadman (1989b) reviewed all the existing information on extinction in East Polynesia, noting that the worst affected seabirds were petrels and shearwaters, which nest colonially in burrows on the ground, and the worst affected landbirds were rails and ground doves, because many were flightless species confined to single islands. By comparing East

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19 Pitcairn Islanders frequently visit Henderson today, and set up temporary camps (Schubel and Steadman 1989: 3).

20 Even today, researchers have problems establishing whether a species is extinct or not: for example, the *Kakerori* was only rediscovered in recent times after decades of being unobserved (McCormack and Künzle 1990), and it is a matter of dispute whether the Barred-winged Rail and the Grass Owl are extinct on Fiji (Watling 1982).

Polynesia to the Galapagos Islands, which have experienced fewer extinctions of their avian populations (often extinctions have been only of a more local nature rather than total), Steadman (1989b) made a number of observations:

1) There had been a shorter period of human occupation of the Galapagos Islands.
2) The human population was smaller because of the unsuitable conditions.
3) Galapagos Islands birds were never a major source of food for humans.
4) For the last 3 decades there has been legal protection for the birds.
5) Introduced birds are absent on most islands.
6) Introduced mammals and plants are scarce or absent on many islands.

In fact, most extinctions on the Galapagos islands had been where human disturbance has been greatest.

Steadman's work at the Urei`a site on Aitutaki produced 19 bones (Allen and Steadman 1990), all but one of which were of the rail *Porzana tabuensis*, the remaining one being of an undescribed whistling duck (*cf. Dendrocygna*). He suggests that this is because the site does not represent the earliest period of human settlement and that the fauna has already been depauperated by human impact. Moturakau lagoon islet, on Aitutaki, has also produced a bone of the above rail (Allen and Schubel 1990). However, he mentions that 3 more land birds exist today and 2 others were extant until the 1940's or 1950's. None of these were in the archaeological deposits[21].

The demise of the pigeons and doves on Aitutaki, Steadman attributes to the construction of an airport during the Second World War, which replaced a large tract of forest (Allen and Steadman 1990). He implies that the birds in the archaeological deposits, in addition to putative birds driven to extinction, were lost due to habitat removal and predation from humans, dogs, pigs and rats.

Steadman (1991) reviewed the work on Aitutaki together with new material from Atiu. Of 15 birds represented in the fossil record from Aitutaki, 5 no longer exist today: these were a petrel, a booby, an extinct whistling duck, a rail and a lorikeet; of 6 birds represented in the fossil record from Atiu, 3 no longer exist: a ground dove, a pigeon and a lorikeet. Human overkill was once more implied.

Steadman and Pahlavan (1992) analysed the bird remains from a site on Huahine, in the Society islands, excavated by Sinoto and McCoy (Sinoto and McCoy 1975) which included both land and sea birds, some of which no longer occur on Huahine. This extended the known range of birds like *Gallirallus*, *Gallicolumba* and *Macropygia*. In addition, they noted that blood-borne protozoan infections were rare in the indigenous avifauna of the Cook Islands and were likely to be so in the Society Islands too. Isolation had protected them from such infection.

Steadman (1993) analysed bird bones from the To`aga site (As-13-1) on Ofu, in the Manu`a Islands of American Samoa. Five of the ten seabirds identified from the site were no longer present on Ofu, and one of the three landbirds. In addition, at least two of the species are now endangered. Steadman suggests that a chiefly tabu on megapodes in Tonga indicates a knowledge that overexploitation would lead to extinction, or alternatively, that they were a prestigious trade item. The awareness that overexploitation might eliminate the resource is claimed to be through past experience. The only appearance of *Megapodius* from To`aga is in the deepest cultural stratum, and so extirpation is alleged for the initial human colonization of the island; all from two fragmentary pieces of bone in a cultural deposit.

Such evidence for the extinction of *Megapodius* on Ofu could be produced through a luxury trade in the birds from elsewhere. This is ethnographically attested for elsewhere in the West Polynesia/Fiji area (Steadman 1993: 223). The fact that *Gallicolumba stairii*, a ground dove, still survives, albeit in a small threatened population, might suggest that shy ground dwelling birds were not automatic candidates for overexploitation and extinction. The fact that the present day population exists at all implies the bird survived over three and a half millennia of human occupation, but does not imply that it has always been endangered: that could easily be due to more recent conditions.

Finally, Steadman *et al.* (1994: 92) have found that nonchicken (native) bird bones from Ahu Naunau, Easter Island, were consistently fourth in rank among vertebrate categories through time, unlike in other East Polynesian sites investigated till now. This may have been due to the short time interval represented, though it is implied that the bird extinctions were a relatively gradual process on Easter Island. Unfortunately, except for a *Porzana* rail, none of the landbirds could be identified beyond the family level.

Alternatively, the fact that later assemblages have fewer native birds and there is relatively little change in this earlier assemblage through time, might support the idea expressed in the model proposed in section 9.2 that fresh extinctions occur when environmental thresholds were crossed (like large scale expansion into the interior of islands). It may be that other assemblages with either less time control or more compressed sequences mask such subtleties.

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21 Archaeological sites are by their nature artefacts. One might note that extant birds are not represented when they clearly must have existed there at the time. Other, now extinct, birds may have been present too. This could be the result of human selection in the past or of choice of where to excavate.

3.2.3 *Pre-human plant dispersal*

Arguments over the pre-human distribution of organisms, with the present scarcity of fossil data, concentrate around innate dispersability and modern distributions. This is important in the argument about what species could have been transported by natural means and what by humans, either deliberately in the case of cultigens or inadvertently in the case of ruderal weeds. It is also necessary to consider how plant communities functioned before human arrival and how humans may have disrupted the natural dynamics of island plant communities by their presence.

Carlquist (1967) investigated the dispersal of the flora of the Pacific Islands by noting the known dispersal methods of individual plants. The ecology of an island was found to be more important than distance in predicting whether a plant could establish itself there or not. Internal transport in birds was the most important vector for establishment on high islands, and oceanic drift for atolls. Other methods were rafting (infrequent drift), air flotation, barbs and bristles adhering to birds feathers, viscid fruits and seeds attaching to birds feathers, and seeds trapped in mud on birds feet. To Rarotonga, the two most important factors were: frequent drift (35.5%) and internal transport by birds (31.8%). Avian transport of one form or another accounted for 52.3% of the dispersal processes on the same island.

A study of plant propagules found on beaches on Viti Levu, Fiji (Smith, J.M.B. 1990) found that 73% were shore species, though there were other species, including those of freshwater habitats. The most abundant species was *Cocos nucifera*, including frequent examples of sprouting nuts. Amongst the other species were *Hibiscus tiliaceus*, *Inocarpus edulis*, *Pandanus tectorius* and *Terminalia catappa*. Coconuts, in particular, have attracted academic attention (Maloney 1993) as regards their dispersion both naturally and as a cultigen (possibly from 3000 or more years ago in India, though the evidence from Thailand suggests a very late domestication).

Van Balgooy (1971) investigated the methods of plant dispersal in the Pacific Ocean, and found that:

1) Wind was not an important dispersant, and transport is usually not far from source areas
2) Genera with diaspores suitable for water transport were generally well represented throughout the Pacific Ocean, especially on low isolated islands
3) On most islands, the best represented group were those species brought by internal bat or bird transport
4) Those genera which can attach themselves to animals externally were not so common, though they were better represented on high islands
5) Those brought by several different means are few in number, and increase proportional with distance for source regions
6) Genera with small non-specialised diaspores are frequent and increase with relative isolation and height of island
7) Genera with large heavy diaspores are also numerous, but decrease gradually east of the Andesite Line.

With regard to the Rarotonga, Van Balgooy (1971) considered it to be floristically allied more with the Society Islands than Tonga. It is not as diverse as the Society Islands or Tonga, Niue and Samoa, and the percentage of genera with world-wide and trans-Pacific distributions is greater than these neighbouring groups. This is presumably due to its increased distance from source locations - as compared to Tonga, Niue and Samoa - and the small, scattered nature of the Cook Islands - as compared to the Society Islands. This might suggest that some caution is necessary when comparing the diversity of Rarotonga today with models of diversity based on evidence from neighbouring island groups.

3.3 Environmental Present

Some ideas of how humans may have affected the biota of islands in the past can be gained through modern studies. A number of theoretical approaches have been taken, as well as studies of individual factors.

MacArthur and Wilson (1963; 1967) developed the equilibrium theory of island biogeography. The equilibrium is between immigration and extinction rates. The rate of immigration is inversely proportional to isolation from a colonizing source, whilst the rate of extinction is directly proportional to isolation and inversely proportional to population size. Simberloff (1974) demonstrated that this equilibrium, which is dynamic due to frequent extinction and immigration, is a multi-levelled process, involving evolution at a higher level and ecological change at a lower level. This has been challenged as being oversimplistic, overemphasising the species-area relationship, at the expense of factors such as habitat diversity, threats from introduced predators and minimum population requirements (e.g Reed 1985). Diamond (1969) points out that small islands with high habitat diversity can harbour as many species as large islands with poor diversity.

Diamond (1984b) shows that the dispersal ability of species, particularly in crossing water, significantly alters their chances of survival. Island area and population density are also vital factors. Habitat requirements can involve a relationship with another species that may itself be threatened (Diamond 1984b; Diamond *et al.* 1987). Indeed, the degree of endemism tends to increase the area requirement of species and their dependence on indigenous forest (East and Williams 1984). Lack of former habitat diversity seemed to be the main factor involved in extinctions studied on Barro Colorado Island (an island created in recent times through raised water levels) by Karr (1982).

Dispersal ability decreases as one approaches the equator (Diamond 1985), the reason being the more frequent occurrence of stable habitats. If habitats are stable, with no decrease in areas of suitable habitat and no increase in areas becoming suitable, like for example large tracts of rainforest, then there is no advantage in dispersing and there may even be a risk in doing so. In this case, species become sedentary.

Intrinsic rate of increase and generation lifetime of individual species are important factors controlling populations (Diamond 1984a). Individual species also have their own particular requirements regarding area and range of habitat (Diamond *et al.* 1987).

Islands may not always be characterised by a marked turnover of species, such as proposed by MacArthur and Wilson (1967), if they are not modified frequently, and especially if propagules from other islands are scarce and limited in range (Williams, G.R. 1981). In such cases, habitats and niches may remain unfilled. For example, introduced harriers on Tahiti have successfully filled the otherwise unoccupied niche of large carnivorous landbird (Bruner 1972).

However, studies by Zimmerman and Bierregaard (1986) on frogs in the Amazon rainforest indicate that far from the static situation that is being proposed as appropriate for island reserves, islands or isolated habitats are characterised by rapid turnover due to a high degree of speciation and the occasional arrival of exotic species. In other words, islands are dynamic places.

Decreasing land area due to rising sea levels can lead to a lowering of species diversity (Diamond 1984a). This response to diminishing area, and sometimes habitat diversity at the same time, may be delayed so that an island may carry more species than the island can sustain in the long term. Other changes brought about by climatic change may also divide up populations and restrict their range, as for example, vegetation communities may shift up and down mountains as the climate warms or cools (Brown 1971; Patterson 1984). This, of course, does not account for the majority of Holocene extinctions, but it can be a contributing factor. Watling (1982) points out that oceanic islands are characteristically low in diversity compared to continents, though endemism is generally high.

The fragmentation of once continuous tracts of forest can be even more threatening to species diversity than the simple reduction of such forest (Diamond 1972; Diamond *et al.* 1987). Significantly large areas of uninhabitable territory prevent organisms forming large enough populations, obtaining sufficient nutrients and recolonizing unpopulated areas. Once an area undergoes fragmentation, although it may initially contain a high diversity of species after a given `relaxation time' it will decline to a level more appropriate to its size and ecological variety (Diamond 1975; 1976).

Diamond (1975; 1976) has listed a series of design principles in the construction of preserves in order to maintain the greatest possible degree of diversity:

1) Larger preserves are better than small ones
2) The least division of the preserve the better
3) If unavoidable, then these fragments should be as close as possible to each other
4) Also these fragments should be arranged equidistant to one another and not linearly
5) The effectiveness of these fragments may be significantly improved by connecting them with narrow strips of protected habitat
6) Ideally, preserves should be as nearly circular in shape as possible in order to minimise dispersal distances within the preserve

It is interesting to note that this last principle covers most high islands in the tropical southeast Pacific Ocean as they were in their natural state. Colonization of radial valleys would instantly partition the circle, though connections would still persist through the central pinnacles. For some species this might mean traversing a hostile climatic or vegetation zone, with the result that for such a species the partition would be very effective.

As far as plants are concerned, the genetic barriers are not as severe as for animals because of the possibilities of hybridisation (Koopowitz and Kaye 1990). What is more crucial is the absence or presence of pollinators in the case of zoophilous cross-pollinators, threats from grazing animals and the alteration of plant communities, such as in the case of exotic invaders and deforestation (Koopowitz and Kaye 1990). Such alteration of plant communities can occur through natural environmental change or human agency.

King (1985) identifies special problems for islands since 93 % of the world's land and freshwater bird species and subspecies that have become extinct since 1600 have occurred on islands. The major cause, he proposes, was the introduction of alien predators, including diseases. The restricted amount of space on islands is the main reason for the vulnerability of insular ecologies.

Atkinson's (1985) study of the effects of commensal species of rats on the avifauna investigates the differential effects of the three rat species: *Rattus exulans* (Polynesian rat), *R. rattus* (ship or black rat) and *R. norvegicus* (Norway or brown rat). The first is the smallest species and preys on fewer species than the others, though it can prey on larger birds than the others. The second is the largest species tends to prey on ground-nesting birds. Finally, the third species is a dangerous predator to tree-nesting birds and is the best climber of the three. For example, recent research indicates the crucial role of *R. rattus* in threatening the ultimate extinction of the *kakerori* on Rarotonga at the present time (McCormack and Künzle 1990), though most of its decline predates the introduction of *R. rattus* and is attributable to the introduction of cats and fire-arms (Atkinson 1985; Gill, W.W. 1885).

