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The geography of Kapingamarangi Atoll in the Eastern Carolines

by

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PREFACE AND ACKNOWLEDGMENTS

The Geography of Kapingamarangi as presented in this report is the result of field research conducted by the author and other members of the 1954 Pacific Science Board Expedition to the coral atoll of Kapingamarangi supplemented by published and unpublished materials from previous expeditions and other sources. I wish especially to acknowledge my debt to Kenneth P. Emory of the Bishop Museum in Honolulu from whose study "The People of Kapingamarangi" I have borrowed often and who not only briefed members of the team prior to their departure from Honolulu, but also kindly provided the expedition with a manuscript copy of his study, then unpublished. Carroll J. Lathrop, technician of the Museum, also was helpful in this briefing. William Niering of Connecticut College, whose association I enjoyed in the cooperative mapping of soils and vegetation and of beach and shore characteristics, must share the credit for such data interpreted in this report.

I wish to express my gratitude to those organizations and individuals that made it possible for the expedition to be realized and for my participation in it. This gratitude must go in the first instance to the Pacific Science Board and to its Executive Director, Harold J. Coolidge, for having organized the Atoll Research Program, and to the Office of Naval Research through its Geography Branch for supporting such fundamental research by Contract N7onr-29104 (NR 388 001) with the National Academy of Sciences. I am grateful to Lenore Smith and Ernestine Akers, the secretaries of the Board at Washington, D. C. and at Honolulu, respectively, for their excellent and untiring efforts in arranging for the transportation of the team members and their equipment.

I wish to thank the Wenner-Gren Foundation for providing supplementary funds that enabled me to acquire a substantial motion picture record of the life and activities of the Polynesian people of Kapingamarangi.

The United States Navy and the Trust Territory Administration both have my sincere gratitude for their share in transporting me by air and sea to my destination. Several individuals were especially helpful in making my travel and temporary stops comfortable and interesting. The hospitality of Joshua Tracey and Mrs. Tracey of the U. S. Geological Survey at Guam was much appreciated. At Ponape I became indebted to Mr. and Mrs. Henry Hedges, Mr. and Mrs. Steve Kemske, Mr. and Mrs. Robert Tolerton for their help and hospitality, as well as to Frank Moulton, Robert Halverson and Kan Akatani, all of the District Administration, for their kind cooperation.

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Finally, I wish to acknowledge the assistance of Don Schutz, a student at Yale University, in map drafting, and of my wife, Betty, who corrected many mistakes and did the final typing.

I cannot end without expressing my appreciation to my fellow expedition members whose companionship I enjoyed.

Herold J. Wiens
June 1, 1955.

THE SITUATION OF KAPINGAMARANGI

Kapingamarangi, also commonly known as Greenwich Island, is the southernmost of the atolls among the Eastern Caroline Islands and lies in the Equatorial part of the Pacific Ocean (Figure 1)[1]. The atoll is shown on U. S. Hydrographic Chart Number 6042 on a scale of 1:50,340 and is located by the Sailing Directions for the Pacific Islands Vol. 1, 1952 at 1° 4' North and 154° 48' East as measured from the east central part of the reef. The Hydrographic Chart is derived from Japanese sources and reproduces the depth soundings shown on a Japanese chart of the area. Taking the farthest extensions of the atoll rim in each of the cardinal directions, the H. O. Chart shows the northernmost rim extending to 1° 6' 15" N, the southernmost rim extending to 0° 56' 20" N, the westernmost rim reaching 154° 42' 0" E, and the easternmost rim reaching 154° 48' 15" E. However, a comparison of the H. O. Chart with vertical aerial photographs of the atoll indicates that the atoll shape on the chart is as inaccurate as the shapes of the reef islets depicted on the chart. Thus the longitudinal and latitudinal situation given above also must suffer from the same degree of error, and they must be regarded as approximate positions. An adjusted hydrographic chart was made by the present writer on a map based on aerial photos and is shown in Figure 2.

The approximate center of the atoll is 65 miles north of the Equator. The atoll is in the path of the prevailing Easterlies, but it is south of the region of frequent typhoon storms. The Sailing Directions place the next nearest land surface in the atoll of Nukuoro, 164 nautical miles almost due northward. Measured on the A.M.S. 1102 Planning Map for Australasia (dated 1943, scale 1:1,336,000), Ponape lies about 470 statute miles northeast of Kapingamarangi, while Truk lies about 500 statute miles to the northwest. The coast of New Ireland lies about 350 statute miles to the southwest, while Niguria, another Polynesia atoll, lies about 285 statute miles almost due south, the nearest land to Kapingamarangi in this direction. For over 800 miles to the east and over 1,000 miles to the west no land breaks the continuity of the Pacific Ocean. It is obvious that Kapingamarangi has an unusual degree of physical isolation from other lands and peoples.

1. All figures will be found at the end of Bulletin 49, since they are referred to both in Bulletins 48 and 49.

THE HISTORY OF KAPINGAMARANGI AND ITS PEOPLE

According to the semi-history recorded in the chants and legends collected by Samuel Elbert on Kapingamarangi,[1] the atoll was discovered by Utamatua, the ancestral chief of the present people on the atoll, a man with magical powers. He was searching the ocean for his wife, Roua, who had swam off to sea in a fit of despondency because of her husband's wandering habits. Utamatua came from the east and found her just before she expired and then sailed on westward to discover the atoll of Kapingamarangi. According to the tale, Utamatua discovered people already on the atoll, but because he demonstrated greater magical power, he was allowed to share the atoll with the predecessors and to become the first ariki or priest of the ancestral cult. He is said to have caused his followers to build up walls or mounds of coral boulders on a raised section of the eastern reef (possibly on old beach rock). This resulted in sand accumulation on the leeward sides to form an islet. Further building up of this islet formed the present main residential islet of Touhou.

When this event is supposed to have occurred cannot be surmised. Emory obtained the names of more than forty ariki.[2] The last 16 are listed in genealogical order and roughly date back, according to Emory, to about A.D. 1800. On the basis of the 120 years occupied by 16 ariki, Emory stated that the list of 40 cannot go back beyond about 300 years. However, he believes that the 40 do not include all the ariki back to the founder Utamatua, and that there is no way to date the founder's arrival on Kapingamarangi. Nukuoro, which has a list of a succession of 101 ariki, would have a genealogical succession going back 700 years if calculations are based upon the average time in office of the 16 ariki of Kapingamarangi. If these two Polynesian atolls 176 nautical miles apart and both a thousand miles west of the main Polynesian realm may be assumed to have been settled at about the same time, then Kapingamarangi must have been inhabited as early as A.D. 1200.

Knowledge of Kapingamarangi first came to Europeans in 1536 when a Spanish vessel despatched by Cortez from Mexico and commanded by Fernao de Grijalvares sighted what appears to have been this atoll. It was named Dos Pescadores (Two Fishermen), implying that there were inhabitants on the atoll. Subsequently, British and French seamen sighted the atoll at various times during the 19th Century, but there are no notices concerning the atoll in the two centuries intervening. This indicates the position of this atoll off the usual route of vessels sailing westward across the central Pacific.

1. Elbert, Samuel, Linguistic Study of Kapingamarangi, Pacific Science Board, Washington, D. C., 1948, p. 115-122.
2. Emory, Kenneth, The People of Kapingamarangi, carbon of a typed manuscript, Bishop Museum, 1954.

The first account of the inhabitants is that entered in the ship's log of Sir Cyprian Bridge who visited the atoll in 1883.[1] He estimated 150 inhabitants for the atoll under a chief by the name of Ru-Manni. He described them as tall, with a deep-brown colored skin infested with a skin disease of the ring-worm variety, the men wearing a frizzled mop of hair, but the women wearing close-cropped hair.

Although this was the first account of the people by Europeans, a British vessel "Fire Queen" under the command of Captain Hamilton earlier visited the atoll in 1877 and learned of the name of Kapingamarangi (spelled by him "Kapinga Malany"). Perhaps it was at this time that the Kapinga people acquired the fire arms which were observed five years later by Captain Bridge.

That the estimated 150 people in 1883 were probably much fewer than the inhabitants a few decades earlier is inferred by an event that took place about 1870. At this time, according to the German account by Eilers,[2] five big seagoing canoes of Marshallese that had lost their way chanced to land upon the atoll. In the savage manner of the days of pre-European control among the Pacific islanders, for no significant reason the invaders who had landed and made themselves at home on the islet of Hare, suddenly set upon the native inhabitants of that islet and massacred them. From this islet the Marshallese proceeded to Matiro, Werua and Touhou, killing men, women and children without discrimination. On Touhou every living soul was reported to be slaughtered. This tragedy may well have reduced the population by as much as two-thirds or more, since these islets and Ringutoru were the chief inhabited areas. A peace offering of coconuts apparently finally mollified the Marshallese who then stayed on the atoll for 20 months in domination of the area, compelling some of the women to live with them. Finally, the strangers sailed away, taking along some men and women as prisoners, and were not heard of again.

This episode is of significance in relation to the population composition and the number of people that may have lived there at this earlier date. Emory states that the account given him in 1950 indicated that eight canoes had come rather than five, and that the Marshallese had killed a "majority" of the people, including the ariki, Takau, and the secular chief Tikoro. How many men were in the Marshallese party was not indicated, but there must have been a fairly large force for them to overcome the Kapinga people so easily. Probably, too, the Kapinga people had been too isolated to have had much knowledge of or practice in warfare, and they are a gentle, peaceful people. The attack no doubt took the Kapinga people by surprise. In any case, several hundred people must have been killed if thirteen years later the estimate of the population was 150.

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1. Eilers, Anneliese, Inseln um Ponape, Ergebnisse der Südsee-Expedition 1908-1910, Hamburg, 1934, p. 5-6.
2. Eilers, op. cit., p. 130-131.

Another indication of the large population then inhabiting the atoll was given us in 1954 by Chief Tuiai who stated that prior to the Marshallese invasion, Hare and Ringutoru islets were about as thickly covered with houses as Touhou and Werua today. He said that there were so many people on the atoll that many people on Hare would be unknown to people on Ringutoru across the lagoon. Today everyone on the atoll appears to be known to everyone else. However, the earlier lack of mutual acquaintanceship is partly attributable to the fact that few canoes are supposed to have been in existence then, and permission had to be secured of the ariki for the use of canoes and for the chopping down of breadfruit trees for making canoes. As a result, fishing was much restricted and largely confined to the reef, while travel across the lagoon was not common for many of the people. If Hare and Ringutoru with their large areas were settled as thickly as Werua and Touhou are today, and if Werua and Touhou then also were thickly settled, the total population must have been considerably larger than the 426 of 1954 and may have been as large as 500-600.

The Marshallese invasion occurred during the period when the atoll was theoretically under Spanish jurisdiction, although there are no records of the Spanish ever having visited the island during that time. Between 1883 and 1892 some visiting ships brought traders, three of whom, Tu, Harry and Jack Lee successively lived for short periods on the atoll. Lui Patterson, an Englishman, arrived in 1892 and lived on the atoll until his death in August 1899. Two of his five children by the daughter of the ariki Tiahirangi were still living in 1954. Patterson exerted very little influence on the Kapinga people and made no attempt to change their religion, although he urged the abandonment of polyandry because he believed it led to trouble. Shortly after Patterson settled on the atoll, a retired American sea captain called Ned lived for some years at Touhou and had some children by a sister of King Tawehi's wife.[1]

Kapingamarangi became part of the German territories in the Pacific when it was bought from the Spanish in 1899 following the Spanish-American War. The United States apparently showed no interest then in the small island possessions of Spain in Oceania. Small freight and passenger ships of the Norddeutscher Lloyd Company visited the atoll of Kapingamarangi during the German administration, but no white man lived on the atoll from 1914 until after World War II.

During World War I when Japan took over the former German possessions in the Pacific, the Japanese stationed a storekeeper and administrator named Huria ashore on Kapingamarangi. He precipitated a famine during the two-year drought that lasted between 1916-1918 by restricting fishing and the taking of coconuts for food and drink, apparently to conserve coconuts for his copra trade and to have an ample supply of labor on hand. Some 90 people died as a result of the famine. The Japanese subsequently jailed Huria and took some of the people to Ponape to relieve the famine situation.

1. Emory, Kenneth, op. cit.

It was at this time that the Kapinga village of Porokiet (Greenwich Village) was established in the Colonia Port area of Ponape.[1]

This series of events was related to another significant change in the lives of the Kapingamarangi people: the introduction of Christianity by Henry, the son of Mauatoto, the king of Nukuoro. He arrived toward the latter part of the famine in August of 1918, having traveled with a number of Kapinga men returning to the atoll. The Sunday after his arrival, the secular king Tawehi, together with several other men who had been disillusioned in the power of the old pagan religion as led by the ariki, dismantled the sacred part of the already neglected cult house and reconstructed part of it to serve as the Protestant church for the new religion. Henry of Nukuoro, who visited Kapingamarangi in 1954 and whom this writer photographed in Nukuoro in September of this year, during his youth had worked on a British merchant vessel and had become converted to Christianity by the captain. He, seconded by Alfred Patterson, son of Lui Patterson, persuaded the leading men to adopt Christianity.[1]

Tawehi continued as king or chief until his death in 1924, although the Japanese had instituted a system of civil government in Micronesia after the League of Nations mandated Micronesia to Japan in 1920. A succession of local affairs officers were stationed by the Japanese on Kapingamarangi from then on and through the World War II period, although there seldom was more than one Japanese resident on the atoll at one time until the war. From the Japanese the Kapinga people acquired some tastes as well as some tools for carpentering. Thus, the eating of raw tuna soaked in soy sauce was learned from the Japanese, and soy sauce is one of the luxury items demanded as an import.

Immediately prior to the war the Japanese set up a weather station and a sea-plane base at Kapingamarangi with a detachment of over 50 men. According to the Kapinga people, the Japanese service men were not permitted to visit the native residential islets at will and the Japanese military administrator maintained good treatment of the local people during the war period. The sea-plane base was located in the north central part of Hare, while the weather station was located on Nunakita. Both were bombed several times by the Americans during 1943 and 1944 and the installations completely wrecked. Many Japanese are said to have been killed, but no Kapinga people were injured or killed. The Kapinga people had followed Japanese instructions in building underground shelters covered with coconut logs and earth. Several sea-planes wrecked in the war still stood on the beaches of Hare in 1954, while the concrete weather tower on the lagoon side of Nunakita and the wrecked concrete structures and steel radio masts on the seaward side of the same islet are still there, although the latter has become overgrown with vegetation. One of the wrecked concrete foundations had collected rainwater and was swarming with mosquito larvae during the summer of 1954.

1. Emory, op. cit.

A bomb carried by an American B-17 bomber coming in low over Hare on July 7 of 1943 was hit by anti-aircraft fire and exploded, according to Emory,[1] tearing the plane in two and hurling it into the lagoon in shallow water. Native divers recovered the bodies from the wreckage, and the bodies were buried by the Japanese on Hare and subsequently removed to America.

The Japanese vacated the island on July 9, 1944, but it was not until May 3, 1945, that an American seaplane landed off the pass to inquire if any Americans were on the island. On September 22 of 1945, another plane landed off the pass and the next day a screening ship arrived and informed the people that the war with Japan was over and that the American Navy had taken over charge of the atoll. Emory also ascertained that during the earlier part of the war the Japanese had taken some 50 or more Kapinga people to Ponape to help the Japanese, and these added temporarily to the settlement of Porokiet at Colonia. The first American vessel subsequent to the screening ship arrived from Ponape on February 18, 1946, bringing with it some of the Kapinga people from Colonia.

According to Emory, in 1947 the Kapinga colony at Ponape numbered 35 and in 1950 numbered 80. The present writer visited Ponape in 1954 and obtained an enumeration of the Kapinga people at Porokiet at this time which came to 148. This increased migration from the home atoll indicates a growing pressure on the food resources of Kapingamarangi. A total of 426 people on the atoll were enumerated by the island secretary during the summer. In addition, there were 10 Kapinga men on Oroluk Atoll laying the groundwork for a small permanent settlement. Eight Kapinga people were residing at Ngatik and another 10 or so at such places as Kusaie and Nukuoro. Thus the total number of Kapinga people in 1954 was about 602, excluding the 10-15 traveling on the trading vessel "The Lucky".

The following table provides a picture of the population changes on Kapingamarangi since 1883:

Table I

Date	on the atoll	on other islands
1883	150 (estimated) (after Marshallese massacre)	
1890	200 (estimated)	
1910	282 (erroneous, according to Emory)	
1920	300 (Japanese count after famine deaths)	
1925	341 (Japanese count)	
1930	378 " "	
1935	396 " "	
1947	527	46
1950	482	104
1954	426	176 (estimated)

1. Emory, op. cit.

The population prior to the Marshallese onslaught and massacre of 1870 is not known but, according to descriptions by Chief Tuiai, it must have been relatively dense. After the Marshallese disaster there was an accelerated growth interrupted by the famine during the drought of 1916-18. The growth continued until 1947 when the atoll population reached a peak. Thereafter, the atoll population declined through 1954 with increased migration to Ponape and other islands. Part of the attraction luring people away from the atoll has been land made available for homesteading at Ponape and Oroluk. Among the younger men and women, interest in the new cultural atmosphere brought to Ponape by the Americans also has been a factor in the desire to move there.

The population distribution among the islets of the atoll in 1954 was not ascertained. Emory gave it for 1947 as follows:

	Males	Females	Total
Touhou	143	150	293
Werua	87	96	183
Taringa	17	14	31
Matiro	8	5	13
Hukuhenua	4	3	7
Total	259	268	527

Although several other islets have canoe and sleeping houses, as in the case of Hare where there are 29 house structures, they may not be counted as permanent residences, because they are used only for several weeks or months at a time for special purposes, such as when copra is being made. This appears to be the reason why such islets are not included by Emory.

Of the 426 people on Kapingamarangi in the summer of 1954, 202 were male and 224 were female. Some 163 of the total were 14 years of age or under, while 28 people were 65 years or older.[1] On the other hand, of the approximately 150 Kapinga people away from the atoll in the summer of 1954, 70 whose sex was recorded showed a division into 45 males and 25 females. The known sex distribution of about 500 individuals thus shows an almost equal balance between males and females. The 80 or so whose sex was not recorded were mostly young children and babies, and these may also be presumed to be about equally divided in sex. The outward migration from the atoll, however, shows a preponderance of males over females, as one would expect.

1. Trust Territory, Statistical Requirements, Ponape District, Fiscal Year 1954, p. 4.

THE DIMENSIONS OF KAPINGAMARANGI

On its journey to Kapingamarangi, the expedition took along a large scale map of the atoll copied from Kenneth P. Emory's CIMA Report No. 8. Some rough maps for the individual islets on an enlarged scale, which were prepared from rough field maps made by Emory in an earlier expedition, also were taken along. These maps showed many inaccuracies, and the first task undertaken on the atoll by the present writer was the production of more reliable maps for field plotting. A high level vertical aerial photo of the atoll taken by the U. S. Navy Air Photo Section was obtained from Guam and a large scale map of the atoll as a whole on the scale of approximately 1:18,460 was constructed from it, double the scale of the aerial photo. Maps for the individual islets were devised by pacing around them and by plotting on a plane table with the aid of a sight alidade and a Brunton compass, the paces being checked with steel tape initially. Mansa, a Kapinga assistant, made simultaneous pacings with the present writer in order to check any major discrepancies or errors.

The field maps thus made were on a scale of 1 inch to 100 feet from which the finished maps included in this report have been reduced to half the scale (Figures 10-27). On all the smaller islets, error of closure in the traverses proved very small. On the two large islets of Werua and Hare, larger errors of closure required additional surveys including the use of the steel tape to eliminate distortion. It is believed that the final maps show the various islets with a high degree of conformity to actual shapes and relative dimensions as well as to orientation. Owing to the complexity of taro pits on Werua and Hare and to heavy underbrush around parts of the fields, a somewhat lower degree of conformity may be expected for the taro pits on Werua and Hare. A complete resurvey was made of virtually all the taro pits on Werua and on a number of pits on Hare to insure a reasonable order of accuracy. The writer believes that as a result of this survey, much more accurate measurements of areas for islets, taro pits and vegetation zones have been made possible. Map measurements for the different areas are presented in Table II. The land area above water is less than had been previously supposed. In the measurement of the various areas, one set of measurements was made with a hatchet planimeter. A second set of measurements was made by the method of counting squares using squares of 1/10 of an inch for a double check. The figures presented are the result of averaging the two sets for the particular areas concerned.

Kapingamarangi Atoll is an egg-shaped reef completely enclosing a lagoon with the exception of two adjacent passes along the southern rim. The maximum length of the atoll from the outside edges of the coraliferous terrace is 8 statute miles in a SE to NW direction. Its north to south width is 6.3 miles. The total area is 31.7 square miles, of which the lagoon occupies 23.8 square miles and the surrounding reef occupies 7.87 square miles.

Within the lagoon are a total of about 114 coral patches of all sizes that were counted on the aerial photographs. Of these coral patches about two dozen including five at the passes are of comparatively large size, with the rest being mostly small sized coral knolls (Figure 3). Excluding the patches at the passes, the area of coral patches within the lagoon totals 0.3 square miles or 192.8 acres. Most of the large patches lie in the central and west-central parts of the lagoon, i.e., toward the leeward side, and most of the small coral heads lie close to the north and west lagoon fringe. Moreover, the width of the reef itself in the north and north-west half is approximately double the width of the reef in the east and south from where the chief storms and prevailing winds come.

Emory's typewritten report summarizing the physical environment, lists "thirty-five flat islets" along the eastern half of the atoll reef. There are actually only 33 such islets (Figure 3), although the islet of Hare (Figure 23) has three separately named sections denoting the previous existence of three islets which long ago became fused into one. The southern end of present Hare has two sections called Ruawa and Herengaua. The former channel between Ruawa and former Hare was closed by a storm, (apparently the great storm of 1858) and is densely overgrown with coconut and various understory vegetation. The former channel between Ruawa and more recent Herengaua was filled in by wave-driven sand because of the construction of a causeway which still is perceivable, and it, too, is well covered with coconut and pandanus trees, although the trees are small and there is little understory growth.

In size these 33 vegetated land areas (defined as those parts of the raised reef areas that stand above customary high tide level) altogether total only 276.4 acres or about 0.422 square miles. This constitutes only some 1.33 per cent of the total atoll area. In dimensions Hare is the longest, almost 1.29 miles, and has the greatest surface, 79.5 acres. However, it is only from 400-500 feet wide. Werua is the largest from the view of having the central parts the farthest removed from the beach rim, as well as having the next largest area, 41.4 acres. Ringutoru and Torongahai follow in areas with 26.7 and 19.5 acres respectively. Nunakita, Taringa and Matiro are the only others with more than 10 acres of surface. Six islets have less than an acre of surface including Pungupungu with .4 acre and Tiahu with .6 acre. Matukerekere with 1400 sq. ft., hardly 100 ft. long and about 20 feet wide, has only one mature coconut palm and five young coconut plants for vegetation.

The following table lists the areas of the individual islets in succession from north to south (Figure 3).

Table II

Islet name	Area in acres
Torongahai	19.5
Ringutoru	26.7
Rikumanu	.9
Turuaimu	2.0
Pepeio	.7
Nunakita	14.2

Table II, cont'd.

Islet name	Area in acres
Hukuniu	.9
Parakahi	3.1
Werua	41.4
Touhou	9.2
Taringa	12.4
Pungupungu	.4
Matiro	10.3
Matuketuke	1.0
Ramotu	3.5
Sakenge	2.3
Matawhei	.7
Hukuhenua	5.0
Hepepa	2.3
Tipae	1.6
Tetau	7.8
Nikuhatu	2.3
Takairongo	3.9
Tangawaka	7.0
Hare	79.5
Herekoro	3.8
Tirakau	1.8
Tariha	2.2
Tiahu	.6
Tokongo	1.8
Tirakaume	1.3
Pumatahati	6.3
Matukerekere	(1400 sq. ft.)

Total land area	276.4 acres
Total area of encircling reef, including patches at the passes	5,079.4 acres
Total area of coral patches in lagoon ...	192.8 acres
Total of all reef areas	5,272.2 acres
Total lagoon area inside reef	15,201.0 acres or 23.79 sq. miles
Total atoll area.......	31.7 sq. miles

The islets with the greatest breadth transversely across the reef area also are located in the broadest half of the reef. The greatest gaps between islets (i.e. the inter-islet channels) also occur in the northern part of the chain of islets. The closest spacing of islets and the narrowest inter-islet channels occur in the central eastern portion of the chain of islets and face the prevailing east wind. These inter-islet channels run in width from the 55 feet between Matiro and Pungupungu to the 3,250 feet between Turuaimu and Rikumanu. Five such channels are over 1,200 feet wide. Eight are between 500-1000 feet wide. Eleven are between 200-500 feet wide, while the remaining eight are under 200 feet wide.

A chart of depth profiles of the lagoon running east-west and based on the adjusted hydrographic chart is shown in Figure 4. Approximately two-thirds of the lagoon has a depth of less than 180 feet and a little more than a third is under 120 feet. The deepest third runs in a slightly arced zone in the north central part of the lagoon, following generally the contour of the reef. Depths run down to 258 feet in the north central area. Outside of the reef, the drop-off is steepest and most abrupt in the areas near the pass in the south (Figure 2).

THE EVOLUTION OF THE TOPOGRAPHY

The atoll is not far removed from the unstable west Pacific zone of tectonic movements and volcanism. It is not surprising, therefore, that earthquakes are well known to the Kapingamarangi people. Eilers wrote of this in relation to the ancestral cult worship of the people. In addition to the regular worship of the Utamatua, the ancestral deity, on special occasions the Kapinga people used to appeal to him to keep earthquakes from them. Earthquakes occurred from time to time without the inhabitants of the atoll knowing from what direction they came. They believed, however, that earthquakes arose from the sea and that they were sent by Utamatua when someone on the atoll had committed a grave wrong and aroused his resentment. In their prayers to Utamatua, the people asked him to cease his anger and to stop the earthquake. The people were especially frightened when earthquakes happened at night, and in the early morning following such an event they would stream together for prayer. The high priest would wait for the men at the tabu place between the sacred stone and the cult-house. Each man would bring an offering of coconuts to lay before the sacred stone. Following the end of the prayers the coconuts would be eaten.[1]

While these earth movements frightened the Kapinga people, there is no evidence of any significant physical effects brought about by the earthquakes upon the structure or topography of the atoll.

The geological structure and evolution of the atoll is described by the geologist on the team, Edwin D. McKee. However, some personal observations made in the field or from aerial photographs by the present writer are included here.

Figures 5 and 6 drawn from an oblique and a vertical aerial photograph respectively illustrate the various elements in the topography at Kapingamarangi. The reef flat comprises cemented and consolidated limestone bedrock under water at high tide and partly exposed at low tide. Where vegetated islets occur this reef flat extends into the channel area and is covered by sand and coral fragment covered tidal fans with underlying bedrock on the lagoon side. Boulders and larger fragments of consolidated beach or reef rock broken loose by storm waves occur scattered about the reef flat, ranging in size from a few inches to several feet in diameter. They are particularly prevalent in the ocean side flats adjacent to the islets from Werua to Torongahai. The tidal currents running into the lagoon through the inter-islet channels carry with and push before them smaller boulders, coral gravels and sands, and quantities of Foraminifera. These build up tongues of shoal areas into the lagoon, giving a scalloped appearance to the lagoon fringes on the eastern half of the reef where the islets occur. Between these tongues of sand and gravel which kill the live coral they cover, greater depths of water reach close to the lagoon beaches of the islets. Here, tidal movement and accompanying wave action

1. Eilers, op. cit., p. 136.

eroding the shore and working over loose material, together with the work of alongshore currents, bring about an irregular and ragged edge to the coral growth extending into the shallow waters off the lagoon shore of the islets. In the lagoon waters off Touhou an aerial photograph[1] reveals what look like five artificial dredged channels leading from the shallow beach area through the coral growth into deep water (Figure 6). They are 10-20 feet wide and 100-150 feet long. How these originated and what the nature of these apparent channels are were not investigated during the team's stay on the atoll.

Where the inter-islet channels are narrow and especially where causeways have been built between islets, sandbars which form tongues extending from the lagoon sides of islets adjacent to the channels curve across the tidal fans to meet each other as shown in Figure 5. This appears due to the work of along-shore currents in conjunction with obstructed and weakened tidal currents running through the channels. Where the channels are wider or deeper as in the case of Figure 6, the sandbars form separate tongues without curving toward each other.

Cross sections of the islets from oceanside to lagoon shore typically show a sharply rising rampart of coarse coral fragments and gravels that reach a peak elevation of 5-12 feet depending upon the size of the islets and then slope more gradually toward a depression in the ocean-side of the center of the islets. In the smaller islets this may be only a foot or so above high tide. The elevation then rises to a secondary height on the lagoon side of the islet, most often a sandy beach ridge from which there is a moderate slope to the lagoon water and a gentle back slope inland. Figure 7 showing a profile across Taringa and Figure 8 showing a profile across Werua illustrate this, but are complicated by the man-made puraka pits and fields which create artificial depressions and elevations in the central parts of the islets. The elevations in these central parts are formed by the piling up of the material excavated from the puraka pits along the edges of the excavations.

In his report McKee notes various evidences of beach migration involving the destruction as well as the formation of land areas above high tide. His conclusion points to the lagoonward building of the land and the erosional destruction of land on the oceanside. While he presumes that the rate of wearing back of the islets on the seaward side has decreased as the distance from the reef front has increased, he states that it is unknown "whether this aggradational process is as rapid or more rapid than the rate of island destruction on the seaward side". The decreased rate of erosion on the seaward side is counter-balanced in part at least by the retarded sedimentation as island building lagoonward meets continually greater depths of the lagoon, requiring greater amounts of sediment to build up the bottom. On the other hand, the present writer believes that evidences are present supporting the conclusion that island building is proceeding at a faster rate at Kapingamarangi than island destruction, and that the total land area available for vegetation is increasing.

1. ONI Number 47162, vertical aerial photo, scale enlarged from 1:15,000 to 1:5000.

Land destruction.

Time was not available for accurate ground mapping of the dipping rock exposures on the seaward sides of islets that might be considered old beachrocks. However, the aerial photos taken by a Navy plane in 1954 reveal numerous patches of such exposed beach rock, a number of which also were roughly sketched in from beach reconnaissance during the team's stay in 1954. It may be presumed that between the seaward edge of these patches of beach rock and the present beach line, vegetated land once existed that now has been eroded away, leaving the remnants of the former beachrock. The largest remnants or patches of beachrock occur on the seaward sides of Torongahai, Ringutoru, and Nunakita in the north, and on the seaward sides of the numerous small islets between Pungupungu and the northern end of Hare. Significantly, little of it is found on the seaward side of the mile-long islet of Hare immediately to the south. Relatively little is found on the seaward side of Werua. Two inferences might be noted from this. One is that small islets erode away proportionately faster than the larger ones. Actually, the ratio of the amount of erosion to the seaward length of shoreline is higher for the smaller islets than for the larger ones, and hence the smaller islets can be said to be eroding away faster.

According to Rikaneti, the present small islet of Matukerekere which has a surface above high tide of only about .03 acre, was about the size of present Pepeio, 0.7 acre, prior to the storm of 1858 which washed off all the vegetation and most of the land surface. The second inference is that while increased distance from the reef edge for a particular beach may decrease the rate of erosion for this beach, orientation and size are more important erosional factors than distance from the reef as such. Thus, the seaward edge of Hare, which shows little beach rock exposure from erosion and also is situated on a narrow part of the reef, is close to the reef edge in contrast to the seaward edges of Nunakita, Ringutoru and Torongahai which have large areas of beach rock exposed by erosion, but are situated on the broadest part of the reef and have seaward beaches much farther from the reef edge than in the case of Hare. Moreover, since the prevalent storm winds and waves sweep in from the east and southeast, the waves must cross the reef in the north diagonally and hence pass over a long stretch of reef flat before hitting the beaches of the northern islets. Yet the erosive force is such as to have apparently caused the greatest extent of land destruction precisely in the seaward parts of these northern islets.

The rate of erosion is hard to estimate and differs in different parts of the atoll and on different sides of the islets, as well as depending upon the character and occurrence of the storm waves. Erosion appears more severe on the lagoon side of the southern section of Hare than on the seaward side. At a part of the lagoon shore 1000 feet from the southern end several living coconut trees stand on tongues of land 3-5 feet wide protruding ten or fifteen feet lagoonward from the main shore-line, showing that long after maturity of the trees, the shoreline here had receded this distance. Much of this may have occurred during a single storm, since the beach and adjacent land area here is composed mainly of sand. This may have been the result of a 1947 storm which destroyed a large part of what remained of the tiny islet of Matukerekere near the southern pass area. (Discussion of the storms of 1858 and 1947 follows in the next section on: The climate and weather of Kapingamarangi.)

Across the lagoon to the north, the seaward side of Torongahai has numerous fallen coconut logs and stumps on the beach, while many of the live Guettarda, Scaevola and Messerschmidia of five to 12 inch diameter trunks have sprawling roots exposed reaching up to ten feet out from the present beach-line. This shows that at least this much erosion has occurred during the mature life of the trees. Such evidences give only vague notions of the rate of beach recession. It is naturally much faster where the shore is formed of unconsolidated cobbles and gravels than where cemented rock forms the shoreline. Thus, in the case of Rikumanu, the tiny islet near Ringutoru, the owner, Materewei, stated that he had not noted any significant reduction of the land surface during his lifetime. Yet the shorefront was very jagged from erosion and at the lagoon end was undercut some six or seven feet, leaving an overhanging rock platform three or four feet thick on which, strangely, bearing coconut trees continued to grow.

Lateral erosion in the inter-islet channel sides of islets also may be of great severity. The east-west elongated shapes of the islets between Matiro and Hare appear to be the result of such lateral erosion from the rush of storm and tidal water through the channels. Ringutoru's incurving eastern shoreline exhibits severe erosion and undercutting which in the course of time may cut the islet into two segments near the middle. The elevated ridge of reef rock between Hukuniu and Parakahi may represent the remnant of a land connection rising above water between the two islets.

Land building.

Land building occurs naturally and also is aided and induced by man at Kapingamarangi. Here we have some definite indications of the rate of building or land enlargement. For instance, on the southwest lagoon beach of Torongahai, Scaevola covers a zone of some 20 feet and represents three stages of growth. The inner part of the zone had Scaevola trees 10 feet or over in height. A middle band of Scaevola was generally around 6 feet high. A third band was composed of seedlings of from a few inches to a foot or two in height. The latter were growing on open beach sand above the usual high tide line.

Torongahai and Ringutoru both have advanced lagoonward considerably during the last 40 years, according to Chief Tuiai, and more land has been added here than has been eroded away on the seaward or channel sides. Tuiai tells of an old tree near the lagoon on Ringutoru whose trunk was near the waterline when Tuiai was a boy. Since then sand has filled in more than 40 feet lagoonward and this new land has become vegetated. Tuiai stated that men used to climb a coconut tree next to the old tree and jump or dive into deep water of the lagoon from the top of the coconut tree.

Since Tuiai was about 52 years old in 1954, his recollection probably refers to a boyhood about 40 years or so ago. This would indicate a rate of beach building lagoonward of about a foot per year on the average. Such rates of beach building do not occur on all lagoon beaches, of course, but there appears to be a noticeable rate of lagoonward building on most of the islets. While impressions of dimensions among the inhabitants are not to be trusted as reliable, they do provide some worthwhile indications of change. Tuiai stated that during his boyhood the islet of Turuaimu was about the size of present Pepeio adjacent to it. The areas of the two islets as mapped in 1954 were 2 acres and 0.7 acres respectively, so that if Tuiai's impressions were taken at their face value, Turuaimu has doubled in size during the 40-45 year's period since his boyhood.

Support for this estimate of the rate of land growth is provided by the speed with which land has been created by man-induced means. The Kapinga people long ago learned that they could build up land areas by piling up walls or mounds of loose coral blocks on the reef and then let the waves and tidal currents accumulate gravels and sands in the leeward sides of such walls or mounds. The chief residential islet of Touhou which now has a surface of 9.2 acres was thus formed by the first inhabitants of the atoll, according to traditional history. Utamatua, who purportedly discovered Kapingamarangi while searching for his despondent wife who had cast herself adrift on the ocean, is said to have chosen the site of Touhou islet for his band of followers. Since he is supposed to have found prior inhabitants at the atoll, he apparently decided to create new land for his group, and he built up Touhou from a mere ledge of rock, according to the account given to Emory. The same account mentions the existence of Turuaimu before Touhou was built, however, so that it would seem that Turuaimu has been building up rapidly only during the last half century since Tuiai said that it had doubled in size during this period.[1] It is probable, however, that the islet may have been enlarged and then reduced several times during its existence, since it is built mainly of gravel and sand.

In addition to Touhou, two other islets are said to have been built by the Kapingamarangi people. One is Pepeio, built only a few decades ago. Meterewei, who was employed by the 1954 expedition, said that his father built up a wall of coral rock on the ocean side of a patch of sand that had risen above high tide. Sprouting coconuts were planted on the coral wall as it was built up. He said that the coconut trees were planted 24 years ago and that over 10 of the larger trees now were producing nuts. (On the other hand, Rikaneti said the wall was started in 1919). Scaevola and Guettarda both were planted there to hold down and bind the sand, rock and rubble. As Pepeio grew larger, more coconut trees were planted. Today, Pepeio has a vegetated surface of 0.7 acres.

Tipae, an islet now having 1.6 acres of vegetated surface, also was man-induced. The coral block wall or mound on the seaward third of Tipae was still clearly in evidence during 1954 and, in fact, the piled up boulders were still loose underfoot when Niering and the present writer walked over them. No date was ascertained for the initiation of the wall.

1. See Emory's section on "Traditional History".

The German South Seas Scientific Expedition of 1910 stated that Kapingamarangi had 31 islets with soil and vegetation and three sand islets. It is probable that at this time, the islet of Herengaua was still separated by a channel from the southern end of Hare. Matukerekere then had not even the one mature coconut tree that now stands guard on the patch of sand and gravel, so that the three "sand islets" no doubt comprised this islet and Pepeio and Tipae.

Another method of creating new land is to build causeways across the channels to connect two islets. This results in the gradual filling in of the channel with sand and gravels on both sides of the causeway. Owing to the closing of former channels, the two former separate islets of Ruawa and Herengaua have been fused with Hare into the present Hare. A storm choked the channel between Hare and Ruawa (apparently the great storm of 1858), while a man-made causeway brought the filling in of the second channel between Ruawa and Herengaua. Field mapping of the former channel shores and of the beach lines of the former islets indicated that the filling in of the channel area between Hare and Ruawa has resulted in the addition of 4.7 acres of land surface now vegetated. The mapping also showed the extent of former Herengaua to be approximately 2.18 acres and of the filled in area of the channel between Ruawa and Herengaua plus the lagoonward extension of Herengaua to amount to 2.6 acres of surface now mostly vegetated.

The causeway between Ruawa and Herengaua is clearly visible on the lagoonward side where part of the old channel forms a depression. The recency of this filling in of now coconut-overgrown land is indicated by the fact that an aerial photograph of World War II (probably dated in early 1943) (ONI No. 47159) shows Herengaua connected by only a narrow strip of sandy land to the Ruawa sector of Hare, with what appears to be seedling vegetation of some pioneer species on central parts of this connecting land.

Although no definitive statement of the rate of land surface increase or decrease can be made, nevertheless, it appears most probable from the evidence pointed out that the total land surface that can support vegetation is increasing in area at a relatively rapid rate and that effort on the part of the inhabitants can further increase the total habitable and productive land.

THE CLIMATE OF KAPINGAMARANGI

The climate of Kapingamarangi remains a matter of estimate derived from weather station data at Ponape and Truk, scattered data from passing ships, some general notes taken by Emory during his several months stay from July 15 to October 16, 1947, and from the seven weeks of systematic meteorological data recording during July and August by the present writer (Appendices I and II). The Sailing Directions for the Pacific Islands, Vol. 1, 1952, H.O. 165A, p. 267-268, give a description of the climate for Kapingamarangi the source of which is not indicated, and there are some doubts of its validity owing to conflicting data from other sources. For lack of more reliable information, however, this description is included below.

The Eastern Carolines lie in the zone of the northeast trade winds which ordinarily prevail from November to April, with considerable variation from year to year. The strongest winds occur during the height of the northeast trades.[1] According to the Sailing Directions, in Kapingamarangi northeast and east winds prevail from December through April, with a frequency of 68% and an average velocity of 11 knots. In May and June variable winds prevail, with an average velocity of 7 knots and with calms occurring about 11 per cent of the time. From July through September winds from the southeast quadrant occur 55% of the time, with an average velocity of 8 knots, and with calms 5% of the time. On the other hand, the directions of winds observed by Emory during the period July to mid-October 1947 and those recorded by the present writer during July and August, 1954, were almost always from the east with the exception of winds during a few scattered days.

In October and November, the Sailing Directions indicate, winds average 7 knots from varying directions, with southeast being most frequent or 24%. From October through January, westerly winds of 15 knots average velocity are experienced 10% of the time. These accompany the storms occurring in these months. Emory states that beginning in November and for several months thereafter, the winds blow rather heavily from the south and rains are heavy.

According to the Sailing Directions, rainfall is heaviest in May and June and again in October and November, during the passages of the doldrum belt, when the average is about 12 inches per month. Rainfall is relatively light from February through April, and from July through September, averaging about 7 inches per month. In December and January, rainfall averages about 9 inches monthly, much of this occurring during stormy weather. From these averages, it would appear that the average annual rainfall is 108 inches. By contrast, Emory quotes Janis Report 104, vol. V, p. 27-30, to the effect that the average annual rainfall is 78 inches, with the greatest monthly rainfall, 8-12 inches, occurring in December and January, and the least, 1 to 2.5 inches, occurring during April, May, September

1. U. S. Navy, Office of Naval Operations, Civil Affairs Handbook, East Caroline Islands, 21 February 1944, p. 6.

and October.

From his own observations, Emory says that in July and August 1947, "rain squalls quickly filled all water barrels, but during September and October in both 1947 and 1950 almost no rain fell, bringing on a shortage of fresh water for drinking, bathing and washing clothes". From the present writer's own records, in seven weeks of July and August 1954, the rain gauge from which daily recordings were made showed only 4 inches of rainfall, while weekly recordings at three scattered points on the atoll indicated 3.39, 3.93 and 1.57 inches respectively. This is in contrast to the 7 inch monthly averages for this period recorded in the Sailing Directions. From Emory's and the present writer's observations, September and October in 1947 and 1950, and July and August in 1954, appear to be extremely dry periods if the averages given in the Sailing Directions are "normal" or derived from many years of observation. The latter situation could only be possible if the Navy has obtained Japanese weather data collected during the period before the Americans destroyed the Japanese weather station on Kapingamarangi in World War II. A concrete tower for meteorological instruments was constructed on the south end of Nunakita Islet in the northern part of the atoll by the Japanese, but was bombed and wrecked by American airplanes.

It is probable that rainfall is highly erratic from year to year as well as during the course of a year. Storms are of small diameters in this part of the ocean and are as likely to miss as to pass over a particular patch of the ocean occupied by a low coral island or atoll. The Sailing Directions state that "Typhoons never occur. Squalls and thunderstorms constitute the major weather hazard. These storms, normally from 20-25 miles in diameter, are accompanied by winds averaging from 15-25 knots, with occasional gusts up to 40-50 knots. Thunderstorms occur on an average of two days per month from May through November, and once a month for the rest of the year." During the Kapingamarangi Scientific Team's stay on the atoll in 1954 there was only one extended period of overcast skies. This occurred at the end of July when rain from overcast skies began at 8:30 P.M. and continued during part of the night. Overcast skies continued through the next day and the following evening. Rainfall during this period at the Touhou Islet station amounted to only 0.74 inches, however.

An interview with Rikaneti, the community secretary of Kapingamarangi, yielded the following information concerning recorded storms of significance affecting the atoll. The first account in the records (handed down by word of mouth and subsequently written down) indicates a very severe storm in 1858 that destroyed much of the tiny islet of Matukerekere in the south part of the atoll. A man was killed on one of the larger islets by a falling breadfruit tree. In 1886 during the rule of the Ariki (priest) Tahikimau, a storm caused much damage to breadfruit and coconut trees. In 1896 a tidal wave damaged the lagoon beach from Werua Islet to Ringutoru Islet, but did relatively little damage to coconut and breadfruit trees. In 1920 a thunderstorm with heavy rains did some damage to coconut trees. In 1937 when the Japanese administrator Sato was at Kapingamarangi, a storm blew down five breadfruit trees. The date of the last great storm is given by Emory as occurring in November 1947, while Rikaneti said it occurred in 1948. According to the latter, this was one of the worst wind storms that have visited Kapingamarangi. The account of damage differs. Emory was informed by Hetata that 201 bearing breadfruit trees were blown over. Rikaneti, however, listed 67 breadfruit trees, 10 coconut trees and 30 houses as having been blown over, while six puraka fields or pits (mostly on Ringutoru) were damaged by salt water.

The worst storms apparently come from the southeast, or at least the effects are most serious when they come from this direction because the water piles up in the lagoon through the passes and open reefs in the south and sweep across the lagoon, causing severe alongshore erosion on the lagoon side of the islets on the eastern rim as well as damaging the northern islets through sea water innundation. The Sailing Directions state that thunderstorms occur on an average of two days per month from May through November, and once a month for the rest of the year. During the stay of the scientific team in 1954 no such storms were noted.

Extended droughts occur at long intervals when famine may visit the atoll. Emory has noted two, one in 1890 and another that lasted from 1916 to 1918. During the latter 80-90 people died directly or indirectly as a result of famine. It has already been pointed out that Emory recorded almost rainless Septembers and Octobers both in 1947 and 1950. The distribution of rainy days during the scientific team's stay in 1954 was as follows. From June 25 to July 17 there were 11 days out of 22 without rain, half the days. A dry spell of 10 days followed, beginning July 18 and ending July 28 when 0.24 inches of rain fell. Between July 27 and August 22 there were 13 days of rain out of 26, again about half the days, with a seven day period of drought from August 10 through August 15. Clouds observed were mostly of the cumulus humilis variety and seldom had enough size, altitude and turbulence to produce rain.

The average maximum temperature over the period recorded during the 1954 visit was 89.1° F. Average minimum temperature over the period was 82.5° F. Absolute maximum was 94° F. while absolute minimum dropped to 74° F. The humidity normally fluctuated inversely in relation to temperature change as would be expected. Maximum temperature readings generally coincided with lowest humidity readings on the hygro-thermograph charts. Average daily maximum humidity reached 83.8 per cent, generally during the period from midnight to sunrise. During less than a quarter of the days recorded, the humidity reached as high as over 90 per cent. The average daily humidity dropped to 57.4 per cent and reached the low point between noon and 4 P.M. Three-fifths of the time recorded, this occurred between 2 and 4 P.M. About a quarter of the time, the minimum humidity dropped to 55 per cent or below. The lowest humidity reading reached 48 per cent on August 14 when the highest temperature reading of 94° F. occurred at 2 P.M.

An anomally from the usual pattern occurred on July 31 when temperatures remained fairly even from 11 A.M. and 7:30 P.M. while humidity dropped. On the following day, August 1, temperatures dropped 2 degrees from 5 A.M. to 7 P.M. with a greater rate of rise in humidity. This period marked the occurrence of the only extended general atmospheric disturbance when overcast skies lingered for two days.

OCEAN CURRENTS AND LAGOON CURRENTS AND TIDES

The Sailing Directions state that the sea and swell are from the northeast from December through April, with heights of 2-4 feet. From May through November the seas and swells come mostly from the southeast, with heights of 2-3 feet. From October through January seas and swells coming from the west average 5-6 feet in height for about 10 per cent of the time. Local squalls and thunderstorms raise choppy and confused seas. That the ocean currents which run past the atoll are very strong is attested to by the German scientific expedition that stopped at Kapingamarangi in January 1910.[1] The course of the expedition ship "Peiho" was driven 15 sea miles to the east, and Eilers speculates that it possibly was because of this current that the Captains Symington and Montraval in 1864 and 1853 respectively, gave up the idea of visiting the atoll. This also may have been in part the reason why information about Kapingamarangi remained so long uncertain and so scarce in spite of the fact, according to Emory, that this was the first atoll occupied by Polynesians that was sighted by Europeans. Captain Blanc of the Steamship Roque on which the present writer traveled to Kapingamarangi informed the writer that in traveling from Nukuoro, he set his course during the August trip for a point about 18 miles to the east of Kapingamarangi to compensate for prevailing westward drift, but that there had been a change in the direction of the drift to a current setting in the opposite direction. As a result he found himself 32 miles off course to the east, since the change had reinforced his compensation by an additional 16 miles. This points to a certain erratic character in the ocean currents here.

On the other hand, the converted Japanese fishing boat named the "Lucky" that the Kapinga people use for trading trips between Ponape and the atoll, started south about the same time as the Roque but drifted far off course westward with the current and wandered about for some 49 days, managing to make a westward and then northward circuit through Puluwat, Truk and back eastward to Ponape, having lost hope of hitting Kapingamarangi. The Sailing Directions have only a brief reference to these currents. It says that in June of 1926, a weak westerly current was experienced between Kapingamarangi and the Namoluk Islands northwest of Nukuoro.

Tidal currents occur at the main passes into the atoll lagoon and the maximum velocity at these passes, according to the Sailing Directions, may reach 5 knots. These currents occur in all the inter-islet channels, of course, running most rapidly with the incoming tide. The maximum tidal fluctuation during the recorded period in July and August was about four feet between high and low tides.

The graph of a tide gauge, which was installed by the expedition at the end of the pier in the lagoon off Touhou village, shows an interesting

1. Eilers, op. cit., p. 11-13.

rhythm of rises and falls. During the 24 hours there generally are two peaks and two troughs, but at 15 day intervals the two peaks merge into one. The two peaks are not of equal height, although they gradually approach this state as they reverse their relative positions of maximum heights near the end of the 15 day cycle.

The graphs for the period from noon of July 11 to noon of July 25 serve to illustrate the evolution of the various stages (Figure 9). A low low-tide occurs at noon on July 11, rising half a foot to a low high-tide peak at 4 P.M. Thereafter, there is a slight drop of less than 1/10th of a foot to a high low-tide trough at about 5:30 P.M. There then is a sharp rise of 1.5 feet to a high high-tide peak at 1 A.M. From this the tide drops steadily 2.4 feet to the low low-tide trough at about noon the next day, July 12. This completes the 24 hour cycle.

However, with each succeeding day, both peaks grow progressively higher, while both troughs drop to successively lower levels until July 16. At this date the maximum difference of almost exactly 4 feet between high high-tide and low low-tide is reached. From this point on to July 21, the level of high high-tide decreases, while the level of the low low-tide, the high low-tide, and the low high-tide all are increasing.

On July 21 the levels of the two high tides between successive noons are approximately equal, and the difference between these two high peaks and the high low-tide trough between them is only 1.3 feet, and that between the former high high-tide and the following low low-tide is only 1.9 feet.

From this point on the two peaks change their relative levels. The former high high-tide level now is surpassed by the level of the former low high-tide which now becomes the high high-tide. In three days the former high high-tide peak has been leveled and disappears, merging into a single high tide in the 24 hours from noon of July 24 to noon of July 25.

July 25 is the beginning of a new cycle of development of the double peak and double troughs for tidal fluctuation within a 24-hour period. This second cycle ends on August 9 when the 24 hours between noon of August 9 and noon of August 10 again brings a single high tide. Thus, each 15 days sees the completion of one cycle on the graphs recorded during the following four periods:

June 27 to July 11
July 11 to July 25
July 25 to August 9
August 9 to August 22.

The coincidence of the cycle with the lunar stages is obvious, of course.

THE VEGETATION PATTERN

The general and specific ecological conditions on the vegetated land areas of Kapingamarangi have been studied by the land ecologist of the team, William Niering, and the discussion of these aspects is largely left to him. A few comments on the vegetational pattern are included here, however, as an introduction to the economic contribution of the vegetated land areas.

Emory made a list of names of plants occurring at Kapingamarangi and collected by Ray Fosberg and Edward Hosaka in 1946. This is given in his report on The People of Kapingamarangi. William Niering collected more extensively in 1954 and describes the plants as he found them. Coconut is universally present on the islets and is the most conspicuous plant. It grows up to the beach edge in either sand or porous coral rock. It is of first importance in the list of economic plants and as a food source, while its fronds are used in roof thatching. Second in economic importance among the tree species is the breadfruit tree, the largest and tallest of the trees on the atoll. It is found only on the larger islets and generally in the middle and higher parts of these islets, because of its sensitivity to salt spray and to saline ground water. However, on Touhou it grows very near the water's edge on the lagoon side, and the edge of its leaf canopy virtually overlaps the high tide line at places. On most of the islets where they occur, however, they tend to be restricted to areas a hundred feet or more from the water's edge. This is in accord with Stone's findings on Arno about which he wrote: "Generally the tree reaches maximum development in the sheltered interior of wider islands but large open-grown trees are found in settled areas and occasionally very close to the beach."[1]

The larger breadfruit trees may rise to 120 feet high and grow to five or six feet in diameter breast high from the ground. While perhaps not as important in the diet as puraka (<u>Cyrtosperma chamissonis</u>), breadfruit is one of the staples together with coconut, puraka and fish. The trunks of the larger trees are used for making the dugout canoes that form the sole means of transportation over the water, although a single whaleboat was a part of the community property on the atoll.

Another important tree is the <u>Pandanus</u>, whose leaves are used in the making of mats and baskets and whose coarse-fibered fruit is chewed to extract a sweet and tasty juice or is cooked and mashed into cakes which supply a starchy, fibrous food. The orange colored segments undoubtedly form an important source of Vitamin A in the diet. The occurrence of <u>Pandanus</u> is sporadic among the islets. On parts of some of the larger islets it may be thickly planted, as in the central puraka field borders on Werua. Typical locations for it are on the ridges of debris dug out of puraka pits, but it grows anywhere, although subject to salt spray damage on the leaves if the plant stands at the beach edge.

1. Stone, Earl L., The Soils and Agriculture of Arno Atoll, Marshall Islands, II Agriculture, p. 16.

Two species of trees are light tolerant and relatively tolerant to salt spray and saline ground conditions. For these reasons they commonly form an outer fringe along the beach ramparts, particularly on the seaward and channel fringes and generally as an understory of the coconut tree. These are Guettarda speciosa known by the native name of pua, and Scaevola frutescens, known as nau. Almost all islets except Matukerekere and residential Touhou appear to have these. Small poles from the former are cut to be used in the lattice walls of the houses. Guettarda is an important understory species especially on smaller islets. Scaevola and Guettarda appear useful primarily as beach binders to retard erosion. Messerschmidia argentea, known as tokotokong, also is a light tolerant tree prominent on the seaward or channel sides of a number of islets, although mainly confined to the larger islets of Torongahai and Ringutoru in the north part of the reef.

Occurring almost always on the lagoonside of the various islets on which it grows is Calophyllum inophyllum, called hetau by the Kapinga people. The trunks of these trees grow to two or three feet in diameter on the atoll, and they are used for the making of coconut graters, boxes and bowls, and for adze handles.

In the interior of the islets and growing as understory vegetation is Premna obtusifolia locally known as woroworo, whose trunks grow to a maximum diameter of about 6-7 inches and are used for making canoe paddles because of its tough, light wood. Another such understory tree of small size is the Hibiscus tiliaceus, locally called hau. Vertically rising branches from almost horizontally growing trunks of this tree provide straight, tall sail poles for the canoes. The raised banks of puraka pits are common locations for the planting of such trees. A small understory tree used for roof rafters is Morinda citrifolia, locally called nonu, and it grows on most of the islets. A small shrub that forms dense thickets at places on some islets is the forsythia-like Clerodendrum inerme, here called hia. Trees of less importance such as Barringtonia asiatica (rakau-iha), Pisonia grandis (puke), Hernandia sonora (pingipingi), Ochrosia oppositifolia (kaniu), and on Pumatahati numerous Cordia subcordata (rakau me) have been noted by Niering.

Among the food plants other than fruit-bearing woody trees, the foremost is Cyrtosperma chamissonis, locally called puraka. According to Emory, its ability to withstand drought has caused it to supplant taro to a very large extent in the pits. Arrowroot is a small understory tuberous-rooted plant that provides a starchy food and is found scattered about the interior of some of the islets. Banana plants are not very numerous because of competition for space with other plants, but they produce good fruit considered a luxury food. A few papaya trees produce rather small fruits considered of little value as food. Nukuoro atoll farther north produces some limes, but although some citrus plants were observed on Kapingamarangi by Niering, no fruit was seen.

A number of weed pests occur. In sections of the beach fringes on Torongahai and Ringutoru a string-like creeper vine (Cassytha filiformis) formed tangled masses choking the Scaevola and Messerschmidia on which it climbed. A daisy-like weed (Wedelia biflora) grew in great profusion on Hare in sunny open areas. Two leafy creeping vines also were found. One of these (Vigna marina) grew over smaller trees and killed their foliage. The other is a morning glory (Ipomoea tuba) which forms a ground cover and has some value as pig feed. On all the larger islets such as Torongahai, Ringutoru, Werua and Hare there grew several types of ferns, of which Asplenium nidus is most widespread, growing on old coconut stumps and on the trunks of older coconut trees as well as on the ground. On Torongahai and Ringutoru especially, the Nephrolepis hirsutula fern formed a luxuriant cover over much of the ground in the interior of the islet.

Data on vegetation character and distribution were gathered and plotted directly on field maps by Niering and the present writer. It was quickly obvious to them that the high degree of manipulation of the vegetation by man obscured the natural vegetation succession and that it was very difficult to interpret the natural ecology and environment from the apparent patterns. This was especially true of the understory vegetation patterns, which depended largely upon the landowner's activity and whims. On the same islet a patch of well-cleaned and weeded ground would occur next to densely overgrown land.

Generalizations of the vegetation pattern for certain major categories, however, may be made. There is a concentric zoning of certain types of plants: On the larger islets, puraka occur in the central portions where pits have been dug down to the fresh water lens. On the peripheral raised banks of these pits breadfruit trees appear to be most abundant and flourishing with Pandanus as a prevalent understory (Figures 8 and 15). A zone where coconut and breadfruit trees occur in mixed stands then surrounds this, with miscellaneous understory vegetation such as Hibiscus, Premna, Morinda, Pandanus and Guettarda, and with a ground cover of weeds, ferns and grass. This zone in turn is followed by a zone where coconut is dominant, but with similar understory vegetation, which extends out to the margins of the land. A narrow zone beyond the coconut zone may intervene between the rubble rampart and the water's edge especially on the seaward and channel margins where Guettarda and Scaevola and sometimes Messerschmidia accept conditions unfavorable to tree forms other than the coconut. Since coconut trees grow all the way to the beach edge, these species may form understories of the coconut in a narrow beach fringe.

On the accretive sand beaches extending lagoonward, Scaevola and certain beach grasses form a pioneer vegetation which may be followed by Guettarda, coconut and Pandanus. On the smallest islets virtually nothing except coconut and Guettarda and Scaevola may grow.

In conclusion, it may be noted that of 98 vascular plants observed by Niering, 38 are classed by him as indigenous, 56 as introduced and 4 as of drift origin as seedlings only. The term "indigenous" appears to distinguish plants present during pre-European times some of which probably also were introduced by man. The term "introduced" indicates that plants were brought in through the agency of man or of man's activities. From the above list, it is obvious that the pre-European "indigenous" vegetation was much more limited than the present-day vegetation on Kapingamarangi. Some of the "introductions" include the highly important Cyrtosperma or puraka and the taro-like Alocasia macrorrhiza, the banana, the arrowroot and some varieties of breadfruit. The "indigenous" breadfruit itself was introduced, according to Eilers,[1] prior to the coming of the white man, purportedly from Woleai Atoll in the western Caroline Islands. This early lack of breadfruit trees may have been the cause of the origin of the priestly control over this valuable tree and their fruit and of the dugout canoes made from the tree.

1. Eilers, op. cit., p. 150.

LAND FAUNA OF KAPINGAMARANGI

Emory states that the only animal on the atoll until foreign vessels introduced dogs, cats, chickens, ducks and pigs was the small brown Polynesian rat. Dogs were present on the atoll in 1910, but were exterminated presumably during World War II or immediately after because they had no function and killed the cats which served a function. Information is not available as to whether the dogs were eaten as on other Micronesian islands. Cats were introduced after 1910 and have become numerous since the extermination of the dogs. On the residential islets of Werua and Touhou, they have killed off practically all the rats, although on the larger outlying islets, especially on Hare, rats are found around the houses.

A count of the pig and chicken population by an animal husbandry specialist with the U. S. Commercial Company in August 1946 and reported by Emory gave a total of 283 pigs and 946 chickens on Kapingamarangi or more than a pig for each two persons and almost two chickens per person. Chickens run wild and ownership is identified by the toes cut off at various joints. Chickens are kept only on the larger islets. Pigs are small, black, inbred specimens for the most part and are kept tethered by a foot to a tree with rope or in pens. Because of lack of feed materials and the relatively high value of copra, pigs are poorly fed. An insufficient amount of water fed them also contributes to a scrawny animal. Pigs were less numerous in 1954 than the reported number in 1946. However, both chicken and pigs provide luxury foods for feast occasions. Three or four ducks were observed on Ringutoru Islet, but they appeared to be more curiosities than economic animals.

The only land crab that is eaten appears to be the coconut crab which grows to large size and is caught around the base of breadfruit trees where it hides among the roots and prowls about the adjacent taro fields. The other forms of land crabs and the hermit crabs serve useful functions as scavengers and as aerators of the soil through their habit of tunneling into the ground and churning up the organic material in the soil. Several varieties of small lizards, i.e., two species of skink and two of gecko, occur which feed upon flies and mosquitoes. Flies sometimes are a nuisance, but mosquitoes are numerous only on some of the outlying islets, especially Nunakita where pools of water collected in remnants of concrete structures erected by the Japanese and destroyed during World War II, form breeding places. Because of the few open pools where mosquitoes may breed, it would be a relatively easy thing to wipe out the mosquito on the atoll. However, on the residential islet of Touhou, they were virtually non-existent, so that no mosquito net was required by the expedition members. Flies were relatively numerous only on the leeward or lagoon side of Touhou, because the usually brisk breeze on the seaward half kept them away from this side.

Emory mentions that cockroaches had become a nuisance. This was not substantiated by the experience of the expedition in 1954 when few were noticed.

The noddy and white-capped tern, the frigate bird, and the starling are the most numerous and commonly seen birds on the atoll. On Werua, Ringutoru, and Torongahai the white-capped terns seemed especially prevalent. They nest thickly on some breadfruit trees, and their excreta dropping on the limbs have killed many of the branches on such trees. On Touhou birds, except starlings, are less numerous because of the presence of people. Frigate birds are largely localized in the southernmost uninhabited islets of Pumatahati and Tirakaume which are the only islets where they roost in large numbers. Their sorties in circling mass flights over various parts of the lagoon inform the fishermen of the presence of schools of fish. Occasional noddies, white terns, reef herons and cuckoo may be seen about the islets. Some of the frigate birds are kept as pets.

FOOD PRODUCING LAND OF KAPINGAMARANGI

In the study of the economic vegetation of Kapingamarangi, the limits of breadfruit tree growing areas were mapped roughly on the islets where these trees occurred. Native assistants were trained to do this on the field maps. The method used was to pace parallel to the beach edge and at every hundred feet to pace inward at right angles to the beach until the edge of the breadfruit canopy was reached. Thus the approximate bounds of the breadfruit zones were demarcated. Twelve of the larger islets grew breadfruit trees, although a few grew only one or two trees. The food producing land could be divided into four general types of vegetation zones: puraka fields or pits, a zone of coconut dominance, a zone of mixed breadfruit and coconut trees with both having about equal importance, and a zone where breadfruit trees are dominant. The smaller islets have neither puraka pits nor breadfruit, because the fresh water lens does not exist or is not significant in them, while salt water spray also inhibits their growth. The designation of a breadfruit dominant zone was made only in the two residential islets of Touhou and Werua where special conditions prevail. In the case of Werua, a large area in the center and adjacent to the puraka pits and fields was covered mainly with a breadfruit tree canopy, although a scattered sprinkling of coconut trees were to be found among them occupying an insignificant amount of space. In Touhou, the breadfruit tree crowns nearly reach over the lagoon beach in places and intermingle with Pandanus trees in the central portions. The density of the canopy is not great, however, because of the numerous thatched houses occupying the space, while coconut trees also are few and are confined mainly to the outer fringe.

To get a basis for estimating tree density for the different types, counts of all the trees of certain species were made in selected and representative plots measured off by tape. Thus, on Werua, in the coconut dominant zone, four separate plots each 52 by 52 feet square were measured off and all the trees in them counted. Two such squares also were measured and the tree count made on different parts of Parakahi Islet. On Hukuniu and Matawhei, all the coconut trees on the islets were counted. Distances between the bases of the coconut trees were measured to get the general distribution pattern and the density, while tree heights were estimated. In the mixed breadfruit and coconut zone on Werua, three representative square plots each 104 by 104 feet were measured and counts made of the number of coconut trees and the number of breadfruit trees. The tree diameter was measured for each breadfruit tree. The same thing was done for two representative square plots 104 by 104 feet in the zone of breadfruit dominance. These tree counts are listed in the following lists:

Coconut dominant zone
(2,704 sq. ft. plots)

Plot number	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	8	2	14	5
2	5	-	9	1
3	4	-	19	2
4	9	-	7	5

Mixed breadfruit-coconut zone
(10,816 sq. ft. plots)

Plot number	Breadfruit	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	5	16	2	25	14
2	5	11	-	18	8
3	4	8	-	8	-

Breadfruit dominant zone
(10,816 sq. ft. plots)

Plot number	Breadfruit	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	11	1	-	125	27
2	13	13	6	130	54

The count on Hukuniu indicated a stand of 85 coconut trees or a per acre stand of 94.4 trees, while the per acre stand on Parakahi was 148 trees. On the basis of the average of the Werua counts in the coconut dominant zone which corresponds to the coconut dominant area on Hukuniu and Parakahi, the per acre stand on Werua was 104.6. If these three figures for the coconut dominant zones are averaged, the per acre number of trees in this zone for all the islets may be estimated at 115.7. For lack of additional sample counts, the counts for breadfruit trees and coconut trees in the other other vegetation zones on Werua may be taken as representative of the per unit numbers of trees in the major vegetation zones for the various islets. The tree counts, translated into per acre number in the following table were used in calculating the relevant figures for the different islets in Table III:

Zone	Number of Coconut trees	Number of Breadfruit trees
Coconut dominant zone	115.7	---
Mixed breadfruit-coconut zone	47.15	18.9
Breadfruit dominant zone	28.2	50.37

Average distances between the bases of coconut trees and the estimated tree heights were as follows:

Islet	Average distance	Number of measurements made	Tree heights estimated
Hukuniu	21.3	14	42-60
Parakahi	16.1	13	60-85
Werua Coconut zone	20.8	25	80-100
Werua mixed breadfruit-coconut zone	26.5	24	80-100
Average for all areas	20.9	--	--

In the mixed breadfruit-coconut zone of Werua, on the basis of the sample counts, the per acre number of breadfruit trees of various diameters as well as the actual number of each diameter within the 32,448 square feet in the three sample plots were as follows:

Diameter of tree in inches	Actual number of trees in 32,448 sq. ft. sampled	Number of trees on per acre basis
6-8	4	5.4
9-10	3	4.0
11-14	3	4.0
24-26	2	2.7
36-39	2	2.7

In the breadfruit dominant zone, the per acre number of breadfruit trees of various diameters as well as the actual number of each diameter in two sample plots totalling 21,632 square feet were as follows:

Diameter of tree in inches	Actual number of trees in 21,632 sq. ft. sampled	Number of trees on per acre basis
1	1	2.0
4	2	4.0
6-8	3	6.5
13-14	3	6.5
16-17	3	6.5
24-27	3	6.5
29-31	4	8.7
35-38	4	8.7
61.5	1	2.0

Counts for the _Pandanus_ tree in each of the sample plots also were made, but because the planting of _Pandanus_ is highly erratic, estimates on the basis of the samples are less reliable. In Werua and in some of the other larger islets, _Pandanus_ trees tend to be planted very thickly on the heaped up rubble dug from the puraka pits and often in the partial shade of breadfruit trees where they constitute an understory. In the coconut dominant zone of Werua the per acre number of mature Pandanus amounted to 196, in the mixed breadfruit-coconut zone it was 68, and in the breadfruit dominant zone 515. On Parakahi, one sample area of 2,704 square feet had only a single Pandanus. Another sample in an equal area at the opposite end of the islet had five. Much of the Pandanus in the breadfruit dominant zone of Werua was of recent planting, since the trees, set 3-5 feet apart, were only from 6-12 feet in height.

The different vegetation zones mapped for the 33 islets of Kapingamarangi have been measured by hatchet planimeter for the larger areas and by 0.1 inch square grid counts for the smaller areas. The results of these measurements are shown in Table III. The sums of the various categories of land-use are indicated as follows:

Coconut dominant zone	157.03 acres
Mixed breadfruit-coconut zone	76.01 "
Breadfruit dominant zone (Werua-Touhou)	18.28 "
Puraka pits or fields	25.11 "
Total vegetated area	276.43 acres

Applying the coconut tree counts for the various zones to these acreages gives an estimated 22,174 mature or bearing coconut trees in the entire atoll. Similar calculations for breadfruit with trunk diameters over 4 inches give an estimated 1,909 breadfruit trees most of which were of bearing size. While the sample counts are too limited for great accuracy, it appears probable that Emory's estimate of about 400 bearing breadfruit trees for the entire atoll is much too low. Emory's manuscript states that during the great storm of 1947 (1948?), some 201 bearing breadfruit trees or "about half the bearing trees" on the atoll were blown down. Emory did not make any actual counts, of course, and the fact that his informant's estimate of trees blown over by the storm was about three times the number recounted to us by the village secretary in 1954 places grave suspicion upon the accuracy of estimates of tree numbers made by the Kapinga people. There would appear to be at least two or three times the number of bearing trees estimated by Emory.

The mimeographed report for Ponape District Fiscal Year 1954 entitled Trust Territory Statistical Requirements, lists the following relevant figures for coconut trees in Greenwich (Kapingamarangi):

Total area in acres	332.8
Area in palm forests	320
Number of bearing trees	44,752
Number of immature trees	22,213

The number of bearing coconut trees given by the Ponape report is just twice that of our estimate. A starred note in the report indicated that the number was "by actual count". In the judgment of the present writer, the above figures are completely erroneous in a number of ways and represent bad guesses on the part of the Kapinga land owners who probably never made any actual count of their trees and who also have little idea of exact dimensions and areas. In the first place, the total acreage of the vegetated land of the atoll is erroneously given, and is probably based upon rough area measurements from inaccurate small scale maps. The actual land area is 20 per cent less than the Ponape report's figure indicates. The difference between the total area and the area in palm forests given in the report would represent puraka land, presumably. That is, 12.8 acres would thus be in puraka land. This compares with the 25.11 acres of puraka fields mapped in 1954, or twice the area in the district report. Moreover, in the breadfruit zone and in the mixed breadfruit-coconut zone, a large part of the land is taken up by breadfruit trees to the exclusion of coconut. This may amount to as much as 40 acres or more in view of the large canopy of breadfruit trees in comparison with coconut trees. This obviously has not been differentiated in the figure for "area in palm forest". If the mapped puraka area of 25 acres is added to the possibly 40 acres of other non-coconut land, there remains only about 200 acres largely occupied by coconut trees.

That the figure of 44,000 mature coconut trees could not be correct can be deduced by the amount of tree crown area occupied by each tree. The average distance between the bases of coconut trees according to our measurement is about 21 feet, where the canopy is pretty much taken up by the tree crowns. This distance should, therefore, closely correspond to the diameters of the tree crowns, so that each tree would require an area of about 21 by 21 feet square or roughly 440 square feet. In a count of a relatively pure stand of palm trees from an enlarged aerial photo of Mokil Atoll,[1] the present writer found that in a rectangular area 200 by 400 feet in dimensions, or 80,000 square feet, contained some 140 mature coconut trees (including doubtful blurs). In another count from another part of the same photo, an area of 40,000 square feet contained 60 mature trees. In each case, an almost closed canopy of tree crowns indicated a closely set stand of coconut trees. Thus, 200 trees here required 120,000 square feet, or about 600 square feet per tree. Furthermore, measurement of individual tree crowns here yielded an average diameter of about 20 feet. From this, it would seem that if all competing vegetation canopy were excluded and coconut trees covered the entire land concerned fairly densely, there would be an average requirement of space per tree of between 440 and 600 square feet. Now, if 44,000 mature coconut trees were occupying approximately 200 acres of land, there would be 220 trees per acre, somewhat short of 200 square feet per tree or a little more than a third of the amount required at Mokil. Such crowding certainly did not occur on Kapingamarangi. It is equally obvious that there were no 22,213 immature coconut trees on Kapingamarangi where relatively few immature trees were in evidence, indicating little recent planting. In contrast to the Polynesians in Nukuoro Atoll northward of Kapingamarangi, the Kapinga people are careful not to allow too many mature nuts to lie on the ground and sprout. This may

1. See photo in Raymond E. Murphy's article: Landownership on a Micronesian Atoll, Geog. Review. October 1948, p. 601.

be merely a reflection of the greater need for food, which leads to some effort to keep the competition down that might reduce nut yields. If our estimate of 22,174 mature bearing trees were taken as correct, the number of square feet required per tree on a hypothetical 200 acres of pure coconut stand would be 385 and there would be some 110 trees per acre. This still represents considerable crowding. This compares with German plantings of coconut palm in newly cleared land in Kili in the Marshalls in 1893-94 at the rate of 78 per acre or in Likiep in 1891-92 at the rate of 69 per acre.[1] Plantings in British Malaya have been about 40 trees to the acre.[2] Newland in 1919 wrote that coconut trees should be spaced 30 feet apart in each direction.[3] Sampson in his very detailed and careful book on the coconut stated that the distance between trees should be four feet less than twice the length of a well developed leaf of a full grown bearing tree. (Since the leaf bends in a bow, the full distance of twice the length of the leaf need not be required). "Too close planting cannot be too strongly condemned," he wrote. "A tree must have full light if it is to carry a full crop of nuts ... The basis of value is not the number of trees to a given area, but the number of nuts which those trees can produce under proper management. It is safe to say that the ordinary copra varieties of coconuts should never be planted closer than 30 feet apart." Since the development of the crown was recommended as the basis for spacing, the most economical method is to plant at the three corners of an equilateral triangle. At 30 feet apart, this will give 56 trees to the acre against 48 when these are planted at the four corners of a square.[4]

It is obvious from the above that the coconut groves at Kapingamarangi, with 110 trees per acre planted about 21 feet apart on the average, and in many cases much closer together, represent heavy crowding. The 22,174 coconut trees of bearing size estimated to be on the atoll provide 52 bearing trees per person on the basis of the 1954 summer population of 426 people. The estimated 1,909 breadfruit trees with trunk diameters of over 4 inches provide an average of 4.5 such breadfruit trees per inhabitant on the atoll, calculated on the same basis.

Table III gives for each islet the total land surface under various categories of vegetation cover, the number of breadfruit trees, if there are any, and the number of bearing coconut trees. Touhou, the chief residential islet, represents a somewhat special case that requires an explanation for the figures applying to it. Because of the space occupied by houses and open yards on Touhou, the breadfruit dominant zone does not have as high a tree count either in breadfruit or in coconut trees. The transitional breadfruit-coconut zone separating the coconut dominant fringe near the shore from the breadfruit dominant interior is not too obvious or

1. Germany, Reichstag, Denkschriften IV, Das Schutzgebiet der Marshall-Inseln 1893-94, Stenographische Berichte über die Verhandlungen des Reichstages IX Legislatur Periode III 1894-95, Berlin 1895, p. 497-500.
2. Kalaw, Maximo M., The coconut industry, The Philippines, National Assembly, Manila, 1940.
3. Newland, H. Osman, The Planting, cultivation and expression of coconuts, kernals, cacao and edible vegetable oils and seeds of commerce, London, 1919, p. 19.
4. Sampson, H. C., The coconut palm, the science and practice of coconut cultivation, London, 1923, p. 119-120.

significant and has been left out. In estimating the number of breadfruit trees, the lower per acre count for the Werua mixed breadfruit-coconut zone is used instead of that for the Werua breadfruit dominant zone. On the other hand, the lower per acre coconut tree count of the Werua breadfruit zone has been used for estimating the per acre number of coconut trees in the Touhou breadfruit dominant zone.

Note: In R. L. A. Catala's report on the Gilberts, he states that in an area on Tarawa where the density of coconut palms appeared to represent average conditions, he counted an average of 231 palms per hectare or 92 per acre. These were irregularly spaced. About the same count, 93 per acre, also was made on a regularly spaced plantation on Abemama (Makin). In village areas where houses and breadfruit trees were numerous he found in 14 countings an average density of only 115 palms per hectare or about 42 per acre. (Data from M.-H. Sachet's abstract translation of R. L. A. Catala, Report on the Gilbert Islands (mimeographed), Noumea, 1952).

Table III - Acreages in different vegetation types

Islets	Acres total area	Coconut Dominant Acreage	Acreage of Breadfruit-Coconut Zone	Number of Breadfruit Trees	Acreage of Breadfruit Zone	Acreage of Puraka Pits	Total Number of coconut trees
Torongahai	19.5	11.75	5.95	112		1.8	1640
Ringutoru	26.7	13.75	10.15	192		2.8	2070
Rikumanu	.9	.9					106
Turuaimu	2.0	2.0					231
Pepeio	.7	.7					82
Nunakita	14.2	11.6	2.55	48		.5	1460
Hukuniu	.9	.9					106
Parakahi	3.1	3.1					358
Werua	41.4	6.52	13.22	770	10.36	11.3	1612
Touhou	9.2	1.27		150*	7.93*		370*
Taringa	12.4	8.25	3.75	71		.4	1130
Pungupungu	.4	.4					46
Matiro	10.3	8.02	2.08	39		.2	1024
Matuketuke	1.0	1.0					116
Ramotu	3.5	3.5					405
Sakenge	2.3	2.3					266
Matawhei	.7	.7					81
Hukuhenua	5.0	4.66	.24	4		.1	541
Hepepa	2.3	2.3					266
Tipae	1.6	1.6					185
Tetau	7.8	5.38	2.02	38		.4	717
Nikuhatu	2.3	2.3					266
Takairongo	3.9	3.9		1			450
Tangawaka	7.0	5.2	1.5	28		.3	671
Hare	79.5	37.2	34.6	655		7.7	5930
Herekoro	3.8	3.74		1		.06	440
Tirakau	1.8	1.8					204
Tariha	2.2	2.2					254
Tiahu	.6	.6					69
Tokongo	1.8	1.8					208
Tirakaume	1.3	1.3					150
Pumatahati	6.3	6.3					726
Matukerekere	.03	.03					1
Totals	276.43	157.03	76.01	1909	18.29	25.11	22,174

*See explanation on page 34.

