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VEGETATION HISTORY OF WASHINGTON ISLAND (TERAINA), NORTHERN LINE ISLANDS

BY

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VEGETATION HISTORY OF WASHINGTON ISLAND (TERAINA), NORTHERN LINE ISLANDS

BY

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INTRODUCTION

Washington Island (Teraina) in the Northern Line Islands is a small atoll with a land area of 14.2 sq. km. situated at 4° 43'N, 160° 25'W. The Northern Line Island archipelago is comprised of four islands alined on an axis which runs from Christmas Island, just north of the equator, to Palmyra Island in the northwest (Figure 1). Washington Island, and its nearest neighbor Fanning Island, about 150 kilometers to the south east, have had close economic and social ties for most of their recent history. The climate of Washington Island is strongly influenced by intertropical convergence and has an average annual rainfall of 2902 mm although Christmas Island, two degrees south, receives only 766 mm.

Washington Island is lens-shaped and about 7 kilometers long by about 2 1/2 kilometers across at its widest point (Figure 2). The interior depression contains a freshwater lake and peat bogs and the ratio of the area of land compared to that of the enclosed water body is high. Similar small islands of this form would include Swains, Pulusuk and Clipperton Islands. Typically they have narrow fringing reefs which shelve very rapidly and do not provide safe anchorages. The Pacific Islands Yearbook describes Washington Island as "the most difficult and dangerous loading port in the Pacific" (Carter, 1984:257). The small size and inaccessibility of this island explains why, despite its unusual characteristics, it has not been investigated in more detail.

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The first map of Washington Island was produced by the United States North Pacific Exploring Expedition in 1874 (Figure 3)(Skerrett, 1873-4). Although a commendable achievement in surveying for its time, it has many inaccuracies but has been used as a base for most of the subsequent published maps (Wentworth, 1931; Bryan, 1942; Tennant and Mutter, 1977; Vitousek, et al., 1980). A map of the island at a scale of 1:4,800 in the Burns Philp archives at the University of Sydney shows sections used for harvesting coconut and was prepared sometime after 1915. Comparison with aerial photographs and ground observations indicate this map to be a more accurate representation of the shape of the island and the lake. Herms (1926) apparently used this as the base for his maps and we have done the same.

The purposes of this study were to survey existing vegetation patterns and summarize known information on the physical environment and history of human occupation as a basis for understanding the history of vegetation change.

In August 1982 Wester spent two weeks collecting and surveying vegetation on Christmas and Fanning Islands and a one day trip was made to Washington island. The following August the three authors spent two weeks on Washington Island. A total of nine transects were completed (Figure 4). These were selected to give typical cross sections of the island orto characterize particular places or circumstances and to sample the existing vegetation, topography and the character of the substrate. Peat samples were taken for pollen analysis to determine prehistoric vegetation change especially with respect to the role of coconut in the vegetation cover since there is uncertainty whether the species is native or a human introduction to the remote islands of the Central Pacific (Spriggs, 1980; Ward and Allen, 1980).

PHYSICAL ENVIRONMENT

Regional geologic setting,

Formation of the Line-Manihiki Ridge, on which the present Line Islands stand, began about 128 million years B.P. and continued until 105 or 80 million B.P. The ridge remained a submarine structure until between 85 and 80 million years ago when a pulse in crustal formation appears to have lifted the basaltic seamounts into the photic zone. Several reefs then developed simultaneously along the entire chain (Jackson and Schlanger, 1976; Schlanger and Premoli-Silva, 1981).

Subsequent cooling of the basement material caused slow subsidence which continues to the present. Those reefs able to keep up with the pace of subsidence created the present-day Line Islands, including Washington Island. A glacially induced sea level change during Oligocene time, 25 to 35 million years ago, perhaps resulted in the emergence of these atolls (Schlanger and Primoli-Silva, 1981) although Haggerty (1982) found no evidence for sub-aerial exposure of limestones in the Southern Line Islands.

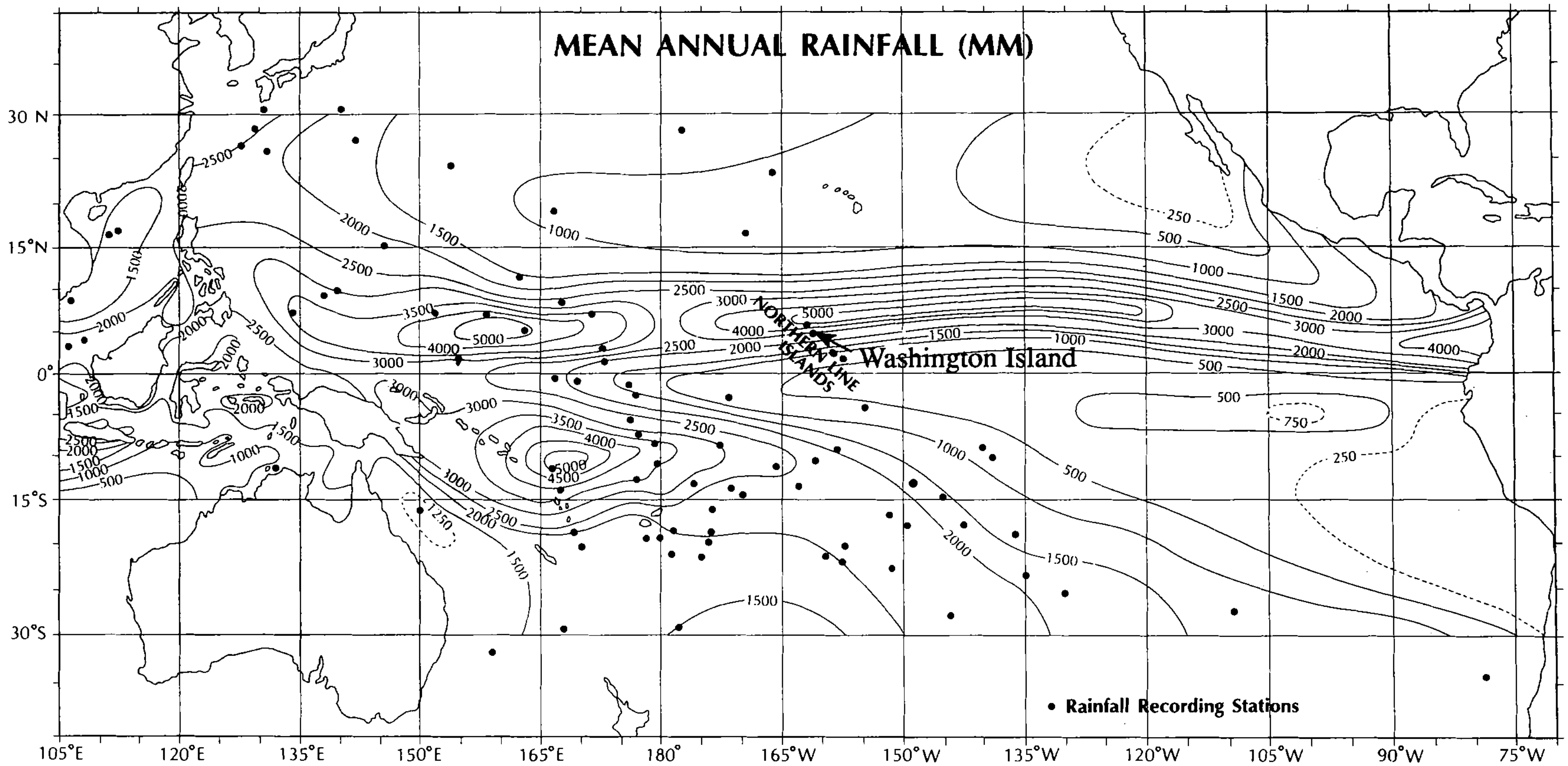

Figure 1. Location / Rainfall

Each of the Northern Line Islands has a distinctly different form. Christmas Island in the south is essentially a single large landmass enclosing a central lagoon and a few islets. Further north, Fanning is formed by three elongated motus forming the shape of a footprint. Washington Island is much smaller in area than the other two. Its reef platform is oval in shape. The freshwater body in the central depression has no natural connection to the ocean except at low points in the rim where water floods to the sea during time of high rainfall. Palmyra consists of a string of tiny motus in a horseshoe shape which barely protrude above sea level. Still further north is Kingman Reef which is completely submerged at high tide. The progressive decrease in elevation and size of the coral platform from south to north implies a tilt of the ridge or more rapid rate of subsidence to the north.

<u>Terrestrial geomorphology of Washington Island</u>

(a) Shoreline and Beach Ridges

A narrow beach composed of fine to medium sand mixed with swash deposits of coral rubble and reef rock debris surrounds much of Washington Island. Exposed patches of beachrock, up to 30 meters long, are found along the southeast and northeast shoreline. Although Wentworth (1931) noted the absence of gravel or shingle around the island's shores, scattered coral rubble and cobble were observed around the eastern end of the island during our investigation. Beach berms (or ridges) around all except the western end of the island are composed of coral rubble, cobble, and shingle typically ranging in size from 5 to 30 centimeters. Occasionally, larger reef blocks are incorporated into these structures. The coarse coral deposits making up the beach ridge may be covered by a layer of sand, with some gravel, especially on the seaward side.

The landward slope of the beach ridge is variable in topography. In some areas, the coarse cobble and shingle slope drops down fairly quickly and levels off at about 1 meter above the reef flat height, where it is overlain with highly organic, peaty material (Figures 5). On the northern and eastern end of the island the band of reef derived material may extend inland up to 400 meters but in the south the beach ridge is narrower but secondary ridges of cobble and shingle protrude through the the peaty soils of the island interior to form a discontinuous rings parallel to the coast. Around some parts of Washington Island, the beach ridge appears to be eroding. At the northeastern end of the island, which is most exposed to the prevailing easterly winds, a rampart is collapsing onto the beach and the root network, formerly helping to bind the ridge together, is exposed.

In places beach berms are poorly developed shallow pools of standing water are found along with freshwater seepage on the adjacent beach. These areas probably allow overflow from the lake and act as a natural control of the lake level.

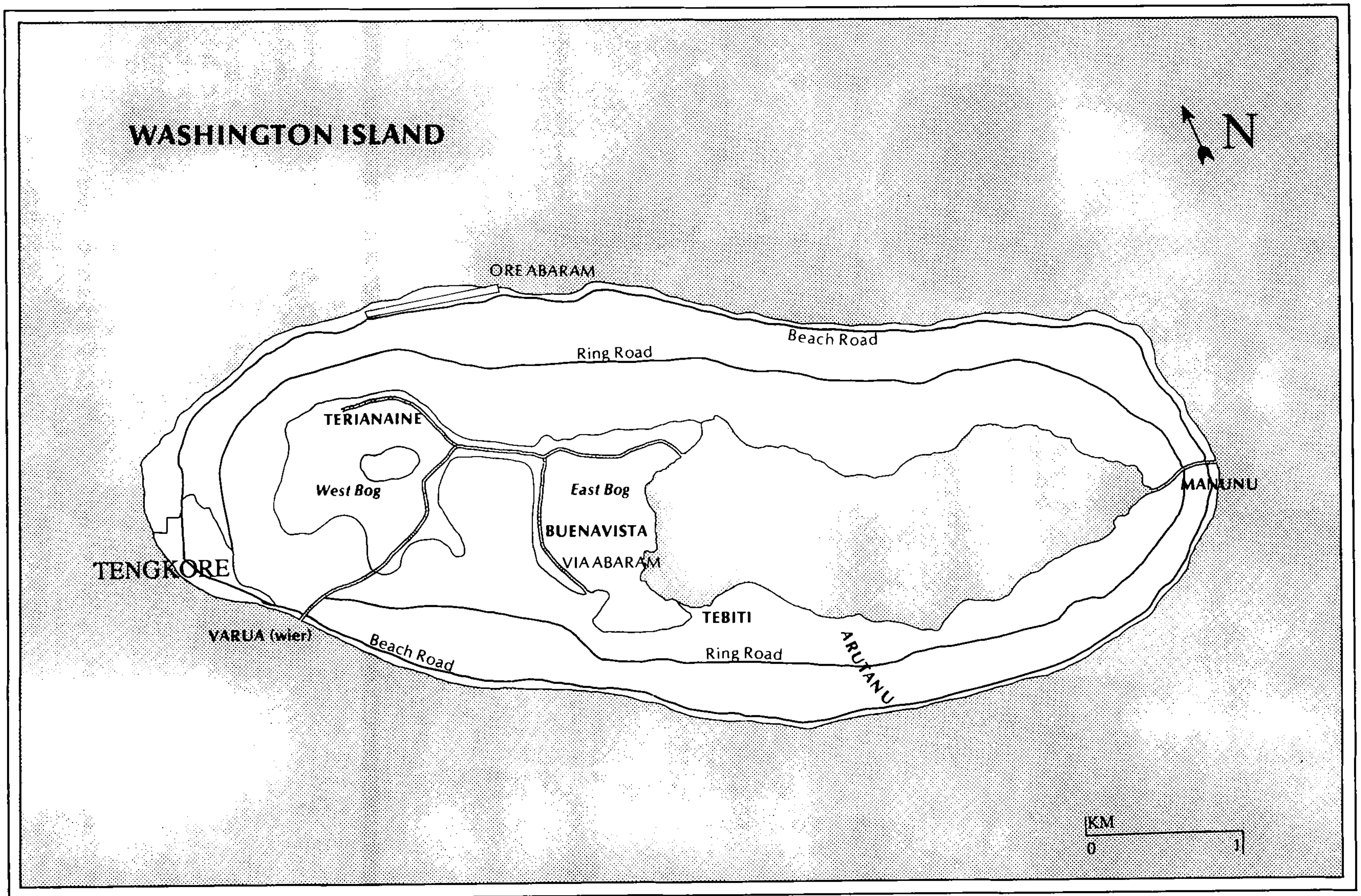

Figure 2. Place names

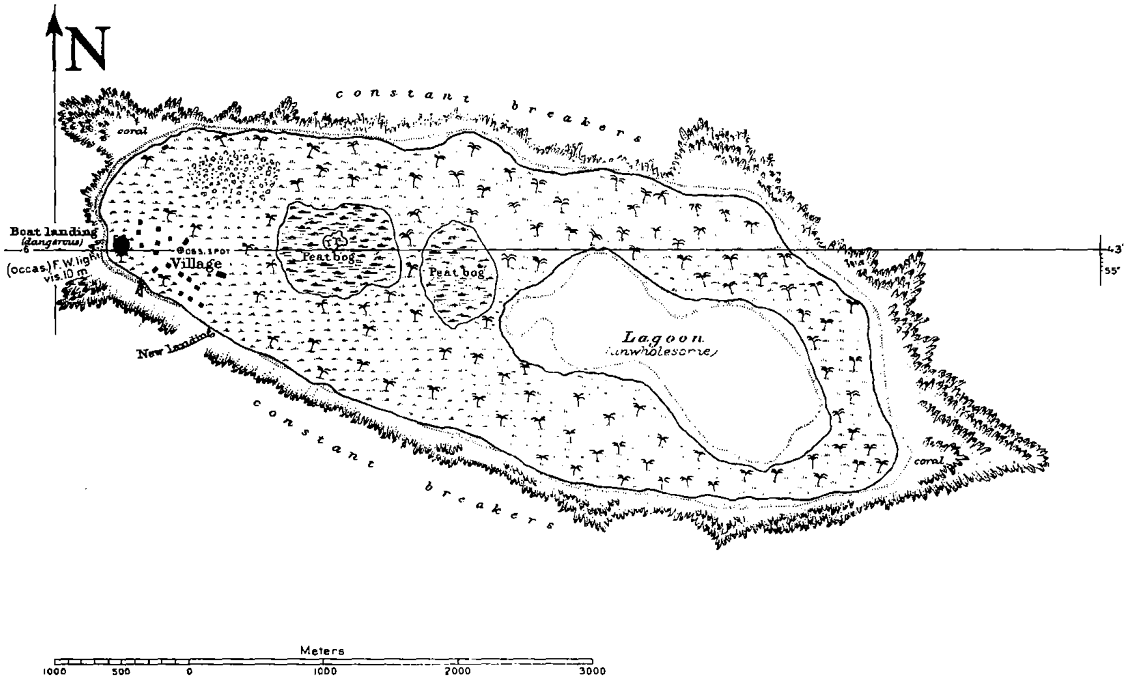

Figure 3. Chart of Washington Island prepared after North Pacific Exploring Expediton

Along sections of the southern shore fine sand deposits, colonized by <u>Tournefortia</u> shrubs, appear to overlie a series of broad, muted coral gravel and rubble ridges. Beaches of sand increase in width and height towards the western tip of the island as a result of westward shore drift along both the northern and southern shores (Wentworth, 1931). The convergence of the longshore drift patterns at the island's western terminus appears to be extending the land area in this direction, as evidenced by the clouds of suspended sand which are observed over the shoaling reef.

The lack of a distinct reef flat, an unstable depositional environment, and rough seas, made it difficult to make and accurate estimate of the extent of the sand deposits at the western end of the island. Wentworth (1931) describes the beach profile as a smooth cycloidal curve reaching a slope of 30 to 40 degrees at its upper end. He estimates its height at 12 to 15 feet, with an overall width of up to 200 feet, which is in accord with our observations. The beach sand deposits extend inland for over 150 meters from the water's edge. Their upper surface is increasingly stained by organic material with distance inland from the open beach. Steep berms, with wide ridgetops elevated about three meters above the reef flat, extend along the northwest and southwest sectors of the island. The backslope of the sand berm slopes down gradually until, at about 1.5 meters, it is ovelain by muds and organic peats.

(b) Inland Beach Ridge and Peat Complex

On the west and southern side of the island the profiles reveal a series of concentric coral and rubble ridges which are presumed to be old beach ridges comparable to those found along parts of the present coast. In low areas, immediately behind the coastal beach berm, localized depressions may be filled with a soft, red-black to black mud, sometimes mixed with small amounts of sand or coarse coral rubble (Figure 5). Between the coral rubble ridges the land slopes gently towards the lake but lies between 1 and 1.5 meters above the adjacent reef flat. These areas are covered by tough fibrous peat-like material under coconut forest which is drier and firmer than the material which forms the substrate to the bog. The surface is lower than the reef deposit ridges, but 10 to 40 cm higher than the adjacent peat bog. Some lower lying sections hold standing water and may, at least in some cases, be abandoned babai pits or other excavations.

Along the northern side of the island, concentric ridges separated by peaty soils are not so evident. Instead there is a broad and slightly irregular platform 200 to 400 meters wide, formed of rubble and reefs of phosphate rock (Figures 7 and 8, Transects 1C and 7). The surface slopes gently towards the interior and until peat soils are encountered at a level of 1 to 2 meters above the reef flat, and extend inland to the lake or bog. In a few areas, the peat soils are found on gentle rises which stand as high as the rubble ridges along the shore (Figure 8, Transects 7). The forested islet in the western bog also seems to lie on a slight rise or irregularity in the underlying reef platform as we found the contact zone between the peats and the lagoon sediments below to be slightly higher under the islet than under the bog. This suggested to us that the islet may reflect an underlying structural feature of the former reef (Figure 5, transect 1b). Christophersen (1927, see his Figure 9) believed that the "bottom of the peat" was lower under the island than the surrounding bog, and also that the forested peat soil, was lower than the open bog. All our profiles suggest the dominant trend of the land surface in the island interior is downwards to the open bog community or lake shore. In this case also our findings do not agree with the those of Christopherson and we found no evidence of the raised peat sill or levee which enclosed the bog.

(c) Phosphate Soil and Phosphate Rock

Where _Pisonia grandis_ trees occur on Washington Island, phosphatic hardpan and soils are found. The occurrence of phosphate rock in association with _Pisonia_ trees, the chemical reactions involved, and the soils which result, are described by Fosberg (1954, 1957). On Washington Island, _Pisonia_, mixed with other species in varying amounts, is found around much of the island's perimeter. Some large trees even occur immediately behind the beach ridge crest.

Phosphatized sand, rubble-sized phosphate, and larger phosphatic rocks orsolid outcrops occur in association with Pisonia areas on the island.

Extensive sheets of phosphate rock hardpan are found at the surface in the Pisonia forest at the east end of the island and in the Pisonia and breadfruit forest just north of Tengkore village, at the island's west end. The large Pisonia woodland between the two bogs contains massive weathered phosphate blocks and outcrops, the upper surface of some reaching almost 1 meter above the surrounding ground level. Above surface phosphate is ascribed by Fosberg (1954) to have been pushed up by Pisonia root systems or heaved up by the roots of falling Pisonia trees. This explanation seems less plausible in this particular situation because of the amount of sub-aerial phosphate rock present, the size of the formation, and its height above ground level. However, no alternative explanation is proposed.

In any case, the presence of phosphatic rock material in conjunction with Pisonia trees leads to the development of particularly rich atoll soils, described by Fosberg (1954) as the Jemo series. The occurrence of phosphate rock on a very wet island such as Washington, is not well understood since most wet islands lack phosphate deposits altogether. As Stoddart (1983) points out, the distribution of phosphate rock suggests a variety of environments or complex environmental histories, may be involved and the occurrence of phosphate rock on wet islands may be an unusual deposit requiring special explanation.

(d) Peat Bog

Two large expanses of vegetated wetland on Washington Island are connected by a narrow drainage corridor and referred to as the East and West Bog. Other small depressions surrounded by coconut forest contain also contain bogs. The substrate is organic peat and supports growth of bulrush (Scirpus littoralis) (Christophersen, 1927).

West Bog was found to be about 1.3 to 1.6 meters above the adjacent reef flat (Figure 7, Transect 1) and slightly lower than the surrounding belt of coconut forest. An obvious drop of 10 to 30 cm was measured in the peat surface at the boundary between the forest and the open bog.

Judd (1859) described the bog as dry and firm and Christopherson (1927) noted the water table was 20-25 centimeters below the soil surface when he was there. However Streets (1877b) observed that the area was covered with water to a depth of six to eighteen inches. During our investigations the bog was covered by a few centimeters of standing water. East Bog bog differs in character from the western one in that there is evidence of degradation of the ecosystem. In parts the Scirpus seems to have died off and only dead roots and stem bases are evident. Christopherson also noted this so it is not a recent development. Some areas are soft and incapable of supporting a person's weight. This condition is very evident from photographs as well as the

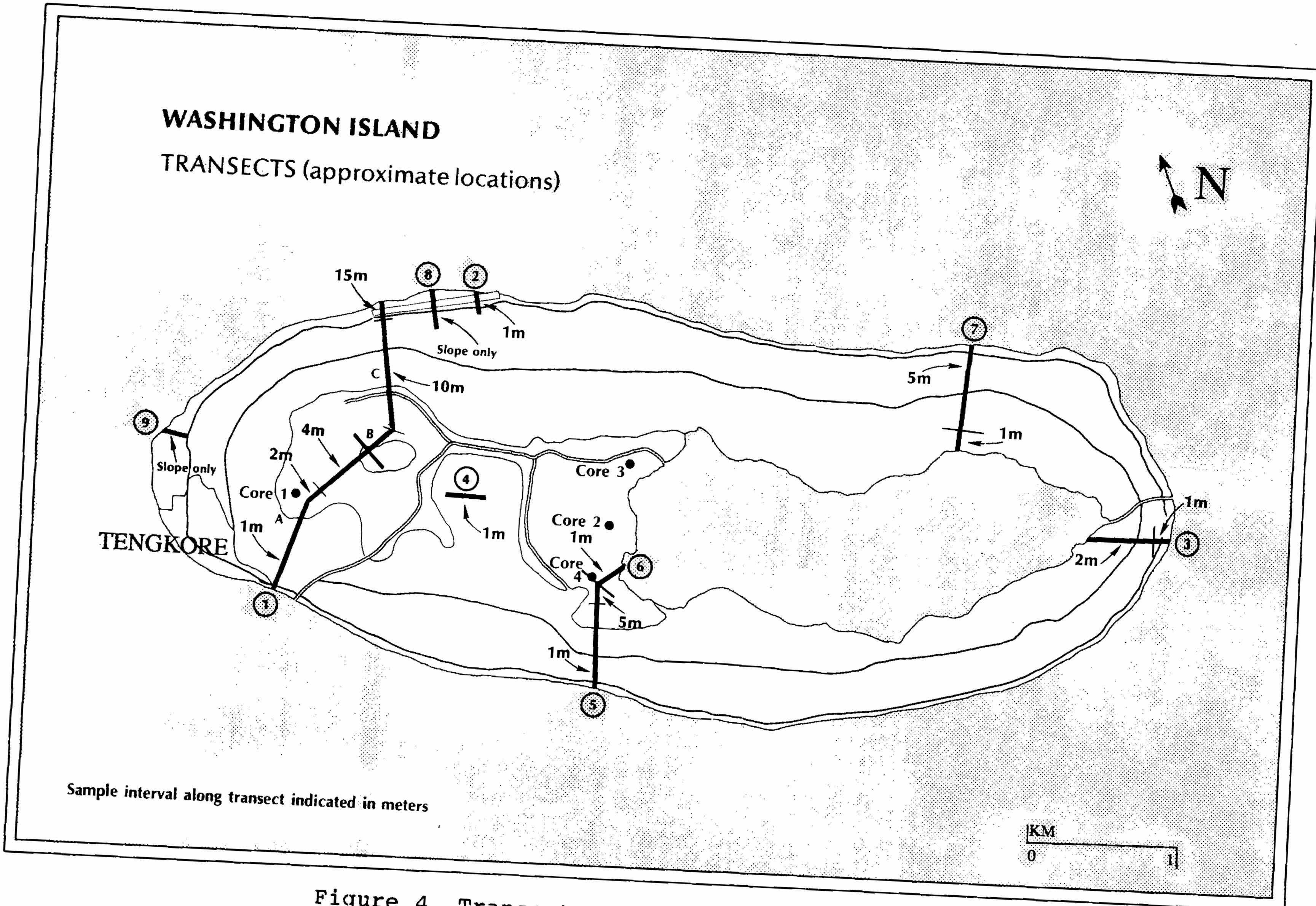

Figure 4. Transects and core locations

ground. Probes throughthe firmer peat revealed an under layer of slush which extended as far as our two meter corer could reach which impied at least part of the peat is floating.

Bordering the lake is a strip of much drier, firmer peat standing about 30 cm higher than the nearby moist Scirpus-dominated bog and supports patches of scattered coconut, Pandanus and fern. Christophersen (1927) felt that the lake was encroaching on the coconut forest and interpreted the fallen palms in the area as evidence of undermining and erosion by the lake. In contrast he also postulated successional encroachment of the Scripus-dominated bog first by Cyrtosperma and Cyperus, later to be followed by Polypodium and Pandanus, and eventually coconut. This sequence is normally observed along the gradient from the bog to the coconut forest. The presence of 'advanced' vegetation along the west or lake side of the eastern bog, he attributed to drift seeds and propagules having been blown westward across the lake to the eastern bog where they became established. The addition of the larger plants would result in the slightly raised peat bog level observed. An alternative explanation might be that the western end of the lake is controlled by the existence of a former ribbon reef that crossed the old lagoon. Structures of this sort are common in atoll lagoons and are evident in the present lagoon of Palmyra as well as in the lake on Washington. This reef provides slightly elevated substrate and suitable structural support for a narrow strip of trees along the lake edge.

Unsuccessful attempts to plant coconut in the western bog observed by Christopherson in 1925 were still evident in 1983 as vegetated rows of low, mounds.

Peat depth across the western bog was measured by Christophersen (1927) to range from 50 to 80 centimeters, with an average depth of 70 cm His probings revealed a maximum peat depth of 112 cm in other portions of the bog. Christophersen (1927) stated that the peat extends, with gradually diminishing thickness, about 170 meters into the coconut woodland from the bog's edge, which represents the distance that the forest species have advanced into the bog by the process of succession.

Our profile across the West Bog confirmed the peat to be uniformly 70 cm deep and overlying lagoon sediments of sand and clay (Figure 5), and quite consistent with Christopherson's findings. However cores in the East Bog reveal that the peat is much thicker and in parts the lagoon sediments lie more than 275 centimeters below the surface (Table 1).

The nearly uniform depth of the peat in the West Bog, and the fact that it lies on marine mollusk shells, implies that the peat bog has formed on a relatively shallow, level surface of a marine lagoon reef flat. This process may still be occurring in the northeastern portion of the lake where narrow reef flat remnants are covered with unconsolidated organic muck and dense Scirpus growth. The accumulated

Table 1. Depth of Peat

Core no.	Location	Maximum depth of peat (cms)	Underlying substrate	Radiocarbon dates age	depth cms.	sample no.
1	West Bog	70	sand and clay	1060 ±100	64- 69	W5655
2	East Bog	275	not reached	860 ±110	255-275	W5686
3	East Bog	180	sand	1150 ±110	160-170	W5695
4	East Bog	145	sand	no date	---	---

detritus has not yet built up enough to form a peat substrate. The east bog presumably formed in deeper water of the central part of the old lagoon depression.

Measurement of bog level in relation to the lake's water level, or large standing pools of water in the surrounding woodland, show the bog to be 10 to 30 cm higher than the water. The construction of canals linking the lake and bogs and connecting them to the ocean, around the turn of the century, allowed the lake's water level to be controlled artificially and perhaps established a new base level. If the western shore of the lake is controlled by a reef structure, the cutting of the canal to the lake may have allowed water to penetrate into the peat and thus causing its degeneration. It is noted that the area of degraded peat is in the quarter where the canal enters the lake. Alternatively the floating peat of the East Bog may be an entirely natural, if slightly unstable, condition.

<u>Lake formation</u>

The formation of a fresh water lake on Washington Island has been the subject of speculation. We found marine mollusk shells and coralline sand beneath the peat and remnant reef structures with dead coral and marine bivalves in situ on the lake bed indicating that the present lake and peat bog were once part of a marine lagoon system.

There are numerous examples in the Central Pacific of low islands made up of a single land mass, like Washington Island. Quite a number of these reef islands have enclosed bodies of water, either ephemeral or permanent, in which salinity ranges from hypersaline or salty to brackish or fresh. Ephemeral or hypersaline lagoons have limited sub-surface exchange with ocean waters and their size and salinity depends on rainfall. Examples are found on Starbuck Island in the Southern Line Islands, and on Birnie, and Sydney, in the Phoenix group (Bryan, 1942). Other enclosed salt water bodies show obvious sea water connections by evidence of tidal fluctuations, direct observation of salt water surging through fissures in the reef platform substrate, or the presence of marine organisms. Among islands with this type of lagoon are Niutao and Nanumanga in Tuvalu, Malden Island in the Southern Line Islands, and Nikunau in the Gilbert chain (Holthus, pers. obs.; Bryan, 1942).

A few islands of the Pacific have enclosed lagoons of brackish or fresh water. Nassau Island, in the Northern Cook Islands, has a swamp-filled central depression with standing water that is fresh and drinkable (Bryan, 1942). Swains Island (Olosega), in American Samoa, is described as a partly raised atoll with an enclosed, shallow, brackish body of water (Cumberland, 1956; Whistler, 1983). Pulusuk, in the Central Caroline Islands, contains a 1 to 4 meter deep, brackish water lagoon, the bottom of which is covered with a layer of fine detritus. On Pulusuk, the lagoon was observed to be at least partly fed from the island's fresh water lens through a fissure in the limestone bedrock. Salinities ranged from 0.0

parts per thousand, just after a rain, to 2.8 parts per thousand (Nelson and Cushing, 1982).

Perhaps the best known example of a low island with an enclosed fresh water lagoon is Clipperton Island in the Eastern Pacific. In this case, the body of fresh water is relatively large and is surrounded by a narrow continuous strip of land which had an open surface channel in historical times and shows evidence of storm wave breaching (Sachet, 1962). Lagoon salinities at Clipperton range from fresh to brackish depending on the amount of rainfall and episodic washover by storm surf. The remains of coral and other marine organisms are found on the lagoon's reefs, which are veneered with mud (Sachet, 1962).

The lake on Washington Island was sounded for depth with a lead weighted line at a number of locations. Maximum depth was found to be about 10 meters, which agrees with earlier lake depth estimates of 30 feet (Wentworth, 1931). However, much of the lake is occupied by remnant reef structures approximately 1 meter deep. Aerial photographs show they form submerged, convoluted platforms and holes like many living reefs. On portions of the lake's northeast edge it appears that submerged reef flat is partly overlain by unconsolidated organic matter and other silt which is colonized by peat forming Scirpus.

The lake's water is very turbid. Although no macroscopic aquatic vegetation, such as is reported from Swains and Clipperton Islands (Whistler, 1983; Sachet, 1962) is found at Washington, the lake water is full of floating algal material. This material settles downward and forms dense clouds which grade into the viscous mud and silty material of the lake bottom. Water samples were taken at three depth intervals at the lake's deepest point. Results obtained from a salinity refractometer reveal the water to be completely fresh at all levels.

The process by which the enclosed body of water on Washington Island has changed from a marine lagoon to a fresh water lake is subject to debate. Neither is there mention of any such feature by earlier visitors to Washington Island. The extent of the land area separating the two water bodies also makes it unlikely that ocean waters have periodically breached the land rim. Christophersen (1927) supposed that the lagoon was isolated from the ocean by gradual emergence of the land. The salt water either evaporated or disappeared through sub-surface drainage and was replaced by fresh water from the island's abundant rainfall. Wentworth (1931) restated the emergence theory, adding that the process of freshening the salt water lagoon would have taken several hundreds of years. However, Huchinson (1950) points out that: "no elevated coral has been discovered in situ high enough to provide unequivocal evidence of emergence".

Elschner (1915), as reported in Hutchinson (1950), provided another theory for the lake's fresh water. He argued that guano material washed into the lagoon could result in the precipitation of colloidal calcium phosphate. With sufficient guano, plenty of rainfall, and abundant organic detritus, this would result in the formation and deposition of a clay-like calcium phosphatic mud capable of sealing the lagoon from its subterranean connections to ocean waters. Over a period of many years, the island's copious rainfall would convert the system to that of a fresh water lake. The length of time involved in this process is indicated by the occurrence of a fresh water fish and eel species in the lake. Presumably, these animals were trapped as the salt water lagoon was isolated from the ocean. The conversion of the lagoon to a fresh water lake was so gradual as to allow the adaptation of these marine organisms to the fresh water environment, although the length of time necessary for this process to occur is uncertain.

The ability of guano deposits to form lagoon bottom substrate is supported by observations of Friederici (1910), as reported in Wiens (1962). On Niau Atoll in the Tuamotus, rain erosion of guano from the land rim allegedly resulted in the deposition of phosphate sediments up to 8 meters thick in the lagoon. Likewise, the water-filled depression on Enderbury Island is reported to be partially filled with "soft, muddy materials which are principally bird guano". Further evidence of the correlation between guano deposits and the formation of isolated bodies of water on reef islands is provided by those islands where the mining of phosphate has left artificial depressions. On a number of such islands, including Flint Island in the Southern Line Islands and McKean and Sydney Islands in the Phoenix group, the guano pits have become filled with rainwater, resulting in the formation of brackish ponds. In addition to phosphate deposition, the density of an island's reef rock platform may influence the retention of rain water. On Kili, a reef island in the Marshall Islands, persistent heavy rains lead to the accumulation of substantial amounts of fresh water in the island's central depression (Bach, 1950 as reported in Wiens, 1962).

The sealing of the bottom of the lagoon on Washington Island would account for a rise in the water level of the enclosed basin. Our survey showed the lake level to lie 70 to 170 cm above the inshore edge of the adjacent ocean reef flat (Figure 7 and 8). This roughly matches the approximate 1 meter submergence of the reef flats in the lake, which would have presumably formed to about the same base tide level as the ocean reef flat. Streets (1877b) reported the Scirpus bog was inundated suggesting perhaps the lake level was higher before the canals were constructed.

On the western end of the lake, we observed portions of the peat bog and coconut woodland peat being eroded. Christophersen (1927), interpreted this to indicate that the filling of the lake by peat formation had ended and statedthat: "the lake will now encroach upon the bog as the bog before encroached upon it". A reason for such a reversal was not supplied.