However, it is noteworthy that in the tropical and subtropical zones the introduction of rats has had much less effect, because of the presence of land crabs (Atkinson 1985), especially *Birgus latro*, the robber or coconut crab (Burggren and McMahon 1988). Previous selective forces have thus immunised the avian populations to some extent against the predation of rats, though perhaps less so against *R. rattus*, which is a very agile climber.

Nunn (1991) points out that studies of feral pig populations show their destructive capabilities: for example, reducing the understorey of a beech forest from 80-100% to 2-15%. Rats, although they do not affect plant communities very much directly, can bring about ecological disequilibrium through predation of other animals.

Introduced birds are sometimes accused of harming indigenous species. This is, however, not thought to be a major contributor to elimination of species. McCormack and Künzle (1990) dismiss the idea that the introduced mynah bird or the long-tailed cuckoo might pose a threat to the endangered *kakerori* on the basis of studies done so far. Watling (1982) observes for Fiji, Tonga and Samoa that it is not threats from exotic species, but rather the inability of indigenous species to colonize habitats modified by humans that is at the root of the problem.

The above research is necessary when considering the various contributing factors to the alteration of the natural environment when human presence took place. This research is helpful when posing questions needed to be asked of the data presented in this thesis, such as: what the amount of area altered was? which areas were involved? were all habitats or microenvironments still represented? what the shape of the remaining undisturbed habitat was? to what degree the habitat was altered? were all remaining natural habitats still connected to each other? were any harmful exotic organisms released into the environment and what was their effect?

3.4 Résumé

Firstly, the questions dealt with in archaeology were the date, nature and economy of first settlement of different Polynesian islands and island groups, and then the nature and economy of settlement in later periods. Secondly, past environments in Polynesia have raised a number of issues, including those of sea-level change, extinctions of various organisms and the nature of the past flora seen from the point of view of natural dispersal mechanisms. Thirdly, questions and research, especially from biogeography, prompted by present day environments were outlined in order to understand the dynamics of natural communities and how they might be affected by, in particular, by human interference. In the next chapter, attention is focused on the southern Cook Islands, principally Rarotonga.

CHAPTER 4 PREVIOUS RESEARCH IN THE SOUTHERN COOK ISLANDS, IN PARTICULAR RAROTONGA

Selected research concerning the southern Cook Islands, principally Rarotonga, is presented here to show how the issues discussed in the previous chapter refer specifically to this smaller study area: that is those relating to the archaeology, environmental past and environmental present. Also more local questions and problems are raised.

4.1 Archaeology

Investigation in to the physical remains of the past in the Cook Islands began in a limited way with Buck (Te Rangi Hiroa), who noted the presence of up-standing monuments and a few details about them, though he did not carry out formal surveys and excavations. He did, however, describe numerous portable artefacts from the past, no longer in use (1927; 1932a; 1932b; 1934; 1944). Serious site surveys did not begin until 1962, when the Canterbury Museum team led by Duff started the first in a series of archaeological expeditions to the Cook Islands (see Figure 4.1). Canterbury Museum expeditions to Rarotonga took place during the summer of 1962-1963 (Duff 1965; Trotter 1974) and latter part of 1964 (Duff 1965; Duff 1968; Trotter 1974), and a Royal Society of New Zealand team led by Trotter and Duff undertook an expedition to Atiu in 1969 to commemorate the bicentenary of the visit of Captain Cook to New Zealand (Duff 1971; Trotter 1974: 87-119). On the 1964 expedition, Aitutaki was visited and monuments there were described though not formally surveyed (Duff 1968).

At the time of Buck's investigations it was thought that subsurface archaeology would not be a useful investigative tool as the time depth would be too short. Buck calculated the period of settlement as beginning in the 12th-13th centuries on the basis of generations from the genealogies (Buck 1944). The introduction of radiocarbon dating into

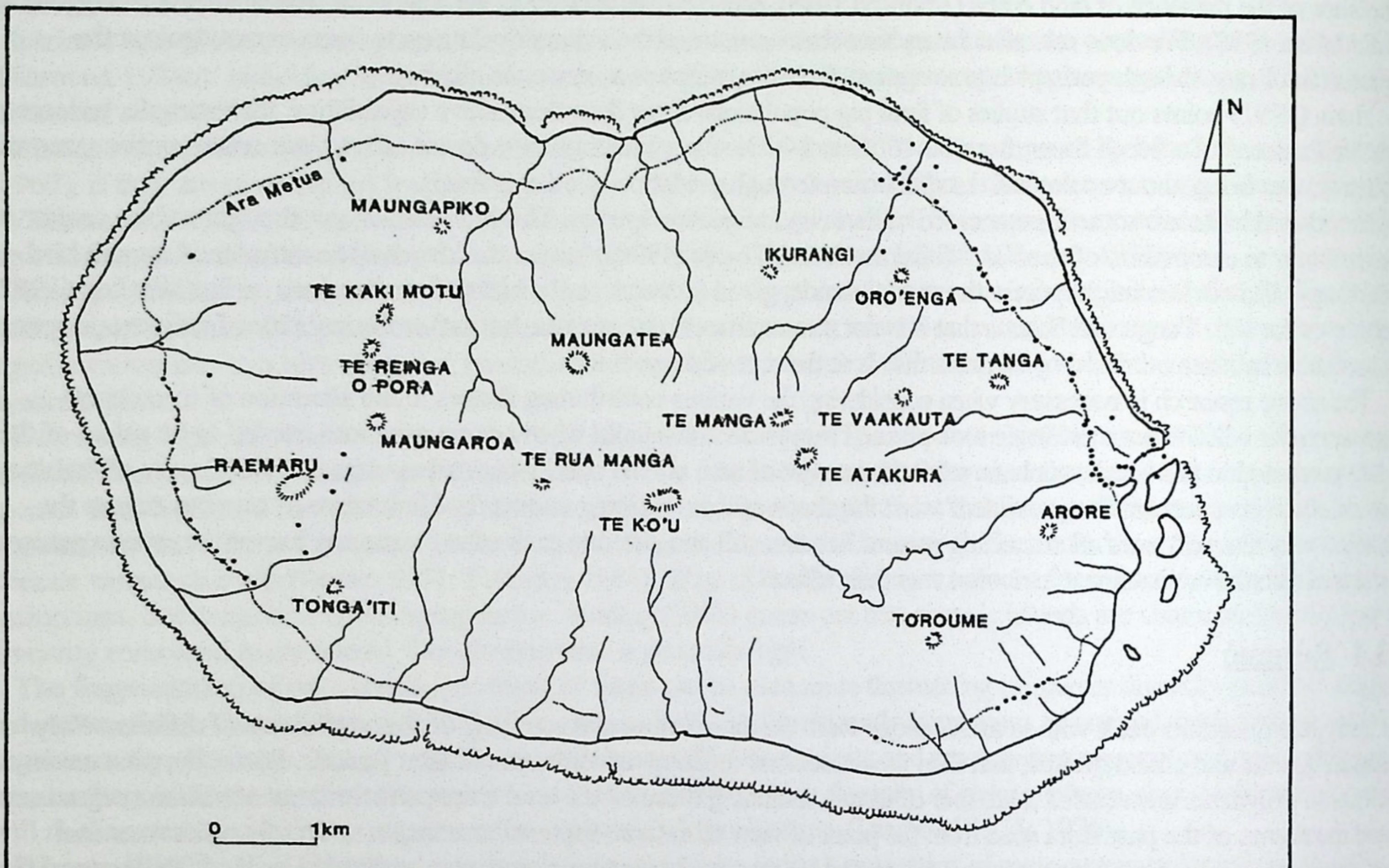

Figure 4.1 Map of Rarotonga, showing archaeological sites.

Pacific archaeology stimulated a new look at the chronology of Polynesian colonization. With its pivotal position between East and West Polynesia, the Cook Islands was an obvious early choice for the application of the technique. The earliest date from the expeditions of the Canterbury Museum and the Royal Society of New Zealand was 650 $\pm$50 BP, which correlated with Buck's chronology.

It was assumed that the earliest settlement sites on Rarotonga would take the form of middens in beach, cave and rock shelter deposits (Duff 1974a: 10), presumably inspired by such finding in the Hawaiian Islands (Emory and Sinoto 1961; Kirch 1985), New Zealand (Duff 1956) and the Marquesas Islands (Suggs 1961). The expeditions to Rarotonga failed to locate such sites, and therefore, turned their attention to the surviving upstanding monuments, about which some oral tradition was collected. Duff believed that early coastal sites had been destroyed by later cultivation. The following types of sites were investigated: the *Ara Metua*, *marae*, *koutu*, T-shaped *paepae* and the *paepae `are*. A total of 103 sites was noted, and a small selection of these were excavated and/or surveyed.

In Tupapa, the *koutu* Arai te Tonga and the T-Shaped *paepae*, Te Maru o te Ta`iti, were surveyed. In the same *tapere*, the T-Shaped *paepae* `Arerangi and Pokata, the `Are Kariei and the marae Marae Manuka and Marae Pureora were surveyed and partially excavated. Elsewhere, *paepae `are* were surveyed and excavated at Vaiakura and Avana, terraced marae, *paepae `are* and *`are kai* were surveyed and excavated on the Maungaroa, and the *Ara Metua* was surveyed.

In 1969, the expedition to Atiu (Duff 1971; Trotter 1974) sought to locate and record house sites and marae on the inner side of the makatea, belonging to the immediate pre-European contact period. Time limits meant that only traditional and obvious structures could be investigated, and no attempt was made to locate putative early coastal sites. Thirty-two sites were noted, a few of these were surveyed and only one, an *umu*, was excavated. The sites investigated included burial caves, marae and house structures. One burial cave, Vaiari, a basalt stone seat with stalactite backrest at Arangirea, the marae Marae Vairakaia and Marae Orongo, the Missionary Period tomb at Paikea and a ceremonial complex at Marau were all surveyed, and an *umu* on the central volcanic hill in the *vaka tangata* Te Enui was excavated.

Bellwood (1978), heading an Auckland University team, carried out a program of fieldwork in the Cook Islands in three campaigns: December 1968-February 1969, December 1969-February 1970 and May-August 1972 (see Figure 4.1). He excavated the Ngati-Tiare site (RAR. 40), noted by Duff as being associated with a cache of stone adzes, in 1968, 1969/70 and 1972 (Duff 1974b; Bellwood 1978). Bellwood also excavated the Urei`a (AIT. 10) and `Are Karioi (AIT. 3) sites on Aitutaki, as well as site surveying on Aitutaki and Mangaia (fieldwork was also carried out on Tongareva in the northern Cook Islands). There was more extensive survey and excavation of the structures on the Maungaroa (Bellwood 1978: 10-53), as well as a series of site surveys in the Rutaki and Turangi valleys, with a survey of the Avana valley taro pondfield terraces.

Bellwood (1971; 1978) believed that settlement had always been primarily coastal, and because of the continued use of the coast for settlement, remains had been destroyed. Thus, he felt compelled to concentrate on the inland valleys, where upstanding surface remains are still to be seen. The Maungaroa settlements were regarded by Bellwood (1969) as being atypical of the island as a whole, Tinomana and his people having being trapped up there for many generations, due to failure in warfare. He cited John Williams (1843: 172) and William Gill (1856: 39) as evidence of this. The settlement therefore was an adaptation to difficult terrain, making use of the meagre flat land available for cultivation and settlement.

In 1984, Chikamori (1987) excavated burial sites on Pukapuka, in the northern Cook Islands. Although culturally different from the rest of the Cook Islands, being a West Polynesian culture (Beaglehole and Beaglehole 1938), this had ramifications for the southern Cook Islands as well in that both groups occupy a middle ground between East and West Polynesia, and were thus expected to yield the earliest dates east of Tonga and Samoa. Chikamori's earliest date (when corrected for the Ocean Reservoir effect) put the settlement of Pukapuka at 2,310 BP.

Katayama (1986; 1987) analysed the evidence of skeletal material from Mangaia, Rarotonga and Miti`aro as well as physical characteristics of modern Cook Islanders to ascertain their biological affinities with neighbouring island populations. He concluded early settlers colonizing East Polynesia passed through the southern Cook Islands, some remaining, or that there was considerable contact between the southern Cook Islands and West Polynesia in the late prehistoric period. Katayama and Tagaya (1988) presented a report of physical and linguistic research in the Cook Islands, which provided information on the physical and linguistic relationship of Cook Islanders to neighbouring peoples. It identified present-day Pukapuka and Mangaian *populations as being most representative of pre-European populations of the Cook Islands.*

Walter (1990; 1991; 1993; in press) excavated a coastal village site at Anai`o on Ma`uke, with an assemblage correlating to the `Archaic East Polynesian Culture' of Sinoto (1970; 1983). Two sherds of Polynesian Plain Ware were also found (Walter 1990; Walter and Dickinson 1989). Also, Sinoto (1988) had previously discovered a sherd of possibly Melanesian origin at Varakaia on Ma`uke. Walter suggested that early sites in the southern Cook Islands, including Rarotonga, were beginning to reveal a pattern of coastal settlement by reef passages, which may have been chosen to control important landing sites at a time when there was regular offshore voyaging. Separate areas of the site were found to have been utilised for cooking, fishhook production and stone tool making.

Evidence of inshore fishing and collection of lagoonal resources was found, and Walter believed this to have been a significant part of the economy of the site (Walter 1991). The presence of pearlshell in the earlier levels suggested that there were formerly wider trade links, including lithic material imported from Aitutaki or Rarotonga for making adzes. These ended with an increasing population abandoning nucleated coastal settlements to occupy the available land directly in order to claim ownership. This gave rise to a dispersed pattern of settlement that continued into the post-European contact period.

