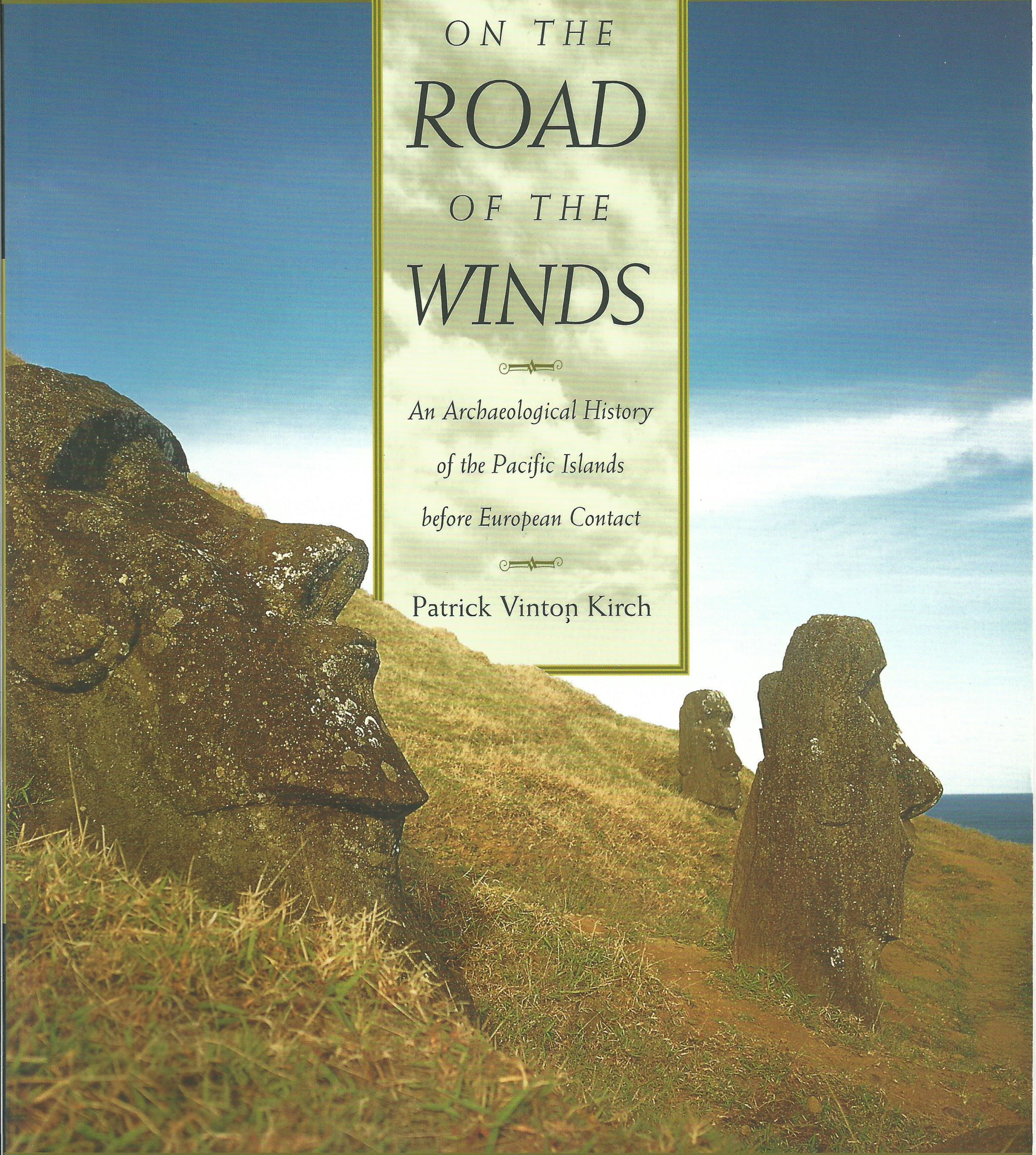

ON THE ROAD OF THE WINDS

An Archaeological History of the Pacific Islands before European Contact

Patrick Vinton Kirch

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AN ARCHAEOLOGICAL HISTORY OF THE PACIFIC ISLANDS BEFORE EUROPEAN CONTACT

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Frontispiece: Restored *Moai* (statue) on Rapa Nui, with replicated obsidian and coral eyes (Photo by Thérèse Babineau.)

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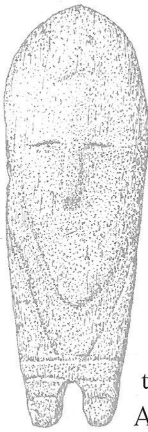
CHAPTER 2

The Pacific Islands as a Human Environment

In no other ocean has it been as difficult for a bit of land to be entirely surrounded by water. In no other has it been as difficult for a piece of the earth's crust to raise its head above the water to become an island. The wonder is not that most islands are small and scattered but that there are so many of them, for the Pacific Ocean contains more islands than all the rest of the world's oceans combined.

Thomas (1963:7)



One of the great joys of a life's work in Pacific archaeology must be the fascination of visiting, exploring, and simply spending time on a myriad of environmentally and ecologically diverse islands. In my own experience these have included tiny and isolated Anuta, which is less than a square kilometer in land area and just 80 meters high, yet the permanent home of about 160 Polynesians; the semi-atoll formed by Eloaua and Emananus, whose reefs and lagoon harbor an almost indescribable array of marine life; Mangaia, with its fortresslike escarpment of upraised pinnacle karst encompassing an ancient, highly eroded volcano; the vast, elongated island of New Caledonia, its ancient rocks and metallic soils a remnant of archaic Gondwanaland; and Moloka'i, whose majestic windward cliffs rise 1,200 meters sheer from the sea, gapped by lush amphitheater-headed valleys with hundreds of waterfalls cascading down their slopes (Fig. 2.1). The contrasts inherent in just these five examples testify to an amazing diversity of Pacific island environments. Such contrasts stem from varied geological origins that have raised islands from the oceanic depths, from different ages, from the varied work of wind and water on landforms, and from biological processes of dispersal, colonization, and evolution that have cloaked Pacific islands in a rich flora and fauna, distinct from those of continents.

In spite of tremendous diversity, some patterns and processes are common to all oceanic islands. Islands can be classified into several major geological types, and important biogeographic trends across the Pacific account for much of the varia-

FIGURE 2.1 Dramatic sea cliffs along the windward coast of Moloka'i were created by massive landslides. Deep amphitheater-headed valleys slice into the central mountain range. (Photo by P. V. Kirch.)

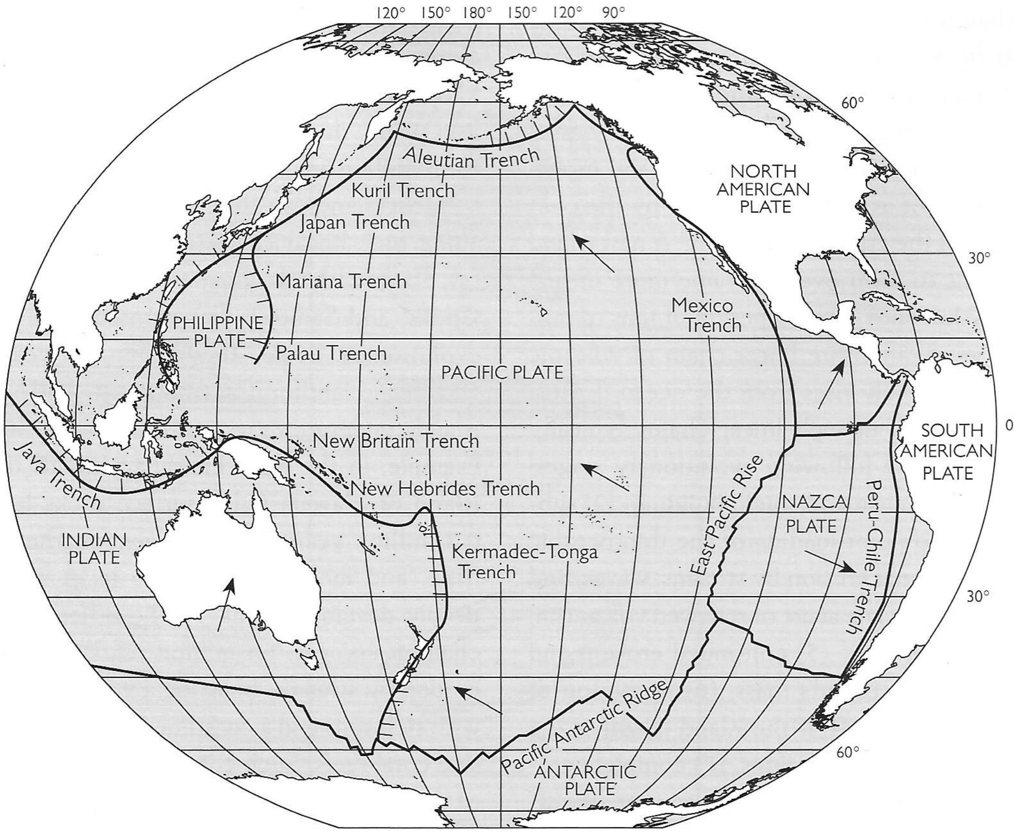
tion in island biota. In this chapter I review these patterns, trends, and processes, providing a background for understanding the human settlement of the Pacific. The story of the movement of *Homo sapiens,* first out onto the larger islands and archipelagoes of Near Oceania, then in more recent times into the vast reaches of Remote Oceania, eventually to discover virtually every habitable speck of land, cannot be fully appreciated without some understanding of these key environmental variables. Winds and currents, along with island distances, have influenced the development of navigational methods and seafaring skills. Limitations in natural plant and animal foods helped to shape the subsistence economies of Pacific peoples, and variations in soil, rainfall, and climate necessitated adaptations to their horticultural practices. The availability or absence of natural materials—basalt, chert, obsidian, shell, plant fibers, and the like—played a role in the development of material culture. None of this is to say that the lifeways or culture of Pacific islanders, any more than that of other peoples, was "determined" by their natural environments. On the contrary, humans everywhere actively modify and shape their world, yet they do so within certain constraints—and sometimes challenges—posed by the environments they inhabit. Moreover, in the islands of Remote Oceania, many of which were biologically isolated before the coming of humans, the advent of people often had a dramatic effect on the island ecosystems themselves. Thus the study of the Pacific islands as an environment for humans does not consist merely in the cataloging of a static "stage set" for the grand cultural play. The setting itself is dynamic through both time and space, and a great deal of this dynamism has been driven by the actions of men and women acting out their lives, making their choices on a daily basis, cumulatively over the centuries.