The shallow sections of the former lagoon would be readily colonized by aquatic plants as soon as the the lagoon was sealed off from the ocean and the lake became sufficiently fresh to support them. The deeper water would receive some sediments but productivity levels in the murky water are low compared to the shallow sections supporting Scirpus. Soundings, which revealed depths of 5 to 6 meters immediately adjacent to portions of the eastern bog, suggest that the lake boundary is controlled by underlying reef structure and not the progress of ecological succession. The formation of peat would not be able to proceed any further than the edge of the shallow reef flat. Coconut palms which had germinated at the lake edge would lean out into the open sunlight of the lake, only to topple into it when their weight became too great to be supported at such an angle by roots anchored in the peat. This might give the impression that lake water erosion has caused the coconut trees to fall into the lake but in fact might occur on a stable shore line.

Climate

Sporadic collection of rainfall data began on Washington Island in 1910 but relatively complete data is available from 1946 to 1972 (Taylor, 1973 and Table 2). The average annual rainfall is 2902.7 mm. The wettest months are from March to June during which an average of at least 275 mm per month can be expected. August to November are generally drier but each have an average above 120 mm. Considerable variation is detectable from year to year and from month to month.

ARCHAEOLOGY

The islands of the Line and Phoenix group were uninhabited at the time of first European contact but there is indication that at least four of them once supported human populations. Two pieces of evidence for prehistoric occupation from Washington Island have withstood careful scrutiny. One was "a round enclosure of coral blocks about 12 feet in diameter inside" which was found on the western end of the island near the site of the present day village. This was described by an informant to Stokes (n.d.) and reported by Emory (1934). In the same area a basalt adze was found near the surface and was described by Finney (1958) who concluded it was decidedly Western Polynesian in character and similar in patination and form to those found on nearby Fanning Island. The styles of these artifacts are not of a sufficiently specialized type to be diagnostic (Bellwood, 1979). To understand their probable relationships it is necessary to consider the wider context of the Line Island archipelago.

The first European known to have visited Fanning Island was Edmund Fanning in 1798. Although he saw "no signs nor vestige of human habitation" himself, he recorded in theaccount of his voyages that, a few years after his visit, a

Table 2. Rainfall of Washington Island

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
Mean	250.6	257.8	291.3	316.6	363.1	329.8	275.2	162.5	142.7	124.9	168.9	219.4	2902.7
Max.	938.0	787.9	1135.1	746.8	981.5	736.9	742.7	554.0	438.4	488.2	660.7	755.1	5181.9
Min.	16.3	6.3	17.8	99.8	59.7	112.8	76.5	9.7	1.0	5.6	0.0	2.8	1129.3

captain of one of his ships, who stopped at the island to procure beche de mer and turtle shell, discovered evidence of occupation.

> ... during this stay he [the captain] frequently walked into the interior, and in one of these walks he had come across some heaps of stones, which, to all appearance, from their order and regularity, were thus placed by the hands of men, although from the coat or crust of weather moss with which they were covered, it must have been at some remote date. Being prompted by curiosity, and a desire for further information upon this subject, he caused one of these piles to be removed, and found it to contain, a foot or two under the surface of the ground, a stone case, filled with ashes, fragments of human bones, stone, shell, and bone tools, various ornaments, spear and arrow heads of bone and stone etc. (Fanning, 1970:224-225)

Furthermore conspicuous evidence of human occupation was noted on Malden Island in the Southern Line Islands at the time of the first European visit to that island by Byron in the H.M.S. Blonde in 1825. Andrew Bloxam, the naturalist for the expedition, noted:

> "In one spot along the coast I observed what is evidently the work of human hands, though apparently of ancient date. It is a parallelogram of coral stones, with a pillar erected in the middle of a single stone 7 feet high. ... The Surveyor, who had walked to another part of the island, informed us that he had met with about 40 such buildings, but in a more perfect state, extending along the shore." (Bloxam, 1925: 80).

The presence of rubbish heaps, numerous structures, graves and house sites suggest occupation for a considerable period of time (Sharp, 1956).

Expeditions conducted under the auspices of the Bishop Museum in the 1924 and 1934 undertook archaeological surveys which were reported by Emory (1934, 1939). Emory himself did the surveys on Fanning, Christmas and Malden Islands, during the Kaimiloa Expedition in 1924, and visited Fanning and Christmas again in the course of the Mangarevan Expedition in 1934 but did not at any time visit Washington (Emory, 1984 personal communication). From Fanning he described dressed stone enclosures with L-shaped cornerstones and a slab lined tomb which he took to be of Tongan affinity. A. Sinoto (1973) investigated the sites himself at a later date and agrees that the structural style points to Tonga where coral and limestone are available and often used for construction, unlike the Marquesas where such materials are not available.

Four basalt adzes found on Fanning, along with the Washington adze, were likened by Emory to those found in Tonga and Samoa, and not similar to those found in Hawaii, the Marquesas, Tahiti, the Cooks or other marginal Polynesian islands. However A. Sinoto (1973) notes that, since Emory wrote his opinion, similar forms have been found widely in Eastern Polynesia. Emory thought the fishooks which were recovered showed no clear relation to those of any other part of Polynesia but the presence of two holes in base and an upward projecting limb of the hooks suggested a connection with the traditions of the western Pacific. A. Sinoto (1973) notes however that identical forms have since been reported from the Marquesas. Finney (1958) seems to accept Emory's interpretation however Bellwood (1979) believes that both the slab lined enclosures and the fish hooks indicate an association with Penrhyn but he adds that we do not know enough to be dogmatic about it. A site studied by A.Sinoto yielded two radiocarbon dates which suggested occupation of one sites in the range AD 350-530 and the other the other AD 1020-1190. The 600 year discontinuity between settlements seems implausible and so sample contamination may have occurred (A. Sinoto, 1973).

Porpoise teeth, bored to be strung, were found in the Fanning tomb and present another problem. As they were employed extensively by the Marquesans but are rare in Polynesian groups elsewhere, Sharp (1956) concluded that the Line Islands were occupied by Marquesans. These people he imagined were carried by chance on prevailing wind and ocean currents, at an early period before Marquesan culture had much opportunity to differentiate.

A species of parrot, the Polynesian lorikeet (<u>Vini kuhli</u>), was found on Washington and Fanning Islands at the time of first European contact. The only other place where this particular species of lorikeet is found today is Rimatara and Tubuai in the Austral Group. As these birds were favorite pets of Tahitians (Bruner, 1972) one possible explanation of this remarkable disjunction is that they were introduced to the Line islands by Polynesisns and have since established wild populations. Related species of <u>Vini</u> occur in the Society Islands and the Marquesas. Although today they are all rare and in danger of extinction, they were once widely distributed through eastern Polynesia.

A. Sinoto (1973) recognized that with small amounts of data many questions were left unanswered including the annomaly that the structural styles discovered on Fanning implied Tongan connections whereas artifacts indicated Marquesan affinities. However he tentatively proposed that decendants of proto-Polynesians who had settled in the Marquesas, but retained some of their earlier cultural attributes, set off on a migratory voyage sometime between AD 400-1100, but most likely after AD 600, and settled on Fanning Island until abandonment or extinction took place. Kirsch (1984) esentially accepteds this reconstruction of Polynesian dispersal.

In 1906 a fragment of a canoe was found on Washington Island when a canal was being dug between the East and West Bogs for the purpose of transporting copra (Stokes n.d.).

The canoe was buried beneath several feet of peat and was thought to made of Callophyllum, which had only recently been introduced to the islands. Emory (1934) concluded that it was of prehistoric origin. The fact that it contained nails was explained as a later repair. An annotation of the record card, citing Douglas Yen as the authority, states that the canoe was either constructed of Pisonia, which is native to the island and present in considerable abundance, or breadfruit, which was probably introduced at an early date. Furthermore the age of the wood has been estimated to be 160 $\pm$ 100 by radiocarbon dating (Preston, Person and Deevey, 1955). This would suggest it was constructed by Polynesian laborers in the nineteenth century but how the canoe came to be buried is still to be explained. Stokes (n.d.) recorded that it was found under four feet of peat whereas a newspaper account by Resterick (1929) stated that it was found eight feet down. In any event it could hardly have been covered to either depth by natural sedimentation in the forty years since first settlement.

Oral histories suggest that Polynesians to the south may have been aware of the existence of the Line Islands and have visited them.

> There is a Manihiki tradition which relates that natives of Manihiki frequently visited Washington Island at a time when it was inhabited. They called the island Arapata and a legend records how it was overwhelmed by a cataclysm. A native of Manihiki, on a visit to Washington Island, once asked for a fish called malatea (Cheilinus undulatus or giant wrass) and was given only the head. Insulted by this, he left in his canoe, and cursed the island which then turned upside down and malatea has not been found there since (Emory, 1934; Stokes, n.d.).

The view that most of the Polynesian islands were populated by chance drift voyages has been taken by Sharp (1956, 1963) who characterized the Line Islands as lonely islands; a haven for unfortunates blown away from their home islands and cast up on these remote atolls. Here, with sufficient water and food they could live out their solitary lives practicing their traditional livelihood. He conjured a melancholy picture of a canoe load of castaway men on Fanning Island making simple tools with the materials available and burying their dead in the ritual way, until the last one died. This image was developed into an evocative short story by Updike (1973). Sharp went further to speculate that a canoe containing women may have drifted to Malden Island allowing a population of several generations to persist there. However recent reassessment of Polynesian navigation skills make it appear distinctly possible that prehistoric navigators conducted purposeful voyages of exploration and possessed the skills to identify the location of their discoveries so as to be able to make repeated voyages. Under these circumstances the Line Islands might have been supply islands or revictualling stations, between eastern Polynesia and Hawaii as early as 400 A.D. (Kirsch, 1984).

In summary it can be stated that the Line Islands were visited in prehistoric times by Polynesians. Colonies appear to have been established on Malden for an extended period of time and perhaps also on Fanning. Occupation of other islands, including Washington, may have been of shorter duration or by smaller populations. Archaeologists are divided in their opinion of the origin of the Polynesian culture found in the Line Islands. Both eastern and western Polynesia have been proposed on the basis of existing evidence. The resolution of this paradox will probably have to await either the discovery of more archaeological material in the Line Islands or a better understanding of the mother cultures in the South Pacific.

HISTORY

Edmund Fanning sighted Washington Island on June 12th. 1798 and was the first European discover of both Washington and the island that bears his name. Although no landing was made on Washington he left a glowing account of it:

> This was of much greater elevation than Fanning's Island, and was, moreover, covered with plants or grass, presenting to our eyes a beautiful green, and flourishing appearance. With the unanimous approbation of every individual on board, both officers and seamen, and with feelings of pride for our country, we named this, Washington Island, after President Washington, the father of his country. Having but recently obtained a bounteous supply of refreshments, there was no necessity for our making a landing here, although the trees and green foliage, among which we plainly saw the tall coconut-tree, presented a very strong inducement for us so to do, but we passed it to the south, we then steered to the west. ... There can be no doubt that at this island a vessel might obtain an abundant supply of excellent refreshments for her crew. As at Fanning's Island, so here, we could perceive no tokens of its being at all inhabited (Fanning 1970).

It is entirely likely that his good report resulted in other visits in the early nineteenth century by traders or whalers. In 1814 a map published by Martin Arrowsmith (Stanton, 1975) showed and island with the name New York at the approximate location of Washington Island (Wilkes, 1970) suggesting an independent discovery. Gardner, in the ship Bowditch, sighted the island in 1833 (Table 3) and tried unsuccessfully to send boats ashore to collect coconuts. In his log he drew of profile of the island which depicted a low

Table 3. Visits of Ships to Washington Island

YEAR	MONTH	SHIP	CAPTAIN/ LOGKEEPER	COMMENTS
1789	Jun	Betsy	Fanning	named for George Washington
1833	Sept	Bowditch	Gardner	sighted island PMB* 833
1833	Oct	Bowditch	Gardner	tried to send in boats for coconut but could not; profile drawing of island.
1840	Dec	Peacock	William L. Hudson	in company of Flying Fish as part of U.S. Exploring Expedition; established position but did not land. PMB 773
1840	Dec	Flying Fish		in company of Peacock on as part of U.S.E.E.; sighted but did not land; PMB 773
1846	Sept	Acushnet		sighted island; PMB 215, 737
1847	Dec	William & Eliza		sighted island; PMB 837
1848	Jul		Lucett	described from sea (Lucett, 1851)
1849	Nov	Pioneer		sighted island; PMB 888
1854	Feb	Washington	Holley	boats sent ashore and returned with sweet potatoes, coconuts and bananas. PMB 369, 370
1855	Nov	Rambler		sighted island; PMB 862

Table 3. Visits of Ships to Washington Island (cont.)