In 1987, Allen and Schubel (1990) carried out excavations at Moturakau Rockshelter (MR. 1), on the *motu*, Moturakau, of Aitutaki. Again seafood, fish in particular, was important to the site economy. Some limited fowling was practised, which suggested to Allen and Steadman (1990) that the site was not of the earliest period. They suggested the site was used as a basalt quarry, possibly for export to other islands, such as Ma`uke. However, its use as a quarry site is disputed (P.J. Sheppard pers. comm. 1993).

In 1990, Kirch excavated the Tangata Tau Rockshelter on the makatea of Mangaia (Kirch *et al.* 1991; Kirch *et al.* 1992). There was evidence of seafood being important, with a number of extinct landbirds and seabirds and numbers of fruit bats. Alleged deforestation of the volcanic interior by humans was put at 1600 BP, and the use of the rockshelter was dated to from 1000 BP onwards. An assemblage of basalt adzes, other basalt tools, fishhooks, abrading tools, tattooing needles among other things was found. The fishhooks were made from pearlshell at first and were later replaced by *Turbo* shell. Since pearlshell would have had to have been imported, for example, from Aitutaki, this was thought to imply that there had been wide trade links in the past which were gradually reduced due to increasing social isolation resulting from spiralling warfare (Kirch *et al.* 1992: 175).

Also in 1990, Kurashina, Stevenson and Sinoto carried out surveys of marae, including some excavation, on Rarotonga, Atiu and Miti`aro (Allen and Schubel 1990).

In 1991, Chikamori investigated three metres of cultural deposits, as yet undated, 6 m a.s.l. in the Avana Valley (cf. Sutton *et al.* in press).

In 1992, excavations were being undertaken on house sites in Mangaia, on the lower slopes of the volcanic hills above the taro swamps by J. Endicott (Endicott pers. comm. 1992).

4.2 Pre-European Contact Environmental Past

Research into the environmental past of the southern Cook Islands only began fairly recently. Steadman (1986) recorded two previously unpublished species of rail, one and probably both of which are now extinct. He attributed their demise to pre-European contact Polynesian overexploitation. Later, he (Allen and Steadman 1990; Kirch *et al.* 1991; Kirch *et al.* 1992) analysed the sub-fossil remains of more such avian extinctions from Aitutaki and Mangaia.

Parkes investigated the pollen record for Lake Te Roto on Atiu in order to determine whether humans may have had an influence on past vegetation changes (Parkes *et al.* 1987). She attributes the growth of open scrub and fernlands to human activities around 1420 ±45 BP on the basis of her analyses (Flenley pers. comm. 1992). She suggests that *Casuarina equisetifolia* was a Polynesian introduction because it appears in the pollen record about this time.

Lamont (1990) carried out similar analyses for Lake Tiriara on Mangaia, and Dawson (1990) undertook chemical and mineralogical analyses for the same site. The results were combined for wider interpretation (Kirch *et al.* 1991; 1992). The period from around 1600 BP was construed in terms of sustained human disturbance, causing erosion and permanent deforestation. More recent work based on pollen cores from nearby swamps has been used to re-interpret the date, so that the first human disturbance of the vegetation has been put at 2500 BP (Ellison in press).

Allen and Schubel (1990) analysed fish and seafood remains from Moturakau, on Aitutaki. The results indicated a preponderence of reef and inshore fish were taken. Pearlshell was also found, and since it does not exist there anymore, it was proposed that there was overexploitation of that resource. Melinda Allen (1992) proposed that erosion due to clearance of forest and agricultural activities caused soil run-off to accumulate in the lagoon, causing changes in habitat that led to the local extinction of pearlshell.

Allen (1992: 191) also draws on the paucity of primary native forest in charcoal remains, except for *Calophylum*, the extinction of native landbirds and the apparent replacement of the native *Partula* landmolluscs by adventives in the occupation levels on Aitutaki.

Some environmental changes have been more exclusively natural. The sea-level debate, in particular, is important to the understanding of former environmental conditions in the southern Cook Islands.

Schofield (1970) puts forward the possibility of a 1-2 metre high stand of sea level. His evidence consists of a raised fossil coral outcrop 1 metre above present sea-level dated to 2,030 ±60 BP, though this may well be earlier due to recrystallisation, and the coral rubble ridge - the `Aroa Sands' of Wood and Hay (1970) - (below the A-horizon at the highest points) dated at Kavera to 3,510 ±50, at Matavera to 2,470 ±63 BP, and at the Black Rock (Tuoro) to 1,235 ±57. This is supported by research elsewhere in the Cook islands - Scoffin *et al.* (1985) on Suwarrow and Yonekura *et al.* (1988) on Mangaia. On Mangaia, emerged microatolls on the emerged shore were dated, and the results implied a maximum sea level of +1.7 m between 4 and 3000 years ago.

There has been some suggestion of tectonism in the southern Cook Islands. McNutt and Menard (1978) proposed that the growth of Rarotonga and Aitutaki caused the uplift of Mangaia, Atiu, Ma`uke and Miti`aro due to lithospheric arching. However, this has not been generally accepted due to disagreement on the extent and synchroneity of these events between the islands in question (Jarrard and Turner 1979; Spencer *et al.* 1987).

4.3 Post-European Contact Environmental Past and Present

European records of the environment of the southern Cook Islands began with Captain Cook in 1777 who visited Mangaia, Atiu, Takutea, Manuae, Aitutaki and Palmerston (Beaglehole 1967). Rarotonga, however, was not generally known to the Europeans until the arrival of the missionaries, who recorded little detailed information on the natural history of the southern Cook Islands, with the exception of William Wyatt Gill (1885).

Flora

Captain Cook recorded that Mangaia had a forested makatea, with the hill in the interior having fernlands with the summit having *Casuarina* woodland (Beaglehole 1967). Later, William Wyatt Gill (1885) made notes on some of the cultivated and wild species of plant on Rarotonga.

The first flora of Rarotonga was compiled by Cheeseman from a visit in 1899 (Cheeseman 1903). Cheeseman divided the flora in to three groups: indigenous, pre-European and post European introductions. These distinctions have been continued by later authors (e.g. Sykes 1983; Merlin 1985). He noted that the upland vegetation was almost exclusively composed of natives, whilst the lowlands, in contrast, was predominantly comprised of exotics. *Hibiscus tiliaceus* and *Aleurites moluccana* were recorded as being common in the valleys and occurring up to at least `800 ft' (264 m). He also claimed that these formed `the major portion of the forest', which was later rejected by Merlin (1985). Cheeseman mentions that in the late 19th century *Fagraea berteriana* was common in the uplands, and occasionally even planted as an ornamental on the lowlands in the villages.

In 1925, 1927, 1929, Wilder visited Rarotonga, and published a new flora (Wilder 1931). This unfortunately contains a number of inaccuracies, both botanical and in terms of the Maori nomenclature (Sykes 1980). He recorded the presence, albeit uncommon, of *Cecropia palmata*, which is now widely distributed, though not common (Merlin 1985), *Coccoloba uvifera*, and *Elephantopus scaber*, which is now present from the lowlands up to the peaks (Philipson 1971): none of these having been observed by Cheeseman in 1899. *Argusia argentea* is listed as common on the shore by Wilder and later by Philipson (1971), though only as a few clumps on the east coast by Cheeseman (1903).

Copeland (1931) presented a report on a fern collection made by H.E. and S. Thew Parks, which was less extensive than those by Cheeseman and Wilder.

Philipson (1971) collected vascular plants from Rarotonga in 1969, and presented a brief discussion of the floristics, in particular, the phytogeographical relations of the Rarotongan flora.

Brownlie and Philipson (1971) investigated the pteridophytes of the southern Cook Islands, and collated all previously existing research. The total of 80 species listed were all either found outside the Cook Islands or closely related to species found elsewhere.

Stoddart (1972) described the environment of the *motu* of Rarotonga, including brief descriptions of the vegetation cover. In the same volume, Fosberg (1972) listed the vascular flora of these same islands, along with distribution maps of vegetation types for the three largest of them. Later, Fosberg presented a similar study for Aitutaki (1975).

Sykes (1980), noting the lack of floristic research in the Cook Islands, began a programme of detailed investigation of the flora, not just of Rarotonga, but the other islands as well (Sykes 1980; 1983; 1992).

On Rarotonga, Sykes (1983) divided the vegetation into three zones: coastal, lowland and upland. The greater part of the coastal zone was found to be much altered by human interference. The indigenous vegetation of the coast which survives is typical of other islands in the tropical South Pacific. The lowland zone comprises, not only the coastal plain, but also the lower gently sloping valley bottoms. The native vegetation of this zone, despite the richest soils, is overshadowed by exotic invaders and cultivated plantations. Finally, the upland zone includes everything above about 50 m a.s.l., and is almost exclusively covered in indigenous species.

Merlin (1985) undertook surveys of Sykes' upland zone (Sykes 1983), and subdivided it into three plant associations on the basis of dendrogram analyses: *Homalium* montane forest, *Fagraea-Fitchia* ridge forest, and *Metrosideros* cloud forest. He also described the *Dicranopteris*-dominated fernlands, and attributed them, like Sykes (1983) to past human activities. Merlin challenged the belief that the uplands had been largely immune to incursions of exotic plants, though accepted that they are still predominantly composed of the native flora. He suggested that this was due to the lack of prolonged human disturbance, though low levels of disturbance were noted, like hunting for birds and collecting plantains.

Merlin (1991) then investigated Mangaia's makatea vegetation, using vegetation surveys and dendrogram analyses and identified a number of plant associations. Sykes (1992) presented a report on the floristics of Atiu.

Animals

Research into the avifauna began with the visit of Captain Cook to Palmerston Island in 1771, when large colonies of seabirds were recorded (Beaglehole 1967). Later, Captain Byron on H.M.S. Blonde to Ma`uke in 1824, when members of the crew made notes and illustrations and took some dead specimens (Holyoak 1974; 1980). The information was not well recorded, but it is interesting to note the absence of one or two species mentioned which are not seen today.

Thomas Nightingale (1835) visited Rarotonga briefly in 1834, and noted a lack of birds (though his description of his visit only really includes episodes on the coastal plain). He says that a certain bird, dwelling in the mountains with feathers that were used in chiefly headdresses, had been hunted to extinction. From Buck's (1944) descriptions of Rarotongan headdresses, this would either be a red-tailed tropic bird or a red lorikeet. The first still exists in Rarotonga (Holyoak 1980), and the second is restricted to the coastal plain or the low-lying valleys, and feeds primarily on coconut nectar (Bruner 1972). It could be that he confused two stories. The fact that he referred to one of the missionaries he was staying with as `Simpson' instead of `Pitman' might suggest that he did not take careful notes (Nightingale 1835). One should also bear in mind that some birds such as lorikeets may have been brought to islands where they did not previously exist because of their economic value[22].

Later, Hartlaub and Finsch (1871) produced a list of Rarotongan birds, including the grey duck, which became extinct on Rarotonga in the 1920's (McCormack and Künzle 1991). William Wyatt Gill (1885) noted that the *kakerori* (*Pomarea dimidiata*) was less frequent than in previous times in the valleys where it served to cut down the number of insect pests on taro. He suggested that this could be due to either the introduction of new predators, especially the cat, and the use of

22 For example, Watling (1982) points out that the Red-breasted Musk Parrot was introduced to Tongatapu and `Eua by the Tongans from Fiji for this very reason.

firearms in hunting. In addition, he thought that cyclones could have contributed: `Consequently the `kakirori', two species of which were once common, especially in the neighbourhood of the sea, was (it was believed) exterminated' (Gill, W.W. 1885: 127-128).

In fact, William Wyatt Gill (1885: 127) states that:

> The woods of Rarotonga, when I first knew the island some thirty-two years ago, were everywhere vocal with the song of birds...I have more than once ridden round the island without hearing the cry of any but sea-birds. The stillness of the forest would be intolerable but for the pleasing hum of insects as the sun declines.

Also, he quotes from an *ariki*:

> the chief justice Vakatini (about seventy-five years of age) spoke as follows: `Let me remind the young of our ancient methods of catching birds before the introduction of fire-arms. Landbirds were then plentiful. [Gill, W.W. 1885: 78].

Not much detailed attention was given to the southern Cook Islands until recent times, apart from a list of birds from Mangaia published by Christian (1920). In the 1970's, a series of small articles appeared including Holyoak (1974; 1976) and Turbott (1977), but it was not until 1980 that Holyoak produced the first comprehensive survey of the avifauna (Holyoak 1980). McCormack and Künzle (1990; 1991) provide some useful additional information.

The landbirds were responsible for the spreading of fruiting plants, for example, pigeons on Rarotonga fed on mistletoe (*Loranthus*) berries, and thus spread the mistletoe seed to other host trees on which it is parasitic (Gill, W.W. 1885: 84). The *Rupe* (*Ducula pacifica*) fed on berries of the banyan tree (*Ficus prolixa*), the *Koka* (*Bishofia javanica*) and the *Karaka* (*Elaeocarpus tonganus*) - Gill, W.W. 1885: 78). *Rupe* sipped the nectar from *Neinei* (*Fitchia speciosa*) flowers (Gill, W.W. 1885: 79), thus presumably pollinating them. *`I`oi* (*Aplonis cinerascens*) did the same with coral trees or *Ngatae* (*Erythrina variegata*) - Gill, W.W. 1885: 78. This is a lowland ornamental tree, and according to this same account, traps were set for the *`i`oi* near the flowers at mid-day while they were asleep in the forest.

Research on other animals is less advanced. William Wyatt Gill (1885) made notes on some marine and lagoon animals, as well as a species of wasp, two varieties of grasshopper, a phasma or spectre insect, various types of land mollusc and some introduced insects. Crombie and Steadman (1986) composed the first overview of the lizards of Rarotonga and Mangaia. Wilson and Taylor (1967) produced the first investigation into Cook Islands ants, listing 17 species. Taylor (1967) added 3 more ant species to the list. Since the ant species were composed of a very small selection of the Indo-Australian fauna and none amongst them were definite endemics, it was concluded in both articles that all were human introductions: some Polynesian introductions and some later European introductions. Wise (1971) made a preliminary list of all types of terrestrial invertebrates in the Cook Islands. Some additional information on the non-avian side of the fauna is presented in McCormack and Künzle (1991).

It is possible that the decline in the *kakerori* led to an increase in insects. William Wyatt Gill (1885) records that insect pests on taro increased on the valley plots, after *kakerori* numbers fell. Perhaps the insects were also infesting forest plants too. In the same book, Gill mentions without the noise of song birds, the `pleasing hum of insects' was all that could be heard in the forest (Gill, W.W. 1885: 127 - see above). This may be more significant than first appears. Some insects, though, may have been predatory on the other insects, creating some natural balance.

4.4 Résumé

The archaeology undertaken in the southern Cook Islands was described and its ramifications discussed. Issues regarding the past and present environments were investigated and the evidence so far amassed was presented.

The next four chapters look at the research undertaken in this project, commencing with an outline of the aims and techniques of the fieldwork.

CHAPTER 5 FIELDWORK

The aims of the fieldwork, conducted by the author on Rarotonga, are discussed as a whole, and then those of the three separate periods of fieldwork are described in more detail. Some general aspects of the methodology employed in this work is indicated, as well as specialist techniques used which are not covered in succeeding chapters. Finally, the achievements of the fieldwork are outlined.

5.1 Aims

5.1.1 *Overall Aims*

Fieldwork was undertaken to locate polliniferous deposits dating back long enough to cover comfortably the period before which as well as during which humans had lived on Rarotonga, and to sample these deposits. Modern vegetation studies, as noted above (Chapter 2), were carried out to establish the current state of the vegetation and together with modern pollen rain studies these were to provide comparisons for the fossil evidence. Reference pollen samples, including voucher specimens of the plants the pollen came from, were to be collected. Topography and location, where they could have a bearing on site formation processes, were to be carefully noted. Oral tradition and local information were gathered where time allowed.

5.1.2 Fieldwork February 1990

Flenley, Barker and Sutton carried out the first phase of fieldwork on Rarotonga in the period February 3-15th 1990 (Sutton *et al.* 1991). It was thought that perhaps the coastal platform was recent, having been formed possibly only since human settlement, with the present-day swamps being remnants of a former lagoon. The swamps were to be examined for depth, age, modes of origin and scientific potential.

The swamps selected were to be assessed in terms of general levels of preservation of organic materials in order to gauge their viability for palynological work. Radio-carbon samples were to be obtained from the cores taken.

Site Locations (Figures 5.1)

Six sites were initially cored by Sutton *et al.* (1991) in February 1990, though many more were visited (Ibid: 12). The topographical map of Rarotonga (Lands and Survey 149, 4":1 mile, 50' contour) was searched for interfluvial swamps, as Flenley had hypothesized that those swamps at the maximum distances from rivers, where sediments from the island core would be thinnest, would be the best to study. These swamps and some others shown on the Land Use Map of Rarotonga (Lands and Survey 146/1&2) were investigated.

The swamps selected for coring were assessed to be adequate for the preservation of pollen. Radiocarbon samples were extracted from the cores taken and they showed fairly late dates except for two. One in particular, a large swamp called Karekare swamp (formerly labelled as `Matavera swamp'), in the north-east of Rarotonga, was later identified from radiocarbon samples as having sediments dating at least to the eighth millennium BP (the date was taken from about a metre above the base). This was thus judged to extend well back before the period of human settlement in the eastern tropical Pacific and more besides. The following descriptions (5.1.2.1 to 5.1.2.6) are after Sutton *et al.* (1991: 12-13).

5.1.2.1 Atupa

This is the largest area of swamp on Rarotonga. The construction of the International Airport in the early 1970's reduced its area, though the greater part of the swamp remains. It is at present cultivated, with some areas left fallow. It was cored at five places along a transect through the swamp from a point on the *Ara Metua*, approximately 500 metres west of the Avatiu Valley *Ara Noa*. The deepest deposit along that transect was located, and is referred to as AT1 in Table 1. The deposit there was sampled at 10 cm intervals down to 3.50 m.

5.1.2.2 The Latter Day Church Site, Arorangi

This site is just inland from the Latter Day Saints church south of Arorangi. It is a narrow swamp, only 20 metres wide, which parallels the coastline. This swamp is shown on the topographical map as a food swamp passing through an area of coconut plantation and bush which crosses the *tapere* boundary between Akaoa and Vaikura. Sutton, Flenley and Barker cored at three locations within the swamp and found the deepest spot (ARM1) which was sampled (as above), using the Feek corer, to a depth of 4.50 m.

5.1.2.3 Aro`a Taro swamp

The site sampled is located on a broad band of swamp near the Aroa Radio Station, 600 metres north of the Rarotonga Hotel. The swamp is intensively used, and stretches from the back of the coastal ridge of coral sand, to approximately 80 metres inland, where there is a high bank which may be an old shoreline. It was cored at 4 spots along a transect approximately perpendicular to the coastline, and the deepest spot (AO1) was traced to the inland edge of the swamp. Then it was sampled (as above) using the Thomas corer to a depth of 3 m.

5.1.2.4 Karekare swamp (originally labelled Matavera swamp - MR)

In February 1990, after exploratory cores, and improvisation of an additional 7.6 m of rods, a continuous 11.5 metres was sampled (as above) into the swamp deposits at a location, KK4 (MR1), just east or seaward of the land islet located at the inland end of Karekare swamp (Figures 5.1, 5.2, 5.3).

When cored, the base of the column proved to be an orange clay similar to those formed by the weathering of the Rarotongan basalts. No coral sand was encountered, although the base was apparently below current sea level.

Subsequently, the swamp was cored to 7.5 metres at two locations north of an islet of dry and raised land (in the swamp) and closer to the inland edge of the swamp in order to record the swamp margin stratigraphy.

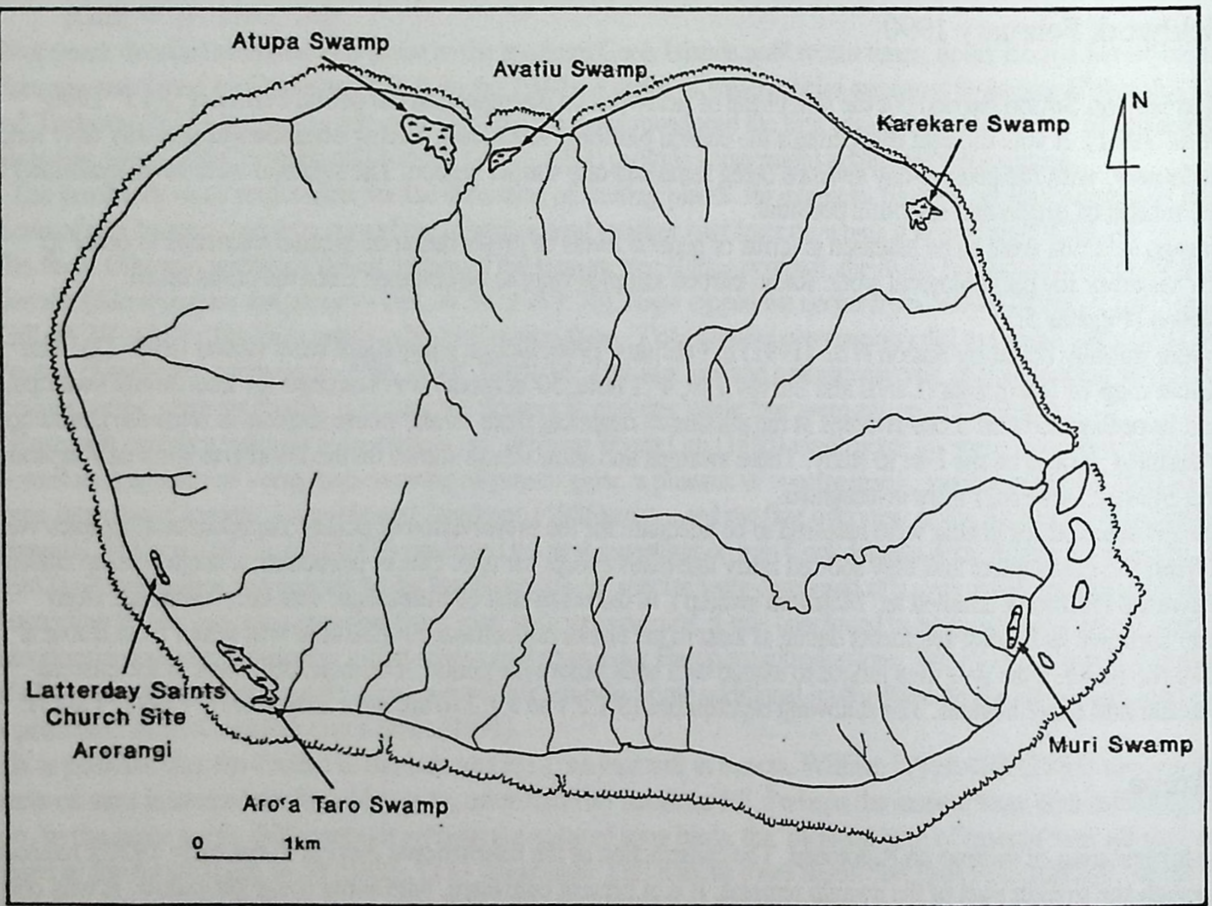

Figure 5.1 Map of Rarotonga, showing the location of swamps cored.

5.1.2.5 Muri

Flenley and Barker cored along a transect of the Muri swamp, in Aremango *tapere*. Two buried soils overlying a basal coral sand, 1 metre below the surface, were sampled for radiocarbon dating but no pollen was collected due to the unsuitable nature of the deposit.

5.1.2.6 Avatiu

The Avatiu swamp was cored at a number of locations in order to ascertain the depths. These were: immediately west of the road to Avatiu from the *Ara Metua*, and north of the inner road opposite the Ruatonga Stream. A coral sand or gravel base was found a short distance beneath the surface throughout this area. The intervening deposit was composed predominantly of soils with a high inorganic content, unsuitable for the preservation of pollen.

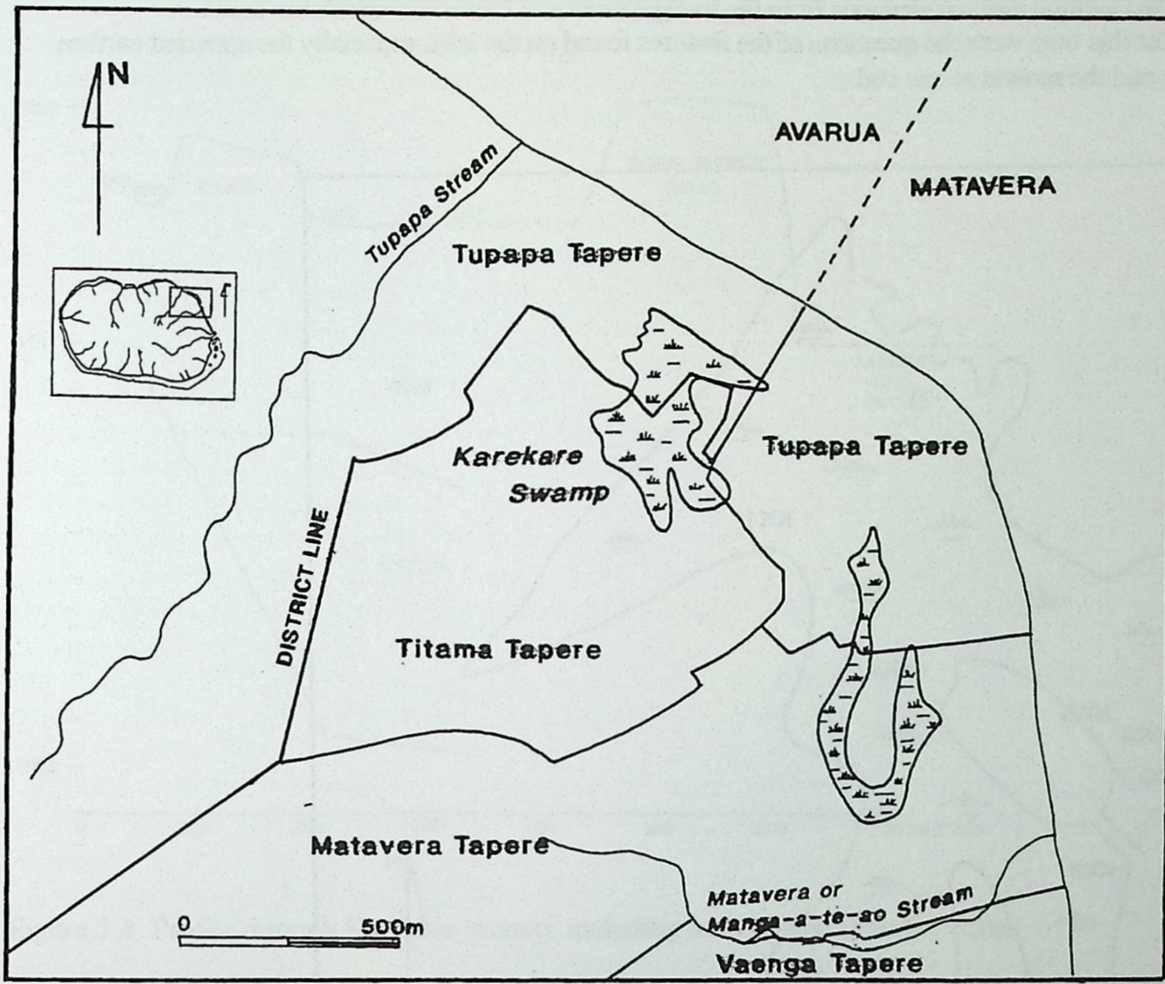

Figure 5.2 Detailed map of the Tupapa, Titama and Matavera *tapere*, showing the location of Karekare swamp.

5.1.3 Fieldwork November/December 1990

Karekare swamp was selected for further investigation in the November/ December 1990 season of fieldwork, after initial pollen analysis showed it to be promising and a date of 8373 BP (calibrated) was obtained from sediment at a depth of 9.5 m. Other swamps sampled on the previous trip were not researched any further as they were felt to offer inadequate material for study.

Swamp stratigraphy would be clarified by cores from the landward side to the seaward side. In the end, time limits meant that cores were taken from the landward side to the centre. This was the more important part of the swamp since that would have been where any erosion would have come from.

A core was taken by Feek and Peters from the centre of the swamp in order to sample what would be likely to be pollen rain from a wider area (*cf.* Moore and Webb 1978; Moore *et al.* 1991), and to get a deeper core sample. Coral sand and weathered basalt were found at the bottom. Two other cores were taken from closer to the swamp margin.

Other work undertaken included modern pollen sampling to broaden the reference collection, electrical resistivity survey, within time constraints and the noting of topographical features and sediment exposures time permitting.

5.1.4 Fieldwork August 1992

The fieldwork season lasted from the 4/08/92 to the 2/08/92.

The tasks to be undertaken were vegetation surveys of the important vegetation types, the gathering of modern pollen rain samples from the vegetation plots, the sampling of wood from different tree and shrub species for a reference collection and the collection of voucher specimens for the identifications made and for the wood samples. Where possible and time allowed, oral tradition and recollections from the living memory of Cook Islanders were noted.

Also, investigated at this time were the questions of the features found on the islet, especially the apparent earthen wall around its edge and the mound at one end.

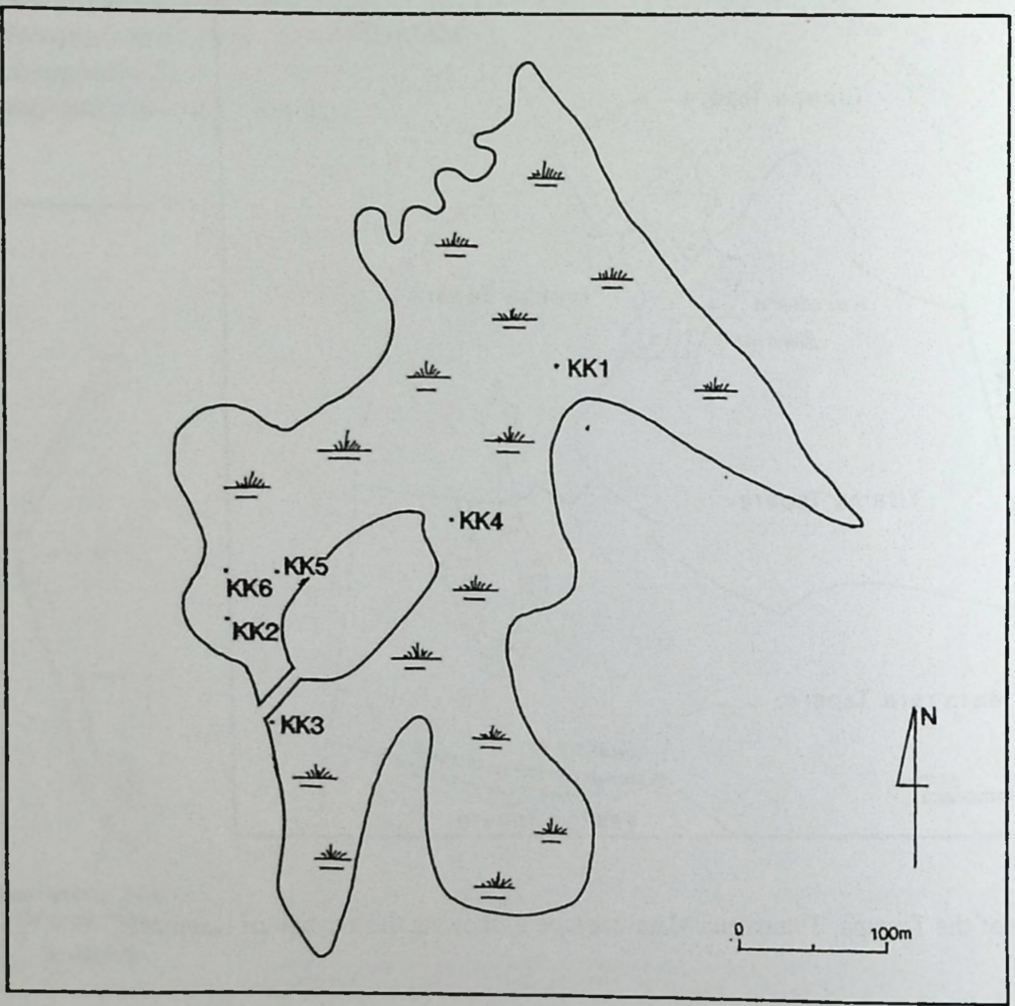

Figure 5.3 Map of Karekare swamp, showing the location of the core samples.

5.2 Methodology

The methodology, as stated here, applies to all fieldwork reviewed here. The methods used included electrical resistivity, swamp coring (see section 7.11), photography, pH tests (see section 7.31), preservation of plant and pollen specimens in alcohol or bioquat (all-purpose biocide), and vegetation survey (see section 2.1).

5.2.1 *Electrical Resistivity Methodology*

A Wenner Array with a spacing of 1 metre between probes was used over Karekare swamp (Coles 1972). Due to the water-logged nature of the terrain, it was clear that the underlying hard geology would not be detected directly. It was hoped, however, that the top layers would follow any pattern of sagging or bulging in the lower levels, albeit in a less marked way.

5.2.2 *Collection and Preservation of Modern Plant Specimens*

Specimens were taken of unopened mature flowers (for pollen), plus samples of leaf and twig. Voucher specimens were also selected in order to confirm identifications in the vegetation surveys. These were then soaked in methylated spirits or bioquat (all-purpose biocide) for preservation. They were then sealed in plastic bags and labelled.

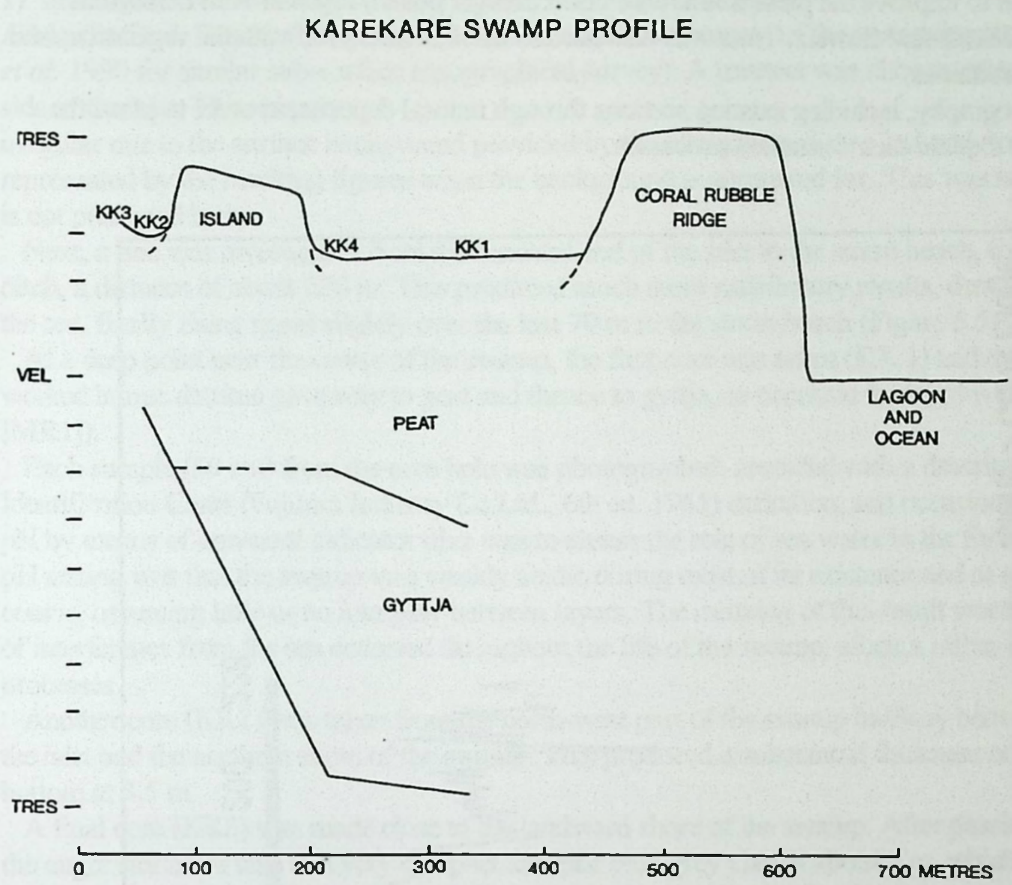

Figure 5.4 Profile through Karekare swamp, including information from the cores.

On the return to Auckland University, all these specimens were dried out at 50 °C over a few days in presses, until ready, in the Botany Department drying ovens. While needed for study, they were kept in freezers in the Anthropology Department. They are now in the herbarium of the Auckland War Memorial Museum.

Identifications were made or confirmed by W.R. Sykes of Manaaki Whenua/Landcare Research NZ Ltd., Lincoln and G. McCormack of the Cook Islands Natural Heritage Project, Rarotonga.

5.2.3 *Photographic Methodology*

On the fieldwork seasons of November/December 1990 and August 1992, a Pentax K1000 was used. For each core sample, both colour and black and white exposures were taken. Black and white film was used to bring out contrasts more clearly. Photographs were also made of sample context and general location.

5.3 Results of Fieldwork

5.3.1 *Fieldwork February 1990*

From Karekare swamp, three cores were obtained KK4, KK5 and KK6. KK4 was the deepest which produced the aforementioned 8373 BP date, and was a few metres seaward of the land islet in the swamp. Core samples and core descriptions were also obtained from five other swamp sites, though with no calibrated dates earlier than 1415 at 2s (Appendix A.6) and with much shallower deposits than Karekare swamp.

5.3.2 *Fieldwork November/December 1990*

The fieldwork consisted of three parts:

1) Investigation of the swamp, including an electrical resistivity survey, a conventional survey, a photographic record of the swamp, and a number of cores through the swamp at different points to sample the stratigraphy.

2) Collection of modern specimens to improve the present reference collection (of pollen) together with herbarium specimens consisting of twigs, leaves and flowers. Time was also used to familiarise myself with the vegetation, and with the present-day plant communities.
3) A study of the surrounding topography, including existing sections through natural deposits, in order to place the swamps into context and try to explain their formation processes.

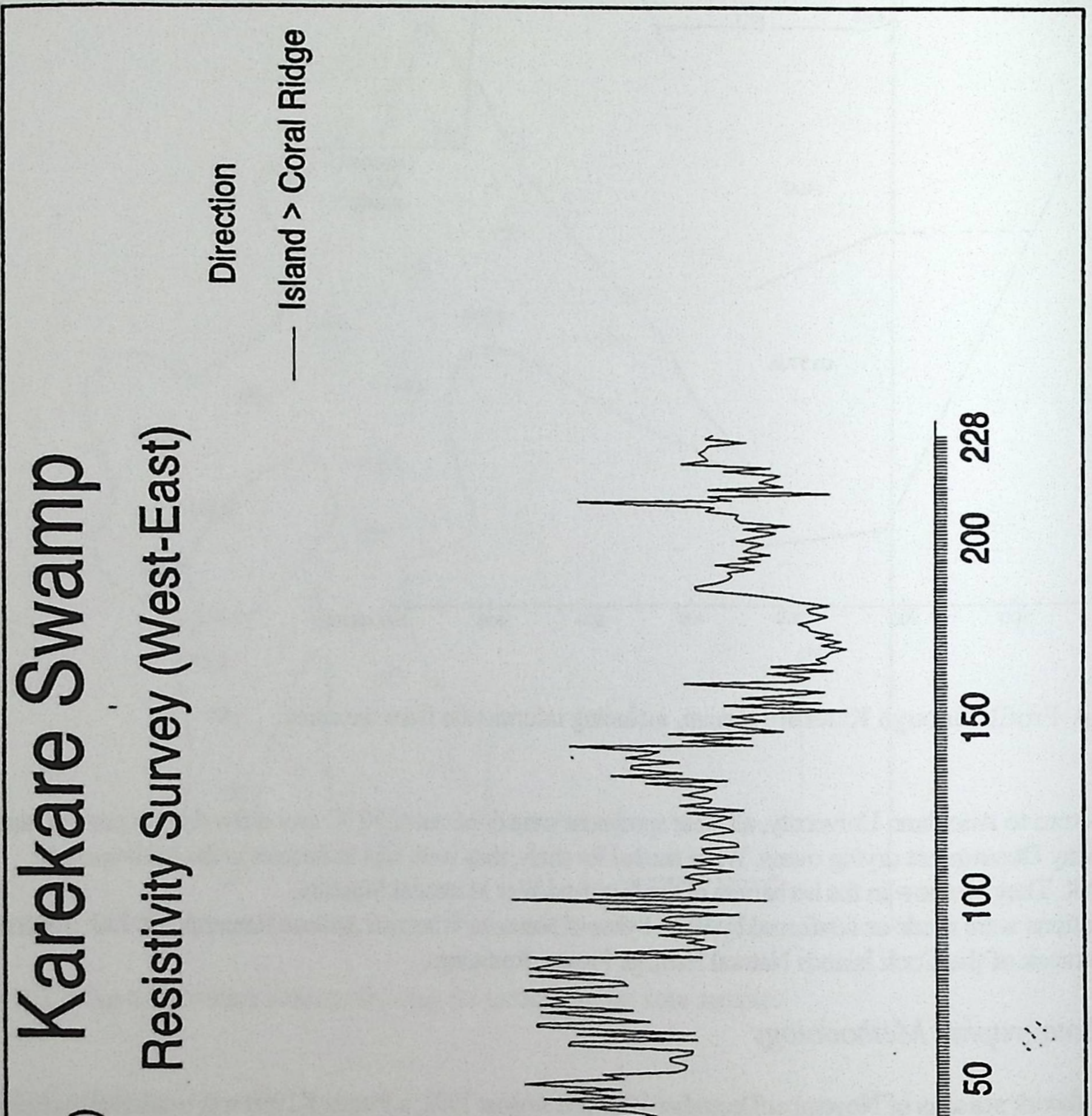

Figure 5.5 Electrical Resistivity Survey across Karekare Swamp, from the island to the coral rubble ridge (West-East).