THE REGIONAL GEOGRAPHY OF THE ISLETS ON THE REEF

In the following section of the report, an elaboration of notes taken about the individual islets is presented. This elaboration is based upon field notes made by William Niering and the present writer either singly or in joint field observations. Errors of fact or generalization in the following account, however, are chargeable solely to the present writer.

The descriptions include information concerning the use of the islets for residence or workhouse sites, the existence of puraka pits, the shore and beach characteristics and effects on these of wave, tide and current action, the general surface soil character, the types, prevalence and condition of dominant and understory vegetation, and some aspects of or effects on human activity.

The order of arrangement is in accordance with the succession of the islets from north to south, beginning with Torongahai and ending with Matukerekere. Maps of the islets on the scale of one inch to 200 feet accompany these descriptions. For convenience in locating the section describing a particular islet, the following list gives the order of succession of the islets from north to south:

1. Torongahai (Figure 10)
2. Ringutoru (Figure 11)
3. Rikumanu (Figure 11)
4. Turuaimu (Figure 12)
5. Pepeio (Figure 12)
6. Nunakita (Figure 13)
7. Hukuniu (Figure 14)
8. Parakahi (Figure 14)
9. Werua (Figure 15)
10. Touhou (Figure 16)
11. Taringa (Figure 17)
12. Pungupungu (Figure 18)
13. Matiro (Figure 18)
14. Matuketuke (Figure 19)
15. Ramotu (Figure 19)
16. Sakenge (Figure 19)
17. Matawhei (Figure 20)
18. Hukuhenua (Figure 20)
19. Hepepa (Figure 20)
20. Tipae (Figure 21)
21. Tetau (Figure 21)
22. Nikuhatu (Figure 22)
23. Takairongo (Figure 22)
24. Tangawaka (Figure 22)
25. Hare (includes former Ruawa and Herengaua) (Figure 23)
26. Herekoro (Figure 24)
27. Tirakau (Figure 24)
28. Tariha (Figure 25)
29. Tiahu (Figure 25)
30. Tokongo (Figure 26)
31. Tirakaume (Figure 26)
32. Pumatahati (Figure 27)
33. Matukerekere (Figure 27)

1. Torongahai - 19.5 acres (Figure 10)

Has three working houses but no residence. One house is adjacent to the western part of the lagoon beach. Two others are in the middle section of the eastern channel shore. At the latter point a 70 feet long wall of coral blocks has been built out into the channel toward Ringutoru, apparently to trap wave and current deposited sand and debris in order to extend the land surface. These had begun to accumulate and to fill in the area on the seaward side of the wall. As the east side of Torongahai is flanked rather closely by the large islet of Ringutoru (420 feet across the channel), protection is afforded from the more severe southeast storm waves. The northern end is exposed, however, and here wave erosion appeared to have reduced greatly a long triangular tongue of land narrowing seaward from the width of the islet. The former northward extent of the islet is outlined by two lines of consolidated beach rock. One, running from the west side of the islet in a northeasterly direction, has a dip toward the northwest of 13°. The second, running from the east side of the islet almost due north to meet the other line, has a dip of 7° toward south of east. Within these consolidated beach rock lines the unconsolidated accumulations of sand and rubble appear to have been scoured out.

Erosion severity on the north and northwest sectors of the shore is indicated by numerous fallen coconut trees. The soil around and under the root clumps have been washed out and the trees killed. Undercutting by wave erosion also has affected numerous other trees such as _Guettarda_, _Scaevola_, _Messerschmidia_ and _Hernandia_. A thin covering of sand lies over the hard reef rock adjacent to the northern sector of the shore, but the beaches on the west, northwest, and northeast are of mixed sand, gravels and rubble with the exception of short stretches where sand may not be a significant ingredient. Except for a 130 feet section of the beach south of the boulder wall on the east channel, the rest of the beaches to the south and facing the lagoon are of sand.

The sandy character of the soils south of the puraka fields which occupy the central parts indicate that the islet is building lagoonward or southward. The seaward half of Torongahai has a gravel and rubble soil intermixed with humus. Several factors give indication of the lateral migration of the islet along the reef in a southwestward direction as well as lagoonward. On the southwest and west sides of Torongahai there appear to be two and possibly three beach ramparts roughly parallel to each other. The first is just back of the shoreline. A second rampart appears about 40 feet inshore of the high tide line, and the back shore sloping from this second rampart measures about 30 feet. Up to 150-250 feet inland a slightly raised though gently sloping ridge may once have been a beach rampart. Thus, the land must have built outward in a westerly to southwesterly direction. Niering made the observation while examining the islet that the northeast part of the islet is the richest in humus and grew the most luxuriant _Nephrolepis_ fern, so that this probably was an indication of the greater age of the northern sector, while the younger land was found near the lagoon. It was also observed that the sandy backshore on the lagoon side measured up to 10-12 feet and that several stages of _Scaevola_ growth graded outward toward the high tide line from the more mature to the young seedlings. Particularly rapid building up of sand was obvious at the southwest corner. _Cordia_ found here overhung the sand 25 feet and was partly sand buried. Three bands of _Scaevola_ grew here, the inner band reaching to 10 feet, the second band to about six feet, and the third band comprising new sprouts a foot or less in height.

Another indication of the southwestward building up of land on Torongahai may be provided by the situation of the puraka pits and the breadfruit zone. These generally are found pretty well centered in the islets or lagoonward of center. On Torongahai the puraka fields are only about 200 feet from the northeast shore, but some 500 feet from the southwest shore. Most of these pits appear to be quite old. If the northeast and southwest parts of the islet were of equal age, the construction of fields probably would have been better centered than they actually are, and would have included more of the southwest central part of the islet.

Coconut trees here generally are healthy and vigorous appearing, although on the island in the middle of the largest puraka field, some coconut trees have yellowish leaves. Large breadfruit grow over a large portion of the islet, particularly adjacent to the puraka fields. A number of these trees here appear badly injured by the excreta of nesting starlings. Limbs on which excreta drop are damaged and large branches then lose their leaves and die. *Premna, Morinda, Pandanus* form important understory vegetation. Ferns and grass also are luxuriant ground cover plants. No particular significance can be attached to the pattern of distribution of the understory which is highly man-manipulated here as on all the other islets of Kapingamarangi. Change from one property to that of another owner may result in sharp changes of undergrowth patterns. These patterns depend upon the inclination and diligence of the owners in cutting undergrowth or upon the stage of cutting or of regrowth. Hetau (*Calophyllum inophyllum*) are numerous along the lagoon shore although not of great size. Most of the trunks of the hetau were one to two feet in diameter. (One hetau tree observed by the writer at Nukuoro Atoll had four branches each about four feet in diameter).

2. Ringutoru - 26.7 acres (Figure 11)

Once said to be thickly set with habitations, it now has only six houses and a cement cistern, two being work houses on the western arm of the islet. The other structures include a canoe house, a dwelling or sleeping house, a work house and a shed which are grouped together with the cistern near the center of the lagoon beach and belonging to one family. Aesthetically, this is one of the most attractive of the islets in the atoll. It is the third largest. It differs from most of the other islets in having a relatively deep miniature lagoon of clear unsullied water about 1000 feet in diameter on its south side, enclosed by reef patches with a shallow channel through which canoes or small boats may reach the sandy beach facing the atoll lagoon. The two great southern lobes of this three-lobed triangular-shaped islet and the connecting beach between are formed of sand advancing lagoonward at a fairly rapid rate (i.e. averaging a foot or more per year). The eastern channel side of the islet with its incurving beachline shows evidences of long and severe erosion. The beach itself is comprised of loose fragments of rock and rubble, and the northern sections of this beach have two large dead coconut trees whose stumps have been washed out by wave action. A similar beach type is found on the western channel facing Torongahai, although a greater amount of gravels and rubble lines the shore. The erosive forces along the shore are just as great and several dead coconut logs with root clumps lie on middle sections of this beach.

The soil in the two southern lobes of the islet are sands intermixed with humus up to 400 feet inland from the tip of the west lobe and up to 600 feet from the tip of the east lobe. In the rest of the islet the outer 100 feet or so of surface has a gravel-sized rubbly soil intermixed with humus. In this zone rubble beach ridges parallel the shore 10-20 feet inland. These are slightly elevated (perhaps a foot or so) above the inward lying ground. Within the central parts of the islet inward from this rubbly zone the ground is covered with many inches of black-brown humus overlying gravelly rubble which also has much humus. Within this central part and generally from 120 to 150 feet from the shoreline are located 13 puraka pits, most of them from 5000 to 10,000 square feet in area, although the largest is almost an acre in area. Around each pit the debris dug out has been piled into several feet high ridges which afford some protection to flooding by salt water from the lagoon during southerly storms. The seaward land area generally is somewhat higher than the sandy lagoonward parts. In the pits a rich mucky soil has been developed through rotted vegetation, coconut husks, and other debris used for fertilization. High waves from the south in the storm of 1948 (1947?) swept northward across the lagoon and flooded some of the puraka pits with salt water, killing all the plants. New plantings were made after the salt was flushed out by rains. The coconut trees in the interior of this islet are among the oldest, tallest and most flourishing on the atoll. Much of the ground underneath them is covered with a luxuriant mass of birds' nest fern (<u>Asplenium nidus</u>) growing waist high especially in the western central portion. With the exception of the 400-600 feet long lobes protruding southward toward the lagoon underlain with sandy soil, the parts of the islet inward of 75-100 feet from the shore form a zone of intermixed breadfruit and coconut trees. Some of these trees here are over four and five feet in diameter breast high from the ground and above the buttress roots. In the northern central parts of the islet the coconut breadfruit canopy is close to 100%. Similar cover extends over the central eastern parts of the coconut-breadfruit zone. The coconut palms here are over 100 feet tall and are only over-reached by the breadfruit trees by 15-20 feet. In the southern two lobes the coconut trees are dominant but form a lower stand, 75-100 feet high, indicating a more recent stage of planting and perhaps pointing to the more recent stage of land development in these lagoonward reaches of sand. The canopy on the eastern lobe is 75-100% as compared to generally 100% on the western lobe.

No pigs were observed on Ringutoru, but numbers of chickens were seen. These were quite wild and flew away like partridges when flushed suddenly from their nests.

<u>3. Rikumanu - 0.9 acres (Figure 11)</u>

Uninhabited islet lying on the seaward half of a 3000 feet wide reef, in dimensions 32 feet by 440 feet. Most of the islet appears to be underlain with reefrock covered by one to three feet of rubble. Its shores are of severely eroded rock which on the lagoon end has been undercut for a distance of six or seven feet under a rock shelf two feet thick on top of which grows a coconut tree 25 feet high. In spite of the signs of severe erosion, the owner informed this writer that no noticeable change had been observed in the dimensions of the islet as long as he could remember.

The dip of the beach rock fringing the islet showed a 7-11° inclination toward the lagoon. A soil pit dug down to two and a half feet depth on Rikumanu showed a very rich humus intermixture with the rubble in which coconut tree roots formed an interlocked mass. Obviously an islet of this narrow width would have no fresh water lens, so that the vegetation must be entirely dependent upon the rainfall absorbed by the top two or three feet of soil.

The coconut trees on the islet were pretty closely crowded, were from 50-75 feet high, and provided a 50-75% canopy. A dense growth of Scaevola was the dominant understory while Pandanus and Morinda formed subsidiary understories. The owner stated that he cut down the Scaevola about once a year to keep it under control.

4. Turuaimu - 2.0 acres (Figure 12)

Without human dwellings and situated on the inner edge of the reef which here is some 3000 feet wide. Protected from easterly storms to some extent by its situation to the leeward of Nunakita Islet. Its lagoon beach is of foraminiferous sand. The northeastern tip facing the sea also had a small sand beach. The rest of the beach was of gravelly rubble, while the shores were severely eroded on the northwest and southeast seaward sides.

The soil throughout was sand mixed with humus. An apparently healthy stand of coconut trees 50-75 feet high provided a canopy of 50-75%. A relatively dense understory of Guettarda (50-75% cover) was accompanied by a lower understory of Morinda.

5. Pepeio - 0.7 acres (Figure 12)

Uninhabited. Gravelly beach on both seaward and lagoonward sides of its triangular shape, the third side facing the channel between it and Nunakita having a sand beach. Its soil is merely sand with a slight humus stain for the top two inches. It was built up by sand trapped by a coral wall on the seaward side constructed by the father of Materewe during 1919. Scaevola and Guettarda were planted at the time to hold down the sand and reduce wave wash. The islet gradually grew larger, and coconut trees were planted as the islet grew. In 1954 ten or more of these trees were producing nuts. These trees were still low, mostly under 25 feet, had yellowish green leaves and provided a canopy of 50-75%. Guettarda, Premna and Pandanus formed a sparse understory. Three young Calophyllum grew on the lagoon side.

6. Nunakita - 14.2 acres (Figure 13)

Uninhabited despite its relatively large size, although there is a sleeping house on the eastern side of the northern end which sometimes may be used. The reason for this possibly is that the Kapinga people did not or were not permitted to stay on it during the World War II period when the Japanese had their chief weather station here, with quarters and a concrete structure on the northern seaward end, as well as two steel radio towers now lying in wreckage on the ground. A two-story high concrete tower still stands on the southeast end of the islet at the water's edge. This had served as a meteorological tower. All the structures were bombed and wrecked during 1943-44.

The lagoon beach and adjacent land is of sand which has been gradually filling in a deep pool fronting the shore and bounded by shallow water 200-300 feet out from shore. On the east and west channel sides, the shores have been severely eroded and the beach comprises gravel and rubble thinly overlying rock. At the northern seaward end the eroded and stratified bedrock standing above the reef flat extends 210 feet northward of the shore in a patch of about equal width. The outer edge of this old bedrock here reaches within 290 feet of the coral terrace at the edge of the reef.

The soil is composed of sand intermixed with humus covering the entire southwest and south sections up to 350 feet inward from the southwest corner and 150 feet inland from the southeast corner. From this sandy area seaward the soil is mostly gravel-sized rubble intermixed with humus.

A zone of breadfruit trees intermixed with coconut trees occurs in the central portion of the southern half of the islet but north of the sandy zone. Two isolated clusters of breadfruit trees occur in the northern half of the islet, both near the eastern channel shore, the smaller one being adjacent to the sleeping house. The breadfruit tree trunks ranged in size from one to two feet in diameter. The taller and older coconut trees were situated in the lagoonward half of the islet, mostly running over 100 feet tall. On the seaward side the coconut trees were from 75-100 feet tall and more sparsely distributed. Partly this is because of the presence of the concrete and steel tower ruins. Some of the wreckage had become quite overgrown with a tangled mass of *Pandanus*, young coconut and other understory plants such as *Morinda* and *Premna*. *Morinda* was the dominant understory tree in the lagoonward half of the islet.

Only two small puraka pits existed on this islet, located within 200 feet of the southeast lagoon shore. In general, Nunakita appeared to be less tended than most of the privately owned islets. The seaward parts especially showed much neglect. Mosquitoes were encountered here in the largest numbers, without doubt owing to the breeding pools of stale rainwater green with algae and full of mosquito larvae that occurred in the concrete ruins.

7. Hukuniu - 0.9 acres (Figure 14)

Uninhabited. The only islet situated considerably to the seaward of another islet. An elevated ridge of bedrock forms a connection on the reef flat between Hukuniu and Parakahi. This may indicate an earlier stage of development when the two islets were connected to form one long islet like Nunakita. The subsequent erosional history may have brought about the severing of the attenuated islet into the present two islets 1225 feet apart. Eroded and jagged bedrock surrounds Hukuniu, jutting out seaward from the shoreline for about 25 feet and rising more than three feet above the reef flat. Small sand patches form the beach off the lagoonward tip. The soil is a coarse rubble with some humus content down to a three-inch depth.

Two representative coconut trees measured 42 and 59 feet high respectively. A complete count showed 85 coconut trees on the 0.9 acres, as well as three mature and two immature Pandanus trees. Morinda and Premna formed the spray-damaged understory vegetation while Guettarda and Scaevola grew on the outer fringes.

8. Parakahi - 3.1 acres (Figure 14)

Uninhabited. Sandy beaches on southwest and southeast leeward sides, the converging beaches building lagoonward into a sand spit. The beach on the north side is a thin veneer of rubble over the eroded bedrock. Undercutting is severe on the north side where parts of old Scaevola roots have been exposed by wave wash. The soil is rubble intermixed with dry humus except for the lagoonward sections within 30 feet of the high tide line where a sandy soil with less organic material occurs.

The coconut trees here are somewhat higher than on Hukuniu, averaging from 60-85 feet. On the basis of sample counts of two plots each 50 by 50 feet square, the number of mature coconut trees on Parakahi are 458, a dense stand. The understory is Guettarda and Morinda. On the north side a Calophyllum tree with a trunk diameter of 11.5 inches showed heavy leaf scarring from salt spray. A healthy Calophyllum stood on the sandy lagoon shore, however. Pandanus also is of some importance as an understory.

9. Werua - 41.4 acres (Figure 15) (Houses are not shown on map.)

The second residential islet connected at the south end of its lagoon beach with Touhou Islet by a causeway and road. Emory stated that in October of 1947 Werua had 183 of the atoll's population as residents, as compared with 293 for Touhou Islet, although it is more than four times as large as Touhou. Werua is the largest islet after Hare, but has a greater excavated area of puraka than Hare and more breadfruit trees because of a larger central area removed from salt spray and the saline sea edge, as well as because of a larger area of elevated land for breadfruit. It is surpassed in the number of coconut trees by both Hare and Ringutoru, however.

A roughly rectangular road runs around the central portion of the islet. The longest side, some 1200 feet, generally parallels the sandy lagoon beach at distances of 70-100 feet from the high tide line. On the south side the road runs closer to the shoreline, but on the north it runs from 300-450 feet from the shoreline. Most of the puraka fields are enclosed by the road, although seven puraka fields are found at the northern end outside the road rectangle.

Canoe houses and accompanying residences face the lagoon beach at closely spaced intervals, and it is here where most of the islet's residences are situated. The eastern and central parts of the islet are mostly without habitations. The elevation of the surface of the ground rises from the high tide line to about 5.4 feet near the central part of the lagoonside road. On the inward side of the road a level terrace constructed from the debris dug out of the puraka pits rises two to three feet above the road, and on this terrace which stands about seven feet above the level of the puraka field on the inland side are additional residences. Residences also border both sides of the south channel road but are not found along the road on the seaward side. Along the north channel shore are a scattering of houses which are spaced most closely near the north lagoon end of the islet. Two or three houses are situated at the shore near the northeast corner of the road rectangle. A single sitting house is located in the center of the seaward shoreline at the end of a path leading from the central road rectangle. A work house is found on the eastern side of the big puraka field on the rubble ridge in a dense thicket of Pandanus trees. On the same side of the large puraka field near the southern end is another work house or sitting house.

No wharf projects into the lagoon from Werua, since there is no need for it. The community canoe is housed in the Werua men's house which is situated near the center of the lagoon shore. Here is kept the longest canoe on the atoll, measuring about 57 feet, dug out from a single log. Inland and on the terrace across the road stands the small Roman Catholic chapel recently constructed by the 30 or so Catholic converts for their services. A brass bell mounted on a post outside the house is utilized for religious purposes.

The lagoon beach here is sandy and the offshore water is shallow. Seaward of the causeway in the south, artificial seawalls line the channel shore below which a rubble beach is exposed at low tide. This runs as far as the last residence on the seaward end. Further seaward the beach continues as a rubble beach while the shore becomes rocky. Most of the seaward beach is of this character, although some sand forms accumulations in small pockets at intervals. Just westward of the northeastern point there is a patch of sandy beach which is about forty feet wide. The north channel beach mostly is of rubble with occasional short stretches of narrow sand beach. The northern tip of the lagoon beach is of sand that is building up lagoonward.

The highest elevation above usual high tides measured in east-west traverse across the islet was 14.5 feet on the rubble ridge west of the northern end of the large puraka field. This drops quickly off the ridge to about 4-5 feet in the vicinity of the smaller eastern puraka fields and eastward across the road for about 100 feet where it begins to rise gradually to 8-10 feet elevation, 50 feet from the seaward beach (Figure 8).

Soil in the residential zone, except at the lagoon beach where it is sand, as on Touhou appears to be a layer of gravelly rubble spread on the surface by man which minimizes dust and dirt and provides for a firm clean surface. To a somewhat lesser degree than on Touhou the residential ground is kept free of leaves and debris, since Werua is not entirely residential and it is more difficult to keep clean. The road around the islet also is weeded and swept at intervals by teams of boys and girls under adult supervision. In the interior two vegetation zones, the soils correspond somewhat to what Fosberg describes as the Arno Atoll series,[1] and is similar to the soils in the interior of Ringutoru, Torongahai and parts of Hare, i.e., black or dark-brown loamy sands with some increment of gravels and with high organic content. Not all of the soil is of this type, however. The main constituent of the soil on the ridges surrounding the puraka fields is limestone rubble dug out of the pits. On the seaward side of the road rectangle most of the soil is of limestone rubble and debris. North of the small paths leading eastward to the seaward shore is a large patch of bedrock exposed on the surface and overgrown with Clerodendrum. That sea water percolates through underground cracks and holes of such rock several hundred feet inland here is indicated by several small abandoned puraka pits where puraka plants were unsuccessful apparently owing to saline water intrusions. In the puraka pits the soil is a muck through which the water of the fresh water lens is moved up and down by the tidal pressures.

Werua is the only islet having four rather clearly discernable vegetation zones (see Figures 8 and 15). These are arranged in a generally concentric zonation with the exception of the outermost zone of Guettarda and Scaevola which have been permitted to grow here only along the north channel and seaward fringe. Aside from this fringe zone a coconut tree dominant zone completely encircles the islet occupying the outermost 50-100 feet. Inward of this, breadfruit trees form an intermixed stand with coconut trees in a zone whose innermost bounds may roughly be delimited by a line running around the entire area of puraka fields and pits and coming close to their outer edges. The area inside this line is dominated almost completely by breadfruit trees among which coconut trees are much less prominent, but under which Pandanus trees occasionally form dense understory vegetation.

A vigorous and healthy tree growth is found throughout the islet and some of the largest breadfruit trees grow in the interior of Werua, the trunk of one of which measured 61.5 inches in diameter waist-high from the

1. Fosberg, F.R., Soils of the northern Marshall atolls, with special reference to the Jemo series, Soil Science, Vol. 78, No. 2, August, 1954, p. 101.

ground. Sample tree counts were conducted on a number of measured plots by William Niering and the present writer. Some generalizations from the results of the count have been given in a preceding section of this report under the heading: "The Food Producing Land". More detailed analysis is provided in Niering's report. As a residential islet, Werua differs from Touhou in that the larger part is non-residential and devoted to food trees and puraka pits. It also has rank and dense understory vegetation in the middle, northern and eastern portions of the islet in which Morinda, Premna and Pandanus all are prominently represented. This islet probably produces more Pandanus than any other islet on the atoll, much of it being recent plantings in the central parts. In the breadfruit tree dominant zone, the dense stand of Pandanus trees stood 3-6 feet apart but were only 6-12 feet high. Ornamental shrubbery around the residences is common, especially in the southern sectors of the islet adjacent to the road. Banana plants occur at rare intervals.

Birdlife is most prevalent in the northern sector of the islet where white-capped terns and noddies nest high on the branches of the breadfruit trees.

10. Touhou - 9.2 acres (Figure 16)

Main residential islet with more than half of the total population of the atoll making its home here. Emory listed the number of people resident on Touhou in October of 1947 as 293 out of the total of 527. Most of the religious and social activities are located here centered around the Protestant church and yard which in pre-Christian times (prior to 1910) was the focus of the cult ceremonies. Adjacent to the church yard is the islet's school-house and the wooden structure that forms the magistrate's (chief's) "office". These formed the living quarters and laboratory for the expedition in 1954. Both the house of the previous chief, King David, and the house of Chief Tuiai are adjacent to the church yard.

The entire surface of this islet is divided up into residential yards, although this interferes only partially with the space for growing coconut and breadfruit trees, since the houses sit under the shades of these trees.

Touhou is reported to be the result of man's work in building up the land plus the sand accumulation in the lee of the ocean waves and currents sweeping in from the sea in the east. The higher elevations are on the seaward side, while the lagoon shore lands are several feet lower. Two elevated areas northeast and southwest of the churchyard are over nine feet above sea-level, the former rising to twelve feet in a patch about 100 feet in diameter. A mound 30-40 feet in diameter to the seaward of this and overlooking the seaward shore also rises to 12 feet. The church yard lies at six feet elevation and the lagoonward side of the road around the islet roughly follows the six-feet contour. On the seaward side the road runs at 8-9 feet elevation above the usual high tide line. From about this height the shore on the seaward side drops off in a bluff to the high tide line. A small sand beach about twenty feet long and ten feet wide has formed in the central section of the seaward beach, probably owing to the projecting platform built of coral blocks out onto the reef flat. Adjacent to this platform which supports a house is the community-men's outhouse, known as the "harepokuku" ('house of explosions'). Most of the shoreline here is artificial, comprising a series of built-up seawalls about four feet above high tide and providing protection against wave wash and erosion of the land behind. A women's community outhouse is situated on the north channel side of the islet. Both north and south channel shores for 150 feet or so from the lagoon shore have straight seawalls protecting the land behind. In the north channel area near the causeway is the only canoe house facing an inter-islet channel. Since the causeway obstructs acess to the lagoon, canoes housed here must wait for high tide to travel around Touhou to get into the lagoon. No canoe house faces the seaward side on this atoll. The lagoon shore rises from shallow water to a sandy beach on which the canoe houses are closely set next to the high tide line. The three feet contour runs 40-50 feet back of this line on the lagoon side.