Origins and Development of Pacific Islands

The geological origins of the Pacific islands mystified scientists of the nineteenth and early twentieth centuries. The possibility that a great Pacific continent had formerly existed, only to sink beneath the sea, was entertained by various scholars and provided the basis for one of the more bizarre theories on the origins of Pacific peoples.[1] The theory of plate tectonics is surely one of the great triumphs of later twentieth-century science, revealing that the earth's crust consists of shifting plates separated by boundaries, themselves variously zones of spreading or of subduction.[2] Along the spreading zones, outpourings of magma constantly create new crust, especially along the East Pacific Rise. At the subduction zones, one plate downthrusts beneath another, and the oceanic crust plunges to great depths to be reabsorbed into the earth's mantle, and partly to reappear as molten lava on the surface through island-arc volcanism, such as along the Kermadec-Tonga Trench.

A tectonic map (Map 3) reveals that the center of the Pacific basin consists of a vast crustal sheet, the Pacific Plate. Originating along its eastern margin, the Pacific Plate extends from the Pacific-Antarctic Ridge up through the East Pacific Rise (on which Easter Island sits) and follows the western coast of North America. As new oceanic crust is continually created along this lineament, the Pacific Plate ever so slowly yet relentlessly moves toward the northwest (arrows on Map 3). At its western margins the Pacific Plate is "consumed" by being downthrust into a complex series of subduction zones, marked by deep oceanic trenches. These include the Kermadec-Tonga Trench, the New Britain Trench, the Palau Trench, the Mariana Trench (notable for having the deepest spot in the earth's oceans), the Japan and Kuril Trenches, and the Aleutian Trench. The sinuous line formed by these trenches has long been known as the "Andesite Line" because the rocks found in islands to the west are predominantly andesitic, whereas islands on the Pacific Plate are dominated by basaltic lavas. To the west of these trenches lies not just one plate, but a maze of interlocking smaller plates.

Strings of island-arcs define the western margins of the Pacific Plate, formed by a characteristic kind of volcanic activity. As geographer Patrick Nunn describes the process, "The magma involved in island-arc volcanism derives from melting of subducted ocean crust. . . . The melting of the crust is the consequence of being heated through burial and from friction along the contact with the buoyant plate" (1994:34). Such plate margin volcanism has formed the extensive Tonga, Vanuatu, and Solomon archipelagoes. The complex geological history of island-arcs can include successive stages of active volcanism, erosion, subsidence, and formation of marine limestones and



MAP 3 A tectonic map of the Pacific basin. The heavy lines indicate major plate boundaries, and the general directions of plate movement are indicated by the arrows. (Adapted from Oliver 1989.)

other sedimentary deposits, producing islands with complex structures of volcanic, meta-volcanic, and sedimentary rocks.

The western margin of the Pacific also incorporates plate fragments derived from the ancient supercontinent of Gondwana, which began to break apart 100 million years ago. New Caledonia is one such Gondwanaland fragment, parts of New Zealand another; both broke off from Australia about 80 million years ago and began a slow, isolating drift to the east. Their origins in the ancient southern supercontinent account for unique aspects of the biota of these islands, such as archaic conifer trees and many species of large geckos on New Caledonia.[3] New Guinea too has a highly complex geological history—also reflecting its Gondwanaland origins—and includes rocks ranging in age from Cambrian or even older formations, up to recent Pleistocene volcanics (Brookfield and Hart 1971:26–29).

Pacific Plate islands have a different origin mechanism from those of island-arcs. These mid-plate or intraplate islands typically originate from a "hot spot" or thermal plume of magma arising from deep in the mantle. Such hot spots are stationary within the mantle, and thus the slowly migrating lithosphere of the Pacific Plate gradually moves over them.[4] This movement is sufficiently slow that there is time for new islands to be created by successive eruptions and extrusions of lava beginning with a rupture on the sea floor, piling up a volcanic mass that eventually rises above the ocean. In time, the new island moves off the hot spot as it is carried along by the conveyor belt of the crustal lithosphere. A new island then begins to form over the same more or less stationary hot spot. Over a period of tens of millions of years, an entire linear chain of volcanic islands successively rises from the ocean depths. Midplate islands in such linear chains typically pass through the following evolutionary stages: (1) initial volcanism and shield building; (2) subsidence due to point-loading of the thin oceanic crust; (3) subaerial erosion by streams, waves, and wind; (4) often, a late stage of renewed volcanism, typically pyroclastic; (5) continued erosion and reduction of the island's mass; (6) formation of extensive coastal reefs, if the island is within the tropical to subtropical regions; (7) complete erosion and subsidence of the volcanic cone, resulting in the formation of a coral atoll; and (8) eventual drowning of the island, forming a submerged seamount.

The textbook example of such a midplate linear island chain is the Hawaiian-Emperor Archipelago, extending from the island of Hawai'i (where the originating hot spot is located), up through the main "high" volcanic islands such as O'ahu, and continuing through the remnant volcanic pinnacles and coral atolls of the Northwestern Hawaiian chain, and finally with the submerged Emperor seamounts that end in Meiji Seamount, a total distance of 3,942 kilometers.[5] The Hawaiian chain is continually being created by the stationary magma plume situated in the southeast (where a new island, named Loihi, is being constructed today off the coast of Hawai'i), and eventually its submerged islands end their evolutionary cycle with subduction into the Kuril Trench. Based on potassium-argon dating of islands along this lineament, the entire life cycle of a Hawaiian island takes something like 75–80 million years, during which perhaps only the first 8–15 million are above water.

Most islands on the Pacific Plate are oriented along such linear chains, including the Marquesas, Society Islands, Tuamotus, Australs–Southern Cooks, and Samoa.[6] As a consequence of their evolutionary cycle, the degree of weathering and hence landform development that midplate islands undergo varies with geological age. For example, in the main Hawaiian Islands the new island of Hawai'i (with surface rocks less than 0.3 million years old) has been weathered very little, and most of its surface lacks streams or deeply developed soils. At the other end of the chain, Kaua'i (ca. 5.1 million years old) is deeply eroded by streams, boasting a valley topography with rich soils and a coastline protected by extensive coral reefs. Such contrasting landforms were of great consequence to colonizing Oceanic peoples who, with their horticultural subsistence economy, preferred environments with ample water and good soils, as well as developed reefs and lagoons in which they could fish. This environmental gradient played an important role in the political dynamics of the late prehistoric Hawaiian chiefdoms (see Chapter 8). The Oceanic peoples themselves were keen observers of geological differences between islands, and they had their own folk theories about island origins. The Hawaiians, for example, clearly recognized that their archipelago had originated progressively from the southeast, the abode of the volcano goddess Pele. The marvelous Pele-Hi'iaka cycle of Hawaiian mythology (Beckwith 1970) explicitly refers to Pele moving her home from Kaua'i successively to the other islands, to end up at her present residence in the crater of Halemaumau on Hawai'i.[7]