1) Investigation of Karekare swamp (Figures 5.1, 5.2, 5.3 and 5.4):
A Martin-Clark Resistivity Meter, was used to obtain an estimate of the underlying topography of the swamp (*cf.* Darwin *et al.* 1990 for similar sub-surface topographical survey). A transect was chosen, oriented north-south, to the landward side of the islet. This was very
irregular due to the surface background provided by the alternation of taro bed and drainage ditch. Little change is represented by the resulting figures when the background is accounted for. This was not a very reliable set of results, and is not presented here.

Next, a line was investigated from the seaward end of the islet to the storm beach, following the line of the drainage ditch, a distance of about 230 m. This produced much more satisfactory results, demonstrating a gradual slope towards the sea, finally rising again slightly over the last 70 m to the storm beach (Figure 5.5).

At a deep point near the centre of the swamp, the first core was taken (KK 1) and descended almost 11 m. Layers of worked humic detritus gave way to peat and thence to gyttja, as occurred in the core taken in February 1990 (KK4 [MR1]).

Each sample (50 cm) from the core hole was photographed, recorded with a description, including a Standard Color Identification Chart (Fujihira Industry Co.Ltd., 6th ed. 1965) definition, and occasionally - where of interest - tested for pH by means of universal indicator (this was to assess the role of sea water in the formation of swamp). The result of the pH testing was that the swamp was weakly acidic during most of its existence and at some periods neutral. This is, of course, assuming little or no interplay between layers. The meaning of this result would seem to be that some small degree of interference from the sea occurred throughout the life of the swamp, albeit a rather secondary force in the formation processes.

Another core (KK2) was taken from the north-west part of the swamp halfway between the coral rubble causeway to the islet and the northern shore of the swamp. This produced a substantial thickness of wood peat before reaching the bottom at 3.5 m.

A final core (KK3) was made close to the landward shore of the swamp. After passing through a layer of humic loam, the auger started to take in a very compact and fine blue-grey clay at about 2 m, which proved impossible to penetrate without damaging the equipment.

A conventional survey was undertaken in order to pinpoint the exact positions of the cores taken (Figure 5.3). The government benchmarks are situated along the coastal road (the *Ara tapu*), which passes over the storm beach. I used the opportunity to undertake a profile (Figure 5.4) from the crest of the storm beach to the back of the swamp, taking in the cores and the government trig points. This demonstrated that the storm beach was about 4 m above sea level, and the swamp surface, excluding the area around the islet, about 2.2 m. The swamp depth is thus about 8.7 m. Finally, the swamp surface around the islet is about 3.5 m a.s.l..

This raised part of the swamp around the islet was wet woodland before the 1940's, according to the owners of the portion of the swamp immediately southwest of the islet. Coconut and *puraka* (*Cyrtosperma chamissonis*) were collected from it as an additional food source. This tallies very well with the evidence of the odd tree stump and the wood peat from the core samples. In the 1940's, the ground was cleared for cultivation of taro, and, thus, taro beds and drainage ditches were created from scratch (see 6.5.2).

Photographs were taken from different positions all around the swamp to create a clear visual record of the location of the fieldwork. Location shots were made for the cores as well.

2) Collection of Modern Specimens
Time was spent for the author to familiarise himself with the various vegetational communities: on the islets in the lagoon near Muri; along the shoreline; around and on the swamp; on the alluvium of the coastal plain - cultivated and non-cultivated areas; up the mountain valleys of Tupapa, Avana, Avatiu, Vaima`anga and Maungaroa -cultivated and non-cultivated areas; along the fern-covered ridges; and finally, the cloud forest.

It was noted that much of the vegetation up the mountain valleys and on the ridges was of a secondary character. On many ridges, there was dense fernland or open *Toa* (*Casuarina equisetifolia*) woodland, and in the valleys, there was *`Au* (*Hibiscus tiliaceus*) thicket with various other pioneer plants as minor components. This gives the impression that much of the upland region of Rarotonga was once cleared. David Todd (pers. comm. 1990), a contract zoologist, then visiting Rarotonga, pointed out that, in some valleys, the *Homalium acuminatum* trees have two trunks, possibly due to coppicing in the past.

3) A Study of the Surrounding Topography:
A number of problems presented themselves in considering the situation of Karekare swamp which could assist in the interpretation of the core samples. Firstly, it is on the only stretch of coastline that has a high storm ridge composed of coral rubble instead of the usual low flat ridge of fine coral sand. Secondly, it has the narrowest stretch of lagoon on the

island with the reef only a few metres away from the beach. Thirdly, the coastal plain is at its widest in the area of Karekare swamp. Another interesting point is that the mountains are at their highest in this northeastern quarter of the island.

5.3.3 *Fieldwork August 1992*

The tasks undertaken were:

1) Vegetation surveys of the important vegetation types (see Chapter 2).
2) The collection of moss, leaf litter and soil samples from the vegetation plots surveyed for evidence of the modern pollen rain (see section 2.2).
3) The collection of samples of wood from different tree and shrub species for the reference collection of the Anthropology Dept. at the University of Auckland, under the care of Dr R.T. Wallace (see Chapter 8).
4) The collection of voucher specimens for identifications made and for the wood samples.
5) Where the opportunity arose, oral tradition and recollections from living memory were noted (see Chapter 6).

5.4 Résumé

The aims of the fieldwork were: to locate and sample polliniferous deposits extending back to before human settlement on Rarotonga; to carry out modern vegetation studies in order to assess the state of the vegetation with modern pollen rain studies to provide comparisons for the fossil data; to collect reference pollen and voucher specimens of the plants the pollen came from; to note topography and location; and to gather oral tradition and local information. Three trips were made to Rarotonga from 1990 to 1992 for the purpose of fieldwork, and these have been described.

CHAPTER 6 DOCUMENTARY WORK

This chapter looks at evidence from historic documents, oral tradition, living memory (of Cook Islanders) and ethnographic literature and extracts information and ideas therefrom about the former ecology, economy and human settlement of Rarotonga at different periods in order to take account of human-environmental changes in later periods of human settlement. A section on pictorial and photographic evidence compares the relatively late images of Rarotonga's landscape with the landscape of other East Polynesian islands (Mangaia and the Society Islands) at the time of Cook's voyages and notes a number of common themes.

6.1 History

In Chapter 1, an outline of Rarotongan history was given. The following section looks firstly at the documentary evidence, then oral tradition in order to ascertain the state of the Rarotongan landscape during the initial period of European contact and if possible prior to European arrival. This not only completes the history of human-environment relations, but also helps to allow for changes which may be recent in origin.

6.1.1 *Documentary accounts*

The earliest documentary accounts are mainly those of missionaries of the London Missionary Society, who evangelised the island from 1823 onwards.

These accounts tend to agree that the central mountainous core of the island was forested, though there is a degree of uncertainty regarding the state of the lowlands. Much of this is due to overstatement by the missionaries (see below), possibly in order to impress audiences back in Britain. Relating missionary success in converting Pacific Islanders was the main purpose of such reports.

Compare the following depictions of Rarotonga. The first is that of 1830 by the Reverends John Williams and Charles Barff:

> June 3. Saw the fine island of Rarotonga early in the morning. It had a fine romantick appearance from the vessel, the lofty mountains separated by deep ravines and all covered with a beautiful foliage, formed a

majestick landscape.....The extent of Cultivation was to us a novel sight, almost every Individual having his kaina/kainga or small farm cultivated with plantains, ti, taro, yams, etc., so that the whole settlement appeared one extensive garden. [Williams and Barff 1830: 5].

The second is that of Aaron Buzacott, the missionary stationed at Avarua, Rarotonga:

The "Industry" reached Rarotonga on 16th February, 1828. The island presented a most romantic ppearance. Range upon range of mountains towered above each other, forming to the eye a gigantic ladder, by which the Titans might ascend far above the clouds, and hold intercourse with the immortals. The low-lands revealed cultivated spots amid stately trees and forests. The very hills and mountains, from base to summit, were covered with dense wood of varied growth and colour. Mountain torrents leapt from crag to crag - forming the most lovely cascades and miniature water falls, and breathing a grateful coolness through the hot atmosphere. A vegetation of wondrous luxuriance grew down to the sea shore, and seemed to contend with the ocean for every inch of ground. The battlefield of this bloodless war was a narrow strip of white sand which fringed the whole island. [Sunderland and Buzacott eds. 1866: 25].

Both are descriptions of the island as seen from an approaching ship, and both indicate a forested interior, but differing on the level of cultivation. However, the former does limit it to the `settlement', which suggests that this concerns the post-contact settlement pattern of villages or *oire*, rather than more scattered dwellings amongst the cultivations (*cf.* Crocombe, R.G. 1961). The latter description suggests that cultivated areas were separated by stretches of forest, and that the cultivated spots were broken up by trees. Some of these trees would no doubt have been crop trees. Forest or woodland appears to have extended right to the shore from the second description.

William Gill (1856), the missionary stationed at Arorangi, Rarotonga[23], mentioned that the staple diet of Rarotongans consisted of vegetables and fish, with pigs and poultry being consumed at feasts.

An explanation for this lack of extensive gardening is to be found in John Williams' missionary memoirs:

Between each district was left a space of uncultivated land, generally about half a mile in width. On these wastes their battles were most frequently fought; for the inhabitants of each district invariably used every exertion to prevent their opponents from making encroachments upon their kaingas or cultivated lands, and therefore disputed, with greatest pertinacity, every inch of uncultivated waste; nor did they, until entirely driven off, yield their possessions to the hands of the spoiler. But since the introduction of Christianity, many of these wastes have been cultivated. [Williams, J. 1843: 210].

Warfare and disputes, therefore, had created bounds to the potential exploitable land. Other examples of such `no man's land' areas in Polynesia include Tongareva (Buck 1932b) and the Marquesas Islands (Melville 1847; Robarts 1974).

William Gill of Arorangi records the presence of woodland before the construction of the church and village, which he attributes to the warfare which prevented its use for settlement, though a reading of the memoirs of Maretu (1983), a Rarotongan who became a missionary, provides a balance to the idea that this had been going on for `many generations':

The site fixed on for their settlement is about 6 miles from Avarua, a level piece of ground two miles long, at the base of a noble range of mountains, and facing due west. It involved no little difficulty and labour to clear this land, for it was covered with trees and brushwood, the growth of many generations. [Gill, W. 1856: 39-40].

William Wyatt Gill, missionary first on Mangaia and later at Avarua, on Rarotonga, also provides evidence of what was occurring:

The outward condition of these islanders has been marvellously improved since the introduction of hristianity. The soil is better cultivated, waste lands have been reclaimed, numerous places once sacred to the gods are now planted for the good of mortals... [Gill, W.W. 1876a: 15]

This supports the oral evidence given below that once there were uncultivated wooded areas between settlements, although these were cultivated under missionary influence. In addition, some areas once considered *tapu* were no longer held in awe and were thus exploitable. However, oral tradition suggests this may have been a very gradual process (see below).

Many scholars have quoted John Williams' extravagant portrait of the agrarian landscape of Rarotonga without looking at the context of the quote. Firstly, Williams was describing one particular scene and not the entire island as is often taken to be the case - he was merely stating that the island was `in a high state of cultivation' and gave an example:

One valuable peculiarity of this lovely island is, the extent of its low land. In many of the Islands, the mountains approach so near to the sea as to leave but little arable land; but this is not, to my recollection, the case in any part of Rarotonga. Its soil also must be exceedingly rich, or the climate peculiarly adapted to the fruits which grow there; for on our arrival, we were astonished to see the *taro* and *kape*, the *ti* and sugar cane growing luxuriantly nearly down to the edge of the sea. The whole island was also in a high state of cultivation, and I do not recollect having witnessed any thing more beautiful than the scene presented to me, when standing on the side of one of the hills, and looking towards the sea shore. [Williams, J. 1843: 205-206].

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23 Not to be confused with William Wyatt Gill (see below).

It is the scene from a hill behind that forms the basis for the well-known quote. Food swamps on Rarotonga stretch from near the mountainside to a coastal ridge of coral rubble or sand, hence gardens could stretch right to the coast. A `high state of cultivation' is not a precise description, and could be interpreted differently from how it has commonly been interpreted.

