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Northern Marshall Islands Expedition, 1951-1952. Narrative

by

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Northern Marshall Islands Expedition, 1951-1952. Narrative [1,2]

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Introduction

The Northern Marshall Islands Expedition, dubbed "Project Atoll" for ready reference, was accomplished during 1951 and 1952 as a part of the Pacific Geological Mapping Program currently being carried out cooperatively by the Office of the Engineer, Headquarters, Army Forces, Far East and the U. S. Geological Survey. The expedition was attached to a large surveying project of the Office of the Engineer, Hq, AFFE for establishing mapping control on the atolls of the Marshall Islands. Transportation and logistic support were furnished by the Engineer surveying vessels. The primary objective of Project Atoll was to collect geological and botanical information. The circumstances of the trip made possible only a reconnaissance study of some of the major islets of each atoll visited. Emphasis was placed on studies of the geology, hydrology, soils, and vegetation; observations of land and marine ecology, land and marine zoology, and other subjects were made as time and circumstances permitted.

The personnel varied from time to time. The four who participated were F. Stearns MacNeil and Charles G. Johnson, geologists, Ted Arnow, hydrologist, and F. Raymond Fosberg, botanist and general ecologist. Principal attention was directed to the following atolls: Pokak, Bikar, Utirik, Taka, Ailuk, Jemo, Likiep, Kwajalein, Lae, Wotho, Ujae, Ujelang, and Wake, with minor observations, either on the ground or from the air, of a number of other islands in the Hawaiian Group, Marianas, Volcano Group, and Japan.

Since much material and information of great scientific interest was collected, and various technical papers are projected on different aspects of the results, it seems worth while to present a preliminary general account, in the form of an itinerary and informal narrative, with dates, series of collection numbers for biological material, and some description of the islands and of the scientific investigations carried out. The account will be given in more detail for the activities of the author of this paper, leaving it to the others, if they care to, to write any detailed story of their own work. Geological and hydrological observations will occasionally be mentioned, however, because of their essential connection with an understanding of the ecology of the islands.

In this article the soils and vegetation of the northern Marshalls will not be described, except incidentally. Since preliminary notes on the birds observed will be presented in papers to follow, as well

as lists of plants and animals collected, these birds, plants and animals will be mentioned only in connections of very general interest in the narrative. This account will serve as a reference for future papers, in which space may not be available for more than the essential observations on the subjects treated. As formality is not necessary, the narrative will be written in the first person.

Owing to circumstances, which will become clear as the account goes on, it became necessary to divide the expedition into two separate parts; one of these, with MacNeil as party chief, worked from October 1951 to April 1952, and the other, with Johnson as party chief, from July to August 1952. The participants met in October in Tokyo, where plans and preparations for the actual trip were completed.

Trip to Japan

My own trip started from Washington, with travel by commercial and military aircraft. After a few days in California and Honolulu, conferring on coral atoll ecology with workers whose fields of knowledge have a bearing on this subject, I left for Tokyo. My first actual atoll stop was a brief one on Johnston Island on the morning of October 22, 1951.

This small patch of sand originally had a vascular flora of three species. After the development of an airbase there at the beginning of World War II, plants introduced both deliberately and accidentally raised the flora to 27 species by 1946 (see Fosberg, Pac. Sci. 3: 338-339, 1949) and to 30 species by 1950.[1] Of these several ornamentals had reached a fair size by 1951. Casuarina equisetifolia was at least 8 meters high. Calophyllum inophyllum, Thespesia populnea, Terminalia catappa, and Hibiscus tiliaceus were 2 or 3 meters high, and the last two were rather chlorotic in appearance. Most sloping surfaces, embankments, bomb shelters, and the like were quite covered by a blanket of herbaceous vegetation--Boerhavia, Cenchrus, Eleusine, and Tribulus. Most flat surfaces were kept clean by traffic. Many weeds, such as Portulaca oleracea, Amaranthus viridis, and Euphorbia hypericifolia, grew around the bases of buildings. Pluchea odorata was common, but not as common as in 1946, while Pluchea indica had also become common. Only one coconut seedling was seen.

After crossing the international date line, we sighted Wake Island late in the afternoon of October 23. The general vegetation in the neighborhood of the airstrip is a scrub of Messerschmidia argentea not over 2 to 3 meters tall, with some admixture of Scaevola locally. Open areas are occupied by pure stands of Fimbristylis, which seems to colonize the most extreme habitats, such as the edges of airstrips, and by Ipomoea tuba, which also climbs in the scrub as well as creeping over the ground. Around the buildings are various weeds, of which Cenchrus is most common and forms pure patches. Heliotropium anomalum is common, with no evident floral dimorphism. There are some marshy depressions, perhaps artificial, along the airstrip away from the terminal. The stop here was also only a brief one for fueling.

Iwo Jima was reached at midnight, therefore little was seen of its features. Chloris inflata was abundant around the airbase.

1/ Additional introductions are listed by Newhouse, Pac. Sci. 9: 91-92, 1955.

Japan, on our arrival, was completely blanketed by clouds. One glimpse through them of green terraced hills and the conical peak of Fujiyama towering far above, proved that we had reached our destination. We came down through the clouds over Tokyo Bay, with its myriad of fishing boats, rows upon rows of fences for algae cultivation, and the gray, smoky cities of Yokohama and Tokyo on its shores.

MacNeil had been in Japan for several weeks, working with Johnson on plans for the expedition. Arnow flew up from Guam for two days to talk over plans, then returned there to join the ship on its first fueling stop at Kwajalein.

The three weeks in Japan, while we waited for last minute preparations, were well spent meeting Japanese botanists, visiting Japanese herbaria, and checking equipement and supplies for the expedition. Weekends and a trip to Fukuoka to visit Prof. Hosokawa gave a few opportunities to see the interesting and beautiful Japanese countryside.

Pokak and Bikar

On November 16 the ship, the Army FS-367, Captain Marvin Shoaf commanding, carrying a Japanese surveying party of some 40 or more men, 10 U.S.Army personnel under the command of Major Paul L. Hudson, and MacNeil and myself, left Tokyo Harbor. A direct course was set for Pokak (Taongi) Atoll, the northernmost of the Marshall Islands and the first scheduled stop of the expedition. Not a living thing was seen on this stretch, except a few flying fish after the fifth day. On the night of November 24 the ship slowed down and the cries of sooty terns told us that land was nearby. Anticipation of the visit to Pokak Atoll was heightened by a rumor of mysterious basaltic megaliths, found there by John Cameron, a Pacific trader and adventurer, and recounted briefly in the story of his life , "John Cameron's Odyssey" (p.397, 1923). Such stones would indeed be remarkable on a coral atoll 600 miles from the nearest volcanic land.

On the morning of November 25 we awoke to a clamor of birds, and the low gray-green strip of vegetation and white breakers half a mile to the north was Pokak Atoll. A black-footed albatross flew by, the only one seen on the trip.

Pokak Atoll is crescent-shaped, with a single, narrow boat passage on the concave western side. This being the leeward side, at high tide the entrance should normally have been passable to small boats, but on this occasion a heavy swell was coming in from the west and breaking clear across the passage, out of which a strong current was pouring. Inspection by small boat parties convinced the Major that landing was dangerous and impractical, and a decision was made to leave for Bikar, the next atoll to the south. Before departing we were able to follow the south and east coast, where there are islets, to the eastern extremity of Kamome Islet. Sea birds were generally abundant, but over Kamome they almost darkened the sky. The vegetation here was in especially poor condition.

No further description will be given here, as Pokak Atoll was visited again later.

Bikar was sighted on the morning of November 26. Its three principal islets were completely covered by what appeared to be Pisonia forest, except for some storm-swept bare areas and a small coconut grove on Bikar Islet.

Here again, there is only one channel into the lagoon, located on the west or leeward side. A short inspection of this passage convinced the Major that this also was impassable, and we departed for Utirik Atoll, which we reached the following morning. We did not get ashore, however, until November 28, and were there until December 4.

Utirik Atoll

Utirik Islet, the main land-mass on the atoll, is very largely covered by coconut groves, except for a belt of thick scrub and forest on the northeast or windward coast and the long, almost bare projection along the reef to the west. The village is on the lagoon shore of this islet. In the northern Marshalls there is usually only one village on an atoll, commonly located on the largest islet. This islet usually bears the same name as the atoll, as also does the village.

The coconut groves on Utirik were rather open and free of undergrowth. It was immediately evident that a typhoon (Typhoon Georgia, March 21, 1951) had recently visited the island. Large numbers of coconut trees were knocked down, mostly in a southerly or southwesterly direction. Practically no ripe coconuts were to be seen in the trees or on the ground, and no copra was drying. On the western projection of the island most of the loose material was removed, exposing large root systems of dead and unrecognizable plants. The Pemphis bushes that grew here were in a very battered and ragged state. Curiously enough, though, the ridge of low dunes along the lagoon side of this strip of land was well vegetated with fair-sized bushes of Scaevola, Messerschmidia, and Pemphis and showed no signs, whatever, of typhoon damage.

Evidence of an earlier typhoon was quite clear in the form of a rubble bar in the lagoon opposite the bare portion of this extension of the island, its end at the point where the coconut grove ended. That this was not a result of the 1951 typhoon was indicated by the facts that all the fallen trees pointed in the opposite direction and that the bare area and rubble bar were both evident on aerial photographs taken in 1944. The earlier typhoon was severe enough that loose material up to substantial boulder size was swept off this narrow portion of the island and piled in the lagoon. Relatively little vegetation, except scattered Pemphis bushes adapted to growing on bare limestone rock, had reappeared in the 35 or more years since this storm. The natives tell of a storm about 1918 but are not certain of the year. It is quite possible, though that we were observing the effects of an earlier storm, in the last part of the 19th century.

Some areas of bare coral sand were characterized by a thin crust of sand held by a mass of blue-green algae. Rains were frequent enough to keep this sand washed fairly free of salt, but once in a while very high tides would give it a salt-water bath in low areas. This happened at least

once or twice in the days that we spent there.

The Polynesian arrowroot, Tacca leontopetaloides, grew in unusual abundance and luxuriance as ground cover in the coconut groves here. Each year, in the late fall, it fruits and dies down to the ground. Here it was beginning to turn yellow, and the fruits were essentially mature. The tubers, mistaken for potatoes by other members of our party, were being harvested in some quantity by the Marshallese. They were grated and the starch was washed out and dried in large balls, about the size of a child's head. Whether this was normally so widely practiced was not certain. It may have been a result of food shortage because of the typhoon. There was some complaint about lack of flour.

Several pit wells were observed, and the water in them was surprisingly fresh. Dragon flies and damsel flies were seen around them, but no mosquitoes were noticed. Several holes were dug in an attempt to get water samples and to study the behavior of the ground-water body, as well as to collect soil samples. The upper layers of the soil were surprisingly black. Digging was extremely difficult because of the amount of rubble in the soil and because bedrock was usually reached above the water table. This bedrock is a curious cemented fine coral gravel, quite hard, but shattering completely under a hard blow of a hammer.

In the central part of the islet are a number of elongate depressions or trenches about 10 meters wide and 2 meters deep. They are said by the natives to have been made by the "old people," and are doubtless long-abandoned taro pits. They have been abandoned long enough to have mature coconut trees growing in their bottoms. In the bottom is a layer of black mucky soil almost 6 decimeters deep. A hole dug in the bottom of one of these reached water at less than 1 meter. The water had a strong hydrogen sulfide odor and a peculiar sweetish taste.

On the northeast part of the islet, near the edge of the coconut plantation, but within it, were noticed some curious low rounded mounds of small, sharp, broken coral fragments. Their origin was not apparent. On these mounds Fleurya ruderalis and Boerhavia diffusa are common.

On Bekrak Islet, north on the reef from Utirik, is a tiny mangrove swamp, serving as a wallow for pigs. On the north passage beach of this islet small pumice pebbles were embedded in a bank of white coral sand that was being cut away. These were, in most cases, entirely enveloped in a casing or capsule of closely matted small Scaevola roots. Apparently there is something in this pumice, floated across the sea from some far-off volcano, that the Scaevola plant needs, and that is deficient in the coral sand.

Eluk Islet, to the north of Bekrak, has few coconut trees and much natural scrub vegetation. Dark-blue velvety butterflies (Hypolimnas bolina), were abundant here, visiting the flowers of Achyranthes.

Here on Utirik, when our ship returned from fueling at Kwajalein, we were joined by Ted Arnow, third member of the scientific party. After this the task of supervising the digging of holes or wells for water and soil samples was largely taken over by him, leaving more time to tramp

the islands, making geographical, vegetational and general ecological observations and collections.

At our camp on the open western projection of Utirik Islet, I had a canvas shelter built to protect my plant drying stand. Unable to get the preferred type of kerosene stove in the United States before starting on the trip I had allowed myself to be sold two stoves of a type I had not seen before. About the third evening, one of these set the plant presses and shelter on fire. Fortunately all specimens were saved, but the shelter was a total loss.

Taka Atoll

On December 4 we departed for Taka Atoll, just over the horizon, with a feeling that we had barely started to learn something about Utirik. The last observation made on Utirik was of a white-tailed tropic-bird flying over the lagoon, the only one I was to see until many months later.

We arrived at Taka the same day but did not go ashore until December 5. Because the ship could enter Taka Lagoon, we did not camp ashore but returned to the ship at night. Here, after some investigation, I decided that plant-presses could be dried in the funnel of the ship. There were doors on the funnel sides, and a rack between the hot exhaust pipes, on which the presses could be laid. Soil samples also could be placed in their bags on this rack to dry. The Chief Engineer, Charles Frey, readily consented to this use of his facilities, and plants were dried this way for the rest of this leg of the trip. For the first week or so, close watch was kept, but there seemed no danger whatever of fire. Drying was quite satisfactory, except when the ship was anchored in lagoons for considerable periods. Then there was not sufficient heat and, in spite of the use of formalin, a few specimens molded.

Taka is an uninhabited atoll with rather little land area. It has one fair-sized islet, two small ones, and several bare sand bars. The largest, Taka Islet, is roughly rectangular, and only a third or fourth of it along the lagoon beach was planted to coconuts. The rest is brushy woods with a few openings and one small grove of typhoon-beaten large Pisonia trees. The ground in the coconut grove is luxuriantly covered locally by the fern Polypodium scolopendria, which is practically absent from nearby Utirik. This islet is occasionally visited by the Utirik people when copra is harvested.

Several pits were dug on Taka Islet to examine soil profiles and to obtain water samples. One of these, dug to a depth of over 2.5 meters, showed an interesting series of buried soil horizons. In most of the holes, rock layers were encountered that prevented us from reaching water.

Lojiron Islet, a very small one to the north of Taka Islet, has a tiny but beautiful grove of Pisonia trees. Some of these had been knocked down by the typhoon, showing their very shallow root systems with no strong taproots. The trees were not dead but were sending up quantities of vigorous sprouts all along the trunks. The surface layer of the soil here is a black peaty material or raw humus a few centimeters thick with a pH of 5.6 to 6 when unmixed with sand, whereas that of the coral sand or materials mixed with it is about 8. This accumulation of humus, as well as its low pH, was a rather unexpected phenomenon on well-drained limestone

soil in the lowland tropics.

The rock slope from the general level of the islet down to the reef flat demonstrated some of the processes by which raised reef surfaces are gradually reduced to a base-level at about low-tide mark. Conspicuous among these processes are the formation of solution basins and the spalling off of slabs. Where this slope was covered with sand and gravel, processes of colonization by plants were also very apparent. Portulaca and Lepturus are the most conspicuous and abundant early contingent, with Messerschmidia and Scaevola appearing in smaller numbers and apparently slightly later.

Wotwerok Islet, west of Taka on the south reef of the atoll, is a barren-looking, rocky flat only a few acres in area but inhabited by great numbers of birds. In order to have more opportunity to study the extreme ecological conditions exhibited, I had myself put ashore there alone, to be picked up the next day. The vegetation is generally a sparse to dense Messerschmidia scrub, with some mixture of Pisonia and Scaevola.

There are irregular openings with Lepturus, if the soil is sandy, and with Fleurya and Boerhavia if entirely stony, and large areas on the two seaward corners are entirely bare. The Fleurya is an unusual population in that it shows no traces of red color in stems or leaves. Obviously two species of Boerhavia are present, showing a series of distinct morphological characters as well as the fact that one is not attacked by the white rust, Albugo platensis, whereas the other is frequently attacked. This fungus changes the habit of parts of its host from elongate prostrate to short erect branches, probably a type of witches-broom effect. For this reason these infections are easily seen, and the parasite is known from plants of the Boerhavia diffusa complex from widely scattered localities in the Pacific.

This islet is a great tern rookery, as thousands of sooty terns, two species of noddies, and fairy terns, all nest there. The sooty terns, or wideawakes, lay their eggs on the bare gravel on the seaward side. When disturbed they fly up in great clouds. They so resented my presence that after I went to bed a large column of them flew screaming above my cot, circling and circling. They kept this up steadily from about 6:30 p. m. until about 7 a. m., making it rather difficult to sleep.

To the seaward of this islet is a definite coralline algal ridge, even though it is on the south reef. The tide was low enough so that a short trip out to the edge of the reef was feasible, and a number of algae, mainly lime-secreting ones, were obtained. The algal flora, however, is relatively meager. The land flora is extremely restricted, only 11 species being observed. Insects and other small land invertebrates were common, however, and a considerable number were collected.

The Taka Atoll plant and animal collections are important because they very likely come closer than those from most other islands to representing the flora and fauna of the northern Marshalls prior to the coming of man. No flies and no rats were seen; but grasshoppers, one mosquito, and two lizards-- a skink and a gecko--were noticed.

Likiep Atoll

On December 10 we left Taka bound for Ailuk. However, Ted Arnow had developed an ailment, and it was necessary to get him to more experienced medical attention than was available on the ship. By radio it was ascertained that the Air-Sea Rescue PBM plane from Kwajalein would not land in Ailuk lagoon but would come to Likiep, so we changed our plan and made Likiep our next stop. We reached it and anchored in the lagoon on December 11, and the PBM arrived promptly to take Ted to Kwajalein. We were sorry to see him go, as he was both an excellent companion and a great help with the work of the expedition. We hoped that his trouble would prove to be minor and that he would return shortly.

Likiep was an atoll that I had visited on the Economic Survey in 1946, so I chose to concentrate my efforts on a different islet than Likiep Islet, studied then. The astronomical party of the surveying team set up their station on Lado Islet, so MacNeil and I moved ashore with them. Before going to Lado, I visited Likiep Village and renewed acquaintance with the local magistrate, Anton DeBrum. Anton, a middle-aged Marshallese halfcaste, is head of the DeBrum family, rivals of the related Capelle family for leadership in northern Marshall affairs. I well remember a celebration of the birthday of an elder of the Capelle family at which I was a guest in 1946. The two families displayed their friendly rivalry in doing honor to this old gentleman, and I had a chance to observe, from a vantage point, Marshallese high society at an important function.

On Likiep, also, I met a priest, Father McCarthy, with whom I later had some interesting talks. A brief walk on the islet confirmed the impression gained in 1946 of very thin soil and sparse vegetation in the coconut groves south of the village, probably an effect of the great typhoon that swept the atoll clean about 90 years ago. This same sparseness of vegetation is apparent on Lado Islet, especially on the east end.

Being entirely planted to coconuts, Lado has a singularly uninteresting vegetation. This, with the fact that I had collected many Likiep plants in 1946, made it possible to concentrate more on other things such as collecting insects, water samples, soils, and algae on the windward reef. The moon was almost full, and one night was largely spent lobster hunting out on the reef flat and algal ridge of the windward reef. The night life of the reef was observed and, incidentally we had lobsters for breakfast next day.

My own visit to Likiep was short, as I had decided to visit Jemo Island with a small party of surveyors who were to spend several days there. Before leaving I spent one night and most of a day on Likiep Islet, talking with Father McCarthy and walking around the islet. With low-level aerial photos taken during the war, it was possible both to test my ability in identifying plants on the photos and to assess changes in the island.

Plants collected on Likiep (mostly on Lado Islet) were largely algae. A search was made for Hippobroma longiflora, a poisonous weed newly established in 1946. I had then advised the natives to destroy it, and they apparently had, as I found none on this visit. Anton confirmed that they had pulled it up whenever they had seen it.

Jemo

Departure for Jemo was on December 18, and the voyage took only two hours. Landing there is never very certain, and this landing could have been exciting, but beyond a wetting there was no especial incident. The ship left for Likiep again as soon as we were ashore.

Jemo is a tiny egg-shaped patch of land, less than one-tenth of a square mile in area, on the end of a reef about 4 1/2 miles long. In pre-European times the Marshallese kept it as a sanctuary for birds and turtles, visiting it only once a year to harvest a limited number of these animals and their eggs for food. It was largely cleared and planted to coconut trees by the Likiep people 50 or 60 years ago. Fortunately for my investigations, they left a strip of vegetation completely around the island. Jemo is uninhabited, though there is a small frame house there for use during the times when copra is harvested. Fortunately we were permitted by the owner to occupy this house during our visit, so that less of our limited time was wasted making camp, and protection from the rain was more effective. My first act on entering the house was to collect a scorpion, which was the first and only record of this species (Isometrus maculatus) from the Marshall Islands. It was the common pan-tropical house scorpion, but that it should have been collected only here, on an uninhabited island, is curious.

On landing, the enlisted men in the party were quite excited at what they first thought were tank tracks going straight up the beach from the water's edge. It was obvious that they were tracks of sea turtles that had come ashore to lay their eggs. When I walked around the island, I counted the number of fresh tracks in the undisturbed sand and found 44 in all, indicating that 22 turtles had come ashore the previous night or two. At the top of the beach, in the edge of the vegetation, were wide, shallow pits and mounds of sand. We dug in several of these pits, looking for eggs. This was exactly what the turtles had intended we should do. They had been smart enough not to lay them in the obvious place. We eventually found the eggs in a small, deep hole under the pile of sand excavated from the main pit. In this hole were 106 eggs, white, spherical, and somewhat elastic, about the size and appearance of pingpong balls, packed together under 2 feet of sand. When cooked, the whites of these eggs did not coagulate; and scrambled, they tasted more like soft cheese than chicken's eggs.

It was just past full moon the first night we were there, and at about 1:30 a. m. I went out with two of the boys to see if any more turtles had come ashore. After walking around almost the entire sandy part of the island we found two sets of fresh tracks, one going up the beach, and one down. A large dark form was seen just about to enter the water. Racing to it, we found a turtle, stopped it, and with some effort, turned it over on its back. After struggling violently for a bit, slapping wildly with its flippers, it calmed down, emitting a sighing "ah'h" sound, with tears running from its eyes. Seeing this, one of the boys, an American-born Japanese interpreter, who had been all excited about having turtle meat, asked me anxiously if I were going to kill it. When I told him that I wanted only to take pictures of it the next day and then to let it go, he was relieved. The tears had changed his mind about turtle meat.

Next day we got some excellent pictures of this large specimen of green turtle before sending it back to sea. The Japanese surveyors did not think much of this procedure, it being considered bad luck to molest turtles. In fact, when the sea got choppy later, and there was some doubt that we would be able to get off the island, there was some muttering that it would have been better if we had not bothered the turtle at all.

When the island was cleared a strip of vegetation 30 meters or more wide was left completely around the island. On the west side this strip is a magnificent forest of giant Pisonia grandis trees. Elsewhere it is lower and of mixed scrubby forest. This forest grows mostly on a ridge of dunes 5 to 6 meters above low-tide level, not high, as dunes go, but striking for a low coral island. It was fortunate for my investigations that this belt of forest was left, as in it I first got an idea of one of the most interesting sets of relationships that were to appear as results of the expedition.[1] It was noted here that the surface of the ground in the Pisonia grove was covered by a thick layer of a peat-like material, similar to the "raw humus" or "mor" of northern forests and heaths. Under this was a layer of cemented sand, the cement dark brown, that corresponded to the descriptions I had been given of phosphate rock on Arno Atoll. Red-footed boobies were nesting in the trees, and the ground was liberally spattered with white guano. Broken and weathered pieces of rock were abundant in the half of the coconut plantation next to the Pisonia grove but were absent in the other half of it. The part of the coconut plantation with the rock fragments was dense and luxuriant; the other part was in very poor condition, and most of the older trees were dead or dying.

The island was combed for plants and land animals, and good collections were made. Descriptions were made of the vegetation, the topography, and the arrangement of beach rock and peripheral ridges; and soil profiles were examined. It would seem that more than four days on such a tiny speck of land might be almost enough, but when the ship came for us on December 23, I felt that only a preliminary examination had been made and that if only a few more days were available I might begin to learn just what was happening in this microcosm.

Much to my delight, Ted Arnow, having recovered completely, was aboard.

Ailuk Atoll

Ailuk was sighted late in the afternoon, and we were able to enter the lagoon through the north passage on the west side, where we dropped anchor not far inside. Two days, including Christmas, were spent on board getting collections taken care of and notes in shape. The Christmas dinner produced by Captain Shoaf's steward's department was a great achievement, and was the gastronomic high point of the expedition. To our surprise we were served everything we would have had at home or in a fancy stateside restaurant.

MacNeil and Arnow had gone ashore on Christmas eve and had established camp on Ailuk Islet, at the south end of the lagoon. I joined them on the 26th, but spent the entire day getting there from the ship.

1/ See Soil Science 78: 99-;07, 1954.

Since we arrived at Ailuk a stiff tradewind had been blowing continuously, and it neither stopped nor slackened the entire time we were there. If I had needed to be disillusioned about calm tropical lagoons this day on Ailuk lagoon would have done it very well. The waves on the lagoon were fully as rough as on an ordinary day in the open sea. Travelling in an open motor whaleboat meant a continuous drenching. The water was not really cold, but because of the wind everyone was sure that it was. With one stop to put up a surveying signal on the reef, and an hour ashore on Akulwe Islet, the only one on the west reef of Ailuk, we spent all day going the 13 miles from the ship to the main island.

Ailuk Islet is by far the largest islet on the atoll, and is situated on the southeast corner of the elongate ring-like reef. It is almost entirely covered by coconut and breadfruit trees, which provide much of the livelihood for the 413 people. At the southwest corner of the islet is a triangular projection of sand with a hook-like spit on the end of it. This small peninsula is bare of trees except for scattered Pandanus, and here the party of surveyors had set up their camp, and MacNeil and Arnow had been comfortably established for two days when I arrived. The people of Ailuk, who are extremely friendly, had welcomed both Americans to their Christmas festivities, and after I arrived, brought presents and invitations to a village party. Their help in digging holes for water and soil samples facilitated our work greatly.

Some distance back of the village on this islet is an area of several acres where the otherwise healthy coconut groves seem to be in sorry condition. They resemble those on the eastern half of Jemo Island in that most of the old trees are dead or dying, but young ones are not present. Also, the soil here is black, as black as any seen on any of the islands visited. Nothing was apparent in the pit dug in the soil, or in the samples secured, that would account for this condition. The remaining trees still standing did show more than usual signs of fire around their bases, so that it is conceivable that a severe fire may have killed most of the trees.

Old taro pits are abundant near the center of the islet, most of them being elongate and winding, with the excavated material piled up as much as 2 meters above the general ground level between them. Coconut trees are growing on their bottoms, and they are choked with Clerodendrum and Ipomoea. One or two pits are in the village near the lagoon. These show a few persisting plants of Cyrtosperma, and still have a good muck layer in the bottom, highly organic and very wet. But taro culture is just as effectively abandoned here as in the other northern Marshalls. And here, as elsewhere, Paspalum vaginatum forms a dense mat on all recently used pits. Ailuk, like Likiep, has abundant and healthy breadfruit trees around the village. They do not, however, extend much beyond halfway to the outer side, and at this distance are very yellow and unhealthy looking. One healthy tree, however, grew on the boulder ridge on the southwest side only about 16 meters from high-tide mark.

After determining that it would be possible to walk from islet to islet at low tide, and that there were low tides about midday, I decided to walk northward along the chain of islets on the east, or windward reef of the atoll. I arranged to be picked up at one of the surveying stations on an islet about the middle of the atoll two days later. With a pandanus

mat, a gift from the villagers, to sleep on, C rations for food, two canteens of water, machete, insect net, and collecting vials, I left in the middle of the morning.

These islands all seem to be remnants of an old higher reef platform that had its surface well above present high-tide level. Most of this platform on every islet is covered by loose material, but the seaward ends have been recently swept clean of loose material and vegetation. Along some passages there are wide exposures of rock surface. On these, though, there is a well developed forest of Pemphis acidula, dense and impenetrable. After a fair number of these islets were examined, a vegetation pattern became apparent. The lagoon side in most places had been planted to coconuts, leaving a crescent-shaped band of native scrub and forest around the seaward sides and extending along the passages between the islets. The outer edge of this is low scrub; principally Pemphis if the substratum is rock; Scaevola, Messerschmidia, Guettarda, and Suriana if sand and gravel. The Pemphis does not seem at all inconvenienced if its roots are covered by the sea at high tide. The trees in this band become taller inward, until a well-developed forest, principally Messerschmidia, Pandanus, Guettarda, and Ochrosia, forms an excellent windbreak to protect the coconut trees against the strong spray-laden trade winds.

The need for haste to take advantage of the low tides did not permit very careful study of these islets, but extensive notes were made and some facts became obvious. Perhaps the most interesting thing was that, at least during the trade-wind season, there is no reversal of the current flowing between these islets with the tide. The flow is always into the lagoon on this side, if the channel is deep enough to contain water at low tide. At high tide the current is like that of a millrace, quite capable of sweeping a man off his feet, as I found out. The water, of course, drains out of the lagoon over the leeward reef, which is lower, mostly below low tide level, and not obstructed by islets.

On some of the islets were native huts, not permanent residences, used apparently only during copra harvesting. On most of these islets were pigs, left to shift more or less for themselves. Correlated with the presence of pigs were plagues of flies, some of the most persistent and ravenous flies that I have ever seen.

After being picked up on schedule, I was able to examine most of the other islets to the north from a boat in the lagoon, landing on only four of them. On one of these, Enejelar Islet, was a ridge of rather well-developed sand dunes; the sand had obviously been caught by the strip of scrub vegetation growing along a long spit. On the windward side of this, as well as earlier on a sand bank on Ailuk Islet, were again found pumice pebbles enclosed in a capsule of closely matted roots, similar to those observed on Utirik, certainly roots of Scaevola, this time. It was the only plant near, and one such capsule was still attached to the root of Scaevola bush. The only reasonable explanation for this seems to be a deficiency in the coral sand of some element needed by the plant that is not serious enough to prevent the growth of Scaevola.

The last stop on Ailuk was on an open stretch of the leeward reef, where the surveyors had set up a tower. The reef here is a broad surface

below low-tide level, thickly studded with coral heads and clumps, strewn with boulders thrown up by storms, some of them quite large, up to 2 meters across, and almost completely devoid of plant life. Among the abundant animal growth, bright pink clumps of Liagora were the only plants seen. The "vegetation" seemed almost entirely animal in nature.

Lae Atoll

On January 4, 1952, we left Ailuk and on January 5 arrived at Lae. Lae is a tiny atoll compared with Ailuk, but a beautiful one. From inside the lagoon the whole atoll is visible at once, and there are many well-wooded islets. For its size, Lae had more undisturbed vegetation than any other atoll we had seen up to this time. Here large patches of a peculiar forest type, very conspicuous on aerial photos, but which until now defied identification, turned out to be pure stands of Ochrosia oppositifolia, except one of very similar appearance, which is a pure stand of Barringtonia asiatica. Pure forests of neither of these trees had been reported previously, to the best of my knowledge, and the pattern that their crowns make on the photos resembles nothing else with which I am familiar.

In addition to much of scientific interest on Lae, there was other excitement aplenty. In the lagoon was anchored a small schooner that proved to be the Laura, from Likiep, which had disappeared on a voyage from Kwajalein to Likiep two and a half months previously and had been given up for lost by almost everyone. Her engine had been disabled and, with the rotten sail-canvas, she had managed to sail down-wind to Lae, far to the westward of her course and destination. Having no radio, her fate remained obscure until we were able to announce her safety.

Our own ship, after putting us ashore, left for Kwajalein. The next news we had of her over the radio was that she was laid up in Kwajalein, awaiting a replacement part, which would have to be brought from Yokohama. We thought that, perhaps, this would give us a day or two more than the scheduled time here, and would enable us to do a somewhat more thorough job of this atoll than we had been able to do on any of the others. This proved a vain hope, as the surveyors finished in less than their allotted time and a patrol boat was sent up from Kwajalein to pick us up.

Meanwhile, we got around the atoll and did the best job we could. As was expected, the vegetation was conspicuously more luxuriant here than on the atolls farther north. In the Marshalls the annual rainfall increases rapidly from north to south. Here in Lae were the first functioning taro pits, a few among the many abandoned ones. These had Cyrtosperma and Colocasia growing in a jellylike brown muck lying on a sandy bottom, with the water table practically at the surface. Alocasia has invaded these pits and in most of them has crowded out the two edible taros. The natives seem little concerned about this, as they can get rice and flour from Kwajalein only 70 miles away.

Here, for the first time on the expedition, we found Intsia bijuga, noted in Guam where it is called ifil, for its fine hard wood. This is not its northern limit in the Marshalls, however, as we later found it on Wotho. It is a notable component of the mixed forest. The mixed forest here, as well as the breadfruit forest and the coconut-breadfruit forest,

have denser canopies than seen on any other atoll so far on the trip, and the usual sparseness of undergrowth when heavily shaded was apparent. In the Ochrosia forest, mentioned above, there is no undergrowth except small seedlings of Ochrosia. In the Barringtonia forest the only other plants were a small colony of Peperomia, growing on boulders, by far the northernmost record for this in the Marshalls. This forest is especially interesting because it is growing on the inner slope of the highest boulder ridge seen in the Marshalls, about 5.5 meters above low-tide level. The trees are very large, the largest being almost 4 meters through, though the average is well under 1 meter. The natives have cut a trail across the boulder ridge, digging well into the loose material. Here it can be seen that the layer 0.5 meter or more thick of boulders was deposited after the trees had reached essentially their present size.

In the mixed forest on the windward islets, which is apparently original uncleared forest, it was noticed that the only Messerschmidia trees are very old ones. Some dead logs are found, but no young trees. Young ones are abundant, on the other hand, around the peripheries of these same islets. The obvious inference from this is that Messerschmidia is not a tree of mature mixed forest. It reproduces itself only under more or less pioneer conditions.

The patrol craft from Kwajalein came for us, all too soon, before we had had a chance to visit all of the 21 islets of Lae Atoll. We left at 3 p.m. on January 11 and arrived at Kwajalein at 10 p.m. the same night.

Kwajalein Atoll

Kwajalein had changed radically since my last visit in 1950. Then it seemed in the process of being slowly abandoned, growing up to weeds. Now it had become, again, a busy base, with much construction going on, and very little to be seen in the way of plants. The prospect of an indefinite stay here was attractive only if transportation to the other islets was available. Kwajalein Islet, itself, would afford little of interest, scientifically.

On January 13 an opportunity afforded itself to fly to Majuro Atoll for a few hours. This gave me a chance to see any obvious changes there since 1950 and to talk to the Trust Territory officials at the district headquarters there. Tobin, the staff anthropologist, provided some information on the history of Pokak, Bikar, and Jemo Atolls. He had been working on land tenure and land use among the Marshallese and had found that these three atolls had been maintained as bird and turtle sanctuaries in pre-European times, and that they were visited periodically and a limited number of birds and turtles and their eggs taken.

Such a short time was available that only a brief ride in the vicinity of the headquarters was possible. The contrast with the northern atolls in greater luxuriance of vegetation even on very narrow islets, was striking. Only one plant, a conspicuous species of terrestrial Nostoc, was collected. En route from Kwajalein, we saw Nama Atoll briefly from the air. During our flight, from a short distance south of Kwajalein to Majuro, and the same distance back, the sea was almost completely covered by a thick layer of clouds, in a season when there had been few clouds

and little or no rain for some time on Kwajalein and the other northern atolls.

The principal observations on Kwajalein Islet during the next two and a half weeks were of the effects of continued drought and severe winds on even the most halophytic plants. Even Triumfetta procumbens and Ipomoea pes-caprae were severely killed back, at least on the areas exposed to the wind. Coconut leaves were turned brown well back from the tips of the leaflets. The effects of even slight shelter were immediately evident in much greener weed growth and cultivated plants. A few weeds previously unrecorded from the atoll were picked up, such as Desmodium canum and Heliotropium ovalifolium, the latter, at least, an obvious recent immigrant from Guam, growing along the airstrip. Since 1950 Paspalum vaginatum had spread completely over the islet, Pluchea indica had increased greatly in abundance, and Pluchea odorata had decreased notably.

Kwajalein Atoll, in dimensions, is one of the largest, if not the largest atoll in the world, and has 92 islets, on its 195 miles of reef. Few of these, except the southernmost ones which were badly devastated during the War and since, have ever been studied scientifically. Efforts were made to get transportation to some of the others with only partial success. A visit to Lojjairok and Lojjaiong, on the windward reef, was managed on a "recreation" trip. These islets have been used as recreation spots for military personnel and have little unaltered vegetation left on them. Trips were also made to Enebuoj and Enewetak Islets, through the kindness of Mr. Henry Wahl of the Island Trading Co. These islets present an extreme contrast. Enebuoj was an active military establishment until 1948, when it was abandoned. Now it is covered by a dense blanket of Wedelia and Ipomoea pes-caprae vines that effectively conceal practically all traces of the former establishments, and certainly retard establishment of much else in the way of vegetation. A short distance off the lagoon shore of this islet lies the capsized hulk of the German cruiser Prinz Eugen.

Enewetak Islet, on the other hand, has scarcely been altered in any way by man. It is almost completely covered by a forest of giant Pisonia trees, the home of innumerable sea birds. This is unquestionably the finest native forest seen anywhere in the northern Marshalls, and probably the best single stand in any of the Marshall group. Here was afforded a further opportunity to study the type of phosphate rock formation first observed on Jemo Island. This islet differs from most atoll islets in being in the lagoon, rather than on the peripheral reef. It seems to be made up entirely of sand, except for the superficial phosphate bed. That it should have been left in forest is interesting, and the reason is not clear. It seems possible that this, also, may have been a bird sanctuary. This is more likely, in view of the discovery by Wm H. Hatheway (personal communication, 1952), that certain islets on Arno Atoll, in the southern Marshalls, were in pre-European times so preserved. It would be a fine thing if this tradition could be continued and such bits of original vegetation as that on Enewetak Islet could be set aside as bird and vegetation reserves for the future Marshallese.

MacNeil, during this time, was enabled to visit several of the southwestern islets, because an extra berth was available on the FS-216,

another ship of the survey then operating in Kwajalein. He made important geological observations during this period.

I was afforded a complete, if extremely quick, look at the rest of the atoll when Lt. Comdr. C.K.Brust, U.S.N., took me on a low-altitude flight around the atoll in a small training plane. Rough notes on the general vegetation patterns on many of the islets were made. On Bikej Islet, which had been visited in 1946 and 1950, it was possible to note that the scrub forest in the old U.S.Navy tank-farm had grown perceptibly, but that the airstrip was still about as bare of vegetation as in 1946. On some of the southern islets, Pemphis forest makes up a conspicuous part of the vegetation. On Nimur and Ruot Islets, at the northern point of the atoll, abandoned military establishments were covered by the usual blankets of Wedelia and Ipomoea. Ochrosia and Pisonia forests occur on some of the smaller islets. At the westernmost point of the atoll, where the reef extends for some distance beyond the lagoon, broad expanses of bare reef were marked by transverse strips of boulders, which from a distance resemble causeways. The origin of these strips does not seem evident.

Several visits to Ebeye Islet were possible through the courtesy of the Island Trading Co. officials, who have their headquarters in the native village there. This islet, also, has little or nothing left of its original character. The most striking observation made here was the amount of spray carried by the strong trade winds. The inside of the porch of the Island Trading Co. house was continually wet and dripping salt water, even though somewhat protected from the wind. The windward windows of the house had to be kept closed in order to keep anything dry in the house, even tough no rain fell during the entire period. The drinking water situation in the native village would have been serious if the Naval Air Station authorities had not sent over water from the station supply.

Ujelang Atoll

After the ship was repaired we promptly left Kwajalein on February 1, arriving at Ujelang on February 3. Here it was again possible to take the ship into the lagoon and work from her. This is a long narrow atoll with about 24 islets scattered fairly well around it. Ujelang, the largest of them, was a German coconut plantation, and the trees are consequently planted in an exact checkerboard arrangement. No Marshallese had lived there for many years until, in 1948, the people from Eniwetok Atoll were moved to Ujelang in order to permit the use of Eniwetok as a testing site for atomic weapons. These people live in a village built for them by the U.S.Navy, on Ujelang Islet. One of the things of interest to me here was to see how well these people had reacted to transplanting. When I had seen them in 1946 on Eniwetok, the war and subsequent events had reduced them to a sad state of dependence. It was interesting that there was little or no complaining, in spite of some obvious homesickness, and that these people were already much at home, though such signs as most of the canoes being out of repair did not look too encouraging.

For the first two days of our visit I had a fast sailing outrigger canoe with a crew of four enthusiastic Marshallese men at my disposal. Consequently I was able to visit briefly most of the islets on the atoll.

This type of canoe, with its lateen sail, is remarkably fast and will sail almost straight into the wind.

Here, on one of the smaller islets, I found coconut crabs for the first time on the trip, small ones only. My boat crew gathered turtle eggs, sooty tern eggs, and young noddy terns for food. Inland on Kirinyan Islet was quite an abundance of pumice pebbles about the size of a man's fist, scattered on the surface of the ground, especially on the lagoon half of the islet. The lower sides of the pebbles were closely invested in a "basket" or cup of closely grown roots. The gregarious nesting habit of the white-capped noddies was very noticeable here, also.

Comparison of photographs taken in 1944 with present conditions showed remarkably rapid growth of Pemphis forest on bare rock flats just at or above high-tide level on Enimoni Islet. On Ujelang Islet was one of the few cases seen anywhere of Pemphis growing in sand.

After two days with the canoe, the rest of the available time was spent on shore on Ujelang Islet. Along the lagoon shore, at about low tide level, was found a rather extensive strip of a sod of Thalassia hemprichii, or turtle grass, the second occurrence of this plant, and the only extensive one, known in the Marshalls. Stenotaphrum micranthum, a grass hitherto unknown from the Marshalls, possibly introduced, was found here, also. These were the only plants seen that are not common generally in the Marshalls, save a few weeds that date from Japanese or German contact with Ponape. It had been thought that, because Ujelang is so far west, there might be some relationship to the Caroline flora, but the two species mentioned are the only suggestions of such a relationship.

My attention was called to a few ostracods, minute crustacea, which were swimming in a water sample brought from Raij Islet by Arnow. To collect some I made a special trip to Raij on the last day of our stay. Returning with a good sample, I found that MacNeil had found them independently in the same well and had brought a bottle full.

Visiting a large number of islets, while giving a better geographical picture of the atoll, resulted in the number of collections of plants and animals from Ujelang being comparatively small. This should not be taken to indicate a smaller fauna than on atolls where more animals were collected.

Wotho Atoll

On January 10, with the usual feeling of not having had quite enough time to make even a good superficial survey, we left for Wotho. We arrived there on January 12. This atoll promised to be very interesting. Its land area is large and its human population small, and the aerial photos showed large areas of apparently undisturbed forest. There actually is on Wotho much more native forest in its original condition than on any other atoll in this climatic belt, and probably more than on any other of the Marshalls, excepting possibly Pokak.

Our camp was set up on the west end of Wotho Islet, the largest of the islets on the atoll. The first distinctive thing noticed here was that the mixed forest contained a large percentage of Soulamea amara, a small tree which, though widespread in the northern Marshalls, is gener-

ally quite local and not very common. The soil in this rather open mixed forest is also unusual, of a fine grayish silty character and naturally rolled up into small pellets like BB shot.

The total population of this atoll is 26. The people live in a row of widely scattered houses along the broad sand ridge at the top of the lagoon beach. These houses are connected by the usual perfectly straight, wide path, lined with slabs of coral set on edge, dating from the German period. Such paths may be seen on every inhabited atoll that I have visited in the Marshalls and Carolines. Here are a very few breadfruit trees. The vicinity of this "village" is well planted to coconut trees, most of which appear to be very healthy. However there is an area of some acres in extent back of the houses that has no coconuts and is in grass, except for scattered Guettarda and Scaevola bushes and some Wedelia. There are no dead coconut trunks and only a few very yellow coconut seedlings; the origin of this grass-covered opening is not clear. Although there are only three or four men who make copra, a considerable amount was piled up, waiting for the Island Trading Co. ship. Something about the bags in which the copra was packed seemed familiar. On examination they turned out to be "fique" coffee bags made in Bogotá, Colombia, identical with many thousands in which we had shipped Cinchona bark from the South American republic during the war. The little old man who was chief of Wotho could be seen husking and chopping coconuts for copra at any time during the day. These people were friendly and helpful and seemed glad to have visitors.

The center of the islet has a series of long, winding troughs and ridges, remains of ancient taro pits. Here and there these have been cleaned out and Cyrtosperma planted, which is struggling with the weeds. Most of the pits support dense tangles of Clerodendrum, Pandanus, Vigna, Canavalia, Wedelia, and breadfruit trees. The breadfruit trees also surround the pits.

Back of the plantation and taro pits stretches a fine expanse of pure Ochrosia forest, identical with that studied on Lae. One could walk for a good distance in the dim light that diffused through the dense canopy of this interesting woods. A feature noted in most large stands of Ochrosia studied here and on other atolls was the presence of patches where the trees are yellow and unhealthy, some even dead. There is no obvious reason for this, but the patches are apparently of long duration, as they were to be seen in exactly their present positions on aerial photos taken eight years before. On the east side of the islet, between the Ochrosia and the beach scrub is a fine strip of Messerschmidia forest of large trees with little undergrowth. The scrub belt is unusually broad here, and the Scaevola leaves at its outer edge are thickened and twisted, somewhat yellow, apparently showing the effects of too much salt spray. Scaevola does not usually demonstrate such symptoms.

The inadequacy of the published charts of these atolls is nowhere better demonstrated than on Wotho Islet. Not showing at all on the available H.O. chart is a tremendous shallow embayment on the windward side that cuts a roughly rectangular section to the middle of the islet. This embayment runs out into a sort of inlet of sand that rapidly narrows and pinches out just back of the lagoon ridge. It has every appearance

of an old stream bed, though stream beds do not exist on coral islands. A similar channel, but one that does not pinch out, cuts the northeast corner of the islet off as a separate islet, "Enerikan" of the natives, which is not shown at all on the chart. Whether these features were simply missed during the surveys on which the chart is based, or whether they came into existence subsequently, and if so, how, are interesting questions.

Ujae Atoll

Before our exploration of Wotho was well started an accident to one of the small boats necessitated stopping work and leaving for Kwajalein, to await spare parts, again to be sent from Yokohama. We left on February 15. The Major decided to call at Ujae on the way, to see what small-boat transportation might be obtained there. We anchored off Ujae on February 16 and went from the passage to the village, on Ujae Islet, in our remaining small boat. To have quieter water, as the wind was making the lagoon very choppy, we crossed to the windward side and skirted the leeward side of the windward reef. This trip to the village took several hours.

On this trip I first noticed a phenomenon frequently seen afterward. Extending out into the lagoon from the reef in the direction parallel with the wind were a series of narrow strips of smooth water resembling oil "slicks." They ranged from several centimeters to half a meter or even a meter in width. They extended out into the lagoon for several hundred meters, becoming more broken up and "braided" by the choppiness further from the reef. They also seemed to be of different "ages," judging by the freshness of appearance and sharpness of margins, the "older" ones appearing "braided" and showing signs of breaking up. They seemed to start at the reef itself, where water from the open sea was crossing it. These were seen actually in hundreds, unevenly distributed along the entire distance from Wotya Islet to Ujae Islet, at the south end of the atoll. Their origin and actual nature are completely obscure.

Ujae Village seemed unusually well kept and prosperous looking, and the people were very friendly. They had a community-owned small sailboat, the "Helper," which they were willing to rent to the surveying party, so it was decided to start surveying this atoll while waiting for the spare parts that had been requested from Yokohama by radio.