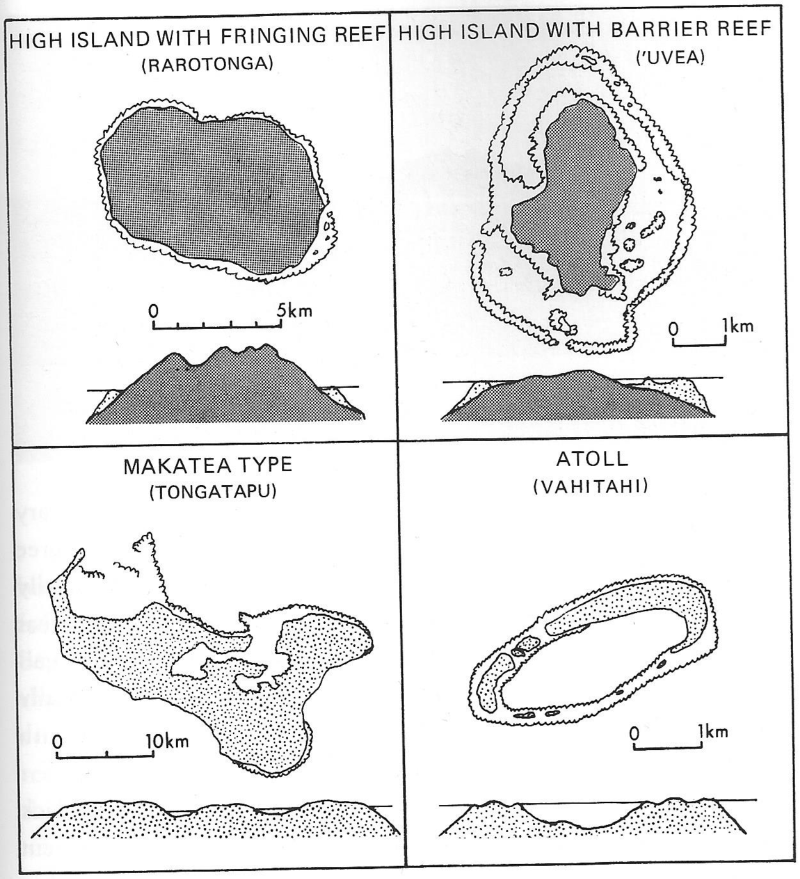


FIGURE 2.2 Examples of the principal geological types of islands. (After Kirch 1984a.)

Types of Islands

Different geological origins of island-arc and midplate islands provide one basis for classifying Pacific islands; another important variable is that of changes in an island's landform resulting from submergence and the formation of coral reefs, or by later emergence of reefs. Geographers (e.g., Thomas 1963) have long used a simple four-part classification of Pacific islands that is extremely useful for understanding the varied island environments to which Pacific peoples adapted. The four island types are: (1) island-arc islands, formerly referred to as "continental" islands; (2) high islands of midplate hot spot origin; (3) coral atolls, formed on volcanic masses that have subsided beneath the ocean's surface; and (4) makatea islands, in which coral atoll or reef formations have been uplifted or have emerged through tectonic activity. The last three types of islands are illustrated in Figure 2.2. This handy classification will be used throughout this book, and the key features of each island "type" are succinctly discussed here.

Island-Arc Islands Formerly labeled "continental" islands because they sometimes incorporate ancient continental rocks, island-arc islands are among the largest islands in the Pacific, concentrated along the western margins of the Pacific basin.[8]

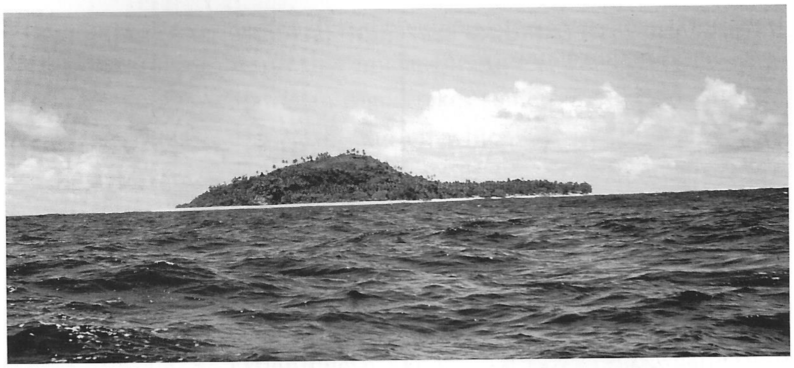


FIGURE 2.3 Anuta Island in the southeastern Solomons group is one of the smaller high islands in the Pacific, but nevertheless home to about 160 Polynesians. (Photo by P. V. Kirch.)

They include New Britain and New Ireland of the Bismarck Archipelago, the Solomon Islands, Vanuatu (formerly the New Hebrides), New Caledonia, Fiji, and New Zealand. Often large in scale, such islands exhibit varied habitats. On large islands such as New Britain, one finds interior-dwelling peoples who have no direct experience of the coast or the sea, although they trade with coastal populations. Because of their complex geological histories, these islands offer a wider range of lithic resources utilized by ancient Pacific peoples to manufacture stone tools. Rhyolite, dacite, various metavolcanic rocks, chert, and in certain locations high-quality obsidian are to be found in such island-arc locations.[9]

High Islands High islands are islands of midplate hot spot origin still in the earlier stages of their evolutionary cycle, before subsidence and erosion have done their work. They will eventually sink beneath the ocean surface to become atolls or seamounts. Tahiti, Rarotonga, Tutuila, and Pohnpei are typical examples of high islands. Most high islands consist of basalt, a hard, dense stone extensively used by Pacific peoples to make adzes and other implements. These islands range considerably in size, from Hawai'i at 10,458 square kilometers down to diminutive Anuta, only 0.8 square kilometer in land area (Fig. 2.3). They also vary greatly in landform, depending to a large degree on age and hence extent of erosion. Geologically younger islands often lack watercourses, whereas older islands are deeply dissected by stream valleys. Some high islands, such as ethnographically famous Tikopia, consist of volcanic cones with lakes in their exploded craters.

When they are still young, high islands lack developed coral reefs and typically have wave-cut cliffs along their shorelines. In time, reefs develop along the shores of high islands, first as fringing reefs and later, as the island continues to subside, in the form of barrier reefs separated from the main island by a lagoon (Fig. 2.4). However, coral reefs are confined to the tropical and subtropical waters, because reef-building corals will not grow north or south of about 24° latitude. Gaps in the reef exist wherever there is substantial freshwater runoff, as at the mouths of large stream valleys.

Atolls The stages in the formation of a coral atoll were originally worked out by Charles Darwin (1842), although he failed to account for the underlying geological mechanism of subsidence, now explained by plate tectonics. As islands migrate westward on the relentlessly moving Pacific Plate, they gradually subside and, in com-

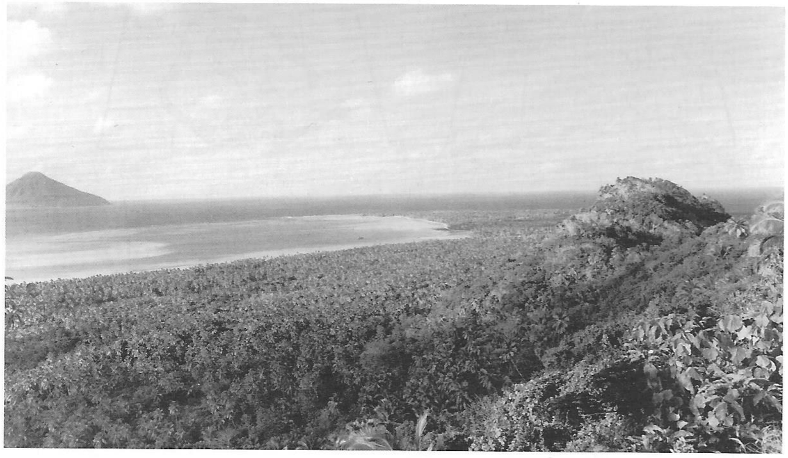


FIGURE 2.4 The high island of Niuatoputapu in the northern Tongan group is surrounded by an extensive barrier reef and lagoon. In the distance looms Tafahi Island, a young volcanic cone lacking reefs. (Photo by P. V. Kirch.)

bination with the erosion of their subaerial surfaces by wind and water, are slowly reduced. Reefs begin to develop around the island's margin, so that in time an older high island will have a small volcanic core surrounded by a lagoon and barrier reef, as in Mo'orea or Aitutaki Islands. Eventually this remnant volcanic core also becomes submerged, and only a ring of coral reef remains above the ocean, since coral will continue to grow upward in the photic zone of the ocean. Coral heads and sand generated by storms and biological processes accumulate at places on the reef to form islets, called *motu* after their Polynesian name. The stages in atoll development are diagrammed in Figure 2.5.