Running out into the lagoon from the center part of the village street on the lagoon side is a wharf suitable for landing whale boats or small launches. This extends out about 175 feet beyond the high tide line and has about three feet of water near the end at low tide. The Touhou community men's house in which the community canoe for Touhou is kept is immediately adjacent to the base of the wharf on the north side. Projecting into the lagoon about 50 feet north of the wharf is a platform built up of coral blocks on which is set a residence house. A similar platform also is found 150 feet south of the wharf. Such structures reflect the crowded residential situation on this islet where additional living space can be had only by building outwards onto the tidal flats and beaches. From the northern end of the lagoon beach a causeway about eight feet wide and six feet high has been built across the channel to connect with the second residential islet of Werua. While the tidal flow continues through the interstices of the coral blocks used in the construction, sand is gradually accumulating on the lagoon side of the causeway and closing up the channel. In time and lacking any major storms, the seaward parts of the channel also will fill in so as to join the two islets into a single large islet.

Breadfruit trees are numerous on Touhou, while coconut trees and Pandanus trees are most numerous in the near shore fringes on the seaward side. However, because of the many houses, the number of trees of different type per unit area averages lower than on other islets. Understory vegetation here comprises mostly of Pandanus and a few ornamentals and some banana and papaya plants. The ground elsewhere is covered with gravelly coral for the most part. The elevated mound and the higher seaward elevations have several feet of fine organic soil exposed by wave erosion. The ground everywhere is kept clean of debris which is picked up daily and thrown over the bluff on the seaward side. Every stray leaf is picked up, so that little organic material returns to the soil. Because of the practice of cooking foods in ground ovens, the ashes from burnt coconut shells and husks form a constituent of the soil in the cooking areas.

Periodically, however, new clean sand is brought in to replace the old in the barbecue pits.

Emory stated that pigs had been banned from Touhou because of sanitary reasons and were not found on the islet during his stay. In 1954 however, a number of pigs were tethered to coconut trees in the beach areas both on the seaward and the lagoonward sides. Garbage and wastes all were thrown over the seaward bluffs near the men's outhouse or were carried out into the lagoon and dumped. Human wastes from the outhouses were scoured away twice daily by tidal waters, so that no sanitation problem was presented here. No outhouses are situated over the lagoon water as was observed by the writer on some other Micronesian atolls, but men and women wade into the lagoon for toileting and the more sluggish tidal action here leads to some fouling of the water near the beach. On the other hand, scavengering by fish disposes of wastes rapidly.

Water for drinking generally is collected on Touhou in above ground cisterns of cement construction at individual homesteads. A community well next to the school yard seven feet below the surface taps the fresh water lens. This water is used for bathing and washing purposes. Frequent bathing in the lagoon is common, and a bucket of fresh water from the well may be used as a rinse as well as for cooling the body during the day. Presumably, little of the fresh water used from the well is lost, since the run-off of washing and bathing promptly filters back down through the porous ground to the water lens a few feet under the surface. Surface evaporation is reduced by the cover of loose gravels.

The lack of dense understory vegetation and the open ground under the shade of the coconut and breadfruit trees permit the almost constant easterly breezes to pass across to the lagoonshore readily, cooling the air which can be very hot on the leeward sides of heavily vegetated islets in early afternoons. The eastern seaward side of the islet provides the most pleasant atmospheric conditions for man, since even during the afternoons when temperatures run over 90° F. there is a constant breeze. During early hours of the morning the coolness is such as to demand a sheet cover for comfortable sleeping. On Werua and other islets, houses are set on the warmer lagoon side because of the need for convenient nearness to the canoes which has paramount consideration.

11. Taringa - 12.4 acres (Figure 17)

Inhabited by at least four family groups, since there are four canoe houses fronting the lagoon, as well as nine other houses grouped around the various canoe houses. Its size and nearness to the main residential islet of Touhou across the north channel from it makes this a desirable residential area. A sandy beach faces the lagoon, but the channel and seaward beaches comprise a thin veneer of rubble lying on eroded bedrock. Coarse rubble is especially prevalent on the seaward beaches. Rapid lagoonward building of sand spits is occurring at both north and south ends of the lagoon beach. This is aided in the north by a wall of coral boulders running 100 feet into the channel. A soil pit dug 50 feet from the central part of the lagoon shore reached bedrock 3.4 feet below the surface. At the center of the islet the bedrock was reached 5.75 feet below the surface.

A 100-feet wide strip of sandy soils with some organic materials runs along the lagoon shore, but in most of the islet, gravelly rubble intermixed with humus forms the soil. In a patch about 70 feet in diameter 150 feet from the southeast shore, bedrock is exposed at an elevation of only about 1.4 feet above high tide. Much of the islet is under 2.5 feet in elevation, although the central part adjacent to the puraka pits and the seaward sectors in the east rise to somewhat over 3.5 feet and in places to as much as 5.5 feet. A bomb crater near the eastern tip contains a fresh water pool owing to the exposure of the fresh water lens. Coconut trees in general appear vigorous and tall, mostly 75-100 feet high in the central and eastern part of the islet. Lagoonward of the breadfruit zone and within 100 feet of the shoreline they are only from 75-100 feet high and more sparsely distributed owing to the house clearings. Pandanus is the dominant understory in the vicinity of the houses and also in parts of the seaward side. Morinda and Premna are relatively dense understory plants in the center to the seaward of the puraka fields. Breadfruit trees with diameters up to 48 inches are found adjacent to the puraka fields. Some pigs and chickens are raised here, two pig pens being located adjacent to the north channel shore.

12. Pungupungu - 0.4 acres (Figure 18)

Uninhabited and connected by causeway to the islet of Matiro only 50 feet away. The causeway has accumulated sand on both sides which in a few years should result in joining the two islets into one.

Pungupungu appears to have shrunk from its former size, since large eroded beach and reef rock patches lie off the seaward side while no beach building in the way of sand or rubble accumulation appears to be taking place except the recent land building on the two sides of the causeway.

The coconut trees on the islet were from 50-65 feet in height, formed a 100% canopy and appeared healthy and flourishing. The rubble and humus soil also supported an understory of Guettarda and Pandanus.

13. Matiro - 10.3 acres (Figure 18)

Inhabited, having ten structures, several of which are sleeping houses, the others being work houses or canoe houses. The islet is a long one, some 1400 feet north and south, but only about 380 feet wide from lagoon to seaside. Its nearness to the residential islet of Touhou as well as its size have probably led to the construction of the residential houses.

All the beaches are sand overlying bedrock which, except along the lagoon shore, extends out seaward and along the south channel shore for a width of about 25 feet. In the vicinity of the tiny "satellite" islet of Pungupungu to which it is connected by a causeway, some tongues of bedrock 60-70 feet wide reach eastward up to 200 feet. A patch of bedrock also borders the south and eastern parts of Pungupungu. This extends seaward 187 feet from the shoreline and is 165 feet wide. Thus, erosion appears to be cutting back the islet from the seaward side.

On the lagoonside the sand which previously had been built up showed subsequent erosion eating away at the roots of established plants on the northern half of the beach. The southern half here showed no significant erosion at work, but rather was building up.

The only notation of coconut and understory vegetation taken was on the south end. This indicated a sparse stand here with only 25-50% canopy, but of flourishing trees over 100 feet high. However, a closer stand occurred in the rest of the coconut plantation. The chief understory on the sandy soil at the south end was Guettarda followed by Pandanus and young coconut plants.

A narrow band of intermixed breadfruit-coconut trees occupies the land immediately adjacent to and between the two small puraka pits set 400 feet apart.

14. Matuketuke - 1.0 acres (Figure 19)

Uninhabited islet 150 by 410 feet in dimensions elongated east and west. On the seaward eastern end a patch of bedrock the width of the islet extended 180 feet eastward along the reef flat. A narrow 10-20 feet wide strip of beach rock also fringed the north channel shore. In the channel about half way between Matiro and Matuketuke a 15 feet wide strip of beach rock stretched 320 feet seaward from a point near the seaward end of Matuketuke. Bedrock formed the beach all around the islet except the lagoonward half of the north channel beach which was of rubble and sand. Moreover, a large sand patch standing above high tide had formed lagoonward of the western tip of the islet and this was connected by a narrow neck of sand to the islet. The sand patch itself measured 44 feet wide and 176 feet long and was used at the time of visit for drying Pandanus leaves, indicating its position above high tide. In the central part of the sand patch a coconut sprout 1.5 feet tall had begun to grow, together with 4 seedlings of the Calophyllum. Provided there is an absence of severe storm waves, this patch eventually might be the nucleus of an additional piece of "permanent" land.

The vegetation cover on Matuketuke differed on the seaward third from the lagoonward two-thirds. On the former no understory vegetation existed on the very coarse rubble ground underneath which, intermixed with some humus, formed the soil of the entire surface of the islet. The coconut trees on this third were under 50 feet high but seemed to be healthy looking. On the rest of the islet a denser stand of coconuts 50-75 feet high had a relatively sparse understory of Morinda, Pandanus, and Premna, with a further understory of Morinda sprouts. Land crabs are few on this as on most smaller islets. A number of new Pandanus slips had been planted by burying a branch with its leaf clump exposed above ground.

15. Ramotu - 3.5 acres (Figure 19)

Has two houses comprising a sleeping house and a shed for keeping coconut husk fuel dry. It is an elongated islet oriented east and west, with a sandy and pebbly lagoonside beach. The seaward and channel sides are bordered by eroded bedrock, 10 to 30 feet wide next to the channels, but widening seaward to 76 feet from the south channel. Off the seaward tip this rock extends for 88 feet seaward in a 200 feet wide strip somewhat wider than the tip of the islet. The beach on the south channel side is of sand and rubble which changes seaward to rubble that follows around along most of the north channel. A wall of coral blocks constructed for a distance of 25 feet from the northern lagoonward corner of the islet protrudes into the channel and has trapped a growing amount of sand on the channel side. The lagoon beach here appears to be growing rapidly with the accumulation of sand.

Coconut trees are dominant throughout the islet, but are low, ranging only from 50-75 feet tall and providing only 50-75% canopy. However, their appearance was good. The rubble intermixed with humus supports an understory in which Morinda dominates followed by Guettarda and Premna over most of the islet. The 100 feet section from the seaward beach, however, has Pandanus dominant, followed by Guettarda and Morinda. The undergrowth was relatively dense.

16. Sakenge - 2.3 acres (Figure 19)

An uninhabited islet of almost rectangular shape 580 feet long by 160-190 feet wide. 110 feet of the lagoonward end is composed of almost pure sand and the beach here also is sand. A line of old Scaevola marking the inner edge of this sand patch indicates an older lagoon shore and points to a rapid advance of the shoreline of about 100 feet lagoonward since these trees were young. From the terminal points of this line of Scaevola on both channel sides the shore is fringed by consolidated bedrock standing above the reef flat. This is only about 10-15 feet wide along the south channel but up to 66 feet wide along the north channel. Seaward from the eastern tip this extends about 80 feet over a width of 200 feet. There was no noticeable dip to this bedrock.

The dominant coconut trees were relatively low, from 25-50 feet on the sand near the lagoon but growing over 50 feet high on the rest of the islet. Two of the taller trees were measured to be 53 and 55 feet respectively. Except on the 110 feet section of pure sand near the lagoon the rest of the soil was rubble and sand intermixed with humus. A pit dug into the soil here showed an 11-inch layer of rich dry brown organic matter grading into grey color. Except for the size there seemed to be no significant difference in the appearance of the coconut trees on the pure sand and on the sand with humus. No yellowing of leaves was apparent. *Guettarda* formed a dense understory, with some *Morinda*.

17. Matawhei - 0.7 acres (Figure 20)

Uninhabited. Fringed by eroded bedrock on all sides, with the western lagoon beach covered with rubble. The dip of the bedrock on the south beach is northward and inward 3-5° toward the islet, but on the north channel beach no dip in the bedrock was noticeable.

A rubble rampart rises just inshore all around the islet. The elevation of the lagoonward two-thirds of the islet is only one to two feet above high tide level. The ground is composed of rubble intermixed with humus. Coconut trees throughout are only from 25-50 feet high and are unhealthy in appearance, with yellowish green leaves. 50-75% canopy is provided by the coconut trees. A few *Guettarda* and *Pandanus* trees form the understory vegetation.

18. Hukuhenua - 5.0 acres (Figure 20)

Inhabited by two household groups and having six structures, three grouped at the north end of the lagoon shore and the other three at the south end. The canoe house at the south end belongs to Tomoki. A sand beach fronts the lagoon. The lagoonward 100-200 feet of both channel beaches are of rubble. Seaward of these rubble beaches cover eroded beach rock. On the south shore the dip of the beach rock is northward toward the interior of the islet, indicating the probable former existence of an islet or the old position of Hukuhenua immediately to the south of its present south shore. This is supported by the southward dip of the strip of beach rock in the middle of the channel between Hukuhenua and Hepepa 35 feet wide and paralleling the channel for 385 feet. That is, this beach rock and the beach rock exposed on the present south shore of Hukuhenua probably were the old channel beaches of a former islet during a period of standstill in the ocean level. Furthermore, the dip of the beach rock on the north shore of Hukuhenua is inward toward the south, possibly representing the south shore and beach of still another ancient islet whose north channel beach may have been the present south channel beach of Matawhei Islet 140 feet away where the dip was found to be 3-5° northward and toward the interior of Matawhei. From these and other similar situations noted, it is deduced that the shapes, sizes and distributions of vegetated islets along the Kapingamarangi reef once were greatly different. The islets, thus, may not be regarded as relatively static units of the landscape, but as constantly evolving elements which have undergone and are undergoing relatively rapid changes under the dynamic forces of erosion, accumulation, deposition and cementation.

On most of the surface of the Hukuhenua a dark, rich, moist, organic soil was observed. Only the central southeast sector from the edge of the breadfruit zone to the seaward shore was the soil a rubble intermixed with humus. A puraka pit occupies the central lagoonward part of the islet with an arc-like zone of breadfruit trees among the coconut trees around its seaward sides. Most of the coconut trees were from 75-100 feet tall, although smaller trees prevailed on the eastern seaward end. Pandanus everywhere was the dominant understory, occurring as planted trees especially dense in the vicinity of the dwellings. Hibiscus were numerous and comparatively large especially in the southeastern two-thirds of the islet. On the northeastern third Morinda followed Pandanus in the understory vegetation. Scaevola was most prevalent along the southeast shore.

19. Hepepa - 2.3 acres (Figure 20)

Uninhabited. Elongated in an east-west direction. It is 180 feet wide by about 600 feet long. A narrow rubble beach overlying bedrock runs along the seaward shores. Wider and deeper rubble accumulations line the channel beaches. A sand beach fronts the lagoon and also a short section of the north channel shore adjacent to the lagoon. Severe erosion of the shoreline has occurred especially on the south channel side. On the seaward part of this shore 10 to 20 feet of bedrock parallels the shore, widening at the eastern tip to 143 feet and extending seaward for 132 feet. In the north channel there also is a patch of old beach rock 385 feet long and 35 feet wide. The soil throughout is rubble intermixed with humus, except near the lagoon where sand and rubble with little organic composition indicate recent formation of the land. A soil pit dug in the seaward third of the islet near the center showed more than 15 inches of highly organic soil with dark brown colored soil down to 17 inches.

Coconut trees generally appeared healthy, but rise only from 50-75 feet high, providing a 50-75% canopy. Understory on the seaward third is formed by young coconut trees followed by Morinda and some Pandanus. Along the 50 feet strip next to the lagoon Guettarda followed by Scaevola forms the understory. In the rest of the islet Guettarda followed by Morinda and some Pandanus forms the understory.

An old Guettarda with a trunk 23 inches in diameter growing some 38 feet from the lagoon high tide line indicates the position of an old shore line generally parallel to the present lagoon shore. Coconut trees near the lagoon were only from 25-50 feet high. The taller trees on the seaward end measured from 65 to 85 feet.

20. Tipae - 1.6 acres (Figure 21)

Uninhabited. Like Pepeio, a man-made islet in its present state, but probably built upon the bedrock foundations of an older islet. This is indicated by the fact that bedrock standing a foot or two above the reef flat extends eastward and seaward the width of the islet for almost 200 feet. An elongated islet, it is about 150 feet wide by 500 feet long. Just to the seaward side of the center of the islet lies a patch of loose coral blocks which may have been part of the original mound or wall constructed for trapping sand and enlarging the land. A 2.5 feet diameter stump of an old Guettarda, a tree generally found in the open sunlight of shore fringes, still sends sprouts from the roots growing from this pile of rocks. This circle of rocks also was the site of the ariki's house at one time, according to Chief Tuiai. A rubble rampart rises two or three feet above high tide 50 feet from the seaward tip of the islet. While some undercutting has occurred here, there also appears to have been some accretion of rubble and sand. This and the inland situation of the rubble rampart would seem to point to land building seaward during the recent period. An accretionary stage of the shore channelward also appeared to have been occurring on the north channel beach. Moreover, beach-building appears to have been occurring also on the southwest end of the islet. There are three separate beach ramparts roughly paralleling each other here, the innermost one being up to 100 feet from the present shoreline. Further supporting this probability is the fact that large, old Guettarda stumps and a cluster of old decayed coconut root stumps line this rampart. Since Guettarda likes sunlight and is generally found associated with beach fronts, the old stumps must once have been at the shoreline. The sandy ground here also supports the land-building supposition.

The coconut trees here are only from 50-75 feet high and form a 50-75% canopy, but they appear to be healthy and flourishing trees. Except near the lagoon shore where sandy soil appears, the soil mostly is gravelly rubble with humus intermixed. Guettarda and Morinda form a 50-75% cover of understory plants.

21. Tetau - 7.8 acres (Figure 21)

A north-south elongated islet with a small working house at the northern lagoon tip. The lagoon beach here is of sand, including the northern tip which is building up at a rapid rate. Bedrock exposures elevated above the reef flat extends off the northern seaward part of the islet for 20-50 feet while a much wider area of bedrock extends 130 feet from the south channel shore the width of the islet. Severe erosion occurs at the two channel sections of the shore, the debris from the south channel shore accumulating and building up the beach lagoonward at the southwest tip. The north beach rock dips lagoonward at an inclination of 7-8 degrees and shows the probability that the lagoon beach once was located here seaward of the present seaward shore. Two layers of rock show up in the dipping strata. The compact and fine grained lower layer is overlain by a cemented conglomerate of coral rubble in which the original shapes of the many coral fragments have been preserved.

The soil is gravel-sized rubble intermixed with humus throughout most of the islet, although on the seaward side a patch of bedrock 20 feet in from the shoreline occurs. Four small puraka pits, the largest about 60 by 80 feet, have been dug in the center part in a north-south alignment. These pits generally are nearer the lagoon shores than the seaward shores, owing to the fact that the coarser ground of the seaward area is less impervious to salt water penetration than the lagoonward sands. Earthworms were numerous under the rotting coconut husk piles. Land crabs also were numerous, performing a valuable function in loosening and aerating the soil by the holes they bored in the ground.

A breadfruit-coconut zone occupies the area around the puraka pits, coming within 60 feet of the lagoon shore but not closer than 90-120 feet from the seaward shore. The breadfruit trees have trunks from 24-48 inches in diameter. The coconut trees inside this zone are from 75-100 feet high but do not appear as green and vigorous as the coconut trees in the coconut dominant zone nearer the shore. Pandanus is found on both seaward and lagoonward sides of the central puraka field. Morinda is most prevalent as an understory in the northern sectors of the islet but follows Pandanus on the eastern side and follows Guettarda in the southern sector. Hibiscus trees are numerous lagoonward of and adjacent to the puraka pits. Premna occurs in most parts in a scattered fashion. A ground cover in the form of grass appears on some of the elevated mounds west of the puraka pits.

22. Nikuhatu - 2.3 acres (Figure 22)

An uninhabited islet connected by a causeway to Takairongo to its south. The causeway was damaged by storm waves in its central portion and had not been repaired in the summer of 1954. A narrow islet only 170 feet wide, it extends east and west for 580 feet. Seaward from the east end a patch of bedrock the width of the islet extends for 154 feet, indicating a retreat of the shoreline lagoonward here. The causeway across the 200 feet wide channel to Takairongo has slowed the tidal currents through the channel and caused the deposition of sand in the channel. Gravel sized coral rubble intermixed with humus forms the soil of the entire surface with the exception of the seaward end where a strip up to 30 feet inshore is of cobble-and-boulder sized rubble.

Low coconut trees are found throughout. On the lagoon third the trees are from 25-50 feet high and on the rest of the islet from 50-75 feet. The canopy cover is from 50-75% and the leaves appear yellow green and less healthy than on most of the larger islets.

Near the lagoon end all underbrush has been cleared, but on the rest of the islet Guettarda is the dominant understory followed by Morinda. Few land crab burrows were noticed here.

23. Takaironga - 3.9 acres (Figure 22)

Uninhabited but has a small workhouse near the causeway that runs to adjoining Nikuhatu. Sand was accumulating near base of the causeway and was building out into the lagoon at both ends of the lagoon shore. The central portions of the lagoon shore, however, showed evidence of recent severe erosion. On the seaward side and the north channel side, eroded old bedrock extended 50 to 60 feet from shore. On the south channel side the bedrock only reached as far as the narrow part of the channel from the seaward side. A rubbly beach continued to the sandy lagoon corner of the islet. The southeast seaward shore was composed of unconsolidated rubble of cobbly size, while a rubbly beach covered the bedrock near shore on the north channel side. A small sand beach was developed for about 50 feet off the seaward point, while the lagoon beach was of intermixed sand and gravels.

A test pit dug in the center of the islet showed 8 inches of humus rubble and sand. The soil throughout was of rubble intermixed with humus. In the central part a small puraka pit 5 by 6 feet had been excavated. Coconut trees were from 50-75 feet high but formed a dense canopy and appeared to be healthy. Two breadfruit trees, the trunk of one nine inches in diameter, grew adjacent to the puraka pit which is situated 100 feet from the north channel shore. Guettarda, Morinda and Premna in respective order of importance formed the understory vegetation. A young undergrowth of Morinda was springing up underneath.

24. Tangawaka - 7.0 acres (Figure 22)

Has canoe house on north part of lagoon beach and a sleeping or work house on the southern part adjacent to a broken causeway connecting with Hare Islet 80 feet across the channel. Both lagoon ends have sand spits building out into lagoon, but the sandy shore between has been undercut by erosion recently. It appeared as though normal tidal waves and currents deposited beach sediment here, but that severe storms resulted in erosion and shore destruction. Several old coconut trees as a result of undercutting are leaning out as far as 40 feet from the base of the trunks. As a result of the causeway to Hare, sand and rubble have been accumulating and filling in the channel which is two to three feet deep in the narrow central parts even at low tide.

The accumulation is aided by a strip of old bedrock extending from within 150 feet of the Tangawaka end of the causeway in a direction about 10 degrees south of east. This tongue of reef and bedrock is 550 feet long by about 50 feet wide. The shore of Tangawaka opposite this rock has a sand and rubble beach that changes into a rubble beach and then to bare rock along the seaward parts. A rubble beach also is found along the north channel shore.

A gravel sized rubble mixed with humus is the prevalent soil throughout the islet except in the puraka pits and in the central parts east of the large puraka pit. In the latter area a fine rich moist humus soil is found. The puraka pit is situated within 100 feet of the southeast seaward shore and is surrounded by a zone of intermixed breadfruit and coconut trees.

Guettarda is the dominant understory followed by Premna in the southern half of the islet where the two-three feet tall arrowroot plants also were abundant. Adjacent to the canoe house and within the breadfruit zone Pandanus has been thickly planted as the dominant understory followed by Premna, Morinda and some Guettarda. Morinda and Premna are dominant understories on the northern half of the islet followed by a scattering of Pandanus, Guettarda and, on the seaward side in the breadfruit zone, some grass. Some Pandanus also is found in the vicinity of the small house near the causeway. Breadfruit trees ranged up to 24-48 inch diameter trunks. In the central parts and adjacent to the breadfruit zones the coconut trees ranged from 75-100 feet tall and were healthy in appearance. On the east shore sectors and on the southern sandy tip the coconut trees were only 25-50 feet high. In the rest of the islet the coconut trees were from 50-75 feet tall.

25. Hare (pronounced as two syllables) - 79.5 acres (Figure 23)

Inhabited islet and the largest on the atoll, although not the widest. Its relatively great length, 1.29 miles compared with about 1,700 feet for Werua, the next longest islet, is not complemented by great width, since at the maximum Hare is only about 570 feet wide compared with about 1,150 feet for Werua. Most of its 29 sleeping houses, canoe houses and sheds are situated on the southern half of the islet, 14 structures being within 1,100 feet of the southern tip and the causeway connecting it with Herekoro Islet. Some pigs and chickens are raised in the area, the pigs mostly being kept tethered by ropes tied to a leg of the beast. Chickens run wild but are identified as to ownership by having various toes cut off at different joints.

Present Hare is the result of the joining of at least three islets into one through the filling in of two inter-islet channels near the south end. Time was not sufficient to permit sufficient soil examination to determine whether additional channels had been filled in in the formation of the northern and central sectors of the long islet. If this had been the case, this would have occurred a long time ago, since the oldest inhabitants on the atoll had no knowledge of such having occurred. On the other hand, the two former channels now filled in are of recent occurrence, the southernmost probably only since the last two decades, and the other at around 1858 when a storm is said to have piled up rubble closing the narrow lagoonward end of the channel between the then Hare Islet and former Ruawa Islet. The southernmost end of present Hare then was the islet of Herengaua, and these two sections of present Hare continue to be known by the names of the former islets.