Bock Islet, on the north side of the entrance to the lagoon, was selected for the astronomical station. This islet looked very well wooded and only partly disturbed by man, so I took advantage of the opportunity and set up camp on shore with the surveying party. Only about one-fourth of the islet had been cleared and planted to coconuts, so that an excellent sample of what seemed to be the original vegetation was preserved. On the south end enormous Pisonia trees towered to about 30 meters, and in the center were Intsia at least 25 meters in height. The undisturbed parts of the islet were quite rocky. Some of this rocky ground supported a few coconut trees, as though an attempt at cultivation had been made at one time. The coconut trees there did not seem to be bearing as well as those on the sandier parts. A small family group of Marshallese had a temporary encampment on this islet and were making some copra.

Large numbers of white-capped noddies were nesting in the Pisonia trees,

and the almost full-grown young were being killed and eaten in large numbers by the Marshallese. Since the Pisonia branches are very brittle, the men did not care to climb the trees to get thebirds. One day I heard a tremendous crash in the forest. When I reached the spot I found half a large tree down and the natives catching the young birds in dozens. They had some hours before lit a fire in a hollow part of the trunk and burned it until it split apart and one half fell. The fallen part was 30 paces long.

A stay of four days made it possible to investigate this islet more leisurely and thoughtfully than was feasible on any of the previous stops. Better collections and perhaps a better understanding resulted. It was also possible to collect a series of logs of the common trees for testing. However, the first attempt of the surveyors to use the local schooner ended in disaster. They tried to enter the narrow curved passage at dusk and ran the boat on the reef, breaking several holes in the hull.

Several days of frantic efforts followed, which resulted in floating the boat off the reef, putting in temporary patches, and towing it across the lagoon to Ebeju Islet, where it was beached. Then we left for Kwajalein to get repair materials, as well as the spare parts for our own disabled whaleboat.

While at Kwajalein, through the courtesy of the Administrative Officer of the Naval Air Station, I was able to accompany a routine photographic flight over Likiep, Jemo, Ailuk, Utirik, Taka, and Kwajalein Atolls. It was most interesting to study from the air the atolls we had previously seen on the ground. Many geographical questions were cleared up, and corrections were made in the sketch maps prepared on the ground. The vegetation was quite drab and brownish after several months of dry weather and wind. Some kodachrome photographs were taken, to record the vegetation patterns of the smaller islets. It was noticed that most of the passes, especially on the leeward sides of the larger atolls, have islets or reef patches in the lagoon opposite them. Some of them also have inward-curving sand horns extending from the corners of the adjoining islets.

Captain Fretz arrived at Kwajalein, from Tokyo, as a replacement for Major Hudson as officer in charge of the surveying party. As soon as the whaleboat was repaired, on March 1, we returned to Ujae to finish the survey, as well as to finish the repairs to the wrecked schooner "Helper." The latter task was taken in charge by our able chief engineer, Charlie Frey, and the hull, when finished, was undoubtedly in better condition than before the boat was wrecked.

During this period I was able to spend time on most of the islets on the windward reef, as well as on the larger islets at the north and south ends of the atoll. Ebeju, at about the center of the east side, has a fair-sized patch of Ochrosia forest showing the same yellow patches as noted on Wotho.

In the interior of Anuij, the small islet connected to Ebeju on the south by a ridge of small dunes, was a patch a few yards square where the sand was literally covered by pumice pebbles. In places where these were

very abundant the surface of the ground was made up of a peat-like mat of roots in which the bottoms of the pebbles were embedded. This seems to be an elaboration of the phenomena described earlier, in which the pumice pebbles were surrounded by roots or enclosed in a basket-like cup of roots.

On this islet Ximenia americana is fairly common, forming small spiny thickets. Elsewhere in the Marshalls it has appeared to be exceedingly rare or absent. Its yellow, acid, plumlike fruit is quite agreeable to the palate on a hot day.

On Wojia Islet, south of Ebeju, the scrub belt, normally found on the seaward sides of windward islets, is lacking. Its place is taken by an irregular platform of rock 3 to 12 decimeters above the level of the reef flat. This platform is of several layers, which are being removed by the waves and other agents. The top layer is of very rough conglomerate, not as well consolidated as the lower, finer layers and only a portion of it, on the outer edge of the platform, remains. The lower harder layers are actively spalling off or exfoliating. It seems probable that the vegetation was at some recent time removed from this platform, exposing it to destruction by waves and weather. On this islet two interesting vegetational phenomena were evident. One was the tendency of Pisonia trees, when knocked down by wind, to send up copses of sprouts, which develop into dense thickets. The other was the ability of Ochrosia to establish itself under Pisonia. Solid stands of Ochrosia saplings were seen in the Pisonia forest wherever a seed tree was present. This suggests that once an Ochrosia tree becomes established in such a forest, eventually the forest will be changed to Ochrosia. That all the forests in this belt are not pure stands of Ochrosia may well be due only to the poor dispersal powers of the seeds. The fruits are about the size and shape of eggs, with a thick layer of corky floating tissue inside the fleshy layer and surrounding the seeds. They float very effectively and are often cast up in drift, but are probably only carried into the shady interior of an islet, where they will become established, by the relatively rare storm waves. Once established they would normally spread by being dropped from the ends of the branches of the parent trees, certainly an extremely slow dispersal. Of course storms and other accidents might greatly increase this rate. The slowness of this succession from Pisonia or mixed forest to Ochrosia forest is one of the best reasons for considering the Ochrosia forest to be one of the original vegetation types of these atolls. Stands of Ochrosia forest such as on Wotho could scarcely have come into existence in less than hundreds of years.

During our stay on this atoll there were several opportunities for further observation of the "oil slicks" extending downwind from the reefs, and described on our first visit to Ujae. These were seen to extend at least half a mile into the lagoon and, some distance from the reef, to become as much as 6 to 8 meters wide. Near the reef, where they are more sharply defined, they range from a few centimeters to 1 meter in width, and are characterized by an abrupt damping out of the surface disturbance of the water and an accumulation of small bubbles and flecks of foam in a streak near the center of the strip. They seem obviously to be caused by continuous emission for a period of time of some substance which changes the surface tension of the water. They are remarkably stable, considering

the choppiness of the water, and are much straighter and more visible when there is a fair breeze than when there is little. They present exactly the appearance that would be expected from a series of small vents of oil situated at close but irregular intervals along the reefs. It was at first thought that oil or some other substance was being carried over the reef from the open sea, but they were observed clearly in the lee of some of the islets, especially the large Enelamoj at the north end of Ujae. An attempt was made later, on Wotho, to follow one of these mysterious "slicks" to its source on the reef. It obviously originated in a consolidated rubble-flat, barely exposed at low tide, but was impossible to follow in the very quiet water in the immediate lee of the reef.

In a small area on Alle Islet, near the north end of Ujae Atoll, pure Cordia forest was seen for the first time. Here also were enormous numbers of hermit crabs, hiding in the day time in and under rotten coconut logs. They occupied many kinds of shells, but mostly those of several kinds of cerithids. A large series of the crabs was collected, as they had various markings.

The chief of Ujae Atoll is a young man named Enti, who had learned to speak English very well at one of the Navy Civil Administration schools on Kwajalein. His father, a dignified, middle-aged man, had also learned English at the same time. Both seemed to grasp very well our reasons for wanting information on the natural history of the island and on the customs of their people. Many points that had previously been in doubt were cleared up in conversation with them, and much information, especially on the utilization of fish, birds, and other animals, as well as the names by which these were called, was obtained. These people are a very attractive and interesting group.

We left Ujae for Kwajalein on March 14 and arrived there the next day. Our stay on Kwajalein this time was brief, with no opportunity to do much more than answer mail and lay in a few supplies. Ted Arnow left the party here and returned to Guam, his part of the expedition finished.

Wotho Atoll

On March 17 we left Kwajalein for Wotho to finish our work there and to make another attempt to visit Bikar and Pokak Atolls. This time, on Wotho, we spent most of our time on the islets other than Wotho itself, which we had not visited at all on our earlier stay on the atoll. These are all completely uninhabited and, except for Kabben, relatively little disturbed. On the east reef is a narrow spitlike islet, several miles long, which does not appear on the hydrographic charts at all. That it is not merely an ephemeral sand spit is evidenced by the presence of beach-rock on one side or other of it for most of the length of the part examined. Near the north end the beach-rock on the lagoon side is conspicuously pot-holed. This ridge of sand is mostly covered by a scrub of Messerschmidia, Scaevola and Terminalia, varying from scattered to continuous, and one large clump of Pemphis, a second occurrence on sand. The effect of vegetation on sand accumulation is very obvious on this islet. Where the scrub is continuous the sand ridge is conspicuous and several feet higher than in the gaps, where it is low and very flat.

On Enejelto Islet, near the south end of the east reef, the lagoon beach is covered by piled-up slabs of beach-rock, apparently thrown there by lagoon waves during storms. The process of quarrying these slabs from the beach-rock beds by small lagoon waves was very obvious, certain beds being more susceptible to solution by the continuously moving water than others, causing the harder upper ones to collapse and crack into large sections.

Kabben Islet, a large triangular piece of land at the southern tip of the atoll is partly in coconut trees and partly in completely undisturbed forest. Much of this forest is solid Ochrosia. The coconut plantation is generally sparse and has a rather dense undergrowth of bushes and small trees. On the south point of the islet is an enormous boulder ridge. Drift seeds were more abundant on the beaches of this and some of the islets on the west reef than anywhere else visited on the expedition. Most of them were of Mucuna, but some other kinds were collected also. The islets on the west reef had conspicuous sand dunes and conspicuous patches of Pisonia forest. Humus underlain by thin layers of phosphate hardpan was found on several of these islets, as well as on Eneobnāk Islet on the north reef. Birds were abundant and the humus was liberally stained with guano. On Eneobnāk the origin of the curious low mounds of coral rubble noticed on Utirik, Likiep and other atolls was clarified. Such mounds were seen around the roots of blown down Pisonia trees, with, in some cases, the mass of roots partially or almost completely decayed away. Some of the Pisonia root systems are enormous and the trees might well pry up a very sizable pile of stones. Once formed, though the sand might wash down from its surface, such a mound would likely persist for a long time, unless swept away by typhoon waves.

On our last day at Wotho, Charlie Frey, the chief engineer, took Captain Fretz trolling in a small boat, and I went along to take advantage of a chance to get ashore on Mejurwon, the third largest islet of the atoll. The fishing was exciting, several large jack and other more unusual fish being brought aboard. Mejurwon was of interest in that it had the only apparently unplanted stands of Calophyllum inophyllum seen in the northern Marshalls. This is ordinarily a tree found in villages and near houses, or solitary along paths. Here, on this completely uninhabited islet were large patches of it, clumps of good sized trees, on sandy areas near the lagoon beach. While we were on the islet we met some of the Marshallese from Wotho Islet, who had been there on a food collecting expedition. They had gathered a large bundle of dried Pandanus leaves for plaiting or thatching, a small amount of copra, a batch of turtle eggs, and three or four dozen coconut crabs (Birgus). They had roasted some of the latter and gave us several of the great claws to eat. They were still hot and the meat was delicious, somewhat similar to lobster, but with a very distinctive flavor of its own. They gave us three enormous live specimens, tied with strips of coconut leaflet. One got loose in the boat and caused quite a commotion. I preserved mine, and it is now in the U.S. National Museum collection.

Bikar and Pokak

Leaving Wotho on March 23 we proceeded northward for another try at Bikar and Pokak. We arrived off Bikar the next day and investigated the

channel. The current flowing out of the passage was too strong for the small motorboat to make any progress against it so the attempt was given up. We spent the rest of the day examining the atoll from all sides, making what notes we could from the ship. On the leeward side the "oil slicks" described above were very conspicuous, extending out from the south half of the reef as much as half a mile. Birds were abundant, and great numbers were scared up by blasts from the whistle.

Departing in the late afternoon, we were off Pokak the next morning. The passage, at low tide, again resembled the traditional millrace. There was obviously no point in trying to enter at this time. We cruised around the atoll examining the islets through binoculars, taking notes. The vegetation had a definitely dry, gray appearance. At almost high tide we revisited the passage. There seemed to be almost no current at that time, and that would clearly be the proper time to enter. However, a west swell had set in and was breaking at times clear across the entrance, so no attempt was made to get a boat in. Again, on the lee side, especially near the passage, the "oil slicks," seen on previous atolls, were very conspicuous, this time extending as much as several miles to leeward and becoming very diffused. In the neighborhood of the mouth of the passage the water seemed to have a somewhat lighter blue color, suggesting the effect of colloidal calcium carbonate. It is possible that a certain amount of very fine sediment was being swept out of the lagoon.

It was with a considerable feeling of frustration that we received the Captain's decision to give up any attempt to land on Pokak. An opportunity to investigate a place never before visited by a scientist does not come every week. Its bleak appearance did not lessen at all its interest. And John Cameron's story of the basalt blocks remained as tantalizing as ever. We started back for Kwajalein that evening and arrived the morning of March 27.

Return Trip

The next two days were spent in packing and stowing our gear in the hold of the ship, and in arranging for air transportation to Guam and Tokyo. Early in the morning of March 31 MacNeil and I left for Guam, arriving at about the middle of the morning. We planned to spend a couple of days here, discussing some of our findings with the party of geologists engaged in working out the geology of Guam. Joshua I. Tracey, chief of the party, was in the hospital, but not especially incapacitated. Ted Arnow met us at the airport, and we had a good visit. He was busy getting ready to go to Palau, so the others in the party took us around Guam, enabling me to check a few details of the vegetation, which I had studied some two years before. Some of the areas of swordgrass that have not been burned since before the war are now conspicuously covered by Casuarina saplings. The obvious effects of the 1949 typhoon have in many places almost disappeared. Rocks that were completely denuded of vegetation, except for root crowns in crevices, are now fairly well covered again by low Pemphis brush. The forest on the north plateau seems to be generally in rather decadent condition. Field work on Guam for the next year was planned to fit in with the program of the geological party.

On April 2 MacNeil and I left for Tokyo. We stopped at Iwo Jima long

enough for a stroll around the airport and to make a few observations on the weedy vegetation that had appeared since the War. We arrived in Tokyo in the afternoon.

Two and a half weeks in Japan were spent in writing preliminary reports, making plans for the reports and papers that will embody the results of the expedition, and in packing and shipping the specimens. The FS-367 arrived a bit late with our collections, having been badly battered by a storm on the way up. We were able to take two short trips into the countryside of Japan, being fortunate enough to arrive during the season of the cherry blossoms, for which Japan is famous. This country was fully as beautiful in the spring as it was when we saw it in the fall.

Wake Island

I had arranged to spend two days making a quick reconnaissance of Wake Island on the way home, so I left Tokyo on the night of April 18 and sighted Wake on the afternoon of the 19th. I was able, while we were landing, to take some kodachrome photos of the atoll from the air. The vegetation seemed to be noticeably affected by the dry weather, the atoll appearing quite as gray as Pokak had looked from the sea.

Good fortune was definitely with me here. One of the first persons I met was Mr. Fred Schultz, in charge of pest-control on the island. He offered to drive me around the island and act as guide. This was an excellent arrangement, as he knew where all of the variations in the vegetation could be seen and was also quite willing to explain his very successful campaign of pest-control. He had, within a year, brought the island's three plagues--rats, flies, and mosquitoes-- so completely under control that in two days we had trouble finding any, even for specimens. We saw one rat, three or four flies, and no mosquitoes at all. He had applied what he knew or could learn of the ecology and habits of these creatures, destroying the breeding places of the insects and systematically poisoning the rats. In poisoning the rats he had apparently accidentally destroyed the hermit crabs also, as we saw none, and he said they were common a few months before.

The vegetation of Wake, described quite well by E.H. Bryan in 1923 (published by Christophersen, 1931), was almost entirely destroyed during the War. The remains of fortifications, Japanese and American, are to be seen practically everywhere. Only three rather small areas of the original forest cover remained. The astonishing thing about the vegetation was the rapidity with which it had recovered. Large Messerschmidia bushes, 3 to 5 meters tall, dominate the landscape; they cover the ditches, tank-traps, platforms, gun emplacements, and revetments and give the appearance of long-established vegetation. Four years earlier the general plant cover on the island was said to have been no more than a foot high. On favorable, sandy places, according to the Civil Aeronautics Administration officials, Messerschmidia had grown as much as 2 meters in a year. Pemphis here seems to favor situations of broken coral rock and of fine silty sand. Two very obvious plants not found in the Marshalls but common here are Sesuvium portulacastrum and Heliotropium anomalum. Quite a flora of introduced weeds has established itself. Indeed, it is hard, sometimes, to tell which plants really belong here. Ipomoea pes-caprae and Gossypium hirsutum var. reli-

giosum, of which one plant of each was reported by Bryan, were now common. One of the old patches of forest, persisting from before the War, was an interesting mixed forest of large low trees of Pisonia and Cordia.

After two very busy days here, I left for Honolulu early in the morning of April 22. There an opportunity was afforded to see Kilauea volcano in eruption, and incidentally to make some study of the vegetation. The return to Washington with a stop in California was without incident.

Another Attempt

Mail and many questions had piled up in my absence, so I settled down to take care of them and to work on reports of the expedition and its results. But only a few weeks had passed, when a cable came from Tokyo asking if I were interested in joining the FS-216 at Wake Island for another attempt at Pokak and Bikar. I was taken aback by this; my mail was scarcely answered, but nevertheless I decided to go.

So preparations were again in order and a few weeks later, on July 9th, I was again flying westward. The principal incidents of this flight were a three-day enforced wait at Travis Air Force Base, California, and notification on arrival in Honolulu that I was expected in Wake within four hours.

Needless to say, I was not there by that time. Several appointments in Honolulu had to be kept. There was also the matter of transportation from Honolulu to Wake to be arranged; and such arrangements are not usually made on a moment's notice. However, because of superb cooperation of the Visitor's Bureau of the U. S. Army, at Fort Shafter, which put a car at my disposal and took care of all the arrangements with Military Air Transport Service, I was on a plane again by the middle of the afternoon and on Wake Island by 2 o'clock the next morning. Enroute I had a short stop, unfortunately just after dark, at Midway and was able to examine briefly from the air Niihau, Gardner Rocks, and Pearl and Hermes Reef, of the Leeward Hawaiian Islands. The size of the trees on Midway was surprising. Some of the Casuarina trees, planted many years ago when the Cable Station was established there, were at least 15 meters high and almost 0.5 meter through above the base. From the air in the dusk the island presented an almost wooded appearance. Albatrosses were to be seen along the runway as the pilots played a searchlight on them. Young ones were objects of much passenger curiosity around the terminal, too.

Arriving at the Wake Island terminal at 2 a. m., I was dismayed at finding no one who had the slightest idea whether or not the FS-216 was still at Wake or had departed. After exhausting the possibilities of finding out, I went to bed for the remaining few hours of the night. In the morning it was almost as hard to find out anything definite. But after the superintendent of the island came to his office it was possible to get transportation to the boatlanding, and it was a relief to see the FS-216 still at anchor and to meet its captain coming in to get his final clearance for departure for Pokak and the Marshalls. On climbing aboard I was greeted by Charles Johnson, my geologist

companion for the expedition.

Our first lunch-table conversation with Captain Clover, the officer-in-charge, allayed, somewhat, my skepticism about getting ashore which was natural after two abortive attempts. There seemed no doubt in his mind about it.

During the drive from the Pan-American terminal to the boatlanding it was possible to observe the striking change from the dry aspect of Wake Island exhibited in April. The herbaceous layer, especially Euphorbia heterophylla, gray and dry then, was green and attractive now. The Messerschmidia trees looked more luxuriant now, but those near the Transocean Air Lines compound that had appeared dead were still very much so. The dry season had been too much for them, especially where they were growing on the loose rubble piled up in the fortifications. Heliotropium anomalum was flowering abundantly south of the airstrip.

Pokak Atoll

On the morning of July 20 we were off Pokak Atoll once again. The sea was quiet, and no breakers were to be seen on the leeward side. A strong current was running out of the narrow crooked passage, just as on the two previous visits, but the small motorboat negotiated the passage easily and the landing operation was under way. Crossing the lagoon to the northeast end of Sibylla Islet, the largest of the string of rock and sand heaps that occupy most of the southeast reef of this remote atoll, we stopped ashore on one of the bleakest, loneliest spots that it has been my privilege to explore.

Pokak is a crescent-shaped atoll, about 11 miles from tip to tip, oriented north and south with the convex reef to the east, and with all the land on the southeast quadrant. At high tide water pours in over the reefs. But as soon as the tide begins to go down, only the single narrow passage on the west serves as an outlet. Though the water rushes out of this as through a millrace, in 6 hours the water level inside is not lowered much, and the level in the lagoon is at all times except at high tide, significantly above that of the surrounding sea. This, of course, makes surveying and the determination of land area a less than usually exact procedure, as altitudes are commonly expressed in relation to mean low tide.

The usual conception of a palm-bedecked atoll does not fit Pokak at all. The vegetation is a low scrubby wood of Messerschmidia trees and bushes, very sparse and, at this season, grayish and dry looking. Large areas in the interior and toward the lagoon side on the wider parts are covered by a thin bunch grass, honeycombed by burrows of wedge-tailed shearwaters, each burrow marked by a pile of white coral sand. These piles of white sand explained the curious salt-and-pepper appearance of these areas on aerial photographs. On the seaward side are vast boulder ridges and boulder flats, some wooded with scattered low Messerschmidia, others open, or with occasional plants of Ipomoea tuba. These presented a curious appearance. Normally this plant is a liana, climbing to the treetops in forest, forming dense tangles over trees and bushes, the stems reaching several centimeters in thickness. Here, in this dry climate the elongate twining stems die during the dry season, remaining in the form of a thin

network over the bare rock flats. These dead stems are utilized by the frigate birds for nesting material. These branches die back practically to the root crown, which forms an erect stem a foot or so tall and half that or more thick, crowned with stubs of branches with a few green leaves and buds ready to produce next season's vegetative growth as soon as sufficient moisture is available. There seems little doubt that this is the same plant that is a liana elsewhere, and that this curious habit is induced by the severe dry seasons common in this forbidding habitat. Scaevola scrub, curiously enough showing less signs of drought than the other vegetation, covers some areas, especially ones where flat reef-rock lies at the ground surface and a few small areas of dune sand. Elsewhere this bush may be mixed with the Messerschmidia. In some of the sand-flats dominance is shared between the bunch grass, Lepturus repens, and the slender low shrub, Sida fallax. In other places, especially certain areas on Kamome Islet, the widest and, curiously, the most treeless of the atoll islets, Sida assumed complete dominance, here reaching a height of two meters, making a thin gray scrub. The response of this plant to the drought is also interesting. At the time of our visit practically every individual plant had all but one or two of its branches leafless, gray, and dead--brittle with no sign of living tissue. Almost invariably, however, one or two branches were healthy, leafy, and even flowering. Also on Kamome Islet are several low patches of Pisonia grandis. This tree, which forms magnificent forests on wetter atolls, there is low, not more than 5 or 6 meters tall, and with small trunks. At this season the canopy is very thin, as the trees lose most of their leaves in the dry season, and here the leaves are not as large as they are elsewhere. The patches are circular and obviously are slowly spreading, as is easily seen by comparing aerial photos taken even as little as eight years apart. These are the only colonies of this tree on the atoll and probably have not been there long. The fruits of Pisonia are extremely sticky and quite capable of being carried stuck to birds' feathers from either Wake or Bikar, on both of which the trees are found.

Previous information on this atoll has been almost wanting. Kotzebue, on his voyage around the world, passed by in 1819, and Chamisso, the famous German naturalist and writer who accompanied him, described it from half a mile away. This description, only two paragraphs long has provided the only reliable information to the time of our visit. John Cameron, Pacific wanderer, adventurer, trader, and guano-digger, visited it in 1893, as recounted in his "Odyssey". He describes huge basalt blocks--one of them 15 feet 6 inches long, 5 feet 4 inches wide, and 3 feet thick--comparable to those on Ponape, and wonders about their origin. The German writer Irmer, in 1896, speaks of the atoll as being covered with guano several meters thick. These last two accounts are interesting but quite untrue. A week of constant searching by Charles Johnson and myself, as well as by the surveyors, revealed no basalt and no thick deposit of guano. Other than coral limestone, there were a few of the usual smaller gray fine-grained pumice pebbles and a large chunk of black scoriaceous pumice cast up on the beach. Great boulders of coral, darkened by algae in their outer layers, some of them of rectangular shape, are scattered over the surface of islets and reefs; also a few remnants of an older, higher reef surface remain in place, especially on the bare southwesternmost islet. The coral boulders may have been mistaken for basalt, or the story may have been pure invention. As for guano, in spite of the presence of

incredible numbers of birds, practically no guano exists on the island. Under trees where birds roost there may be up to an inch or so, very locally, but guano was so scarce that it was difficult to get a proper specimen for analysis. And in the great rookeries of sooty terns, according to some authorities the source of large guano deposits, there was no visible accumulation on the ground, even around the nesting places.

The largest islet is called Sibylla. On its lagoon shores are conspicuous lobes of blackened reef-rock, with rough pitted surfaces just above high-tide level. At several places these lobes are arranged in pairs, as though they marked the inner ends of channels. No evidence of the former existence of channels across the islet at these places was to be found on large-scale aerial photos or on the ground, though considerable search was made. However, on photos at a scale of 1: 20,000 or smaller, traces of the channels were quite evident. Further to the southwest were several much more obvious former channels across the islet, now filled with sand and gravel. In fact, it was possible to walk dry-shod as far as Pokak Islet, the next to the last on the reef, with the channels becoming more and more obvious until the last, west of Pokak Islet, was impassable. On Sibylla some elongated areas looked, on the photographs, to be grassy, at least similar to areas on photos of other islets known to be grassy. Here, however, examination showed them to be enormous boulder or cobble flats, in places absolutely bare of vegetation.

Pokak Islet was the site of the Japanese establishment on the atoll, said to have been a radio relay station and obviously, also, a small bomb dump. The pathetic remains of this tiny base, a blackened heap of rusted-through galvanized iron, half burned timbers, broken bottles and utensils, a cement cistern, scattered unexploded bombs, and, off to one side, a rude "torii" marking a temple site, even here, should serve very well as a lesson to would-be empire builders. Here was the remotest outpost of the former Japanese Empire, a place of unimaginable loneliness and discomfort for the exiled, normally socially inclined Japanese garrison. It was bombed completely out of existence in one day, in April 1944.

A well at this site, dug down through the sand and gravel to the water table, had only salt water at the time of our visit, during a long dry season. It seems reasonable, however, that the water may have been useful during more favorable seasons. Two other wells that we dug at the widest part of Sibylla Islet also yielded water too salty for drinking purposes.

South Islet, or Bokdik of the Marshallese, is bare of all visible vegetation. Its exposed rock platform is interesting geologically. The general level is above high tide. On the lagoon side it is conspicuously undercut. Here and there on its surface are masses of rock, at first appearing to be boulders cast up on the platform by storm waves, as seen elsewhere. Examination showed, though, that they are actually a part of the island, itself, remnants of a higher surface, with no joint or suture between them and the underlying rock. This is an important part of the overwhelming mass of evidence to be seen on this atoll, of a relatively higher sea level in the not too remote past. The surface of the general platform of this islet is most peculiar in being scarcely pitted, with no sharp edges to the pits and solution surfaces. Also it is light gray, rather than the usual dark or almost black. It is clearly a surface

subjected to abrasion, and the low deposit, on the seaward side, of white cobbles and gravel is the obvious abrasive. This is well above high-tide level, but its whiteness and rounded character is mute evidence of the fury and frequency of the storms that must roll these pebbles around to abrade the general surface of the islet.

Another spectacular evidence of a higher sea level was found on the south coast of Sibylla Islet. It is a huge perched boulder, resting on a much narrower pedestal of reef rock, the base of the boulder about 2 meters above the present reef flat. The top of this pedestal corresponds in level with remnants of reef rock which protrude from under the mass of loose material that make up the islet nearby. This mushroom-shaped structure stands erect at the outer edge of the beach and inner edge of the present reef flat. A distinct suture is obvious between the boulder and its supporting column. Clearer proof could not be wanted of a higher stand of the sea in relation, at least, to this island. The boulder is in no way different from the ones which occur sporadically scattered on the present reef flat, on this and other atolls. In a wetter climate it would probably have been gradually dissolved away. The impressive thing is the enormous expanse of reef flat that has been planed from this level down to the present lower level at about mean low tide. Even with maximum estimates of time involved since the post-glacial high stand of the sea this cutting has been remarkably rapid. One of the major interests of the geologists on the expedition was to discern and establish the processes responsible for this degradation.

Except for the enormous numbers of sea birds, the land fauna of Pokak is meager. The Polynesian rat, Rattus exulans, is present in some abundance. That the birds, even ground-nesting ones, do not seem to be seriously bothered by these rats is most interesting. A lizard, a dwarfed form of the common blue-tailed skink, was occasionally seen. Here it is to be found most frequently under loose bark of dead trees, rather than in its usual habitat on the ground, though it is also seen on the ground at times. The most evident animal is the large red hermit crab, Coenobita perlata, which inhabits Turbo shells. It would be interesting to know if the factor that limits the population of this animal is the restricted food supply or the number of Turbo shells. The shell commonly used by this species of hermit crab, when adult, is Turbo lajonkairi, apparently not a common shell elsewhere, but by far the commonest Turbo seen here. Its habitat is in cavities in the flat reef surface, expecially on the small reef patches in the lagoon. None of these shells were seen empty on the beaches or islets. And since very few of the large hermit crabs were seen inhabiting any other shell, and of course none were without shells, the relation between the number of crabs that reach maturity and the number of available Turbo shells is close, indeed.

Two species of moths were very common, and they were the only ones seen in any abundance. One or two individuals of other kinds were caught, including a sphinx moth. A few other kinds of insects were found, including a large carrion fly, several species of ants, several bugs and a number of beetles. Two wingless primitive insects, belonging to the Lepismidae and Psocidae, respectively, were common, as were one or two kinds of spiders. Mites and pseudoscorpions were also present. It is not immediately obvious how the wingless creatures, including a minute land snail,

came here. Absent were termites, houseflies, mosquitoes, and butterflies.

The heat on this waterless, practically shadeless atoll was, at least in this midsummer season, excessive. It was noticeable even to one sitting quietly. Tramping around the island was a desiccating experience. But the fascinating studies to be made, and the shortness of the visit and resulting urgency about making them caused a certain amount of forgetfulness of the heat. When the available week was up, and it was time to leave on July 27 for Kwajalein, I, at least, thought more of the things I had not yet got to look at than of the frying-panlike surroundings I was leaving behind.

Back aboard the ship there was the problem of getting my plant specimens and soil samples dry. On the FS-367 I had dried them in the funnel of the ship, next to the hot exhaust pipes. The arrangement on the FS-216 was a bit different, but this seemed a practical solution. So I got permission from the Chief Engineer and piled plant presses and soil bags around the hot pipes. The first few times I had done this on the FS-367 I had kept careful watch over the materials, being afraid of fire. It soon was evident that the problem was to get the things warm enough, not danger of overheating. So, on the FS-216 I paid no attention to the specimens after putting them in to dry. That evening, before we had left the vicinity of Pokak the crew began to smell smoke. Soon it was discovered that my specimens were on fire. Getting them out, putting out the fire, and keeping the sailors from throwing everything overboard provided a busy two hours. Most of the plants were saved, but, surprisingly enough, most of the soil samples were lost. The bags were charred and burst when they were thrown out on deck. A few of the plants, mainly calcareous algae, were lost in the fire.

Kwajalein Atoll

We went to Kwajalein to refuel and to enable the surveyors to recheck their astronomical observations made there the previous winter. We renewed acquaintance with a few of our friends from the previous visits, but the usual Navy turnover had replaced most of the ones we knew. The vegetation on Ebeye and Kwajalein Islets had practically recovered from the winter's drought. A short visit was made to Enelapkan Islet, on the south reef, where there is a small amount of forest vegetation in addition to coconut groves. By no means all of the islets of Kwajalein have been studied, in spite of its being the center of activity in the Marshalls. It is so big that transportation is a major problem. The demand for boats is always greater than the small number available, and seldom do the boats go to the more remote islets.

On this visit only one plant was collected, and a few animals. Some of these were insects that were infesting stored rice in the Island Trading Co. warehouse at Ebeye.

Bikar Atoll

On August 4 we left for Bikar and arrived there on the 6th. Here we did not even bother about the narrow passage but landed over the reef on the leeward side of Bikar Islet in rubber rafts. At high tide this

presented no problems at all, but as the tide went down there was some danger of the corals on the reef edge tearing the bottoms of the rafts. On this side of the islet there is no algal ridge, and the reef has a rounded sloping edge.

Bikar, previous to our visit, was almost as little known as Pokak, but there were no reputed mysteries or exaggerated accounts to disprove. We knew, from our own examination from the sea last winter, that the islets are mostly densely wooded with Pisonia, that there are a few coconut trees that have been planted by visitors from Likiep, that a few birds have been recorded from there, and that the Japanese had found a thick buried layer of phosphate rock. Mr. Jack Tobin had also found out from the Marshallese that, previous to annexation by Europeans, Bikar, along with Pokak and Jemo, had been regarded by them as a bird reserve. Birds, their eggs, and turtles could be taken in limited numbers, after proper ceremonies, on the one visit made during the year. That this wise policy was effective was immediately obvious to us when we arrived. Birds were present in large numbers, and it was clear that this is the turtle breeding-place above all others in the Marshalls.

The Bikar reef is oval, about 6 miles long, and has three wooded islets and two small gravel bars on its southeast quarter. Its one pass is on the west side, and is rather narrow, but not like the one on Pokak. The water rushes out of this one most of the time, also, but not in the torrent found in Pokak Channel. The boats used it repeatedly and had no difficulty at any time. The largest islet, Bikar, is on the south point of the atoll. It is actually very tiny, and the south third of it is bare reef-rock, stripped of all soil and vegetation, probably by storms. This rock flat is mostly above even extreme high-tide mark and has some small ridges and irregularities that are even a meter or more higher than the general surface. There is practically no loose material accumulated here. The north point is a sand flat with scattered bushes of Scaevola and Messerschmidia, both of which form a thin belt around the periphery of the wooded part of the islet. We camped on this open north part. The small coconut grove is at the north edge of the forest next to our camp spot. We had looked forward to a supply of drinking coconuts on Bikar, an island luxury which we had sadly missed on Pokak. In this we were disappointed. There were few nuts on the trees and what there were were small, malformed, and had bitterish water. Shells of large nuts littered the ground, so it is probable that the dry season just ending was responsible for this stunted condition.

Turtle tracks across the beaches were even visible on our large-scale aerial photos of Bikar Islet, so we were not surprised to find tracks in abundance when we arrived. My first activity after getting our equipment carried up the beach to the campsite was to walk around the island and count the turtle tracks. There were almost 600 of these, representing 300 turtles. The pits from which sand had been scooped to cover the egg-pits were so abundant that they were the dominant feature of the surface of the sand in the peripheral belt of this island. That night young turtles hatching out scurried through camp, heading directly for the sea; but only a few escaped the clutches of rats and hermit crabs. Several adults came ashore and were seen laying eggs. One blundered right through the cook tent. Observations on their habits will be given

in a later article on the reptiles collected on the expedition. Curiously enough, turtle tracks were almost absent from the other islets, probably because of the lack of loose sand, of which a large part of Bikar Islet is made up.

The Pisonia forest, which covers the greater part of this islet, is dense and contains some great trees, though it is uneven and shows the usual effects of typhoons in the form of fallen trees. Ordinarily these take root wherever they touch the ground, but a number seen here on Bikar were dead. Probably they were blown down during a severe dry spell. The Pisonia forest contained two remarkable things--white-tailed tropic birds nesting in holes in the tree trunks, and water collected in cavities and irregularities in the large tree bases containing swarms of ostracods. Where these fresh-water animals came from on an island that has absolutely no other fresh water is indeed a mystery.

By this time I had learned to look for a humus layer underlain by phosphatic hardpan on the floor of a Pisonia forest. Here was no exception. Aso, a Japanese expert on phosphate deposits, had reported phosphate on Bikar, but he reported it buried under 2 feet of sand and gravel. The buried layer was easily found. In places it was under as much as 2 feet of sand, elsewhere much less, and in places it was not buried at all. Usually where it was buried there was also an additional layer of very fresh brown hardpan near the surface, under an inch or so of humus. The situation was clear after a study was made of the terrain, of the bases of the trees, and of a few test holes. Apparently a severe storm from the west had spread the material of the large dune ridge along the west side inward in a layer thinning toward the east, burying the greater part of the surface of the islet. The humus thus buried had gradually disappeared by oxidation, staining the sand, and leaving the hardpan layer. Then another layer had started to form on the surface of this new sand. Birds are abundant enough on Bikar to provide the necessary guano for this process almost everywhere in the forest.

Rats and blue-tailed skinks were here, as on Pokak. The big red hermit crab, Coenobita perlata, again inhabits the two kinds of Turbo shells, but the proportions were different, the common Turbo setosus here supplying about one-fourth of the shells. Land shells were not common but at least two genera were represented. Insects were much more abundant than on Pokak, but by no means as varied as on the atolls to the south. As on Pokak, the higher plant species numbered nine, but the lists differ somewhat. And the vegetation is almost completely different. On the three principal islets the main body of the vegetation is Pisonia, surrounded by a thin sparse belt of Messerschmidia, this on Bikar Islet mixed with Scaevola. Bare areas have a thin cover of Portulaca and Lepturus, very locally mixed with Boerhavia, or nothing at all. On Jaboero Islet, which is a gravel bar and a sooty tern rookery, the entire vegetation is made up of Portulaca lutea.

Jaliklik Islet is interesting in having a well-developed boulder ridge along its lagoon side. Its seaward side has extensive denuded reef-rock flats. Almeni Islet is of rather coarse gravel. On Bikar Islet we attempted to dig down to the water table. This islet is higher than usual, and no water was reached after a laborious full day of

digging by two strong boys, surveyor's helpers. Sand kept caving down, so the hole had to be made very large. It afforded an interesting opportunity to study the buried phosphate layer and the stratification of the materials of which the islet is built.

The reef to the east of the south point of Bikar Islet was briefly examined and showed several interesting features. A conspicuously undercut "mushroom" rock a meter or more high protrudes above high-tide level on the outer reef flat. It was not easy to be sure whether it was part of the reef or the remains of a boulder that had been cast up by a storm. There were striking tide pools on the outer part of this reef, with bright-green coral (Millepora) and pink algae, and with great numbers of the large black-purple slate-pencil sea urchin, Heterocoentron trigonarius Lam. The edge of the reef here is especially interesting. It appears to be an algal ridge in the last stages of being removed by solution. Apparently the rate of deposition of calcareous material in this position is barely or not quite able to keep up with the rate of removal by solution. North of this there is a better developed ridge, while around the point in the other direction the ridge disappears altogether. Well back of this, on the flat, the tops of the corals are abruptly truncated, as though they had been shaved off, presumably indicating the exact level at which there is too much exposure to air for survival of the corals.

As usual, we had to leave before we were completely satisfied with our survey. Even islands as small as these provide much opportunity for observation. And in such relatively simple situations one feels that perhaps only a little more time would have sufficed to give an understanding of what is actually happening, ecologically. It is to be hoped that the present-day Marshallese and the American Administration will see fit to continue the wise policy of the ancient Marshallese and maintain this atoll, and Pokak, as bird and turtle reserves. Then, perhaps, another expedition can start where this one left off and really get a grasp of the ecology of these tiny bits of land. Certainly the number of people that would ever be able to eke out an existence on them would not justify destroying these fascinating microcosms.

On August 12 we left for Kwajalein, spending a last night there on August 14, entertained by my friend Kenneth Moy and his wife, of the Island Trading Co., to whom thanks are due for many favors and assistance both while we were there and later, when I wrote for needed specimens and observations. Here the expedition ended, Charles Johnson leaving for Tokyo and I for Honolulu.

Condensed Itinerary of Localities where Collections and Observations were made

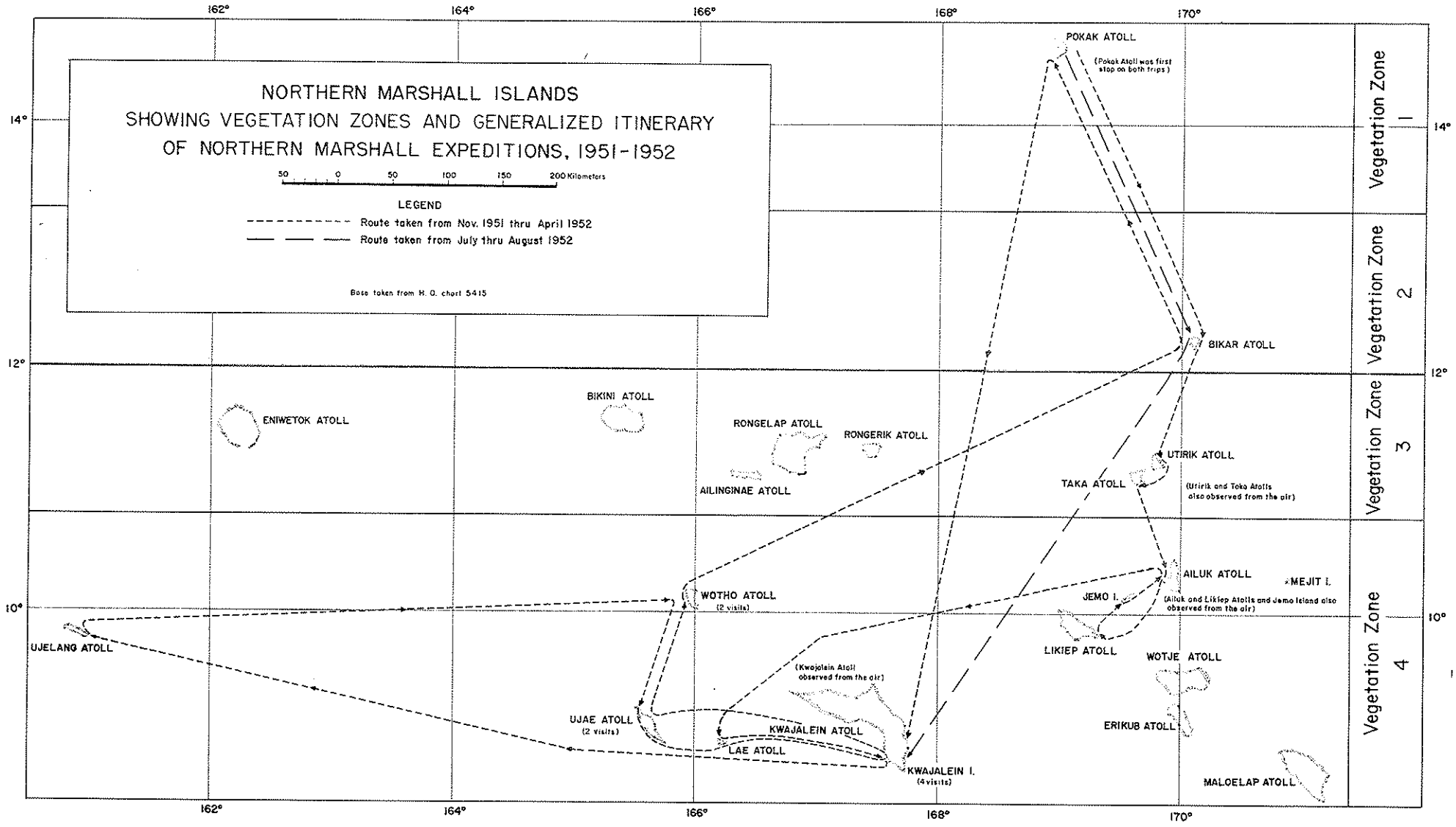
Date	Locality	Collector or Observer
Oct. 22, 1951	Johnston Island	Fosberg
23	Wake Island	Do.
23-24	Iwo Jima	Do.
24	Tokyo, Japan	Fosberg, MacNeil
28	Hakone, Japan	Do.
	Kanagawa Pref., Japan	Do.

Date	Locality	Collector or Observer
Nov. 3	Chiba Peninsula, Japan	Fosberg
6-8	Fukuoka, Japan	Do.
16-25	At sea, Yokohama to Pokak	MacNeil, Fosberg
25	Pokak Atoll*	Do.
26	Bikar Atoll*	Do.
Nov. 26-Dec. 4	Utirik Atoll	MacNeil, Arnow, Fosberg
Dec. 4-9	Taka Atoll	Do.
11-18	Likiep Atoll	MacNeil, Fosberg
18-23	Jemo Island	Fosberg
18-23	Likiep Atoll	MacNeil
Dec. 23, 1951-Jan. 4, 1952	Ailuk Atoll	MacNeil, Arnow, Fosberg
Jan. 4-10	Lae Atoll	Do.
10-Feb. 1	Kwajalein Atoll	Do.
13	Majuro Atoll	Fosberg
Feb. 3-10	Ujelang Atoll	MacNeil, Arnow, Fosberg
12-16	Wotho Atoll	Do.
16-24	Ujae Atoll	Do.
Feb. 25-Mar. 1	Kwajalein Atoll	Do.
28	Air circuit of Likiep, Jemo, Ailuk, Utirik, Taka, and Kwajalein	Fosberg
Mar. 1-14	Ujae Atoll	MacNeil, Fosberg
15-17	Kwajalein Atoll	Do.
18-23	Wotho Atoll	Do.
24	Bikar Atoll*	Do.
25	Pokak Atoll*	Do.
27-30	Kwajalein Atoll	Do.
Mar. 31-Apr. 2	Guam	MacNeil, Arnow, Fosberg
Apr. 2	Iwo Jima	MacNeil, Fosberg
6	Yokosuka, Japan	Do.
13	Chichibu Mountains, Japan	MacNeil, Fosberg
19-21	Wake Island	Fosberg
July 16	Niihau Island**	Do.
16	Gardner Rocks**	Do.
16	Pearl and Hermes Reef**	Do.
16	Midway Island	Do
16-18	Wake Island	Johnson, Fosberg
20-27	Pokak Atol	Do.
July 29-Aug. 4	Kwajalein Atoll	Do.
Aug. 6-12	Bikar Atoll	Do.
14-15	Kwajalein Atoll	Do.

* Did not go ashore.
** Observed from air.

List of Collection Numbers by Islands

	Plants	Animals
Wake	33614-33628	
Iwo Jima	33629	
Japan	33630-33641	
Utirik	33642-33719	45-50 111-181
Taka	33720-33778	51-59 182-302
Likiep	33779-33861	60-63 303-368
Jemo	33862-33907	64-72 369-484
Ailuk	33908-33990	73-79 485-556
Lae	33991-34107	84-90 557-663
Majuro	34108	
Ujelang	34142-34216	36-44 692-750
Kwajalein	34109-34141 34381-34382 34422 34549	80-83 664-691 1299-1327 1438-1447 1494-1496
Ujae	34284-34380 34383-34421	1-24 874-1063
Wotho	34217-34283 34423-34443	25-35 751-863 872-873 1484-1493
Pokak	34497-34548	1064-1072 1092-1120 1184-1298
Bikar	34550-34596	1073-1091 1121-1182 1326-1437


NORTHERN MARSHALL ISLANDS
SHOWING VEGETATION ZONES AND GENERALIZED ITINERARY
OF NORTHERN MARSHALL EXPEDITIONS, 1951-1952
50 0 50 100 150 200 Kilometers
LEGEND
Route taken from Nov. 1951 thru April 1952
Route taken from July thru August 1952
Base taken from H. O. chart 5415
162°
164°
166°
168°
170°
14°
12°
10°
POKAK ATOLL
(Pokak Atoll was first stop on both trips)
BIKAR ATOLL
BIKINI ATOLL
ENIWETOK ATOLL
RONGELAP ATOLL
RONGERIK ATOLL
AILINGINAE ATOLL
UTIRIK ATOLL
TAKA ATOLL
(Utirik and Taka Atolls also observed from the air)
AILUK ATOLL
*MEJIT I.
(Ailuk and Likiep Atolls and Jemo Island also observed from the air)
JEMO I.
LIKIEP ATOLL
WOTJE ATOLL
WOTHO ATOLL
(2 visits)
UJELANG ATOLL
(Kwajalein Atoll observed from the air)
UJAE ATOLL
(2 visits)
KWAJALEIN ATOLL
LAE ATOLL
KWAJALEIN I.
(4 visits)
ERIKUB ATOLL
MALOELAP ATOLL
Vegetation Zone 1
Vegetation Zone 2
Vegetation Zone 3
Vegetation Zone 4