Atolls are among the most precarious environments settled by Pacific peoples.[10] At most, atoll *motu* are only 2–3 meters above sea level, vulnerable to inundation by waves and storm surges during cyclones. There are no streams, but atoll-dwellers have learned that a thin lens of fresh water (the Ghyben-Herzberg aquifer) floats on the heavier salt water within the sandy body of *motu* and can be tapped by excavating shallow wells. Certain crops, such as the giant swamp taro (*Cyrtosperma chamissonis*) can be cultivated in pits dug down to expose this freshwater lens. However, cultivation on atolls is risky, and many crops simply will not tolerate the saline conditions. On the other hand, atolls are remarkable for their rich marine resources, and atoll peoples tend to be at home as much on and in the sea as on the land. Since atolls lack stone of any kind, their inhabitants have also had to adapt their material culture, using coral and various species of shell, such as the giant clam (*Tridacna gigas*), to make adzes and other tools.

Makatea Islands When an atoll, or an old high island surrounded by a barrier reef, becomes elevated above sea level it forms what is called a *makatea* island. *Makatea* is a Polynesian word meaning "white stone" (reef limestone), and it is also the proper name of an island of this type in the Tuamotu Archipelago. Makatea islands are formed by tectonic uplift at plate margins, or by "lithospheric flexure," in which a new volcanic hot-spot island point-loads the thin oceanic crust, causing an upwarping at a certain distance from the hot spot.[11] For example, the heavy mass of Rarotonga in the southern Cook Islands caused a warping of the oceanic crust in its vicinity, elevating

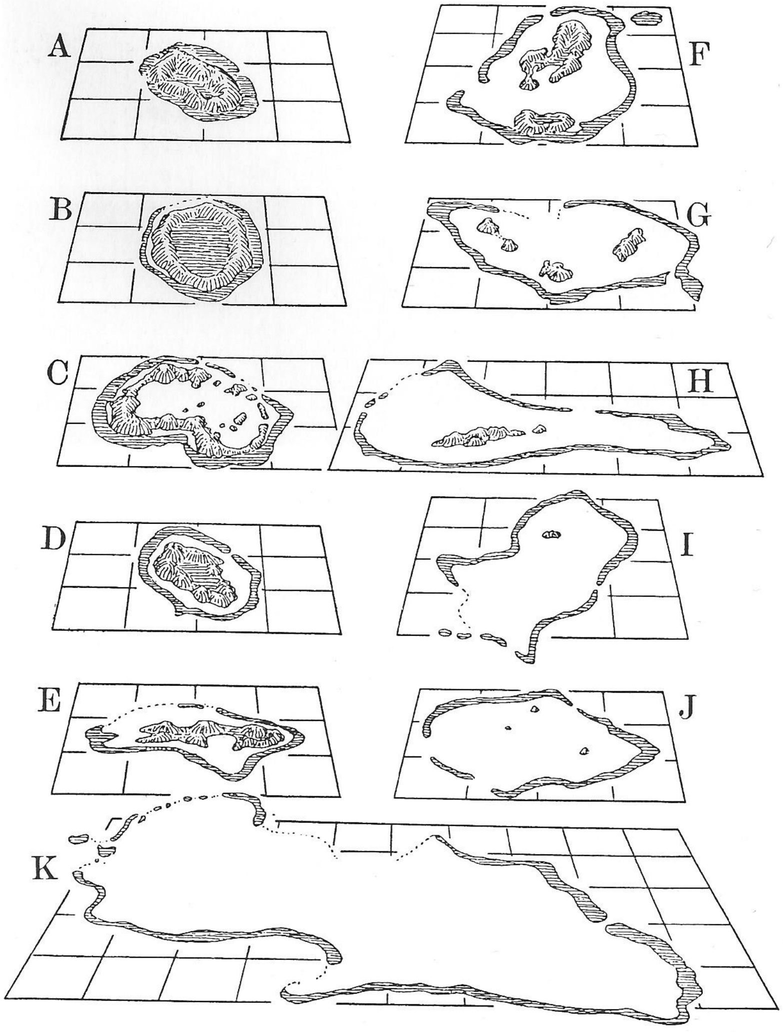
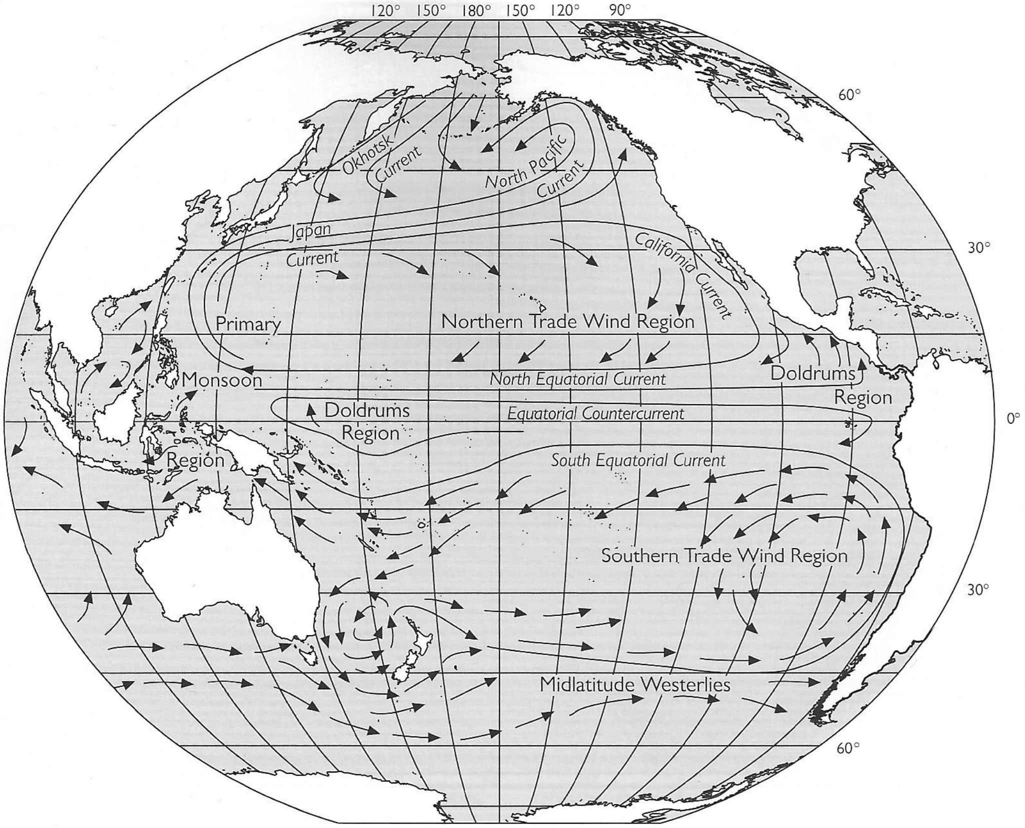


FIGURE 2.5 Stages in the development of an atoll, illustrated by block diagrams of various near-atolls and atolls. A, Naiau; B, Kambara; C, Fulanga; D, Tuvutha; E, Namuka; F, Ongea; G, Yangasa; H, Oneata; I, North Argo; J, Reid; K, Great Argo. (After Davis 1928.)

several nearby islands as much as 80 meters above sea level. Mangaia was one of those elevated, and its former barrier reefs now form a limestone rampart up to 2 kilometers wide, riddled with solution caverns used by the Mangaian people as fortress refuges and as burial places. Some makatea islands are marginal environments for human habitation, lacking surface water (rainfall disappears immediately into the spongelike karst) and even soil for cultivation. One such is Henderson Island, yet prehistoric Polynesians managed to maintain a settlement there for 600 years (see Chapter 8).[12]

Climatic Factors in the Pacific

Pacific island climates span the humid tropics to the temperate zones (in New Zealand), but most of the islands we will consider in this book lie within the tropical to subtropical range. On some



MAP 4 The dominant wind and current directions in the Pacific Ocean. (Adapted from Oliver 1989.)

islands, high mountains create microclimates, as on Hawai'i and Maui, where the higher elevations span humid temperate to alpine and tundra environments. The summits of both these islands receive regular snowfalls during the winter months, and Mauna Kea on Hawai'i was capped by a small glacier during the late Pleistocene.[13] New Guinea too not only had Pleistocene glaciers but also, as befits its larger land mass, exhibits even greater altitudinal climate differences.

Knowledge of the wind and current systems of the Pacific basin is essential to understanding human history in this region, for they had great effects on voyaging and settlement, as well as important influences on island ecology.[14] A wind and current map of the Pacific (Map 4) reveals two great gyres or circulation cells, one each in the Northern and Southern Hemispheres. Both of these flow from east to west across the equatorial region (the intertropical convergence zone); the northern gyre thus flows clockwise while the southern gyre flows counterclockwise. Given that the prevailing winds and currents are from the east throughout the main zone of tropical islands, Pacific navigators had to develop strategies for sailing from west to east, a topic considered in more detail in Chapter 7. There is some temporal variation, however, and the trade winds dominating

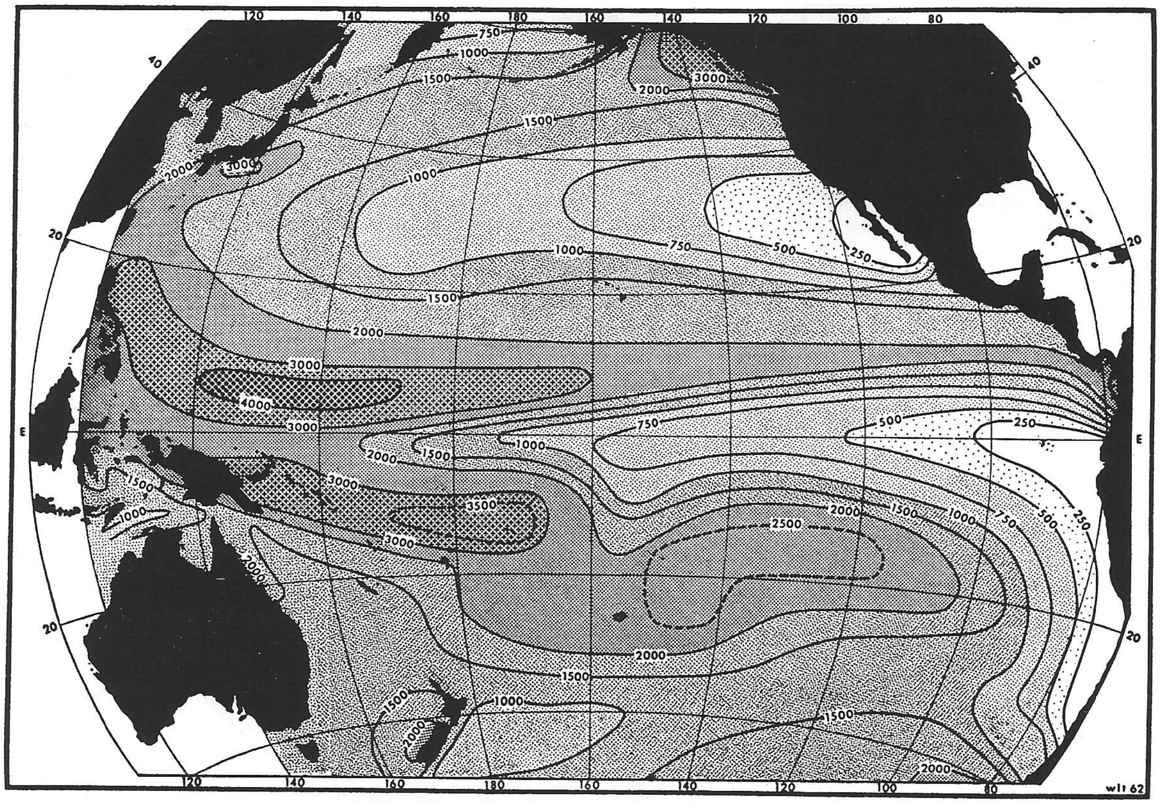


FIGURE 2.6 Average rainfall distribution (in millimeters) over the Pacific Ocean. (From Thomas 1963.)

the eastern Pacific are concentrated between May and September. In the western Pacific, there is a stronger seasonality between trade wind and monsoon seasons, influenced by the cyclic heating and cooling of the nearby Asian and Australian land masses.

The persistent trade winds, coming as they do year after year from the same direction, have a major environmental effect on high islands in their path. As moisture-laden trades flow across the windward side of a high island, they are heated and rise, resulting in heavy rainfall (known as orographic precipitation). The island's leeward side remains in a rain shadow, with significantly reduced rainfall. Over time, greater windward rainfall results in accelerated stream erosion and the creation of broad, amphitheater-headed valleys, while leeward landforms remain relatively dry and undissected. Vegetation is also affected, with lush rainforests on windward slopes and dryland shrub or parkland on leeward slopes. These windward-leeward contrasts were an important consideration to Oceanic peoples in establishing their settlements and gardens. Not surprisingly, the Polynesians developed a terminology for this windward-leeward axis, *tonga/tokerau,* which they carried with them throughout their colonizations.[15]

To horticultural peoples such as those of Oceania, rainfall is critical to the sustenance of life. A map of rainfall over the Pacific (Fig. 2.6) shows a gradual decline from west to east, with the Melanesian archipelagoes of the Bismarcks and Solomons receiving the greatest rainfall. However, there is sufficient rainfall throughout the zone of most islands to make horticulture feasible. The exceptions are along the equator (the Kiribati and Tuvalu Archipelagoes) and in northern Micronesia, where, for example, certain of the Marshall Islands suffer from periodic drought, making habitation tenuous.

We cannot leave the topic of climate without briefly discussing El Niño and the Southern Oscillation, terms that have become familiar to many people due to the effect of the process on contemporary patterns of rainfall or drought in North and South America as well as Australia. The El Niño–Southern Oscillation (ENSO) process consists of a periodic thermodynamic redistribution of energy over the Pacific basin, resulting from differential heat buildup in the western Pacific. During an ENSO event, the normal aridity of the western-central Pacific is broken by periodic heavy rainfall episodes, trade winds decrease in intensity, and there is a significant eastward flow of warm water. ENSO events can have dramatic consequences for particular islands, including droughts in the western and central Pacific, and heavy rains, floods, and increased cyclone frequency in the eastern Pacific. Fish populations, and the seabird colonies that depend on them for food, are sometimes devastated. Paleoclimatologists are only beginning to develop a historical record of ENSO activity over the past several thousand years, but these events presumably had serious impacts on Pacific island populations in the past.[16]

Island Life and Biogeography

When a new volcanic island emerges above the ocean swells (as Fenua Fo'ou has done in recent years in Tonga), it consists merely of barren rock and cinder—but not for long. Plant colonization begins surprisingly quickly, with floating seeds washed ashore by the waves, or with tiny seeds passed through the digestive tracts of visiting birds. Insects and spiders arrive either under their own power or passively dispersed on high-altitude winds. Seabirds may colonize an island even if it is still relatively barren of plant life. Over a few hundred thousand years, the new island will have acquired a significant biota, its slopes cloaked in trees, shrubs, and herbs, inhabited by a diversity of invertebrates and of volant vertebrates (e.g., birds, fruit bats, or microbats).

Dispersal is one of the most fundamental aspects of Pacific biogeography.[17] Groups of plants and animals that are good dispersers (because, for example, their seeds float and remain viable in salt water, or because they are capable of over-water flight) have managed to colonize oceanic islands time and again. Other groups, such as most vertebrates, have found it generally impossible to get far beyond continental shores. Because of this, the biota of Pacific islands differs radically from that of continental regions, with certain groups well represented and others wholly lacking; biogeographers sometimes refer to this phenomenon as "disharmony."

Distance—both from mainland source regions and between stepping-stone islands that aid in the dispersal process—is a critical aspect of island biogeography. Examining a map of the Pacific, one sees that the majority of islands are clustered in the western sector and that interisland distances increase dramatically as one moves eastward. Due to this uneven clustering of islands, Asia and New Guinea have served as primary source areas for Pacific floras and faunas, with a much lesser contribution from the Americas. Moreover, the large archipelagoes closest to Asia and New Guinea, such as the Solomons and Vanuatu, have much more diverse biotas, in terms of the numbers of higher-order taxa represented (genera and families), than those in the central and eastern parts of the Pacific.

Another key aspect of island biogeography is the tendency for new species to evolve, especially through the process known as adaptive radiation. When a species of plant or animal succeeded in colonizing an isolated island, it often found itself without its former predators and in a position to exploit what ecologists call an empty niche. Generations descending from this original colonist would multiply and diverge as some offspring adapted and moved into different microhabitats. The classic textbook case of adaptive radiation is that of Darwin's Galápagos finches, but numerous other examples abound throughout Oceania, such as the achatinellid and amastrid land snails of Hawai'i or the cryptorhynchinid weevils of Rapa. Speciation on oceanic islands led to high degrees of endemism in certain islands and archipelagoes. In the Hawaiian Islands, for example, no less than 94 percent of all flowering plant species, and 13 percent of the plant genera, are endemic (i.e., found nowhere else in the world).

These aspects of island biogeography, whose complexities I have only touched upon, had important consequences for colonizing human populations. First, as people moved from the large Near Oceanic archipelagoes into Remote Oceania, they increasingly found the newly discovered islands lacking in many familiar plants and animals. Moreover, east of the Bismarcks, there were few indigenous plants with edible tubers or fruits; the would-be colonizers had to bring crop plants and other economic species with them. On the other hand, sizable populations of land birds and nesting seabirds offered a ready source of meat, a resource that was frequently hit very hard within the first few decades after human settlement.

Vegetation on Pacific islands varies tremendously according to island size and altitudinal range, but a few typical plant communities are noteworthy from the perspective of human use.[18] In the tropical Pacific, the immediate coastal or strand vegetation is everywhere similar, dominated by salt-tolerant trees such as *Pandanus*, whose leaves were widely used to weave mats; *Barringtonia asiatica*, whose fruit produces a poison used to catch fish; and the ubiquitous coconut palm (*Cocos nucifera*). A wild form of coconut had naturally dispersed at least as far as central Polynesia (Cook Islands) prior to human settlement, but domesticated varieties with their larger fruit were evidently carried by canoeloads of would-be colonists.[19] In the western Pacific, the coastal zone is often characterized by extensive mangrove (*Rhizophora* and other taxa) swamps, or by lowland swamps of the sago palm (*Metroxylon* spp.), which is harvested for its starchy pith. Moving away from the coast into the interior lowlands of island-arc or high islands, one encounters rainforest, eventually giving way to even wetter montane and cloud forests on the higher islands. On some islands, the lower and middle elevations are dominated by grasslands or fernlands, especially in the drier leeward zones. This is the case over large parts of Viti Levu in Fiji (Ash 1992) and on New Caledonia, as well as on some smaller islands, such as Futuna, Mangaia, or Mangareva (Fig. 2.7). These pyrophytic savannas, characterized by fire-tolerant *Miscanthus* grass or *Dicranopteris* ferns, often were the result of millennia of human activities, such as forest clearance and repeated burning.

Island faunas, as I have noted, are frequently disharmonic in comparison with those of nearby continental regions.[20] Within the Pacific, mammals are limited to a few marsupials (e.g., wallabies, wombats, cuscus) and to several genera of rats (*Rattus, Melomys, Uromys*), along with fruit bats

FIGURE 2.7 Large tracts in the interior of Futuna Island in Western Polynesia are covered in pyrophytic *Dicranopteris* fernlands, the result of former land use practices such as shifting cultivation. (Photo by P. V. Kirch.)

(Pteropodidae). Of these, only fruit bats dispersed into Remote Oceania, the marsupials and rats being restricted to the Bismarcks and Solomon Islands. Reptiles too are of fairly limited distribution, with the majority of species of snakes, frogs, diurnal lizards, and geckos being found in Near Oceania or in the larger island-arc archipelagoes. Because of their excellent dispersal abilities, many kinds of birds managed to colonize Pacific islands, where they account for the greatest diversity of vertebrates. Seabirds (including frigates, shearwaters, petrels, noddies, and boobies) and various kinds of land birds (megapodes, pigeons, fruit doves, rails, and parrots among them) were especially abundant on many oceanic islands at the time of first human arrival (Steadman 1989, 1995, 1997). Moreover, flightlessness developed in a repeated evolutionary process on many Pacific islands, especially in various genera of rails.

The richest terrestrial faunal diversity on Pacific islands was among the invertebrates, including insects and landsnails, but most of these were of little direct consequence or interest to people. However, a large and highly delectable land crab, *Birgus latro*, the "coconut robber" crab, was a prized food of islanders. The presence of certain insects—most of all the *Anopheles* mosquitoes, which are vectors for several kinds of *Plasmodium*, the cause of malaria—also had health implications for humans.

The Pacific islands were not rich in edible terrestrial species other than birds and fruit bats, and, as we have seen, their floras were particularly impoverished in terms of edible plants. Far more important sources of animal food were the reefs and lagoons surrounding most islands. The same general pattern of a west-to-east decline in diversity, as we have seen in terrestrial biota, holds for the fish and mollusks of the Indo-Pacific faunal province.[21] Thus the waters of the Bismarck Archipelago teem with several thousand species of fish, while remote Easter Island has a mere 126 species. Most important to Oceanic peoples were the inshore and benthic (bottom-dwelling) fish, in such families as the parrotfish (Scaridae), wrasses

(Labridae), tangs (Acanthuridae), squirrelfish (Holocentridae), jacks (Carangidae), and groupers (Serranidae). These were taken with an amazing variety of fishing techniques, including the use of hooks, nets, spears, traps, and poisons. Oceanic peoples also knew how to troll the open sea for pelagic fish such as tunas (Scombridae) and *mahimahi* (Corphyraenidae), but compared with the inshore reefs the open ocean is a relative desert, and the yield from pelagic trolling was fairly minor. Bivalves and gastropod mollusks of all kinds were collected from reef and lagoon floors, both to eat and in many cases to manufacture artifacts from their durable shells. Other important marine foods were sea urchins, octopus, crabs of many kinds, seaweeds, and marine turtles (especially the green sea turtle, *Chelonia mydas*).

The Microbiotic World and Human Populations

It may be a universal cognitive feature of *Homo sapiens* to think of the world primarily in terms of our own bodily scale, and this bias carries over even into scientific notions about human history. Thus we take great account of human interactions with macroscopic animals and plants (even when the evidence for these is sometimes microscopic, as with pollen grains used to identify ancient species of plants), but in general pay little attention to the vast microscopic world that not only surrounds us, but also lives *within* us. We need to step back from our modern, first-world perspective of relatively healthy populations, with ubiquitous medical care in which most infectious and epidemic diseases have been minimized or eliminated, to consider the role of parasitic and infectious diseases in prehistory. Archaeologists have paid too little attention to these matters, partly because the evidence for disease among prehistoric populations can be difficult to obtain.[22] However, the historically documented distribution of disease-causing microorganisms in the Pacific islands raises several important hypotheses regarding the impacts and effects of disease in Oceanic prehistory.

The same biogeographic patterns that hold for macroscopic biota in the Pacific also apply to the microscopic world. Thus the diversity of microorganisms drops off sharply between Near Oceania and Remote Oceania, as does the diversity of such disease-bearing vectors as *Anopheles* mosquitoes. Generalizing broadly, the archipelagoes of Near Oceania (and here we must extend the boundary to encompass Vanuatu as well) are replete with infectious and parasitic viruses, protozoa, bacteria, and other disease-causing microorganisms, whereas the islands of Remote Oceania are (or were, prior to the expansion of disease after Western contact) relatively disease-free. Anyone who has done fieldwork in both Near Oceania and Remote Oceania will have learned this difference for themselves, often the hard way. I have spent many months on islands in both regions, and whereas neither I nor my Western team members have ever suffered serious health problems in Remote Oceanic field sites, it has been quite the opposite story in the Solomon Islands, or in Mussau in the Bismarcks. There we have contracted malaria (at times life-threatening), ulcerating skin infections resistant to even broad-spectrum antibiotics, persistent respiratory ailments, and gut-racking intestinal infections. It is not just that we are "soft" Westerners unaccustomed to the rigors of the "bush." The indigenous villagers with whom we lived in close contact in the Solomons and Mussau are themselves beset with these same ailments, and they often exhibit high levels of anemia from endemic malaria.[23] In contrast, the indigenous peoples with whom I have worked in Remote Oceania generally enjoy good health, even where little or no modern medical care is available (see Howe 1984:47–50). Tellingly, the exceptions occur where the adoption of a Western diet and lifestyle has led to such new diseases as hypertension and diabetes.

Without doubt, the most significant parasitic disease preying on the human occupants of Near Oceania (again extending into Vanuatu) has been malaria, a highly debilitating and often fatal disease resulting from infection by one or more of several *Plasmodium* species. In historic times, *Plasmodium vivax, P. malariae,* and *P. falciparum* have been found throughout the low- to midaltitude elevations of New Guinea, the Bismarcks, the Solomon Islands, and Vanuatu. The first two of these have probably been in the region for as long as humans (Groube 1993a), whereas the more virulent and often fatal *P. falciparum* may have been introduced somewhat later in prehistory. At least five species of *Anopheles* mosquito are also present, providing the necessary vector. In a study of four Solomon Islands populations, Damon (1974) found that as many as two-thirds of the adults (in Kwaio and Baegu) had enlarged spleens and lowered hemoglobin as a consequence of high malarial infection rates. In contrast, both the *Plasmodium* parasite and the *Anopheles* vector are absent from all of Remote Oceania other than the Reef–Santa Cruz group of the southeastern Solomons, and Vanuatu. (Indeed, in some Remote Oceanic island groups such as Hawai'i, mosquitoes were entirely absent prior to European contact.) As we shall see in later chapters, this disjunct distribution of malaria probably had major consequences for the demographic history of human populations in the two regions.

Near Oceania is also replete with other kinds of infectious and parasitic microorganisms, many of which are little studied and not well documented in either the anthropological or the medical literature. Epidemiological surveys of several human groups in the Solomon Islands, however, reported frequently high infection rates for such parasites as hookworm (nearly 45 percent of some populations) and intestinal parasites like *Entamoeba coli* and other species (causing amoebic dysentery), *Ascaris, Trichuris, Iodamoeba, Giardia,* and *Dientamoeba* (Damon 1974; Friedlaender and Page 1987). Brown (1978:60–61) refers to the "high incidence of enteric and respiratory disease" among the Highlands peoples of New Guinea, as well as the presence of various "parasite and worm infections." The pervasiveness of these diseases in Near Oceania presumably lowered the overall resistance levels of indigenous populations, thereby increasing the probability of mortality from malaria or other fatal diseases, especially among high-risk individuals (such as infants and pregnant women). While we must be cautious about overgeneralizing, it nonetheless seems certain that the distribution of diseases within the pre-European Pacific islands was far from uniform, and that the concentration and persistence of disease-causing microorganisms in Near Oceania had serious consequences for long-term human history.