YEAR	MONTH	SHIP	CAPTAIN/ LOGKEEPER	COMMENTS
1856	Dec	Petrel		sighted island; PMB 887
1857	Nov	Triton 2nd		sighted island; PMB 869
1858	Dec	Cicero		sighted island; PMB 231
1859	Sept	Josephine	W.C. Stone	claimed for U.S. and American Guano Co. (Judd, 1859)
1861	Dec	Massachu- setts	Daniel B. Greene	Natives had been there a short time; fished, traded for coconuts. PMB 349
1864	Dec	Adeline		sighted island; PMB 304
1866	Nov	Onward		sighted island; PMB 898
1867	Dec	James Maury		sighted island; PMB 335, 336
1874	Jan	Portsmouth	Joseph S. Skerrett	North Pacific Exploring Expedition; surveyed island; (Skerrett, 1873-4; Streets, 1877a)
1875	Jan	Arnolda		sighted island; PMB 721
1875	Mar	Arnolda		sighted island; PMB 721
1879	Jan	Helen Mar	Koon or Deshon	landed passengers and lumber; PMB 244
1889	May	Cormorant	Nichols	annexed for Great Britain

* Pacific Manuscripts Bureau document see Langdon (1978)

shore lined with palms.

Before longitude could be fixed accurately the same island was often reported in several different positions under different names. At least five islands had been reported in the vicinity of Washington Island and Commodore Wilkes of the United States Exploring Expedition dispatched two ships in December 1840, under the command of William L. Hudson, to investigate the area. They searched five different locations and were satisfied that there was only one island. Like Edmund Fanning, and probably others before him, Hudson did not attempt to land because of the absence of a safe anchorage. However he left a description:

> It is three and three and a quarter miles long by one and a fourth wide, and is entirely covered with cocoa-nut and other trees, exhibiting a most luxuriant growth. There is a reef off its eastern point, which extends for half a mile. At the western end, a coral ledge extends two miles in a northwest-by-west direction, on which the water appears much discolored, but the water was not seen to break upon it, except close to the point of the island. The island is elevated about ten feet above sea level. The surf proved too heavy to allow of their landing and the island affords no anchorage (Wilkes, 1970).

This did not dispel the errors regarding the position and name of Washington Island as Edward Lucett, a trader, searched for "Prospect Island" which appeared on his chart at the same latitude as Washington but 80 miles to the west. He concluded that they were one in the same. He also was deterred from attempting a landing and left a description; presumably based on what he could see from his ship.

> It is about three miles long, and rather more than a mile in width; elevated from twelve to fifteen feet above the level of the sea; and its surface presents an unbroken mass of vegetation. A deep verdant foliage forms the basement to columns of cocoa-nut trees, which rear their tall shafts in such seried ranks, the eye could not penetrate them. We endeavored from the masthead to ascertain if any lagoon existed, and believed not. Surf breaks close to the beach all round the island; dangerous landing for boats. Green water runs off the west point, in a north-west by north direction, for nearly two miles, but we saw no breakers except those on the sandy beach. Sailed over part of the green water; bottom was clearly discernible - white sand and patches of coral. Made no attempt at landing, from the uninviting aspect of the surf. Birds seemed the sole tenants of the island; they flocked around us in great numbers, and the beach was swarming with them - a certain sign of the absence of that carnivorous animal, man (Lucett, 1851).

These early descriptions are of interest because they establish that coconuts were present on the island before Europeans arrived. The impression that these accounts leave is that the coconuts were abundant and not just a fringe along the shore however since no landings were made the inland extent can not be established.

From the earliest times the history of Washington Island was tied to that of Fanning. The latter had a larger land area and, perhaps most importantly, it had a safe harbor. Thus Fanning Island was always the center of operations and Washington Island was relegated to the position of a satellite. Although there were attempts as early as 1820 to establish a colony on Fanning by one Navarro, a Captain Green, Mr. Dean and 37 Hawaiians, it apparently failed because by 1822 most of the party had returned (Maria Loomis, 1819-24; Elisha and Maria Loomis, 1820-24; Restarick, 1929a). Whalers and traders who stopped on Fanning Island during the 1840's reported castaways or the presence of small groups attempting to settle (Wester, 1985). It would seem that Washington Island had been colonized by 1854 because when a whaler stopped there he reported trading for "sweet potatoes, coconuts and bananas" (Holley, 1853-57). It is not clear who founded this colony but it is evident that it did not persist.

In 1852 Henry English acquired Fanning Island from Charles Burnett Wilson who had inturn purchased it from Messrs Lucett and Collie who had established an enterprise to produce coconut oil on the island. English intended to continue this work and provide supplies for whalers and traders (English, 1857). In 1857 William Greig, a Scot who had a dry goods store in Honolulu, went to work for English as Assistant Manager of Fanning Island. English formed a partnership with William Greig and James Bicknell in 1859. The coconut business changed from oil to copra and prospered. Operations eventually branched out into several other endeavors including guano, beche de mer, ship repairing, victualling and honey production (Anderson and Kelly, 1980).

In the 1850's considerable interest developed in the dry islands of the Central Pacific as possible sources of guano. In 1858 a newspaper article (New York Tribune, March 5) listed 48 islands which were claimed as U.S. possessions on the basis of an Act of Congress passed in 1856 (United States Congress, 1859) allowing U.S. citizens to claim islands which were not inhabited or under the jurisdiction of any other government and on which guano was present. Among this list was "Prospect Island" which is believed to be a synonym for Washington (McClellan, 1940; Motteler, 1986). It is not clear which individual visited Washington and claimed it for the United States. However it is evident that Americans were actively seeking guano islands in the region because in 1857 Henry English appealed to the British Consul in Honolulu for permission to "hoist the British flag as protection to his Property" (Miller, 1857). In recommending approval to this request to his superiors the Consul noted that HMS Dido had touched on Fanning in 1855 and obtained "a supply of fowles". In 1859 Gerrit Parmile Judd, an American who had become a naturalized Hawaiian citizen, sailed to the Line Island as an agent for the American Guano Company to press claims. They stopped on Washington Island (referring to it as New York Island) between August 1st. and 3rd. 1859 and made one of the earliest descriptions of the island from the land. He makes no mention of any inhabitants so it must be assumed that the colony, which had been present in 1854, had been abandoned.

> Sept. 1 1859 Went ashore. Went through corner of the island, came out on north shore.
> Sept. 2. 1859 Set out to find the lagoon. Came out of trees to the south. Walked to east or windward side and found self in a forest of large, tall and stately trees - 10 ft. through (Babian) - Pursued as thought straight course blazing trees - but came on track a second time. Set off in another direction and came on lauhala and coconut trees and in less than an hour found lagoon -1000 acres covered with rushes but dry. Took a few specimens - one from the lagoon where small birds had nests, - no phos-lime; 2 from near beach - Phos. and lime.
> Sept. 3 1859 Took possession of island in the name of USA and Am. Guano Co. Put a document in bottle and hung from a tree. Came aboard. "Adieu to New York Island, a beautiful spot capable of sustaining 1000 natives" (Judd, 1859).

Despite the encouraging report, the American Guano Company focussed its operation in the Southern Line Islands and paid no more attention to Washington.

Permanent occupation of Washington Island appears to have been the result of expansion of Henry English's operations from Fanning in 1860 (Stokes n.d.). This is confirmed by a log kept by a number of people, including possibly Henry English (Palmer, 1973), and a whaler who stopped there in 1861 and noted that the natives could provide nothing because they had only been there a few months (Greene, 1860-65). In 1864 English sold his share of the islands to Greig and Bicknell and left because of ill health. Greig took charge of Fanning while Bicknell managed Washington Island. They imported laborers from various parts of the Pacific. In 1874 it was reported that "Tahitian" laborers were used (although this term is often used loosely for any Polynesian indentured laborers). However it was noted by James Bicknell, the nephew and later heir to his uncle's share of the operations, that Manihiki laborers were used in 1882 but in 1894 the laborers were Gilbertese (Stokes, n.d.).

Another search for guano was made in 1878 this time by John T. Arundel a British trader and guano digger who later became one of the principle shareholders in the Pacific Phosphate Company which later mined the deposits of Nauru and Barnaba (Ocean) (Langdon, 1974). With the assistance of Greig and Bicknell he surveyed both Fanning and Washington Islands and, while on Washington, made the following notes in his diary:

> Arrived Washington Tuesday (Nov. 12) ashore by 10 am. Went with Bicknell to lake - slept there. Went to see guano at the weather end of the island. Returned to lake house for breakfast. Afterward walked home calling on route at guano bed where ape grows. Took a lot of samples. Left at about 5:30pm. (Arundel, 1870-1919).

As a result of these surveys Arundel undertook a guano mining operation on Fanning between 1878 and 1880 and some digging continued until 1885 (Republic of Kiribati, 1983). However no evidence can be found of an attempt to exploit the deposits on Washington. It may have been because they were of inferior quality or because the island itself was less accessible.

In 1874 the USS Portsmouth under the command of Joseph S. Sterrett was dispatched to Palmyra, Washington and Christmas Islands Island as a part of the North Pacific Surveying Expedition for the purposes of surveying the islands and to ascertain if Prospect Island, shown close to Washington Island on some charts, did in fact exist. They spent January 1st. and 2nd. surveying Washington with steam cutters from the ocean and with a landing party on shore (Skerrett, 1873-4). Thomas H. Streets, the Assistant Surgeon, left the first scientific description of the island. He noted that, as a result of recent heavy rains, the bogs were covered with water to a depth of six to eighteen inches. He reported the existence of a species of eel and a shrimp in the lake as well as the Polynesian lory, a warbler, like that on Christmas Island, and a new species of duck which was described on the basis of the specimens he was able to obtain. He also collected plant specimens which are presently preserved in the National Herbarium, Washington D.C. (Streets, 1876, 1877a, 1877b).

Confusion about the position, name, and number of islands in the northern Line group persisted for many years in publications and on maps and charts (Behm, 1859; Findlay, 1884). The British claim to Washington Island was reinforced by a landing on May 29th 1889 by Commander Nichols in the HMS Cormorant at which time it was formally annexed.

George Bicknell died in 1884 leaving his share of the plantation to his brother, James Bicknell, then the auditor of the City and County of Honolulu. However William Greig continued to operate the copra production industries on both islands with his large family of four sons and five daughters until his death in 1892. The elder son George Greig took over the management. James Bicknell remained in Honolulu and was considered half owner of the islands by the Greigs. In 1903 Humphrey Berkeley obtained an option to purchase Bicknell's share in the islands and attempted to interest the English company of Lever Brothers in acquiring them. Levers wished to obtain copra plantations in the Pacific to supply their soap manufacturing business. They were discouraged from taking action when it became clear that Berkeley could convey clear title to the property. It appeared that Bicknell's interest was an undivided half share which was entailed. Meanwhile the heirs of the estate of William Greig were disputing the execution of the will and eventually engaged in a legal battle which resulted in a court case heard in Suva, Fiji in 1903 (Unilever, 1903).

In the same year George Greig disposed of his interest in the company and a younger brother William (Willie) became the manager and his brothers David and James remained to assist. Financial difficulties, already apparent before the legal battle, reached a head in 1907 and 1908 when creditors took legal steps to obtain the return of the money they had advanced. Proceedings in Suva resulted in the sale of both Washington and Fanning Islands for debt. The purchaser was a French priest, Petrico Emmanuel Rougier, who had renounced his ministry and became a plantation owner (Anonymous, 1958). He organized Fanning Island Plantation Ltd. which included both islands and eventually resold them at a considerable profit to a British syndicate represented by C. M. Armstrong. Greig family members continued to work on the plantation at least until Hugh Greig died on the Fanning Island in 1956 (Palmer, 1956). The family was on Fanning Island when it was attacked by a German warship during the First World War. The objective was of course the Cable Station which was an important link in the trans-Pacific communication line established across the Pacific between Sydney, Australia and Vancouver, Canada in 1902 (Restarick 1929b).

Washington and Fanning were purchased in 1935 by Burns Philp Co. Ltd., of Australia. They operated them as a copra plantation under the name of Fanning Island Plantations Ltd. until 1983 when they sold the islands to Kiribati Republic. Since that time the price of copra has fallen and harvesting of coconuts has been intermittent on Washington Islands. The government of the Republic of Kiribati is meanwhile investigating the economic potential of the islands for future development (Republic of Kiribati, 1983).

VEGETATION

The earliest recorded description of Washington Island were from the sea from which vantage observers agree that it was lushly vegetated and that coconut was a prominent feature. The first known account of the island from the land reported forests of "Babian" (*Pisonia*) as well as coconut and *Pandanus* (Judd, 1859) as is found today. However groves of *Artocarpus* (breadfruit), occasional banana, extensive tracts of *Cyrtosperma* and large *Ficus*, often marking abandoned camps, are reminders that the island has been manipulated by humans for the last 130 years. A map in the Burns Philp archives indicates the extent of coconut planting in the early decades of this century. Except for the cleared areas around villages and abandoned camps, road and canal sides, the vegetation of Washington Island has the outward appearance of being a natural vegetation community especially since the harvesting of nuts has ceased. The navy chart produced by the North Pacific Exploring Expedition in 1874 implies the whole island, other than the bogs, was essentially covered by coconut (Figure 3). A patch of some other vegetation is indicated at the western end of the island which corresponds with a present day stand of large Pisonia, and lends credibility to the accuracy of representation of vegetation on the map.

Methods

For the purposes of making a general description of the vegetation of Washington Island, and in the absence of existing aerial photography, a set of oblique aerial photographs were obtained using 35 mm color print film during an over flight in a small plane. A preliminary analysis of the photographs was done before going to the island and conspicuous vegetation entities were identified. Ground surveys were conducted in August 1983 with the purpose of characterizing the observed vegetation patterns. One meter wide belt transects were run between the beach and the lake or bog (Figure 4) to include a maximum number of patterns identified from photographs. The sample interval along the belt transects varied. Near the shore, where transitions were sharp, each square meter was sampled; as the vegetation became homogeneous, such as in the closed coconut forest or across the bog, the interval was extended to every two, four, five, or ten meters. At each sample site the substrate was noted. The topography was surveyed with the use of a transit and pole. A final vegetation map (Figure 6) was drawn with reference to the uncorrected aerial photographs, data obtained from transects, photographs taken on the ground and general observations.

Voucher specimens of all native, adventive and cultivated plants were made. These specimens have been placed in the herbarium of the Bishop Museum, Honolulu and reported by Wester (1985).

General Description of the Vegetation

The transecting technique is useful to interpret the patterns observable from aerial photographs and give a realistic impression of the gradational character or homogeneity of plant assemblages. Transect data of this sort does not lend itself to statistical analysis but for the purpose of this study, the identification and description of broadly defined types, it is quite satisfactory (Figure 7 and 8).

Today most of the island is luxuriantly wooded with coconut and other trees as it appears to have been in the nineteenth century. A survey of the terrestrial vascular flora revealed a total of 91 species of which 25 were considered indigenous. Others were cultivated species (46) or adventives (20) (Wester 1985). Adventive species were mostly concentrated around the village, along roads or paths or other

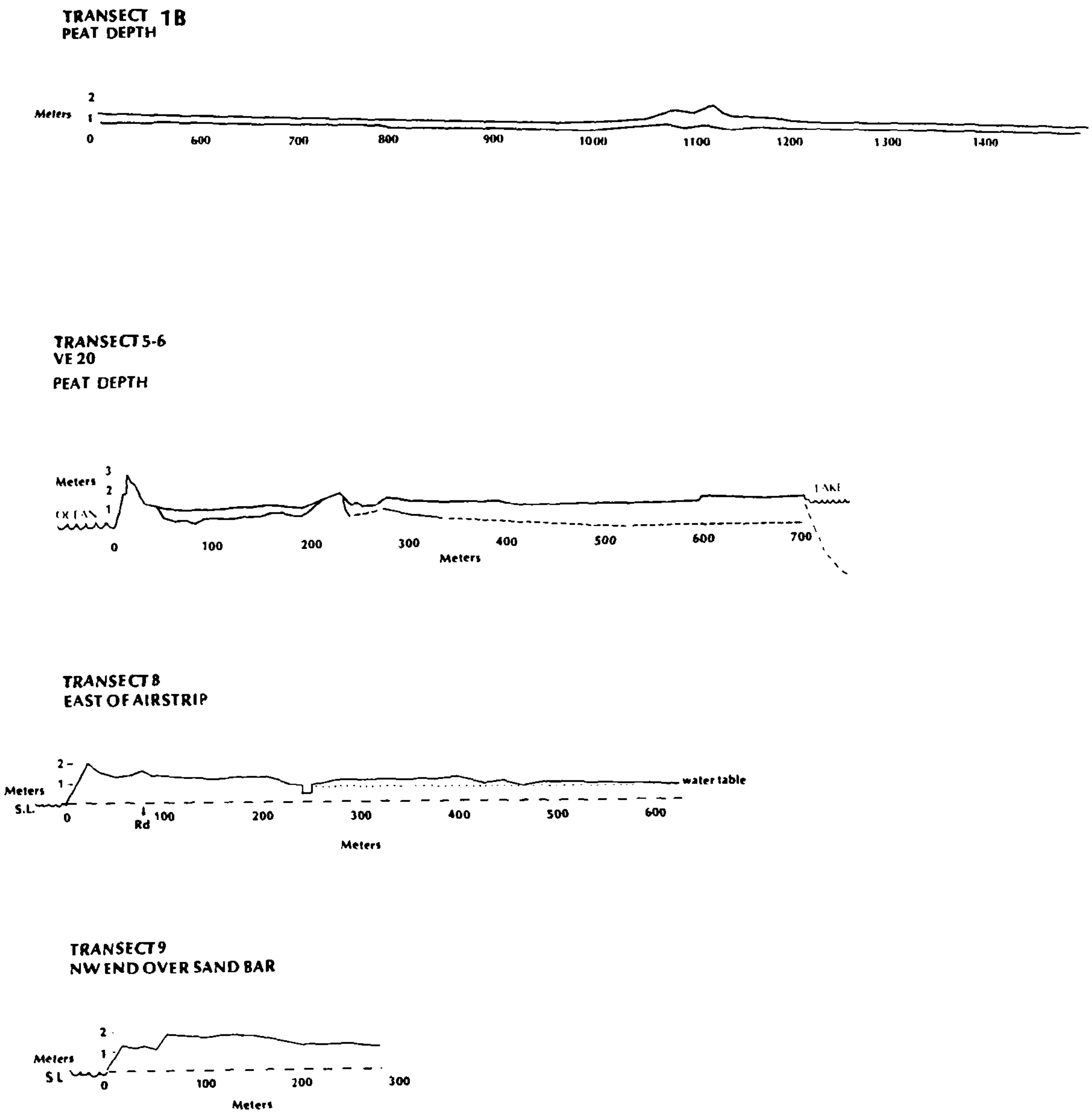

Figure 5. Island cross-sections

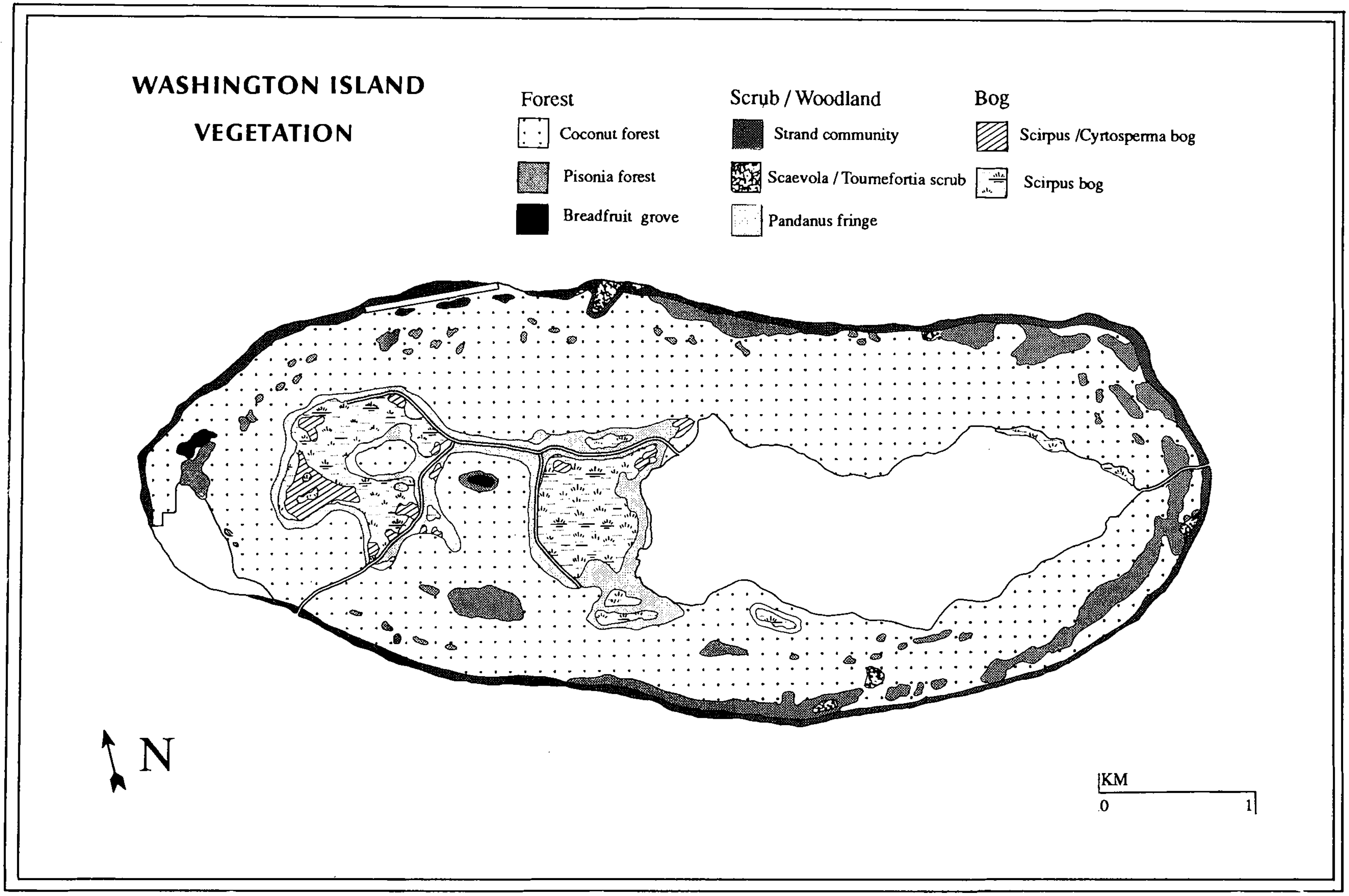

Figure 6. Vegetation

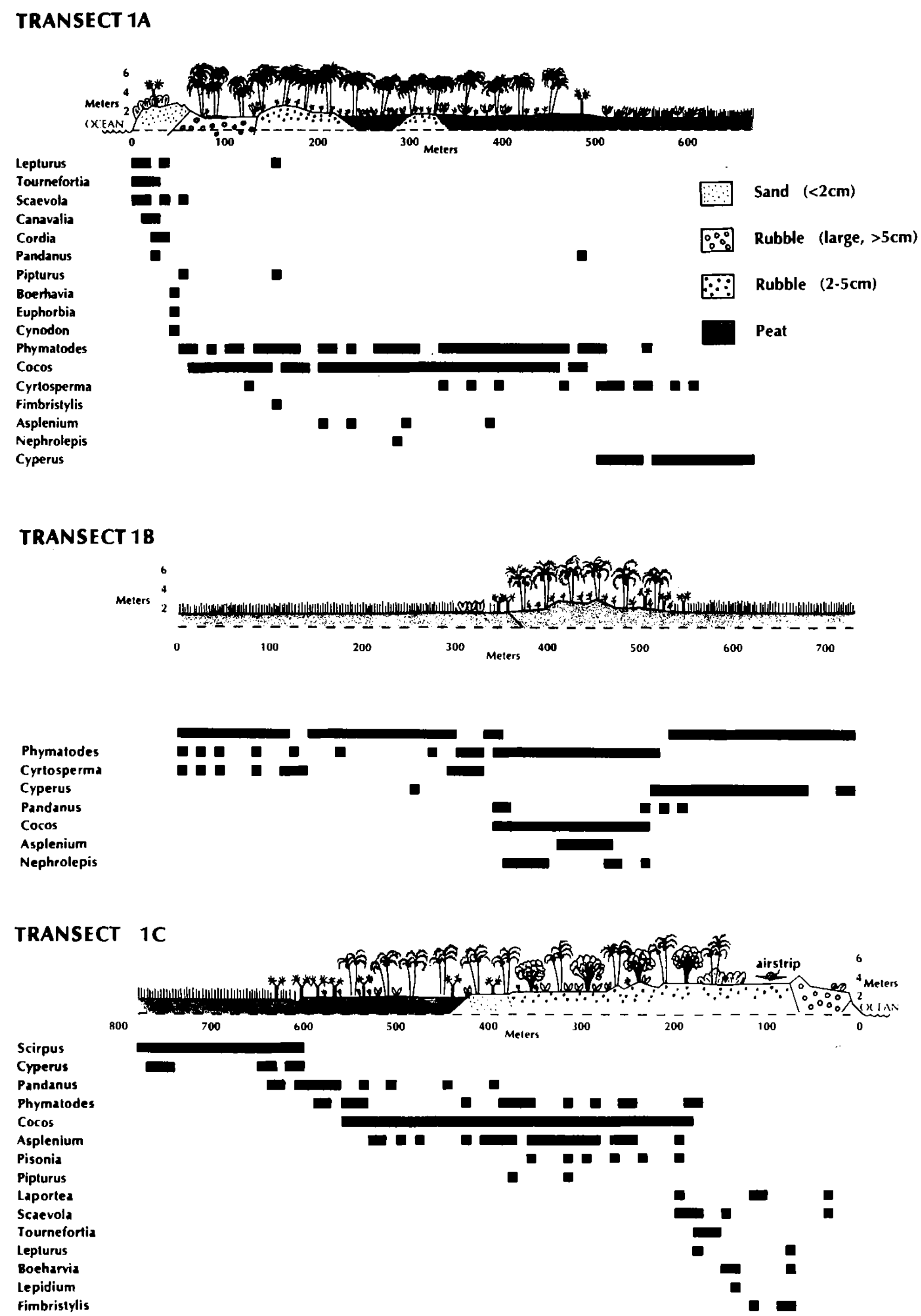

Figure 7. Transect 1A, 1B, 1C

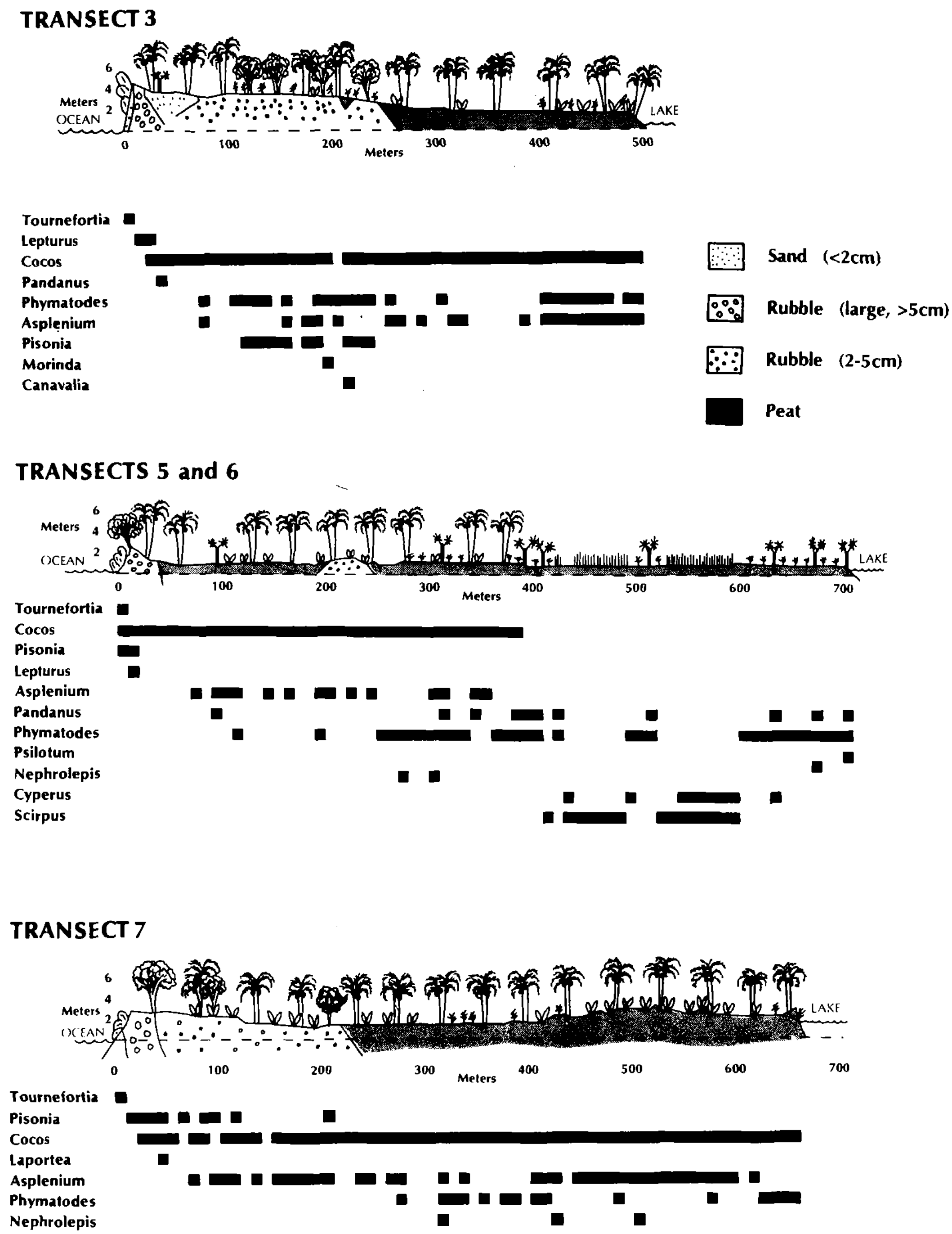

Figure 8. Transect 3, 5 - 6, 7

disturbed areas such as former temporary camps, roads and the airstrip. These areas were largely excluded from this study. The main non-forested terrestrial habitat is the bog whose herbaceous flora is most distinctive and separated from the other communities by a very narrow ecotone.

The forested areas are largely dominated with *Cocos* with admixtures of other species which could be sometimes extensive, such as *Pisonia*, or in other instances highly localized as in the case of some breadfruit forests. Closed canopy communities of this sort cover 80% of the land surface.

Ecotonal communities include the narrow ring of strand vegetation that skirts the coast, and which is characterized by the presence of *Tournefortia* with a the rich understory. In certain places no tree layer is present at all and instead dense thickets of *Scaevola* have become established. Also ecotonal in character is a narrow zone separating the forest and the bog communities, presumably susceptible to occasional inundation, where a curtain of *Pandanus* can be found.

The five major vegetation entities are compared in Table 4. Belt transects were partitioned and assigned to one of the main vegetation classes. Frequency of each species in the vegetation class was determined by summing the number of one square meter quadrats which contained that species. As each vegetation class was represented by different numbers of samples, relative frequency was calculated for each species to facilitate comparison. This value is simply the percent calculated in the following way:

$$\text{Relative frequency} = \frac{\text{Frequency}}{\text{number of quadrats}} \times 100$$

Pandanus and the understory fern *Phymatodes*, were the only ubiquitous species found in all vegetation classes reflecting their ecological adaptability (Table 5). The coconut was by far the most commonly occurring species in the transects and it was an important component of all vegetation classes except the bog where the saturated substrate presumably excluded it all together. Of the other frequently occurring species *Scirpus* was confined to the bog and the *Pandanus* community which formed the transition from the bog to the closed forest. *Asplenium*, on the other hand, was restricted to the understory of the Coconut and *Pisonia* forest.

The vegetation types described in this work agree in general with those defined by Christophersen (1927), except in two instances. Christopherson did not recognize the forest dominated by *Pisonia*, perhaps because his interest focused on the bog community. Furthermore Christopherson did not mention the stands of breadfruit. This is not surprising since they are small in area and would not be easily found without the aid of aerial photographs.

Vegetation Communities

(1) Coconut Forest

Dense coconut forest covers perhaps eighty percent of

Table 4. Species composition of major vegetation types as measured by relative frequency*.

Species	Community Type Strand	Coconut Forest	Pisonia Forest	Pandanus Fringe	Bog
Tournefortia argentea	35.5	0	4.1	0	0
Lepturus repens	35.5	0	0	0	0
Scaevola sericea	21.4	0	4.1	0	0
Canavalia carthartica	21.4	0	0	0	0
Cordia subcordata	7.1	0	0	0	0
Pipturus argenteus	7.1	1.0	2.0	0	0
Cocos nucifera	28.6	93.2	84.6	12.5	0
Phymatodes scolopendria	7.1	46.7	44.9	56.3	10.9
Pisonia grandis	0	0.5	51.0	0	0
Asplenium nidus	0	3.6	40.0	0	0
Morinda citrifolia	0	0	2.0	0	0
Pandanus tectorius	7.1	3.6	10.2	59.4	1.0
Nephrolepis exaltata	0	7.6	0	15.6	0
Psilotum nudum	0	0	0	0.5	0
Scirpus littoralis	0	0	0	21.9	92.1
Cyperus polystachyos	0	0	0	21.9	20.7
Cyrtosperma chamissonis	0	3.0	0	0	14.6
Number of quadrats	14	197	49	32	101

$$* \text{ Relative frequency} = \frac{\text{Frequency}}{\text{Number of quadrats}} \times 100$$

Table 5. Total frequency of occurrence of species in transects and number of vegetation types where species found

Species	Frequency*	Ubiquity#
Cocos nucifera	235	4
Phymatodes scolopendria	144	5
Scirpus littoralis	100	2
Asplenium nidus	99	2
Pandanus tectorius	33	5
Cyperus polystachyos	28	2
Pisonia grandis	26	2
Cyrtosperma chamissonis	21	2
Nephrolepis exaltata	20	2
Tournefortia argentea	7	2
Lepturus repens	5	1
Scaevola sericea	5	2
Pipturus argenteus	4	3
Canavalia carthartica	3	1
Psilotum nudum	1	1
Morinda citrifolia	1	1
Cordia subcordata	1	1

* Number of samples containing species

Number of major vegetation types where species occurs. Maximum possible value would be five where species occurred in all types viz. Strand, Coconut Forest, Pisonia Forest, Pandanus Fringe and Bog.

the land surface of Washington Island. The trees are tall and vigorous and regeneration is abundant. The understory is usually composed of Phymatodes or occasionally Asplenium or Nephrolepis. All these ferns grow both on the ground and as epiphytes. Phymatodes is more abundant in sunnier and more exposed sites. Nephrolepis also occurred widely but in much less abundance than the other two ferns. It typically grew as an ephiphyte in the closed forest. Immediately to the east of the village extensive areas of Cyrtosperma are cultivated in pits under the coconut canopy. Here the water table is close to the surface, and the base of the plants in their shallow pits, are submerged. The coconut in these circumstances grows on elevated patches and are surrounded by extensive pools of standing water which are presumably a human artifact. Coconut is not tolerant of truly saturated substrate, as was demonstrated by an unsuccessful attempt to plant them in the bog. Pandanus was occasionally encountered in the coconut forest but here its growth form has a tall spindly aspect as a result of competition for light with taller palms.