The entire length of the lagoon beach and shore of Hare is sandy, although short sections near the houses on the south end have some coral gravels intermixed with the sand. The seaward beaches across the former channel openings on either side of former Ruawa are sandy but most of the seaward beaches are of gravelly rubble, mixed at places with sand. Occasional short stretches of the central and northern seaward beaches also may be of sand. The southern channel between Hare and Herekoro had filled in considerably with sand near the causeway built expressly for this purpose. Underlying the seaward beaches at the northern end is bedrock standing one to three feet above the reef flat and extending 25-30 feet from shore. The northern channel between Hare and Tangawaka has a rubbly beach except near the lagoon where the causeway has trapped quantities of sand. This channel is one of the deepest of the inter-islet channels, about three feet at low tide. When the tide is coming into the lagoon the current running through this channel resembles that of a rapid mountain brook.

Except adjacent to the lagoon or seaward shores, in the old causeway areas and on the ridges around the puraka pits, there is a rich moist organic soil many inches in depth. Hare, as well as the other larger islets, has high quality soils over much of its area and supports some of the most luxuriant vegetation. On the bordering ridges of the puraka pits the soils are rather coarse, being derived from the rock and rubble dug out of the pits. Breadfruit trees appear to thrive on such locations, however, perhaps because the porous coral debris has a great capacity for holding water while at the same time the elevation permits good drainage. In the filled in channels, the soil is sandy. The Herengaua-Ruawa channel site especially has almost pure sand, with little humus accumulation owing to the recency of formation of its land surface. In these sandy areas, breadfruit trees do not appear, while coconut trees generally are smaller and less healthy. One tree on the southern part of the seaward side of the old Ruawa-Hare channel was found to have lemon yellow leaves, while others near it had leaves less than a healthy dark green. Along the seaward shores rises a continuous rubble rampart except on the sandy former channel sections which runs the length of the former islet. A rubble intermixed with humus also is the soil in the northern 1000 feet or so of the seaward half of the islet.

Because of the largeness of Hare and the numerous people who own sections of land on Hare, the vegetation types here especially form no significant patterns. Different land owners treat their land differently. Some assiduously keep down undergrowth and even attempt to pull out grasses growing under the coconut trees. Others in an adjacent plot may let the understory grow rank and dense, so that one may have to push one's way through to cross the breadth of the islet. Generalizations are not entirely valid for such large expanses, but one may say that on the whole in the northern half of the islet Morinda and Premna have been permitted to be the dominant understory, while in the southern half Morinda is more prominent. On the seaward shores Guettarda appears sometimes thickly, at other times in a scattered fashion along the entire length of the islet. Pandanus is most apt to be found on the fringes, especially the lagoonward fringes of puraka fields where they are more conveniently reached for carrying to the houses along the lagoon shore or for taking to canoes for transport across the lagoon. In the lagoonshore fringe, creeping vines one of which is of the morning glory variety, and grasses often become a heavy ground cover. The morning glory is pulled up and fed to the pigs, or pigs may be tethered to browse on it. The most common vine here is the legume Vigna marina. Grass was very prevalent in fringe parts of the sandy old channel sites. On the seaward half of the northern 2000 feet of the islet Pandanus is the dominant understory.

Hare has the largest area in which breadfruit trees grow, some 34 acres, almost half the entire area of the islet. Some are among the largest on the atoll, i.e., over 4 feet in diameter waist high from the ground and above the buttress roots. Some 655 breadfruit trees with trunk diameters of over four inches are estimated to grow in the coconut tree-breadfruit tree zone occupying the middle parts of the islet except at the former channel areas. Coconut trees in general are tall (in the 75-100 feet and over category) and are healthy in appearance in most of the islet. Lower stands of coconut trees are found in the former channel areas now filled in. In the former Herengaua channel area the coconut trees are only from 25-50 feet tall and most of these represent young trees planted since World War II. In the former Ruawa-Hare channel, the coconut trees are from 50-75 feet in the central and lagoonward parts but taller on the seaward northern half of the old channel. Along the lagoon shore, younger trees growing on the sandy shore also are lower than the trees in the center and seaward sides. Finally in the central section of the islet, severe bombing by American planes during World War II resulted in the destruction of numerous coconut and breadfruit trees, so that most of these types of trees in this section are younger and lower trees. This shows up clearly in silhouette pictures of the skyline of the islet from the lagoon. Northward of here is an underground concrete lined munitions or gasoline storage pit used by the Japanese during World War II. In 1954 the pit was half full of fuel oil taken from the post war Japanese fishing boat stranded on the reef which later was refloated and re-named the "Lucky" by the Kapinga people. Nearer the northern tip are two concrete cisterns above-ground formerly utilized by the Japanese but now damaged and abandoned. A large bomb crater near the lagoon shore has created a water-filled pit here in which some mosquito larvae were breeding. Partial filling in of this crater might bring it into use as a puraka pit, although perhaps it is too close to the lagoon shore. Puraka pits are strung out in the center along most of the length of the islet, but are not found on the recently added section comprising the former southern islet of Herengaua, which originally was too small apparently to support an adequate water lens.

Relics of World War II remain on the lagoon beach near the northern end in the form of three wrecked Japanese seaplanes and several engines, all badly corroded. Since these planes stand partly buried by sand, it is obvious that the beach here is building up rather than eroding, although the southern part of Hare's lagoon beach along the length of former Ruawa shows evidences of severe erosion of the shoreline. Ten stumps and logs of overturned coconut trees lie next to the shore here, while one coconut tree still grows on a two feet wide neck of land projecting 10 feet lagoonward of the rest of the shoreline. On the other hand between 45 and 80 feet of now vegetated sandy land has been added lagoonward from the old shoreline of former Herengaua since the now almost buried causeway with former Ruawa was constructed. The new causeway to Herekoro is further extending this land building.

26. Herekoro - 3.8 acres (Figure 24)

Has a small working house on the northeastern lagoon side tip connected by a causeway built in 1953 connecting with the southern end of Hare (former Herengaua). The house belongs to the Protestant pastor Leon, and the causeway was built by him to trap sand and debris to fill up the channel and create new land. The causeway was about six feet high and five feet wide, made by piling up loose coral blocks. Some of these were recently live coral, so that the blocks must have been hauled from the lagoon by canoe. During January of 1954 high waves from rough weather destroyed the central part of the causeway which was reconstructed in the summer of 1954. A small puraka pit 60 by 50 feet was located on the lagoon-side of the center of the islet. One breadfruit tree with a 14" diameter trunk was standing on the east corner of this pit.

On the seaward side bedrock outcrops a foot or two above the reef flat extend up to 25 feet from the shoreline, while along the north channel it extends lagoonward in a ten feet wide strip. On the south channel shore 6" diameter boulders grade into smaller rubble and gravel toward the lagoon. Both north and south corners of the lagoon side of the islet are formed of sand in process of building up. The central part of the lagoon shore shows an equilibrium position between erosive and building forces.

The lagoonward third of the islet has sandy soil with some humus. The north channel side up to 100 feet inland from the shoreline has a moist fine soil with high humus content. The rest of the islet has a soil of rubble with humus content.

Coconut trees with 75-100% canopy coverage occupy most of the islet. A patch 100 feet in diameter adjacent to and seaward of the puraka pit showed less than 25% canopy, and an old stump of a large breadfruit tree stands here. In the north channel sector of the islet young coconut trees prevailed, badly spray damaged and from 50-75 feet high. The coconut trees in the rest of the islet were mostly from 75-100 feet high.

In the lagoonside of the islet between the puraka pit and the shore, Premna formed the dominant understory as it also did in the center patch around the old breadfruit tree stump. In the rest of the islet, Morinda was the dominant understory. Pandanus was found scattered from the center of the islet northward to the channel. A moderate scattering of arrowroot was found within 100 feet of the seaward shoreline. Here as on most of the islets Guettarda and Scaevola formed an outward fringe and understory to coconut along the shore. A small lone Calophyllum stood on the lagoon shore. A few Hibiscus and some low grasses also were found.

27. Tirakau - 1.8 acres (Figure 24)

Uninhabited N-S elongated islet. Sandy beach along lagoon shore. Bedrock exposure for 10-15 feet wide strip off north channel shore, extending along seaward half of channel. No notation for south channel shore features.

Healthy stand of coconut trees averaging 75-100% canopy, 75-100 feet tall in central part of islet, 25-50 feet on seaward end, and 50-75 feet on lagoon end.

Premna understory predominates except on lagoon third where Pandanus leads. In central part Pandanus follows Premna, but on the seaward end dense Guettarda follows. Young Morinda forms a lower understory with 25-50% leaf coverage of all except seaward third where Clerodendrum thrives on rough rubble and bedrock.

Rubble with humus forms the soil cover, although on the seaward third bedrock exposures occur with the rubble.

28. Tariha - 2.2 acres (Figure 25)

Uninhabited. Sandy beach on all sides except for the southwest channel beach and on eastern seaward corner where jagged bedrock is exposed. The two corners of the lagoon beach are building sandspits lagoonward. Coconut trees were 50-75 feet high and appeared in relatively good condition. The understory particularly on the seaward fringe was a Scaevola-Guettarda combination. Some Premna and Pandanus as well as Scaevola formed an understory to the coconut trees.

29. Tiahu - 0.6 acres (Figure 25)

Uninhabited. 20 feet wide beachrock fringes all except lagoon side where a sand beach is advancing in two prongs lagoonward. On the southwest side some sand and rubble have accumulated over the beachrock. The coconut trees from 50-75 feet high forms a 50-75% canopy. The fronds are yellow-green and salt damaged. The soil is gravelly rubble intermixed with humus. Guettarda forms the fringe vegetation, although there is some Scaevola on the lagoon beach fringe.

30. Tokongo - 1.8 acres (Figure 26)

Uninhabited. Seaward southeast shore is of jaggedly eroded bedrock. This changes to a rubble beach on the northern corner. Here the exposure to the easterly waves and currents has resulted in the rounding off of this corner of the islet and the building up of a sand beach and spit lagoonward on the western corner.

A single breadfruit of small size was found about 90 feet from the seaward shore. The coconut trees were from 50-75 feet tall, providing a 25-50% canopy which on the seaward side showed the damaging effects of salt spray, but otherwise appeared healthy. Bedrock overlain with humus formed the surface of the ground in the central part of the islet. Sand and rubble intermixed with humus covered the rest. Digging with a stick showed a 7 inch top soil of rich brown color above a grey layer. In the lagoonward parts the layer with rich humus was 18 inches thick. Morinda was the dominant understory, followed by Premna in a dense stand. A few Pandanus also were found.

31. Tirakaume - 1.3 acres (Figure 26)

Uninhabited by people and with no dwellings. Like Pumatahati, it was also once a sacred islet which has become community property, and is also similarly inhabited by nesting birds.

The seaward half is fringed by clastic limestone or bedrock extending from the rocky shore for 20-50 feet. This appears to be old beach rock and is eroded in a jagged fashion. Moreover, the seaward third of the islet has a surface of broken beach rock, some of which is upturned and in chunks from 3-5 feet in diameter. The eastern channel shore is especially severely eroded and undercut with a beach of sand and rubble. A large Guettarda tree here has had its sprawling roots washed free and overturned by the waves. Rubble and sand form the beach on the west channel side and on the lagoon side. The soil is coarse rubble with some humus content. A tongue of sand was building up and extending lagoonward in a westerly direction from the west corner of the islet.

Somewhat yellowish-green leaved coconut trees covered the seaward third, growing from the porous rock and providing a 50-75% canopy. These trees mostly were from 25-50 feet high. On the other two-thirds of the islet the trees were from 50-75 feet high and more flourishing.

The understory in the rocky seaward part was a combination of young coconut, Pandanus, Morinda and on the south side a dense thicket of Clerodendrum. On the rest of the islet Guettarda formed the only significant understory.

32. Pumatahati - 6.3 acres (Figure 27)

Uninhabited, but having a community house in state of neglect on the western lagoon end of islet. The islet formerly was a sacred islet used for cult purposes. Since the people have been Christianized, the islet has become community property.

The beach area exhibits the effects of exposure both to the easterly and southerly storms. The southeastern shores show severe erosion undercutting the fringe vegetation. A rampart of very coarse coral blocks has been built up inland 35-50 feet. Some of the blocks are up to one foot in diameter, indicating the force of the storm waves from the southeast. A 25 feet wide strip of eroded old bedrock extends along the southern seaward side of the islet. On the eastern channel side the beach is mixed sand and rubble. The west channel beach is quite bouldery and the shore is strongly undercut. An unusually high beach rampart of coarse cobbles also extends along the lagoon shore, 15-20 feet inland. This lagoon shore is exposed to storm waves from easterly storms in contrast to those of most of the other islets. On the southwestward seaward side severe undercutting of the shore has washed the soil and rubble from the base of old coconut trees, leaving the stumps exposed. On this side the ground is clear under the coconut trees in contrast to the heavy fringe of Guettarda and Cordia subcordata that forms a wide zone on the northeast seaward and channel sides. Cordia also forms a dense cover along the eastern two thirds of the lagoon shore. On Kapingamarangi, Cordia appears to be largely restricted to these shore sections of Pumatahati Islet. A 100 feet section of the western channel shore facing Matukerekere has a Scaevola border adjacent to the community house.

Contrasting ground and soil conditions occur on the islet. In a 100 by 200 feet patch at the center, the soil is a rich black-brown humus with no rubble intermixture. A 50 feet diameter patch of bedrock is exposed between this and the east channel shore. The rest of the islet has a soil that is of coarse rubble with particles up to one inch in diameter intermixed with some humus. This islet and the adjoining islet of Tirakaume have large bird populations because both formerly were rarely visited by people owing to the sacred character of the islets. The birds therefore roosted or nested here in large numbers in the trees and the soil has a high guano content in contrast to the general lack of bird deposits in the other islets. These two islets generally can be identified by the swarms of birds soaring above them. On the ground under rotting piles of coconut husks were numerous land crabs, while scavengering hermit crabs swarmed the beach fringes.

The general impression left by the vegetation is that of neglect as contrasted with the privately owned land on other islets. Large numbers of young coconut trees in the understory show that nuts have been left to sprout pretty much as they fell. A much denser undercover of other vegetation also appears here among which Premna, Pisonia sprouts and occasional Pandanus were the most prevalent. Upon the occasion of one visit the writer picked up half a dozen exceptionally large nuts from the southern seaward side of the islets, which however were found to be very light in weight, containing little juice and meat. The cause for this condition was not ascertained. This may be related to the high guano content of the soil beneath the trees. Nuts examined on the uninhabited island of Gaferut where two coconut trees grew in soil with excessive guano content showed similar characteristics.

The neglect in clearing the understory vegetation and in keeping down excessive competition among coconut trees may be attributed to the fact that no one owns this land privately. At intervals, which probably are far between in time, the village council decides on a community work expedition to Pumatahati and Tirakaume to clear underbrush, reap coconuts, cut logs and rods for house construction or gather coconut leaf fronds for thatching roofs of community buildings such as the school, church, dispensary, and the like.

The community house on Pumatahati is merely a shelter for work parties or for fishermen who may wish to spend the night. During the summer of 1954 the thatched roof was dilapidated and no longer provided effective protection from rains.

33. Matukerekere - 1400 sq. ft. (Figure 27)

Uninhabited sand patch which formerly was much larger. It now has only 0.03 acres of land above high tide, but once this amounted to about 0.7 acres and this was covered with coconut trees. After a storm washed the islet away (apparently in 1858) no coconut trees were planted here until 1919 when ten coconut trees were established. In 1948 (1947?) another big storm from the southeast scoured out nine of these trees, leaving the lone adult palm seen in 1954. The only other significant vegetation were four young trees planted in February of this year which had grown to about five feet high by summer. Their leaves were yellowish and showed the effect of salt spray as well as of lack of fresh water around the roots.

That the extent of Matukerekere once was much greater was evident from the eroded beach rock extending far beyond the present high tide line of the sand patch. A measurement of the dip of the rock showed an 8-15° downward dip toward due magnetic north. This obviously is a relic lagoon beach the present position of which south of the islet indicates the northward, lagoonward migration of the islet. Pumatahati 1455 feet to the east provides Matukerekere some protection from eastern storm waves, so that the most important destructive agents in pushing the islet northward and lagoonward are the storms from the south.

LAND, HOUSING, FOOD AND LIVELIHOOD

Emory has made an extensive study of the problems of land ownership, canoe and house ownership, food sources and fishing activities, as well as the social customs of the Kapingamarangi people. A summary of some aspects of these problems and activities as described by Emory and confirmed by the writer will be given at this point together with some observations made by the writer during 1954. For detail and amplification, Emory's report should be consulted. For material objects and aspects of Kapingamarangi life, Peter Buck's work on the Material Culture of Kapingamarangi is a full study of great value.

Land.

All land on the atoll is privately owned except the following: Matukerekere, reserved for fishermen's use; the former sacred islets of Pumatahati and Turuaimu, which now are community property; the area formerly occupied by the cult house on Touhou which now is occupied by the Protestant church and the school; the men's house on Touhou and that on Werua; and, finally, one or two wooden-frame houses formerly occupied by resident Japanese administrative officers on Touhou now considered public property by the District Administrative office. Land is divided among heirs or given to friends, but leasing or selling of land or houses is not practiced. According to Emory, there are no disproportionately large land holdings, while everyone has a place in which to live and from which to draw their sustenance. Women have the same kind of rights as men in land ownership.

Housing.

Kapingamarangi has preserved its traditional type of house with a thatched roof made of woven panels of coconut leaf fronds tied down to the roof rafters with coconut husk fiber cords. The frame underneath the roof is constructed of various types of wood. Corner posts are generally of *Guettarda* trunks, with cross beams of coconut or *Pandanus* logs. Permanent walls are found on most of the sleeping houses, with vertical rods set a few inches apart and tied to cross pieces, the lower ends of the rods being set into holes in *Pandanus* logs. *Pandanus* mats then are added for privacy and protection from wind and rain. The aspect from the outside is charming and superior both from the aesthetic and the comfort point of view to the corrugated tin-roofed shacks that have appeared on other islets in the East Carolines and on Ponape. It is far cooler under the thatched roofs than under tin or wood in the hot sunshine of midday. Only a half dozen houses on Kapingamarangi have the rusty tin roofs, including the wooden board house in which the expedition made its headquarters, and the shed in front of it. Canoe houses are the largest structures in size and may be as large as 20 feet by 60 feet in ground dimensions. Residences are smaller.

Food and livelihood.

Since puraka will only grow in the centers of islets that have a significant fresh water lens and since islets large enough for this are few, not all land owners own puraka land. Some also may not own or have rights to breadfruit trees. Because of the scarcity of land for producing such foods, puraka fields often are divided up into very small parcels by rows of stone slabs set on end or by footpaths.

As population has become more dense and land fracturing has increased, land disputes also have become more prevalent. Formerly disputes would be settled by fighting, but now they are settled through public hearings under the chief. If a solution cannot be reached, the District Administration holds hearing and decides the matter.

On the residential islets of Touhou and Werua, lagoon frontage is important since canoes must be housed at the lagoon edge. Canoes must be sheltered for preservation, and it would be inconvenient to carry the heavy dugouts more than a few yards each time use of them was required. Many canoe owners without the necessary land frontage on the lagoon may have canoe houses on the land of relatives or friends.

Breadfruit trees serve the double function of supplying food in the form of fruit and of supplying trunks for dugout canoes. The Germans counted only 47 canoes in 1910. In 1950 Emory counted 122 in use and 122 canoe hulls stored away in canoe houses which appeared no longer serviceable. According to Emory, it takes 20 years for a tree to reach full bearing stage. Trees used for canoes are generally old trees past their prime for bearing fruit, and such trees are from 70-80 years old. There are several varieties of breadfruit trees growing on Kapingamarangi (see William Niering's report on vegetation). Emory stated that the "native" Kapinga variety bears for about two months, then rests three or four months before bearing again. In 1950 one bearing period for the native variety was finished by September 15. The fruit of a second variety introduced from Nukuoro was expected to begin ripening by the middle of November. When breadfruit ripen in larger quantities than are desired for current eating, they are cooked, dried and rolled into rolls which are then covered by Pandanus or coconut leaves and bound with cord. In this state they may be preserved for several years. Breadfruit seeds also are eaten after being cooked.

Coconuts furnish several varieties of food, depending upon the stage of ripeness of the nut. When about full-sized but still green, the crisp but soft husk under the tough outer skin next to the stem may be eaten raw. At this time and before the inside meat hardens, the juice has a delicately sweet flavor and forms an excellent substitute for water. A practiced person with a sharp machette can hold the nut in one hand and chop off several chips of the husk at the stem end without cutting the hand, thus exposing the soft shell for drinking. When a number of green nuts are to be used for drinking, however, the Kapinga men will sharpen a stake, push one end into the ground or prop it against a support and then husk the coconut on the other end. After this, it is a simple matter to cut a hole in the stem end of the coconut for drinking. When drained, the green coconut may be split or broken open. A wedge-shaped slice of the husk cut off to be used as a spoon is fashioned to scoop out the jelly-like flesh which at this stage has an entirely different consistency and flavor from the mature nut. The latter contains juice that generally is not drunk because of the poor flavor. At the mature stage the meat is cut out in chunks and eaten or the meat may be grated on a shell or aluminum grater attached to a stool with a neck. The grated coconut is used in various concoctions in cooking. From it also is made coconut cream for cooking purposes. In making this, skeins of coconut husk cord are mixed in with the grated coconut and some water and then twisted between the hands, thus forcing the oily cream out of the coconut shreds. When the mature coconut is allowed to sprout, the spongy mass filling the nut can be eaten although, according to Earl Stone who studied the problem on Arno, this is not an economic use of copra nuts. On Kapingamarangi as on other atolls coconut palm sap is collected in bottles from the flower stalk, the tip of which is cut before the nuts are formed. Two beer bottles full per day may be collected. The sugary sap is used for feeding babies, for cooking use, and for a fermented alcoholic drink.

Productivity of coconut trees and the situation in Kapingamarangi.

No systematic or reliable figures have been compiled on the productivity of coconut trees on Kapingamarangi, but some inferences may be obtained by a study of figures from elsewhere. The nut yield per tree varies widely in different parts of the coconut-producing realm and in accordance with soil properties. In Brazilian plantations production numbered from 15-40 nuts per tree per year.[1] On three plantations in Bahia the averages were 25, 35, and 56 nuts respectively.[2] In Malaya where trees were planted 40 to the acre, the nut yield averaged 50 per tree per year, while in the Philippines the accepted average has been about 30 nuts per tree per year.[3] In Ceylon trees well planted and looked after were said to yield an average of 60 nuts per year, but with manuring and attention under favorable conditions a far higher yield could be obtained. A German source stated that in East Africa the average production was estimated at 75 nuts per year per tree but that palms well cared for would yield 100 nuts per year.[4] Sampson stated that on the Malabar coast of India where the soil was relatively poor "An average of 60 nuts per

1. Bondar, Gregorio, Instrucoes Bara Plentio e cultivo de coquiero, Boletim da Seccao de Fomento Agricula da Bahia, No. 2.
2. Brazil, Ministry of Agriculture, Producao agricola, 1948.
3. Kalaw, Masimo M., The coconut industry, Manila, 1940.
4. Curtis Gardner & Co., Ltd., The cult of the coconut, London.

tree is nothing out of the usual, while an average of 90 nuts per tree is not uncommon. Taking good and bad trees, a large number will produce as many as 128 nuts".[1] Bondar asserted that the "best averages" in Africa and Oceania were from 120-150 nuts per tree per year.[2]

It must be pointed out that most of these figures pertain to plantations where spacing of coconut plantings at least on the better plantations have been systematically and somewhat scientifically worked out. Earlier in this paper it has been noted that the best spacing (on the basis of leaf crown requirements) would allow some 56 trees per acre, and that on some German plantations in the Marshalls the number of trees per acre averaged between 69 and 78. The "best averages" for Oceania probably would be from such better spaced plantations than from the crowded spacing of some 113 per acre of coconut land that is estimated to prevail on Kapingamarangi. However, if it were assumed that the Kapingamarangi average amounted to less than the best, say 100 nuts per tree per year instead of the "120-150" of the "best averages", then the average production of the 22,684 trees of bearing size would be in the neighborhood of 2,268,400 nuts annually or 11,342 nuts per acre of producing land.

How much copra this would make also is uncertain, since the size and weights of nuts varies again with different soil and moisture conditions. A comparison of coconut composition by weight of different components given by Sampson indicates the differences on representative samples of rich and poor soil:[3]

Coconut components by weight in grams

	On rich soil	On poor soil
Husk	520	329
Shell	201	145
Meat	453	298
Water	384	101

From this it is seen that the nut meat grown on the poorer soil is only about 65% the weight of the nut meat grown on the richer soil.

The fresh meat of the coconut contains 45% of water and the greater part of this has to be driven off in the manufacture of copra.[4] Assuming that all except 5% of water is driven off, there is thus a shrinkage of 40% in the coconut meat, and only 60% of the original weight remains in the dried copra. The copra per nut on the rich soil in the table above, therefore, would be 271.8 grams and that on the poor soil 178.8 grams, or 0.6 pounds and 0.39 pounds respectively.

The average production per acre of coconut plantation per year on Nauru on the basis of production figures for two years (1905-1906) amounted to about 2,423 pounds of copra.[5] If the plantings here by the Germans

1. Sampson, H. C., The coconut palm, London, 1923, p. 181-82.
2. Bondar, op. cit.
3. Sampson, op. cit., p. 183.
4. Ibid, p. 223.
5. Germany, Reichstag, op. cit.

were at the same rate as the average on their plantations on Kili and on Likiep, i.e., 73.5 coconut palms per acre, the average yield per tree would be about 33 pounds of copra. If the nuts were large and weighty, as in the case of Sampson's nuts from the rich soil, the palms here must have yielded only about 55 nuts per tree per year. On the other hand, if the nuts were lighter and poorer as in the case of Sampson's nuts on the poorer soil, then the palms must have yielded as many as 84 nuts per tree per year in order to get the 33 pounds of copra per tree per year. If it be assumed that Kapingamarangi soils are superior to those of Kili and Likiep these figures give some indication that the assumed 100 nuts per tree per year for Kapingamarangi may not be too far out of line.

If the above Nauru copra yield of 2,423 pounds per acre were used as a comparable basis for calculating Kapingamarangi yield, then the 200 acres of coconut producing land would be producing only 242.3 short tons of copra annually. On the other hand, if the calculation were made on the basis of the assumed 33 pounds per tree on Nauru, the higher figure of 113 trees per acre estimated to prevail on Kapingamarangi would mean that the average annual production would be as high as 374.3 short tons, provided the denser crowding of trees were sufficiently compensated for by higher fertility of soil.