Island Ecosystems

Just as island biotas differ in fundamental ways from those of continents, so island ecosystems also have their peculiar characteristics. The brilliant Pacific botanist Raymond Fosberg (1963a) drew attention to some of the key aspects of island ecosystems that are relevant to our understanding of the role of humans in adapting to—and frequently changing—Pacific environments. Fosberg delineated two features as "basic to insularity": *isolation* and *limited size.* Naturally, both of these are relative and become more significant as one moves from the larger and less isolated archipelagoes of

Near Oceania into the vastness of the central and eastern Pacific. Fosberg cataloged some of the consequences of isolation and limited size: "limitation in, or even absence of certain other resources; limitation in organic diversity; reduced inter-species competition; protection from outside competition and consequent preservation of archaic, bizarre, or possibly ill-adapted forms; tendency toward climatic equability; extreme vulnerability, or tendency toward great instability when isolation is broken down; and tendency toward rapid increase in entropy when change has set in" (1963a:5). The last two of these are of particular relevance to the human settlement and occupation of the Pacific islands, for insular ecosystems were more vulnerable than others to disturbance at human hands. As Fosberg put it, "Perhaps the thing that most distinguishes islands, at least oceanic islands . . . is their extreme vulnerability, or susceptibility, to disturbance" (1963b:559).

Oceanic ecosystems have never been static or changeless, and natural and cultural processes are always at work to foster change. I have already noted such short-term natural processes as ENSO events that trigger episodes of drought or high cyclone frequency. In various parts of the Pacific, volcanic eruptions have had dramatic consequences for human populations. In Melanesia, explosive eruptions have occurred within the period of human occupation in New Guinea, New Britain, the Manus Islands, and Vanuatu.[24] Some of these volcanic events blanketed vast areas with scalding ash and pyroclastic debris, doubtless killing many people and making human habitation impossible. The Kuwae eruption, which occurred in the mid-fifteenth century A.D., blew apart an originally larger island, creating a vast caldera between what are now Epi and Tongoa Islands in Vanuatu. This eruption, which is recorded in Vanuatu oral traditions, probably had some effect on world climate, and it is recorded in ash falls from the South Pole dating to A.D. 1452 (Robin et al. 1994). About 300 years ago, Long Island off the northeast coast of New Guinea similarly exploded in a cataclysmic eruption, spewing 10 cubic kilometers of tephra westward across the interior of New Guinea, blanketing about 80,000 square kilometers with an average depth of 1.5 centimeters of airfall tephra; this momentous geological event is likewise recorded in oral traditions throughout the region (Blong 1982). In the Hawaiian Islands, volcanism is rarely explosive but no less significant for the Polynesian inhabitants, since large portions of Hawai'i Island (and some parts of Maui) have been extensively covered with lava flows since the time of initial human arrival (Somers 1991).

Longer-term dynamism comes from such changes as the subsidence and formation of atolls, tectonic uplift of makatea islands, and eustatically fluctuating sea levels. Sea level change, in particular, has had important consequences for human settlement of the Pacific. During the Pleistocene, sea levels were periodically as much as 100–120 meters lower than at present, facilitating movement of people into Near Oceania (Chapter 3). Sea levels rose rapidly during the early Holocene, and throughout much of the central Pacific they reached a level 1–1.5 meters higher than at present by about 4,000–6,000 years ago. Thus archaeological sites dating to this time period are frequently found on older beach terraces, sometimes a considerable distance inland from present coastlines (see Chapter 4).

With the arrival of humans, the dynamism of oceanic ecosystems acquired a new tempo, for as Fosberg correctly observed, insular environments are particularly susceptible to disturbance. I conclude this chapter with a brief review of the mounting archaeological and paleoecological evidence for human-induced changes to Pacific island environments.

Human Impacts on Island Ecosystems

It has not always been realized that Pacific islanders played an active role in modifying and molding their island worlds. Eighteenth-century voyagers to the Pacific helped to shape European notions of the "noble savage," *l'homme naturel,* living in a state of harmony with nature.[25] Arriving at Tahiti in April of 1768, the French navigator Louis de Bougainville thought himself "transported into the garden of Eden" (Smith 1985:42). As natural history studies gained sophistication in the nineteenth and early twentieth centuries, the role of humans in causing disturbance to island ecosystems became increasingly evident, but often this was attributed to changes that occurred after the arrival of Western peoples, who introduced a host of new plants and animals, many of them competitive and destructive (such as goats, sheep, and cattle), as well as new land use practices (large-scale plantation agriculture among them). Thus for most anthropologists, until relatively recently, the disturbances caused by indigenous populations in the Pacific were thought to be minor or insignificant. Social anthropologist George P. Murdock summed up the prevailing view when he claimed that even the colonization of islands by Polynesian agriculturalists resulted in "little net change in organic diversity" (1963:151).[26]

This Rousseauian view was based on unquestioned assumptions, untested with direct empirical evidence of environmental changes before and after the colonization of islands by indigenous Pacific populations. Evidence for pre-European anthropogenic change began to accumulate in the late 1960s and early 1970s, when archaeologists working in the Pacific started to shift their research agendas away from an emphasis on origins and cultural sequences to investigate ecological relationships between indigenous human populations and island environments. Working collaboratively with palynologists, avian paleontologists, geomorphologists, and other natural scientists, Pacific archaeologists have now amassed a substantial body of data, demonstrating that the nonindustrialized peoples of the Pacific often exerted major impacts on island ecosystems.[27] Indeed, this should not come as a surprise, given the inherent fragility or vulnerability of oceanic ecosystems (as Fosberg had pointed out), combined with the high human population densities observed on many Pacific islands and the intensive modes of land use practiced by Pacific peoples.

Human-induced changes on islands often commenced with the first arrival of would-be colonists, for these people usually were equipped to establish permanent settlements, which meant that they had to transport and transplant their crop plants and domestic animals. Moreover, voyaging canoes carried inadvertent "stowaways," such as the Pacific rat (*Rattus exulans*), whose bones show up in virtually every Pacific settlement site.[28] Rats, whose numbers soon increased in the absence of predators, may have had significant impacts on ground-nesting land bird and seabird populations. In addition to the rat, we have evidence for the accidental transport of geckos and skinks, certain species of garden snails (e.g., *Lamellaxis gracilis*), and various weeds (e.g., *Ludwigia octivalvis*).

The modification of island ecosystems began in earnest as native forests were cleared to make way for root-crop gardens and for orchards of tree crops. Oceanic peoples widely practice swidden or shifting cultivation, in which patches of forest are cut, allowed to dry, and burned prior to planting.[29] Under conditions of low population density it is possible for forests to regenerate, but more often than not the cleared land is gardened repeatedly and a highly transformed, "second-growth" vegetation comes to replace the

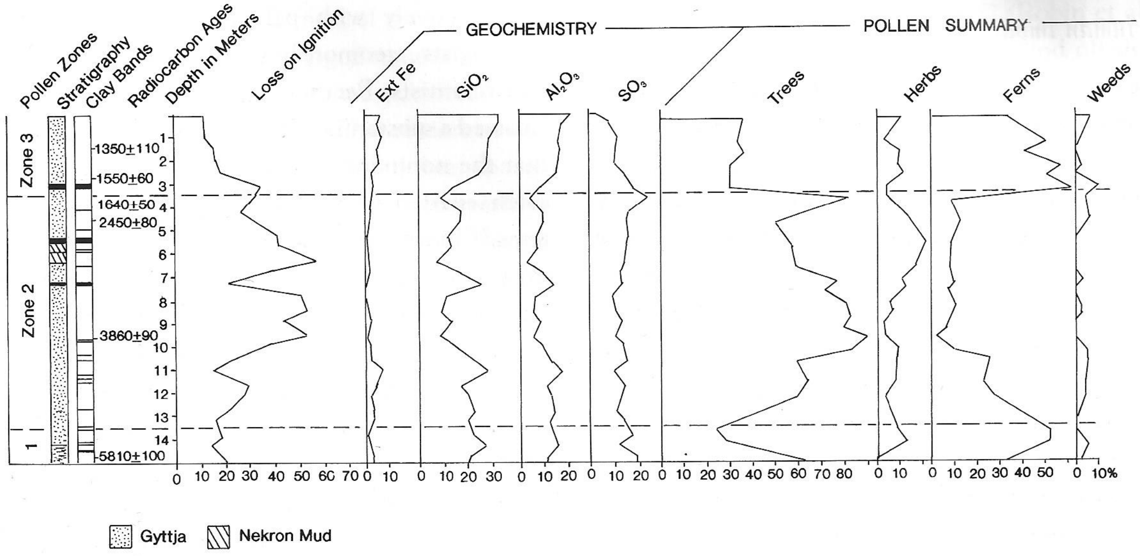


FIGURE 2.8 Summary pollen diagram for the TIR-1 sediment core from Veitatei Valley, Mangaia Island. This diagram shows a decrease in trees and an increase in *Dicranopteris* ferns beginning around 1600 B.P., associated with human activities.