> In the first place, there are rows of superb chestnut trees, *inocarpus*, planted at equal distances, and stretching from the mountain's base to the sea, with a space between each row of about half a mile wide. This space is divided into small taro beds, which are dug four feet deep, and can be irrigated at pleasure. These average about half an acre each. The embankments round each bed are thrown up with a slope, leaving a flat surface upon the top of six or eight feet in width. The lowest parts are planted with taro, and the sides of the embankment with *kape* or gigantic taro, while on the top are placed, at regular intervals, small beautifully shaped bread-fruit-trees. The pea-green leaves of the taro, the extraordinary size and dark colour of the kape lining the sloping embankment, together with the stately bread-fruit trees on the top, present a contrast which produces the most pleasing effect. [Williams, J. 1843: 206-207].

The spacing of the rows of *Inocarpus* do not fit in with the scale of the swamp gardens today. Nor has any swamp on Rarotonga ever been large enough to take more than three rows even if the sides of the swamp were included as two rows. Clearly the description was written far away in time and space from the reality. One should not therefore take the measurements and details too literally. From the oral tradition mentioned below, taro was not necessarily grown every where on the lowlands. The context of this quote shows he is remembering one particular spot, no doubt the main station at Avarua. It does, however, give a broad impression of economy of space, cultivating as many different items in one area as possible.

Cultivation on the coastal plain presented a number of difficulties: lack of running water, drought, cyclones, flooding and tidal waves (Afsenius 1988a; 1988b; 1988c). For example, Buzacott describes the cyclone of December 1831 thus: `All the way inland was one sheet of water to the foot of the mountains' (Sunderland and Buzacott 1866: 86). Buzacott then explains the resulting problems:

> In a few days it was certain that not a breadfruit, or banana, or taro (wild arum) could be obtained by rich or poor, at any price...The taro, washed by salt water, began to wither and rot. Some few patches had been drenched by rain floods, and these remained, and became more precious than gold. [Sunderland and Buzacott 1866: 89].

The crops were badly affected by such conditions especially the taro, so it is not surprising that oral tradition (as presented below) stresses the importance of the valleys. That the valleys were cultivated is indicated by William Wyatt Gill who mentions the chestnut trees (*Inocarpus edulis*) at the top of the valleys:

> The whole island is clad with rich tropical verdure...primeval forest, with its many shades of green; immense chestnut trees, laden with fragrant blossoms, marking off the actual domain of man... [Gill, W.W. 1876a: 11].

On should note also the order of the crops mentioned by Buzacott above: breadfruit and banana <u>before</u> taro. William Wyatt Gill stated:

> The staple diet of the Rarotongans consists of bread-fruit (*Artocarpus incisa*[24]) and plantains. The bread-fruit harvest marks the arrival of summer, so that its name is a synonym for plenty. These islanders speak of `bread-fruit and winter', *i.e.* summer and winter. Plantains mostly grow in distant and almost inaccessible valleys whilst bread-fruit groves often surround their dwellings. When in season and no untoward gale has destroyed the young crop, an air of contentment rests upon the countenances of the islanders...Seven varieties of breadfruit are indigenous to Rarotonga...At Rarotonga the trees bear only once a year; at Aitutaki and some other islands twice or even thrice. [Gill, W.W. 1885: 175-176].

This is supported by a letter written by Charles Pitman, the missionary stationed at NgaTangi`ia, Rarotonga, in 1832 to the LMS:

> a most dreadful hurricane....destroyed also, nearly the whole of their breadfruit, + other trees on which they chiefly subsisted. Since which period the Natives have been obliged to seek their food in the mountains, + are forced to feed upon the roots of the Banana + ti trees. [Pitman 1832: 3-4].

Thompson (1900), a missionary who made a tour of LMS missionary stations in the Pacific Ocean, records that whereas Mangaia is famous for its taro and Aitutaki for its breadfruit, Rarotonga had always been noted for its plantains. Williams and Barff mention that

> August 20^{th}. Early in the morning took our leave of the People at Natagnia but they were at Arorangi on the 19^{th}, and travelled in land to Avarua, Mr Buzacott's Station. The Distance between the two stations we

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24 Known as *Artocarpus altilis* today.

supposed to be about eight miles through a countryside under cultivation almost all the way with Bananas, Mountain Plantains, & c. The soil appeared a fine rich clay all the way. [Williams and Barff 1830: 31].

On the other hand, sweet potatoes or kumara do not appear to have been cultivated according to Buzacott, though archaeological evidence from Mangaia suggests otherwise (Hather and Kirch 1991).

Mr. Buzacott found great difficulty from the strong prejudices of the people. Having procured at no small trouble, a quantity of sweet potatoes for planting, the natives refused to accept them and to plant them, declaring in true old tory fashion, that their fathers had managed to live without them, why could not they? [Sunderland and Buzacott 1866: 90].

Cultivation on the coastal plain appears to have taken place in the swamplands and along the *Ara Metua*

There is a good road round the island, which the natives call *ara medua*, or the parent path, both sides of which are lined with bananas and mountain plantains; and these, with the Barringtonia chestnut and other trees of wide spreading foliage, protect you from the rays of the tropical sun, and afford even in mid-day the luxury of cool, shady walks of several miles in length. The houses of the inhabitants were situated from ten to thirty yards or more from this pathway, and some of them were exceedingly pretty. The path leading up to the house was invariably strewed with white and black pebbles; and on either side were planted the tufted top *ti* tree or *dracaena*, which bears a chaste and beautiful blossom, interspersed alter-nately with the gigantic taro. Six or eight stone seats were ranged in front of the premises, by the side of the "parent pathway". [Williams, John 1843: p.207].

Also, together with Barff in 1830, he records that the stretch of road between Avarua and NgaTangi`ia was cultivated on both sides:

June 4 th. Visited, in company with Mr. Buzacott, Mr. Pitman's Station. The distance from one station to the other is about seven miles. The road is a tolerable good one in most Places and shaded from the sun by the branches of the spreading trees. The land on each side of the road was cultivated all the way. [Williams and Barff 1830: 5-6].

It could be that he is generalising from this area, as this is from archaeological evidence and oral tradition (see below) the more populous side of the island. Note `the branches of the spreading trees': this was not an open landscape.

However, this should not be taken to imply that the whole of this area, let alone the whole of the coastal plain, was continually under cultivation. Firstly, there were the contested areas between lineages; secondly, the swamp-lands are not as extensive as Williams claims, even allowing that the construction of the airport in the area of Nikao to Atupa in the 1970's reduced the size of the swampland in the area; and thirdly, between the area neighbouring the road and the coast, there is documentary evidence of coastal forest before the building of the *Ara Tapu*, the `Holy Road' of the missionaries, the main road used today.

at the end of the year the missionary Gill[25] arrived and shifted Matavera village to the coast because there was too much mud on the inland road. The sites for the houses were cleared together with the village road. The people of Avarua cleared [their section of the coastal road] until they reached Pue where they stopped .....Ta stopped us because he wanted it[26] left as shelter for his home. So we came back here to Ngatangiia. Pa said "Let's clear our area until it is in line with Matavera." *The east coast had been completed, but*[27] there was still Ta's [to be cleared] and Matavera still had to join on to Avarua, who had stopped at Pue. [Maretu 1983: 192].

So before 1857, there was no *Ara Tapu*, and there was clearly coastal forest in abundance. The road was then completed by William Wyatt Gill, missionary at Avarua, Rarotonga, formerly stationed on Mangaia, after 1860:

Wyatt Gill and some other missionaries had come. George Gill and some friends [Cook Islands missionaries] had sailed for the heathen lands[28]....Wyatt Gill then completed the new road, clearing from Pue to Matavera. He then went to see Ta to ask his permission. Ta thereupon cleared his section. [Maretu 1983: 192-193].

This does not include from NgaTangi`ia to Avarua via Arorangi, which must have been even later therefore. The fact that Maretu does not discuss this may reflect his greater personal interest in the eastern side, though it may also reflect the lower population and thus interest paid generally in the western side. William Wyatt Gill (1876b: 138) mentions in recording the story of the origins of pigs on Rarotonga a `dense ironwood forest, not far from the beautiful white sandy beach of Nikao', which supports the idea of the existence of such coastal forest on the eastern side of Rarotonga too.

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25 George Gill, was the missionary at Avarua between 1857 and 1860. From Maretu's narrative, this appears to be late 1857.

26 I.e., the bush.

27 Connecting italics inserted by author (C.Peters).

28 This would put the date at 1860.

The population of Rarotonga was put at between 6 and 7000 people by Williams (1843), which is obviously an estimation having such a wide margin of potential error. The first figure that appears to have a more accurate basis is that of December 1843, when the population was 3,300 (William Gill 1856: 72). This was after diseases had reduced the population, so the population when the missionaries arrived would have been greater. However, it should be borne in mind that despite Williams' claim to have converted the entire population (1843), the missio-naries may well have brought in some degree of guess-work into their figures as some sections of the population were not converted (*cf.* Pitman 1827-842; Utanga pers. comm. 1992). The round figure of 3,300 might suggest this too. Estimates erring on the generous side would have been more impressive for the LMS board of directors back in London.

Williams' figure of 6 or 7,000 may be rather large, especially when one considers the hyperbole used in his description of the size of the taro swamps (Williams, J. 1843: 205-207). Williams was writing to impress and persuade not to provide an accurate scientific account. His idea, that `the richest soil on the island would have been found on the Arorangi to Avarua side' (Williams and Barff 1830: 31), shows that his knowledge of the island was also not good (*cf.* Leslie 1980 for information on soils).

The idea that Polynesian rats (*Rattus exulans)* may have been a factor in altering the ecology of the island (because in significant numbers they can extirpate other animals and consume plant seeds and seedlings) certainly receives support from missionary accounts - for example:

> When we arrived on the island, it was literally filled with rats. Often have we counted droves of fifty at a time come into our room while at meals. [Pitman 1833: 3].

William Gill (1856) states that pigs and poultry were eaten on festive occasions. Williams (1843) believed that pigs were not that common, but it is apparent from Maretu (1983) that the Rarotongans had hidden them in case the missiona ries wished take them away, because the Tahitian pastors had led them to believe that as part of a ploy to hold on to more power. Some animals were even more restricted with regard to who was entitled to eat them:

> All turtle were formerly sacred, being eaten only by kings and priests. It is quite otherwise now (except at Rarotonga, &c.). [William Wyatt Gill 1885: 128].

Cash crops or at least barter crops were started early under missionary influence. Buzacott (Sunderland and Buzacott 1866) claimed to have introduced the kumara as a crop for trade (probably new varieties). William Gill (1856) describes how cotton was grown from the 1830's onwards and coffee was established at least by 1852. William Wyatt Gill (1876a) mentions the growing of coffee `plantations' under the shade of coconut trees.

Europeans had already introduced several other crops by the 1830's. Daniel Wheeler, a Quaker minister who visited Rarotonga in 1836, described the lowlands of Rarotonga thus:

> These districts team with bread-fruit, plantains, bananas, citrons, limes, vis, papaws [*sic*], taro, sweet potatoe [*sic*], sugar-cane, cocoanuts, palms, and many other tropical productions of majestic growth. [Wheeler 1842: 776].

Wheeler (1842: 544) also mentioned that Alexander Cunningham, a trader, had set up a sugar cane plantation on Rarotonga by 1836, so capitalism had taken root relatively rapidly.

6.1.2 *Oral Tradition, Living Memory and later documentary records*

Recorded oral tradition and living memory provides evidence as to the former landscape, some of it reinforcing the missionary records. The following discussion deals with each part of the landscape separately: valleys, coastal plain, coast, marine and lagoon resources.

List of informants:
Kiriau Maoate (Turepu), Totoko`itu Research Station, and also a *Mata`iapo* of Takitumu.
George Cowan, Minister of Public Works, Rarotonga.
George Tara`are, Dept. of Agriculture, Rarotonga, and also a *Tumu Korero* for Matavera.
William Hosking, Minister of Agriculture, Rarotonga.
Anthony Utanga, Dept. of Marine Resources, Rarotonga.
Alamein Vakapora, a *Mata`iapo* of Tupapa, Rarotonga.
Teariki Rongo, Minister of Conservation, Rarotonga.
Ngatoko Ngatoko, Dept. of Agriculture, Rarotonga.
Gerald McCormack, Cook Islands Heritage Trust, Primeminister's office, Rarotonga.
Stuart Kingan, resident of Tupapa, and former civilservant.
Sir Thomas Davis, former Primeminister of the Cook Islands and writer, Rarotonga.
Rangi Moeka`a, Dept. of Education, Rarotonga.
Inatio `Akaruru, Deputy Primeminister of the Cook Islands, Rarotonga.

Valleys:

The settlement of the valleys is evidenced in the ancient chants, which refer to the valleys being full of "sounds and noises" - i.e. human activity. The tracks up to the mountains were also ancient to post look-outs to watch out for raiders coming over the ridges from other areas (Moeka`a pers. comm. 31/08/92). Some archaeological structures on Raemaru and the upper Maungaroa Valley have been suggested as look-outs (Bellwood 1978: 38 and 40 respectively).

The valleys were used up until fairly recent times on a much greater scale than is now seen. There were the banana plantations, though, through the influence of European traders, these were used for cash cropping. Scott (1991: 41) and Gilson (1980: 39-40, 52-53, 79-80) discuss the early export industry in produce in the 19th century and early 20th century to Auckland, Tahiti, California and Samoa. Some European merchants regarded the islands in the Cook group as their own personal empires (Scott 1991).

Johnston (1959) suggested that the inland forest had had larger trees removed for building material and boxwood, and many spurs supported only low fernland due to continued burning and accelerated soil wash. According to Johnston, until a decade before his article, the gentler slopes on the sides of the inland valleys were major banana-producing areas.

Banana leaves were also important (though *Musa paradisica* or the `Cavendish Banana' was a missionary introduction - see below). *Rau meika*, the green banana leaf, made useful platters if passed over a fire as this process prevented the leaf splitting. *Rau uru*, the dry dead leaf of the banana, was used as mulch in the food swamps (Cowan pers. comm. 30/08/92).