/R. L. A. Catala gives a mean consumption per person at Tarawa Atoll of 4 nuts per day and a mean consumption per pig of 3 nuts per day. He also estimates the use of 2 palms for each 5 persons in toddy production. Taking this consumption into account and dividing the weight of copra exported by the average weight of 0.34 lbs. of copra per nut, Catala estimates an annual production per tree of a mean of only 23.1 nuts. This seems a rather low estimate, and Catala states that the figure used for pig consumption is low, that no account has been taken of nuts lost in the brush, destroyed by rats and coconut crabs, fed to chickens, or sold or given to outsiders by the land-owners. Finally, Catala admits that the figures for density of trees and the copra yield may not be representative enough. Moreover, the 1947 census report for the area's population and number of pigs also may suffer from inaccuracies./[1]

On the other hand, if the two figures given by Sampson for the coconut meat per nut for large and small nuts are used in calculating Kapingamarangi's production at the rate of 100 nuts per tree per year, then the total cured copra production would amount to between 443 short tons on the basis of small nuts and 680.5 short tons on the basis of the large nuts. Thus, we have the following possible figures from which to choose for the approximate amount of total copra production possible from Kapingamarangi:

242.3 short tons calculated on acreage basis and Nauru yields
374.3 short tons calculated on basis of 33 pounds per tree
443 short tons calculated on basis of Sampson's small nut
680.5 short tons calculated on basis of Sampson's large nut

These figures are highly hypothetical, to be sure, but they still provide a useful yardstick for evaluating the Kapingamarangi situation with

1. Data from M.-H. Sachet's abstract translation of R. L. A. Catala, Report on the Gilbert Islands (mimeographed), Noumea, 1952.

respect to food production from coconuts, with respect to the food requirements, and with respect to the effect of exporting varying amounts from the atoll. If, as Chief Tuiai informed us, Japanese exports of copra from Kapingamarangi Atoll reached as high as 300 (metric) tons of copra in at least one year, and if the production averaged 374 short tons or less per year, then it is understandable why famine occurred during the drought years 1916-1918.[1] Tuiai stated that individual shipments during the Japanese period came to 40 to 70 tons. We know that the Japanese sent a ship to the atoll about three times a year, so that the average yearly export then may have been between 100-200 tons of copra. This drain must have forced a much greater reliance by the people upon fish, puraka, and breadfruit, and two of these at least are subject to effects of the occasional droughts and storms. On the other hand, if good prices were paid the people, they probably were able to import some foods such as rice. Tuiai gave the writer the impression that the economic situation or at least the trade situation had been better during Japanese times than in the post-war period because of better copra prices.

Kapingamarangi's coconuts varied in size greatly. Some of the "drinking nuts" given us were half the size of others. The soil conditions under which the coconuts grew varied from almost pure sand to soil with extremely rich humus content. An average sized nut thus should be assumed for Kapingamarangi. If the Kapinga people during the Japanese period exported willingly as much as 100-200 tons of copra annually, the atoll production probably was higher than the lower two figures given of the possible total amount of copra production from all the coconut trees on the atoll. An average of the higher two figures seems more likely to represent the true situation, i.e., about 561 short tons per year.

Whatever the true situation may have been, the exports of copra since the American administration took over have been relatively low, only 48 short tons for 1954. Yet there did not appear to be any significant waste of nuts. The fallen coconuts were picked up often enough to keep the ground fairly clear and few were allowed to sprout where they fell. This must mean that most of the unexported copra was consumed either by people or by the pigs. However, there were relatively few pigs on the atoll, as indicated by the count of 288 in 1946, and they were relatively small. The inference would be that most of the coconuts are required for consumption by the populace unless substitute foods can be had. Export of additional amounts of copra can be made without much food loss if other types of food are imported to take its place at regular intervals. Actually, this is what occurs, the Kapinga people import moderate quantities of rice, and some flour, as well as small quantities of luxury foods. The amount of such trade would depend largely upon the relative prices for the exported copra and for the imported foods. With higher copra prices and lower rice and flour prices, the atoll people can afford greater exchange while preserving their food adequacy. There appears to be little surplus beyond local food requirements, however.

1. On the basis of Catala's estimate, almost exactly half of the coconut plantation of Tarawa Atoll is consumed on the atoll and half is exported.

Puraka may be boiled in water or may be baked in coconut casseroles in barbecue pits, often mixed with breadfruit or with coconut cream. The dried coconut husks and shells form the primary fuel source for cooking.

Fishing.

Fishing provides one of the important staples of the diet. A great variety of food fishes are available, both of the reef and the open sea variety. Many ways of catching fish are utilized. In the shallow inter-islet channels, adjacent land owners may construct V-shaped fish traps from coral blocks and boulders, with the open end of the V facing the seaward side. The other end facing the lagoon will have an opening a foot or so wide leading into stone enclosures in which the fish swimming toward the lagoon can be readily caught. Throw nets are utilized along the reef at night in conjunction with torch fires. Generally this fishing is done near the outer edge of the reef in the vicinity of the algal mat. Spear fishing in channel areas or in conjunction with fish drives along the reef across the lagoon from the village is a common practice. Hook and line fishing is done both in the deep water of the lagoon and outside the pass on the open ocean not far from the reef. In the latter area tuna or bonito is a common and much prized fish.

Two types of fishing are quite spectacular. One is the catching of flying fish at night, and the other is the community fish drive. Catching flying fish by torch light formerly was led by the ariki or priest, according to Emory. Now individual canoes go on the trips, but two or three canoes may be raced along abreast by the paddlers. Outrigger canoes outfitted for the catching of flying fish embark with an expert wielder of a small scoop net attached to the end of a 12-feet long tough but light *Hibiscus* pole. A number of six feet long bundles of dried coconut fronds bound tightly into torches are carried on the outrigger platform. Two to four people go along to paddle the canoe. This enterprise is done only when there is no moonlight, since the reflected light of the moon from the surface of the water makes it difficult to see under water. The men set sail in their canoe just before sun-down, so as to arrive near the ship passes just as darkness sets in. It appears that the flying fish enter the passes to sport about or feed in the shallow water of the lagoon near the passes shortly after dark and return to the open ocean before dawn. In this shallow water, the fishermen have set a number of stakes into the coral rock and sand and erected small racks or platforms upon which they lay their sails after sailing across the lagoon. The sails are cumbersome and interfere with the fishing operation.

Here the paddlers take over and send the canoe in great sweeping circles over the shallow water of the lagoon near the passes. A coconut leaf torch is lit by the scoop net wielder who balances himself at the bow of the canoe, his torch held high in his left hand, while his strong right arm carries the pole and scoop net. As the canoe begins to pass over schools of flying fish, reflected light from their backs enables the fisherman at the bow to see them just under the surface. Many flying fish now will break the surface and sail past or over the canoe. The net wielder is busy scooping fish out of the water at this time. A swoop, a twist of the pole to pin the fish in the net, a half-turn toward aft and a flick of the wrist slams the fish into the ten inch slot that forms the open belly of the dugout canoe. In another few seconds this is repeated, and so on as long as fish remain in sight and reach. Sparks from the torch shower backward toward the paddlers as the canoe skims along. When the school is lost, another circle over the area is made. Then when enough fish are caught or when the men are tired, the canoe is paddled to the sail rack, the mast and sail are set up and the canoe is raced home. Hundreds of flying fish have been caught by a single net wielder in a few hours upon occasion. About 60 flying fish were caught in 3 hours by the crew of the canoe in which this writer rode. Each fish was from 8 to 10 inches long. The catch was divided equally among the fishermen involved. Flying fish may be smoked and dried in the sun before eating, or they may be baked after being wrapped in breadfruit leaves.

Community fishing drives are open to all men who have canoes or wish to go along. These drives take place regularly on Saturday morning but may occur before any special celebration or feast. Each of the two residential villages have a fishing master, and the base of the operations is the men's house on each of these two islets. The fishing master or leader is considered the guardian of the net for his village. He has charge of portioning out the work in making and repairing the net and directs field operations, and he commands the community canoe. However, he is at the direction of the atoll chief as to when joint operations are to take place such as for special celebrations.[1] During 1954 when this writer went along to observe this type of fishing upon two separate occasions, ten or twelve canoes with about 30 men went on one such drive. Twenty-one canoes with over 60 men and boys went on the second.

Peter Buck has described the equipment and method of community fishing done with a trap or purse net[2] while Emory has described fish drives in which a mere naked rope is used, held at ten to fifteen feet intervals by men who gradually move inward, restricting the circle. The fish appear frightened of the shadow that the rope makes in the water and will not readily cross such a shadow. With this rope the fish are driven towards pockets of shallow water on the reef. A circle of men closes in gradually, while the fish mill about in the center. Finally, a coconut fiber net is thrown around the cordon of men. The men step outside the net which then is used to bag the fish and to haul them aboard the leading canoe. Sections of the reef are named individually for locations where fish drives are made.[3]

Two types of fish drives were observed by the writer in 1954. These drives were made across the lagoon from the villages. In both cases

1. Emory, op. cit.
2. Buck, Peter, The material culture of Kapingamarangi, 1950, p. 226-230.
3. Emory, op. cit.

V-shaped net traps made of coconut husk cord, suspended from wood floats and weighted down with stones at the bottom were set up on the lagoon side edge of the reef with the open end of the V facing the reef. A cotton twine purse net formed the end of the trap into which the fish were finally driven. In the first type of drive the men fanned out from each side of the V into a great circle perhaps two hundred yards in diameter armed with steel fish spears and light poles with which to beat the water. The men most distant then began closing in, walking slowly at first and hitting the water with their sticks to frighten the fish toward the net trap. When the circle closed in to about 100 feet diameter, all the men were leaping and stumbling over the coral toward the net, splashing and shouting in a frenzy almost as great as that of the various schools of fish which were finally panicked into the net bag. This drive was repeated about ten times until it was thought enough fish had been caught. Each time the fish were hauled into the leading community canoe from Touhou. This type of drive was essentially the same as those described by Buck, although those which he witnessed were in the inter-islet channels or near the various islets on the east and southeastern parts of the reef. It is in this type of operation that the men suffered frequent coral scratches on their legs which bear numerous scars from infections.

The largest drive observed in 1954 was made for a community farewell feast for the expedition near the end of August. About 60 men in 21 canoes joined in the drive which took place around the southwestern pass area of the reef. Several small drives of the above described method were first made from the north along the reef toward the pass. The great drive of the day utilized long ropes of coconut fiber to which were tied green coconut leaves at intervals of about a foot. The canoes were tied up and anchored to a large coral patch bordering one side of the deepest pass and on which the V-shaped net-trap or purse-net had been set up. Swimmers took one end of the rope and swam with it across the mouth of the pass. Then the rope now stretching across the pass was gradually moved lagoonward up the pass. The waving green leaves and the shadow cast by them and the rope presumably frightened fish to a considerable depth to flee into the lagoon before the advancing rope. Gradually the rope was let out as swimmers towed it into the lagoon in a great loop extending from one end of the V-trap. Another rope also tied with green leaves at the same time was extended from the other side of the V-trap and carried by swimmers in an equally great loop into the deep water of the lagoon. The rope was kept from sinking by swimmers holding it at intervals near the surface. The two ends of the loop were joined and tied at a point perhaps a thousand feet or more from the net trap, thus forming a huge circle of rope several thousand feet in length.

The men holding the ends of the rope at the mouth of the trap under the direction of the drive master now began pulling in the rope as the swimmers moved toward the trap. The rope was hauled into canoes as it was pulled in. Finally, the loop shrank inward onto the patch reef itself, while the circle of men closed in with it. In the meantime the men used their poles to poke the fish out of holes in the coral rock and to drive them toward the net.. By this time several large schools of fish were dashing madly about seeking an escape from the cordon. With a final rush, the fish were driven into the purse net and the trap closed. The men and boys wearing simple Japanese goggles, - pieces of glass framed in wood tied together with string, and armed with spears, now searched the holes in the coral rock under water for fish that had sought refuge there. Numerous fish were caught with spears during these drives.

Upon the conclusion of these drives, the pastor or an elder said a prayer of thanks and the canoes set sail and raced for home. The community canoe from Touhou which carried the fish bagged in the drive was emptied of the fish and carried into the canoe shed. The fish now were divided into as many individual piles as there were participants in the fishing expedition, each pile having the same number and approximately the same size of fish. The fish then were given to the various participants and were carried home in coconut leaf baskets made from a single frond to be cleaned and cooked by the women.

Most of these reef fish caught were from 12-16 inches long, and numerous varieties were included in the catch. No exact record was kept of the number caught during the various drives in the summer of 1954, although during the two drives described individual piles of fish divided among the participants numbered about ten fish. In eight such drives described by Emory, the number of fish caught varied from less than 300 to over 1600. There was no great correlation between the number of men involved in a drive and the number of fish caught, although for a successful drive enough persons must go along to form relatively large circles without too great gaps between persons. These fishing expeditions no doubt served a social and recreational function as well as an economic one, and were looked on by the men as full of sport and fun.

Note: A summary account of the life and environment of the atoll of Kapingamarangi is provided by the excellent article by Ralph E. Miller: Health Report of Kapingamarangi (Atoll Research Bulletin No. 20, September 30, 1953). In this, the problems of food and water supply, diet and sanitation are clearly presented, as well as a detailed study of the health and diseases, and the local remedies and remedial practices. While no specific references have been made to this article in the present study, the writer has familiarized himself with its contents and has found confirmation in field observation for many of the aspects discussed in the article. The fresh water problem, one of the most important on coral atolls, has not been discussed at length in the present report, although it is briefly described in the sections on Climate and on The Regional Geography of the Islets on the Reef under the subheading TOUHOU. The reader is referred to the section on water supply in Miller's article and to the detailed discussion of the fresh water lens in the report of Edwin McKee, the geologist of the 1954 field team.

EXTERNAL ECONOMIC RELATIONS

The trade of Kapingamarangi.

Little is known of the pre-European contacts of the Kapingamarangian people with outside peoples, but because of the isolation of this atoll and the fact that they early had lost the art of building large seagoing canoes, it is improbable that there occurred other than rare chance visits by stray canoes such as those of the Marshallese. The first European ship visited the atoll shortly after 1870 and before the departure of the Marshall islanders. What the mission of this ship was is not known, although it may well have been a trader. A second ship known only as "John's" ship entered the lagoon after most of the Marshallese had sailed away and took the last of the invaders with it. This ship was a trading vessel searching for beche-de-mer (sea cucumbers) which were dried and taken to sell in China where they were in demand for exotic soups. A chant collected and translated by Emory indicates this mission: "Two boats landed in the surf, looked on the reef (for sea cucumbers) in quantity". The crew of the boats were uncertain of their reception by the Kapinga people and pointed their guns at an inquiring group of men, but were pacified when the Kapingans offered them a gift of drinking coconuts. Whether any trading was conducted is not told.

A third ship may have been the Fire Queen which was said to have come from New Zealand in 1877. The fourth ship reaching the atoll possibly was Sir Cyprian Bridge's vessel, the "Espiegle". The fifth ship is remembered as having brought Captain "Harry" Williams who stayed with his Nauru wife on one of the islets and supervised the curing of beche-de-mer. The sixth ship brought Tiaki (Jack) Lee with his native wife Nuri from Nukuoro. He was responsible for the introduction of the valuable puraka plant which has become one of the staples of diet and which supplanted the smaller taro plant in the pits and dugout fields. Following the visit of the seventh ship, an eighth, the schooner Kiritie from Rarume, Rabaul, New Britain, brought the Englishman Lui Patterson, apparently in 1892. All of these ships no doubt introduced various outside goods and commodities hitherto strange to the natives. Thus, when the first steamer arrived under the German administration, some individuals already had the tobacco habit as indicated in the following translation of a chant by Emory: "Pauroti (seeing the ship) rejoiced, because he was on his last carefully conserved tobacco. If so-and-so (is on the boat) and is kind, there will appear bundles of tobacco". Today, although smoking is frowned upon by stricter members of the Protestant church, cigarettes are in great demand and form one of the objects purchased from traders. The market for beche-de-mer, on the other hand, appears to have disappeared, while the natives themselves do not eat it.

Prior to the German administration there appears to have been little trading in or export of copra, the dried coconut meat. Chief Tuiai told the writer that 70 years ago many people lived on the islet of Hare in contrast to only a few today. Houses occupied much of the land, so that coconut trees were much fewer in number. Most of the coconuts were eaten and few were made into copra. After the great massacre by the Marshallese, the vacant houses provided land for a large increase in coconut trees. Since the population did not increase as rapidly, there was an ample surplus for export, and the Germans sent occasional small freight and passenger ships, the "Langeroog" and the "Sumatra", operated by the Norddeutscher Lloyd Company to Kapingamarangi. These were small enough to enter the lagoon. Some of the types of objects acquired by the Kapinga people were mentioned by the members of the German South Sea Expedition of 1910: "They have received some objects most favorably and through purchase or imitation they have become quite familiar sights. This is especially true of deck and rocking chairs, white suits, and colorful cotton materials. The natives also like all kinds of furniture and household goods, e.g., chests of drawers, bedsteads, cooking pots, lamps, sewing machines, tables and chairs. On the other hand, they scorn some goods, e.g., European fishing gear".[1] By 1954, a change had occurred in the latter attitude, since steel fishing hooks and fishing line were much desired and highly prized.

In exchange for such foreign objects there was little aside from copra which the Kapinga people had to offer that was desired by the outside world. No information is available on the amount of copra which on the average was exported or taken from the atoll during the German administration. By the beginning of the Japanese administration, the new coconut plantings on Hare had come into the height of their bearing stage, while the Japanese also made efforts at extracting large amounts of copra which, at least during the drought period of 1916-1918, brought about severe food shortages.

During the Japanese administration, the "Ponape Isolated Isles Steamship Line" operated a trading route starting from Ponape and calling at Pakin, Ngatik, Nukuoro, Kapingamarangi and Oroluk, covering the distance of 1,240 miles in 24 days. Three trips per year were made on this run.[2] Tuiai stated in 1954 that the Japanese informed him that annual copra export at times had reached as high as 300 (metric) tons. Tuiai's records were destroyed during the American bombings in World War II, but he said that he recalled individual shipments of 40 to 70 tons. Under the American occupation prices had not been as good as during pre-war period when world market prices were higher. This and perhaps the increased population during the American administration has resulted in much decreased copra shipments. The highest single shipment in this recent period has been about 30 tons, and some shipments have been as low as 3 tons. The

1. Emory, op. cit., as translated from Eilers.
2. United States Navy Department, OPNAV 50E-5, Civil Affairs Handbook, East Caroline Islands, 1944, p. 117.

shipment made on the occasion of the July visit of the District trading ship in 1954 amounted to about 15 tons. Tuiai also ventured the opinion that the trees, which were in their prime during the Japanese period, now were past their best bearing age. Information obtained from the Ponape District Administration indicates that the total amount of copra exported from Kapingamarangi in 1954 amounted to only 48 short tons. As in the pre-war period, the post-war market for Micronesian copra has been in Japan.

In an effort to supplement the meager economy of Kapingamarangi and other Micronesian islands following World War II, the U. S. Navy and subsequently the ITC (Island Trading Company) together with the Trust Territory Administration solicited handicraft work from the islanders for outside sale, mostly in the United States or in U. S. military and naval activities. A successful sustained market for handicrafts other than for Pandanus mats has not yet been developed for Kapingamarangi. The Kapinga men are excellent model canoe builders and fine craftsmen in the making of a variety of objects fashioned from wood, such as wooden bowls, and coconut grating stools, while their women make some of the finest Pandanus and coconut mats for table or floor in the Pacific and do fine work in basketry. Perhaps the largest order for such handicrafts was placed in the history of the atoll in 1954. At this time ITC placed an order for 100,000 sq. ft. of Pandanus floor matting for the U. S. Navy Housing Office. This order apparently was filled in four months by the Kapingamarangi people through strenuous effort involving long hours of night work for some of the women. Many women worked late at night by the light of coconut shell fires or kerosene lamps. An inquiry about such industrious application and what seemed like unhealthy overwork brought out the response from Tuiai and others that this was an "order" from the American administration to produce so many square feet of matting, and they felt obligated to fill it in time to meet the schedule of the trading vessel which was sent to Kapingamarangi once every two months. The price paid for the mats amounted to 9 cents per square foot, so that this order netted the atoll inhabitants a total of about $9,000 or the equivalent of about $21 per capita. This represents a considerable sum of cash available to the atoll inhabitants for the purchase of trading goods. No attempt was made to ascertain the types and amounts of purchases the Kapinga people made from the outside.

Our scientific team members also had placed orders for a variety of handicraft objects including canoe models, place mats, kamit boxes (fishermen's waterproof boxes), bowls, coconut grating stools and models of such stools, baskets and "Panama" hats. Some additional articles of these types were sold to the American sailors from the destroyer escort on which the team departed, while other articles were sent to Ponape for sale through one of the commercial companies there. Such outlets for Kapingamarangi crafts should be considered exceptional, however. Moreover, the trading vessel which had been under charter by the District Administration at Ponape had proved expensive to maintain, so that in 1955 the Kapinga run had been discontinued. This left the isolated atoll with only the services of a small (about 60 feet long) former Japanese fishing boat owned and operated by some Kapinga people making infrequent and irregular runs between Ponape and Kapingamarangi. While this is in line with the Trust Territory Administration efforts to channel the trade into local hands and thus provide more income to the native peoples, this move also has resulted in decreased opportunities for outside contacts and services. At the same time, this compels the inhabitants of Kapingamarangi to revert to a higher degree of self-sufficiency. As an instance, the two local storekeepers had run out of matches prior to our departure so that boxes of matches were prized gifts, although the Kapinga people make fire by rubbing sticks when necessary.

ASPECTS OF CULTURAL AND SOCIAL CHANGE

The introduction of Christianity liberalized many former restricted aspects of the economic and social life while introducing new restrictions upon certain liberal aspects of former practices. The former belief in the sacredness of breadfruit trees and canoes provided the ariki with religious sanction for his control over acquisition and use of these important economic items. The ordinary population had to secure permission from the ariki through the intermediary of the secular chiefs in order to cut down breadfruit trees for canoe building and also required similar permission to utilize canoes. The difficulty of securing such permission resulted in the restriction of most of the fishing to reef areas reached by foot, according to Chief Tuiai. This also must have restricted across-lagoon travel between such places as Hare and Ringutoru, so that people on one of these islets often would be unacquainted with people on the other. Christianity brought the abolition of such priestly sanctions and improved economic welfare. Anyone owning his own breadfruit trees could thereafter cut them for canoe making at will, so that mobility and fish production increased. Emory expressed surprise at the great increase in canoes between the time of the German expedition and 1947 when there were 122 canoes as compared with only 47 in 1910. This increase most probably was related to the abandonment of the ariki religious control.

Moreover, two of the islets, Pumatahati and Turuaimu, in the southeast part of the reef once were taboo except for cult purposes. All the rest of the land had been privately owned and parceled out with the exception of these islets, Matukerekere, and the cult house on Touhou. The adoption of Christianity resulted in the transformation of these islets into community property which provided a source for building material for community projects such as the school and dispensary buildings, the community men's houses, outhouses and the like. From time to time, community parties organized by the chief would harvest the coconuts which were divided up among the community or used for other agreed to purposes.

Christianity brought with it the observance of Sunday as a day of rest during which no work is done. This applies not only to work on the land, construction, or fishing, but also to food preparation which must be done the day before. A type of work schedule for Fridays and Saturdays geared to laborless Sunday has become customary. Thus, Friday is a day when women gather puraka, men and women gather and prepare coconuts. Saturday mornings appear to be reserved for community fishing expeditions that involve group participation, such as the fish drives. Foods are prepared by the women and cooked in pots or in covered pits for eating Sunday. Church services, picnicking and visiting or resting occupy Sunday. Religious services are not limited to Sundays. Every day just after sunrise and at dusk at least small groups of earnest Christians gather in the church for prayers and singing. Even out on the reef when community fishing drives have come to a conclusion, the fishermen pause for a moment while an elder or the pastor gives a prayer of thanks for the catch.

Emory indicated that certain forms of social segregation have been broken down with the advent of Christianity. No longer are women taboo in the community men's house. Women not only speak up in the general community council meetings, but are active leaders in church affairs, especially in the choir groups, and women lead in intoning hymns in church. The church activities appear to form a highly significant portion of the community's social activities. Membership in church and the Christian Endeavor also represents important prestige factors.

A more recent change in the social situation has come with the conversion of the son of Chief Tuiai and a number of other people totaling about 30 men, women and children to Catholicism. This has had an unfortunate divisive effect upon some aspects of community activities. For instance, all construction or repair work on buildings of a public or community nature formerly was a community undertaking directed by the chief and carried out by men designated by him with the concurrence of the adult men and women (the latter having to do with the provision of food for the working party). During the postwar period the small Catholic group decided to erect a chapel for services on the property of one of the converts. Chief Tuiai, as usual, designated a working party from the community to help erect the building and thatch the roof, However, the Catholic group was enjoined by the Spanish priest then on the atoll against accepting such help. The reason for this refusal appeared to be related to a desire to avoid having the Catholic group involved in the repair to the Protestant church which was scheduled for a subsequent occasion. By refusing the traditional community participation, the Spanish priest apparently felt that his converts would feel it easier to refuse their participation in the improvement and enlargement of the Protestant church to which he was opposed religiously.

This type of schism is unfortunate in any once tightly knit and smoothly functioning community, and on a small atoll such as Kapingamarangi, this is particularly deplorable. It was not ascertained whether this problem had as yet involved the question of use of the building materials on the community owned islets but such a question has within it potentialities of friction and conflict for the community.

Finally, the acquisition of both material objects and ideas from abroad especially during the postwar period is building up a certain amount of dissatisfaction among some young people with the restricted life and culture of the atoll. This dissatisfaction is evident particularly among the group of the "brighter" young men who have had opportunity to attend the Intermediate School at Ponape, some of whom even have had further training at the Pacific Islands Central School (PICS) at Truk, or at the Oa Mission School on Ponape. The attractions of the outside world of the high islands, limited as they are, have added to the urge created by population pressure on the atoll to move to Ponape to settle. The student group especially has acquired tastes and demands stimulated by what the young people have seen among or acquired from the foreign (i.e., American) administrative group on Ponape and Truk which involve expenditures that the atoll livelihood cannot support.

A difficult problem educationally is that education above the primary school level brings with it expectations of remunerative positions which generally are limited to a few teaching posts or a position as a medical aide. In the past, education on the atoll has been limited to the equivalent of the 6th grade level of grammar school in the vernacular. Two or three selected students per year have been brought to Ponape for further schooling, and further selection has brought a few individuals to Truk where they acquired the equivalent of the sophomore level in high school. Medical aides get experience in the Ponape hospital for a year or more. At this stage they are looking for positions. On the atoll itself, however, three teachers with such training and two medical aides are all that are needed or can be supported by the Kapinga people. Both because of cultural and language differences and because other areas supply their own trained personnel in the same fashion, there is virtually no remunerative outlet for excess trained personnel from Kapingamarangi.

CONCLUSIONS

1. Natural forces are building up and enlarging the land area above ordinary high tides at Kapingamarangi at a faster rate than they are eroding and destroying such surfaces. The process of land building generally is in a lagoonward direction, while land destruction generally is occurring on the seaward and the channel sides of islets.

2. The land surfaces above ordinary high tides have and are in process of slow migration. Along the eastern and southeastern sectors, this migration is lagoonward, while in the northeast sector of the reef the migration is partly lateral toward the west along the reef, although it is mainly lagoonward. This migration is related to the direction of the prevailing ocean winds and currents here modified somewhat by the situation of the individual islets on the reef. These movements lagoonward are the results of the accretion of sand and gravels derived from the outer edge of the reef and the reef flat, as well as from the erosion of the seaward and channel sides of the islets.

3. Additional land surfaces above ordinary high tides can be built up for planting to coconut and other vegetation by man's initiative at relatively rapid rates by the building of causeways across narrow inter-islet channels and by the piling up of rubble and coral boulders at selected locations on the reef behind which sand and gravels may accumulate through wave, tide and current action. Such land building processes should be actively encouraged in view of the population pressure. No significant ecological harm need be anticipated through the closing of the smaller inter-islet channels in the east central reef areas, since the wider channels in the northeast and southeast as well as the main ship passes in the south provide ingress for fresh ocean water. The western reef areas also offer potential land building sites.

4. Vegetation is highly man-manipulated, so that observable patterns are of little use in deducing "natural" biological processes or of soil conditions. A few valid generalizations may be made with respect to the zonation of certain vegetation types inward from the shores of the islets.

5. Since the entire land surface is generally in productive use, the increased planting of one type of useful tree must be at the expense of another type. Thus, coconut trees and breadfruit trees are in direct competition for space, while increased excavation of pits for puraka cultivation also means decreased tree space for coconut and breadfruit trees. An increase in pandanus palm leaf production for mat weaving also involves some sacrifice in food production.

6. Not all land owners keep their coconut land free of understory weed plants that compete for plant food and moisture. Plantation practices on other islands indicate that improvement in such practices would lead to higher coconut production.

7. There is a considerable crowding of coconut trees on the islets of Kapingamarangi. It is probable that more careful spacing of replacement plantings to give individual trees more room also would result in greater nut output, provided other competing growth also were limited or eliminated.

8. A large number of the coconut trees here appear to be too old for high nut yields. They need to be replaced gradually with young trees for realizing the maximum potentiality in nut production.

9. Growth of reef fish appears to be sufficiently rapid to keep up with present depletion rate through the fishing activities of the people on the atoll. However, according to Robert Harry, the expedition's ichthyologist, this growth is only rapid enough to maintain an ecological balance. The production of a large enough reef fish catch to make worthwhile the export of fish in refrigerated ships might readily result in the destruction of reproductive stock and a disastrous depletion of the fish food upon which the atoll people depend so heavily. On the other hand, tuna or bonito and other open sea fishes may furnish considerable unexploited resources for export or local use. Since these open sea fishes do not long survive being penned up in the coral rock pens such as are in use in Mokil, commercial exploitation of tuna or bonito would require modern fishing boats, equipment and preservation methods. The atoll people do not have the resources for providing such capital equipment and also would need to be trained for this sort of fishing.

10. Handicrafts in the way of woven Pandanus and coconut leaf mats, hats and basketry, canoe models and carved wooden bowls and platters, and trinkets made from seashells all provide possible commodities for sale outside the atoll were market outlets made available through organized commercial channels. No dependable income from such sources can be expected for the Kapingamarangi people, because of their isolation and the uncertain visits of ships to the atoll, as well as because of the difficulties of marketing at such great distances from the sources of the handicrafts.

11. Three types of unutilized energy sources are potentially available for use on the atoll which one day may become useful. Since there is almost vertical sunshine a large percentage of the time, the cheap solar stoves being developed for cooking purposes in some tropical or semitropical lands could be utilized effectively here. An almost constant easterly breeze of considerable briskness could furnish motive power to turn windmill driven electric generators

to provide light and power. Finally, the strong tidal current through the inter-islet channels furnish water-power potential for either direct mechanical conversion or through electrical power generation.

12. A fair degree of literacy seemed to prevail in the written use of the vernacular language among the younger generation, some of the young people in addition having acquired facility in the use of the Ponape language. This is in part the result of residence of several of them in Ponape and in part is the result of the use of the Bible and hymn book in church services for which no books in the native language exists. Six or seven of the young men and several of the young women also have learned enough English to act as interpreters. A few of the men also can speak a little Japanese. None of the atoll people here have had more than the equivalent of about the second year of high school education. On the other hand, further education does not provide equivalent job opportunities to those seeking them. The acculturation of the population to Western civilization has been proceeding rapidly with the travel back and forth of many of the atoll people to Ponape and back. Students attending school at Ponape and Truk return to pass on new ideas and tastes. Increased demands for numerous outside commodities has been accompanied by increased monetary income derived from the sale of Pandanus mats and copra. However, the demands or wants exceed the capacity of the atoll resources to purchase and acculturation thus has created some measure of dissatisfaction with the limitations of atoll livelihood among some of the young men. This dissatisfaction also extends in part to what is considered the "old-fashioned" ways of life. On the other hand, except for limited land available for homesteading at Ponape, opportunities for livelihood outside the atoll appears rarely. Efforts in the educational program should be directed toward increasing the appreciation of the students of the values of atoll life and toward improvements within the atoll sphere.

Appendix I

Rainfall data for Kapingamarangi

July - August
1954

Rainfall data was recorded from Weather Bureau rain gauges (copper tube type) placed upon four widely separated islets, Matukerekere Islet at the extreme southern end; Torongahai at the extreme northern end; in the middle of a large puraka patch near the middle of Hare Islet; and in the open church yard on Touhou Islet.

Readings were made once a week on the non-residential islets, but not necessarily at similar times of the day owing to travel time across the lagoon. On Touhou Islet, however, the gauge was read twice daily.

The following data give the weekly rainfall for the different islets read in inches of water. The dates indicate the reading date and the amounts are for the week preceding the date given.

Date	Torongahai	Touhou	Hare	Matukerekere
July 8	1.5	1.856	1.17	0.98
15	1.2	0.92	0.405	0.401
22	0.2	0.415	0.53	0.2
29	0.11	0.255	0.52	0.1
August 5	1.75	1.93	1.2	1.4
12	0.1	0.15	0.1	0.1
19	0.01	0.035	0.1	0.21
25*	1.0	0.46	0.26	0.24
Total for 8 weeks	5.87	6.021	4.285	3.631

*The rain gauges were removed for packing for departure on August 25, so that only six days' readings were taken. However, no rain was observed on the following day, so that this reading also may be taken as for a seven day period.

It is seen from the above that there are considerable variances in the amounts of rainfall on the different areas separated by distances of between 2 and 4 miles. There is no correlation with size of islets. The average for all gauges is 4.951 inches of rainfall which may be taken as the average amount for the atoll during the two months of July and August, 1954.

Appendix II

Meteorological data for Kapingamarangi

Prior to the arrival of the geographer who was responsible for the meteorological recordings after his arrival on July 3, other expedition members who had arrived earlier had set up the rain gauges on four different islets and attached a Taylor maximum-minimum thermometer to the shaded doorway of the thatched house used as a laboratory by the expedition. This was fixed approximately a meter from the ground. Maximum and minimum readings on June 25 were for the preceding 18 hours, thereafter for the preceding 24 hours. Taylor instrument readings were made by Niering from June 25 to July 10, accompanied by notes on rainfall occurrence.

Beginning with July 6, recordings were made on the Weather Bureau 10-day weather form. The maximum-minimum readings were made with standard Weather Bureau thermometers. However, on July 9 the maximum thermometer broke. Subsequent temperature recordings again were made by the Taylor instrument. On July 21, the Taylor instrument and the hygrothermograph were moved to a shelf under a tin roof of an open shack nearby where they were shaded and open to the breeze.

The following recordings and notes were made by Niering:

Date	Max. Temp.	Min. Temp.	Time	Remarks
June 25	87.5° F.	79.0° F.	7:50 a.m.	light breeze
26	90.5	79.5	8:00	" "
27	93.0	81.0	10:45	" "
28	94.0	81.0	8:00	" "
29	92.0	78.0	8:30	" " , shower, 6:30 p.m.
30	88.0	78.0	8:30	light breeze, intermittent rain p.m., evening
July 1	93.0	82.0	8:00	light shower 3 p.m.
2	92.0	79.0	9:00	light shower 4 p.m.
3	91.0	79.0	8:15	
4	92.0	79.0	8:45	
5	91.0	78.5	9:15	heavy showers 8 p.m.
6	89.0	76.0	8:40	
7	88.0	80.0	8:00	heavy showers p.m., night
8	91.0	78.0	8:15	
9	89.0	81.0	8:00	
10	91.0	82.0	8:15	

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- Twp. ---- Range----
Meridian 155E

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ------
Pres. Table ------

TIME USED (check one): PST | MST | CST | EST

Month JULY
Year 1954
Dates 5 To 15, incl.

Time ---- a. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
5															
6	81.5	77.5	78.7	75.5			O	O	SC	5	L1	O	E		
7	83	81.2	82.5	76.5			E	2	SC	3	H8	E	E		
8	84	78	82	77			E	2	SC	4	L1	E	E		
9	83.8	81.1	82.5	77.5			E	1	C	1	L1	E	E		
10	83	81.5	83	76.5			E	2	SC	3	L2	E	E		
11	82	76	81.2	77			E	2	OC	9	L5	E	F		
12	81.5	78	82	78			E	1	SC	5	L1	E	G		
13	82	79	82.5	76.2			E	2	SC	2	L1	E	E		
14	84	78	80.5	76.5			E	1	OC	10	L5	E	G		
15	83	79	82.5	78			SE	2	SC	2	L1 H6	E	E		
Sums															
Means															

Time 7:30 p. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Hygro. Check: Temp.	Hygro. Check: Rel. Hum.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
5	89	78	78	74.5			81.5	86	E	1-2	SC	9	L5	E	G		
6	85.5	77.5	82.5	76.5			84	72	E	0-1	C	0			E		
7	86.5	82	82.1	78			83	86	E	0-1	SC	9	L1	E	G		
8	91	82	83	78			84	70	E	0-1	C	0			E		
9	92	82	82	76.2			84	70	E	0-1	C	0			E		
10	85	79	81.5	77			83	78	E	1	C	8	H7	E	G		
11	85	79	81.5	77			83	75	E	2	OC	10	H7	E	G		
12	90	79	81.5	76.5			84	75	E	2	C	0			E		
13	92	81	83	77			86	70	E	2	SC	4	L4	E	E		
14	91	81	83	78.5			85	73	E	1	SC	1	L1	E	E		
15	90	81	82	77			84	79	E	1	SC	4	H6		E		
Sums																	
Means																	

Date	Humidity: Highest	Humidity: Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Time Began	Time Ended	Amount: a. m.	Amount: p. m.	Amount: 24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
5			E	C	R	5 PM	7:30PM	025	0.7	0.7			3								
6	90	65	E	C	O					0			0								
7	86	62	E	SC	R	2 PM	2:30PM	0	.09	.09			1								
8	94	62	E	C	R			.35	0	.35			0								
9	88	58	E	SC	O			0	0	0			1								
10	90	58	E	BC	R					.25			2								
11	94	66	SE	OC				.42		.42			1								
12	88	60	E	SC	R			.015	.15	.12			0								
13	78	54	E	C				0	0	0			1								
14	89	58.5	E	SC	R			.075	T	.075			0								
15	90	57.5	E	SC	R			.055	0	.055			0								
Sums					Number of days*: .01"+	.10"+	.25"+	.50"+						No. thunderstorm days ------*							

REMARKS

41

The figures or letters used for cloud data are from the Cloud Code Chart of the Weather Bureau. The rain of 0.25 inches at 10 p.m. on July 5 was part of the shower that occurred in late afternoon.

Under Visibility: E means Excellent; G - Good; F - Fair; P - Poor.

July 9 - The maximum thermometer used up to this date was broken during this evening. Thereafter maximum and minimum readings were taken with a Taylor Maximum-Minimum Thermometer.

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- *Twp.* ---- *Range* ----
Meridian 155E

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet)

Pres. Table ------

TIME USED (check one): PST | MST | CST | EST

Month JULY
Year 1954
Dates 16 *To* 26, *incl.*

Time 7:30 a. m.

Date	TEMPERATURE Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
16	84	81	82	77.5			E	2	C	1	H6	E	E		
17	84	79	82	77.5			E	2	C	1	LI	E	E		
18	83	81	83	77			E	3	SC	2	LI	E	E		
19	84	81	83	72			E	3	OC	9	LI	E	E		
20	84	81	83	77			E	3	SC	2	LI	E	E		
21			82.5	76.5			E	1	C						
22	84	78	82.5	75.5			E	1	SC	1-2	H1 LI	E	E		
23	84	82	82.5	75.2			E	2	SC		H6 L8	E	E		
24		81	82.9	76.5			E	3	SC	1	LI	E	E		
25	84	81	84	77			E	3	C	0	0	0	E		
26	83	81	83	75.2			E	3	C	5	LI	E	E		
Sums															
Means															

Time ------------ m.

Date	TEMPERATURE DRY	WET	Dewpoint	REL. HUM.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
Sums													
Means													

Time 7:30 p. m.

Date	TEMPERATURE Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	HYGRO. CHECK Temp.	Rel. Hum.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
16	90	82	82	77.5			84	74	E	2	C	1	LI	E	E		
17	90	82	83	76.5			84	65	E	1	C	0			E		
18	89	81	83	77.5			85	74	E	2	C	1	LI	E	G		
19	92	81	83	77.5			85	74	E	2	C	0	0	0	E		
20	91	84	80	77			84.5	68	E	2	SC	2	LI	E	E		
21	89.5	82	82.7	75			84	69	E	3	C	0	0	0	E		
22	94	81	83	76			84	70	E	2	C	0	0	0	E		
23	92	81	83.5	76			84	69	E	2	C	0	0	0	E		
24	87	82	83.2	76.2			84	70	E	3	C	0	0	0	E		
25	87.8	81	83	77.5			84	78	E	3	C	0	0	0	E		
26	90	81.5	83.3	76.5			85	72	E	3	C	0	0	0	E		
Sums																	
Means																	

Date	HUMIDITY Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	PRECIPITATION Kind	Time Began	Time Ended	AMOUNT ... a. m.	... p. m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	THUNDERSTORMS INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
16	86	62	E	SC				.08	.06	.14											
17	90	58	E	SC				.275	0	.275											
18	76	58	E	SC				0	0	0											
19	85	58	SE	SC				0	0	0											
20	80	53	E	SC				0	0	0											
21	75	60	E	BC				0	0	0											
22	85	56	E	C				0	0	0											
23	76	53	E	C				0	0	0											
24	74	60	E	C				0	0	0											
25	78	62	E	C				0	0	0											
26	74	57	E	C				0	0	0											
Sums					Number of days* .01"+ | .10"+ | .25"+ | .50"+									No. thunderstorm days ------*							

REMARKS

41

The maximum-minimum readings for the p.m. of July 20 were from the hygrothermograph. At same time the maximum on Taylor instrument was 93, minimum was 80. Hygrothermograph also used on p.m. July 21 when Taylor instrument read 91 maximum, 81 minimum. The BC clouds on the 21st were high stratus, with low LI underneath.

After July 21 Taylor instrument was moved to the shed with Hygrothermograph where conditions appear to be more a reflection of natural conditions.

Data on July 25 a.m. was taken at 9 a.m. rather than usual 7:30 a.m.

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- *Twp.* ---- *Range* ----
Meridian ----

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ----
Pres. Table ----

TIME USED (check one): PST | MST | CST | EST

Month JULY
Year 1954
Dates 27 *To* 31, *incl.*

Time 7:30 a. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
27	83	81	82.5	77			E	3	SC	1	L1	E	E		
28	83	81	82.5	77			E	3	SC	1	M3	E	E		
29	82.2	78.2	82	77			E	3	C	0			E		
30	83	79	82	77			E	3	SC	1	L1	E	E		
31	82.5	77.9	82	77.8			E	3	OC	10	L8	E	F		
31															
Sums															
Means															

Time ---- m.

Date	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
27													
28													
29													
30													
31													
31													
Sums													
Means													

Time 7:30 p. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Hygro. Check: Temp.	Hygro. Check: Rel. Hum.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
27	89	81	83.2	75.5			85	72	E	3	C	0			E		
28	89	80	81.8	78			85.5	84	E	2	SC	1	L1	E	G		
29	89	81	82.5	77.5			84	80	E	3	C				E		
30	93	81	83.2	77			83	76	E	2	C	5	L1	E	E		
31	86	78	82.5	75			84	68	E	3	OC	10	L5	E	F		
31																	
Sums																	
Means																	

Date	Humidity: Highest	Humidity: Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Precipitation: Time Began	Precipitation: Time Ended	Amount: ---- a. m.	Amount: ---- p. m.	Amount: 24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Thunderstorms: Time First Observed	Thunderstorms: Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
27	82	60	E	C				0	0	0											
28	84	62	E	SC		2:30		0	.245	.245											
29	84	62	E	SC				.01	0	.01											
30	90	52	E	C				.04	0	.04											
31	94	68	E	OC				.7	T	.7											
31																					
Sums					Number of days*: .01"+	.10"+	.25"+	.50"+							No. thunderstorm days ----*						

REMARKS

41

On July 30 rain from a totally overcast sky began about 8:30 p.m. and during most of the night the sky was overcast, continuing through the morning of July 31. Occluded weather continued through the afternoon and evening.

Form 1009-E

(See instructions on cover)

Location: Kapingamarangi Eastern Carolines	Section ---- Twp. ---- Range---- Meridian ----	U. S. DEPARTMENT OF COMMERCE WEATHER BUREAU 10-Day Fire-Weather Record	Elevation (feet) ---- Pres. Table ----	TIME USED (check one) PST MST CST EST	Month AUGUST Year 1954 Dates 1 To 11, incl.

Time ---- a. m.

Date	Temperature Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
1	84	81	86	77.5			E	3	C			E			
2	83	81	82.8	72.8			E	3	SC	S	M3 LI	E	E		
3	83	81	82.8	77			E	2	C	5	LI	E	E		
4	84	75	78.5	76.5			E	1	OC	9	M3	E	G		
5	81	75.8	81.2	76			E	2	SC	3	LI	E	E		
6	83	81	82	74.6			E	3	SC	1	M3	E	E		
7	83	79	82	75.2			E	3	C	0			E		
8	84	80.5	84.5	78			E	2	SC	1	LI	E	E		
9	83	79	83	77			E	2	SC	2	LI	E	E		
10	83	80	81.8	75.8			E	3	SC	2	LI	E	E		
11	83	80	82	74			E	3	C	0	0		E		
Sums															
Means															

Time ---- m.

Date	Temperature DRY	WET	Dewpoint	REL. HUM.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34

Time ---- p. m.

Date	Temperature Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Hygro. Check Temp.	Rel. Hum.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
1	87	82	83	76.5			85	72	E	3	C				E		
2	87	82	83.4	75.3			85	68	E	3	C				E		
3	90	81	83	76.5			85	70	E	1	SC	4	M3	E	E		
4	88	77	81	75.5			83	78	0	0	OC	8	M3	E	E		
5	86	80	82.8	76.8			84	72	E	3	C	5	LI	E	E		
6	86	81	83	76.3			84	73	E	3	C	2	LI	E	E		
7	86	82	82.8	76			84	72	E	3	SC	1	LI	E	E		
8	87	82	83.3	77.2			85	74	E	2	C	2	LI	E	E		
9	93	81	83	77.3			84.2	80	E	3	SC	2	LI	E	E		
10	86	80	82.8	77.8			84	78	E	3	SC	3	LI	E	E		
11	86	81	82	76			84	71	E	3	C	0	0	0	E		
Sums																	
Means																	

Date	Humidity Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation Kind	Time Began	Time Ended	Amount ---- a.m.	---- p.m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms Intensity	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
1	70	60	E	C				0	0	0											
2	78	61	E	SC				0	0	0											
3	82	54	E	SC				0	T	T											
4	90	61	NW	SC				.75	.44	1.19											
5	90	63	E	SC				0	0	0											
6	76	60	E	SC				0	0	0											
7	81	60	E	SC				0	0	0											
8	78	66	E	C				0	0	0											
9	86	59	E	SC				0	.15	.15											
10	81	61	E	SC				0	0	0											
11	81	59	E	SC				0	0	0											
Sums					Number of days* .01"+ .10"+ .25"+ .50"+										No. thunderstorm days ----*						

REMARKS

41

August 1 temperature and other data were as of 11:20 a.m., one hour ahead of Australian time or one hour ahead of Guam time, when the Hygrothermograph needle indicated 10 p.m., so that the graph for this past week is in error. A new graph sheet is being inserted as of 11:30 a.m.

August 3, 9 p.m., - wind of Force 4 coming from SSE, light rain starting.

August 4, light surface winds during day from NW but rain clouds came from the east.

August 8 data was taken at 9 a.m. for the morning period.

Form 1009-E

(See instructions on cover)

Location: Kapingamarangi Eastern Carolines	Section ---- Twp. ---- Range ---- Meridian ----	U. S. DEPARTMENT OF COMMERCE WEATHER BUREAU 10-Day Fire-Weather Record	Elevation (feet) ---- Pres. Table ----	TIME USED (check one): PST / MST / CST / EST	Month AUGUST Year 1954 Dates 12 To 21, incl.

Time ---- a. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
12	84	83	83	75.8			E	3	C	5	LI	E	E		
13	83	80.8	82.8	75.1			E	3	SC	1	LI	E	E		
14		79	82	74			E	2	SC	5	H6	NE	E		
15	82	76.8	78.5	73.5			O	O	SC	6	H6	N	E		
16	83	78	81	75			E	1	SC	3	LI	E	E		
17	82.5	78	82	76			E	2	C				E		
18	82.5	79	83	76			E	3	SC	1	LI	E	E		
19	83	79	83.2	76.2			E	3	SC	2	LI	E	E		
20	83	79	82.1	76.5			E	3	SC	1	LI	E	E		
21	83	81	82	76			E	3	SC	2	LI	E	E		
31															
Sums															
Means															

Time ---- m.

Date	Temperature: DRY	Temperature: WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
31													
Sums													
Means													

Time ---- p. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Dewpoint	REL. HUM.	Hygro. Check: Temp.	Hygro. Check: Rel. Hum.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
12	89	82	83	75			84	69	E	3	C	2	LI	E	E		
13	88	81	81.5	74			83	68	E	2	SC	7	H6	NE	E		
14	93	81	81	73.8			83.5	67		0	SC	8	H6	NE	E		
15	90	83	83	75			84.2	68	E	2	SC	3	M3		E		
16	90.5	80	82.5	75			84	69	E	2	C				E		
17	94	81	81	76			84	74	E	2	SC	2	H6 M3	E	E		
18	87	81	82.3	74.5			83.7	71	E	2	C				E		
19	90	82	83	77			84.3	76	E	2	C				E		
20	92	81	82.5	76.2			84	77	E	3	C				E		
21	94	81	82.2	78			83	83	E	2	C				E		
31																	
Sums																	
Means																	

Date	Humidity: Highest	Humidity: Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Precipitation: Time Began	Precipitation: Time Ended	Amount: ---- a. m.	Amount: ---- p. m.	Amount: 24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Thunderstorms: Time First Observed	Thunderstorms: Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
12	76	57	E	C				0	0	0											
13	77	51	E	SC				0	0	0											
14	72	48	E	SC				0	0	0											
15	80	52	E	SC				0	0	0											
16	82	53	E	C				0	.005	.005											
17	85	54	E	SC				.02	0	.02											
18	81	61	E	C				0	0	0											
19	92	58	E	SC				.01	0	.01											
20	89	55	E	C				.07	0	.07											
21	87	55	E	SC				0	T	T											
31																					
Sums					Number of days*: .01"+ / .10"+ / .25"+ / .50"+										No. thunderstorm days ----*						

REMARKS

41

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section .... *Twp.* .... *Range*....
Meridian ....

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ......
Pres. Table ......

TIME USED (check one): PST | MST | CST | EST

Month AUGUST
Year 1954
Dates 22 *To* 23, *incl.*

Time .... a. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
22	83	77	81.2	77			E	3	OC	9	L8	E	G		
23	82	80	82	76.3			E	3	SC	4	L1	E	E		
31															
Sums															
Means															

Time .... m.

Date	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
22													
23													
31													
Sums													
Means													

Time .... p. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Hygro. Check: Temp.	Hygro. Check: Rel. Hum.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
22	85	77	82.2	76.2			83.5	77	E	3	OC	10	L8	E	E		
23	86	81	82.5	76.5			84	75	E	3	C				E		
31																	
Sums																	
Means																	

Date	Humidity: Highest	Humidity: Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Precipitation: Time Began	Precipitation: Time Ended	Amount: .... a. m.	Amount: .... p. m.	Amount: 24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Thunderstorms: Time First Observed	Thunderstorms: Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
22	93	86.5	E	OC				.39	0	.39											
23	77	62	E	SC				T	0	T											
31																					
Sums					Number of days*: .01"+	.10"+	.25"+	.50"+							No. thunderstorm days ....*						

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