original rainforest. On certain kinds of substrate, where soils are thin or poorly developed (as on many tropical islands), the removal of forest and repeated burning can seriously degrade a landscape, which then comes to be dominated by fire-resistant (pyrophytic) grasses or ferns. Other landscapes were, over time, thoroughly reworked by Pacific agriculturalists into highly intensive forms of land use. Examples of such "landesque capital–intensive" agriculture include the Highlands valleys of New Guinea, the vast irrigated systems and yam fields of New Caledonia, the extensive hill and ridge terraces of Palau, and the stone-faced taro pondfields of Hawaiian valleys.[30]

Evidence for vegetation changes resulting from such land use practices as shifting cultivation has now been obtained from a number of Pacific islands, primarily through the analysis of pollen grains (palynology) in sediment cores. Pollen sequences from sites in New Guinea, Vanuatu, New Caledonia, Fiji, Yap, the Cook Islands, the Society Islands, New Zealand, Easter Island, and Hawai'i all demonstrate major vegetation changes that can be linked to human land use actions.[31] A typical example is the pollen sequence obtained from the Veitatei Valley on Mangaia Island during our interdisciplinary paleoecology project in 1991 (Fig. 2.8). Prior to the arrival of humans, probably as early as 2,400–2,000 years ago, Mangaia had a significant forest cover on its volcanic interior, which later came to be dominated by *Dicranopteris* fern and scrub *Pandanus* savanna. The critical signal in this and most other Pacific island pollen sequences is the correlation between human arrival and the advent of significant burning (indicated by microscopic charcoal particles in the sediment samples). In the Mangaian case, there was virtually no burning on the island until the arrival of people, in this case Polynesian horticulturalists who used fire to help clear forest to make way for gardens.[32]

Easter Island presents a dramatic case of human-induced vegetation change, for this entire island was essentially deforested through hundreds of years of intensive land use.[33] Botanists who once thought that the island was a natural oceanic grassland "steppe" now realize that it was originally covered in forest dominated by an extinct species of giant palm (*Jubea* cf. *chilensis*), closely related to the Chilean oil palm. On Easter Island, the ultimate extinction of the palm and other woody plants had a further consequence: the inability to move or erect the large stone statues (see Chapter 8).

Forest clearance had additional consequences on certain islands, due to the exposure of steep hillslopes and accelerated erosion. Matthew Spriggs (1986) has shown that on the island of Aneityum in Vanuatu, a process of valley-bottom infilling and extension of the coastal plains began about 2,000 years ago, as a direct result of forest clearance and increased erosion rates on the interior hills and ridges. Similar sequences have been suggested for Futuna, Mo'orea, and O'ahu Islands, and the extensive iron sand dunes at the mouth of the great Sigatoka Valley on Viti Levu (Fiji) probably also owe their existence to land clearance and increased erosion rates in the interior.[34] In addition to sedimentation in valleys and on coastal plains, increased sediment loads in streams and rivers may have had effects on inshore marine ecology. In the Koné region of New Caledonia, for example, changes in the kinds of marine mollusks available through time are linked to changes in littoral substrates or turbidity resulting from erosion (Miller 1997). Vast tracts on both North and South Islands, New Zealand, were converted from temperate forest to open terrain, typically dominated by *Pteridium* ferns, as a consequence of human-ignited fires (Bussell 1988; Elliot et al. 1995; McGlone 1983; McGlone and Wilmshurst 1999).

Human impacts on islands were by no means limited to forest clearance and the development of savannas, or to erosion and valley-infilling. Dramatic evidence for human impacts on island ecosystems comes from the record of bird bones excavated from Pacific archaeological sites. David Steadman has analyzed such assemblages of bird bones from sites in Tonga, Tikopia, the Cook Islands, the Society Islands, the Marquesas, Henderson, Mangareva, and Easter Island, and his data are reinforced by other studies for Hawai'i and New Zealand. Case after case demonstrates that the Pacific islands before the advent of humans had a far richer bird fauna than that historically documented, with large populations of certain kinds of birds occupying oceanic islands at the time of initial human arrival.[35] On Easter Island, for example, Steadman's work shows that at least 25 species of seabirds and possibly 6 species of land birds were originally present, yet only one seabird species survives (barely) on the island today, and there are no endemic or indigenous land birds at all (Steadman et al. 1994; pers. comm., 1995). In New Caledonia, a large mound-building megapode (*Sylviornis neocaledoniae*) went extinct soon after the arrival of humans in the mid–second millennium B.C., as did other endemic fauna, including a terrestrial crocodile (Fig 2.9).

In 1989 and 1991, Steadman and I excavated a large rockshelter site on Mangaia Island, called Tangatatau. From the well-stratified ashy midden layers of this rockshelter, which had been occupied by Mangaians repeatedly for about eight centuries, we recovered a remarkable collection of bird bones, revealing a typical story of the reduction, local extirpation, and extinction of a large part of the island's original avifauna.[36] Among the bird species that were once present on the island, and which had been hunted, eaten, and their remains discarded in the shelter, were rails, crakes, a gallinule, a sandpiper, fruit doves, pigeons, and lorikeets. In all, a prehuman avifauna consisting of at least 19 land bird species and 12 seabird

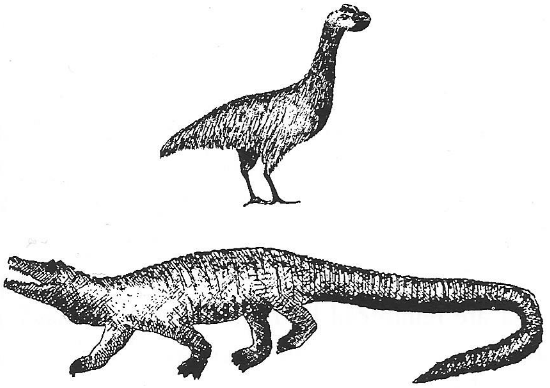


FIGURE 2.9 Reconstruction of the extinct giant ground-dwelling megapode *Sylviornis neocaledoniae* and the extinct terrestrial crocodile *Mekosuchus inexpectatus*, both from the island of New Caledonia. (After Sand 1995.)

species was reduced during the period of Polynesian occupation to 5 land bird and 6 seabird species, many of these today holding on to a most precarious and endangered existence.

For no island group in the Pacific is the record of bird extinctions more dramatic than New Zealand. On these large subtropical to temperate islands, a marvelous array of bird life had evolved prior to the arrival of the first Polynesian settlers. Most distinctive were several genera and species of flightless birds known collectively by their Maori name, *moa*.[37] The biggest of these *moa*, *Dinornis giganteus*, stood almost 4 meters tall, probably the largest bird ever known to exist. However, New Zealand wildlife was not limited to the *moa*, and at least 37 native bird species and subspecies went extinct during the period of Polynesian settlement (Anderson 1997:280). By the time of European arrival, all 11 *moa* species had been completely eliminated. The larger *moa* were extensively hunted for food, especially on South Island, where some archaeological middens were so packed full of *moa* bones that they were commercially mined in the late nineteenth and early twentieth century in order to make bone meal fertilizer! Equally important as a cause of the decimation of New Zealand's bird life was forest clearance for gardening, and clearance by fire for hunting, which has been estimated to have drastically reduced the native forest cover of the two main islands (McGlone 1983, 1989).[38]

Recognizing that indigenous Pacific peoples were responsible for significant changes to their island environments—as documented by mounting archaeological and paleoecological evidence—is not to single them out as environmentally insensitive eco-vandals. In my view, Pacific islanders were not more or less environmentally conscious than most other human groups; it is only our outdated Rousseauian notions that make it appear so. Pacific peoples certainly have a fond and often deeply emotional attachment to their island homes, and their songs and traditions frequently speak to the great beauty of these islands. It is also the case that traditional Oceanic societies practiced certain kinds of conservation practices and land management strategies, but these were generally aimed at conservation of resources for future use.[39] Yet the simple truth is that human populations everywhere live not in some idealized "state of nature," but in various forms of exploitative relationships with their environments. The impact of low-density hunters and gatherers may be *relatively* slight,[40] but the cumulative effects of high-density agricultural peoples on their landscapes are inescapably significant. Pacific islanders did much—with the "neolithic" technology at their disposal—to create viable subsistence economies on the islands they settled and to manage their resources wisely. That they were not always successful is a lesson that humanity today has yet to fully hear or heed.