Huge orange trees used to be found up in the valleys: As a boy Utanga was sent to pick the fruit from them (Utanga pers. comm. 10/08/92). Maretu (1983) related that the Bounty brought them. Wild oranges occurred on Rarotonga, Miti`aro, Mangaia, Atiu and Ma`uke. In the 1960's, terraces were created at Muri for attempts at producing pineapples (Hosking pers. comm. 6/08/92).

Kava also was still planted up the valleys this century for medicinal purposes, right up the top of the stream valleys among the boulders and the *`au* thickets. Utanga recalled that as a boy, he was sent to harvest the kava (perhaps because the missionaries had disapproved (*cf.* Gilson 1980), people used this as a device to hide it - author's suggestion). It is planted today as well, though not up in that locality any more - i.e. the valleys (Utanga pers. comm. 10/08/92).

One introduction was not so useful: the mile-a-minute vine, introduced by the American troops during the Second World War, has proved a pest (Hosking pers. comm. 6/08/92).

Trackways, now used by tourists wishing to observe Rarotonga's natural scenery, were and are important to Rarotongans, themselves. The Cross-Island Track, the most well-known of these routes, was an ancient trackway, though the original route is not exactly the same track as used today (this was created in the 1970's). The original track went up the Avatiu Valley as at present, but instead of heading up the left-hand ridge after the village at the back of the valley and going down the Papua Valley, one had to take the right-hand ridge and cross over to the Rutaki Valley, passing Te Rua Manga on the left (Utanga pers. comm. 31/08/92; Rongo pers. comm. 31/08/92).

Savage (1962), who used Te Ariki Tara`are as his source, records that people used to climb up Oro`enga, the small mountain by Karekare swamp, to collect the feathers of certain birds, which nest there, to adorn chiefly headdresses. The descendant of Te Ariki Tara`are, George Tara`are (pers. comm. 7/08/92), informed the author that *rakoa* (*Phaethon lepturus*) and *tavake* (*Phaethon rubricauda*) nested on Oro`enga in small holes in the rock.

Evidence for any clearance of mountain forest is lacking (*cf.* Ch4). The forest appears to be primary on the mountains themselves, but not in the valleys, because, for example, there is the presence of *`au* (*Hibiscus tiliaceus*) thickets and coconut trees planted at the end of the valleys sometimes (McCormack pers. comm. 1992). Also, one can observe abandoned taro pondfields at the back of some valleys like the Tupapa Valley, just below the zone with *Inocarpus edulis* trees and *Alocasia macrorrhiza* (Afsenius 1988c and personal observation). The theory of David Todd, a contract botanist, is that the *Homalium* were coppiced. There is evidence according to Todd at one place where a *Homalium* patch is divided by a fence: on one side all the *Homalium* have a single trunk, and on the other they have several trunks (McCormack pers. comm. 1992).

On some of the lower ridges of the mountains there are fernlands. Fernlands have a long history, for instance, there is Cook's description of Mangaia with ferns and *Casuarina* (Beaglehole 1967).

The slope immediately behind Karekare swamp was planted (see below) - Tara`are pers. comm. 7/08/92 - so some lower slopes may have been utilised.

On the south side of the island, there is the long gentle slope of the terrace, composed of lateritic soil, from the base of the mountain to the thin strip of swamp, which is only partially utilised. On the other side of the swamp is a well-sorted coral sand zone which extends to the beach (Author's field notes 9/08/92).

Coastal plain:

The *Taura `oire* led people to move from valleys to the coast. Some people were without land on the coast, so the law made provision for all to have access to a house site on the coast (Crocombe 1961; Gilson 1980). The laws of 1906/7 and

1915 governing the operation of the land court encouraged the further development of the coastal plain for agriculture (Crocombe 1961; Gilson 1980).

Not all areas were even then cultivated. The area around Tuoro (Black Rock) was avoided by the generation before Moeka`a because of fears engendered by its association in the pre-Christian religion with the departure of the spirits of the deceased for `Avaiki (the land of the ancestors) from a *Pu Pua* tree (*Fagraea berteriana*) that grew there. Other areas included the Paringaru stream, Tikioki, and Mimiti o Apara[29] (an area extending from the bend in the *Ara Tapu* south of the Education Department to Matavera - this included Karekare). These were wild tracts between the cultivated and settled village lands. Until about 20-30 years ago, there were still clear boundaries between the villages which have now largely disappeared under expanded settlement. In the south, there were larger boundaries between the settlements (Moeka`a pers. comm. 10/08/92).

It could be argued that this was due to later regeneration of the vegetation after the population decline during the nineteenth century, but the accounts of the missionaries mentioned above (pp.130-131 and 134-135) suggest that such wild tracts existed at the time of initial European contacts too.

There was less settlement on the south coast between Arorangi and Titikaveka, because the *tapere* in between were disputed territory between the *vaka* and they might be lost through warfare (*cf.* Crocombe 1961; Maoate pers. comm. 31/08/93; *cf.* Maretu 1983). There are less attractive marine resources in the area too (Maoate pers. comm. 31/08/93). The idea of a lack of settlement between Titikaveka and Arorangi may also in part be due to the fact that that is where the European growers had their plantations - for example, Hosking, McKegg, Wigmore and Smith (Cowan pers. comm. 30/08/92; Scott 1991).

Another area with a lack of settlement was the area around Karekare swamp. People considered the Karekare area to be haunted by ghosts up until the 1970's. It was still covered in bush until the 1970's and 1980's (Utanga pers. comm. 5/08/92).

Coastal swamps were used as food gardens, though there a number of problems connected with coastal agriculture. The flooding and hurricanes on the coastal plain, which would have put people off settling there in the first place (Cowan pers. comm. 30/08/92), were a hazard for crops too. Examples of this are the tidal waves of 1835 and the 1840's mentioned by the missionary Buzacott (Sunderland and Buzacott 1866).

Karekare swamp had problems with freshwater flooding and saltwater tidal waves not draining away for months, which made it difficult to grow taro. Atoll taro or *puraka* was grown as the main crop instead (Tara`are pers. comm. 30/08/92). Other areas have similar problems, for example, Puaikura has had drainage difficulties associated with lowlying areas affected by flooding (Jonassen 1979)

Other useful plants could be grown on swamps too. *Mata* (*Paspalum orbiculare*) grew naturally on swampland in uncultivated areas. Areas were set aside to permit its growth. *Mata* was used to cover the *kirikiri* flooring in houses to provide a soft surface. Later, it was used to stuff mattresses. It was replaced by the introduction of kapok/*mamau*, which in turn was replaced by artificial foam mattresses purchased in the shops. People used to mulch the taro patches with *mata* as well (Cowan pers. comm. 30/08/92).

Mauku (*Mariscus javanicus*[30]), a sedge, was used as a coconut strainer. Its stalks were scraped and beaten out in order to extract the white fibres. *Puru* (coconut husk) was used only in the bush as a makeshift alternative, because it stains the coconut cream a brownish grey. Cook Islanders preferred the *mauku* because it was cleaner. It was used to strain juices out of other plants - for making *vairakau* or traditional medicines in particular. It has been replaced in more recent times with store-bought muslin cloth. *Mauku* was also permitted to grow on the swamps. Both *mata* and *mauku* are still used on the outer islands, but on Rarotonga, only the old people still remember (Cowan pers. comm. 30/08/92).

*I`i*/Tahitian chestnut (*Inocarpus edulis*), *ava*/banyan (*Ficus prolixa*), and *kuru*/breadfruit (*Artocarpus altilis*) were all planted as boundary markers and wind-breaks (Crocombe 1961; Moeka`a pers. comm. 10/08/93).

Plantations of coconut were also useful. Some coconut trees grew at the back of Karekare swamp up to the 1940's (see below). *Kkau* or coconut leaf was a major source of raw material for thatching and basketry (Cowan pers. comm. 30/08/92; Buck 1944).

Much land was in the hands of the European growers (though not through outright ownership, but via long-term leases). Supplies of tropical fruit (and cotton up to the 1890's) were exported to Sydney and Auckland. Wood was also need for the fires to prepare whale oil and blubber, and food was required to feed the whalers and merchants that passed through (*cf.* Gilson 1980; *cf.* Scott 1991). Rarotonga also had a thriving citrus industry until the mid 1970's (Cowan pers. comm. 30/08/92).

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[29] The original boundaries of Takitumu stretched from the Paradise Inn to the Sheraton. Takitumu was envisaged like a fish with its head (Mimiti o Apara) between the Paradise Inn and Matavera, its stomach at NgaTangi`ia and its tail between Titikaveka and the Sheraton (Moeka`a pers. comm. 10/08/92). Alternatively, it was seen as a canoe (`Te Vaka Ta`unga' – Crocombe, M.T. 1979).

[30] See Whistler (1990) and list in Appendix A.5.

A certain number of the alterations to Rarotonga's natural landscape are recent and not ancient ones. Jim Allinson (1991) showed that the greatest threat to the conservation of Rarotonga's natural resources has been and is urban development as population increases, not so much from internal growth as from returners from New Zealand and Australia, and to a lesser extent from immigration of Outer Islanders (Cook Islanders not from Rarotonga). As a side effect of this escalated population, there has been and is more pressure to use up land so that the new-comers can earn a living. However, a large proportion of the community were employed by the government and the tourist industry, and many people consumed imported foods, so housing was the most extreme threat (Allinson 1991).

Population figures given by the missionaries for the time of their first contact with Rarotonga may well be flawed. John Williams would not necessarily have had access to all the population from which to make his estimate. There were probably still significant portions of the population who were still heathen, even though Williams claims to have converted the whole population (Williams 1843). For example, Utanga's great grandfather died in the early years of this century still a heathen. This was apparently not an isolated example (Utanga pers. comm. 31/08/92). Missionary figures are therefore likely to be estimates, not precise numbers. Indeed, Williams states the population to have been 6 or 7,000 (Williams 1843). If Williams' descriptions of cultivation are anything to go by, he probably was extrapolating from the richest areas of the island where he spent most of his time, and was not including areas like the southernmost *tapere* which appear to have been occupied by heathens (see above).

Another more recent problem, has been the introduction of pests like the Mile-a-minute vine introduced by the American troops during the Second World War (Hosking pers. comm. 7/08/92).

Davis does not believe the *Manu kura* (*Vini kuhlii)* - see section 4.3 - to have become extinct until it ceased to be *tapu*. *Tapu* and *ra`ui* were tools of chiefly resource management. Red lorikeet feathers were used for chiefly costumes (*cf.* Buck 1944; Davis 1992), and their over-exploitation may have been prevented by chiefs placing a *tapu* on them. Any trade in feathers would not have overly affected them as the feathers could only be used by chiefs, the chiefs also would be the only people likely to be able to afford to travel. Once *tapu* was removed, the bird would not have lasted long (Davis pers. comm. 29/08/92).

On Mangaia, there has been the question of how ancient the problem of erosion off the central volcanic hills into the taro swamps has been and whether there had been any local attempt at conservation (Kirch *et al.* 1991; 1992). Rongo noticed that stakes of coconut wood were placed on the side of the hills as silt traps. This was also the case in the streams. Local people told him that this was traditional practice, but that it was no longer as effective as it had been in the past, because of slope cultivation for the pineapples. The siltation has started to block the water outlets through the makatea to the sea, and has made the swamp land closest to the makatea unusable (Rongo pers. comm. 10/08/92).

Coast:

The coastal vegetation used to be, until recent times, mostly *`utu* (*Barringtonia*), *puka* (*Hernandia nymphaeifolia*) and *`oronga* (*Pipturus*), with some *`ara ta`a tai* (*Pandanus*) areas. A great expansion in building has also contributed a substantial amount to the disappearance of much of this vegetation (Cowan pers. comm. 30/08/92).

50 years ago, *`ara ta`a tai* (*Pandanus*) was a common shoreline plant, but then a blight affected them (`Akaruru pers. comm. 6/08/92). The *Pandanus* problem was confirmed by Cowan (pers. comm. 10/08/92).

Pandanus stands were affected by a white mealy bug about 50 years ago. Before then, it was a common shore plant (Tara`are pers. comm. 7/08/92). In the early 1940's, the *Pandanus* had already been hit badly by the blight, although there were still plenty between Avatiu and Arorangi. In the earlier part of this century, there used to be inland plantations of *Pandanus*. About 10-15 years ago, there was still the odd patch left. There were some patches in the area of the present Education and Conservation departments. Coconut crabs were much more common then, as the *Pandanus* scrub was where they lived - underneath the aerial roots (Moeka`a pers. comm. 10/08/92).

Documentary sources provided to me by McCormack contributed some additional data for elucidating the story. The mealy bug - *Pseudococcus pandanii* - was preyed upon by a ladybird, so did not present a problem in 1913 (Reid 1914). However, Dumbelton reported a problem occurring in the period 1926-1930, caused by a *Pseudococcus* species (Dumbelton 1950).

The *Pandanus* grew on either side of the *Ara Tapu*, not just on the shore. For example, at Kingan's house in Tupapa (on the coral rubble ridge at the edge of Karekare swamp), there were many *Pandanus* growing on the shore, and at Kiikii, there were *Pandanus* thickets on either side of the road (Utanga pers. comm. 10/08/92).

Pandanus posts were used for temporary dwellings associated with fishing on the shore. The thatching was made from *k kau* (coconut leaf). The coast was bushy, and was reached by means of paths coming down from the *Ara Metua* (Tara`are pers. comm. 7/08/92).

A *Barringtonia* canopy used to exist along the roadside, with trees planted on either side of the road for shade and as wind-breaks. This was because long journeys were made on foot in the full glare of the sun before the advent of the car -