(2) Pisonia Forest

Although there are large tracts of forest where Pisonia is the conspicuous dominant, it is usually mixed with coconut to a greater or lesser degree. The largest stands are on the eastern end of the island where, in places, the trees are exposed to the prevailing winds and show the effect of wind shear. There is also a stand of extremely large trees about a mile from the western end of the island on the southern side and about a quarter of a mile from the shore. In the northwestern quarter of the island Pisonia is found mixed with coconut in greater amounts (Figure 6). Pisonia is most common on the raised outer rim of the atoll and is found on coral rubble or reefs of phosphate rock. In no case was it observed on the saturated substrate or peat.

Pisonia seemed to cast less dense shade than the coconut forest, which may explain why the understory of the community was more diverse. The most common understory plants were Phymatodes which occurred with about the same frequency as in the coconut forest and Asplenium, which was largely concentrated in the Pisonia forest (Table 4). However a number of low growing species such as Scaevola, Morinda, Tournefortia and Pipturus were encountered which were otherwise mainly associated with the strand vegetation which often lay adjacent to the Pisonia forest.

(3) Strand Communities

The strand vegetation around most of the island consisted of a thin band of Tournefortia mixed with Cocos, Cordia or Pandanus. Reflecting the more open character of the tree layer Scaevola was quite often present as an understory plant and Lepturus was encountered as a ground layer. Where there has been disturbance, such as around the village of Tengkore, at the site of the abandoned village of Manunu or at the location of old camps and the air strip, the strand species have acted as the colonizers. Scaevola, Pipturus, Lepturus and the Canavalia and Ipomoea vines are abundant. On the western end of the island, a broad sand beach exists, there is an opportunity for Ipomoea and other extreme beach outpost species to gain a temporary foothold. Elsewhere wave action was typically found undercutting the shore such that high waterline usually lay under the canopy of the strand trees.

The outpost index of each species was calculated (Table 6) which is a measure of the tendency of species to act as extreme pioneer out on to the beach. Tournefortia had the greatest tendency and often its branches overhung the beach. Where beach sand was actively prograding herbaceous species such as Lepturus or Ipomoea were the extreme pioneers.

(4) Bog

The bog community is the simplest from the floristic point of view. Extensive areas are vegetated only with Scirpus which, at the time of our observations, was growing in water perhaps two or three centimeters deep. Others have noted that the bogs were dry (Judd, 1859; Christophersen, 1927) or covered with water to a depth of six to eighteen inches (Streets, 1877b). In places where the Scirpus was growing vigorously the substrate was firm. However in parts of the east bog the Scirpus had died in patches and only the dead root mat remained. Here the mud was soft and would not support the weight of a person. Around the margins of the bog, and in slightly elevated areas, Cyperus was found, sometimes growing in dense patches. On the remnants of mounds built in an attempt to establish coconut on the bog, colonies of Phymatodes and Cyrtosperma were found. Christophersen (1927) believed that the Cyrtosperma was invading into the bog. However there seems to have been no further advance in the fifty years since he was on the island and it would appear from his photographs that the Cyrtosperma is less vigorous now. A better explanation might be that these patches are relicts of former attempts to plant Cyrtosperma in the bog.

(5) Pandanus Fringe

In the narrow zone, often only a few meters wide, between the almost permanently saturated substrate of the bog and the raised land surface of the coconut forest, is a habitat in which the adaptable Pandanus dominates. The same community can be found in slightly raised islands within the bog, along the lake margin and adjacent the canals where material excavated from the canal was dumped.

The Pandanus in some places forms dense thickets and in others only scattered trees. In most instances sufficient sunlight penetrates to encourage low growing herbs such as Phymatodes, Nephrolepis, and Cyperus. Psilotum, may occasionally be found as an epiphyte.

(6) Scaevola - Tournefortia Scrub

Patches of dense scrub were found in a number of locations around the outer fringe of the island. In most instances they extended away from the beach a quarter of a mile inland. However they were also observed as islands

Table 6. Tendency of species to act as extreme pioneer on beaches as measured by outpost index*.

Species	Outpost index*
Tournefortia argentea	1.6
Lepturus repens	2.6
Ipomoea pes-caprae	2.6
Scaevola sericea	3.0
Portulaca oleracea	3.0
Laportea ruderalis	4.0
Pisonia grandis	4.3
Pandanus tectorius	5.0
Phymatodes scolopendria	5.4
Cordia subcordata	6.0
Cocos nucifera	6.3
Synedrella nodifera	6.5
Canavalia carthartica	8.0
Spermacoce assurgens	9.0
Asplenium nidus	9.4
Morinda citrifolia	10.1
Euphorbia hirta	11.0
Phyllanthus amarus	11.0
Cynodon dactylon	11.0
Cyperus polystachyos	11.0
Cyperus javanicus	11.5
Nephrolepis exaltata	13.3
Pipturus argenteus	15.0
Cyrtosperma chamissonis	18.0
Fimbristylis atollensis	19.0
Psilotum nudum	22.0
Scirpus littoralis	23.0

$$* \text{ Outpost index} = \frac{\text{Rank order of species from the sea}}{\text{Number of transects where species present}}$$

surrounded by coconut forest but never very far inland. They are conspicuous on aerial photographs and the outer road cuts through them in a number of places but they are so dense it was not feasible to penetrate far by foot. It appears that Scaevola forms dense thickets and is in places associated with Tournefortia parasitized by Cassytha. A similar community was encountered on Fanning Island landward from the shore on substrate of sand and coral rubble.

It is unclear why coconuts were not growing on these areas. It is possible that these may have been sites of guano digging although we have no independent evidence of this. The land may have been cleared of coconut and the substrate disturbed. The strand species would be the natural colonists of such disturbed sites and may have created a dense cover that the coconut has so far been unable to become established. The plantation managers attempted to make all possible land productive, and even went so far as to plant the bog which would seem to be a most inhospitable habitat for them. One would have thought that, even if the coconut could not colonize disturbed sites by themselves, they would have been planted artificially. The composition and physical environment of this community requires further investigation.

(7) Breadfruit Forest

On the northern flank of Tengkore is a patch of large Artocarpus (breadfruit) which are not tended and seem to be vigorous and reproducing. It is assumed that these are feral stands which have escaped from gardens where they were grown for food and wood. Another stand was found between the East and West Bogs completely surrounded by coconut forest but associated with an outcrop of phosphate rock but far from any present habitation. A small stand of bananas nearby suggests this might have been a former camp or satellite settlement especially since it is near the place where an old (but apparently not prehistoric) canoe was dug up in 1906.

Prehistoric vegetation

Four peat cores were taken in the bog (Figure 4, Table 1). They ranged in depth from 70 centimeters in the West Bog to 275 cm in the East Bog. The oldest deposit was from the base of the West Bog and was dated at 1060 ± 100 years BP. This would suggest that the peat facies slope downwards to wards the lake as would be expected. Pollen content from the peat was analyzed and is illustrated in Figure 9. The pollen concentration was extremely low throughout the core and all samples were dominated by grasses and sedges (mostly Scirpus) and fern spores which are produced in abundance in the immediate vicinity or the adjacent forest understory. Pollen from the Cocos, Pandanus, Pisonia and Tournefortia were present throughout the core but in very low numbers which might be expected from insect pollinated species. Although numbers are too small to allow any meaningful statistical analysis the results indicate no major vegetational change in the last millennium. The presence of Cocos throughout the core suggests that its importance in the

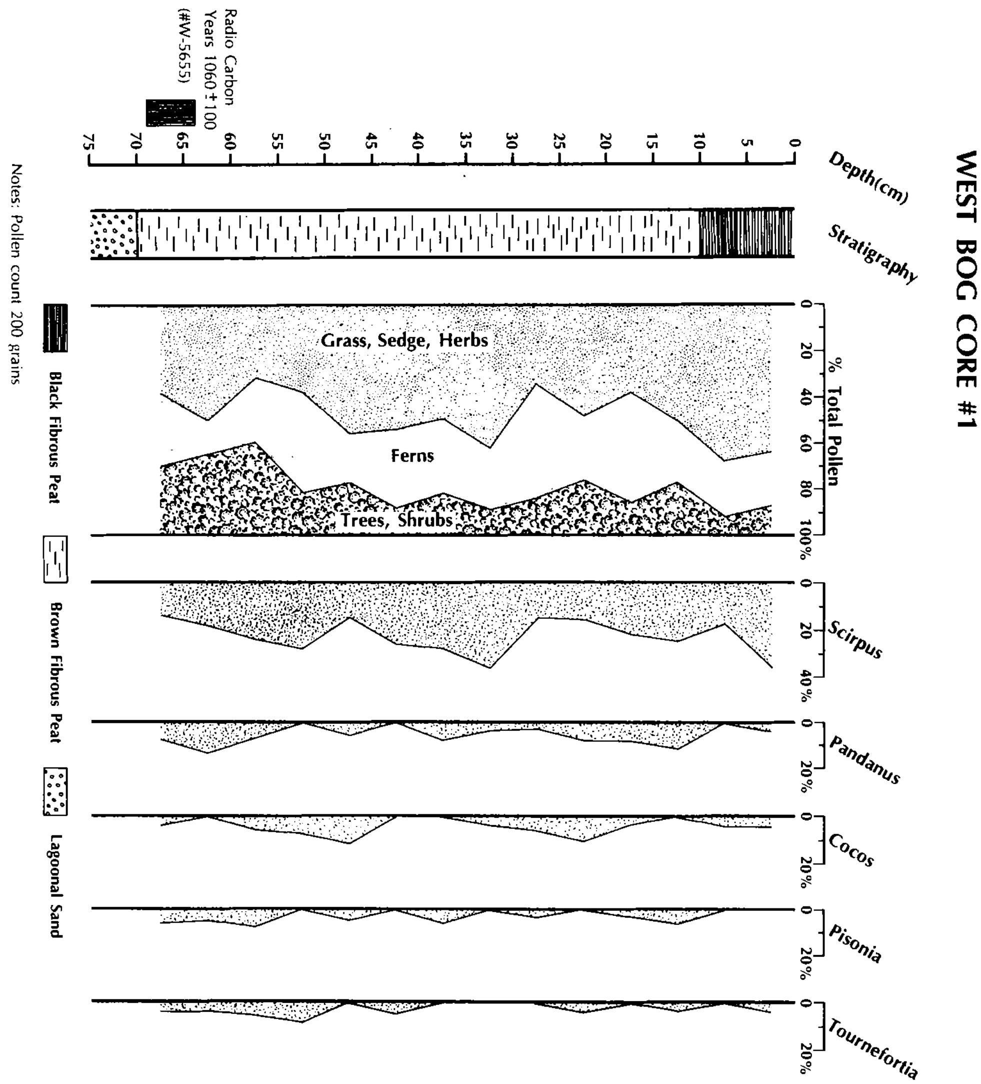

Figure 9. Pollen diagram

vegetation cover is of long standing. However as the core does not predate the period before Polynesian colonization which might be as early as 350 AD. If the coconut were a Polynesian introduction rather than an indigenous species its introduction resulted produced a profound change in the vegetation cover prior.

CONCLUSIONS

The earliest historical records of Washington Island, both from written descriptions and maps, indicate that almost all of the land surface was then dominated either by coconut or bog species. In essence this is what one would observe today despite 130 years of settlement, the construction of a village and camps as well as a road and canal system. In addition to the two main types of vegetation cover, natural ecotonal communities exist along the coast and at the transition between the coconut forest and the bog. Although the flora has been increased from 25 to 91 species, almost all the cultivated or adventive species are confined to disturbed areas around present or past settlements and along roadsides. However some food plants, such as breadfruit, babai and banana, persist in areas rarely visited today.

The record of the peat deposit suggests that the organic material accumulated rapidly and mostly in the last one thousand years during which time no environmental fluctualtion is evident. Coconut pollen was present throughout the core but, since the whole sedimentry sequence postdates possible Polynesian occupation, it does not shed light on the role of prehistoric navigators in spreading the coconut through the Pacific.

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