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ATOLL RESEARCH BULLETIN

192. THE NATURAL HISTORY OF JOHNSTON ATOLL, CENTRAL PACIFIC OCEAN

by A. Binion Amerson, Jr., and Philip C. Shelton

Issued by
THE SMITHSONIAN INSTITUTION
Washington, D.C., U.S.A.

Errata

In Atoll Research Bulletin #186 the names of the authors, Roger B. Clapp and William O. Wirtz, II, were accidently omitted from the cover.

On the title page of #186 the publication information at the bottom should have read as it appears below. The part of this page below the dotted line may be cut out and pasted over the bottom of the title page of #186.

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February 15, 1975

In ARB #184 a line was omitted in final typing. On page 5, in paragraph 4, line 4, after the word nesting there should be inserted "does occur to some extent. It was not determined if increased nesting".

We regret the occurrence of these errors.--Eds.

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ACKNOWLEDGMENT

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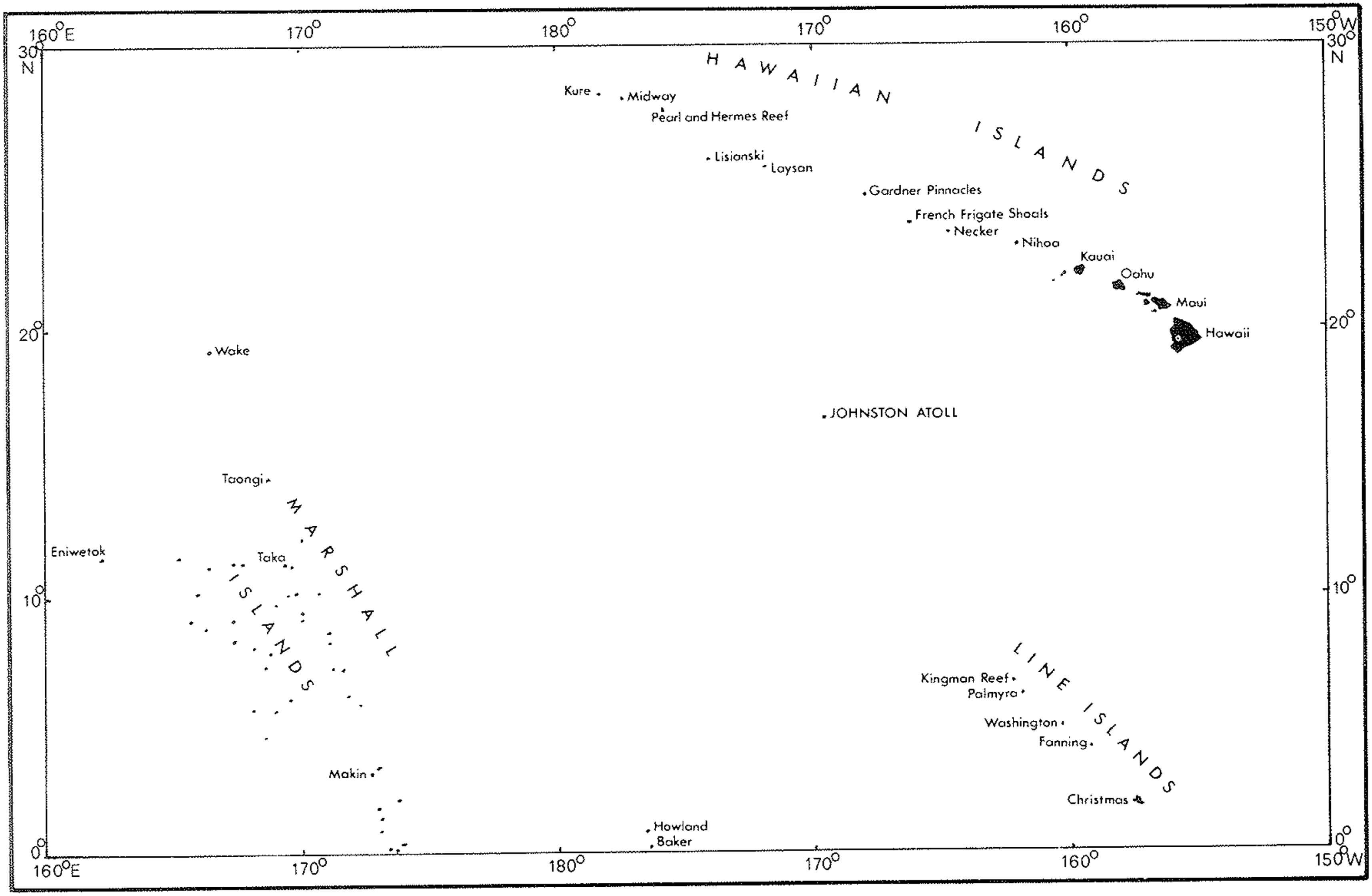

Figure 1. Map of the central Pacific Ocean.

THE NATURAL HISTORY OF JOHNSTON ATOLL, CENTRAL PACIFIC OCEAN

by A. Binion Amerson, Jr., and Philip C. Shelton

INTRODUCTION

Johnston Atoll consists of two highly modified natural islands and two completely man-made islands totaling about a square mile in surface area lying on a 14 by 7 mile coral reef platform in the tropical Pacific Ocean at 16°45'N, 169°31'W (Figure 1). The nearest land is French Frigate Shoals in the northwestern Hawaiian Islands, about 450 nautical miles north-northwest; Honolulu, Hawaii is 717 nm northwest; the Marshall Islands lie almost 1,200 nm southwest, Howland Island is 1,050 nm south-southwest, and Kingman Reef in the Line Islands is about 850 nm southeast.

Although the atoll was discovered in 1796 and claimed by the United States in 1858, it was uninhabited except for brief visits by guano miners, adventurers, government scientists and military personnel until 1936, when the U.S. Navy began developing first a seaplane base and later an airstrip and refueling facilities which served as an important link from the Hawaiian Islands to the western Pacific during World War II.

After the war, operations diminished until the late 1950's when the atoll was used for atmospheric nuclear testing. Although the last tests were executed in 1962, facilities have been maintained "...for resuming nuclear testing in the Pacific Ocean should the Test Ban Treaty of 1963 be abrogated by a foreign world power" (Bauer, 1965: 1).

Most recently the atoll has become the storage site for obsolete chemical warfare agents, including nerve gas formerly stored on Okinawa, and herbicides used in southeast Asia.

The atoll was made a federal bird refuge by executive order of President Calvin Coolidge in 1926. This order remains in effect, although

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subsequent executive orders have given primary jurisdiction over the atoll to military agencies, first to the Navy, later to the U.S. Air Force. Presently a Joint Task Force has jurisdiction over all the atoll except for Sand Island, which is the site of a U.S. Coast Guard LORAN station.

The atoll is an unincorporated territory (=possession) of the United States. This is distinguished from an incorporated territory (=territory) in that it is "...territory to which the constitution [of the United States] has not been expressly and fully extended" (U.S. Department of State, 1965: 9).

Although the oceanic region in which Johnston Atoll lies is relatively unproductive, life is abundant on the atoll itself. At least half a million seabirds use the atoll for roosting and nesting. Most of these are of one species, Sooty Tern (*Sterna fuscata*), but the total known avifauna is 56 species, including 12 regular breeders and half-a-dozen regular migrants. Other terrestrial forms are scarce, and are limited mainly to introduced species, including five species each of mammals and reptiles, all of which were introduced, at least 87 species of insects, many of which were introduced, and well over one hundred species of plants, only three of which are native.

The inshore marine biota is richer. To date 194 species of inshore fishes have been recorded, sea turtles visit the atoll regularly in small numbers, porpoises are occasionally seen outside the lagoon, and in 1968 and 1969 Hawaiian Monk Seals visited the islands for the first time so far as is known. Tropical marine invertebrates are abundant in the lagoon.

Military occupation and construction during the past 40 years have so drastically altered the physiography of the islands that little of the original habitat type remains. Breeding populations of three of the 15 seabird species known to have bred on the islands were eliminated, while a few others were able to increase through adaptation to man-made changes. For most bird species the alteration of habitat and continued disturbance, sometimes through planned efforts to move birds to less critical areas, sometimes through ignorant or malicious persecution, has resulted in severely decreased roosting and nesting space and consequently in reduced populations.

As part of its study of populations, breeding biology, and movements of seabirds of the central Pacific Ocean, the Pacific Ocean Biological Survey Program (hereafter referred to as the POBSP) of the Smithsonian Institution, Washington, D.C., maintained one or more biologists on Sand Island, Johnston Atoll almost continuously from 7 July 1963 until 9 September 1969 (Appendix Table 1). Former POBSP employees have visited the atoll twice since 1969. Brian A. Harrington studied Sooty Terns from 18 March through 3 June 1971; A. Binion Amerson, Jr. visited Johnston 6-12 November 1973 for the Office of International and Environmental Programs, Smithsonian Institution, to update ecological data.

Although primary emphasis was on the 12 species of breeding seabirds, POBSP studies also included arthropods, reptiles, mammals, and terrestrial plants. This report is an attempt to summarize the major results of these studies and to compile a comprehensive summary of other scientific efforts made on Johnston Atoll. The major thrust of the report is island-oriented rather than species-oriented, and discussions presented are primarily descriptive rather than analytical. Hopefully the data presented will be useful in developing a detailed analysis of the central Pacific ecosystem, and for comparison of population and breeding phenomena of the seabirds and other groups with similar data from other islands where the same species occur.

This report is based primarily on the field notes and semi-monthly reports made by the 29 POBSP personnel (Appendix Table 1) who maintained the Sand Island station. These voluminous data are stored in the National Museum of Natural History, Washington, D.C. This final report is a combination of a manuscript by Shelton and a technical report by Amerson (1973). Amerson's ecological baseline report was used as part of a 10 May 1974 U.S. Air Force Environmental Impact Statement concerning proposed disposal of chemical herbicide on Johnston Atoll.

PHYSICAL ENVIRONMENT

The physical characteristics of Johnston Atoll and its surrounding waters are relatively well studied. The following descriptions are based primarily on accounts published by government agencies or by scientists under government contract.

Johnston Atoll lies between the latitudes of 16°40'26" and 16°47'25" North and the longitudes of 169°24'15" and 169°33'58" West (USNOO Chart 5356).

Islands

The two natural islands, Johnston (16°45'N x 169°32'W) and Sand (16°45'N x 169°30'W), originally 46 and 10 acres in extent, lie a mile and a half apart on the southern margin of the lagoon, which is the shallow portion of the reef platform (Figs. 2 and 3). Summit Peak, near the northwest end of Johnston Island, originally stood 48 feet above sea level (Christophersen, 1931: 3) (Figs. 4 and 5). The highest point on Sand Island was and remains about 15 feet above sea level. Both islands were formed of beachrock--sand and gravel cemented by calcium carbonate--and loose sand, presumably wind and wave transported material (Emery, 1956, and Ashmore, 1973).

From 1939 through 1942 construction for military operations leveled Johnston Island and enlarged it to 211 acres (Fig. 6), and built another islet about the size of Sand Island and connected it to Sand Island by a narrow causeway. These additions were built mostly of coral material dredged from the lagoon in deepening and lengthening ship channels and seaplane landing areas. By 1944 Johnston Island had a

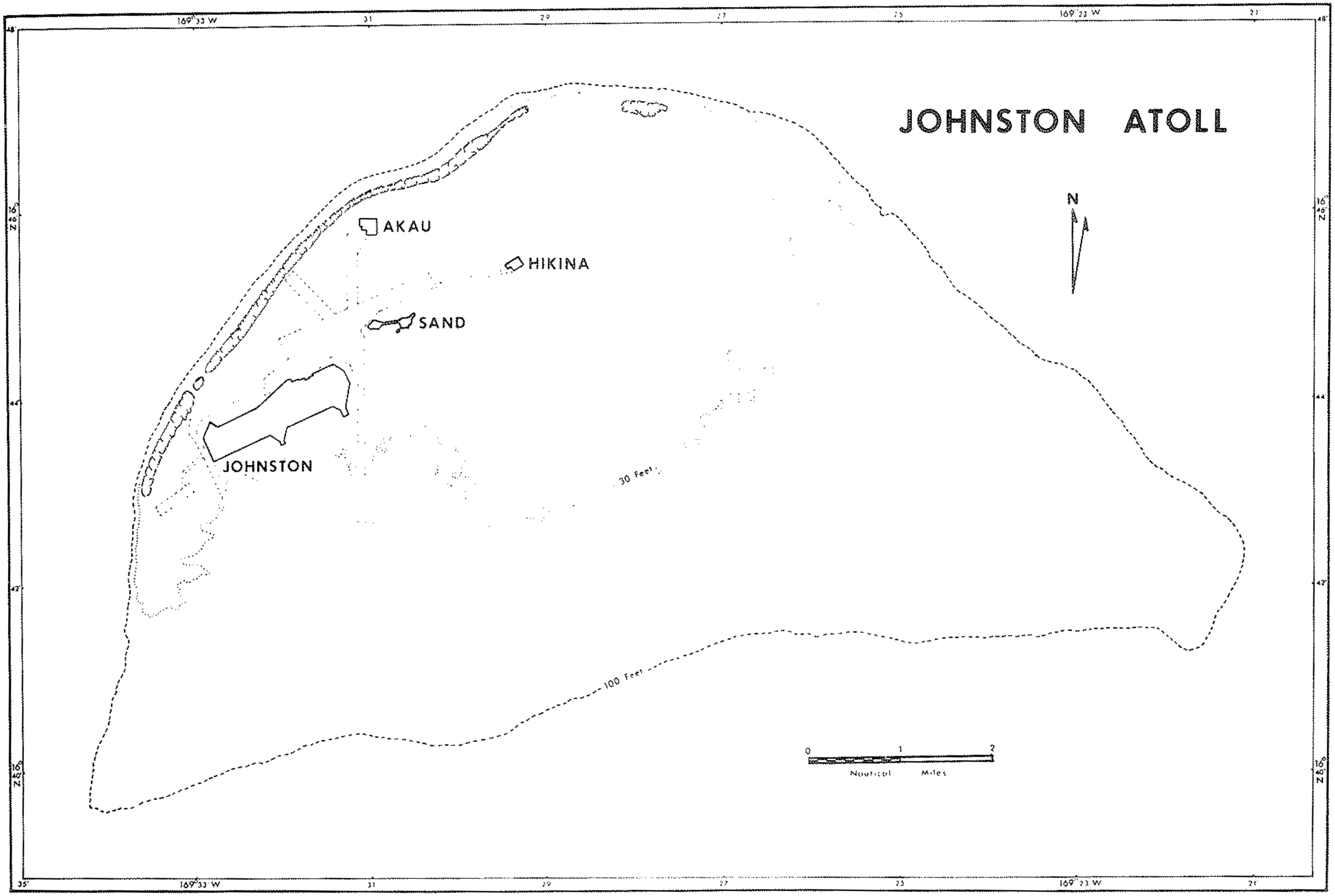


Figure 2. Map of Johnston Atoll; adapted from Wennekens (1969) and Ashmore (1973).

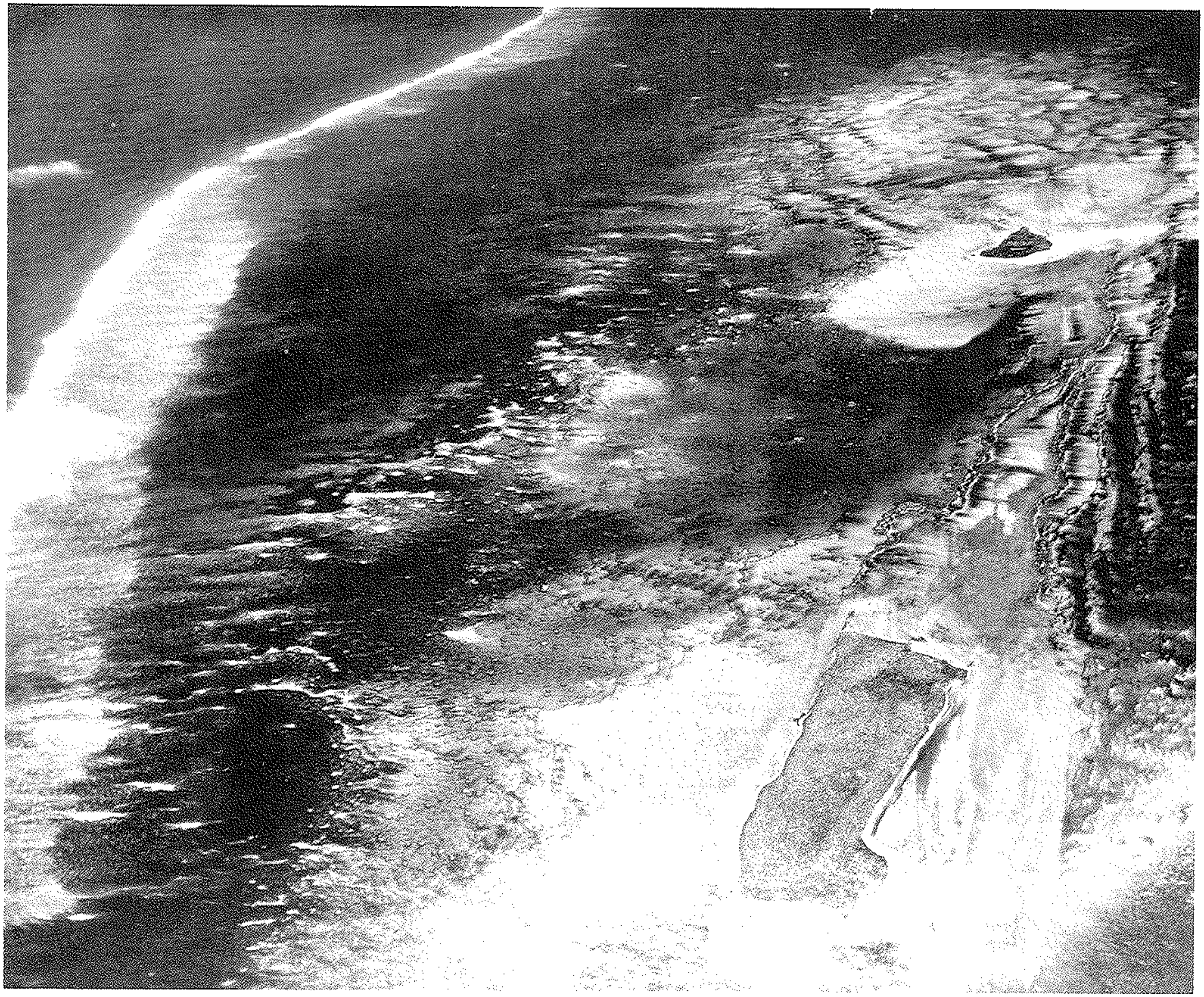


Figure 3. Looking northeast over Johnston and Sand Islands from 3,000 feet, 12 November 1935 (U.S. Nat. Archives, R.G. 80 photograph).

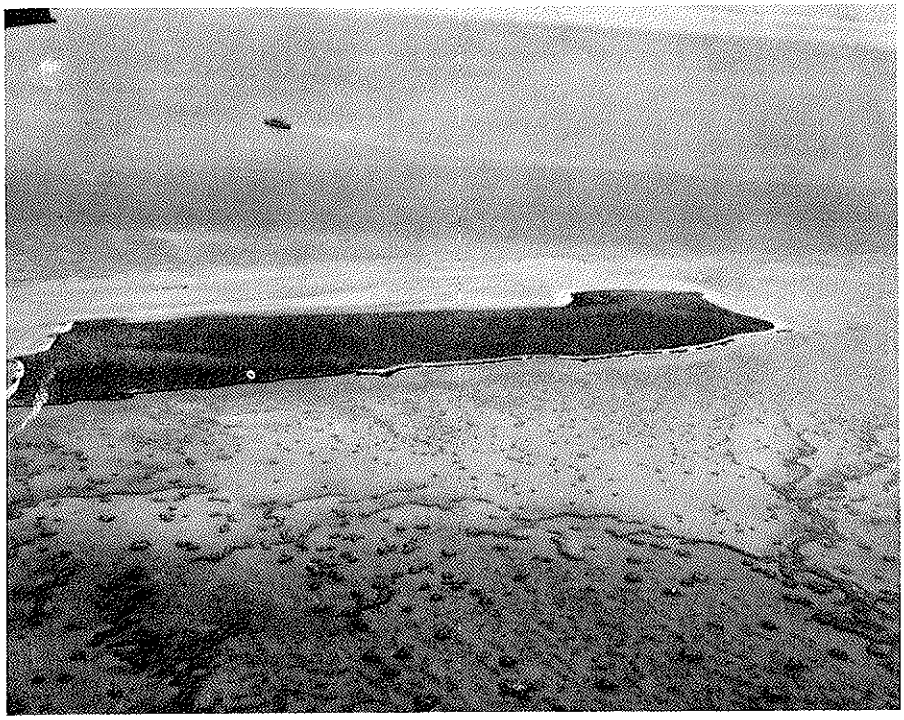


Figure 4. The northeast end of Johnston Island as it appeared from the south in July 1923 (B.P. Bishop Museum photo by R. S. Palmer).

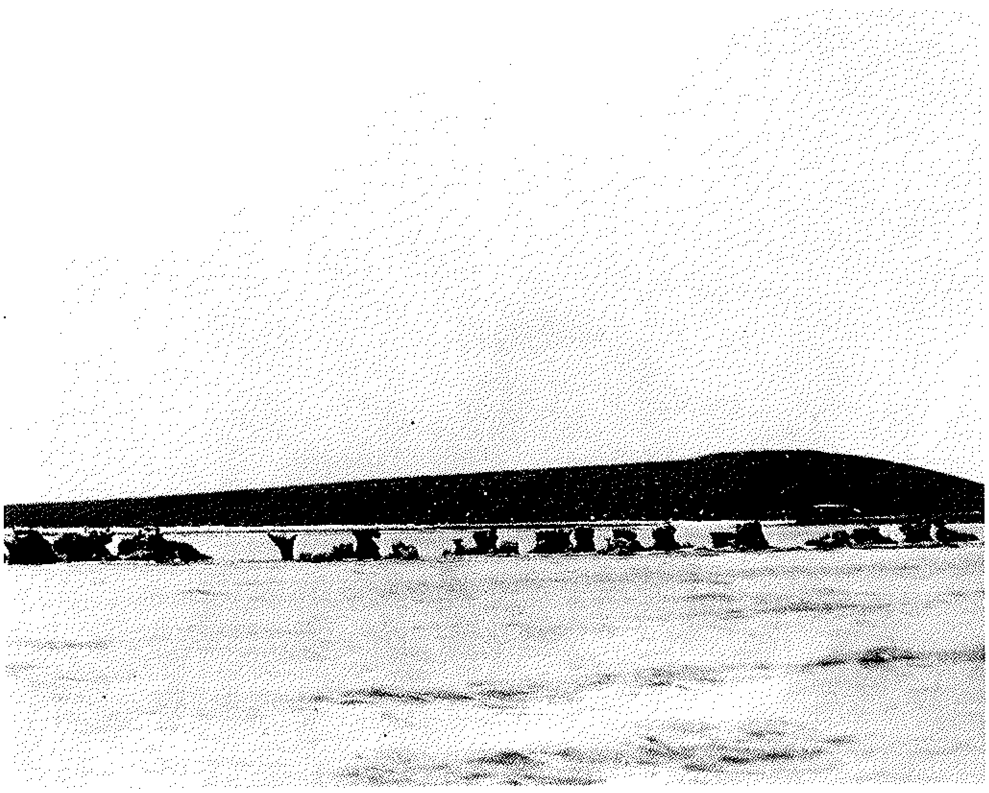


Figure 5. Johnston Island, seen from the north at 3,500 feet, 10 October 1939 (U.S. Nat. Archives, R.G. 80 photograph).

6,100 foot runway, and both islands were virtually covered with buildings, roadways, and gun emplacements. None of the original shoreline or vegetation of Johnston Island remained.

The airstrip on Johnston was again enlarged in 1951-52, and in 1963-64 additional construction with coral dredged from the lagoon enlarged Johnston Island to 570 acres (Fig. 7), with a 9,000 foot runway, added a few acres to the artificial portion of Sand Island, and built two entirely new islands, Akau (North) at 16°45'52"N x 169"31'03"W and Hikina (East) at 16°45'26"N x 169°29'19"W, of 24 and 17 acres respectively, within the lagoon (Bauer, 1965).

The present surfaces of Johnston, Akau, and Hikina Islands, and the artificial portion of Sand Island, consist of hard packed coral material ranging from sand to cobble size. Buildings, antennas, roads, and (on Johnston only) runways and taxiways dominate these islands. Vegetation is restricted to sparse lawns, scattered bushes and trees, and thinly scattered weedy species on areas that are not frequently disturbed.

Although buildings formerly occupied most of the original portion of Sand Island (Figs. 8 and 9), these were removed in the late 1950's. A few concrete foundations and gun emplacements remain. The only new structures added since then are the LORAN-C transmitter building and the 625-foot transmitter tower. Ground wires radiate from the base of the tower on or just below the surface, and guywires extend to concrete pillars, most of them beyond the shores of the island in the lagoon (Figs. 10 and 11). A roadway leads to the transmitter building from the causeway connecting the two portions of the island. Except for these structures, the surface of this original island is approximately like that of both Johnston and Sand Islands prior to their disturbance. The interior is covered with deep, loose coral sand, bound by roots of the grass, *Lepturus repens*, and perforated by burrows of Wedge-tailed Shearwaters. A beachrock layer is exposed around most of the perimeter of the island.

Geology

Emery (1956) described the geology of Johnston Island based on information from 56 borings for building foundations, ranging to 36 feet below mean low water, and from six wells drilled to depths ranging from 86 to 191 feet below mean sea level. None of these holes reached non-calcareous rock. Two layers of beachrock were encountered, one above sea level, and presumably correlated with the one still exposed on Sand Island but covered or destroyed on Johnston, and one at 4.3 to 6.4 feet below sea level. This lower layer was also found 8 feet below sea level along bases of the parallel, linear algal reefs that extend between Johnston and Sand Islands. These reefs were thought to result from growth of coralline algae on the outcropping edges of submerged beachrock.

Below the beachrock the deeper parts of the wells showed alternating sand, loose coral, and sand and coral, with little certainty of

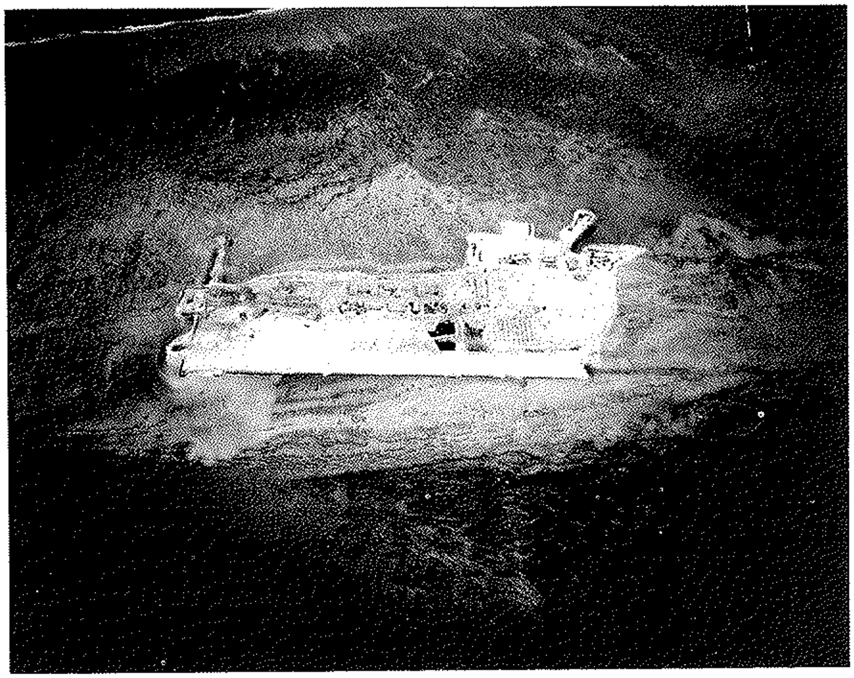


Figure 6. Looking north over Johnston Island, 9 April 1942 (U.S. Nat. Archives, R.G. 80 photograph).

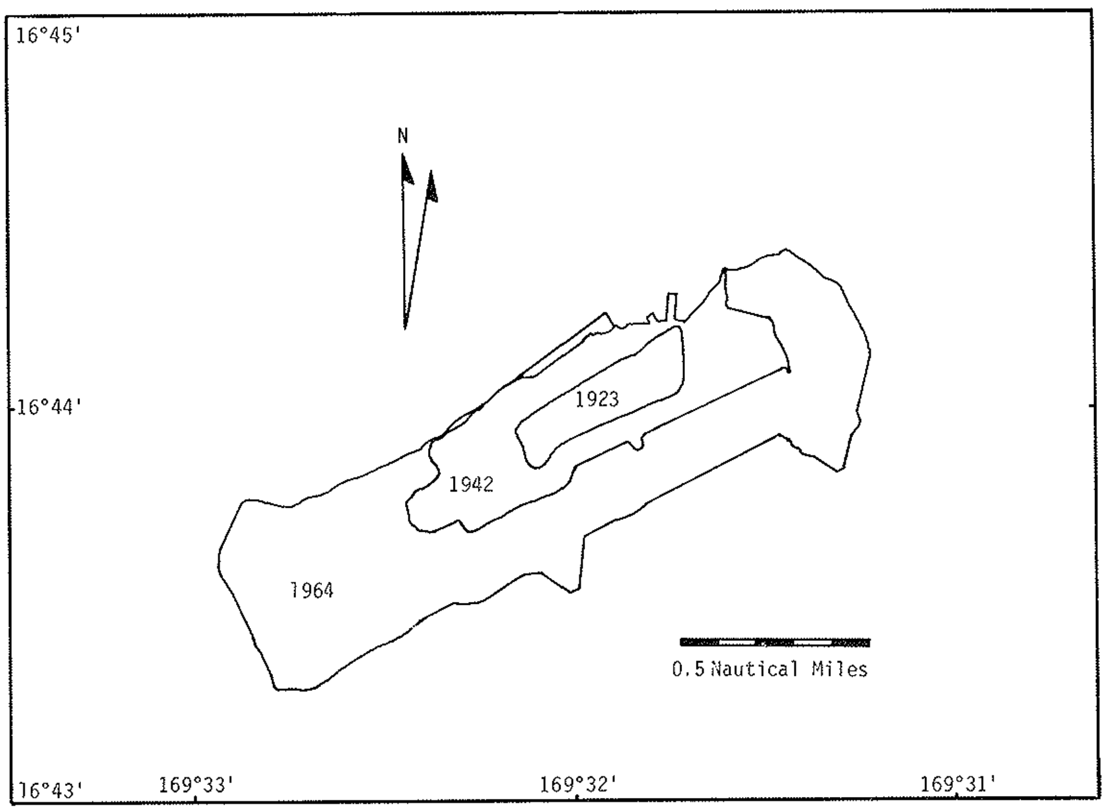


Figure 7. Profile map of Johnston Island, Johnston Atoll, 1923, 1942, and 1964; adapted from Ashmore (1973) and USNOO Chart No. 5356, 20 May 1963 and 23 December 1967.

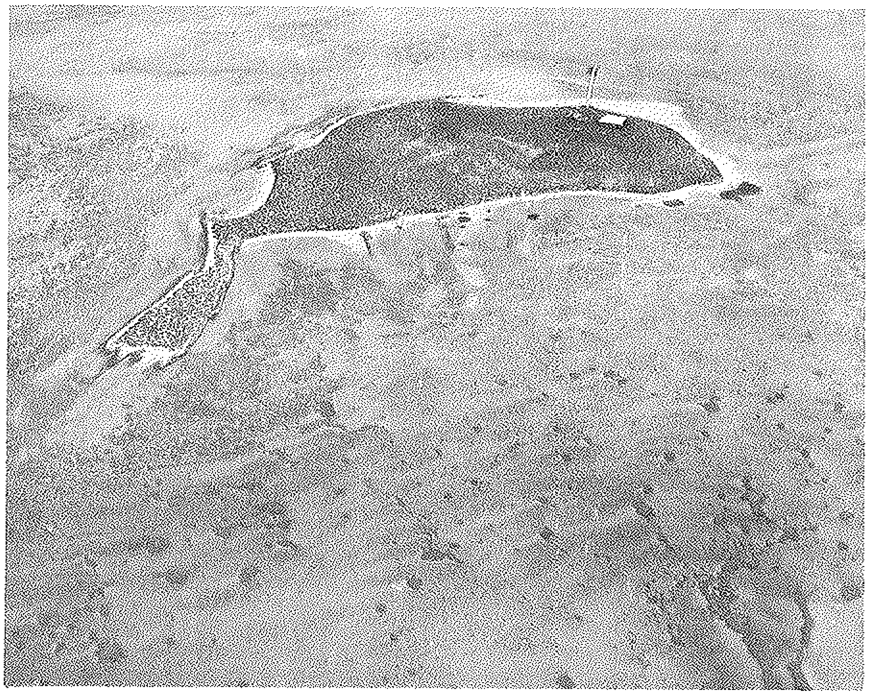


Figure 8. Sand Island from the north, probably in 1939 (U.S. Nat. Archives, R.G. 80 photograph).

Figure 9. Sand Island from the southeast, 18 March 1940; buildings later covered the entire island, including the northeast peninsula (U.S. Nat. Archives, R.G. 80 photograph).

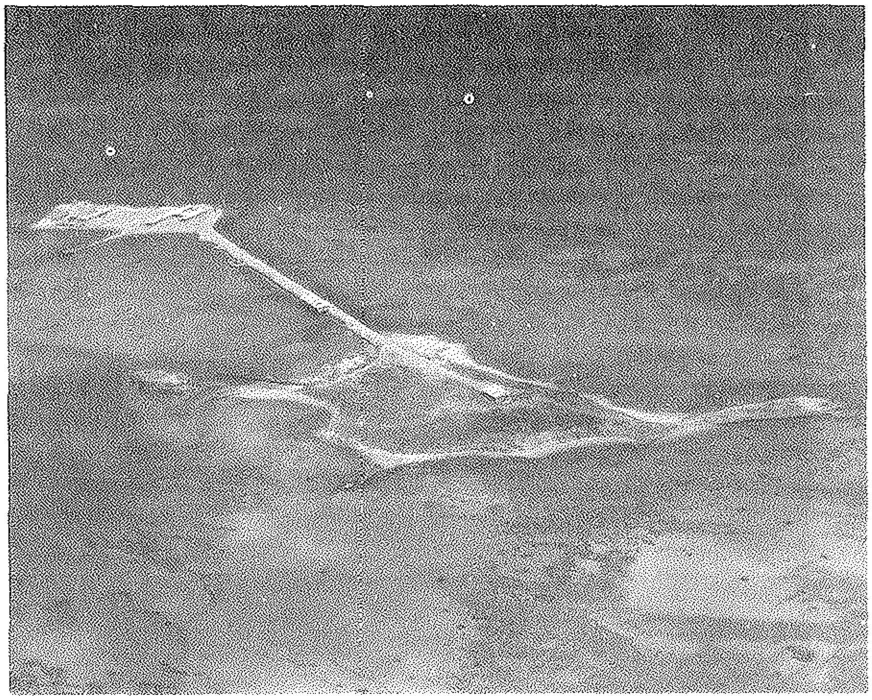


Figure 10. Sand Island as it appeared from the southeast about 1962, with the U.S. Coast Guard LORAN Station completed (official U.S. Coast Guard photograph).

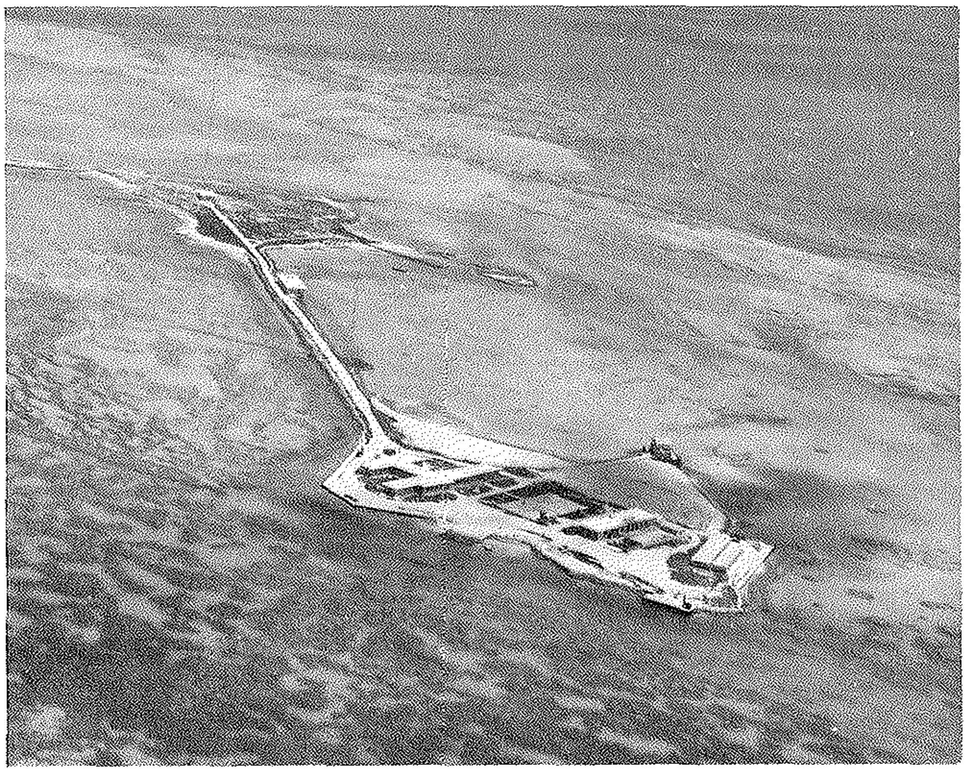


Figure 11. Sand Island as it appeared from the west, circa 1965, after 1964 construction had added a few acres to the south side of the man-made portion of the island (official U.S. Coast Guard photograph).

correlation from well to well. Mud of unknown origin occurred in several wells.

Several occurrences of non-calcareous rock are known from the islands. Several hundred pounds of pumice floated ashore in 1953, presumably from volcanic activity on San Benedicto Island off Mexico (Emery, 1956: 1516, and Richards, 1958). Maxwell S. Doty found a small piece of rhyolite imbedded in beachrock on Sand Island. This could have been rafted on driftwood or could have arrived as ship's ballast (Emery, 1956: 1516). Pumice also floated ashore in the 1960's.

Although Johnston Atoll lies several hundred miles from the nearest island, it is fairly closely associated with two submerged mountain ranges. The nearest is the Mid-Pacific Mountains, also called the Marcus-Necker Rise, which lie in an arc extending from near the middle of the Hawaiian Ridge (Necker Island) first southwesterly, then westerly to Wake Island, then northwesterly to Marcus Island. Barkley (1962: 3) considered Johnston to be a part of this range, but Kroenke and Woollard (1965: 365) and Ashmore (1973: 3) considered it to be the northeastern extremity of Christmas Ridge (formerly the Line Island Ridge). Johnston lies about 100 nm southeast of the crest of the Mid-Pacific Mountains and is separated from it by water over 5 km deep. It is more directly aligned with the long axis of the Line Islands, but it is separated from the nearest of these (Kingman Reef) by a distance of about 740 nm and by depths of over 5 km, although submerged mountains rise to much shallower depths in several places between the two (Menard, 1964: Figs. 1.7, p. 14 and 1.12, p. 19).

Both ranges were built up from the ocean floor by repeated volcanic flows. Subsequent isostatic readjustment and erosion at and above sea level then lowered the mountains. Corals and coralline algae grew in shallow waters around these peaks, and under favorable conditions maintained islands by growing upward as rapidly as the underlying range sank. But not all peaks subsided at a time when coral growth was favored, or they sank too rapidly for corals to maintain the surface. Particularly in the Mid-Pacific Mountains, a large number of flat topped "guyots," presumably drowned islands with their tops 1 to 2 km below the surface, were discovered during World War II (Hess, 1946).

Menard (1964: 92) discussed the relative ages of the central Pacific mountain groups. In summary, many of the volcanoes forming the Mid-Pacific Mountains were thought to be high islands by middle Cretaceous time (roughly 100 million years ago) on the basis of fossils dredged from the summits of Hess, Cape Johnson and other guyots a few hundred miles west of Johnston (Hamilton, 1956, and Matthews, *et al.*, 1974). Although vulcanism and island formation continued for some time in the region, the islands were eroded and the region gradually submerged. Some of the islands probably still existed into late Mesozoic-early Cenozoic time, but except for Wake none has survived to the present in the central Pacific. The Line Islands probably were formed in late Mesozoic or early Cenozoic time, 60 to 70 million years ago.

Details of the geological history of Johnston Atoll itself are lacking. When it first appeared as an island, its original size, rate of erosion and subsidence, and rate of coral growth are unknown. No deep drilling or seismic studies which would reveal the depth of the coral cap have been reported.

Gravity measurements by Kroenke and Woollard (1965) show Johnston Atoll to be intermediate between the main Hawaiian Islands and the Line Islands in Bouguer anomaly values, which may indicate that the base of heavy volcanic material is more massive under Johnston than under the Lines but less massive than under the Hawaiian Islands, where heavy basalts stand far above sea level in the southeast and lie at most a few hundred feet below sea level at Midway at the northwest end of the chain (Ladd, Tracy, and Gross, 1967). Bouguer anomaly gradients on Johnston were lower by about half than in the Hawaiian Chain, which may mean that there are no volcanic necks or plugs involved in the upper structure of Johnston in contrast to the Hawaiian Islands, including the northwest chain.

Geomorphology

The atoll consists of a coral platform with over 50 square miles of area under less than 100 feet of water. A marginal reef, exposed only at lowest tides, extends for 9 miles along the northwest margin of the platform. A broad shallow ridge, on which lie Johnston, Sand, and Hikina Islands, extends from the west end of the marginal reef eastward, then northward to enclose a lagoon approximately 7 by 2 miles in extent, with depths generally between 10 and 30 feet. The remainder of the platform lies south and east of the lagoon and is mostly deeper (see Fig. 2).

Emery (1956) studied the composition of the reef platform by making visual estimates of the relative percentages of sand, coral, and coralline algae on photographs of about 4 percent of the platform, in which the bottom material could be identified by color to a depth of about 10 fathoms. Surfaces of coralline algae dominated along the main outer reef, and many patch reefs less than 4 fathoms deep throughout the lagoon were topped with coralline algae (Fig. 12). The deep eastern part of the platform showed no evidence of algal patch reefs. Coral-dominated areas occurred throughout the lagoon and platform, and coral made up the substrate of many algae-topped patch reefs. Between patches of coral and coralline algae were strips of sand, including dune-like structures near Johnston and Sand Islands. Sand dominated the eastern half of the platform.

The Johnston Atoll platform differs from typical atolls in that the main outer reef extends only about one-fourth of the way around the perimeter. In addition, neither the well-defined northwestern marginal reef nor the poorly developed southern reef is in a clearly defined windward or leeward position; most atolls display better developed reefs on the windward side.

Emery (1956) thought that either the windward portion of the reef had been removed by erosion during a time of lowered sea levels or that the platform had tilted southeastward. He slightly favored the tilting hypothesis. E.H. Bryan, Jr. (ms.) noted that the coral beds on Sand Island dipped 4 to 5 degrees southeastward, which would indicate possible tilting in that direction.

Ashmore (1973) studied the morphology of the atoll on the basis of data collected mainly by a team of U.S. Naval Oceanographic Office engineers and Naval personnel from the USS MAURY during 1964. These data showed features that were not evident to Emery, and led Ashmore to favor a sea level change to explain the present morphology of the atoll, although he acknowledged the possibility of a combination of sea level change and tilting.

The major feature Ashmore found that did not fit the tilting hypothesis was that the platform was composed of two more or less distinct levels, neither with measurable slope (Fig. 13). These were separated by an uneven scarp, 500 to 1,000 yards wide, with an average gradient of 1 to 2 percent, extending across the entire platform.

The higher level is approximately 25 to 30 feet below mean low water and, including the lagoon, covers about 24 square miles. It is irregular in outline with significant embayments south of Johnston Island, at the eastern tip of the platform, and at a break in the northernmost section of the outer reef. The most striking feature of this level is the great number of sink-like holes, commonly 55 to 60 feet deep, and some exceeding 1/2 mile in length.

The lower level has depths of 55 to 65 feet below mean low water and extends over an area of about 30 square miles. A depression at least 90 feet deep and about 5 square miles in area lies in the extreme eastern portion of this level. Otherwise the lower level is somewhat dished, with a distinct rim extending to within 33 feet of mean low water, along much of the southern and western edge. In contrast to the upper level, the lower level has few knolls, no sinkholes, and no patch reefs.

Ashmore suggested that these terraces were formed as sea levels fell at the end of the Sangamon Interglacial, about 75,000 years ago, or with rising sea levels at the end of the Wisconsin glaciation, 10 to 12 thousand years ago. The sinkholes in the upper level were thought to have been formed by fresh water erosion and hence were interpreted as strong evidence that this level was older than the lower, which would indicate formation of the terraces during stable periods within a general period of falling sea levels. But the upper level appeared to Ashmore to be too well preserved to have withstood 65,000 years of subaerial erosion during low waters of the Wisconsin glacial period, which would indicate more recent formation, during rising sea levels. Present data are insufficient to resolve the problem.

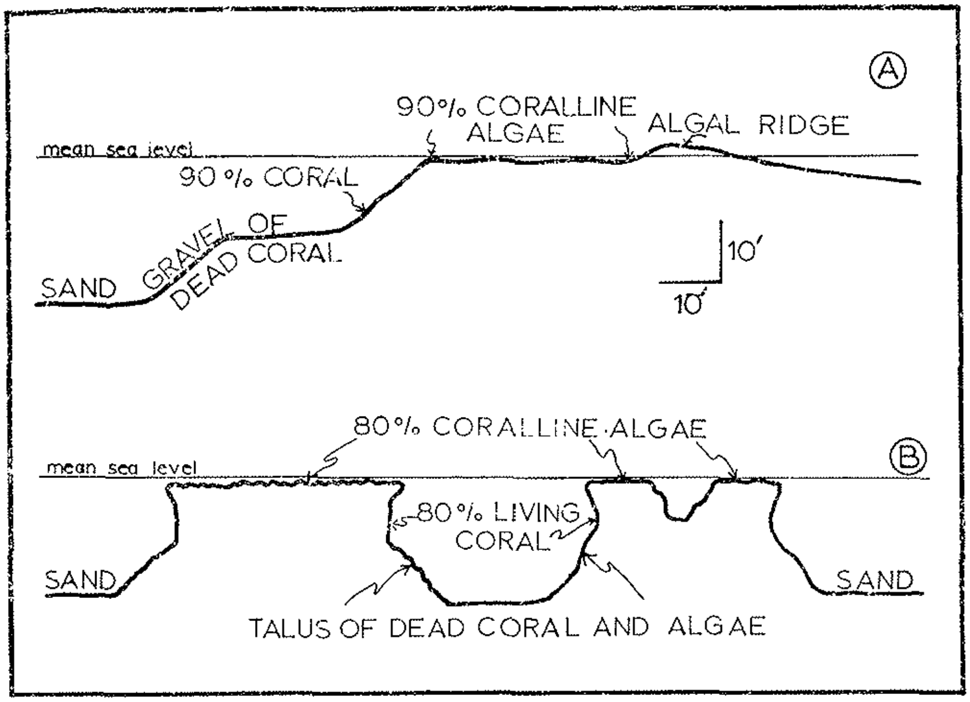


Figure 12. Johnston Atoll reef profiles; A: outer reef, B: isolated patch reef. Adapted from Emery (1956) and Wennekens (1969).

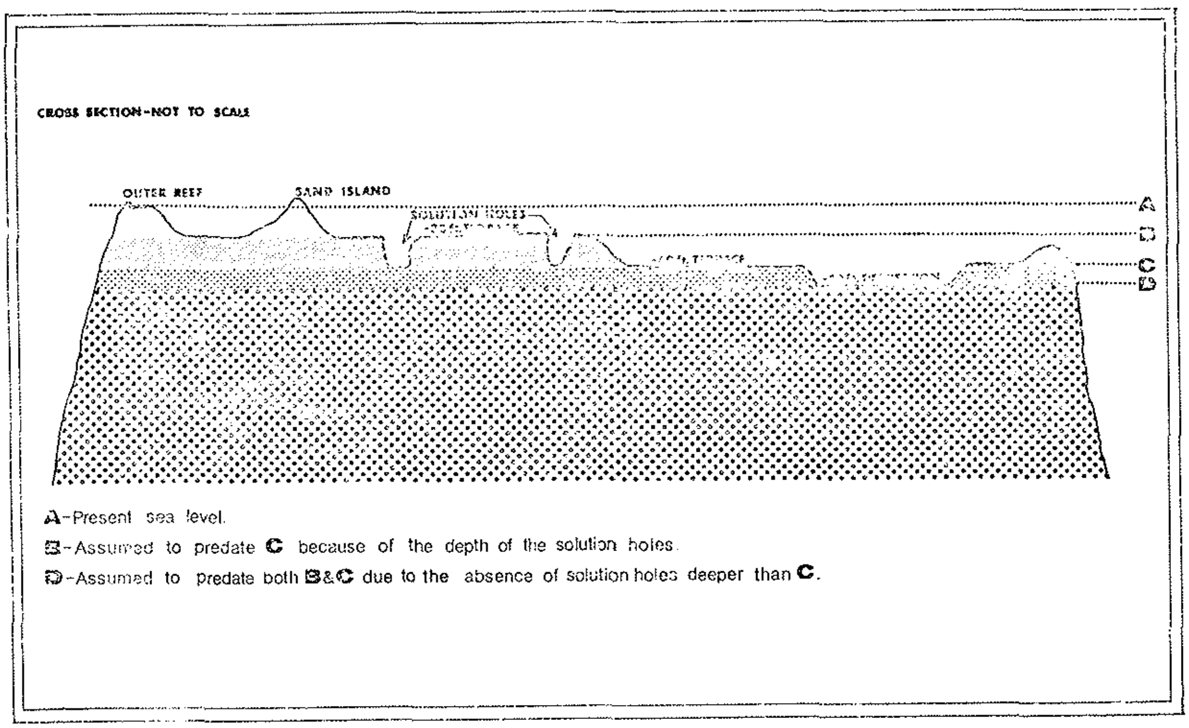


Figure 13. Sequence of sea level changes, Johnston Atoll (Ashmore, 1973).

Climate

Weather records are available for the atoll from about 1931 to the present, but standardized data have been recorded only since 1952 (Joint Task Force Seven, 1959, and U.S. Dept. of Commerce, 1972). These records show a tropical marine climate with little variation in temperature and wind speed, but great variability in rainfall.

There is no evidence that climatic conditions differ from one part of the atoll to another. The islands are too low and small to affect their own weather significantly. The only observed influence of the islands on their own weather was the development of well-organized thermal updrafts generated by solar heating of air next to the surfaces of Johnston and Sand Islands on the rare days when winds were less than 8 to 10 knots. Attention was drawn to this updraft from Sand Island by the column of soaring Great Frigatebirds and Sooty Terns that developed within it. Individual birds entered this column near the west shore of the island and rose to near the cloud bases at over 1,000 feet altitude in 15 to 30 minutes. During this time they drifted a third to half a mile downwind from the island. Above the birds there appeared to be a cumulus buildup at the top of the column of air. There appeared to be a similar but larger cumulus buildup downwind from Johnston Island at the same time, but fewer birds used this updraft, probably because it was farther from the bird colony on Sand Island. There was no indication that precipitation was generated from this phenomenon.

In terms of winds, temperature, and precipitation, two broad seasons can be distinguished on the atoll. The 4-month "winter" including the months December through March is characterized by slightly lower temperatures, more variable winds, and heavier precipitation than the 8-month "summer" extending from April through November.

Temperature

The mean annual temperature is 79.3°F (26.3°C). Daily ranges are usually only 7 or 8 degrees (F), and the daily maximum and minimum temperatures vary only a few degrees throughout the year (Fig. 14). The extremes range from a low of 62°F (16.5°C) (December 1964) to a high of 89°F (31.5°C) (October 1968, July and November 1969), which is lower than the daily range frequently encountered in continental areas.

The constancy of temperature results from the air masses passing over the atoll having been modified by close contact with the ocean for thousands of miles. Thus the air temperature is near that of the water. Sea surface temperatures (Fig. 14) vary little from day to day and change only slowly with the seasons.

Winds

Johnston lies within the belt of strong easterly trade winds throughout most of the year, but these reach a maximum in depth, speed, and

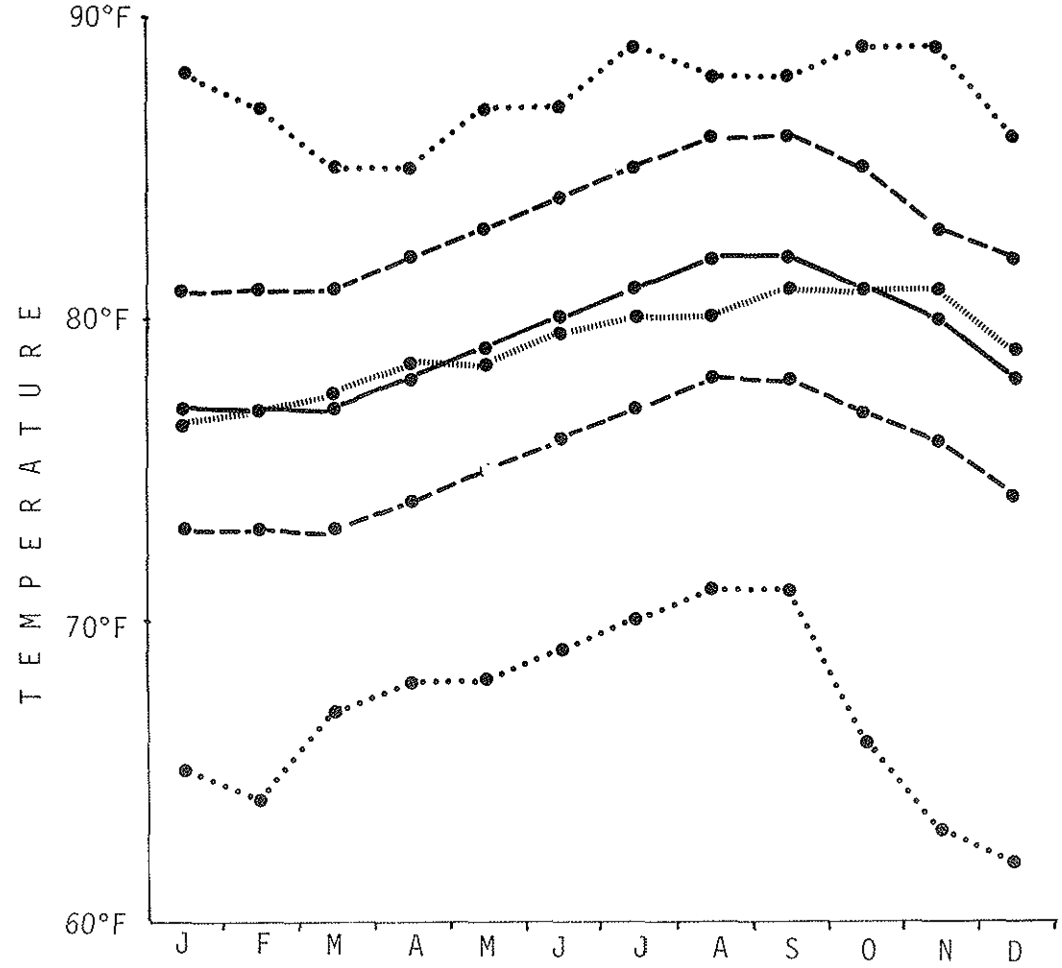


Figure 14. Mean monthly air and sea temperatures, Johnston Atoll, 1931-1972; air: (solid line), daily maximum and minimum (dashes), extremes (dots); sea: means (barred). Adapted from Seckel (1962) and U.S. Department of Commerce (1972).

steadiness during the summer. Only during the winter period, when the world wind belts shift southward to their maximum extent, do trade winds (NE through ESE) occur less than 80 percent of the time (Fig. 15). During this period light variable winds and westerlies occur occasionally associated with the passage of organized disturbances--easterly waves, troughs aloft, and weak cold fronts--characteristic of more temperate regions.

Mean annual surface wind speed is 15.1 miles per hour, and the monthly means range only from 13.6 to 16.0 (Fig. 16). Monthly extremes, excluding 1972, range from 35 mph in July to 49 mph in March and November. Mean monthly extremes are 43 mph. Until 1972 there was no

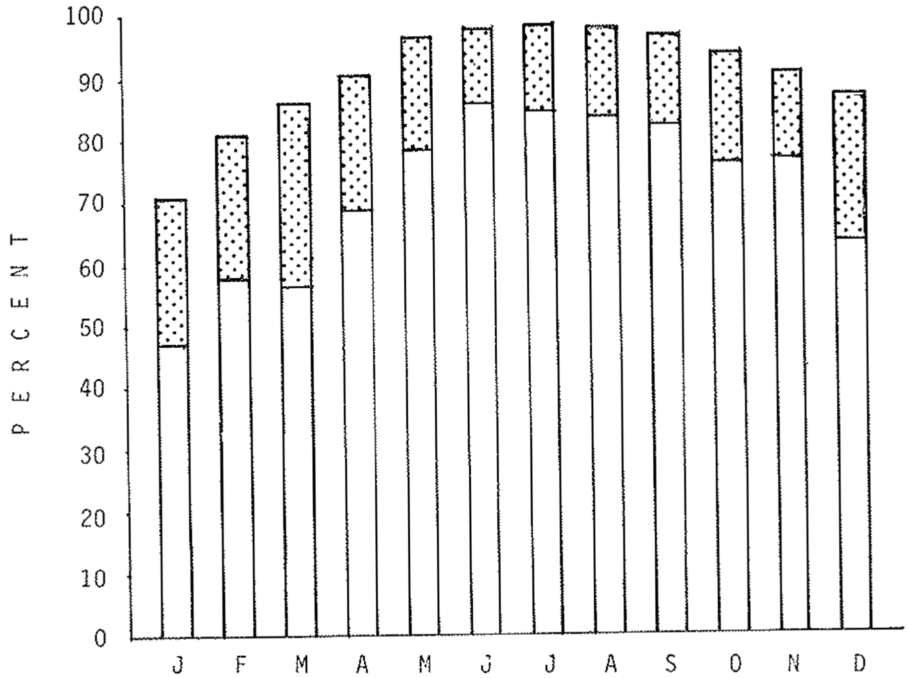


Figure 15. Percent frequency of wind from E and ENE (open bar) and ESE and NE (stippled bar), Johnston Atoll.

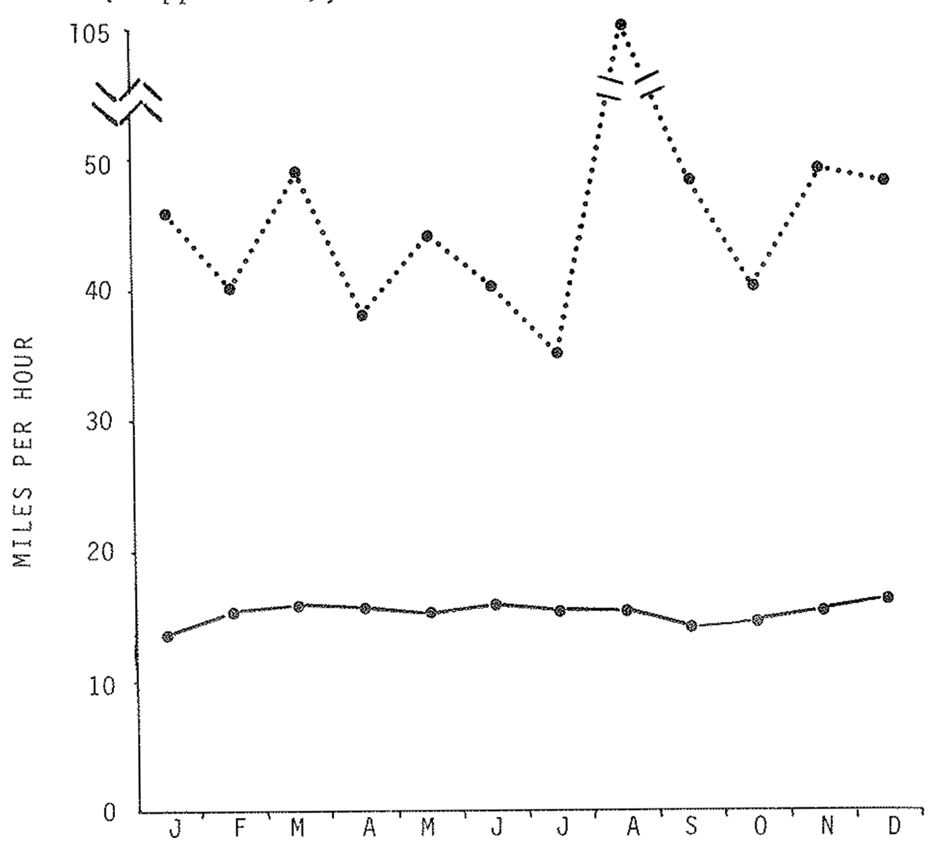


Figure 16. Mean monthly wind speed, Johnston Atoll, 1931-1972; means (solid line), upper extremes (dots). Adapted from U.S. Department of Commerce (1972).

record of a storm of hurricane force (winds of 64 knots or more) having passed over Johnston. On 19 August 1972 hurricane Celeste, spawned off the southern coast of Mexico some 3,000 nm to the east nearly 2 weeks earlier, passed 25 miles northeast of Johnston. The wind speed on the island hit an all time high of 104 mph, and did minor damage on the atoll. Observations from weather satellites indicate that tropical storms in the Johnston Atoll area, though infrequent, may not be as unusual as was once supposed.

Aloft winds are described by Figures 17 and 18 in which east-west or "U" components and north-south or "V" components of wind direction and velocity are plotted against altitude in feet and barometric pressure in millibars. Since the air flow is predominantly east-west at all altitudes, the "U" components show by far the highest velocities.

The comparatively shallow trade winds are shown below the lowest 0 isopleth of Figure 17. Above the trades, air currents in the upper trophosphere (20,000 to 60,000 feet) are predominantly westerly throughout the year, with a maximum of speed, depth, and steadiness in March and April. These winds have a considerable north-south component in December and January, with an especially strong northerly component in February (Fig. 18).

Above the trophosphere (above the highest 0 isopleth on Figure 17), stratospheric flow is dominated by the Krakatoa easterlies, but there is considerable seasonal variability. Winter is characterized by relatively light winds generally with east predominating in the lower stratosphere (60,000 to 90,000 feet), west dominating the mid-levels (90,000 to 110,000 feet), and easterlies again above 110,000 feet. A fairly rapid transition occurs during spring to strong, steady easterlies, reaching a maximum in July and August. There is a sharp transition back to light variable winds in the fall.

Precipitation

Mean annual precipitation is 26.11 inches, but year-to-year variation is great (Fig. 19). For example, the total for 1968 was 42.27 inches, making it the wettest year on record, while 1969 had only 17.11 inches, next to the lowest yearly total recorded. Lowest was 12.86 inches in 1953. This variation is reflected strongly in growth of vegetation on the islands. Twice during POBSP studies, in spring 1966 and in late 1969 and again in November 1973, extended dry periods resulted in the original portion of Sand Island becoming a virtual desert. March, April, and May 1966 were driest on record for these months, and May 1966, with only 0.11 inch was the driest month ever recorded.

Atmospheric disturbances that occur during the four winter months bring in cooler, less humid, less stable air, which results in more cumulus build-up and heavier, more frequent precipitation than occurs during the 8-month summer season, when light showers resulting

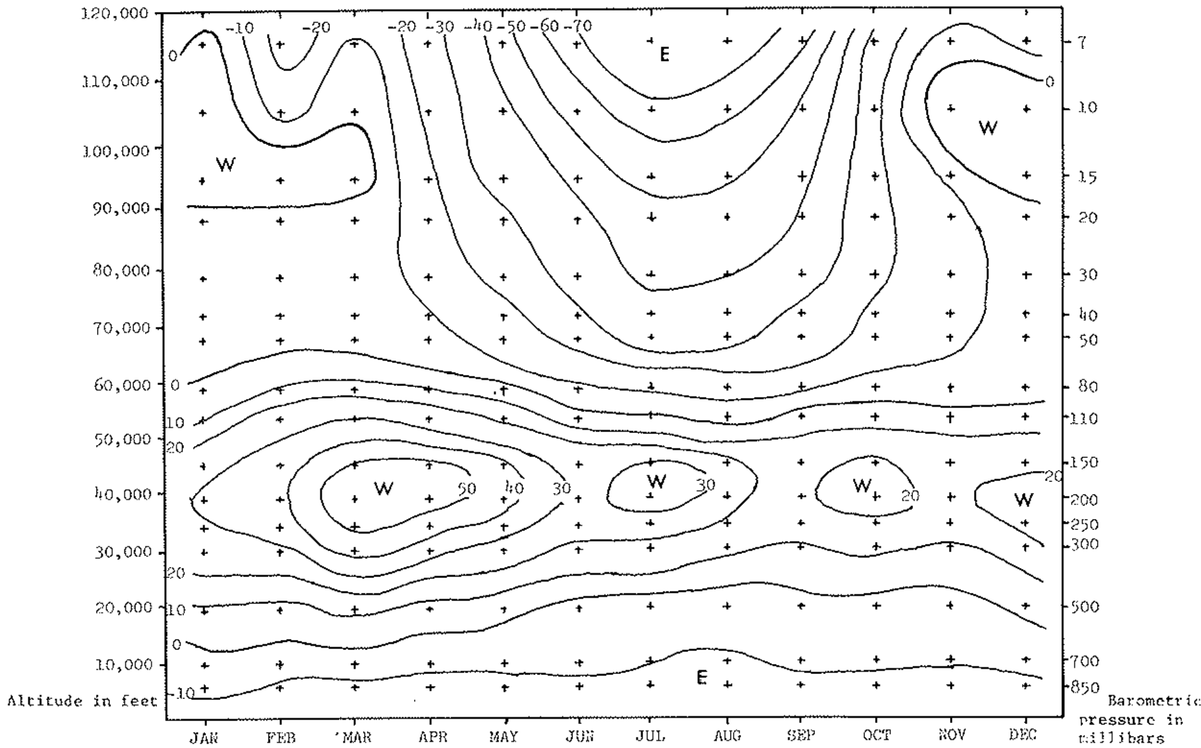


Figure 17. Johnston Atoll mean U components; adapted from Joint Task Force Seven (1959).

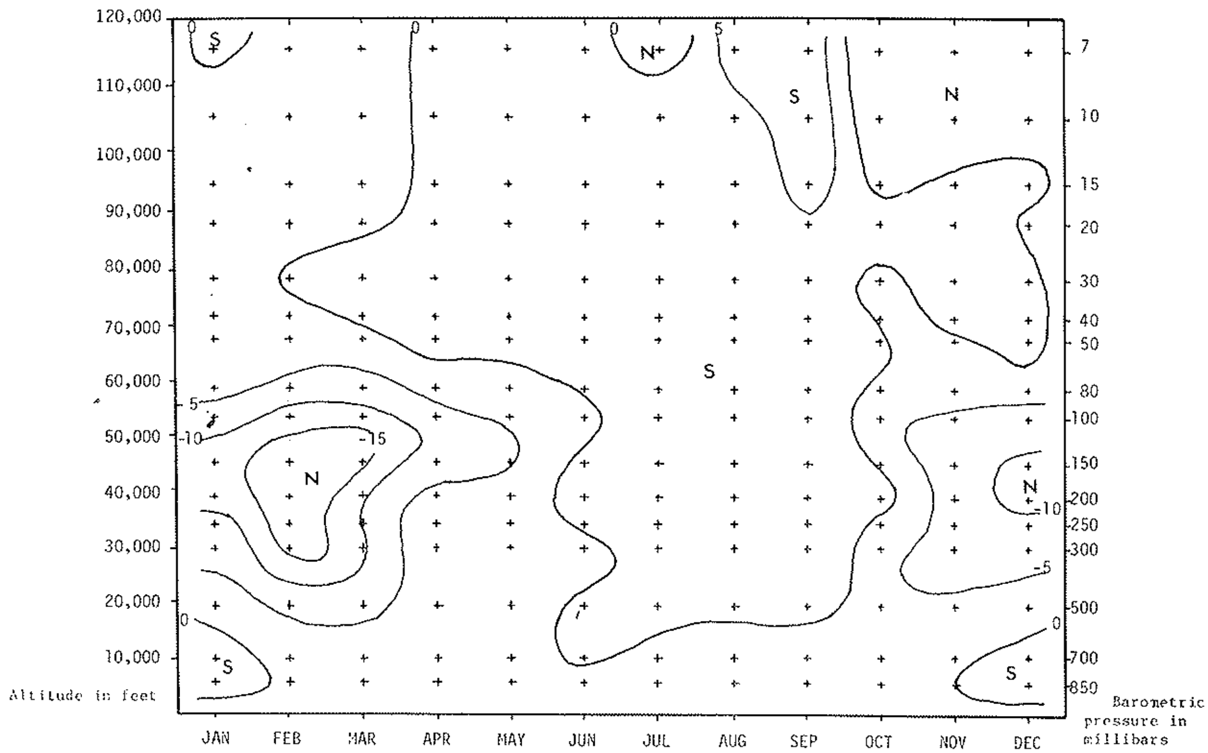


Figure 18. Johnston Atoll mean V components; adapted from Joint Task Force Seven (1959).

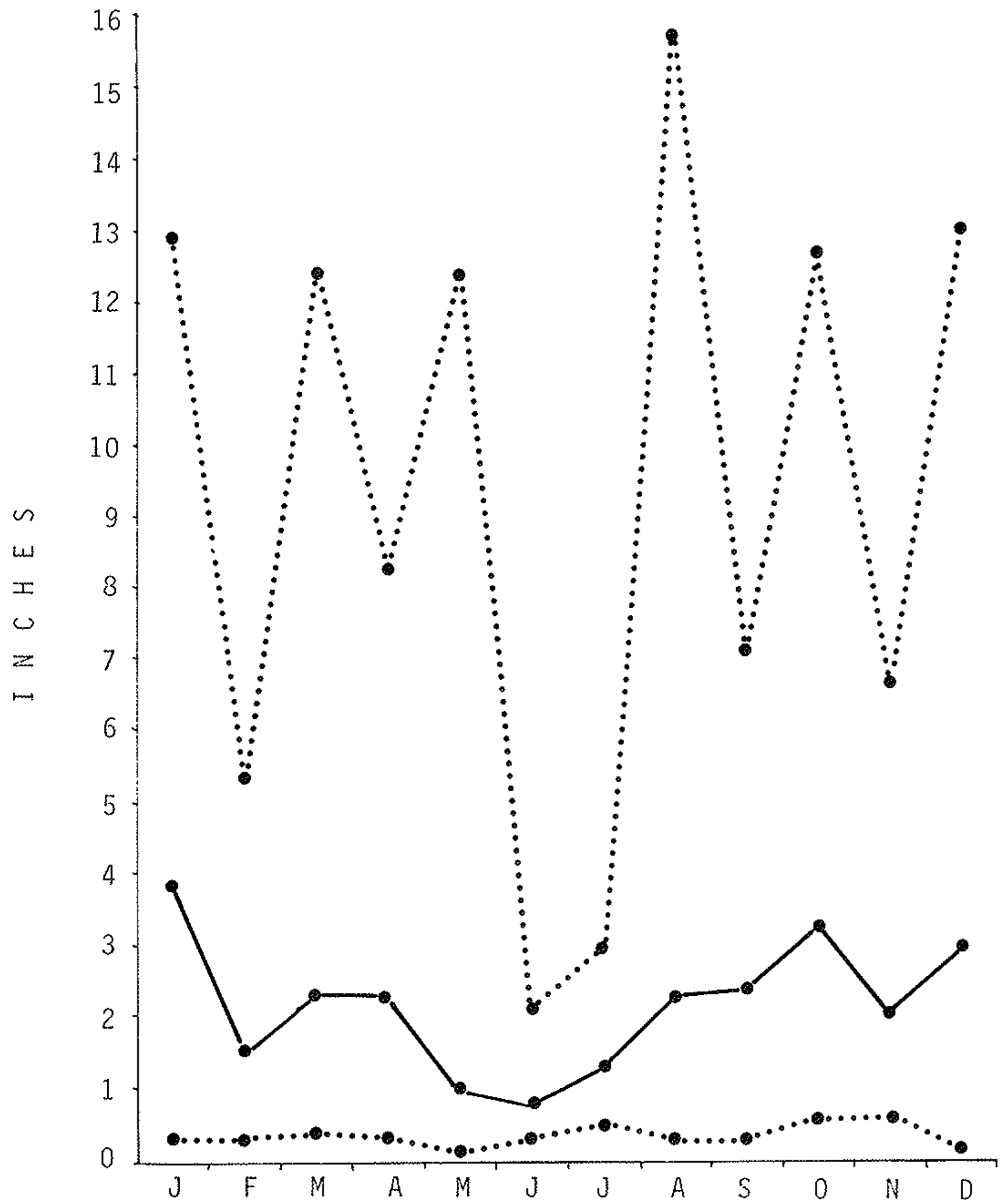


Figure 19. Mean monthly precipitation, Johnston Atoll, 1931-1972; means (solid line), extremes (dots). Adapted from U.S. Department of Commerce (1972).

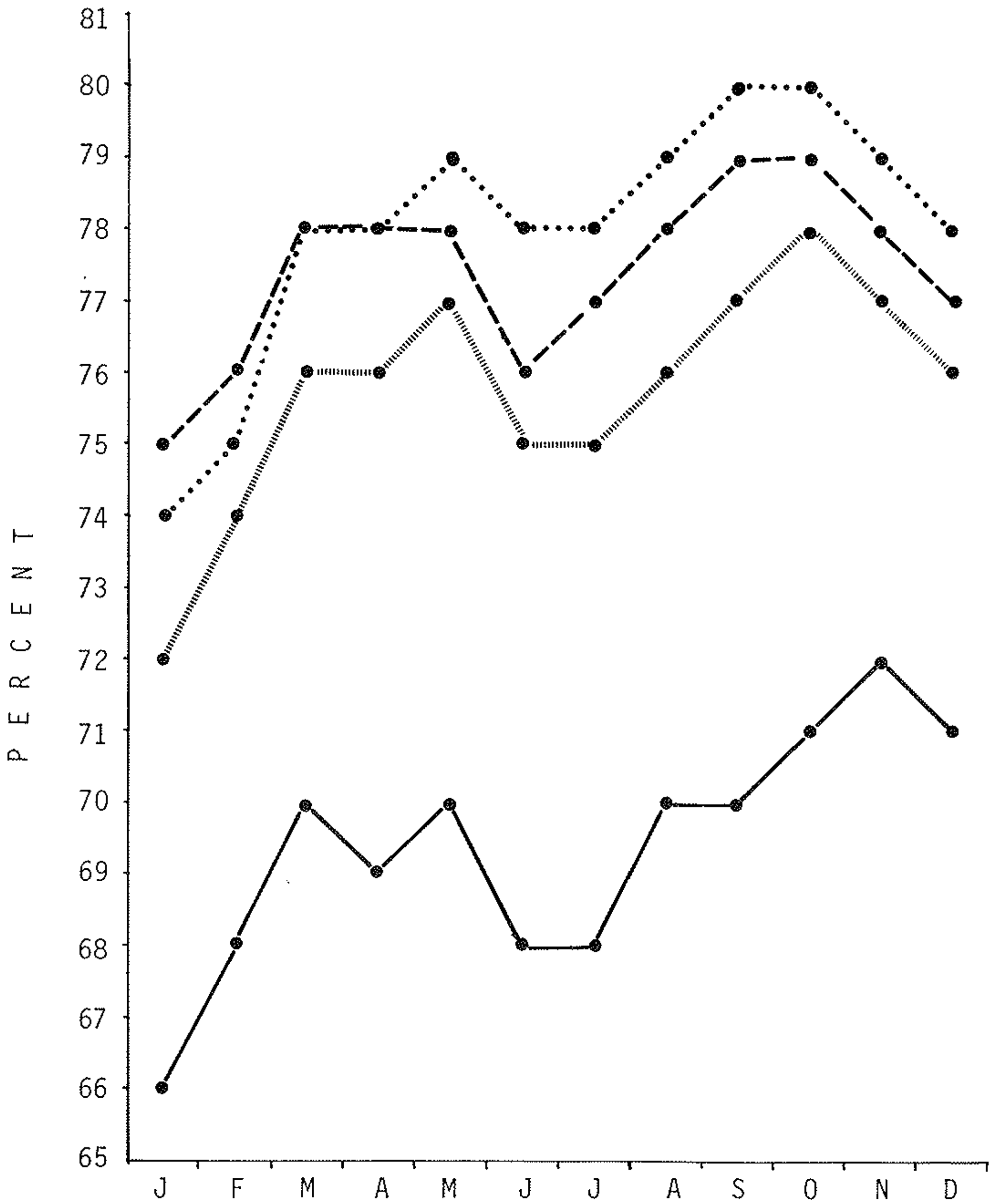


Figure 20. Mean monthly relative humidity, Johnston Atoll, 1931-1972; 0100 hours (dots), 0700 hours (dashes), 1300 hours (solid line), 1900 hours (barred). Adapted from U.S. Department of Commerce (1972).

from small build-ups of cumulus clouds generated by the shallow trade winds are the usual source of precipitation. The four winter months average 2.75 inches of rainfall and the eight summer months 1.87 inches. However, in April and again in September-November heavy showers associated with the passage of tropical storms or depressions are not uncommon.

Relative Humidity

The mean relative humidity is 75 percent, being highest at 0100 hours (78 percent) and lowest at 1300 hours (69 percent). Monthly mean values vary little throughout the year, but are definitely lower in January and February and in June and July than during the rest of the year (Fig. 20).

Sky Cover

Mean monthly sky cover, sunrise to sunset only, is 6.0 on a scale of 0 for no clouds to 10 for complete sky cover (Fig. 21), with little variation throughout the year. During an average year there are 75 clear days, 172 partly cloudy days, and 118 cloudy days (Fig. 22)

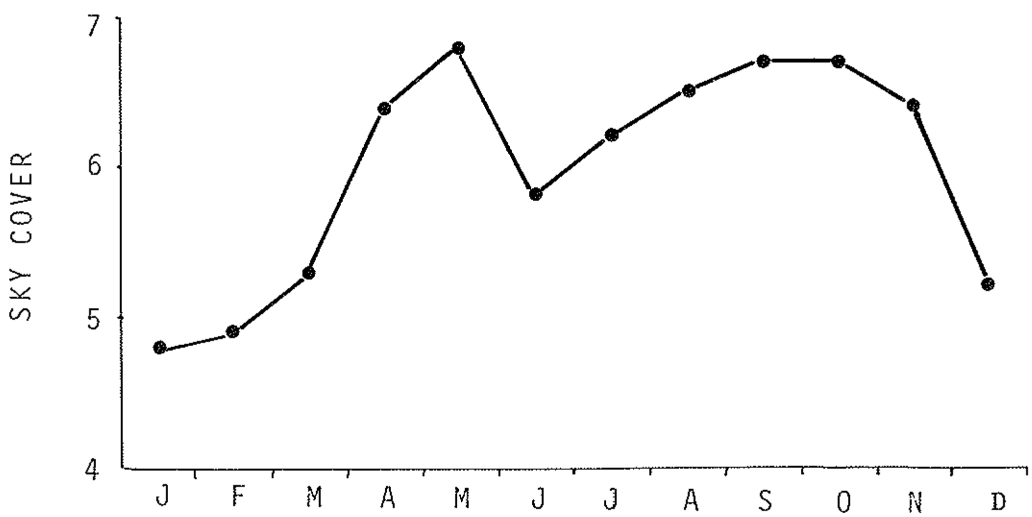


Figure 21. Mean monthly sky cover, sunrise to sunset, Johnston Atoll, 1931-1972. Sky cover is expressed in a range of 0 to 3 as being clear, 4 to 7 as partly cloudy, and 8 to 10 as cloudy. Adapted from U.S. Department of Commerce (1972).

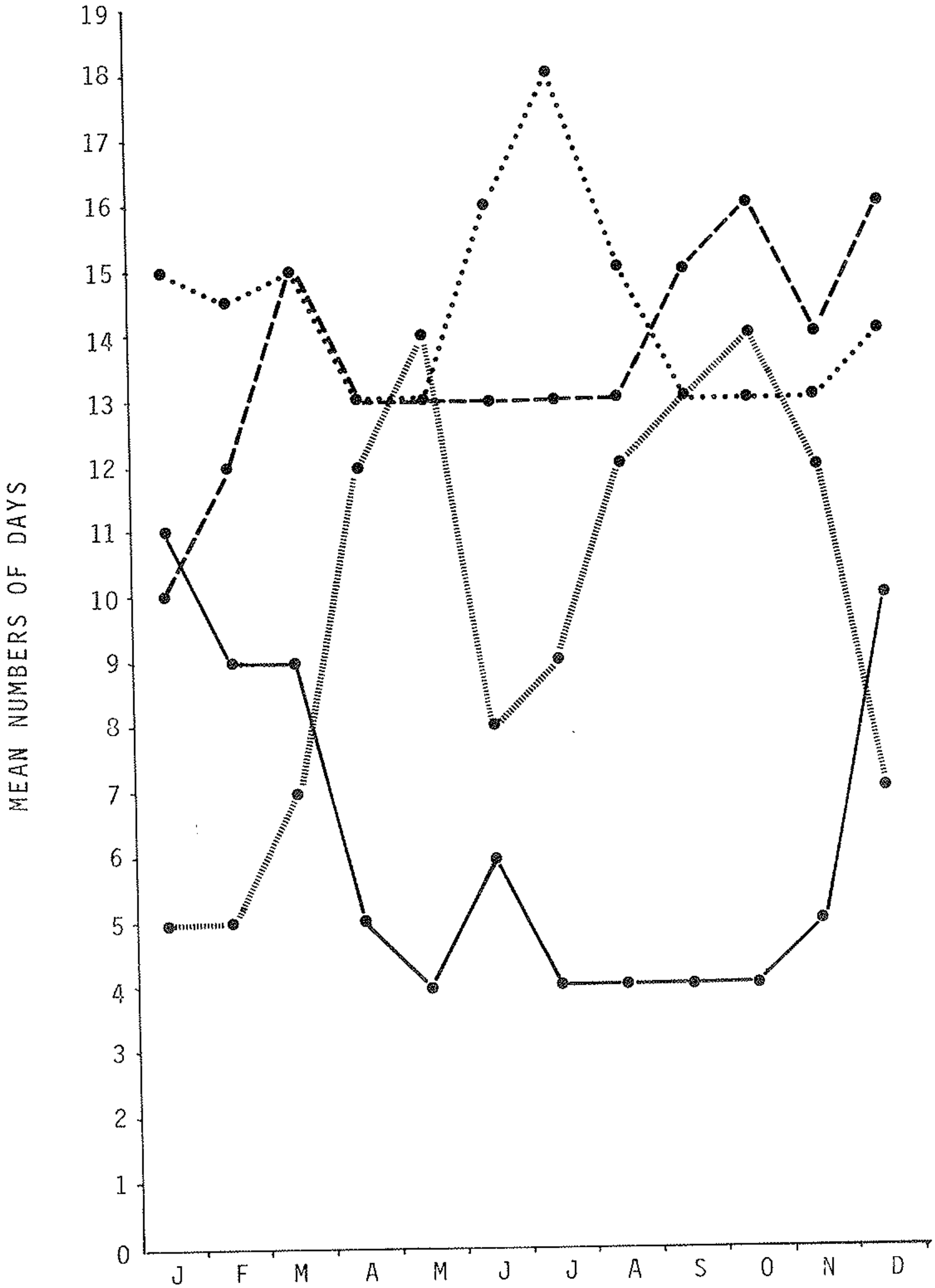


Figure 22. Mean monthly number of days of clear skies (solid line), partly cloudy skies (dots), cloudy skies (barred), and precipitation of 0.01 inch or more (dashes), Johnston Atoll, 1931-1972. Adapted from U.S. Department of Commerce (1972).

Oceanography

Characteristics of the waters surrounding Johnston Atoll are described on the basis of studies made by the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service (Seckel, 1962 and 1968, and Barkley, 1972) and more detailed studies of the immediate vicinity of the atoll and within the atoll are based on studies by the Office of Naval Research (Kopenski and Wennekens, 1966, and Wennekens, 1969).

Major Water Masses and Currents

The major surface water mass of the Hawaiian and Johnston region is called North Pacific Central (Fig. 23). These waters have a salinity generally greater than 34.8 o/oo and range up to 35.3 o/oo (Seckel, 1962 and 1968). They flow in a huge clockwise gyre, the southern limb of which moves past the Hawaiian Islands and Johnston Atoll as the North Equatorial Current, a belt of water several hundred miles wide and several hundred feet deep moving at up to 1/2 knot. South and east of this water mass is the California Current Extension, consisting of waters transitional between North Pacific Central and North Pacific Equatorial, a smaller mass of lower salinity, usually less than 34.2 o/oo. The California Current Extension stretches westerly during the summer to recirculate into the Equatorial Countercurrent west of 175° longitude, but weakens in the fall to recirculate between 160° and 170°W (Seckel, 1962: 407). Seckel pointed out that the spring and summer invasion of the Hawaiian Islands region by the California Current Extension correlates with the availability of skipjack (*Katsuwonus pelamis*). He thought the correlation could be a direct result of the invasion of the lower salinity waters or could result from a dynamic effect produced when this current entered the region. This season also correlates fairly well with the breeding seasons of most Hawaiian and Johnston Atoll seabirds.

The Equatorial Countercurrent does not reach the immediate vicinity of Johnston Atoll, but may be near enough to make a significant contribution to the atoll's biota. It is a shallow easterly flowing current, with salinity less than 34.5 o/oo, which flows at up to 2 knots roughly between 5°N and 10°N latitude (Svedrup, Johnson, and Fleming, 1942). During spring and summer, when it is farthest north, it may reach to within 300 nm of Johnston Atoll and thus probably is within feeding range of Johnston seabirds (Gould, 1974a).

This current spirals clockwise to an observer facing east, with the lateral (north-south) component about a fifth the velocity of the west to east velocity. Thus there is upwelling and divergence along the boundary between the countercurrent and the westerly flowing waters of the North Equatorial Current. Svedrup, *et al.* (1942: 712), Ashmole and Ashmole (1967), and Gould (1974a) present evidence that this boundary and waters flowing away from it are highly productive of marine organisms.

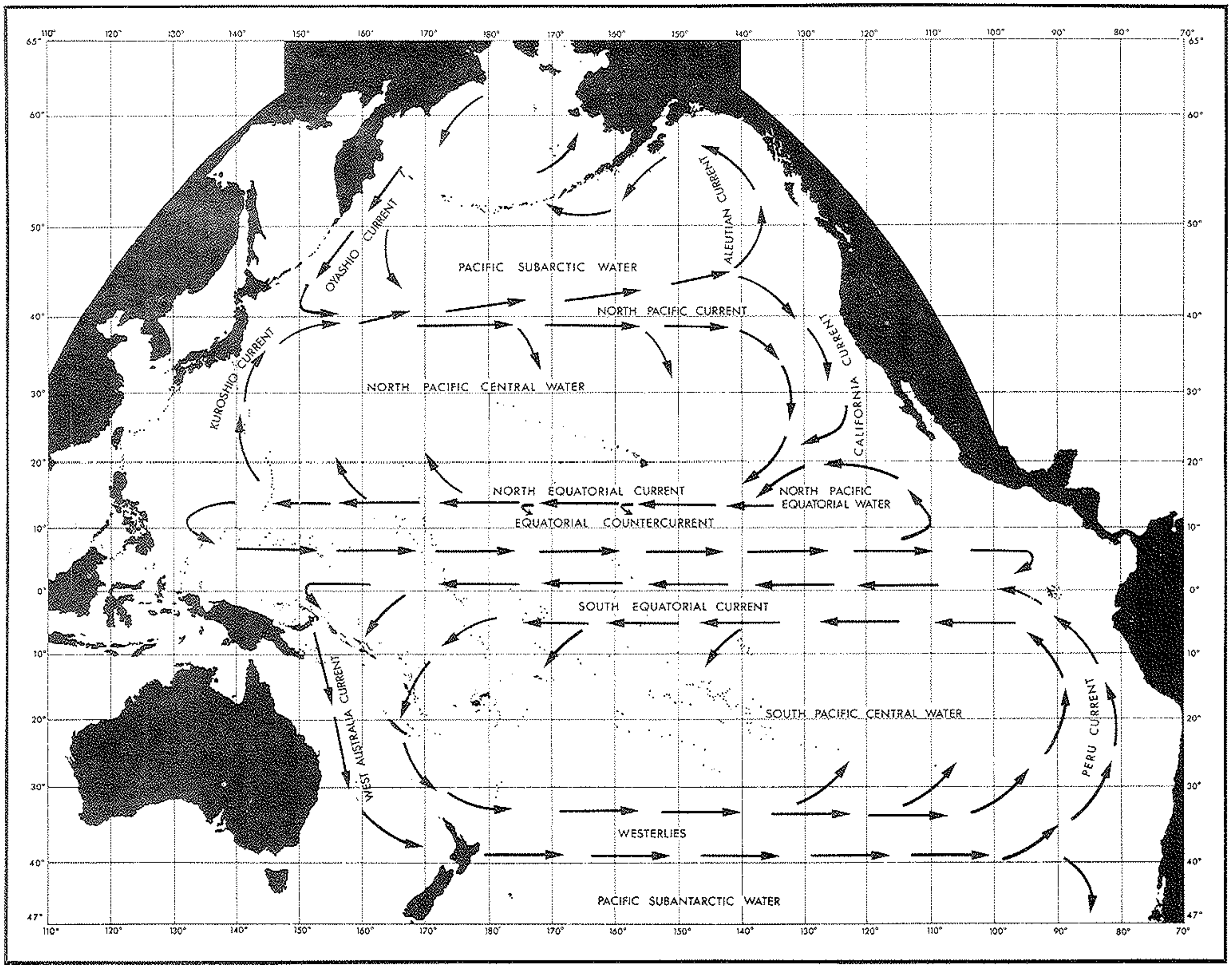


Figure 23. Pacific Ocean currents (King, 1967).

Local Waters and Currents

Waters near the atoll were described by Wennekens (1969) as having temperatures ranging between 25 and 27°C and salinities between 34.6 and 34.8 o/oo in the upper 100 meters. Salinity increased with depth to a maximum slightly in excess of 35 o/oo between 100 and 200 meters, then decreased to a minimum of slightly over 34.3 o/oo at about 400 meters, then decreased slowly to about 34.6 o/oo at 2,000 meters. The main thermocline was found between about 100 and 400 meters, with temperatures decreasing from about 25 to about 7°C. Below 400 meters temperature decreased slowly to about 2°C at 2,000 meters. The region of steep gradients in both temperature and salinity between 100 and 400 meters was highly stable because of rapid change in density correlated with these changes in physical characteristics. Intermixing of waters above and below this region was inhibited.

Although Timme (1963) reported zooplankton levels in the waters moving past Johnston to be very low, and Ashmore (1973) reported that fishes were seldom seen beyond the immediate atoll area, the large submerged bases of atolls such as Johnston deflect the waters and cause leeward eddies with local areas of nutrient turnover and enrichment (Sette, 1955). King (1967) and Gould (1974a) show that areas within 100 miles of these island upwellings provide most of the food resources for large seabird colonies.

Wennekens (1969) described the interactions of the North Equatorial Current and local tides with the atoll, based on extensive studies with dye markers and parachute drogues designed to measure flow at depths down to 3,000 feet. The purpose of his study was to obtain information useful for minimizing effects of pollution of atoll waters. His information indicated that deeper waters flowed rather smoothly around the atoll, but that a distinct "island wake" formed in the surface layers. He recognized three seasonal flow regimes or patterns around and over the atoll (Fig. 24).

One regime extended from late November to early March and was characterized by a strong offshore current setting generally southwest, with island wake confined mainly to the southwestern quadrant and a prominent convergence forming along the seaward margin of the island platform during rising tide. Barkley (1972) suggests that in February Johnston's wake extends some 600 km downstream.

The second regime lasted from early March through mid-June and was characterized by a strong offshore current setting generally northwest with island wake confined mainly to the northwest quadrant. An active easterly counterflow developed along the seaward edge of the reef during periods of falling tide.

The third regime extended from mid-June to early December and was characterized by moderate offshore current setting generally westward. Island wake was confined mostly to the western and northwestern quadrants.

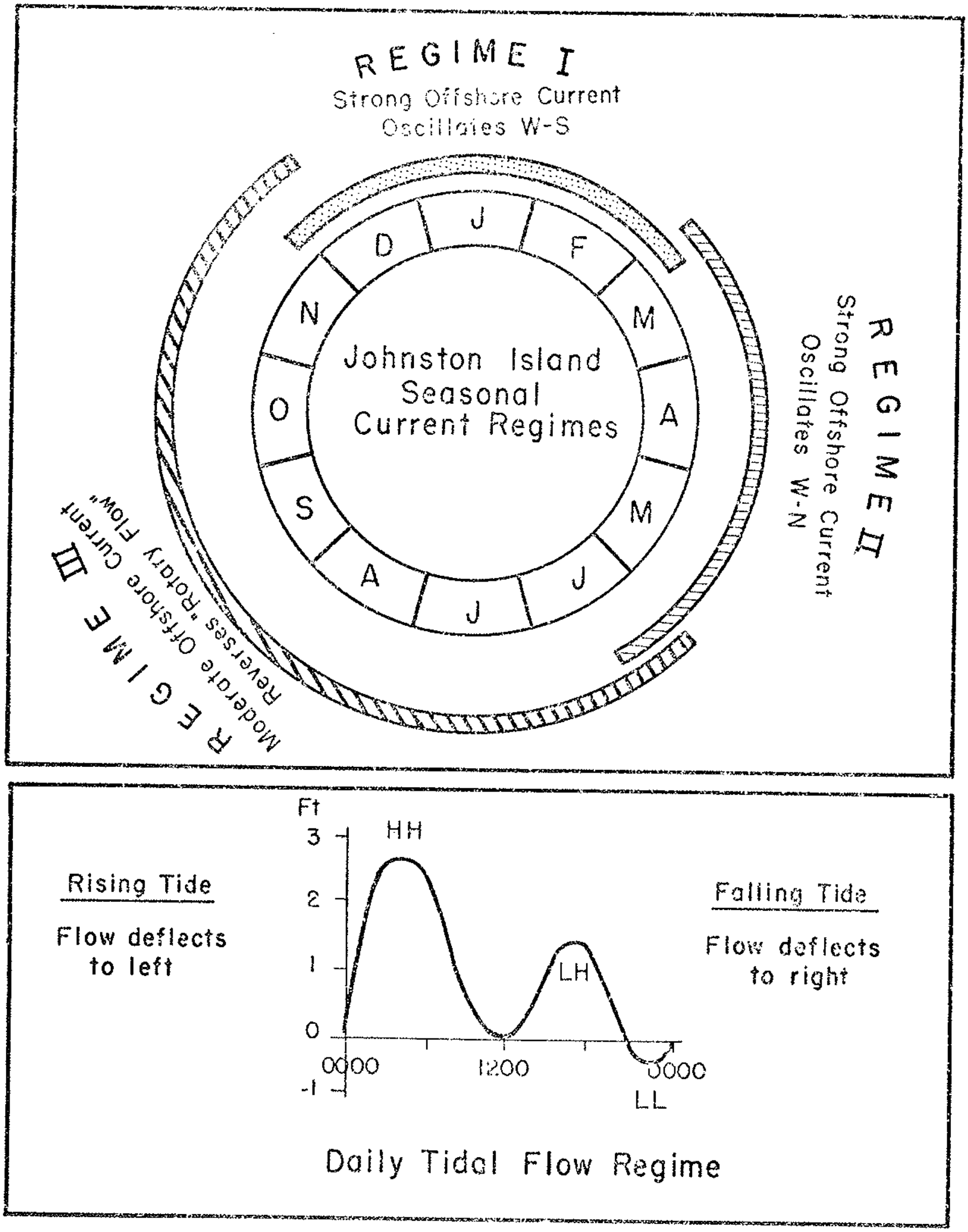


Figure 24. Seasonal and tidal flow regimes, Johnston Atoll (Wennekens, 1969).

The effects of local tides were to deflect currents to the left during rising tide and to the right during falling tides. During the June to December period, when offshore currents were only moderate, local tides induced a rotary or semi-rotary motion to the currents, reversing the westerly flow during falling tides.

The flow within the lagoon was complicated by the effects of tide and the presence of islands and channels. Some of the patterns inferred from earlier work (Kopenski and Wennnekens, 1966) are shown in Figures 25 through 27. Wennekens' (1969) publication contains numerous diagrams and aerial photographs showing these flow patterns in great detail.

Kopenski and Wennekens (1966) thought the disturbing influence of man on the marine environment of Johnston Atoll to be minimal, except for localized destruction of living coral and the release of fine sediments. They suggested that the enlargement of Johnston and Sand Islands and the creation of the two small islands affected the general circulation only in a minor way. At the local level, however, they found that circulation had been greatly affected. The dredging of boat channels, turning basins, etc., especially between Akau Island, Sand Island, and the southern tip of the main reef had created new and artificial flow channels. The geometry of the shoreline of the man-made islands also contributed to the creation of vortexes, stagnation points, and venturic effects, which shift in location and vary in

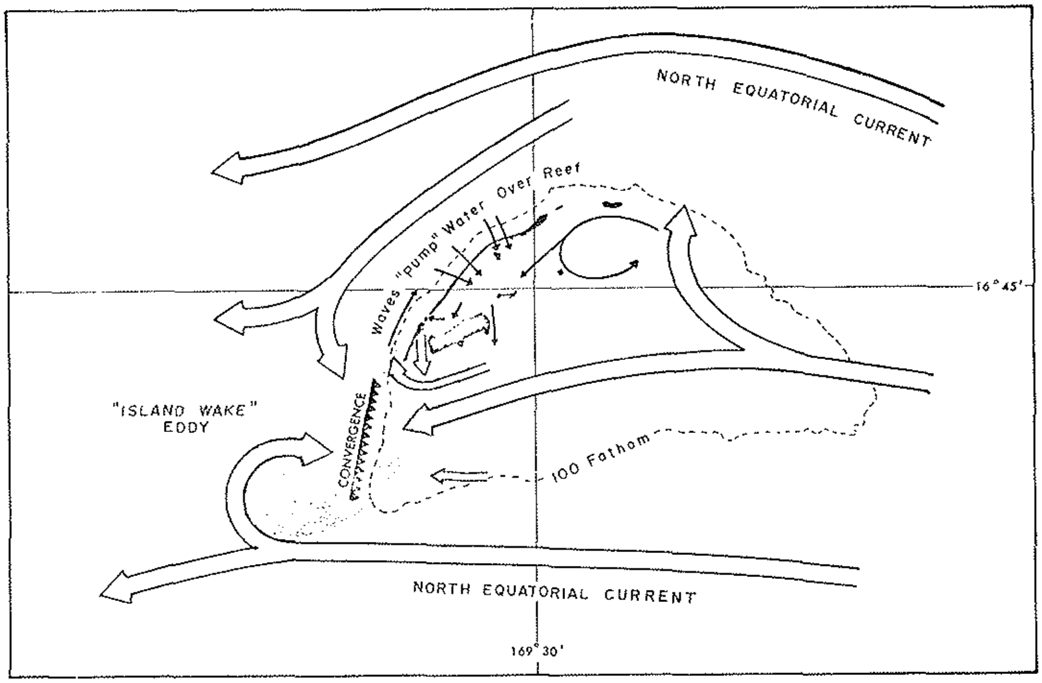


Figure 25. Johnston Atoll inferred lagoon circulation, January-February 1965 (Kopenski and Wennekens, 1966).

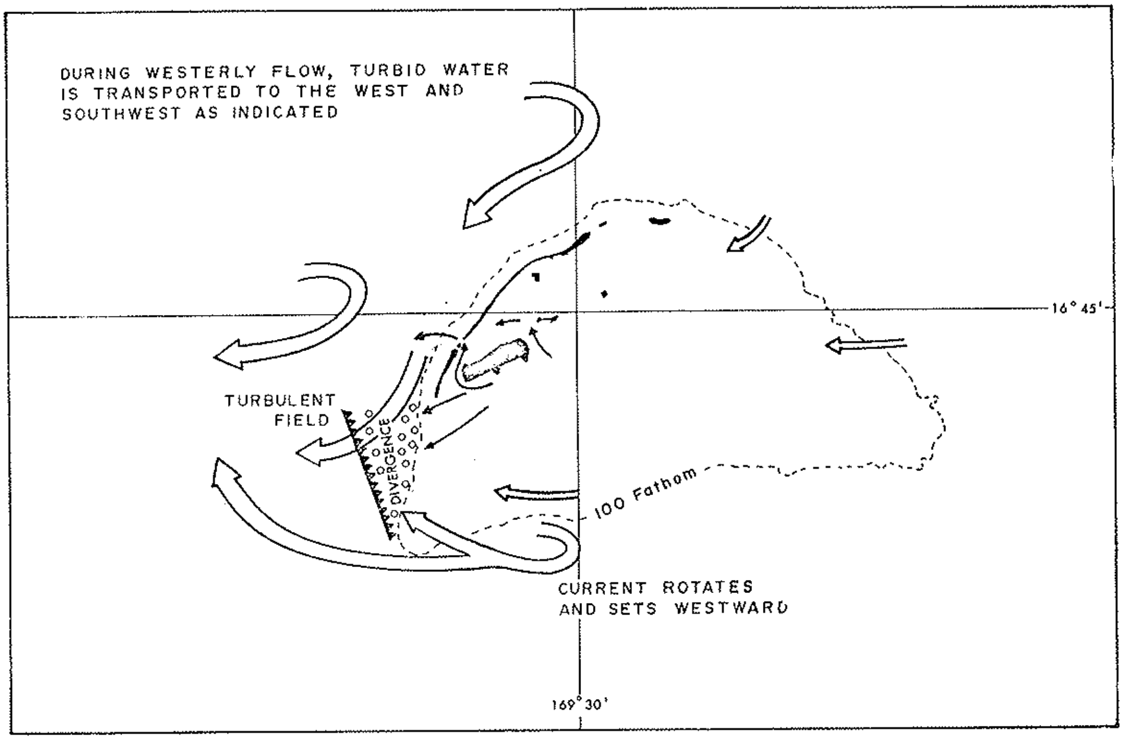


Figure 26. Johnston Atoll inferred lagoon circulation and turbid outflow (westerly flow), July-August 1965 (Kopenski and Wennekens, 1966).

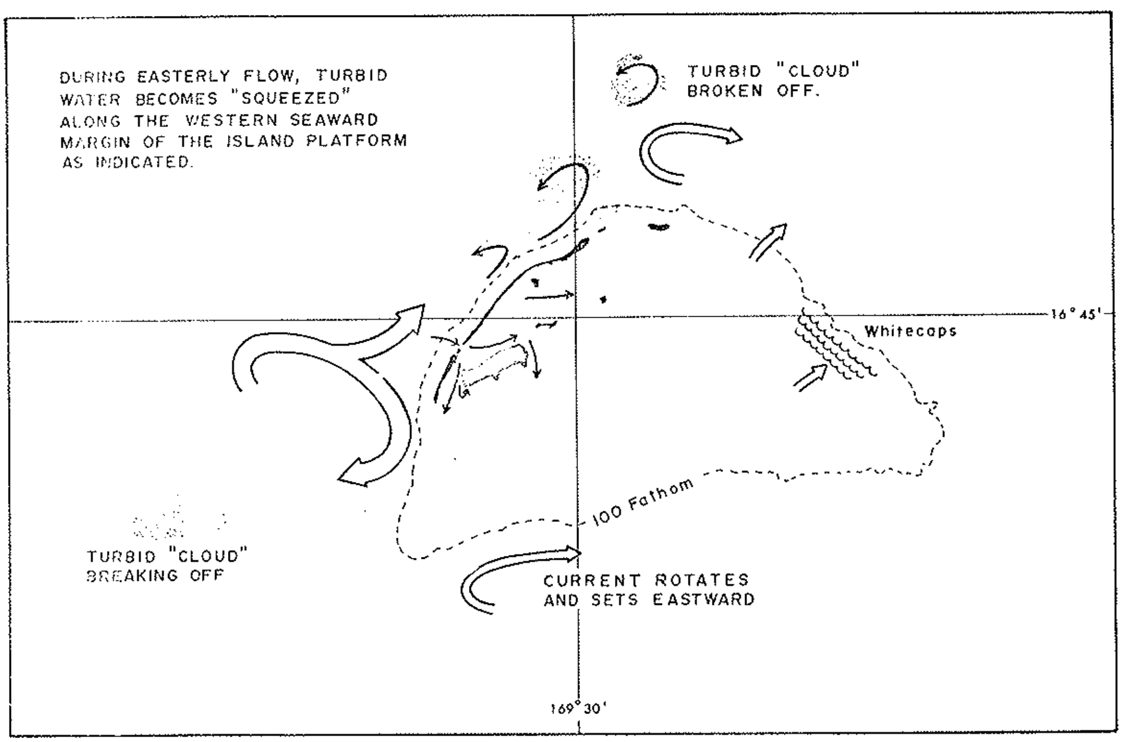


Figure 27. Johnston Atoll inferred lagoon circulation and turbid outflow (easterly flow), July-August 1965 (Kopenski and Wennekens, 1966).

intensity as the regional circulation changes. In addition, the westerly extension of Johnston Island created a backwash immediately south of the island during the summer, resulting in very limited mixing of waters in that area.

Tides

Wennekens (1969) described the local tides as "...mixed type, predominantly semi-diurnal, usually with two daily high and low waters exhibiting strong inequalities in the amplitudes of the high waters. The inequalities in the high reach a maximum at the time of maximum moon declination...." His tide graphs show the highest high tides to have amplitudes of a little under 3 feet and the lowest high tides with amplitudes of under 2 feet.

Seismic or Tsunami Waves

The characteristics of seismic or Tsunami waves--long gravity waves caused by submarine earthquakes, landslides, or plutonic activity--at Johnston Atoll were described by Wennekens (1969). From available historical data (Fig. 28), he found the largest amplitude wave recorded to be about 3.4 feet, resulting from the Chilean earthquake of 22 May 1960. The crest of the wave at Johnston Island appeared as a progressive rise in sea level, with maximum elevation being reached in 25 to 30 minutes. The period of seismic waves at the island appeared to be between 45 and 60 minutes.

Wennekens (1969: 6-7) further suggested that historical records "...indicate the effects of a Tsunami at Johnston Island should be minimal, consisting of transient rise in water levels, occasional breakers to higher than normal levels, and local flooding of low areas ...[and] that no large breaking wave or bore is likely to occur at the island."

HISTORY

Johnston Atoll has had a varied history. From two small, insignificant islands, the atoll has grown into a large Department of Defense complex. Previous historical accounts have been written by Bryan (1942), Thorp (1960), and Bauer (1965).

Major sources of information for this history of Johnston Atoll were the Bernice P. Bishop Museum Library, Hawaii State Archives, Hawaii State Library, Hawaiian Mission Children's Society Library, Hawaii Historical Society Library, Library of Congress, Library of the National Museum of History and Technology of the Smithsonian Institution, U.S. National Archives, U.S. Naval Archives, and the University of Hawaii Library. The staffs of all these institutions were most helpful, and their contributions are hereby acknowledged. Although these sources were carefully searched, none of them was exhausted for information. What is presented here should, however,

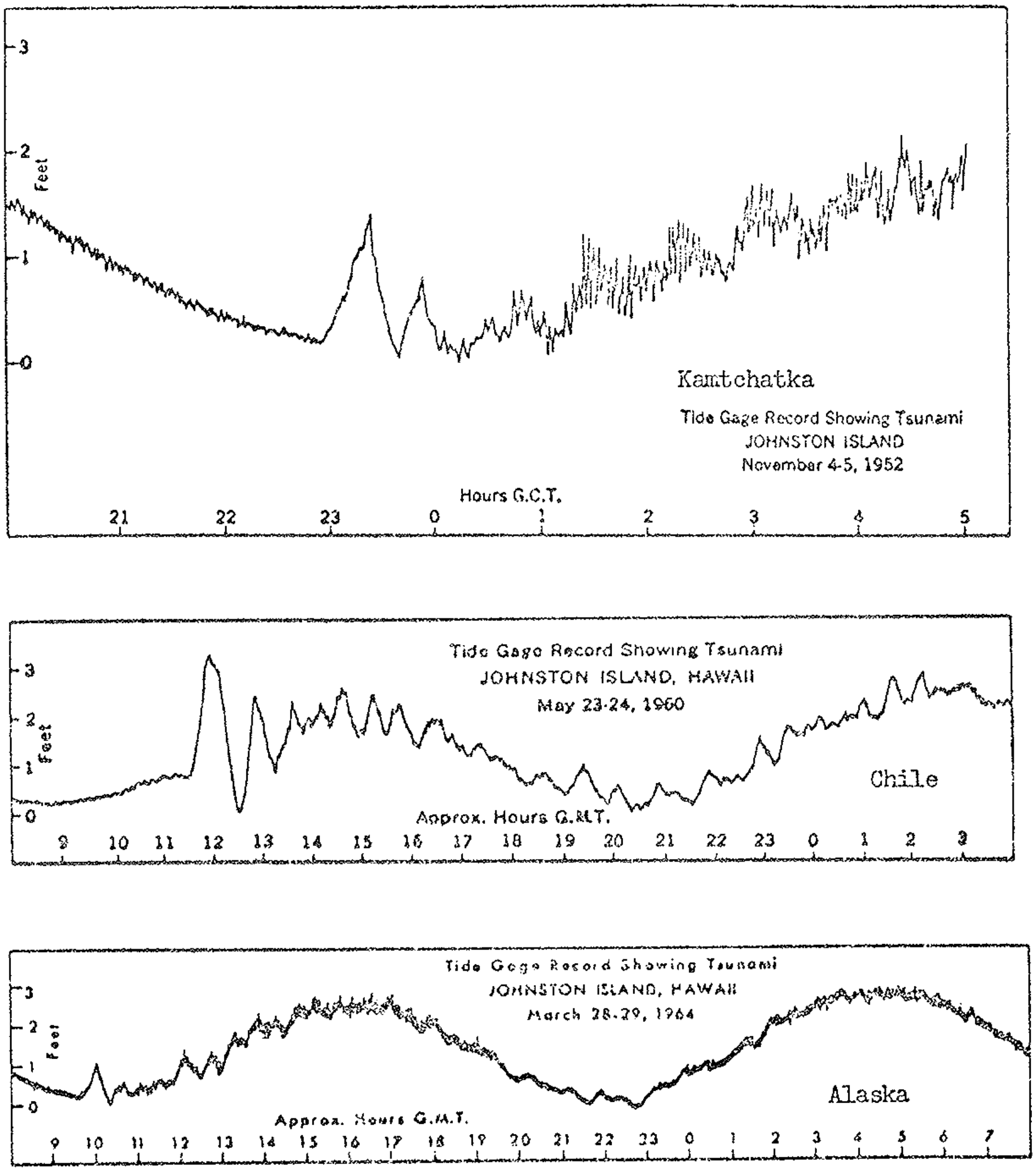


Figure 28. Tidal wave records, Johnston Atoll (Wennekens, 1969).

provide a reasonable starting point for anyone preparing a definitive history of the atoll. A fruitful source of information for recent history, which we scarcely tapped, is the few thousands of military and civilian personnel who have spent time on Johnston Atoll during the last 40 years.

Discovery and Early Exploration

Nowhere have we found any evidence or suggestion that Johnston Atoll was inhabited or even visited by Polynesians. Habitation would hardly have been possible, and any visits that may have occurred left no mark upon the islands that was discerned by later visitors.

The Spanish sailed Central Pacific waters for two and a half centuries before any sightings of Johnston Atoll are known to have been recorded. Annual trips in the trade winds from Acapulco to Manila (between 13° and 14°N latitude) took them less than 200 miles south of the Atoll. The return route, in the prevailing westerlies, took them north, not only of Johnston but of the entire Hawaiian Archipelago. Dahlgren (1916) and Stokes (1939) thoroughly explored the possibility of Spanish discovery of the Hawaiian Archipelago, a myth that grew and spread from several sources but is negated by both these authors. We have not seen Dahlgren's paper, but Stokes contains no hint of anything that might have been Johnston Atoll. Stokes does not entirely discount the possibility of a sighting of the Hawaiian Islands by other than Spanish, since they were not tied to the trading routes as were the Spanish. The junior author perused a number of maps in the Map and Cartographic Division, Library of Congress, finding only two possible islands that could have been Johnston. These were the Basse de Villa Lobos, which appears on Arrowsmith Chart of 1798, and Izle Solitaire, on a 1706 map by Godallett. Positions of these were too crudely determined to give any certainty as to exact locations, and no descriptions could be found of either of these. It is possible that a sighting of Johnston could have been responsible for the placing of these islands on the charts, but there is no evidence that such was the case, other than that they appear in the general area.

The discovery of Johnston is usually attributed to HMS CORNWALLIS, Captain Charles James Johnston, on 14 December 1807. At least one account of the island, by Captain Joseph Pierpont of the SALLY, out of Boston, predated the CORNWALLIS sighting by 11 years, and Krusenstern (1811) declared that the Spaniard Don Jose Comisares saw the atoll in 1786, 21 years before the CORNWALLIS sighting. The Comisares' sighting is poorly documented, but the 1796 grounding of the SALLY and the PRINCE WILLIAM HENRY was reported in several newspapers and is here regarded as the earliest account of the atoll on record.

Captain Joseph Pierpont of the SALLY published the following note in several newspapers, including the Columbian Centinel of Boston on 24 June and 13 September 1797. It is here copied from Ward (1967: 417):

> In lat. 16,45 N. long. 169,38 W. from London, on my passage from the Sandwich Islands to China; the 2d of Sept. 1796, at midnight, in company with the schooner Prince William Henry, William Wake, Master, of London, we both ran ashore on the south side of a reef of coral rocks and sand, where we continued until next day noon -- at which time the weather being very clear. We saw two small islands of sand, bearing W. by N. 4 or 5 miles distant, and from our topgallant-mast-head. We saw the shoal extending E.S.E. southerly round to W.S.W. -- but how far we were not able to determine.
>
> Keep the Lat. 17 N. and this shoal will not be seen.
>
> Joseph Pierpont
>
> N.B. It is hoped that the printers of America, will give the above a place in their papers.

Krusenstern himself (1811: 288) suspected the presence of land in the vicinity of Johnston Atoll in 1804:

> On the 15th of June we saw in lat. 17° and long. 169°30' an extraordinary number birds that hovered round the ship in flocks up upwards of a hundred; this raised our hopes of meeting with land very considerably; but although the night was perfectly clear and we kept a good lookout, there was none to be percieved. I cannot; however, but think, that during the night, we must have passed near some island or rock, standing above water, that serves as a resting place for these birds, for we again saw several the next morning, nor did we lose sight of them until noon.

The CORNWALLIS sighting was announced by Lt. Wm. Henry Smyth, an officer on the ship. He placed the islands at 16°53'20" N, 169°31'30" W. The ship's log described the islands as "Two very low islands having a dangerous reef to the eastward of them, and the whole not exceeding four miles in extent" (Marshall, 1827: 173).

Otto von Kotzebue (1821: 258-259), another Russian explorer, described the islands but it is doubtful if he actually saw them:

> The islands which Mr. Johnstone [sic] discovered in 1807, on board the frigate Cornwallis, in the W.S.W. of the Sandwich Islands, and which we looked for in the spring of 1817, are, like the island of Sala y Gomez, perfectly naked rocks which do not seem to belong to the formation of low islands. The reefs which are united to them form shoals extending to great distances from them, which are very dangerous to vessels that navigate these seas.

No further sightings of the islands are known between the possible Kotzebue sighting of 1817 and that of one of the ships of the Wilkes Expedition in 1841 (Wilkes, 1844, 5: 288):

> Mr. Knox [S.R. Knox, Acting Master of the U.S. Schooner FLYING FISH] reported to me that after his separation, on the 30th of November [1841], he stood for the position of Cornwallis Island, as laid down by Arrowsmith in longitude 169°31'W., latitude 16°50'N., without seeing any indication of land. Twenty-two miles to the south-by-east of this position, he discovered a reef, which surrounded an extensive lagoon, extending north-east and southwest ten miles, and in the opposite direction five miles. On the northwest side of this reef there are two low islets: the one to the westward was covered with bushes, but no trees; the other was no more than a sand bank. This reef lies deep. The longitude of the westernmost islet was found to be 169°45'36" W., and the latitude 16°48' N.

Guano Period

This section is taken primarily from sources in the U.S. National Archives, Record Group 59, U.S. Department of State, Guano letters.

The next known possible sighting of the island was by William H. Parker, captain of the REINDEER, who passed through the area in January 1852 on a trading voyage to the Ladrone Islands and China, and later claimed to have seen several islands at Johnston Atoll. What he actually saw is difficult to determine, because his descriptions fit nothing actually present. It is possible he saw nothing, but knowing islands had been described in the area, made up a good-sounding story.

After the U.S. Congress passed the Guano Act 18 August 1856, Parker attempted to claim the islands under the act. On 26 August 1857 he formed a partnership with attorney Richard F. Ryan, of San Francisco, giving Ryan one half of all profits from discovery. On 29 August Ryan wrote Secretary of State Lewis Cass, giving notice of Parker's discovery and asking prompt action on their claim to the islands. The petition was refused on grounds that Parker and Ryan were not occupying the islands and could not finance their exploitation. On 19 November Ryan submitted an analysis of the guano to the State Department. This states: "The guano on Cornwallis Island is of extraordinary good quality, consists of 82.53 of Azote [nitrogenous material] in 100 parts and 17.47 of Hydrogen, the deposits are large and from its dryness is most valuable as an article of commerce." The source of this guano, or its report, sound suspicious, for there was no mention that Parker actually landed on these islands in 1852, and no one had been back. On 19 December 1857 Parker and Ryan made an agreement with Robert G. Byxbee and Asa B. Stoddard, owners of the 100-ton schooner PALASTINE, giving the ship owners five-eights interest in the venture, they in turn agreeing to send the ship to the islands to claim them and to bring back a load of guano. On 20 December Ryan dispatched another letter to Cass, enclosing an amended declaration of Parker's claim, stating that a vessel was to be sent for a load of guano in 2 weeks. It also pointed out the potential importance of the islands to the United States as a coaling station.

The PALASTINE departed San Francisco 8 January, under Captain William R. Perriman, and with Parker on board. They arrived on the island 9 March 1858, and left 16 March, arriving back in San Francisco 22 April. Subsequent statements, most of them sworn and notarized, varied greatly as to exact procedures on landing. Parker's statement, dated 28 April 1858, stated that he and Rich, the mate of the PALASTINE, and two seamen went ashore on Johnston Island and erected a flagstaff with a cross on top with the inscription "this island was taken possession of by W.R. Perriman, master of the schooner Palastine on behalf of the owners and charterers of the schooner Palastine in the name of the United States of America, James Buchanan, President." He took latitude and longitude 16°46'N, 169"28'W, and with the mate explored the island and took 13 "gunny bags" of guano (about 1,200 pounds). They also landed on Sand Island (called by him Agnes, for his daughter), and erected a flagstaff with a similar inscription as the one placed on Johnston Island. Parker described the islands quite accurately in his statement and gave the position as 16°46'N, 169°28'W.

The signed statement dated 1 May 1858 by Perriman and Rich did not differ significantly from that of Parker but added that there was no sign of previous occupation. It too gave a good description (neither description, however, mentioned birds) and the position given differs only slightly from that given by Parker. Position given in the various letters and statements all tended toward minor variations, some of which probably resulted from actual variations in measurements, and some from mistakes in copying. The most significant part of the statement, for later questions of ownership, was: "...that possession was immediately taken of the said islands by the deponents Perriman and Rich in company with the said Parker, and same were occupied by them during this time."

In May, Ryan and Louis Blanding (an attorney for the group) corresponded with Secretary of State Cass, calling attention to Parker's claim and giving notice that a ship had been sent, guano removed, etc., and including the sworn statements of Parker and of Perriman and Rich.

On 8 June, Byxbee, Stoddard, and Ryan, together with William Thompson and Cornelius L. Place, formed the Pacific Guano Company, incorporated under California law. Parker was not included, but apparently he owned stock in the company, for records dated between 26 June and 6 November of 1858 show that he sold a total of 80 shares of stock in it to five different people.

Meanwhile, a second attempt was made to claim the island, this time for the Government of the Kingdom of Hawaii. Samuel C. Allen, recorded as being from Honolulu and from San Francisco, obtained from King Kamehameha IV a royal commission dated 31 May 1858 to take possession of unclaimed islands in the name of the King. Aboard the KALAMA, under Capt. Watson, he arrived at Johnston Atoll 14 June, and according to a sworn statement by Edward Watts, a cook and steward on the KALAMA, Allen and the Captain removed the flagstaff and cross put up by the PALASTINE crew, and presumably destroyed these and the inscriptions. They claimed the islands, Cornwallis (Johnston) on the 14th and Kalama (Sand) on the 19th; after erecting a Hawaiian flag on them and taking a small sample of guano, they returned to Honolulu. Kamehameha IV formally claimed the islands for his Kingdom in a Proclamation 27 July 1858, in which it was stated that the islands had been found "derelict and abandoned," by the KALAMA crew.

The PALASTINE returned to Johnston, arriving 22 July and the crew found their flags, etc., replaced by those of the KALAMA. They remained on the islands 13 days, loading about 70 tons of guano, before leaving two men on the island and returning to San Francisco, arriving 31 August. Meanwhile, Louis Blanding, attorney for the Pacific Guano Company, wrote on 13 August to James W. Borden, U.S. Commissioner in Honolulu, asking Borden to inform the Hawaiian Government of his company's prior claim to the island, and requesting "some positive disapproval of the act." The company had most likely heard of the trespass via the King's proclamation in Honolulu, since their ship had not yet returned when the letter was written.

On the return of the ship, Blanding wrote Lewis Cass, U.S. Secretary of State, informing him of the details of the trespass by the KALAMA, and placing the blame on the crew of the KALAMA, stating that the King probably did not know of the prior claim at the time he issued his proclamation. When the Hawaiian Government was informed of the facts, via dispatch from Commissioner Border, 8 September, Allen's royal commission was rescinded as far as Johnston Islands were concerned, and it was amended to the effect that the commission was void in cases of prior claim by other powers. This had been the intent of the original commission, but it was not specifically worded. The King then solicited from Borden an opinion as to whether the flag, cross, and inscriptions left by the PALASTINE's crew 9 March fulfilled the requirements for claims under the Guano Act. This act required that the islands be occupied by the claimant or their agents. Byxbee, President of the Pacific Guano Company, had requested similar information from Cass in a letter dated 19 August 1858 requesting a statement as to the validity of Parker's claims and the means by which all requirements of the Guano Act could be met.

On 9 November the Hawaiian Government requested Borden to ask the Pacific Guano Company not to send vessels to the islands to load guano, adding that the Hawaiian Government was asking the same of Allen, until ownership had been settled, to avoid a confrontation by the two participants on the island. Newspaper articles at the time indicate the King relinquished claim to the island, but our search has not produced the actual documents.

A confrontation did occur, however, for Allen sent Captain Borland in the ship GAUNTLET to the island for a load of guano. On arrival, he found the two Pacific Guano Company men in possession of the island and told them he intended to load the GAUNTLET, using force, if necessary. The Pacific Guano Company had in the meantime sent A.D. Piper in the ship RADIANT, under Captain Hallett, to take command of the island and to prepare for shipping guano. The GAUNTLET was at anchor when Piper arrived and he immediately protested its presence to Borland, but offered to sell him a load of guano at $4.00 per ton, or to charter his ship for his own firm--the Pacific Guano Company. Borland apparently was more intimidated by the difficulties in loading from the islands than by threats or deals, so he accepted neither offer. Captain Hallett concurred that loading was impossible, and refused to load the RADIANT. Both Borland and Hallett then left the island, leaving Piper and 11 men in armed possession of the island. Piper set his men to work preparing a wharf, railway, etc., for shipping guano. The FENIMORE COOPER, under Captain John M. Brooke, was ordered to the island in March 1859, to survey the islands and make soundings. He arrived 14 March and learned the above story from Piper (Brooke, ms; see also, Brooke, 1955).

Meanwhile, it appeared that Parker was being squeezed out of the Partnership which had become the Pacific Guano Company. The company had pursued the claim, through protests over the intrusion by Allen's ships from Honolulu, and by letters to the State Department requesting information as to proper means of complying with and fulfilling the requirements of the Guano Act. In support of the contention that Parker himself had no claim to the islands, Perriman and Rich again on 25 and 26 October 1858 made sworn statements as to the happenings on the first landing on the islands in March. They stated that Parker had said there was but one large island with trees on it, which was visible on the horizon for 20 miles, and which had no reefs around it. What they found instead after beating about for 7 days, was the two small islets, visible only 8 miles, with no trees, and with extensive dangerous reefs all around. There is suspicion that this story was at least in part concocted, because Parker's original claims described no less than 7 islands and islets, some said to be no more than cays; it is therefore not too likely that he would have told Perriman there was only one island while they were searching for them.

Perriman further claimed that he and two others went ashore on Johnston at 0900 on the first day, and that Parker did not land until the second boat in the afternoon. In his first statement, Perriman said he and Rich "...in company with...Parker..." had taken possession of the island. Here he asserts that Parker was not along on the first landing, although he does not say what part Parker had in the claiming ceremonies. Interestingly, in a newspaper interview in 1892, 34 years after the first landing, Perriman asserted that Parker did not go ashore at all.

Who was trying to pull what on whom in the hassle that took place over the claim to the island is not clear from the available documents. Parker may not have even seen the islands before the first PALASTINE trip--his descriptions up to that time certainly did not fit any existing islands. Whether the organizers of the Pacific Guano Company were trying to get rid of him as a partner in the business, or whether he was trying to use the company as a means for claiming the islands for himself, or both, is not clear. But that both were occurring simultaneously is not out of the question.

In any case, by 6 November 1858 Parker had sold all his ownings in the company--80 shares. On 22 February 1859 Parker died in a hotel in Washington D.C., supposedly there to perfect his claim to the islands.

Parker's supposed widow, Harriet B. Parker, pursued his claim to the islands, but a judicial ruling from Jeremiah Black, later in 1859, stated that since Parker had not actually occupied the islands, and the Pacific Guano Company had, the company was the proper possessor of the islands. Consequently the company posted bond for $100,000.00 for rights to exploit the island. In 1859 attorneys for Parker's heirs and for the Pacific Guano Company wrote several letters to the Secretary of State and to President Buchanan attempting to verify their claims.

The amount of guano being taken off during 1859 and subsequent years must have been fairly substantial, if the number of ships and the statements of their captains can be trusted. There is, however, some question as to the value of the product shipped. It was reputed by at least two ship captains to be of high quality, easily obtained, etc., but Hague, in 1862, wrote that: "...from Johnston's Islands one or two cargoes have been brought to this country [the United States], the greater part of which proved, I believe, to be sand. These are described as three small islands (probably islets of one atoll) containing but little guano and that mixed with coral sand." Whether the companies continued in contention is not known, but they probably did, for ships of the American Guano Company were reported in and out of Honolulu to and from Johnston Island in 1860 and 1861.

The Civil War caused an interruption in both guano exploitation and in attempts to pursue claims, but shortly after it was over, Parker's only heirs, his widow Harriet B. Parker and their daughter Agnes Parker Burtt (for whom Agnes Island, now Sand Island, was named by Parker) again took up the claim of the guano islands. William H. Parker, Jr., Parker's only son, had died of wounds suffered while serving with the Union Army at Antietam.

In 1872, Parker's widow was successful in getting Congress to amend the Guano Act to allow legal heirs to claim islands of deceased original claimants. She had no success, as far as is known, in obtaining clear title to the islands, or any compensation for whatever guano was removed. Their principal claims were that a document awarding the islands to the Pacific Guano Company bore the forged signature of Secretary of State Cass; that Parker was acting alone in claiming the islands; that he had not sold stock in the Pacific Guano Company; and that Perriman and Rich made statements in October which conflicted with those made in May in order to help the Company beat Parker out of his claim.

About 1879 a third heir appeared. Mrs. Malvina H. Parker, of San Francisco, who claimed to have been married to W.H. Parker 16 July 1858 in San Francisco, and furnished proof in the form of sworn statements by the Justice of the Peace who performed the ceremony. She, together with Agnes Parker Burtt, disclaimed the assertions by Harriet B. Parker, whom they now referred to as Harriet B. Fisher, of her rights to the guano islands claims. Apparently Parker had divorced Harriet B. Parker sometime before 1858. Records of this were not searched for, but probably could be found. Malvina H. Parker actually sold her claims to the island to a man named Hueston, of Michigan, who in turn sold it back to her.

Ships known to stop at Johnston Island after the Civil War were few. Presumably most of these stopped for guano, but as far as is known, there was no permanent, continuous occupancy during this time. The only major shipwreck known to have occurred on the atoll happened in 1889. This is remarkable in view of the difficulty in seeing the island, and the number of whalers, guano ships, etc., plying these waters throughout the 18th and 19th centuries. The whaler J.B. HOWLAND wrecked on the island 26 December 1889. One or two men were lost in getting the men ashore over the coral heads of the lagoon. All survivors were subsequently picked up and returned to Hawaii.

In 1892 Great Britain attempted to claim Johnston as a potential cable station. HMS CHAMPION was dispatched from Honolulu with orders to leave for the island without telling anyone where they were headed. This they did, and finding the island totally abandoned, claimed it for Great Britain. The CHAMPION's captain described the island and made a small sketch map of it--quite accurate for Johnston, but crude for Sand which they saw only from a distance. They also found remains of the wreckage of the whaler.

On learning of the British claim, an agent, Lomberg, for the Pacific Guano Company claimed the company had not given up possession of the islands, and expected to return there to resume operations, and also expected protection by the United States Government. There are no records indicating that the company did return to the islands. The State Department, however, still listed Johnston as an island bonded to the U.S. as late as 1893.

In 1905 there was renewed interest by Parker's heirs. Mrs. Agnes Parker Burtt York, Parker's daughter, in agreement with William H. Underwood and LeGrande Brown, visited the islands aboard the Steamer IWILANI 14 February 1905 and brought off a small cargo of guano. Shortly after this visit, Mrs. York sold the islands to Underwood for $250,000.00, most of which was to be paid from a 10 percent royalty on all guano sold. On 9 June 1905 Underwood sold the islands to Phineas Coleman for $1.00 plus unnamed "considerations." On 3 August Coleman sold the islands to the United States Guano Company for $10,000,000.00. Whether Mrs. York had a clear title to the islands before she sold to Underwood, or if any money actually changed hands in these deals is not known. Furthermore, as far as is known, no further ships were sent out by any of these parties.

In 1909 the Territory of Hawaii leased the islands to Max Schlemmer, of Honolulu, for 15 years (Govt. lease #661, 20 September 1909, filed with office of Commissioner of Public Lands, Territory of Hawaii). Johnston had not, however, been included in the Territory of Hawaii when the latter was annexed by the United States on 30 April 1900. Schlemmer never removed guano nor did he fulfill the requirements of his lease, which included planting 500 coconut trees per annum and maintaining them throughout the lease. During June 1914 Captain George Pliltz, in company with Edward M. May, visited the atoll and found it to be uninhabited and unimproved with no sign of coconut trees. Consequently, in 1918 the lease was voided, and another lease was given to C.K. Ai, of Honolulu, whose Japanese firm, C.K. Ai and Company, proposed to use the island as a fishing station. His party of Chinese stayed on the island only one day, however, before they mutinied and returned to Honolulu.

The first scientific expedition to visit the islands, excepting the possible visit by the Wilkes ships in 1841, and the surveying done from the FENIMORE COOPER in 1859, was done by the party visiting the islands aboard the minesweepers TANAGER and WHIPPOORWILL in July 1923. This party was headed by Alexander Wetmore, then of the Bureau of Biological Survey of the Department of Agriculture, later to become Secretary of the Smithsonian Institution. Other members of the expedition represented the Bernice P. Bishop Museum of Honolulu. Their special interests and the published results of their trip are discussed under the Biota section in this report. Commander John Rodgers, later to become famous for seaplane flight from California to Hawaii, and two other aviators were along and made aerial photographs of the islands and reefs with the aid of a small seaplane. The party was on the islands from 10 through 20 July 1923.

Because of this visit, the atoll was made a federal bird refuge on 29 July 1926 by Executive Order No. 4467 of President Calvin Coolidge and placed under control and jurisdiction of the Department of Agriculture. In 1940 this responsibility was transferred to the U.S. Department of Interior. This Order still remains in effect, although subsequent executive orders have given jurisdiction over the atoll to military agencies (Table 1).

In 1924 the TANAGER and WHIPPOORWILL returned to the islands as part of Mine Squadron Two, which included the LUDLOW and the BURNS. These four ships, together with the tender PELICAN, with one seaplane on board, left Honolulu 3 June 1924 and all but the PELICAN which had

Table 1. Ownership and control of Johnston Atoll (Bauer, 1965)

Period	"Owner"	Operational Control	Purpose of Document	Authority	Event/Use
1923	Dept. of Agric.	Agric.	Plant and sealife surveys	Exec. Order 4467*	Bird refuge (Exec. Order June 29, 1926) (see also Anon., 1926)
1934	Dept. of Navy	USN	Pacific defense	Exec. Order 6935*	
1941	" " "	USN	Established Naval Defense Sea Area for military sea and air operations	Exec. Order 8682*	Became Johnston Island Naval Air Station
1944	" " "	USN	--	--	Defense of area; Air Transport Command operations; Oceanic Air Traffic Control
1947	" " "	USN	--	Secy. of Navy	Became a Naval Air Facility
1948 July 1	" " "	USAF	Transfer of operational control to USAF	Agreement	Pacific Air Command (MATS, ARS, AACS, AWS Dots) (Secy. Navy ordered transfer to USAF
1949 June 1	" " "	USAF	--	--	Pacific Air Command inactivated; Pacific Division MATS took over
1951-52	" " "	USAF	--	--	Korean airlift support
1957 Jan. 25	" " "	USAF	--	--	USAF granted Treasury Department five year use for USCG LORAN Station
1957 Sept. 13	" " "	USAF	--	--	USAF granted Department of Commerce five year use for U.S. Weather Bureau

Table 1. (continued)

Period		"Owner"	Operational Control	Purpose of Document	Authority	Event/Use
1958	Apr. 22	Dept. of Navy	CJTF-7	--	Agreement	Atomic tests in Pacific area until August 19, 1958; then roll-up
1959	July 24	" " "	USAF	--	--	Formal meeting in Hawaii to propose transfer of operational control to Army for Nike-Zeus test program
1959	Sept. 23	" " "	USAF	To transfer operational control to Army	--	Proposed agreement sent to higher headquarters
1959	June 30	" " "	USAF	--	--	Secy. of Treasury asked Secy. of Defense for Sand Island as LORAN Station, to be under operational control of Commander in Chief, Pacific
1962	Jan. 17	" " "	CJTF-8/ AEC	--	Agreement	USAF signed Operations Agreement for 1962 nuclear tests
1962	Jan. 18	" " "	CJTF-8/ AEC	--	Agreement	Commander in Chief, Pacific, signed agreement with Commander Joint Task Force Eight
1963	June 11	" " "	CJTF-8/ AEC	--	--	Joint Chiefs of Staff reaffirmed operation control of Joint Task Force Eight
1973	spring	" " "	Defense Nuclear Agency			

*Executive Orders are still in effect; have not been amended or rescinded so as to affect "ownership."

mechanical difficultues and was delayed a day, arrived off Johnston on the 6th. On the 7th work began in setting up signals on the islands for surveying the lagoon, which was done from 10 through 20 June. Accurate position determinants were made, currents were studied, a tide guage was operated, and extensive soundings were made throughout the lagoon. Although there was no record of any scientific personnel on board, collections of coral, marine growth, land shells, etc., were made for the Bishop Museum. Eight coconut and 12 ironwood trees were planted "...in favorable locations" on Johnston Island. Recommendations were made for use of the atoll for seaplanes, as it was thought that seaplane runways could be developed easily by blasting coral heads. The signals erected on the island were removed so subsequent visitors, notably the Japanese, would not know the survey had been made. The expedition left the atoll 22 June and arrived back at Pearl Harbor on the 26th (U.S. Nat. Archives, R.G. 37, Letter from G.V. Stewart, Commander, Mine Squadron Two, to Chief of Naval Operations).

During the late 1920's the island was visited by at least one fishing vessel out of Honolulu, the LANIKAI; Captain Bill Anderson (who was along on the 1923 expedition with Wetmore, and who had been on the island, again from a fishing vessel, in November 1922) and Lorrin A. Thurston, a Honolulu reporter, were the principal members of the crew. Thurston reported his 1927 experiences, including the finding of the wreckage of the J.B. HOWLAND, in the Honolulu Advertiser, 5 and 26 August 1928.

Military Occupation

No further military activity occurred on the atoll until 1933, when Johnston was included in an exercise in extended reconnaissance flights by Navy patrol planes. Data obtained from the 1924 survey were to be rechecked "...with view to actually determining the practicability of utilizing Johnston Island as a temporary aircraft base" (U.S. Nat. Archives, R.G. 45, Chief of Naval Operations to Commander in Chief, U.S. Fleet, 26 January 1933).

The USS PELICAN left Pearl Harbor 17 April 1933 and arrived off Johnston 20 April. A small boat attempted to enter the lagoon through a reef blasted through the reef west of Johnston Island by the 1924 expedition, but was unsuccessful because of high surf. Entry was made around the southwest end of the reef, and landing and mooring areas for seaplanes were searched for in vain in the west and northwest parts of the lagoon. On the 21st a desperate attempt was made to find suitable mooring areas, and finally the area between Johnston and Sand Islands was picked and a message sent out to that effect.

Meanwhile, a squadron of seaplanes had left Hawaii and flown to French Frigate Shoals, following a line of ships spaced at intervals along the route. After the planes arrived at French Frigate Shoals, the ships realigned themselves between there and Johnston Atoll, and on 22 April four planes left for Johnston, arriving at noon. The only adverse incident was the striking of a large bird by one of the planes as it landed. The damage was repaired successfully on the island. All planes were fueled and serviced and departed for French Frigate Shoals on the morning of 25 April (see Amerson, 1971).

A general description was made, including the information that there was no vegetation except for "long grass." Apparently the trees planted in 1924 did not survive. Johnston Island was considered long enough for landing small land planes, with considerable grading necessary beforehand. The presence of large numbers of birds on both islands and the islands being riddled with holes made by the birds were considered as major hazards to aircraft operations, especially if land planes were to be used. It was concluded that the atoll offered "...only fair possibilities for making a good advanced base" (U.S. Nat. Archives, R.G. 45, letter, Lt. F.M. Hughes, USN, to Commander, Aircraft Squadrons and attending craft, Fleet Air Base, Pearl Harbor, T.H.). Several photographs were made during this operation, and these are on file in the National Archives.

On 18 December 1934 the atoll was visited by the Coast Guard ship ITASCA in a vain search for the lost aircraft STAR OF AUSTRALIA. Both islands were briefly explored by Captain C.T.P. Ulm and two companions and described very generally by Jan Jabulka (1934), a reporter on board the ship.

Because of the atoll's strategic military location, President Franklin D. Roosevelt, on 29 December 1934, by Executive Order No. 6935, placed the atoll under the Department of the Navy. Provision was made within the new Order to keep Executive Order No. 4467, thus protecting the breeding birds and habitat.

In 1935 the ITASCA again visited the atoll on 23 June and 23 September. The general description of the islands noted that an old guano shed was present, but lying flat, and that narrow guage railroad wheels were still present. On 12 November 1935 a squadron of 6 Navy planes flew to the islands from French Frigate Shoals and they returned on the 13th.

In 1936 the Navy began developing the atoll. By 19 October 1936 a 210-foot pier had been built out from the south side of Sand Island and a sinuous, narrow boat channel had been opened through the reefs from the south into the seaplane landing area northwest of Sand Island (see Fig. 8). Reports indicate that a reconnaissance flight to the atoll had occurred earlier in the year by VP Squadron Ten. First blasting operations were carried out by the advance party, and in October the USS WRIGHT arrived with more explosives (U.S. Nat. Archives, R.G. 45, letters of 15 October and 23 November 1936, from Commander K. Whiting, Aircraft Squadrons and attending craft, Fleet Air Base, Pearl Harbor, T.H., to Hydrographer).

The PELICAN and TANAGER arrived on 30 March 1937, and the SWAN on 31 March, all carrying explosives for enlarging the channel. As a result of this last effort, the area for seaplane landing and mooring was about doubled and 24 planes could be accommodated. Blasting was also done around the pier. Recommendations were made for further improvements to allow tenders to get closer to the anchorage area or the planes. A map of the lagoon dated 14 April 1937 showed a straight boat channel from the south side of the lagoon into the seaplane landing area, and on Sand Island a mess hall was marked at the northwest side of the base of the pier, and on the southeast side a signal tower (U.S. Nat. Archives, R.G. 45, letter from Lt. Commander J.L. Cotton, USN, Johnston Island Expedition, to Commander, Minecraft, Battle Force).

On 8 April 1937 two VP-6's made a round trip from Pearl Harbor to Johnston and back in 10 and a half hours to rescue a sick seaman (Bryan, 1939).

In late 1939 the Navy awarded a contract for construction of a small base and in October or November a force of 60 men were sent to the atoll to begin work on a $1,150,000.00 warplane, minecraft, and submarine base for the U.S. Navy, to be completed in a year (Anon., 1939). At first a lagoon seaplane landing area with headquarters on Sand Island was built. But this tiny islet soon was overcrowded (see Fig. 9), and expansion in 1940 was made to Johnston Island itself (see Fig. 10). The work, details of which can be found in Woodbury (1946), was rushed and the Naval Air Station was commissioned ahead of schedule on 15 August 1941 (Bauer, 1965). On February 14 of 1941 Presidential Executive Order 8682 set up the Johnston Island Naval Defensive Sea Area and Johnston Island Naval Airspace Reservation to include respectively the "waters between extreme high water marks in the three-mile marine boundaries surrounding the island, and the airspaces over these waters and islands."

On 15 December 1941, four months after being commissioned, Johnston Island was shelled for 10 minutes by Japanese surface craft. Again on 21, 22, and 29 December both Johnston and Sand Islands were shelled from offshore ships; one Japanese submarine was reported sunk by land guns. There were no injuries to personnel but civilian workers were demoralized. The shelling caused considerable damage to various facilities (see Bauer, 1965).

Construction continued until April 1942; projects included dredging channel approaches and seaplane landing areas, construction of bomb shelters, living quarters, landplane runways, storage sheds, and gun emplacements.

In addition to being an air station during early World War II, patrol submarines used the atoll as a refuel base. By 1944 and throughout the rest of the war, it became one of the busiest air transport terminals in the Pacific, servicing planes going to and from the Pacific front some 4,000 miles to the west.

At the end of World War II, the Navy continued the Naval Air Station at reduced strength but as activity decreased, the status was degraded to that of a Naval Air Facility. Sand Island was abandoned in 1946. By order of the Secretary of the Navy, operational control of Johnston Atoll was transferred on 1 July 1948 from the U.S. Navy to the U.S. Air Force; Navy, however, retained technical jurisdiction.

During the Korean airlift in 1951 and 1952, Johnston Island again assumed military importance. The airstrip was enlarged by dredging and new buildings and improved utilities were added. For a short time, military personnel were permitted to have their dependents accompany them to Johnston; this ended in October 1956.

On 25 January 1957, the Treasury Department was granted a permit for the U.S. Coast Guard (now under the Department of Transportation) to operate a LORAN transmitting station on Johnston Island. Also on 13 September 1957, the Department of Commerce was permitted to operate a Weather Bureau Station on the Island.

On 22 April 1958 operational control of Johnston was assumed by the commander of Joint Task Force Seven. As part of Operation Hardtack, two missiles carrying thermonuclear devices were fired from Johnston Island into the stratosphere to obtain information on the effects of nuclear detonations at high altitudes. Teak, the first of these shots, was detonated at 2150 hours on 1 August 1958, at an altitude of 252,000 feet. The second shot, Orange, was detonated at 2130 hours on 12 August at approximately 100,000 feet. These were the first megaton devices detonated in the stratosphere by the United States (Hines, 1962). The Pacific phase of Operation Hardtack lasted until 19 August 1958.

Operational control of Johnston was again assumed by Joint Task Force Eight (JTF-8) and the Atomic Energy Commission (AEC) on 17 January 1962 for the purpose of conducting additional high-altitude nuclear tests. Shot Starfish, an explosion of about 1.5 megatons, was conducted at an altitude of 200 kilometers on 9 July 1962. Another test, scheduled for 25 July 1962 was aborted after the test missile was destroyed.

During these nuclear tests, an elaborate water sprinkler system was installed on the original portion of Sand Island to protect the birds living there. In addition, other protective devices were used, including smoke pots placed upwind as a shade screen and aerial flares to divert the birds' attention from the flash of the blast itself.

The Secretary of Defense granted permission on 10 December 1959 for transferring the U.S. Coast Guard LORAN-A and -C Station to Sand Island. The Coast Guard facility on Sand Island was completed in 1961 and presently maintains a complement of approximately 25 men. A U.S. Air Force Satellite Tracking Camera Station was established on Sand in 1964.

As of 1965, Johnston Atoll was under joint operational control of JTF-8 and AEC. It serves as headquarters and base of operations for resuming U.S. atmospheric nuclear testing in the Pacific should the Test Ban Treaty of 1963 be nullified by a foreign world power. Tenants on Johnston Island included: U.S. Air Force and Navy units, and personnel of the Air Defense Command, Space Systems Command, and Pacific Missile Range.

In the early 1970's various chemical agents, including herbicides left over from the Vietnam Conflict, were brought from the western Pacific and stored on Johnston Island. These were placed downwind in a security area on the southwest end of the island. As of 10 May 1974 measures were being considered by the Environmental Protection Agency to safely dispose of these agents.

In the spring of 1973, operational control of Johnston Atoll came under the Defense Nuclear Agency. The atoll is still a Naval Defensive Sea Area and Air Space Reservation, and access is restricted. The atoll is a bird sanctuary under the Department of Interior.

BIOTA

The following treatment of Johnston's biota does not treat taxa evenly. Some are entirely deleted because they are so far outside the knowledge of the authors and others who worked on the atoll, and outside the objectives of the POBSP, as to make their discussion meaningless. References to all pertinent papers are included where they are known, but there is implied no pretense that the references included comprise a comprehensive bibliography.

Emphasis of the POBSP was on analysis of the natural history of the terrestrial vertebrates and the terrestrial vascular plants, with by far the greatest emphasis on the birds. In the following treatment the only groups listed in detail besides these two categories are the inshore fishes and insects.

Plants

The marine and terrestrial plants of Johnston Atoll are well known. Both have been heavily disturbed by man.

Algae

Only one marine algal species was known from Johnston Atoll prior to 1965 (Moul, 1964). As part of a study of the effects of dredging on Johnston's marine environment, 67 species of benthic marine algae were collected by the Hawaii Institute of Marine Biology, University of Hawaii, 17-22 August 1965 and 17-21 December 1965 (Buggeln and Tsuda, 1966). Collections were made in 14 habitat areas (Fig. 29). Additional collections from 16 other habitat areas were made 14-24 June 1966 by the Department of Radiation Biology, University of Washington; from these collections 26 more species of algae were added to the known species list (Buggeln and Tsuda, 1969).

The distribution of the 93 species of benthic marine algae known from Johnston Atoll (Table 2) shows that 12 species were found only from the marginal reef, while 33 species were found only in the lagoon waters.

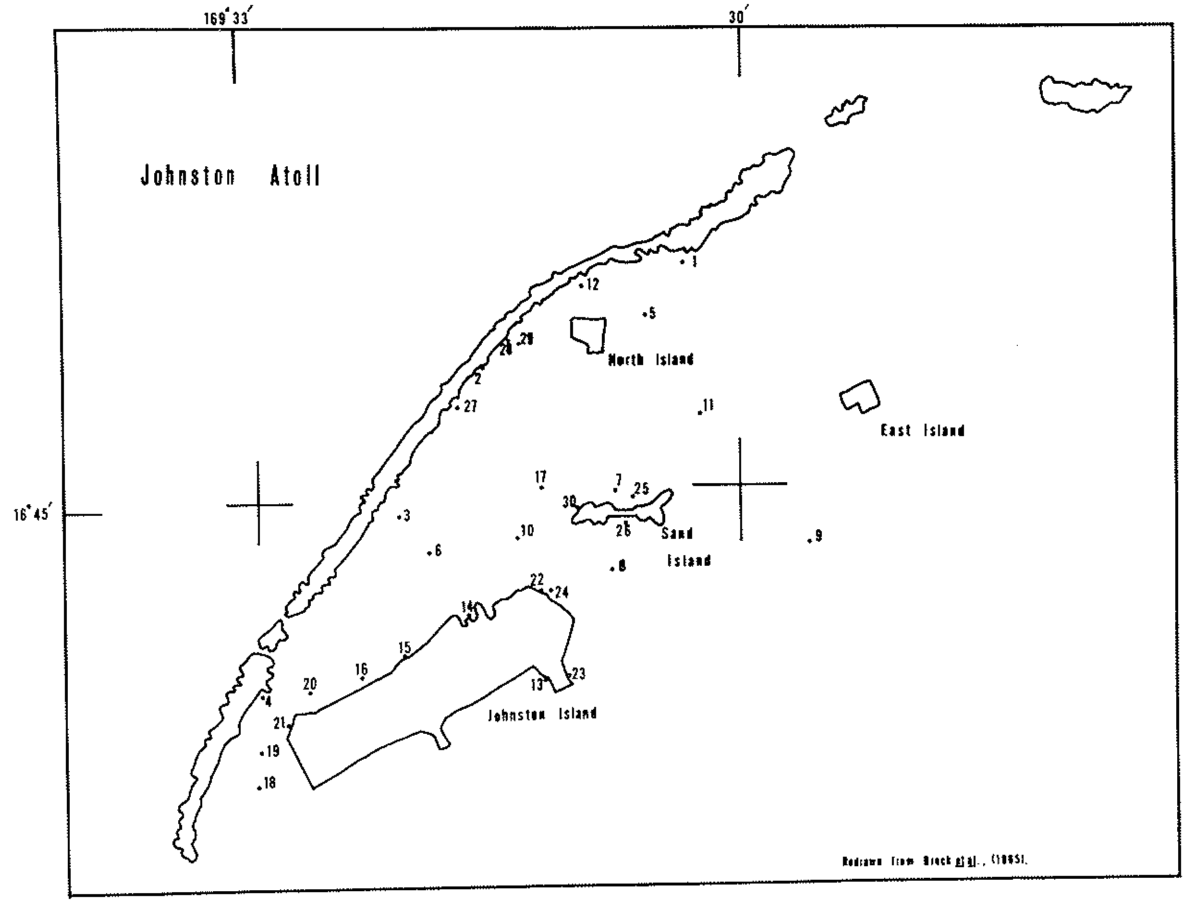


Figure 29. Algae collection stations, Johnston Atoll, 1965–1966 (Buggeln and Tsuda, 1969).

Of these 33 lagoon species, 11 were found only in open water, 11 occurred only in the inshore Johnston Island area, and 2 were taken in the inshore Sand Island area.

Buggeln and Tsuda (1966) suggest a vertical distribution of the Johnston algae--especially Chlorophyta and Rhodophyta--in the sublittoral zone, such that as light intensity decreases with depth, the number of algal species also declines. These authors, as well as Brock, Henkelem, and Helfnich (1966), found a correlation between increased silt in dredge-affected areas and decreased number of algae species. The silt caused a reduction in light intensity at all depths; lack of light reduced photosynthesis and thus eliminated plants.

They also found that in the newly dredged and widened ship channel (areas 10 and 11), the new surface had been invaded by sparse Cyanophyta and Rhodophyta species. In some of the dredged areas rather thick algal mats developed over the whole bottom. The blue-green alga *Lyngbya majescula* was the dominant species; others included *Schizothrix calcicola* and *Phormidium submembranaceum*.

Table 2. Distribution* of benthic marine algae at Johnston Atoll

Division / Species	Marginal Reef	Lagoon Open Water	Lagoon Inshore Johnston	Lagoon Inshore Sand
Cyanophyta				
Anacystis dimidiata		1		1
Entophysalis deusta			3	
Schizothrix calcicola	3	6	5	2
Hydrocoleum lyngbyaceum	1		1	1
Microcoleus chthonoplastes		4		1
Microcoleus tenerrimus	1		1	
Microcoleus vaginatus	1			
Lyngbia aestuarii	1		1	1
Lyngbia confervoides				1
Lyngbia lutea		1		
Lyngbya majuscula	1	3	1	2
Spirulina tenerrima		1	1	
Symploca atlantica	1		1	
Oscillatoria nigroviridis			1	
Phormidium submembranaceum	3	3	1	
Hormothamnion enteromorphoides		2	1	
Calothrix crustacea		1		1
Calothrix scopulorum	3	3	4	1
Isactis plana	2		5	1
Chlorophyta				
Palmogloea protuberans			1	
Enteromorpha kylinii			1	
Cladophora crystallina	2	2	1	
Cladophoropsis sp.	1			
Valonia ventricosa		1		
Dictyosphaeria versluysii	6	6	4	1
Broodlea composita	1			
Microdictyon setchellianum	5	2		1
Dervesia marina			1	
Derbesia sp.		1		
Caulerpa ambigua	1	1	2	1
Caulerpa racemosa macrophysa		1		
Caulerpa urvilliana	3	1		1
Bryopsis pennata	5	4	4	1
Pseudochlorodesmis parva	2		3	
Codium arabicum	1			
Codium sp.	3	2	4	
Halimeda discoidea	3	2	1	
Halimeda tuna	3			
Acetabularia clavata			2	
Acetabularia mobii	3	2	2	
Acetabularia tsengiana			1	
Acetabularia sp.	1			1

Table 2. (continued)

Division Species	Marginal Reef	Lagoon Open Water	 Inshore Johnston	 Inshore Sand
Chrysophyta				
Ostreobium reineckei			2	
Phaeophyta				
Ectocarpus breviarticulatus			3	
Ectocarpus indicus	3	3	4	1
Ectocarpus irregularis			1	
Ectocarpus sp.		1		
Sphacelaria furcigera		1	1	
Sphacelaria novaehollandiae	5	7	5	2
Sphacelaria tribuloides			1	
Dictyota sp.	2	1	1	
Pocockiella variegata	6	5	3	
Rhodophyta				
Asterocystis ornata		1		
Goniotrichum alsidii		1		
Erythrotrichia sp.		1		
Gelidium crinale perpusillum		3	3	1
Gelidium pusillum pusillum		4	3	2
Wurdemania sp.	3	1	2	
Jania capillacea	3	6	2	2
Jania decussato-dichotoma	4	2	2	1
Amphiroa sp.	1	1		
Hypnea esperi	4	4	4	1
Lomentaria hakodatensis	1	1	1	1
Champia parvula	2			
Antithamnion antillarum	2	1	1	1
Callithamnion marshallensis	2		2	
Callithamnion sp.	1			
Centroceras apiculatum	5	5	4	2
Centroceras clavulatum	1	3	1	1
Crouania minutissima	1			
Ceramium affine	3	5	1	1
Ceramium fimbriatum	1			
Ceramium gracillimum byssoideum	4	4	4	1
Ceramium huysmansii	3	3	1	
Ceramium maryae	1			
Ceramium vagabunde	2	2		
Ceramium zacae	1		2	1
Ceramium sp.		2		
Crouania minutissima	1			
Griffithsia metcalfii		2		
Griffithsia ovalis	1			

Table 2. (continued)

Division Species	Marginal Reef	Lagoon Open Water	 Inshore Johnston	 Inshore Sand
Rhodophyta (cont.)				
Griffithsia tenuis	4	1	2	
Griffithsia sp.				1
Dasya adherens	1	1		
Dasya sinicola	3	1		
Dasya sp.	1	2		
Taenioma macrourum	1	3		
Caloglossa leprieurii		1		
Heterosiphonia wurdemanii laxa	2	2		
Herposiphonia spp.	4	3	1	1
Polysiphonia spp.	3	7	5	1
Laurencia sp.	4	5	1	
Chrondria repens	4	3		

*Figures indicate total number of collection stations from which samples were taken. See Figure 29 for collection station localities; Marginal Reef localities: 1,2,4,12,27,28,29; Lagoon Open Water: 3,5,6,8,9,10,11,17; Lagoon Inshore Johnston: 13,14,15,16,18,19,20,21,22,23,24; Lagoon Inshore Sand: 7,25,26,30.

Vascular Plants

Table 3 lists the 51 families, 109 genera, and 127 species of vascular plants that have been identified from the four islands at Johnston Atoll. This number is remarkable, for in 1859 Brooke (ms.) noted only two plants and in 1923 the TANAGER-WHIPPOORWILL expedition found only three species of vascular plants (Christophersen, 1931). By 1946, 27 species were recorded from Johnston Island (Fosberg, 1949), and by 1954, 43 species occurred there (Newhouse, 1955). By 1963, 77 species were known from both Johnston and Sand Islands (POBSP, 1964).

The three plant species recorded by 1923 probably reached the atoll through natural means either by water currents, air, or birds. A few species found since possibly also arrived via these same ways, but the majority of the remaining 124 species has been man-made introductions. Some of these introductions were intentional, others came as stowaways or adventives.

Original Flora

Lt. John M. Brooke (ms.) noted the following in his journal for 16 March 1859: "There is a downy creeping plant bearing a yellow flower, and grass, these are the only representatives of the vegetable kingdom."

Table 3. Vascular plants known from Johnston Atoll

Family / Species / Common Name	Islands: Akau	Hikina	Johnston	Sand Orig.	Sand Man-made
Polypodiaceae Ferns					
Polypodium scolopendria					
Nephrolepsis sp.	A				
Araucariaceae					
Araucaria heterophylla			P		
Norfolk Island pine					
Pandancaceae					
Pandanus tectorius?			P		
Screw-pine, hala					
Graminea Grasses			A	A	A
Cenchrus echinatus					
Sandbur					
Chloris barbata			A		
Fingergrass					
Cynodon dactylon	A		P	A	P
Bermuda grass					
Dactyloctenium aegyptium	A		A	A	A
Crowfoot grass					
Digitaria sanguinalis					A
Crabgrass					
Echinochloa crus-galli			A		
Barnyard grass					
Eleusine indica	A	A	A	A	A
Goose grass					
Eragrostis tenella	A		A		
(incl. *amabilis*)					
Lovegrass					
Lepturus repens		A	N	N	A
Bunch grass					

A = Adventive; N = Native; P = Planted; S = Seed only

Table 3. (continued)

Family Species Common Name	Islands Akau	 Hikina	 Johnston	 Sand Orig.	 Sand Man-made
Graminea (cont.)					
Paspalum dilatatum Dallas grass			A		
Saccharum officinarum Sugarcane			P		
Setaria verticillata Bristlegrass			A	A	A
Sporobolus virginicus Dropseed			A		
Zea mays Corn	P				
Cyperaceae Sedges					
Cyperus rotundus			A		
Fimbristylis cymosa?	A	A	A		A
Palmae Palms					
Cocos nucifera Coconut palm	P	P	P		P
Araceae					
Anthurium andraeanum Anthurium			P		
Liliaceae					
Allium fistulosum Welsh onion			P		
Allium sp. Chives			P		
Aloe sp. Aloe					P
Cordyline fruticosa Cordyline			P		
Sansevieria trifaciata Bowstring Hemp			P		

Table 3. (continued)

Family Species Common Name	Islands Akau	 Hikina	 Johnston	 Sand Orig.	 Sand Man-made
Amaryllidaceae					
Crinum asiaticum			P		
Crinum sp.	P		P		P
Hymenocallis littoralis	P		P		P
Spider lily					
Bromeliaceae					
Ananas comosus					P
Zingiberaceae					
Alpina sp.			P		
Ginger					
Musaceae					
Heliconia humilis			P		
Strelitzia reginae			P		
Bird of Paradise					
Orchidaceae Orchids					
Epidendrum sp.			P		
Vanda sp.			P		
Casuarinaceae					
Casuarina equisetifolia	P		P		P
Ironwood					
Moraceae					
Ficus microcarpa		P	P		P
Banyan					
Urticaceae					
Pilea microphylla					A
Artillery plant					
Polygonaceae					
Coccoloba uvifera	P		P		P
Sea-grape					
Chenopodiaceae					
Chenopodium murale			A	A	A
Goosefoot, Pigweed					
Amaranthaceae Pigweeds					
Amaranthus dubius			A	A	A

Table 3. (continued)

Family Species Common Name	Islands Akau	 Hikina	 John- ston	 Sand Orig.	 Sand Man- made
Amaranthaceae (cont.)					
A. spinosus			A		
A. viridis	A		A	A	A
Nyctaginaceae					
Boerhavia sp.	A		N	N	A
Bougainvillea sp.			P		P
Aizoaceae					
Tetragonia tetragonioides					P
New Zealand Spinach					
Sesuvium portulacastrum	A	A	A	A	A
Portulacaceae					
Portulaca oleracea	A	A	A	A	A
Purslane					
Caryophyllaceae					
Spergularia marina	A	A	A	A	A
Lauraceae					
Persea americana			P		P
Avocado					
Cruciferae					
Lobularia maritima			P		A
Sweet Alyssum					
Rosaceae					
Eriobotrya japonica					P
Loquat					
Leguminosae					
Acacia farnesiana	A		A		
Sweet Acacia					
Crotalaria incana			A		
Rattlebox					
Leucaena latisilique			A		A
Phaseolus sp.	P				
Bean					

Table 3. (continued)

Family Species Common Name	Akau	Hikina	John- ston	Sand Orig.	Sand Man- made
Leguminosae (cont.)					
Pisum sativum Pea	P				
Mucuna sp.		S		S	
Pithecellobium dulce Manila Tamarind			P		
Prosopis pallida Algarobe, Kiawe			S		
Vigna marina Beach pea	A		A	A	
Zygophyllaceae					
Tribulus cistoides Puncture Vine			N	N	A
Ruthaceae					
Citrus aurantifolia Lime			P		
Citrus sinensis Orange	A				
Euphorbiaceae					
Aleurites moluccana Candlenut, Kukui		S		S	
Codiaeum variegatum var. *pictum* Croton	P		P		P
Euphorbia atoto? Spurge			A		
E. prostrata Spurge			A		
E. prob. *heterophylla* Spurge			A		

Table 3. (continued)

Family Species Common name	Islands Akau	 Hikina	 John- ston	 Sand Orig.	 Sand Man- made
Euphorbiaceae (cont.)					
E. glomerifera Spurge	A		A		A
E. hirta Spurge			A		A
E. pulcherrima Poinsettia			P		P
Pedilanthus tithymeloides Slipper flower			P		
Ricinus communis Castor bean			A		
Anacardiaceae					
Mangifera indica Mango	P		P		
Schinus terebinthifolius Christmas berry tree			P		
Tiliaceae					
Triumfetta procumbens			P		
Malvaceae					
Hibiscus tiliaceus Hau			P		
Hibiscus sp.			P		P
Thespesia populnea Milo tree, Portia tree			A		
Sida sp.			?		
Sterculiaceae					
Waltheria indica			A		
Guttiferae					
Calophyllum inophyllum False Kamani	P		P		

Table 3. (continued)

Family Species Common Name	Islands Akau	 Hikina	 Johnston	 Sand Orig.	 Sand Man-made
Combretaceae					
Terminalia catappa Indian almond, Kamani		S	P	S	P
Myrtaceae					
Eucalyptus sp.					
Araliaceae					
Brassaia actinophylla Octopus tree			P		
Polyscias guilfoylei Wild coffee			P		
Caricaceae					
Carica papaya Papaya			P		
Plumbaginaceae					
Plumbago auriculata Plumbago, Leadwort			P		
Apocynaceae					
Catharanthus roseus Madagascar Periwinkle			P		
Nerium oleander Oleander			P		P
Plumeria acuminata Frangipani			P		
Plumeria rubra Frangipani	P		P		
Thevetia peruviana var. *aurantiaca*			P		
T. peruviana(=*nereifolia*) Yellow Oleander			P		
Convolvulaceae					
Ipomoea indica				A	

Table 3. (continued)

Family Species Common Name	Akau	Hikina	John- ston	Sand Orig.	Sand Man- made
			Islands		
Convolvulaceae (cont.)					
I. pes-caprae Beach Morning Glory			A	A	A
I. macrantha			?		
Merremia tuberosa Wood Rose			P		
Hydrophyllaceae					
Nama sandwicensis			A		
Boraginaceae					
Cordia sebestena Kou, Geiger-Tree			P		P
Heliotropium curassavicum			A	A	A
Tournefortia argentea Tree Heliotrope		P	P	P	P
Verbenaceae					
Stachytarpheta jamaicensis			A		
Vitex ovata	P		P		
Solanaceae					
Capsicum frutescens Papper	P		P		
Nicotiana glauca			A		
Solanum lycopersicum Tomato	P?	P?	P		P?
Solanum melogena Eggplant			P		
Bignoniaceae					
Tabebuia pentophylla West Indian Boxwood			P		
Rubiaceae					
Gardenia sp.			P		
Coprosma sp.			P		

Table 3. (continued)

Family Species Common Name	Islands Akau	 Hikina	 John- ston	 Sand Orig.	 Sand Man- made
Cucurbitaceae					
Citrullus lanatus var. *vulgaris* Watermelon	P		P		
Cucumis melo Muskmelon	P				
Goodeniaceae *Scaevola taccada*			P	P	P
Compositae					
Bidens pilosa Burmarigold			A		
Conyza bonariensis	A	A	A		
Emilia sonchifolia			A		
Helianthus annuus Sunflower			P		
Pluchea indica	A	A		A	
Pluchea carolinensis	A	A	A	A	A
Pluchea x *Fosbergii*			A		
Sonchus sp. (*oleraceus* x *asper*)? Sow-thistle			A	A	A
Tagetes sp. Marigold	P		P		
Vernonia cinerea Ironweed			A		A
Zinnia elegans Zinnia	P		P		

"The nearest approach to the plant I could find in my elementary Botany is the portulaca, the same plant grows on Laysan. I gave a specimen to Dr. Hilebrand at Honolulu."

Brooke (*loc. cit.*) also mentioned that Capt. A.D. Piper, in charge of the island, had "...planted potatoes and pumpkins, but they withered away." Brooke gave Piper seeds of the following: watermelons, muskmelons, squash, egg plant, pepper, asparagus, sorrel, lettuce, and leek. If Piper planted these, their ultimate fate was the same as that of the potatoes and pumpkins, for none survived until the next known description of the atoll's vegetation, made 64 years later.

Members of the TANAGER Expedition found only three species of vascular plants growing on Johnston Atoll in 1923: *Lepturus repens*, *Tribulus cistoides*, and *Boerhavia* sp. [usually referred to as *diffusa*] (Christophersen, 1931: 4).

The grass Brooke found growing in 1859 almost certainly was *Lepturus*, and the "downy creeping plant bearing a yellow flower" was most likely *Tribulus*. Brooke's tentative identification of it as a *Portulaca* seems unlikely in view of the lack of downiness of *Portulaca* and of its absence from the atoll in 1923. It is curious, however, that Brooke did not mention the armed fruits, if indeed the plant was *Tribulus*. Although these fruits are not so consciduous in March as later in the season, old fruits remain sharp enough to penetrate thin shoes for many months, and certainly should have been present and noticeable to Brooke.

If *Boerhavia* were present in 1859, it apparently was not abundant enough for Brooke to notice it readily. While it seems unlikely that such a plant could be missed if it were present in anything near the abundance it was found in 1923, it seems equally unlikely that such an easily distributed species would have to await the help of man to reach Johnston Atoll.

The ambiguity of this situation leaves us in doubt as to whether the original vegetation of the atoll consisted of two or three species. In either case, it is, as Fosberg (1949) pointed out, one of the smallest floras known. All three plants in question have propagules that could be transported easily by birds by sticking to or in the plumage (*Boerhavia* and *Lepturus*) or by sticking into the feet (*Tribulus*).

It is not surprising that the cultivated plants Brooke and Piper introduced to the atoll died out, but it is remarkable that none of the common weedy species from other parts of the world became established from ship's cargoes. It would be most interesting to know if any of these were indeed introduced prior to 1923, and if so, how long they persisted. Perhaps this situation is evidence that many common weeds require continued disturbance by man to assure their persistence.

Recent Vegetation

In the years since 1923, the atoll's flora has been enriched by numerous introductions, both intentional and otherwise. Wetmore (ms.b) planted eight "clips" of Hau (*Hibiscus tiliaceus*) 18 July 1923. These may not have survived for the species was not included on the next list of the flora, compiled by Bryan (ms.b) in 1944. This list showed 29 species of native and introduced plants. The next published list was that of F.R. Fosberg (1949) based on collections made 1 November 1946 by his brother, K.P. Fosberg. This showed 27 species, including eight not listed by Bryan in 1944, bringing the total known flora to about 35. Doty and Newhouse (ms.) summarized previous findings, including additional data from Fosberg, together with results of a study of the vegetation fostered by Lt. Col. Jack Bently, Base Commander, in 1953 in which 44 additional species were found. Of these 44, 20 were grown only in yards under care of residents. About 51 species apparently grew untended then, with an additional 18 tended, for a total flora of 69 species.

POBSP studies, principally by A. Binion Amerson, Jr., Charles H. Lamoureux, and Philip C. Shelton, added 48 species to the Johnston Atoll flora. Included were the first collections from the two new islands, Akau and Hikina.

Island Accounts

Appendix Tables 2 through 6 present annotated lists of all vascular plant species known to have occurred on each island at Johnston Atoll, with the exception of introductions that have failed, such as some of the cultivated species introduced by Brooke and Piper, and certainly many others.

Land clearing and dredge fill have increased the size of the two original islands and have made two new islands, thus bettering the opportunity for more plant species. Disturbed soil together with freedom from competition by an established flora have provided conditions suitable for many kinds of plants. But some plants have not been able to survive the poor soil and climate conditions of Johnston. Thus, many of the ornamental species intentionally introduced by man would not survive if not frequently cared for by man.

Because of human disturbance, the plants occurring on the four islands are different in species composition.

Akau Island: There are 38 species of vascular plants known from Akau Island. This island has a much larger flora than Hikina Island, both of which were built at the same time, partly because of its closer position to Johnston and Sand Islands, but more importantly because of more interest in plants by workers on Akau than on Hikina. Most of Akau's flora consists of species transplanted from Johnston Island. Six species recorded from Akau, however, are not known from the other three islands.

This man-made island was completed in 1964; by September 1967, 31 species were growing there. Sixteen of these 31 were obvious introductions; the remaining 15 were considered to be adventive and not intentionally planted. