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THE NATURAL HISTORY OF KURE ATOLL, NORTHWESTERN HAWAIIAN ISLANDS

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p213

107. Curé Island

In 1827 Captain Stanikowitch, of the Russian vessel *Moller*, found a small, low, dangerous island, placed by him in latitude 28° 27′ N., longitude 178° 23′ 30″ W. The Russian hydrographer Krusenstern suggested that this was the same as Curé Island, a previous vaguely reported discovery.[4]

This was the modern Kure Island, in the north-western sector of the Hawaiian Islands.

[1] Starbuck, A., *History of the American Whale-Fishery*, in Appendix to the Report of the Commissioner for Fish and Fisheries for 1875–6 (Washington, 1878).

[2] *Pacific Islands Pilot*, vol. ii, p. 472.

[3] Stackpole, E. A., *The Sea-Hunters* (Philadelphia–New York, 1953), p. 378, citing *Nantucket Inquirer*, 8 Dec. 1827.

[4] Krusenstern, A. J., *Supplémens* (St. Petersburg, 1836), pp. 109, 162.

"The Discovery of the Pacific Islands by Sharp 1960

TABLE OF CONTENTS

FIGURES

TABLES

THE NATURAL HISTORY OF KURE ATOLL,

NORTHWESTERN HAWAIIAN ISLANDS[1]

by Paul W. Woodward [2]

INTRODUCTION

Kure Atoll, located at 28°25'N and 178°10'W, is the northernmost coral atoll in the world and the westernmost land of the Northwestern Hawaiian Islands. It is approximately 1,175 nautical miles northwest of Honolulu, 2,165 nautical miles southeast of Tokyo, and 3,240 nautical miles west of Baja California. The nearest land is Sand Island, Midway Atoll, 49 nautical miles to the southeast.

Green Island, the only permanent land in the atoll, is located near the fringing reef in the southeast sector of the lagoon. Crescentric in shape with the long axis curving from north to west, it is 1.43 miles in greatest length and 0.37 miles in maximum width. Sandy beaches encircle the entire island. Along the lagoon beach there is a series of sand dunes, some as high as 25 feet, that decreases in elevation southwest along the beach. Behind the dunes, to the east, the surface settles gently into a low, relatively flat depression. The elevation here is from 6 to 10 feet. Dunes are absent along the ocean side and elevations here do not exceed 15 feet.

Presently the dominant features on the island are man-made: the 625-foot LORAN tower and transmitter building in the central plain, the 70-foot-high radar reflector on a dune along the southwest beach, the 4,000-foot runway, and the building complex near the center of the island.

A dense growth of Scaevola taccada covers much of the island except for the man-made open areas and the natural central plain

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where only low herbaceous plants grow. A total of 46 vascular plant species has been recorded; the majority (31) was intentionally or accidentally introduced.

Sixty-six species of birds have been recorded from the atoll; 15 breed there, 6 are common visitors, 7 are regular visitors in small numbers and 38 are accidental. The Hawaiian Monk Seal and Polynesian Rat are resident species, while another seven mammalian species have been recorded. Small numbers of two gecko species live on Green Island and Green Turtles visit the atoll infrequently.

Prior to 1950 Kure Atoll was visited infrequently, especially by biologists. In the 19th century at least 13 different ships came to the atoll and another 4 wrecked upon the reef. These visits were generally brief and no permanent settlements were made. Visits were more frequent in this century and the first systematic bird observations were made in 1915. Detailed observations were also made in 1923, 1957, 1958, and 1959.

In June 1960 the construction of a United States Coast Guard LORAN station was begun; it was completed in April 1961. This was the first permanent settlement on the island. Presently (1970) 24 men live there.

In the 1960's visits by biologists became more frequent and culminated in the detailed survey of the atoll by the Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institution from 1963 to 1969. This survey substantially increased our knowledge of the atoll's fauna (especially birds), not only of what species occurred there but of their biology and movements. This work composes the bulk of this paper.

HISTORY

19th Century

Prior to 1827 Kure Atoll was probably visited by at least 6 different ships and received a different name after each visit. In 1799 Captain Don M. Zipiani, commanding the Spanish vessel Senhora del Pilar, found an island three miles from north northeast to south southwest in latitude 28°9'N longitude 175°48'E and named it Patrocinio (Findlay, 1870). Krusenstern (1835) lists four islands in the vicinity of Kure (Staver at 28°N 181°20'E, Ocean at 28°10'N 181°20'E, Massachusetts at 28°20'N 181°20'E, and Cure at 28°27'N 181°35'E) and states that they were in fact all the same island. Since there are no details of any of these visits it is impossible to state unequivocally that they were Kure Atoll or which one actually discovered the atoll.

The first visit definitely to Kure Atoll was in 1825 when the schooner Tartar, under the command of Captain Benjamin Morrell, Jr., spent two days (Morrell, 1841). On 11 July the ship left Pearl and Hermes Reef and sailed westward. The next day it arrived at Byer's Island (probably Midway) which they left at 6 p.m. At 4 a.m. on 13 July 1825, approximately the time it would take to sail from Midway to Kure, they arrived at an unknown island.

> At 6 a.m. we were within half a mile of the breakers, and no land in sight. We bore up and passed around the west end of the reef, which was distant about two miles. We then hauled on a wind under the lee of the reef at the rate of seven miles an hour, for two hours in a north-by-west course, we saw the land from the mast head, bearing north-west. We immediately kept off for it, and at 10 a.m. we were close in with a small low island, covered with sea-fowl, and the shores of which were lined with sea elephants. Green turtles were found here in great abundance, and two hawk's bill turtles were seen. This island presents all the usual indications of volcanic origin.
>
> On the west side of this island there is a reef which runs off about fifteen miles, while that on the south-east side extends about thirty miles, in the direction of south-south-east. These reefs are formed of coral, and afford good anchorage on the south-west side, but on the east side the water is bold close to the reef. The island is low, being nearly level with the surface of the sea, and about four miles in circumference. Its centre is in lat. 29°57' north, long. 174°31' east (Morrell, loc. cit.).

They left on Thursday the 14th of July. Although the position is incorrect, it is obvious from the sailing times and description that this was Kure Atoll. Krusenstern (1835) named it Morell (sic) Island.

In 1827 Captain Stanikowitch, of the Russian shop Moller, found a small, low, dangerous island at 28°27'N, 178°23'30" (Sharp, 1960). It was this discovery that prompted Krusenstern to synonomize all the previous names under the single appellate of "Cure Island."

In 1837 the first of many ships wrecked on the reef surrounding the atoll. At 11:30 p.m. on 9 June the British whaler

Gledstanes, Capt. John R. Brown commanding, struck the northern reef (Sandwich Island Gazette, 1837). Three boats were lowered and the captain, officers, and crew laid off the wreck until daylight when they rowed about fifteen miles to land (presumably Green Island). They returned to the wreck and were able to salvage a little bread, a few clothes, eighteen casks of flour, one cask of salt provisions, and a few casks of oily water.

Most of the time the crew was engaged in the construction of a small vessel from the remains of the Gledstanes. On 12 October the vessel was launched and named the Deliverance. Three days later Capt. Brown, the Chief Mate, and eight men sailed for Hawaii. Sometime in November they arrived in Honolulu and several months later the remaining crew was brought off the atoll by a vessel dispatched by the H.B.M. Consul in Honolulu (Ibid.).

Capt. Brown described the island as such:

> The island in lat. 28°22'N and long. 178°30' W, which I suppose to be Ocean Island, is about three miles in circumference. It is composed of broken coral and shells, and is covered, near the shore, with low bushes. In the season, it abounds with sea-birds and at times, there is a considerable number of hair seals. There is always an abundance of fish, and in a great variety. The highest part of the island is not more than ten feet about the level of the sea. The only fresh water is what drains through the sand after the heavy rains. From the specimens of dead shells lying about the beach, there appears to be a great variety of shell (Hawaiian Spectator, July 1838).

In May 1838 Capt. Daggett of the ship Oscar saw Cure's Island in latitude 28°15' N, longitude 177°35' W and noted that the reef extended westward (Sandwich Island Gazette, Dec. 22, 1838). It was noted in this article that Cure's Island was a little to the east of Ocean Island, suggesting that there was still some confusion as to the exact location of Kure Atoll.

On 24 September 1842 at 2:30 a.m. another whaler, the Parker from New Bedford, Massachusetts, struck the reef about 8 miles north northwest from the center of Ocean Island (Temperance Advocate and Seamen's Friend, June 27, 1843). The ship was completely wrecked and four men were lost. Only a peck of beans and 20 pounds of salt meat were saved. After struggling for eight days and seven nights they reached land on a raft they had constructed from the wreck of the Parker.

Here they found some remains of the Gledstanes which served for firewood and building materials. From the Parker they obtained some pieces of copper which were made into cooking utensils.

While on the island the men killed 7,000 sea fowl and about 60 seals for food (Whalemen's Shipping List, November 7, 1843). A dog remaining from the Gledstanes' wreck was on the island and after several weeks they caught and ate it. Every morning and evening the captain conducted religious services and on Sabbath mornings a bethel flag was hoisted (Ibid.).

On 16 April 1843 the James Stewart of St. Johns, New Brunswick was spotted, but the wind carried it to the south of the island. The next day Capt. Smith, the carpenter, the cooper and cabin boy boarded the ship. Before leaving they left 20 pounds of bread and 20 pounds of beef for each remaining man, besides a barrel of salt, and cotton cloth sufficient for one shirt each and numerous minor articles of essential benefit. The captain of the James Stewart promised to return to pick up the remaining crew after the end of his cruise. This proved to be unnecessary, however, for on 2 May the whaleship Nassau, Captain Weeks commanding, arrived and took the remaining crew off the island.

In late June or early July 1859 the American barque Gambia visited Kure. Capt. N.C. Brooks reported (Brooks, 1860):

> ...consisting of three small islands or rocks, surrounded by a reef thirty miles in circumference.... A bank makes off round this reef at a distance of a mile with twenty-five to thirty fathoms water. The three islands are on a line East and West. The surf makes off to the East a quarter of a mile, and to the N.W. twelve miles. The reef opens to the S.W. for about three miles. The best anchorage is found by bringing the N.W. point of the breakers North, in water from seven to twelve fathoms, one mile from the reef. Currents sets north and south about two knots. Tide rises twenty-two inches. They can be approached from any point, and can be seen from the masthead eight miles, being about twenty feet high and covered with bushes. On the north end of the large island, which is 3 1/2 miles long by 1 1/2 wide, there has been a lagoon, but it is now overgrown. On this island I found the remains of the wreck of a merchantman, which had evidently been recently lost. She was not an American vessel. I found the beach strewn with remains of the cargo and wreck, consisting of bamboos, China mats, and tubs. The vessel was undoubtedly from China or Manila. On the north end I found washed ashore the broadside of the vessel, that had the fore and main channels on from plankshear to below 6 sheets copper. I brought away copper and door locks, which I found on her cabin

> doors on the beach. On the stern of a jollyboat I found the name Issac Holder branded, probably the builder's name. Good water may be obtained on this island. The second island in size is about two miles long and a half a mile wide, with little vegetation, few fowls, and plenty of turtle. The third is a mere sand spit.

Kure Atoll was next visited by the U.S.S. Lackawanna, Capt. William Reynolds commanding. On 31 August 1867 the ship circled the reef and the following report was made (RG 45 National Archives Log of the Lackawanna May 20, 1867 to November 24, 1867).

> Island 14 3/4' in circumference, somewhat oval shaped. Wall extended from middle of green island to NW extreme as at Brooks island, but showing about water to the westward, a low sand island, west of green island as at Brooks but not so high. A large tree with roots on beach. A lower mast of a ship on green island NE corner. Lagoon all shallow water. No sign of entrance or inside anchorage from aloft.

At approximately 4 a.m. on 28 October 1870 the U.S.S. Saginaw, Lt. Commander Montgomery Sicard commanding, left Midway Atoll, after seven months of work, for San Francisco. Before setting sail for California, however, the Captain decided to go to Kure Atoll and confirm its position and look for shipwrecks. Early in the morning on 29 October the ship was resting on the northern reef of Kure Atoll and taking on water rapidly. The Friend for February 1, 1871, reports that:

> It was in truth, a remarkable shipwreck. The night had been clear straight, with a moderate breeze. The ship was heading direct for an island whose position and distance - and that a short one - were known, approximately if not precisely. She was making not over two and a half to three knots, yet she ran directly, without any particular lack of vigilance, on a reef which was above water, and on which the breakers where dashing furiously.

Nonetheless, Lt. Commander Sicard was cleared of negligence by a board of inquiry.

Since the ship did not break up until several weeks had passed, much gear was salvaged and a comfortable camp was erected on Green Island. Readers are referred to George H. Read's The Last Cruise of the Saginaw for details of life on the island. Much of the time was spent building a gig and another larger boat to effect their rescue.

On 18 November 1870 the gig, with Lt. J.C. Talbot, Peter Francis, James Muir, John Andrews, and William Halford aboard, left Kure for Honolulu. After a long, arduous journey they sighted Kauai on 18 December. One day later the gig went through the surf and capsized killing all crew members except Halford (The Friend, Jan. 1, 1871). When news of the Saginaw reached Honolulu the American Consul dispatched the Kona Packet to rescue the crew and the Hawaiian King dispatched the steamer Kilauea for the same purpose because he was afraid that the slower-moving Kona Packet would not arrive in time. On 3 January 1871 the Kilauea reached Kure and the next day the crew was taken off the island.

The next recorded visit to Kure was in 1881 when the British schooner Ada spent about two days there from 30 December to 1 January collecting turtles, bêche-de-mer, and eggs. They took 6 turtles, 140 beche-de-mer, plenty of bird eggs, and at least 2 rotten turtle eggs (Hornell, 1934).

On 15 July 1886, the Dunnottar Castle, H.A. Martin captain, bound for Wilmington, California, from Sydney, Australia, wrecked upon the reef of Kure Atoll (Honolulu Almanac and Directory, 1887). Nine days later Mr. Norman and six men left in a boat to get relief from Honolulu. After a journey of about 52 days they arrived at Hanalei, Kauai, and on 14 September the Waialeale left Honolulu to rescue the crew. However, the remaining 22 crewmen had been taken off the island by the Birham Wood of St. John's, New Brunswick. During their brief stay on the island they evidently ate turtles and seafowl.

The Waialeale arrived on 20 September and the island was taken possession of by James H. Boyd for King Kalakaua of Hawaii with the following words:

> I Colonel James Harbottle Boyd by the power in me vested by His Hawaiian Majesty King Kalakaua's Commission as His Special Commissioner do in His Royal Name take formal possession of Ocean Island or Moku Papapa as a part and portion of His Royal Domain.
>
> Done at Ocean Island or Moku Papapa this 20th day of September A.D. 1886.
>
> Jas. H. Boyd
> His Hawaiian Majesty's
> Special Commissioner
> (Hawaiian Archives, Letters Book 28, p. 298).

The next day the relief party erected a house 20 feet by 12 feet with a corrugated iron roof, placed water tanks, and

sowed seeds of alegeroba, pride of India, Kamaui, monkey pod, noouki, and ohia trees. They reported that the island is now barren of trees with a stunted vegetation. The trunk of a tree fifteen inches in diameter and four feet high was found standing on the island. On 21 or 22 September the Waialeale left the atoll.

Apparently in 1889 Captain Johnson of the Norma visited Kure before going to Midway to rescue the Wandering Minstrel castaways (Cameron, 1928). He found that the building had blown down and was mostly buried in the sand.

There were also two visits in the late 1880's or 1890's for which details are lacking. John Cameron of the Ebon reported that the island was sandy and barren with a very exposed anchorage (Cameron, op. cit.). He went ashore to see the building erected by the Hawaiian Government in 1886 but found only sheets of corrugated iron, which he took back to the ship, scattered about. He reported that he had heard that a party of Japanese feather hunters had stolen the provisions.

In the Log of the Kaalokai (1909) Captain F.D. Walker reports that the provisions from the shelter were stolen less than twelve months after it was erected. He also has a picture of the remains of the shelter and of the lagoon. No mention of any visit was made in the text.

On 15 February 1894 the North Pacific Phosphate and Fertilizer Company leased Kure Atoll for 25 years at a rental of a dollar a year. The company was also granted the exclusive rights to mine the phosphate deposits thereon, provided a royalty of 50 cents a ton was paid to the Hawaiian Government. However, if mining was not begun within five years of the signing of the contract, the lease would be withdrawn. Since evidently no guano was mined at Kure, the lease expired in February 1919.

Kure Atoll was acquired by the United States of America as part of the Territory of Hawaii on 7 July 1898.

20th Century

In contrast to the 19th century, most 20th century visits to Kure were purposeful. The first systematic bird observations were made in March 1915 and April 1923 (Biological Survey Section).

On 18 May 1905 the U.S.S. Iroquois, Lt. Commander A.P. Niblack commanding, visited the atoll for about six hours, sent a boat ashore, found no people, and then left for Midway (RG 24 Log of the U.S.S. Iroquois 1905). An equally brief visit was

made on 23 January 1910 by the Thetis, Captain W.V.E. Jacobs commanding (RG 26 Log of the Thetis 1910). A party landed on both islands, found a number of sea lions, numerous birds, no people, and no sign that people had landed there recently.

Kure Atoll became part of the Hawaiian Islands Reservation on 3 February 1909 when President Theodore Roosevelt signed Executive Order 1019 reserving Kure Atoll for the use of the Department of Agriculture as a preserve and breeding ground for native birds.

A party from the U.S.S. Hermes, Lt. John T. Diggs commanding, was unable to land due to heavy surf on 15 September 1918. This was unfortunate since they were observing birds. They reported:

> Ocean Islands consists of three islands, lying fifty-six miles west of Midway and reminds one very much of Midway in formation, with another natural reef breakwater inclosing them, about fourteen and three quarter miles in circumference.
>
> Green Island, the first of the three approached, is about twenty feet above the sea line at its highest end and is covered with shrubbery along the top level. It is about one and a half miles long by three quarters of a mile wide and appears alive with birds of about the same species that inhabit the other islands. The Laysan Albatross, White Tern, White-breasted Petrel, boobies, Black-footed Albatrosses were observed flying around the vessel.
>
> To the westward of Green Island appear two more Islands composed of sand, the westernmost of which is about ten feet above sea level, upon which no vegetation could be observed (RG 45 Report of Commanding Officer to Commandant 14th Naval District).

The U.S.S. Marblehead, Capt. H.K. Cage commanding, passed by the atoll on 24 April 1928 and reported that there were no signs of habitation or wrecks on the reef (RG 80 Log of the Marblehead 1928).

During the 1930's and early 1940's several ships visited the atoll briefly. As part of the United States Navy's Fleet Problem XVI, the U.S.S. Dobbin visited Kure from 12 to 22 May 1935 and the U.S.S. Ramsay was there 15 and 16 May 1935 (RG 24 Logs of the Dobbin and Ramsay 1935).

On 13 June 1940 the U.S.S. Childs, Lt. Commander J.L. Pratt commanding, surveyed the lagoon and island, and installed permanent shoal markers. They reported no evidence of recent activity except a wrecked Japanese boat still on the northern part of the reef (RG 24 Log of the Childs 1940 and RG 37 Aircraft Advanced Base Report of U.S.S. Childs). The HMAS Manoora was there in February 1941 (Pacific Island Pilot, Vol. III, 1946), the U.S.S. Saury and U.S.S. Spearfish on 26 August 1941 (RG 24 Logs of the Saury and Spearfish 1941), and the U.S.S. Preble on 20 April 1942. The Preble reported that they saw the remains of two fires and a small lean-to on the southwest end of Green Island (U.S. Navy, War Diary U.S.S. Preble).

On 23 June 1934 the USCG ship Itasca, J.S. Baylis commanding, briefly visited the atoll. The captain, officers, and guests left the ship and investigated the island (RG 26 cruise report for the Itasca for the month of June 1934). They reported thousands of birds, 50 or 60 seals, no inhabitants or boats, and hundreds of glass balls, one of which was thrown overboard on 6 April 1931 east of Honolulu by the Chichibu Maru.

On 20 February 1936 President Franklin D. Roosevelt signed Executive Order 7299 placing Kure (Ocean) Island and surrounding reef under control and jurisdiction of the Secretary of the Navy for naval purposes.

From 5 to 13 April of that same year the U.S.S. Oglala, Commander F. Cogswell commanding, and the U.S.S. Quail, Lt. H.T. Wray commanding, surveyed the island and the lagoon for possible use as a military airfield (RG 37 Report of the Survey of Kure Island and Pearl and Hermes Reef). Under the direction of Lt. W. Nyquist they made soundings in the lagoon, astronomical observations, and tide observations. They reported:

> Green Island is on the southeastern side of Ocean (Kure) reef. The island lies in a northeast southwest direction and is about 1 1/2 miles long and 1/2 mile wide. It is covered with very irregular sand dunes which rise to about 20 feet. These sand dunes are covered with a thick growth of wild magnolia 6 to 8 feet high. The beach on the lagoon side is about 75 feet wide at high water and a camp could be established. There is quite an area where boats can easily beach. Quite a few seals and birds inhabit this island. One turtle was seen. The lagoon abounds with mullet and rock fish...It is covered with wild magnolia and nesting albatross.

The Japanese steamer Stato Maru with a crew of 25 to 30 men wrecked at Kure Atoll on 25 February 1938. Presumably they were taken off the island by the Japanese vessel Aomori.

I have no records of any activity at the atoll during World War II but undoubtedly it was visited by naval vessels and possibly by groups from Midway. Walter Lord (1967) reports that as part of their invasion of the Hawaiian area, the Japanese planned to build a miniature submarine base there.

Bailey (1952) reports seal counts made at Kure in summer 1949, 2 August, and 12 October 1951 by people from Midway Atoll.

On 17 November 1952 President Harry S. Truman signed Executive Order 10413 restoring Kure Atoll to the Territory of Hawaii. The Navy had the right to maintain a radar reflector there. Apparently this reflector was built in 1955, but I have no details of its construction.

The 1950's saw an increase in the number of visits to the atoll. Most of these were made by United States Fish and Wildlife Service personnel and are discussed in the Biological Survey Section.

The most lasting change at Kure was the establishment of a United States Coast Guard LORAN (Long Range Navigation) station. Construction began in June 1960 and was completed in April 1961. The major features of the station are a barracks, a signal/power building, a transmitter building, a pumphouse, seven fuel tanks, a 4,000-foot-long runway and a 625-foot-high LORAN tower.

On 17 March 1961 the station was commissioned with a crew of 1 officer and 23 enlisted men. The station is still operating (1970) as part of the world-wide aids to navigation system of the U.S. Coast Guard. Kure Atoll is also a Wildlife Refuge under the jurisdiction of the Hawaii Fish and Game Department. Under the terms of the lease from the Hawaiian Commissioner of Public Lands, the Coast Guard will protect "all species of turtles and the Hawaiian monk seal, and so far as practicable and with Coast Guard operational requirements the Lepturus repens, Solanum nelsoni var. intermedium, and all other animal (except rodents), bird and vegetable life on the island."

DESCRIPTION

Kure Atoll is situated on the top of a submerged volcano, part of the submarine Hawaiian Ridge which extends southeastward to the high mountainous island of Hawaii. Drilling at Midway

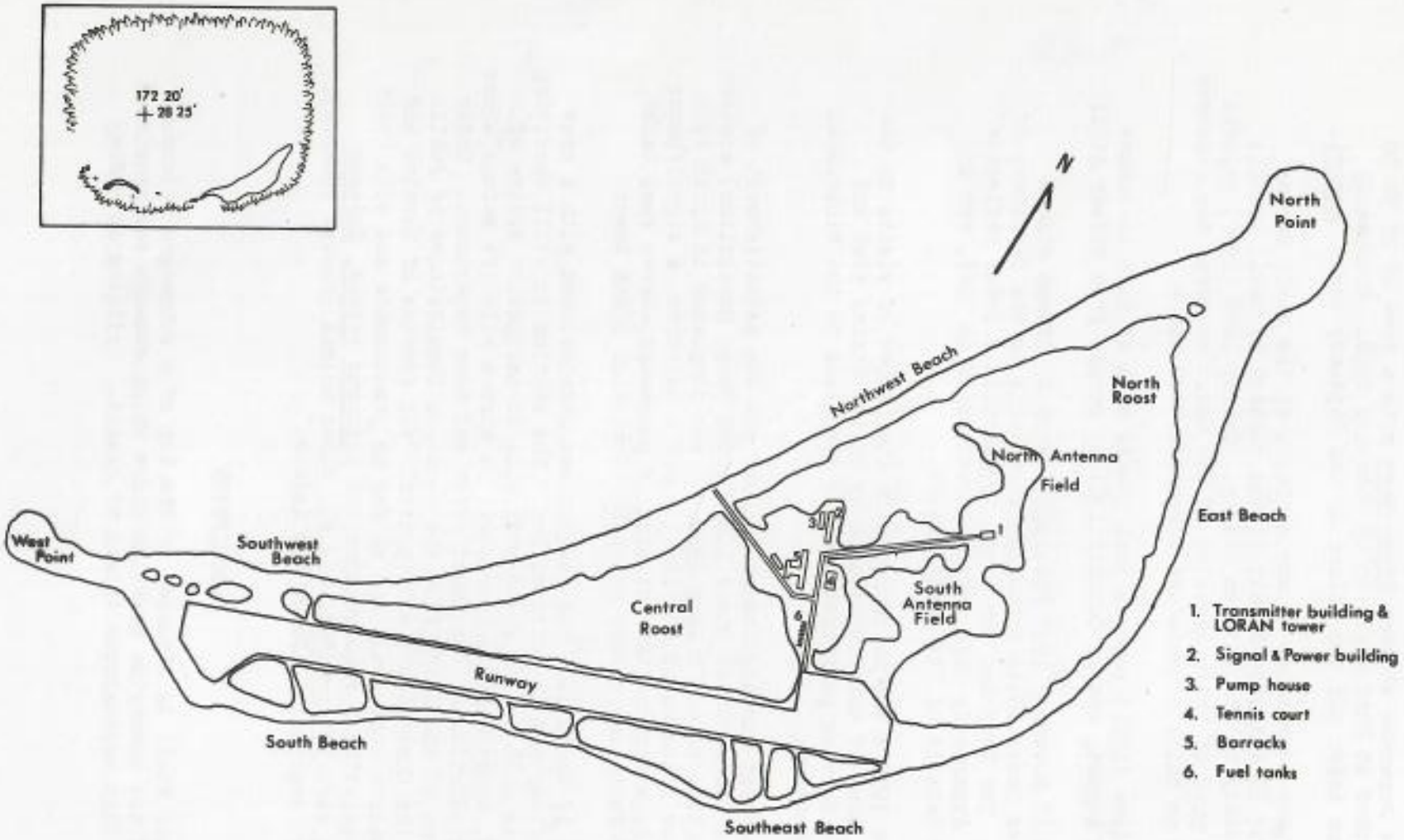

Figure K-1. Green Island, Kure Atoll.

Atoll indicated that the reef there dates back to Miocene times, some 28 million years ago (Ladd et al., 1962).

The atoll is nearly circular with the outer reef almost completely enclosing the lagoon except for passes on the southwestern side. It is oriented on a northwest to southeast axis and has a maximum diameter of 9.5 kilometers. Unusual features are the elongated reef patches and coral ridges in the lagoon and the presence of an emergent rock ledge on the outer reef. The ledge is composed primarily of coralline algae and of algally bound and encrusted pieces of coral and other carbonate materials, mainly aragonite and magnesium calcite. This material was dated by the Carbon-14 method at 1,480 ± 250 years BP. The reef, comprising an area of about five square kilometers, is composed of coralline algae and corals (Gross et al., 1969).

The lagoon has a maximum depth of fourteen meters. Six square kilometers of the lagoon terrace are greater than five meters high and forty square kilometers are less than five meters high (Gross, op. cit.).

On the outer reefs, the lagoon terrace, and seaward island beaches, gravel and coarse sand are the dominant textural types, while on the lagoonward side coarse sand or medium to fine sand generally predominate. In the lagoon, medium to fine sand and fine debris are the common sediment (Gross, op. cit.).

Green Island, the only permanent land mass in the atoll, is located near the fringing reef in the southeast sector (Figure K-1). Crescentric in shape with the long axis curving from north to west, it is 1.43 miles in greatest length and 0.37 miles in maximum width. Sandy points, whose shapes and sizes vary seasonally and with local weather conditions, are present at both ends of the island.

Standen (ms.) studied the changes at the north point from 7 February to 7 March 1965. His results are briefly summarized here. During the first two days the point lengthened about 100 feet. On 18 February the point had grown by another 25 feet, but strong wave action had eroded away a narrow section and the last 50 feet were separated from the main body of the island at high water. On 6 March the point was 100 feet longer than on 27 February and 200 feet longer than on 9 February and it curved westward. A storm on the night 6 to 7 March washed the entire point away. Standen concluded:

> First, wind direction and the wave action associated with it are key factors in determining island shape, especially regarding availability of material upwind to be transported. With the main body of land to

the upwind side, waves are provided with a large source of sand. Stronger winds may also initiate wave action that picks up and carries sediments from the lagoon bottom. Waves from a direction with no source of material for transport become erosive agents to small islands at a rate increasing with their velocity and size.

Wind speed determines where and how sand will be deposited by water currents. Waves and currents driven by winds less than Beaufort 4 deposit sand parallel to the wind in shallow areas to the lee of already existing islands or on sandbars. Waves and currents driven by winds above Beaufort 4 deposit sand perpendicular to the wind or parallel to the wave fronts. Thus the main axis of the island is perpendicular to the strongest waves, i.e., northwest where lagoon wave fetch is greatest. Vertical growth of the island through wave action occurs when the beach runs at right angles to the wind and thus the wave fronts and when the winds are strong enough to generate waves which cast sand high on the beaches (farther back) without breaking entirely over the island.

Any new sequence of wind directions may temporarily cause a difference in the amount of transported material owing to new sand recently deposited upwind. The usual sequence of winds is clockwise with the passage of lows, but occasional reversals do occur.

In summer the west point is well developed to the west and the north point is hooked slightly to the northwest. During the winter, however, the west point is typically absent and the north point curves to the east.

A sandy beach encircles the entire island. On the ocean side it is narrow and fairly steep with much coral rubble and other debris strewn about, especially on the southern side. Further north it widens and the slope is gentler. The lagoon side is wide, as much as 200 feet, and considerably less steep than the ocean side. Here the sand is finer than on the ocean side. In winter water may wash up to the edge of the vegetation around the entire island. Exposed coral boulders are present along the southern beach and near the west point.

Along the lagoon beach there is a series of sand dunes, some as high as 25 feet, that decreases in elevation southwest along

the beach. Behind the dunes, to the east, the surface settles gently into a low, relatively flat depression. The elevation here is from 6 to 10 feet. Dunes are absent along the ocean side and elevations here do not exceed 15 feet.

Presently the dominant features on the island are man-made: the 625-foot LORAN tower and transmitter building in the central plain, the 70-foot-high radar reflector on a dune along the southwest beach, the 4,000-foot runway, and the building complex near the center of the island. A dense growth of Scaevola taccada and the open central plain are the main natural features.

The area to the south of the runway is relatively level and covered with a continuous growth of Scaevola which is dissected by a series of seven paths leading from the runway to the beach. In contrast, the area to the northwest is rolling with dunes along the lagoon and the runway. Scaevola covers most of this area but there are many open areas (Fig. V-1).

North of the building complex and the runway the terrain is relatively level. In the center of the area is the open central plain, some 20 to 25 acres in extent. It is oriented along a north to south axis. Surrounding this plain of low herbaceous plants is tall, dense Scaevola. A series of paths runs through this vegetation.

Figures D1-11 show island scenes and should convey to the reader a better impression of Kure than could ever be expressed in words.

To the west of Green Island are three sandbars known collectively as Sand Island. These islets are variable in size and shape throughout the year. Generally they follow the pattern of the north and west points of Green Island. The largest one may be as long as 400 meters and as wide as 20 meters. Birds breed only on this largest islet. During the winter these islets may wash away.

VEGETATION

Christophersen and Caum (1931) reported 13 species of vascular plants collected at Kure Atoll by the Tanager Expedition. In 1959 Clay (1961) found an additional 6 species and Lamoureux (1961) reported another 23 in 1961. During POBSP studies four previously unreported species were found; thus 46 species of vascular plants have been recorded at Kure Atoll (Table P-1). The majority of these species was intentionally or accidentally introduced during the construction of the LORAN station.

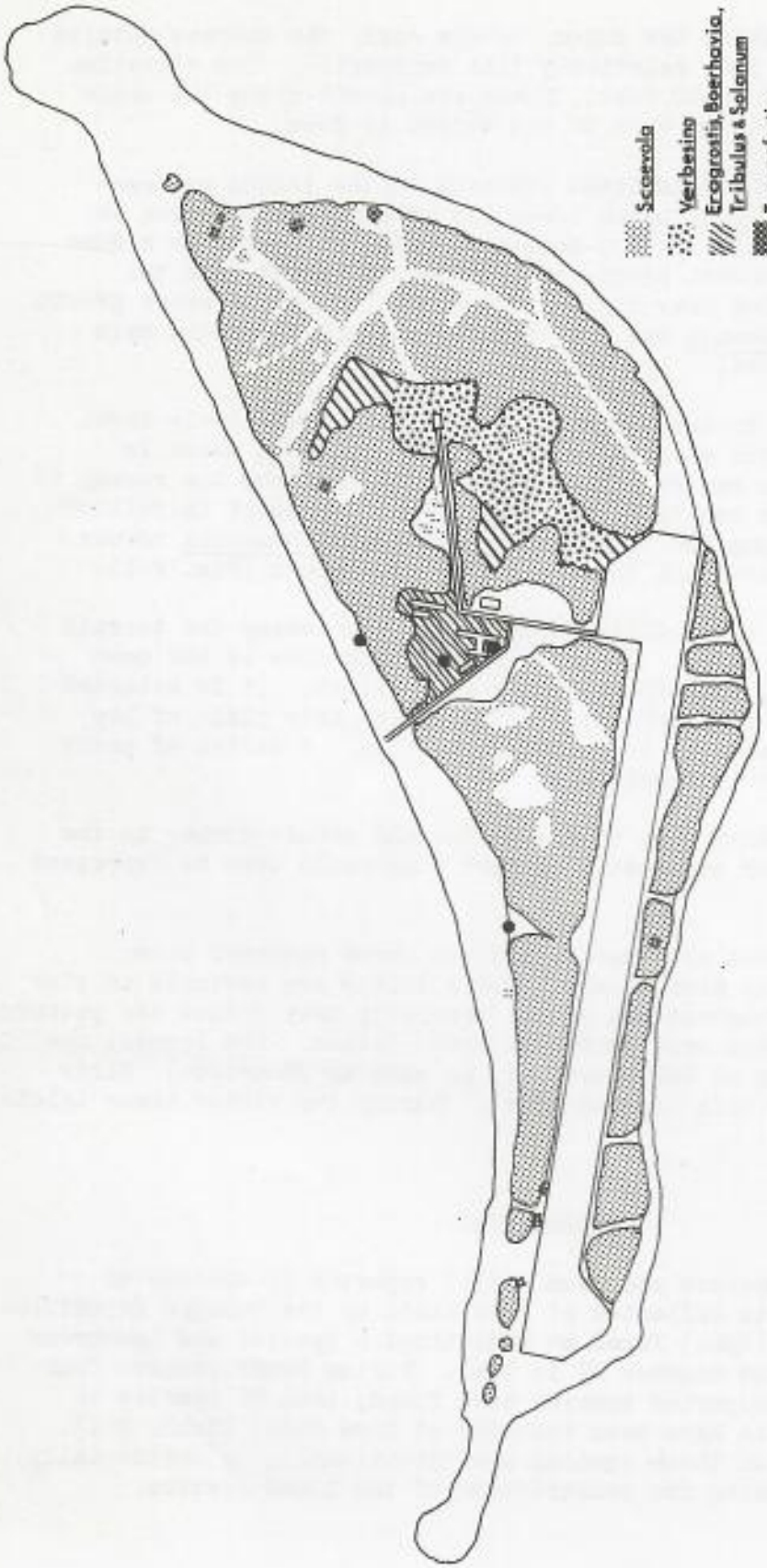

Figure V-1. Vegetation of Green Island, Kure Atoll.

Figure D-1. Aerial view of Green Island, Kure Atoll, looking north, 6 April 1966. Official U.S. Coast Guard photograph.

Figure D-2. Aerial view of Green Island, Kure Atoll, looking south, 27 February 1968. Official U.S. Navy photograph.

Figure D-3. Aerial view of building complex on Green Island, Kure Atoll, 13 October 1964. Official U.S. Navy photograph.

Figure D-4. North antenna field from north tower, Green Island, Kure Atoll, 1 July 1968. POBSP photograph.

Figure D-5. Blue-faced Boobies in north antenna field, Green Island, Kure Atoll, 1 July 1968. POBSP photograph.

Figure D-6. Looking towards west point from radar reflector, Green Island, Kure Atoll, 1 July 1968. POBSP Photograph.

Figure D-7. Breeding Red-footed Boobies in central roost, Green Island, Kure Atoll, 1 July 1968. POBSP photograph.

Figure D-8. South beach, Green Island, Kure Atoll, 1 July 1968. POBSP photograph.

Figure D-9. Edge of runway, Green Island, Kure Atoll, 1 July 1968. POBSP photograph.

Figure D-10. Looking towards north point from north tower, Green Island, 1 July 1968. POBSP photograph.

Figure D-11. Sooty Tern colony in south antenna field, Green Island, Kure Atoll, 1 July 1968, POBSP photograph.

Christophersen and Caum (1931) described Green Island in 1923 as

> covered with a dense, almost impenetrable growth of Scaevola frutescens..., which averages 5 to 6 feet in height, except in small areas, generally on the tops of the sand hills, where it is only about waist high and fairly open. In these openings and along the outer rim of the thicket are a few other plants, principally the tall bunch-grass, Eragrostis variabilis, and the creeping Boerhavia diffusa. Toward the east central part of the islet is a large, open plain, probably 20 to 25 acres in extent, entirely surrounded by the tall Scaevola frutescens....With the exception of a few "islands" of Scaevola frutescens, scarcely any vegetation in this central plain was over 2 feet high, and most of it was considerably under that height.

Achyranthes splendens, Tribulus cistoides, and Lipochaeta intergrifolia were found only on the plain, while Eragrostis variabilis, Boerhavia diffusa, Lepidium owaihiense and Solanum nelsoni grew on the central plain and in open areas among the Scaevola. Two clumps of Cenchrus agrimonioides were found, one among Scaevola and one on the edge of the central plain. Other plants were found as follows: Eragrostis whitneyi grew sparingly on the outer edges of the dunes at the northwest corner; Lepturus repens at one spot among Scaevola; Ipomoea indica on Scaevola; and Sicyos hispidus on Scaevola islands in the central plain and on the inner edge of the scrub.

In October 1959 Clay reported a vegetative condition similar to that recorded in 1923. However, he found Cynodon dactylon, Casuarina equisetifolia, Pluchea odorata, and Verbesina encelioides growing near the radar reflector and surmised that seeds of these plants were brought on equipment from Midway Atoll in 1955 when the reflector was built. Two other new species were reported: a young Tournefortia argentea growing on the windward shore and Solanum nigrum on the central plain.

By the time Lamoureux visited Kure in September 1961 the island had been greatly altered by the construction of the LORAN station. As a result, there were more open areas: along the runway, around the building complex and roads and through the Scaevola on the south side of the runway (the remains of the albatross paths built in 1959). He reported (1961) the following changes in these areas:

a. Margins of roads and runway. Boerhavia diffusa has covered most of the margin of the runway, with Tribulus cistoides and some weedy grasses occurring as scattered individuals. Along the roadsides Boerhavia is somewhat less abundant with a larger proportion of weeds.

b. Albatross runways. Covered with Boerhavia.

c. Clearings around living quarters. Gnaphalium sandwicensium is extremely abundant in areas where Cynodon dactylon has not been planted. Euphorbia glomerifera, Emilia javanica, Conyza bonariensis, and Eragrostis amabilis were found only here.

d. Clearing around LORAN Tower. A series of cleared strips a few meters wide radiate out from the base of the tower to the guy-wire anchors. These strips cut through most of the eastern part of the central plain. Boerhavia diffusa, Lepidium owaihiense, Lipochaeta integrifolia and Solanum nigrum are moving into these areas.

Twenty-three new species were found on this trip. Only one, Phyllostegia variabilis, was native and had probably been overlooked by earlier observers. Cocos nucifera, Codiaeum sp., Hibiscus sp., Thespesia populnea, Terminalia catappa, Nerium oleander, and Helianthus annuw were cultivated around the buildings while the other new species were found in disturbed areas and were undoubtedly accidentally introduced to the island during construction work. Scaevola was still the most abundant plant and the central plain was still present.

During POBSP studies the vegetation on Green Island remained similar to that found by Lamoureux, although much of it had grown taller. The following is an account of the vegetation on Green Island in 1968 and applies to most years POBSP personnel worked on the island.

Scaevola taccada covers most of the island (Fig. V-1) except for the original central plain and man-made open areas. The extent of these areas varies. For example, after the station was built, most of the area under the LORAN tower and its supporting guywires was devoid of Scaevola. By 1963, when POBSP studies began, most of this area, except for that portion of the central plain where Scaevola has never grown, was again covered with this species. Given enough time, the majority of these man-made areas would again by covered with Scaevola.

There are three types of open areas--the central plain, the area around the buildings, and the other man-made areas. On the central plain, the dominant species are Eragrostis variabilis, Boerhavia diffusa, Lepidium owaihiense, Tribulus cistoides, Solanum nelsoni, Sicyos hispidus, and Verbesina encelioides. Cenchrus echinatus, Achyranthes splendens, Ipomoea indica, Solanum nigrum and Lipochaeta integrifolia also grow there.

Around the buildings Cynodon dactylon was planted as a lawn grass and is now the dominant ground cover; most native species are rare or lacking. Cocos nucifera, Casuarina equisetifolia, Hibiscus sp., Thespesia populnea, Terminalia catappa, Nerium oleander, and Pluchea odorata were planted as ornamentals.

In the other open areas the commonest species are Eragrostis variabilis, Boerhavia diffusa and Gnaphalium sandwicheum. Elusine indica, Tribulus cistoides, Solanum nelsoni, Solanum nigrum, Sonchus cleraceus, and Verbesina encelioides are also common.

Besides Scaevola, Casuarina equisetifolia and Tournefortia argentea are the major shrub or tree species on the island. The former species is present in three groups around the barracks and in one group along the southwest beach near the radar reflector. These trees are about 20 feet tall. Great Frigatebirds, Red-footed Boobies, and Black Noddies commonly roost in them but no birds nested in them during POBSP studies. Tournefortia is found at the north end of the island (4 trees about 10 feet high), northwest of the central plain (1 tree about 10 feet tall), south of the runway (1 tree about 10 feet tall), and along the southwest end of the runway (3 trees 3 to 4 feet tall) (see Fig. V-1). Red-footed Boobies and Great Frigatebirds breed in the northernmost tree along the northeast beach, while the others are utilized only for roosting. Scaevola provides roosting areas, breeding areas, and/or shelter for most avian species.

Verbesina encelioides is the most important of the introduced species to the island's avifauna. First found in October 1959 growing near the radar reflector, it is now widespread and growing in most of the open areas, mainly the central plain and near the radar reflector. Growing in dense stands and up to 4 feet tall, it is a potential danger to the island ecosystem, especially its ground nesting birds and native vegetation. Birds have difficulty moving through Verbesina stands and when the plant becomes dense enough are no longer able to breed where it grows. Presently the breeding habitat of the Blue-faced Boobies is threatened in such a manner. Other plants cannot grow under it, so native plant species in the central plain are also threatened. The range of this species continues to expand rapidly on the island.

Other species of importance to the birds include Boerhavia diffusa, Tribulus cistoides, and Solanum nelsoni. These plants are used as nesting materials by Red-footed Boobies and Great Frigatebirds.

There is a definite seasonal growth and reproductive period for plants, mainly from June through October. In summer, for example, Tribulus and Boerhavia cover the cleared breeding sites of the Blue-faced Booby and probably prevent the building of nests at this time. There is little growth from November through March. During this period wind and sand may scour and defoliate Scaevola, primarily on the windward side and to a lesser extent elsewhere on the island.

Table P-1. Vascular plants recorded at Kure Atoll by various people.

	Christophersen and Caum	Clay	Lamoureux	POBSP
Pandanaceae				
Pandanus sp.			x	
Gramineae				
Brachymenium sp.				x
Cenchrus agrimonioides Trin. var. laysanensis	x		x	x
Cenchrus echinatus L.			x	x
Choloris inflata Link			x	x
Choloris virgata Swartz			x	x
Cynodon dactylon (L.) Pers.		x	x	x
Digitaria sanguinalis (L.) Scop.			x	
Digitaria henryi Rendle				x
Eleusine indica (L.) Gaertn.			x	x
Eragrostis amabilis (L.) W & A.			x	
Eragrostis variabilis (Gaud.) Steud.	x	x	x	x
Eragrostis whitneyi var. caumii Fosb.	x	x	x	x
Lepturus repens (Forst.) R. Br.	x	x	x	x
Setaria verticellata (L.) Beauv.			x	x
Cyperaceae				
Cyperus rotundus L.			x	x

Table P-1. (continued)

	Christophersen and Caum	Clay	Lamoureux	POBSP
Palmae				
Cocos nucifera L.			x	x
Casuarinaceae				
Casuarina equisetifolia		x	x	x
Amaranthaceae				
Achryanthes splendens var. *reflexa* Hbd.	x		x	x
Amaranthus spinosus L.				x
Nyctaginaceae				
Boerhavia diffusa L.	x	x	x	x
Caryophyllaceae				
Spergularia marina (L.) Griseb.			x	x
Cruciferae				
Lepidium owaihiense C. and S.	x	x	x	x
Lepidium virginicum L.				x
Zygophyllaceae				
Tribulus cistoides L.	x	x	x	x
Euphorbiaceae				
Codiaeum sp.			x	
Euphorbia glomerifera (Millsp.) Wheeler			x	x
E horbia hirta L.				x
Malvaceae				
Hibiscus sp.			x	
Thespesia populnea (L.) Sol.			x	
Combretaceae				
Terminalia catappa L.			x	
Apocynaceae				
Nerium oleander L.			x	x
Convolvulaceae				
Ipomoea indica (Burm.) Merr.	x	x	x	x

Table P-1. (continued)

	Christophersen and Caum	Clay	Lamoureux	POBSP
Boraginaceae				
Tournefortia argentea (L.F.)		x	x	x
Labiatae				
Phyllostegia variabilis Bitter			x	x
Solanaceae				
Solanum nelsoni Dunal	x	x	x	x
Solanum nigrum L.		x	x	x
Cucurbitaceae				
Sicyos hispidus Hbd.	x	x	x	x
Goodeniaceae				
Scaevola taccada	x	x	x	x
Compositae				
Conyza bonariensis (L.) Cronq.			x	x
Emilia javanica (Burm.) Rab.			x	x
Gnaphalium sandwicheum Gaud.			x	x
Helianthus annuw L.			x	
Lipochaeta integrifolia Gray	x	x	x	x
Pluchea odorata (L.) Cass		x		x
Sonchus cleraceus L.			x	x
Verbesina encelioides (Cav.) B. and H.		x	x	x

CLIMATE

The climate at Kure is subtropical marine and is influenced by two main air masses and by the surrounding ocean where surface variables are relatively small. For example, sea surface temperatures vary from a low of 69°F. in February to a high of 80°F. in August and September, and salinities from 35.2‰ in April to August and 35.0‰ in November to February (Seckel, 1962).

Most of the year Kure is in the path of the northeast trade winds from the Pacific subtropical anticyclone, but in the winter

it is on the southern edge of the Aleutian low, with resultant westerly winds. Table C-1* lists the wind direction at Kure for the years 1961 to 1968. From November to February winds were variable, with a strong westerly component which in some years was not well-developed. Winds were again variable from March to June and September to October, but with a major easterly component. The northeast trade winds were best developed in July and August when almost all winds came from the east.

Windspeeds ranged from 0 to 8 on the Beaufort Scale (0 to 46 knots), with a yearly average of about 2 (4 to 7 knots). From 1961 to 1968 average semi-monthly windspeeds (Table C-2) varied from 1.5 to 4.0 (2 to 18 knots). Although there was no consistent yearly pattern, there was a tendency for the strongest winds to occur in winter and early spring, and the weakest winds in summer. In 1967 windspeed varied little throughout the year.

Although there is yearly variation in the average semi-monthly temperatures (Tables C-3 and 4), the pattern of temperature change throughout the year is the same. The average maximum varies about 20°F., from 65°F. to 85°F., and the average minimum varies about 17°F., from 58°F. to 75°F. The absolute variation was 39°F. to 99°F.

From December through April the average semi-monthly maximum is about 70°F., in May, June, and November between 70°F. and 80°F., and from June through October 80°F. to 90°F. The average semi-monthly minimum is between 60°F. to 65°F. from December through May, between 70°F. and 75°F. in November.

January and February are usually the coldest months and July, August, and September the warmest ones. In 5 of the 7 years of POBSP study the average temperature began to increase in May, in one year in June, and the other in April. It began to decrease in September in 4 years and in October in 3 years.

Since rainfall data were not collected at Kure, the Midway Atoll data were used (Table C-5). As with other climatic parameters, rainfall was variable from year to year. Some years the wettest months were in the summer, in other years in winter.

At Midway rainfall averages about 40 inches annually. On the average it rains 12 days each month. March is the driest month and December, January, and February are the wettest months. Heavy rainfall is most common; light rain and drizzles are almost unknown. Rain occurs on only 6% of all hourly observations. Days

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* Weather data were extracted from the station logbooks. Observations were made at four-hour intervals.

with 0.02 to 0.05 inches of rain are most common, days with 0.06 to 0.10 are next commonest, followed by days with 0.11 to 0.20 inches. Thunderstorms are relatively uncommon, averaging six a year (Standen, ms.).

Table C-1. Wind direction at Kure Atoll by semi-monthly periods, 1961-68 (expressed as percentages).

January 1-15

Direction	1961	1962	1963	1964	1965	1966	1967	1968
0-30	-	10.1	0.0	7.1	14.8	6.8	15.6	20.0
31-60	-	8.9	0.0	10.6	2.3	3.5	13.3	10.0
61-90	-	6.7	0.0	11.8	0.0	2.3	13.3	10.0
91-120	-	6.7	0.0	8.2	0.0	2.3	15.6	4.4
121-150	-	4.4	1.1	11.8	2.3	6.8	8.9	5.6
151-180	-	6.7	3.4	12.9	4.6	11.5	14.4	3.3
181-210	-	7.8	15.7	9.4	1.1	23.0	7.8	2.2
211-240	-	7.8	20.2	9.4	19.3	8.1	3.3	12.2
241-270	-	19.1	39.3	8.2	28.4	11.5	3.3	8.9
271-300	-	12.3	18.0	5.9	6.8	11.5	0.0	10.0
301-330	-	8.9	2.2	2.4	14.8	8.1	0.0	11.1
331-359	-	0.0	0.0	2.4	5.7	4.6	4.4	2.2
16-31								
0-30	-	6.5	0.0	2.1	3.2	6.6	12.5	9.4
31-60	-	5.4	0.0	0.0	4.2	2.2	3.1	0.0
61-90	-	4.3	0.0	4.2	2.1	1.1	0.0	1.0
91-120	-	3.2	0.0	12.6	8.4	4.4	1.0	1.0
121-150	-	5.4	3.2	9.5	14.7	8.8	2.1	5.2
151-180	-	7.6	5.3	6.3	14.7	13.2	13.5	5.2
181-210	-	15.2	8.4	13.7	4.2	15.4	31.3	13.5
211-240	-	14.1	32.6	21.1	8.4	8.8	9.4	11.5
241-270	-	20.6	33.7	15.8	11.6	14.3	11.5	26.0
271-300	-	4.3	15.8	12.6	13.7	9.9	4.2	11.5
301-330	-	9.7	0.0	2.1	6.3	14.3	4.2	12.5
331-359	-	3.2	1.1	0.0	8.4	1.1	7.3	3.1
February 1-15								
0-30	-	6.9	0.0	3.4	17.9	26.1	15.6	0.0
31-60	-	4.6	0.0	6.8	9.0	14.8	14.4	1.1
61-90	-	6.9	0.0	4.5	6.7	21.6	8.9	0.0
91-120	-	3.4	0.0	5.7	4.5	8.0	3.3	0.0

Table C-1. (continued)

February 1-15

Direction	1961	1962	1963	1964	1965	1966	1967	1968
121-150	-	5.8	0.0	11.4	7.9	5.7	0.0	0.0
151-180	-	2.3	2.3	10.2	16.9	6.8	4.4	4.4
181-210	-	2.3	22.7	18.2	14.6	2.3	7.8	25.3
211-240	-	17.4	20.5	9.9	1.1	3.4	7.8	26.4
241-270	-	24.4	42.0	17.0	1.1	1.1	18.9	31.9
271-300	-	5.8	12.5	10.2	2.2	2.3	11.1	8.8
301-330	-	13.9	0.0	3.4	6.7	4.6	5.6	2.2
331-359	-	5.8	0.0	0.0	11.2	3.4	2.2	0.0
16-28								
0-30	-	10.5	1.3	7.1	12.8	31.6	11.1	0.0
31-60	-	5.2	2.6	3.6	10.3	35.5	16.7	0.0
61-90	-	26.3	0.0	6.0	10.3	19.7	22.2	0.0
91-120	-	7.8	1.3	4.8	7.7	4.0	2.8	0.0
121-150	-	5.2	5.1	13.1	12.8	4.0	2.8	0.0
151-180	-	9.2	12.8	15.5	26.9	0.0	9.7	1.2
181-210	-	7.8	7.7	7.1	5.1	0.0	6.9	17.7
211-240	-	11.8	11.5	16.7	0.0	1.3	4.2	29.4
241-270	-	6.5	37.2	9.5.	3.9	1.3	2.8	34.1
271-300	-	2.6	16.7	7.1	2.6	0.0	5.6	11.8
301-330	-	5.2	3.8	7.1	6.4	2.6	8.3	5.9
331-359	-	0.0	0.0	2.4	1.3	0.0	6.9	0.0
March 1-15								
0-30	-	17.9	27.8	5.7	6.8	11.4	38.9	7.8
31-60	-	5.6	21.1	8.0	2.3	1.3	10.0	23.3
61-90	-	10.1	7.8	16.1	3.4	6.3	3.3	15.6
91-120	-	8.9	7.8	13.8	3.4	8.9	1.1	6.7
121-150	-	16.8	14.4	13.8	4.6	10.1	5.6	3.3
151-180	-	20.2	6.7	9.2	9.1	26.6	5.6	7.8
181-210	-	2.2	1.1	5.7	10.2	5.1	4.4	12.2
211-240	-	1.1	4.4	2.3	15.9	3.8	4.4	4.4
241-270	-	2.2	0.0	4.6	26.1	15.2	10.0	7.8
271-300	-	1.1	1.1	9.2	8.0	1.3	8.9	7.8
301-330	-	5.6	4.4	9.2	5.7	8.9	5.6	2.2
331-359	-	7.8	3.3	2.3	4.6	1.3	2.2	1.1
16-31								
0-30	7.6	47.3	6.3	16.1	6.3	10.4	14.6	13.1
31-60	2.5	21.5	9.5	33.3	6.3	5.2	4.2	38.4
61-90	3.8	9.6	13.7	19.4	32.3	1.0	36.5	21.2

Table C-5. Semi-monthly rainfall (in inches) at Midway Atoll, 1963-68.

	January		February		March		April		May		June	
1963	3.2	3.5	1.5	1.7	3.9	9.3	2.8	0.5	1.4	0.1	0.1	1.4
1964	1.2	3.5	1.8	0.5	6.8	2.4	1.9	0.2	3.0	0.1	1.3	0.9
1965	1.3	1.2	2.0	1.5	2.0	1.1	0.1	2.1	0.2	0.1	1.8	3.7
1966	0.8	1.6	0.5	0.4	1.1	0.6	0.8	0.1	1.3	1.2	0.1	0.7
1967	0.7	2.2	3.1	5.0	1.7	0.5	0.5	1.8	0.7	0.4	3.0	0.1
1968	2.7	3.6	3.9	0.6	0.1	0.1	1.0	0.1	0.7	1.8	1.7	0.8

	July		August		September		October		November		December	
1963	1.3	5.3	2.7	0.3	0.4	2.7	3.8	2.4	9.2	1.7	1.6	0.4
1964	0.7	1.9	0.8	0.4	0.3	0.8	1.4	4.7	7.0	2.1	1.7	3.9
1965	0.3	1.0	0.2	1.3	1.3	2.2	0.2	0.6	0.8	3.2	0.5	3.4
1966	0.3	1.9	0.8	0.9	4.4	0.1	7.4	1.3	1.4	1.3	0.9	0.5
1967	5.9	7.4	6.5	0.3	0.9	1.0	1.3	0.3	7.0	3.3	2.8	2.0
1968	0.3	1.6	0.5	6.7	3.1	2.3	0.9	0.5	1.1	2.8	6.0	11.9

SCIENTIFIC VISITS

Biological Surveys

Kure Atoll received minimal attention from biologists prior to POBSP studies. In the first half of this century only two detailed surveys were made--one in 1915 and another in 1923.

On 28 March 1915 Lt. W.H. Munter of the Coast Guard Cutter Thetis spent about 5 hours on Green Island. He recorded 9 avian and 2 mammalian species. From 16 to 22 April 1923 the Tanager Expedition, a joint venture of the Bureau of Biological Survey of the U.S. Department of Agriculture and the Bernice P. Bishop Museum, visited the atoll. Led by Dr. Alexander Wetmore, the expedition collected representatives of most biological groups. Most of the data except bird observations were subsequently published. Dr. Wetmore kindly permitted me to utilize his bird observations and publish those records here. Ten additional avian species were added to the Kure checklist.

An earlier expedition sent to the Northwestern Hawaiian Islands by the U.S. Bureau of Biological Survey was unable to land at Kure when it visited the atoll on 18 September 1918. However, Lt. John T. Diggs of the U.S.S. Hermes reported 5 avian species, including the first White Tern, flying around the ship.

It was not until 34 years after the Tanager Expedition that the atoll was again systematically surveyed. On 5 June 1957 Karl W. Kenyon and Dale W. Rice of the United States Fish and Wildlife Service (the successor to the Bureau of Biological Survey) spent about 9 hours ashore and made detailed bird and seal observations. One year later, on 9 May, Rice again visited the atoll, but restricted his activities to the beach. These men also made aerial surveys on 9 and 21 December 1956; 12 February, 14 May, 18 December 1957; and 14 April, 2 May, and 28 June 1958. No new avian species were recorded.

The next to last visit prior to the construction of the LORAN station was 3 to 8 October 1959. Chandler S. Robbins, Thomas C. Horn, Horace F. Clay, and a team of Navy personnel landed on Green Island to improve the habitat for breeding albatross. A series of 18 trails connecting the open central plain with the beach was bulldozed. During this period Clay collected vascular plants and Robbins estimated bird populations. This was the first of six trips that Robbins, of the United States Fish and Wildlife Service, made to Kure prior to POBSP studies. During each stay he estimated avian populations and banded a total of 3,445 birds (Robbins, 1966). Three additional avian species were recorded during these visits.

James Hunt, a member of the United States Coast Guard, banded 400 birds of 5 species in April and May 1961. He made no systematic observations.

The only other significant biological survey prior to the POBSP surveys was from 12 to 14 September 1961 when the Harold J. Coolidge expedition visited Kure. Plants and insects were collected and limited bird observations were made.

In the winter and spring of 1963 POBSP personnel visited the atoll four times but made systematic bird observations on only one visit. Full time POBSP operations began on 13 September 1963 and continued until 19 August 1965. Extended surveys were also made from 17 April to 6 October 1966, 4 May to 9 July 1967, and 26 May 1968 to 20 June 1969.

Robbins surveyed the atoll in February 1966 and 1967 when POBSP personnel were not present. His observations are listed under POBSP records.

During POBSP studies emphasis was placed on determining what avian species occurred, when they occurred, in what number, if and when they bred, and on studying the detailed breeding biology of selected species. To facilitate this work, 60,282 birds were individually marked with numbered aluminum bands, thus allowing us to follow the life history of individuals and trace their movements. It is this work that forms the major portion of this paper. Lesser emphasis was placed on studying mammals and plants.

Table BS-1 lists major biological surveys of Kure, Table BS-2 lists minor biological surveys, and Tables BS-3 and 4 list the POBSP survey team.

Other Scientific Visits

Hydrographic surveys were made by the U.S.S. Lackawanna in 1867, the U.S.S. Tanager in 1924, and the U.S.S. Oglala in 1936. These trips were discussed in the History Section. The Lackawanna survey produced Hydrographic Office Chart 4 which showed Green Island incorrectly as approximately rectangular in shape. The latter two surveys corrected this mistake as shown in the recent United States Coast and Geodetic Survey Chart 4177.

Geodetic markers were established on Green Island in June, October, November 1959 and during 1961 by the United States Hydrographic Office, United States Coast and Geodetic Survey, and the Army Map Service. I have no details of these visits.

A study of the marine geology of the atoll was conducted by T.S. Chamberlain, M.G. Gross, G.V. Keller, and J.I. Tracey, Jr., from 29 August to 7 September 1965. Results of this work were published by Gross, et al. (1969) and Keller (1969). Thomas F. Dana reported on the corals of Kure [Dana (1971)] as a result of his work at the atoll with Scripps Institution of Oceanography in September 1968 and with the POBSP in 1969.

KURE AVIFAUNA

Introduction

Prior to POBSP studies twenty-six avian species were recorded from Kure Atoll through the combined efforts of Munter (1915), Wetmore (ms.), Kenyon and Rice (1958), and Robbins (1966). These observers recorded fourteen of the fifteen breeding species, all six of the common non-breeding species, and six rare or accidental species. The POBSP recorded an additional forty species and one hybrid; all but one, the Sooty Storm Petrel,

Table BS-1. Major biological surveys of Kure Atoll.

Date of Survey	Personnel	Resultant Publications and Manuscripts
1915 March 28	Thetis: Lt. W.H. Munter	Munter (1915), Pilsbury (1917).
1923 April 16-22	Tanager Expedition: Alexander Wetmore Edward L. Caum David T. Fullaway Chapman Grant Ditlev Thaanum	Bryan, et al. (1926), Christophersen and Caum (1931), Edmondson et al. (1925), Fowler and Ball (1925), Wetmore (1925, ms.).
1957 June 5	USFWS:* Karl W. Kenyon Dale W. Rice	Kenyon and Rice (1958, 1959), Kenyon (ms.), Rice (1960a), Rice and Kenyon (1962).
1958 May 9	Dale W. Rice, USFWS	Kenyon (ms.), Rice and Kenyon (1962), Rice (1960a, b, pers. corr.).
1959 October 3-8	Chandler S. Robbins, USFWS Horace F. Clay, University of Hawaii Thomas C. Horn, USFWS	Clay (1960), Robbins (1966).
1960 March 28	Chandler S. Robbins, USFWS Cdr. Edward P. Wilson, U.S. Navy	Robbins (1966).
1961 January 19-21	Chandler S. Robbins, USFWS Cdr. Edward P. Wilson, U.S. Navy	Robbins (1966).

Table BS-1. (continued)

Date of Survey	Personnel	Resultant Publications and Manuscripts
1961 September 12-14	Harold S. Coolidge Expedition: George D. Bulter, Jr., University of Arizona Edward C. Jestes, University of Hawaii Charles H. Lamoureux, University of Hawaii A. Starker Leopold, University of California Miklos D.F. Udvardy, University of British Columbia William Usinger, University of California Martin J. Vitousek, University of Hawaii Ronald L. Walker, Hawaii Fish and Game Richard E. Warner, University of California David Woodside, Hawaii Fish and Game	Bulter and Usinger (1963), Lamoureux (1961), Udvardy (1961), Udvardy and Warner (1964).
1962 February 2-4	USFWS: Chandler S. Robbins Paul A. Stewart	Robbins (1966)
August 6-8	Chandler S. Robbins, USFWS	Robbins (1966)

Table BS-1. (continued)

Date of Survey		Personnel	Resultant Publications and Manuscripts
1963	February 3-7	USFWS: Chandler S. Robbins John Waters	Robbins (1966).
	May 8-10	POBSP:** Robert W. McFarlane Fred C. Sibley	This paper.
1963 1965	September 13 to August 19	Various POBSP personnel	Amerson (1968), Clapp and Woodward (1968), Fleet (ms.), Kepler (1967, 1969), Maa (1968), Sibley and McFarlane (1968), Steele (1967), Tsuda (1966), Wirtz (1968, ms.), this paper.
	November 12 to December 16	POBSP: T. James Lewis	This paper.
1966	January 16-18	POBSP: T. James Lewis Max C. Thompson	This paper.
	February 6-10	Chandler S. Robbins, USFWS Norman E. Holgersen	Robbins (ms.), this paper.
	April 17 to October 6	Various POBSP personnel	This paper.
1967	December 30 to January 5	POBSP: Lawrence N. Huber T. James Lewis	This paper.

Table BS-1. (continued)

Date of Survey		Personnel	Resultant Publications and Manuscripts
1967	February 9-12	USFWS: Chandler S. Robbins, Van T. Harris	Robbins (ms.), this paper.
	March 26-30	POBSP: C. Douglas Hackman	This paper
	May 4 to July 9	POBSP: Walter Bulmer, Paul W. Woodward	This paper.
1968	March 28-31	POBSP: Robert L. Pyle, Roger B. Clapp	This paper.
1969	May 26 to June 20	Various POBSP personnel	This paper.

* United States Fish and Wildlife Service
** Pacific Ocean Biological Survey Program

Table BS-2. Minor biological surveys of Kure Atoll.

Date of Survey		Personnel	Nature of Survey	Resultant Publications and Manuscripts
1918	September 18	USS Hermes Lt. John T. Diggs	Offshore observations	RG 45, National Archives Report of Commanding Officer USS Hermes to Commandant 14th Naval Dist.
1956	December 9	USFWS*	Aerial	Aldrich et al. (ms.), Kenyon and Rice (1959).
	December 21	USFWS	Aerial	Kenyon and Rice (1958, 1959), Kenyon (ms.).
1957	February 12	USFWS	Aerial	Kenyon and Rice (1959), Kenyon (ms.).
	May 14	USFWS	Aerial	Kenyon and Rice (1959), Kenyon (ms.).
	December 18	USFWS	Aerial	Rice (1960b), Kenyon (ms.).
1958	April 14	USFWS	Aerial	Rice (1960b), Kenyon (ms.).
	May 2	USFWS	Aerial	Rice (1960b), Kenyon (ms.).
	June 28	USFWS	Aerial	Rice (1960b), Kenyon (ms.).
1959	September 26-28	Chandler S. Robbins, USFWS	Offshore observations	Robbins (ms.).
1960	March 25	Chandler S. Robbins, USFWS	Aerial	Robbins (ms.).
1963	January 17	Chandler S. Robbins, USFWS	Banded Black-footed albatross	Robbins (ms.), this paper.

* United States Fish and Wildlife Service

Table BS-2. (continued)

Date of Survey	Personnel	Nature of Survey	Resultant Publications and Manuscripts
1963 January 27	Robert Klemm, University of Southern Illinois	Cursory survey	Fisher (1965).
February 20	POBSP: Robert W. McFarlane William O. Wirtz, II	Cursory survey	No systematic observations.
March 10	POBSP: A. Binion Amerson, Jr. Robert W. McFarlane Fred C. Sibley		Clapp and Woodward (1968). No systematic observations.
June 30	POBSP: A. Binion Amerson, Jr. Robert W. McFarlane		No systematic observations.
December 11	Harvey I. Fisher, University of Southern Illinois	Cursory survey	Fisher (1965).
1964 January 16	Carl W. Buchheister, President, National Audubon Society	Cursory survey	--
	Ira N. Gabrielson, Wildlife Management Institute		
	W. Michael Ord, Hawaii Audubon Society		

Table BS-2. (continued)

Date of Survey	Personnel	Nature of Survey	Resultant Publications and Manuscripts
1964 January 16	Charles Zirzow, U.S. Navy	Cursory survey	--
	Ross Leonard, U.S. Navy		
	Chandler S. Robbins, USFWS		
March 12-15	Chandler S. Robbins, USFWS		
March 15-20	Ronald L. Walker, Hawaii Fish and Game	Capture seals, help POBSP	--
April 7-9	David Woodside, Hawaii Fish and Game	Discuss Sooty Tern problem	
August 13-16	Charles H. Lamoureux, University of Hawaii	Plant survey	This paper.
September 8-10	James Kelly, Sea Life Park	Capture seals	--
September 14	John W. Beardsley, University of Hawaii	Cursory survey	Beardsley (1966).
	Eugene Kridler, USFWS		
	Robert Long, POBSP		
	Ronald L. Walker, Hawaii Fish and Game		

Table BS-2. (continued)

Date of Survey		Personnel	Nature of Survey	Resultant Publications and Manuscripts
1965	April 2	Stanley A. Cain, Assistant Secretary of the Interior	Cursory survey	Trip report, Assistant Secretary for Fish and Wildlife, Hawaii, March 31-April 11, 1965.
		Eugene Kridler, USFWS Chandler S. Robbins, USFWS		
1966	March 15-16	Chandler S. Robbins, USFWS	Band albatross	This paper.
	April 4	Ronald L. Walker, Nelson Rice, Hawaii Fish and Game	Cursory survey	--
1968	March 28	Karl W. Kenyon, USFWS	Count seals	--
		Ernest F. Kosaka, Hawaii Fish and Game		
1969	January 31-February 3	Harvey I. Fisher, University of Southern Illinois	Cursory survey	--
		Robert Klemm, Kansas State University		
	April 10-13	Ronald L. Walker, Hawaii Fish and Game	Seal survey	--

Table BS-3. Total man-days spent at Kure Atoll by POBSP personnel.

Personnel	Days
William O. Wirtz II	316
Robert R. Fleet	267
Paul W. Woodward	220
Vernon M. Kleen	150
Dennis L. Stadel	149
David A. Bratley	106
Cameron B. Kepler	103
Thomas F. Dana	85
T. James Lewis	82
Paul G. DuMont	81
James P. Ludwig	80
Alan H. Anderson	70
George R. Wislocki	70
Robert L. Brownell	68
Robert A. Sundell	57
Roger B. Clapp	56
Robert L. DeLong	56
Ralph W. Schreiber	54
Norman N. Heryford	50
Robert S. Standen	49
Kenneth A. Amerman	44
Warren B. King	37
Richard L. Maze	36
Walter Bulmer	11
Robert L. Pyle	9
Lawrence N. Huber	6
Charles A. Ely	4
C. Douglas Hackman	4
Robert W. McFarlane	2
Fred C. Sibley	2
Max C. Thompson	2
A. Binion Amerson, Jr.	1
Total Man-Days	2,327

Table BS-4. Man-days spent at Kure Atoll by POBSP personnel (listed by years).

Personnel	Dates	Days
1963		
James P. Ludwig	September 13-December 1	80
William O. Wirtz II	February 20; September 20-November 27	69
Kenneth A. Amerman	October 30-December 12	44
Roger B. Clapp	December 5-31	27
Warren B. King	December 26-31	6
Robert W. McFarlane	February 20; March 10; May 8-10; June 30	2
Fred C. Sibley	March 10; May 8-10	2
A. Binion Amerson, Jr.	March 10; June 30	1
	Subtotal	231
1964		
Robert R. Fleet	January 26-June 7; October 11-December 23	209
William O. Wirtz II	February 23-May 4; July 23-November 25	197
Dennis R. Stadel	July 12-October 4; December 10-31	107
Paul G. DuMont	August 6-October 25	81
George S. Wislocki	May 1-July 9	70
Robert A. Sundell	June 7-August 2	57
Cameron B. Kepler	October 26-November 29; December 23-31	44
Warren B. King	January 1-31	31
Roger B. Clapp	January 1-26	26
Charles A. Ely	November 8-12	4
	Subtotal	826
1965		
David A. Bratley	May 6-August 19	106
Alan H. Anderson	February 15-April 25	70
Cameron B. Kepler	January 1-February 28	59
Robert R. Fleet	March 4-April 30	58
William O. Wirtz II	March 28-May 16	50
Norman N. Heryford	April 22-June 10	50
Robert S. Standen	January 24-April 2	49
Dennis R. Stadel	January 1-February 11	42
T. James Lewis	November 12-December 16	35
	Subtotal	519

Table BS-4. (continued)

Personnel	Dates	Days
1966		
Paul W. Woodward	April 17-July 3	77
Ralph W. Schreiber	August 14-October 6	54
T. James Lewis	January 16-18; July 14-August 21; September 18-22; December 30-31	46
Richard L. Maze	June 30-August 4	36
Max C. Thompson	January 16-18	2
Lawrence N. Huber	December 30-31	2
	Subtotal	217
1967		
Paul W. Woodward	May 4-July 9	66
Walter Bulmer	April 30-May 11	11
Lawrence N. Huber	January 1-5	4
C. Douglas Hackman	March 26-30	4
T. James Lewis	January 1	1
	Subtotal	86
1968		
Paul W. Woodward	May 26-August 11	77
Robert L. Brownell	July 28-October 4	68
Robert R. DeLong	October 18-December 13	56
Vernon M. Kleen	December 10-31	21
Robert L. Pyle	March 28-31	3
Roger B. Clapp	March 28-31	3
	Subtotal	228
1969		
Vernon M. Kleen	January 1-March 28; April 10-May 23	129
Thomas F. Dana	February 10-April 4; May 19-June 20	85
Robert L. Pyle	April 18-24	6
	Subtotal	220
	Total Man-Days:	2,327

were rare or accidental visitors to the atoll. Clapp and Woodward (1968) summarized the records of thirty-four of these species. Since that paper was written, another five species were recorded and a previously unreported sighting of a Bulwer's Petrel was found. Therefore, by June 1969, sixty-six avian species and one hybrid were recorded from the atoll. These species fall into four categories: breeding, common non-breeding, rare visitors, and accidental visitors.

Breeding Species

Fourteen species definitely breed at the atoll and the Sooty Storm Petrel probably breeds. These species are classified according to their breeding seasons as follows:

Winter-Spring Breeders

Black-footed Albatross, *Diomedea nigripes*
Laysan Albatross, *Diomedea immutabilis*
Bonin Petrel, *Pterodroma h. hypoleuca*
Sooty Storm Petrel?, *Oceanodroma tristrami*

Winter-Summer Breeders

Red-tailed Tropicbird, *Phaëthon rubricauda*
Blue-faced Booby, *Sula dactylatra*
Red-footed Booby, *Sula sula*
Great Frigatebird, *Fregata minor*

Spring-Summer Breeders

Christmas Shearwater, *Puffinus nativitatus*
Brown Booby, *Sula leucogaster*
Sooty Tern, *Sterna fuscata*
Gray-backed Tern, *Sterna lunata*
Brown Noddy, *Anoüs stolidus*
White Tern, *Gygis alba*

Summer-Fall Breeders

Wedge-tailed Shearwater, *Puffinus pacificus*

Besides breeding on Northwestern Hawaiian Islands, the Black-footed Albatross breeds on Torishima, the Laysan Albatross breeds nowhere else, the Bonin Petrel breeds on the Bonin Islands, the Sooty Storm Petrel breeds on the Volcano Islands, and the other species breed commonly on islands throughout the central Pacific.

Common Non-breeding Species

The American Golden Plover (Pluvialis dominica), Ruddy Turnstone (Arenaria interpres), Bristle-thighed Curlew (Numenius tahitiensis), Wandering Tattler (Heteroscelus incanum), Sanderling (Crocethia alba), and Black Noddy (Anoüs tenuirostris) commonly visited the atoll. The Bristle-thighed Curlew and Wandering Tattler are Nearctic forms, while the other shorebird species breed in both the Palearctic and Nearctic regions. Black Noddies breed commonly on other Hawaiian Islands.

Rare Non-breeding Species

Seven species are regular visitors (more than five records) to the atoll in small numbers. The Sooty Shearwater (Puffinus griseus), which regularly washed up on the beaches, is a southern hemisphere species that migrates commonly through the central Pacific. The other six species, Sharp-tailed Sandpiper (Erolia acuminata), Herring Gull (Larus arsentatus), Short-eared Owl (Asio flammeus), Pintail (Anas acuta), Pectoral Sandpiper (Erdia melanotos) and Glaucous-winged Gull (Larus glaucescens) are northern migrants; the former three breed in Siberia and the others breed in the Palearctic and Nearctic regions.

Accidental Species

The remaining thirty-eight species were recorded less than five times. These species can be classified by origins as follows (number in parentheses is the number of records):

Breed on other Hawaiian Islands

Bulwer's Petrel, Bulweria bulwerii (1)
White-tailed Tropicbird, Phaëthon lepturus (1)
Black-crowned Night Heron, Nycticorax nycticorax (1)
House Sparrow, Passer domesticus (1)

Breed on Equatorial Islands in the Central Pacific

Lesser Frigatebird, Fregata ariel (2)

Occur at Sea in the Area but Only Rarely or Not at All on Islands

Northern Fulmar*, Fulmarus glacialis (4)
Kermadec Petrel**, Pterodroma neglecta (1)
Murphy's Petrel**, Pterodroma ultima (1)

Leach's Storm Petrel*, Oceanodroma leucorhoa (2)
Red Phalarope*, Phalaropus fulicarius (2)
Black-legged Kittiwake*, Rissa tridactyla (2)
Arctic Tern*, Sterna paradisea (1)

Northern Vagrants

Emperor Goose*, Philacte canagica (1)
European Widgeon***, Mareca penelope (2)
Tufted Duck***, Aythya fuligula (3)
Bufflehead****, Bucephala albeola (1)
Peregrine Falcon*, Falco peregrinus (1)
Dotterel***, Eudromias morinellus (1)
Black-bellied Plover*, Squatarola squatarola (3)
Pintail Snipe***, Capella stenura (1)
Common Snipe****, Capella gallinago (1)
Wood Sandpiper***, Tringa glareola (2)
Lesser Yellowlegs****, Totanus flavipes (1)
Dunlin***, Erolia alpina (2)
Long-billed Dowitcher*, Limnodromus scolopaceus (1)
Western Sandpiper****, Ereunetes mauri (1)
Bar-tailed Godwit*, Limosa lapponica (1)
Ruff***, Philomachus pugnax (1)
Ring-billed Gull****, Larus delawarensis (1)
Slaty-backed Gull****, Larus schistisagus (1)
Glaucous Gull*, Larus hyperboreus
Black Tern*, Chlidonias niger (1)
Horned Puffin*, Fratercula corniculata (5)
Skylark***, Alauda arvensis (1)
Barn Swallow***, Hirundo rustica (1)
Water Pipit***, Anthus spinoletta (1)
Red-throated Pipit***, Anthus cervinus (1)
Snow Bunting****, Plectrophenax nivalis (1)

Populations

The term "island population" can be defined in at least five ways: (1) maximum number of birds on the island at any one time during a given period, (2) maximum number of birds using the island during a given period, (3) maximum number of birds using the island during the breeding season or year,

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* Breeds in Palearctic and Nearctic Regions
** Breeds in Southern Hemisphere
*** Breeds in Palearctic Region
**** Breeds in Nearctic Region

Table BC-2. (continued)

Species	1964	1965	1966	1967	1968	1969
Gray-backed Tern	?	Last 2 weeks June	Mid-May(?)	Last 2 weeks April	Last week April	?
Brown Noddy	June	Last week May-mid-June	First 2 weeks June	May	Last 2 weeks June-1st week July	?
White Tern	?	?	?	1st week May	26 April-11 May	?

Table BC-3. Range of egg laying and peak egg laying at Kure Atoll, 1964-69.

Species	Egg laying	Peak egg laying
Black-footed Albatross	November 14-mid-December	Late November
Laysan Albatross	November 17-mid-December	Late November-December 12
Bonin Petrel	January 17-mid-February	Late January-February 10
Wedge-tailed Shearwater	June 8-mid-July	Late June-early July
Christmas Shearwater	Late April-late June	May
Red-tailed Tropicbird	Late February-mid August	First 2 weeks April-June
Blue-faced Booby	January 5-early August	Late January-late May
Brown Booby	February 8-August 28	Mid-April-late May
Red-footed Booby	Late January-late June	Late March-mid-June
Great Frigatebird	February 21-early June	Mid-March-early May
Sooty Tern	April 25-late June	May 1-1st week June
Gray-backed Tern	April 3-late June	Mid-April-last 2 weeks June
Brown Noddy	Late April-early September	May-1st week July
White Tern	April 18-June 25	Late April-early May

Presumably the timing of these cycles reflects the periods for each species when food was most abundant for egg production and raising of young (see Lack, 1966, for full discussion). It is not surprising that, at Kure Atoll, with well-defined seasonal variation in air temperature, sea surface temperature, day length, et cetera, birds bred in well-defined cycles; their food supply probably varied regularly and predictably throughout the year. During POBSP studies only 4 Red-tailed Tropicbird, 2 Blue-faced Booby, and 8 Brown Booby nests were found outside the species' normal breeding periods. The majority of these nests failed, indicating that environmental conditions at these times were unfavorable.

It has been demonstrated on numerous occasions that lenghtening days stimulate breeding in temperate zone species (Rowan, 1929; Blanchard, 1941; Wolfson, 1952). At Kure the same stimulus is probably responsible for the initiation of breeding in spring and summer breeders. Shortening days may stimulate the albatross. Although the causes for these variations are unknown, it is probable that they are related to an actual scarcity or to the unavailability of food to the birds near the atoll. High winds, low temperatures, rain, and local storms are the most likely factors influencing food abundance and availability.

Factors Affecting Nesting Success

Details of nesting success are recorded in the appropriate Species Accounts. The following discussion summarizes those factors that affected success. Not all of them were equally important, and accurate quantitative data are lacking that showed the relative contribution of each, although rat predation and winter storms were obviously the most important.

Polynesian Rats

By far the most important factor affecting nesting success at Kure for most species was Polynesian Rat, Rattus exulans, predation. This mammalian predator has been present since at least 1870 when they were abundant (Read, 1912). Although unproven, it is probable that Polynesians accidentally introduced them long before Europeans discovered Kure. Thus, rats and birds have long been associated on Green Island, yet apparently no species has been extirpated by their predation.

The first record of rat predation was Robbins' (1966) observation that they ate Brown Noddy eggs that had been left uncovered for only a few minutes. Since 1963 an additional 9 species (Table NS-1) have been recorded as victims of rat predation. Laysan Albatross, Bonin Petrels, Red-tailed Tropicbirds, Sooty Terns, and Gray-backed Terns have suffered most heavily from this predation.

Adult and young birds that were attacked typically had open wounds, sometimes 1 to 2 inches in diameter, between the scapulae, slightly

anterior to the uropygial gland, or slightly posterior to the legs. Kepler (1967) describes the method of attack on Laysan Albatross in detail. Typical rat-damaged eggs were hollow, with a large opening at one end.

Predation was not equally intense in all years. In early 1964 only a few Laysan Albatross and Red-tailed Tropicbirds were preyed upon. By the time albatross began breeding again in the fall of 1964, and through the summer of 1965, predation was extremely heavy. Black-footed Albatross, Red-tailed Tropicbirds, Sooty Terns, and Brown Noddies were also victims of rat predation. The peak of predatory activity was reached in the spring and summer of 1966 when large numbers of birds were destroyed, the area of predation increased, and more species were recorded as being preyed upon.

Table NS-1. Avian species preyed upon by Polynesian rats on Green Island, Kure Atoll, 1963-69.

Species	Stage Preyed Upon		
	Eggs	Young	Adults
Black-footed Albatross		x	
Laysan Albatross		x	x
Bonin Petrel	x	x	
Wedge-tailed Shearwater	x	?	
Red-tailed Tropicbird	x	x	
Great Frigatebird			x
Sooty Tern	x	x	
Gray-backed Tern	x	x	
Brown Noddy	x	x	
White Tern		?	

One year later only young Sooty Terns were noted being eaten. Predation became serious again in 1968 when rats destroyed most eggs and young of Sooty Terns, and all young and eggs of Gray-backed Terns. However, no albatross were known to have been lost. From mid-December 1968 through February 1969 several Laysan Albatross were destroyed. By June 1969 rats were noted preying heavily on eggs and young of Red-tailed Tropicbirds.

Details of predation on each species are discussed below:

Black-footed Albatross: One nestling was eaten in early June 1965. In late April and early May 1966 at least seven nestlings in the northwest beach-Scaevola ecotone were destroyed. Nestlings on the open sand near the north point escaped predation.

Laysan Albatross: During the latter part of the 1963-64 breeding season at least 12 adults and a few nestling Laysans were eaten. In

the 1964-65 season over 50 adults and several nestlings were destroyed. The damage in these seasons was confined to the central plain, mainly the south antenna field.

Laysan Albatross suffered most heavily from predation in the 1965-66 breeding season. From 8 to 10 February 1966 Chandler S. Robbins found 57 adults that had been eaten by rats. Another two rat-destroyed adults were found in late April.

Robbins estimated that there were 310 nests, mainly with nestlings, northeast and east of the barracks, primarily in the north (90) and south (110) antenna fields. By mid-April only four remained: one in the north antenna field, one in the south antenna field, one along the northwest beach, and one adjacent to the central plain. Only the latter bird fledged; the others were eaten by rats during mid-May.

Robbins banded 400 nestlings in mid-March. At least 46 of these birds were eaten by rats. An additional 14 nestlings were destroyed in May and June. Predation was heaviest in the central plain, along the northwest beach, along the road to the pier, and behind the fuel tanks.

No predation was noted in 1967 or during the 1967-68 breeding season.

From mid-December 1968 through mid-January 1969 at least 32 adult Laysans were destroyed by rats. By February few adults were being molested by rats, but over 30 nestlings were killed and eaten, primarily along the runway, in the central roost, and along the southwest beach.

Bonin Petrel: Rats probably caused the complete breeding failure of this species from 1964 to 1968. Rats were commonly seen running in and out of burrows and the remains of eggs were found in these burrows.

To test this hypothesis, three study areas were established in 1969: one control area and two areas that were poisoned with Warfarin. No young Bonin Petrels were raised in the control area, but several fledged in the other two areas. Although other young fledged from areas that were not poisoned, it was probable that the poisoning had reduced the rat population in these areas as they were close to the study areas. One young Bonin Petrel, which was collected, had rat damage on the back.

Wedge-tailed Shearwater: Several egg shells broken in typical rat fashion were found. Rats were also suspected of eating chicks.

Red-tailed Tropicbird: In all years eggs and young of Red-tailed Tropicbirds were heavily preyed upon. Fleet (ms.) found that in 1964 53.6 percent of all eggs laid in a study area and 88.9 percent of nestlings hatched were lost to predation. Comparative figures for 1965 were 64.9 percent and 100 percent, respectively.

Great Frigatebird: On 16 May 1966 an adult male Great Frigatebird with a typical rat wound on its back was captured. Another adult male and 2 adult females with openings in the back were found on 10 June 1966. All of these birds were roosting. There was no evidence of predation on eggs or young.

Sooty Tern: In 1965 rats were seen carrying Sooty Tern eggs from the colony when the incubating birds were disturbed. They straddled the eggs and punctured the end before carrying them away. From 1966 to 1968 both eggs and young were destroyed by rats. In 1968 they destroyed all the eggs and young.

Gray-backed Tern: Two nestling Gray-backed Terns with openings in the back were found in May 1968. Eggs opened in typical rat fashion were also found. In 1968 the rats evidently destroyed all the eggs and young.

Brown Noddy: Both eggs and young were eaten. Nests on the open beaches generally escaped predation. In 1965 there was a 27.9 percent nestling loss in a two-week period. Only 8 of the 147 chicks lost were found, and all had wounds in the body cavity.

White Tern: A White Tern nestling with its whole back ripped open was found in June 1968. This bird may have been eaten by rats.

Discussion: Two distributional patterns of predation were noted. In those species, such as Brown Noddies and Red-tailed Tropicbirds, where only eggs or young were eaten, predation was widespread, occurring almost everywhere the species was present. The exception was individuals breeding on the open beaches who appeared to be immune to predation; individuals breeding in the densest vegetation appeared to be most susceptible.

In the case of Laysan Albatross, however, where adults were eaten, the area of predation was localized. In 1964-65 it was confined to the central plain, mainly the south antenna field. In spring 1966, predation was again extensive there, and had spread to areas north of the central plain, mainly along the northwest beach, where Black-footed Albatross were also eaten. By May it had progressed to the area by the barracks and behind the fuel tanks. Before the young fledged in July, a few along the runway were eaten. During the 1968-69 breeding season predation was noted along the runway, in the central roost, and along the southwest beach.

The localized nature of albatross predation suggests that only a small group of rats, which had learned to attack these large birds, was involved. Possibly they had overcome an initial fear of size. The fact that Fleet (ms.) found that tropicbird chicks more than 17 days old were not preyed upon supports this theory. Also, the progression of predation in 1966 suggests that a group was moving around the island attacking albatrosses.

As stated previously, predation reached a peak in 1966, when rats were extremely numerous. Starting in the fall of that year the Coast Guard began intensive poisoning around the island. By spring 1967 very few rats were noted, possibly as a result of the poisoning program or possibly as a naturally occurring population crash. Almost no predation was noted that year. In 1968 and 1969 rats were again numerous and predation was heavy. Thus, there was an apparent correlation with the number of rats present and the amount of predation.

Not all species were equally susceptible to predation. Species such as Red-footed Boobies or Sooty Terns, whose breeding adults were either aggressive towards intruders or flew away quickly when disturbed, were predation-free in the adult stage, while others such as Blue-faced Boobies, whose adults vigorously defended their young, were free from nestling predation. Apparently rats could not break through the shells of albatross and booby eggs, so these were not eaten.

The following model of predation is presented: Rats prey on eggs and young of many species every year, with the intensity of predation directly proportional to the size of the rat population. Another important factor is probably the amount of plant matter, which composes the bulk of the rats' diet (Wirtz, ms.). In years when plant food is scarce predation is heavier. During periods of peak rat abundance larger birds are preyed upon. The localized nature of this predation suggests that certain individuals learn to feed on larger birds and then move around the island. During the 1966-67 and 1967-68 albatross breeding cycles predation on albatrosses was reduced or eliminated, suggesting that most of the individuals that had learned to eat albatrosses had died. It seems likely that there must be this type of predation cycle (i.e., intensive one year, reduced the next) on these birds or otherwise they would have become extinct at Kure Atoll.

Storms

Winter storms, with accompanying winds and high water, accounted for much of the loss of albatross nests. In 1964 from 16 to 22 December the island was battered by winds up to 65 knots and received several inches of rain. Water came up over much of the western beach and ca. 400 yards of the ends of the island were washed away. During this storm 12 of 25 Black-footed Albatross study nests and at least 54 Laysan Albatross nests along the exposed lagoon beach were destroyed.

On 13 and 22 December 1968 storms with heavy winds hit the atoll. Several nests (exact number unknown) of both albatross species were destroyed by these storms. Some incubating adults were almost entirely buried by the drifting sands.

Although POBSP observers were not present during the complete albatross breeding cycle each season, late spring observations suggested that wind-blown high water was responsible for at least some nest loss

every year, especially along the eastern beach where water usually reached the Scaevola. In May 1968 the high-tide line along the lagoon beach was within 5 feet of the Scaevola and 3 to 4 feet of the vegetation along the edge showed evidence of extreme sand scouring.

High Tides

On 8-9 January 1969 water caused by high tides washed to the edge of the runway and into Scaevola along the northeast and southeast beaches. Several (exact number unknown) Black-footed Albatross nests were washed away.

In early September 1968 high tides washed away 5 Brown Noddy eggs at the north point. If these tides had occurred earlier in the year when most noddy nests contained eggs, almost all the nests would have been destroyed as the waves washed over the entire breeding area.

Rain

Heavy spring and summer rains were not known to have caused directly any nest loss, but an observation in May 1967 suggested that rain could indirectly be responsible in Red-footed Booby nest loss. After several days of heavy rains many Red-foot nests became waterlogged and were bending over. Possibly nestlings and eggs fall out if the nests become too heavy.

Undoubtedly long exposure of young birds to cold and rain could cause death, but this was probably a minor mortality factor.

Human Disturbance

Human disturbance affected nesting success indirectly, generally by causing the eggs or nestlings to be exposed to rain or cold. Some species, such as the Red-footed Booby, deserted their nests if handled or flushed repeatedly.

Great Frigatebird Predation

Although Great Frigatebirds are known to prey on other seabirds (Schreiber and Ashmole, 1970), none was seen to do so at Kure. However, when flushed from their nests, adult frigatebirds would occasionally return to the nest and peck a hole in the egg, or pick the nestling up, fly away, and drop it to the ground. This action probably occurs rarely in an undisturbed situation.

Great Frigatebirds also destroyed Red-footed Booby nests when humans flushed the boobies from them.

Seals

Seals occasionally destroyed nests when they hauled out. For example, on 26 May 1965 a seal crushed 18 Sooty Tern eggs in a study plot near the northeast beach.

Dogs

Dogs occasionally destroyed nestling Brown Noddies and probably nestling Christmas Shearwaters.

Starvation

No mass starvation, such as occurred on Ascension Island (Ashmole, 1963), was noted. However, every year a few emaciated Laysan Albatross nestlings were found. Some young Brown Boobies also apparently starved to death.

Miscellaneous Factors

Nesting success was also affected by infertile eggs, nest desertion, and adults attacking the young in such species as the Sooty Tern.

Movement

Through the recapture of previously banded birds it has become well established that seabirds of several species travel between various islands in the central Pacific Ocean. At Kure Atoll individuals of 13 species banded on other central Pacific islands or atolls were captured (Table M-1). In addition, an American Golden Plover and five Ruddy Turnstones banded in the Pribilof Islands, Alaska, were collected at Kure. Four hundred and sixteen individuals of fifteen species from Kure were recorded in the central Pacific (Table M-2). Figure M-1 shows the location of these islands.

Details of inter-island movement are recorded in the individual Species Accounts. Rigorous mathematical analysis of movement is difficult due to the following: (1) only a few individuals of some species were captured at Kure and/or banded on other islands, (2) some species were not banded on other islands, and (3) the banding and recapturing effort was inconsistent with respect to year and seasons--important parameters to consider in any analysis. Therefore, no detailed analysis of inter-island movement is attempted in this paper. Discussion of the movement of each species in the Hawaiian area will be published elsewhere.

Although the POBSP banded thousands of seabirds in the Line and Phoenix Islands, there was only one definite movement recorded between these areas and Kure Atoll. It appears that in the central Pacific movement to and from Kure Atoll was restricted to the Northwestern Hawaiian Islands, Wake Atoll, and Johnston Atoll.

Besides the inter-island movement in the central Pacific, forty-one individuals of seven species were recovered at sea or on islands outside the central Pacific. Figure M-2 shows the general location of these movements, which helps reveal the post-breeding dispersal patterns of several species. How much actual movement there was between Kure and

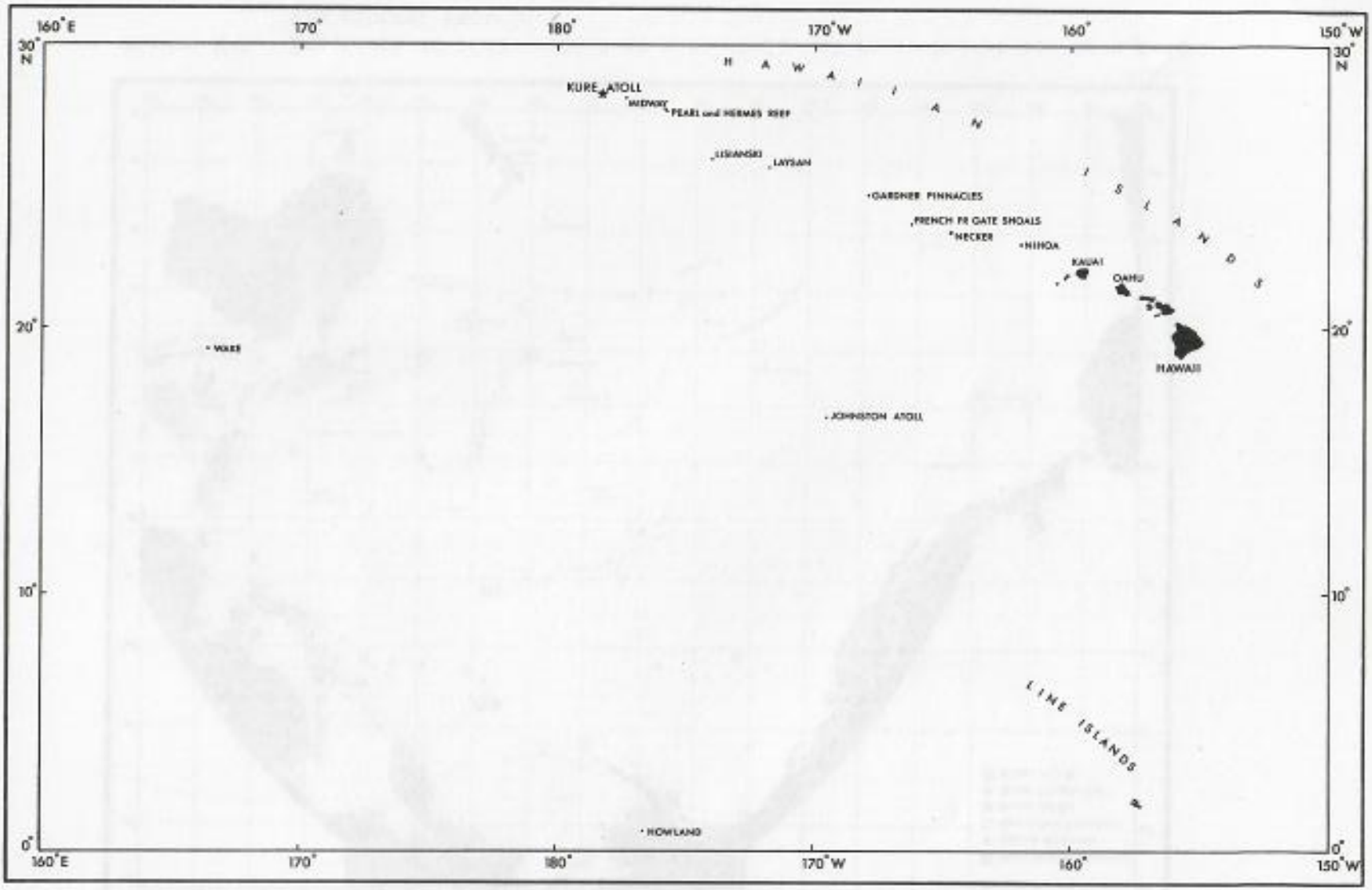

Figure M-1. Location of islands or atolls in central Pacific where Kure-banded birds have been recaptured or vice-versa.

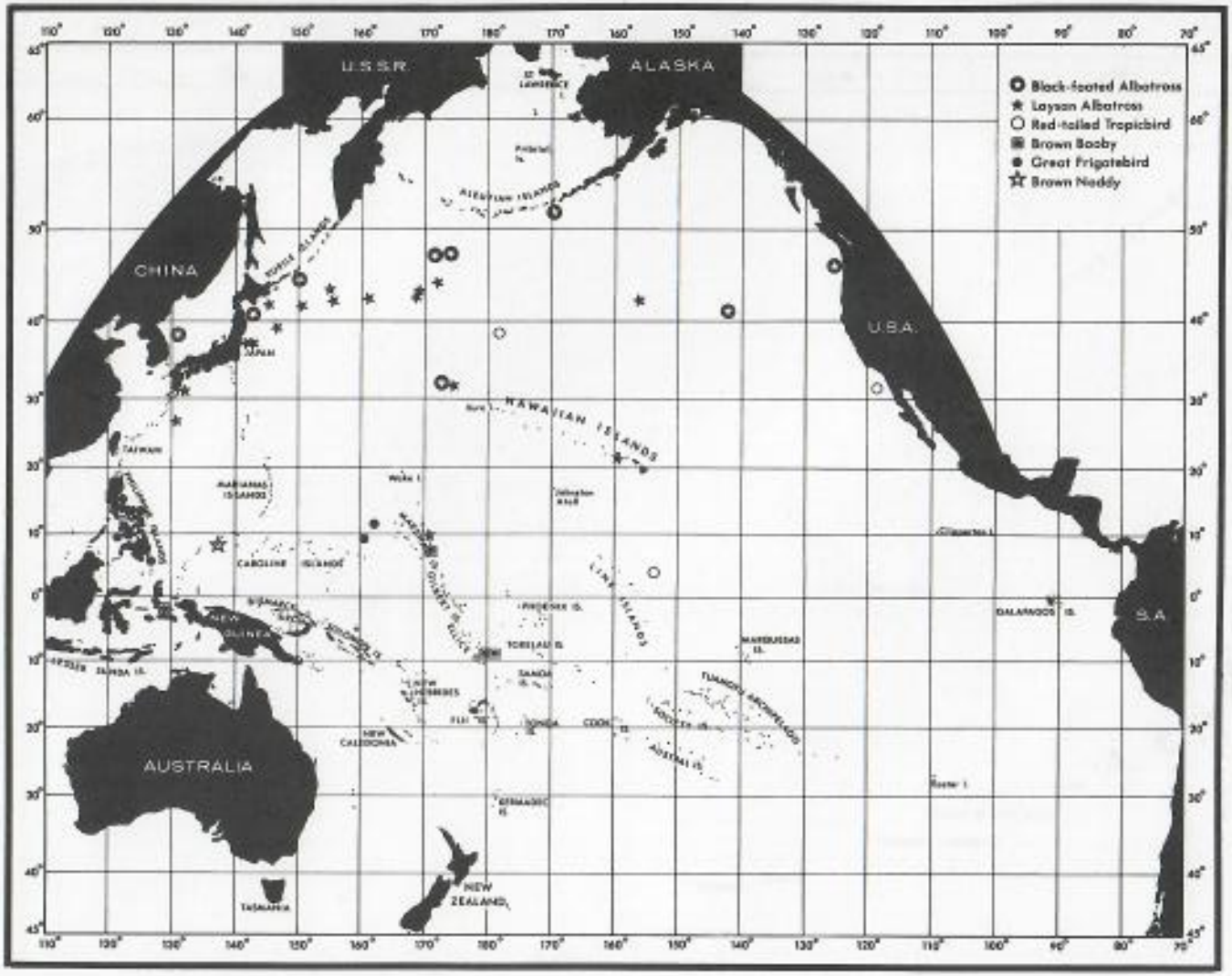

Figure M-2. Locations of birds banded at Kure Atoll and recovered at sea or outside the central Pacific.

Table S-1. (continued)

Species	Number of: Skins	Skeletons	Alcoholics	Totals
Glaucous-winged Gull	9	0	0	9
Black-legged Kittiwake	2	0	0	2
Arctic Tern	1	0	0	1
Sooty Tern	23	4	0	27
Gray-backed Tern	4	0	0	4
Brown Noddy	19	2	2	23
Black Noddy	5	1	0	6
White Tern	7	0	0	7
Horned Puffin	2	2	0	4
Short-eared Owl	1	0	0	1
Skylark	1	0	0	1
Water Pipit	1	0	0	1
Red-throated Pipit	1	0	0	1
Snow Bunting	1	0	0	1
Totals	356	56	28	440

KURE REPTILES

Four species of reptiles were recorded from the atoll. Green Sea Turtles were occasionally seen swimming in the lagoon and a small population of Stump-toed and House Geckos was resident on Green Island.

There was one hypothetical record of Hawksbill Turtles.

Species Accounts

HAWKSBILL TURTLE — *Eratmochelys imbricata*

Morrell (1841) reported that two Hawksbill Turtles were seen 13 to 14 July 1825. The validity of this record is uncertain.

GREEN SEA TURTLE — *Chelonia mydas*

Morrell (1841) found Green Turtles abundant at Kure in 1825. Although few of the early visitors to the atoll reported them (Table GT-1), they probably killed them for food and were thus responsible for these reptiles' scarcity today.

During POBSP studies, turtles, presumably Green, were occasionally seen, generally swimming in the lagoon (Table GT-2). They were found only four times on land and there was no indication of breeding at the atoll.

? see 13-28 August →

Table GT-1. Previous records of Green Sea Turtles at Kure Atoll.

Date of Survey	Population Estimate	Breeding Status, Remarks, References
1825 July 13-14	great abundance	(Morrell, 1841).
1859 late June or early July	plenty	(Brooks, 1860).
1870 October 29 to 1871 January 4	?	4 large turtles captured on sandspit (Read, 1912).
1881 December 30 to 1882 January 1	?	Collected 6 turtles and found 2 rotten eggs (Hornell, 1934).
1886 July 15-August 18	?	Turtles available as food (Hawaiian Almanac and Directory, 1887).
1936 April 5-13	1	1 turtle seen (R.G. 37 Report on the Survey of Pearl and Hermes Reef and Kure Ocean Island).

Table GT-2. POBSP observations of Green Sea Turtles at Kure Atoll, 1963-69.

Date of Observation	Number	Remarks
1963 October 29	1	--
November 6	1	In lagoon.
1964 May 29	1	On Sand Island; caught, tagged, photographed and released.
July 7	2	Offshore near the west end of the runway.
August 13-28	?	Numerous tracks and diggings found along southeast beach.
October 19	1	2' long; offshore near the west end of the runway.
1965 May 1	2	Small; off east beach.
July 20-31	3	In lagoon; 2-3' diameter.

Table GT-2. (continued)

Date of Observation		Number	Remarks
1967	June 10	1	20"; in lagoon along west beach.
	June 29	1	20"; swimming in lagoon near the pier.
	July 2	1	ca. 3' long; in lagoon; caught, photographed, tagged and released.
	July 8	1	Off west point.
1968	July 31	1	Off southeast beach.
	August 17	1	Off pier.
	August 26	2	Off southwest beach.
	November 11	1	On Sand Island; 250-300 pounds.
	December 13	1	On northwest beach.
1969	January 25	2	Off west point.
	January 27	3	Off southeast beach; 20-24" carapace.
	February 16	1	Off northeast beach; 18" long.
	February 21	1	Off southeast beach.
	March 2	1	Off northeast beach.
	March-April	?	Occasionally sighted, largest individual not over 24".
	May	?	Small individuals continued to be sighted around reef.

B26 Carr tag ?

STUMP-TOED GECKO — Gehyra mutilata

HOUSE GECKO — Hemidactylus frenatus

Two species of geckos, the Stump-toed and the House, were recorded on Green Island. Based on the specimens collected, the former species was the more common. Undoubtedly they were accidentally introduced from Midway Atoll.

Geckos were seen in small numbers around the barracks, the transmitter building, and the casuarinas along the southwest beach. They were

noticed more commonly in late spring and summer than during the rest of the year. Nothing was known of their life history at the atoll.

KURE MAMMALS

Nine species of mammals were recorded from Kure Atoll. Two, the Bottle-nosed Dolphin and the Spinner Dolphin, were found in the lagoon or just outside the reef, while the Sperm Whale and Goose-beaked Whale washed up on the beach. The Squirrel Monkey, the Pig, and the Domestic Dog were brought to the LORAN station as pets. The Polynesian rat was probably accidentally introduced by the Polynesians, and the Hawaiian Monk Seal evolved in the Hawaiian area.

Species Accounts

SQUIRREL MONKEY — *Saimiri* sp.

A male Squirrel Monkey was released by the Coast Guard in late 1961. It remained on Green Island in a semi-wild state until January 1967 when it disappeared. Before it disappeared it was frequently seen on the island, and in 1965 it began sleeping on the top of the radar reflector where it could be fed by hand. It was observed taking an albatross egg, feeding on *Scaevola* berries and leaves, and chasing roosting Red-footed Boobies and Great Frigatebirds. Apparently it only rarely disturbed the birds and, in fact, appeared to be afraid of some, such as breeding Sooty Terns.

POLYNESIAN RAT* — *Rattus exulans*

Status

Abundant resident, populations ranging from 20 to 70 animals per acre in 1964 to 1965. Most common in summer and fall.

Populations

Polynesian rats were first recorded at Kure Atoll by George H. Read (1912) of the U.S.S. *Saginaw*, who reported, "Rats more in evidence of late. At first small and timid they are now growing larger and bolder." All biologists visiting the atoll prior to POBSP investigations also recorded these mammals. Although unproven, it is probable that the Polynesians accidentally introduced the rats long before Europeans discovered the atoll.

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* Wirtz (ms.) studied this species intensively at Kure from 1963 to 1965. Pertinent data are summarized here from his paper. Readers are referred to his work for details.

Population estimates were made from March 1964 to May 1965 and in April 1966, by live trapping in a 6.94-acre study area of mixed habitats adjacent to the north antenna field. Figure PR-1 summarizes the 1964-65 data. In late April 1966 there were an estimated 340 rats in the area.

Mean monthly density from March 1964 to May 1965 was 45 animals per acre, with a range of 20 to 77. Projecting for the whole island gave an average total population of 6,480, fluctuating from 2,880 to 11,090 animals.

Although little or no quantitative data were collected from 1966 to 1969, observations indicated that rats were extremely abundant in 1966, almost absent in 1967, and common again, although less so than in 1966, in 1968 and 1969.

Annual Cycle

Polynesian rats were most abundant during the fall. They were uncommon from January to May and then began increasing in June, reaching a peak in September or October.

In fall 1963 there were an estimated 7,200 rats, or 50 per acre, on the island. From December 1963 to February 1964 the population declined to an estimated 30 animals per acre, and then increased to a peak of 75 rats per acre after the breeding season. Following this peak, numbers declined to about 20 rats per acre by 1965.

Breeding occurred from January through September, with most litters being produced from March through August. The average litter size was 4.07. In a sample of 100 live-trapped adult females, 7 produced 2 litters in a year, 1 produced 3, 47 produced 1, and 45 produced none. The observed pregnancy rate in the study area was about 90 litters per season, or about 360 new rats per breeding season.

Ecology

Polynesian rats occurred in all the vegetated areas on the island. They appeared especially abundant in the central plain and adjacent areas. The garbage area near the barracks was also attractive to them, and during the fall when they were abundant, they would often be found inside the buildings.

The diet of Polynesian rats consisted of 62 percent plant material, 30 percent insects, and 8 percent vertebrate flesh. They were known to have eaten the seeds of Boerhavia, the tender shoots and heads of Eragrostis, the berries of Scaevola, and the seeds of Lepidium, Tribulus, and Sicyos. Insect families identified from fragments in stomachs were Scarabaeidae, Elateiidae (larvae), Noctuidae (larvae), Blattidae, and Formicidae. The relationship of rats and birds was discussed earlier in this paper.

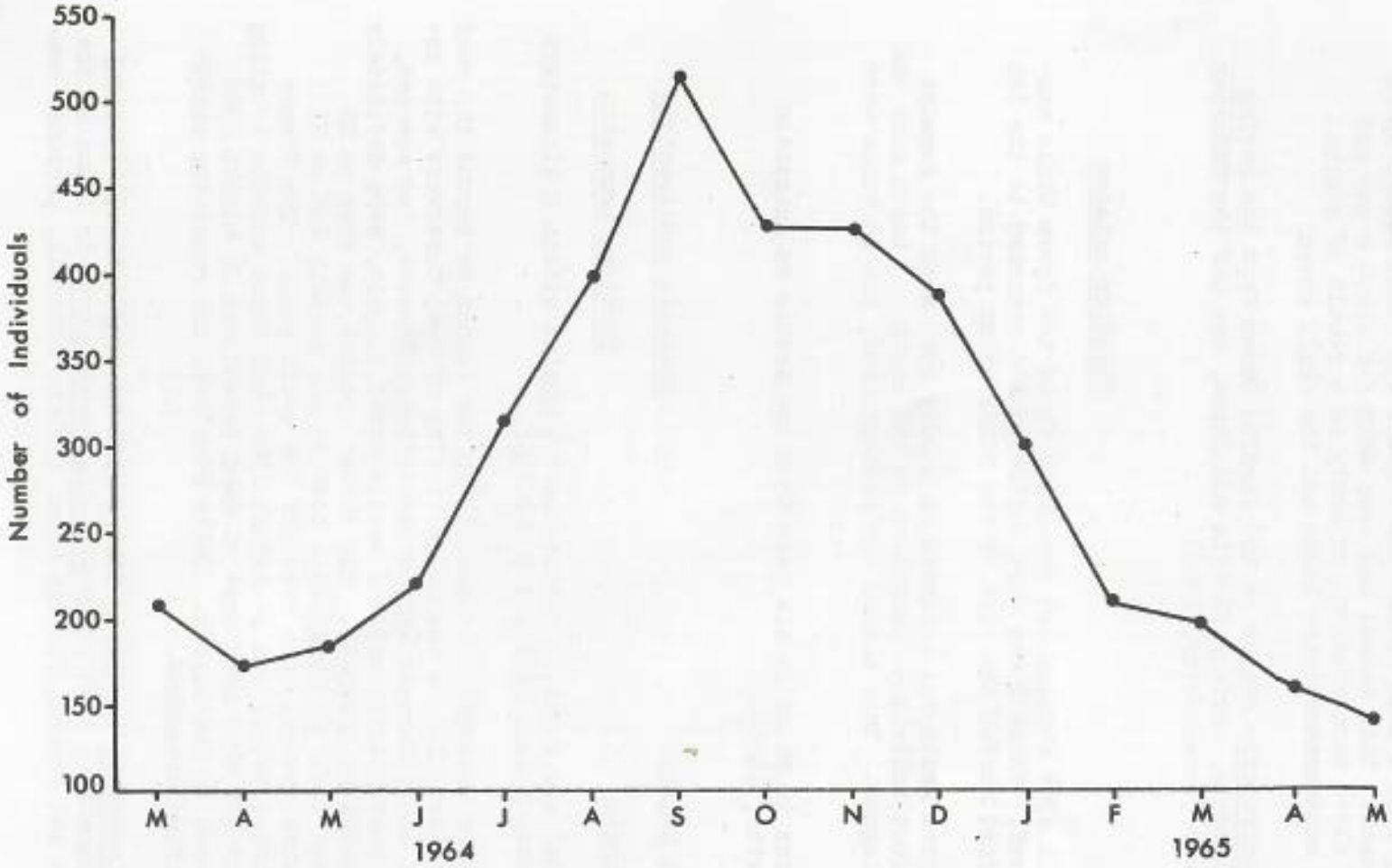

Figure PR-1. Population size of Polynesian Rats in a 6.94 acre study area on Green Island, Kure Atoll, March 1964-May 1965.

GOOSE-BEAKED WHALE — Ziphius cavirostris

On 25 July 1966 a dead Goose-beaked Whale was found washed up on the northwest beach. This animal had been dead for about a day and large chunks of flesh were missing, probably as a result of sharks. Photographs and measurements were taken and the skull saved.

Ziphius cavirostris ranges in the Pacific Ocean from the Bering Sea to Baja California, eastern Siberia and Japan, and off the Hawaiian and Midway Islands (Hershkovitz, 1966).

SPERM WHALE — Physeter catadon

On 23 April 1964 Coast Guard personnel found two Sperm Whale mandibles on the reef. These bones were collected and returned to the lab where they remained during the rest of the POBSP study period.

Another Sperm Whale was recorded on 8 July 1967 when the remains of a 30- to 40-foot individual washed up on the south beach near the channel to the lagoon. This animal was photographed, but no bones were collected.

This species is found in all seas from the Arctic to Antarctic Oceans (Hershkovitz, 1966).

HAWAIIAN SPINNER DOLPHIN — Stenella roseiventris

BOTTLE-NOSED DOLPHIN — Tursiops truncatus

Rice (1960a) saw about 12 Bottle-nosed Dolphins within 2 kilometers of the reef on both 5 June 1957 and 9 May 1958.

Dolphins were recorded infrequently in the lagoon or beyond the reef during POBSP studies. Due to the unfamiliarity of most observers with cetaceans, most of these mammals were unidentified. However, two species, the Hawaiian Spinner Dolphin and the Bottle-nosed Dolphin, were definitely identified by Robert L. Brownell. The latter species was seen on 16 November 1964 when 50 to 60 followed a boat in the lagoon, and on 21 September 1968 when several were seen off the south point. The former species was recorded twice: on 14 August 1968 when three schools totaling 80 to 100 individuals were seen east of Sand Island and 28 August 1968 when they were seen in the lagoon. Table PO-1 lists the remaining sightings of unidentified cetaceans.

Tursiops truncatus is widely distributed in temperate and tropical seas (Rice and Scheffer, 1968), and Stenella roseiventris is found in the tropical eastern and central Pacific Ocean (Robert Brownell, personal communication).

Table PO-1. POBSP observations of unidentified cetaceans at Kure Atoll, 1964-69.

Date of Observation	Number Seen	Remarks
1964 January 1	25+	East of Green Island.
September 18	school	Within 100 yards of eastern reef.
September 25	school	Close to eastern reef.
October 2	?	Off eastern reef.
October 4	several	Off northeast reef; leaping out of water.
November 27	20	Swimming slowly up eastern edge of the reef.
1965 January 21	12	Swimming northeast along outer edge of reef.
May 24	50±	In lagoon near Sand Island.
1969 January 18	2	Near Sand Island.
April 16	30±	Off south side of Green Island.
May 7	50±	Off reef beyond Sand Island.

HAWAIIAN MONK SEAL — *Monachus schauinslandi*

Status

Common permanent resident; 150 to 200 animals. Population apparently decreasing. Pups usually born from February to June.

Populations

Hawaiian Monk Seals were first recorded from Kure Atoll by Morrell in 1825 (Table MS-1). Most other earlier visitors also noted these mammals, but unfortunately did not quantify their observations. Undoubtedly seals were common in the 1800's, but the population probably fluctuated drastically with the repeated killings by the crews of wrecked ships. For example, the crew of the Parker reportedly killed 60 seals during their stay on the island in 1842-43 (Whalemen's Shipping List, November 7, 1843). Lt. Commander Montgomery Sicard, captain of the U.S.S. Saginaw, reported (in Annual Report of the Secretary of the Navy on the Operation of the Department for the Year 1871) that "I commenced by sending out parties to

kill seal...but after about a month I found that, owing to the rapid diminuation of the seal, I was obliged to cut the allowance down, and only killed one seal...per day for the whole crew." Thus at least 60 Monk Seals were killed in 1870.

Kenyon and Rice placed the Kure population at 128 in winter 1956-57 and 142 in winter 1957-58. Based on the number of seals tagged and the number of previously tagged seals seen, the island population was 139 in 1964 and 141 in 1965. Wirtz (1968) estimated the total atoll population as 200 for both years. From the fall of 1963 to the summer of 1965, 112 adults, 22 subadults, and 71 juveniles (57 of them born at Kure) were tagged; thus the previous estimates were probably accurate.

Besides these total population figures, population estimates were made at weekly or semi-monthly intervals by counting seals on Green Island as an observer walked around the island. These counts varied yearly. In 1964 and 1969 only those seals seen on Green Island were counted; in 1965 and 1968 all seals seen on Green Island, and Sand Island as seen from Green Island, were enumerated and the counts separated. However, in 1966 and 1967, although the same method was used, the counts were not separated. Finally, several ground counts were made on Sand Island. These data are summarized by month and year in Tables MS-2 to 5.

These data suggested that Monk Seals were decreasing as most counts made from 1967-69 were lower than previous counts. Especially significant were the 1969 counts when very few seals hauled out on Green Island. This decrease probably resulted from the increased disturbance by man and by the station dogs who often chased the seals back into the water after they had hauled out. Continuous harassment of this type will lead to the disappearance of this mammal from Green Island. Kenyon (in prep.) discusses in detail disturbance as a population control factor.

Annual Cycle

Hawaiian Monk Seals were present throughout the year, with peak populations on Green Island from December through May. When Sand Island washed away, all seals hauled out on Green Island. POBSP data suggest that after the main pupping season, adult seals moved either to Sand Island or away from the atoll.

Actual copulation was not observed so it was not known when the breeding season began; it probably started in late summer or fall. The first pups were born on 20 February 1964, 14 February 1965, and 18 January 1969, and the last ones in late July 1964 and 9 June 1965. Figure MS-1 shows the number of pups born each semi-monthly period in 1964 and 1965. Pups spend about 5 weeks ashore before leaving (Wirtz, 1968).

Table MS-1. Previous records of Hawaiian Monk Seals at Kure Atoll.

Date of Survey	Population Estimate	Breeding Status, Remarks, References
1825 July 13-14	?	"the shores...were lined with sea elephants" (Morrell, 1841: 218).
1837 July 9 to 1838 ?	considerable number	(Hawaiian Spectator, July 1838).
1842 September 24 to 1843 May 2	?	Killed ca. 60 seals (Whalemen's Shipping List, November 7, 1843).
1870 October 29 to 1871 January 4	?	"main source of food will be the seal" (Read, 1912: 32).
1910 January 23	?	Number of sea lions (Log of Thetis, R.G. 26, U.S. Nat. Archives).
1915 March 28	large number	Hauled out on the beach (Munter, 1915: 136).
1923 April 17-22	40-50	At least one pup born (Wetmore, ms.).
1934 June 23	50-60	(R.G. 26, U.S. Nat. Archives, Cruise report for Itasca for month of June 1934).
1936 April 5-13	?	Photographs of U.S.S. Oglala (R.G. 80, U.S. Nat. Archives).
1949 Summer	20-30	(Bailey, 1952: 19).
1951 August 2	30-40	Aerial survey (Bailey, 1952: 19).
October 12	ca. 70	(Bailey, 1952: 19).
1956 December 9 to 1957 June 5	128	25 pups born in spring of 1957 (Kenyon and Rice, 1959: 221).
1957 December 18 to 1958 June 28	142	25 pups born in spring of 1958 (Rice, 1960b; 379).
1959 September 28	53	(Robbins, 1966: 54).
October 3	59	(Robbins, pers. comm.).

Table MS-1. (continued)

Date of Survey	Population Estimate	Breeding Status, Remarks, References
1960 March 25	40-60	(Robbins, pers. comm.).
1961 September 12-14	65-70	(Udvardy and Warner, 1964: 3).

Table MS-2. Summary of POBSP Hawaiian Monk Seal Counts on Green Island, Kure Atoll, 1964-69.

Date		Number of Counts	Average Number Seen	Range
January	1964	2	28.0	22-34
	1965	4	27.5	8-74
	1969	4	1.3	1-3
	Total	10	17.1	1-74
February	1964	4	34.3	24-42
	1965	4	22.3	9-35
	1969	4	1.0	1-2
	Total	12	19.2	1-42
March	1964	4	24.5	21-30
	1965	4	46.7	31-71
	1967	1	10.0	-
	1969	4	5.5	2-8
	Total	13	24.4	2-71
April	1964	1	26.0	-
	1965	4	53.0	32-65
	1969	5	6.2	4-8
	Total	10	26.9	4-65
May	1965	5	40.4	25-61
	1969	4	14.3	10-20
	Total	9	26.6	10-61
June	1964	2	18.5	12-25
	1965	3	30.3	23-38
	1968	4	13.0	5-17
	1969	3	13.3	11-15
	Total	12	18.3	5-38

Table MS-2. (continued)

Date		Number of Counts	Average Number Seen	Range
July	1964	5	22.0	17-26
	1965	3	30.0	23-38
	1968	3	5.0	0-12
	Total	11	19.5	0-38
August	1964	4	16.0	9-23
	1965	1	7.0	-
	1966	1	11.0	-
	1968	2	2.0	0-4
	Total	8	10.8	0-23
September	1964	4	11.5	9-19
	1966	2	21.0	11-31
	1969	4	0.8	0-2
	Total	10	9.1	0-31
October	1964	6	7.2	2-13
November	1964	5	21.4	13-36
December	1964	5	41.8	16-78
	1968	1	4.0	-
	Total	6	35.5	4-78

Table MS-3. Summary of POBSP Hawaiian Monk Seal counts on Green and Sand Islands, Kure Atoll*, 1965-68.

Date		Number of Counts	Average Number Seen	Range
January	1965	3	62.7	48-74
February	1965	1	53.0	-
March	1965	4	71.0	51-85
April	1965	4	80.3	55-92
	1966	2	33.0	22-44
	1967	1	24.0	-
	Total	7	58.7	22-92

Table MS-3. (continued)

Date		Number of Counts	Average Number Seen	Range
May	1965	3	60.3	52-69
	1966	4	36.3	25-46
	1967	4	30.0	22-36
	Total	11	40.6	22-69
June	1965	3	39.7	32-47
	1966	2	28.0	24-32
	1967	2	16.0	15-17
	1968	4	17.3	7-23
	Total	11	25.1	7-47
July	1965	2	29.5	26-33
	1966	2	19.0	16-22
	1968	2	12.5	8-17
	Total	6	20.3	8-33
August	1965	1	14.0	-
	1966	1	8.0	-
	Total	2	11.0	8-14

Table MS-4. Summary of POBSP Hawaiian Monk Seal Counts on Sand Island, Kure Atoll*, 1965-68.

Date		Number of Counts	Average Number Seen	Range
January	1965	3	30.0	0-50
February	1965	1	18.0	-
March	1965	4	24.3	14-40
April	1965	4	29.8	27-33
May	1965	3	10.0	8-13
June	1965	3	9.6	9-11
	1968	4	4.3	2-6
	Total	7	6.6	2-11

Table MS-4. (continued)

Date		Number of Counts	Average Number Seen	Range
July	1965	2	6.0	5-7
	1968	2	5.0	-
	Total	4	5.5	5-7
August	1965	1	7.0	-

* Made from Green Island.

Table MS-5. POBSP Hawaiian Monk Seal ground counts on Sand Island, Kure Atoll, 1964-69.

Date of Count		Number Recorded
1964	May 29	30
	August 13	47
1965	March 27	45
	May 24	49
	July 30	26
1966	August 3	31
	August 25	25
1967	June 29	13
1968	July 4	24
	August 14	37
1969	January 18	25
	February 16	30
	April 12	34
	April 19	18
	June 12	15

Breeding Success

Table MS-6 summarizes Hawaiian Monk Seal productivity at Kure Atoll for 1964 to 1969. Only the 1964 and 1965 data are complete.

Wirtz (1968) reported that the annual reproductive rate was 15 live pups per 100 adults, that about 19 percent of the adult females bred in successive years, and that only 56 percent of the adult females had pups in either of the 1964 or 1965 seasons.

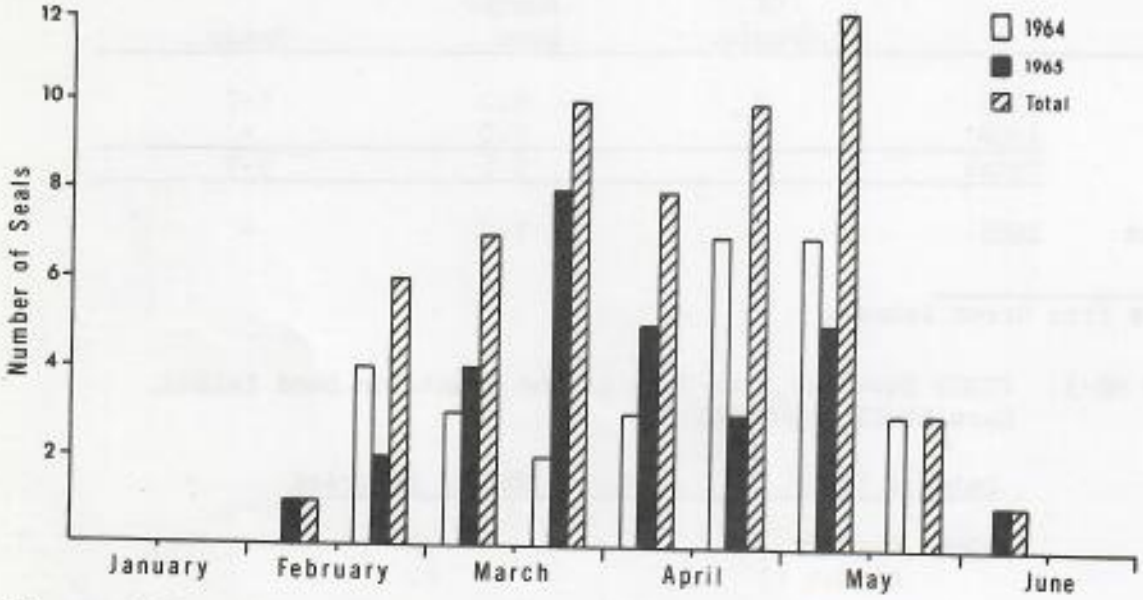

Figure MS-1. Number of Hawaiian Monk Seal pups born each semi-monthly period at Kure Atoll, 1964-65.

Table MS-6. Productivity of Hawaiian Monk Seals at Kure Atoll, 1964-69.

Year	Green Island	Sand Island	Total
1964	28	3	31
1965	29	2	31
1966*	8	-	8
1967*	13	1	14
1968*	7	5	12
1969	5**	5**	10

*Incomplete coverage. **Minimum counts.

Ecology

Hawaiian Monk Seals were found either hauled out on the beaches or swimming in the surrounding waters. At night, and sometimes during the day, they hauled out into the Scaevola where they slept. They were more common along the lagoon beach than the ocean beach.

Several seals that appeared to have been bitten by sharks were found. They either had circular holes in the back or greatly lacerated skin.

Movements

A subadult male tagged on 4 October 1963 was found at Midway Atoll on 4 November 1964 by Harvey Fisher. An adult male, tagged on 16 October 1963 and last noted at Kure on 27 March 1964, was found on Lisianski 12 March 1965.

DOMESTIC DOG — Canis familiaris

In 1843 the crew of the Parker found a dog on Green Island that apparently had been there since the Gledstanes wrecked in 1837 (Whalemen's Shipping List, November 7, 1843).

During POBSP studies from 1 to 3 dogs have been kept as pets by the crew of the LORAN station. A female mixed cocker spaniel was present from 1961 to the winter of 1966-67 when she died. In early 1964 she was bred with a mongrel from Midway and produced five pups. One of these pups was kept until August 1964 when it was sent to Midway. In 1967 a new pup was brought to the atoll and during the winter of 1967-68 another arrived. Both animals remain on the atoll at this writing. Another dog was present from January to May 1969.

Generally, the dogs did not harm the wildlife on the island, although they did catch rats. However, the pup born in 1964 killed at least 7 adult Christmas Shearwaters and 7 nestling Brown Noddies; in 1968 at least 5 adult Christmas Shearwaters and a few Brown Noddy chicks were killed by the dogs. The effect of the dogs on seals is discussed in the Hawaiian Monk Seal account.

PIG — Sus scrofa

A pig was brought to the atoll in January 1966 to be cooked at a luau, but, instead of cooking the pig, the Coast Guard kept it as a pet until August 1966 when it was sent to Midway Atoll. This animal confined most of its wanderings to the area surrounding the barracks and caused no damage to the native flora or fauna.

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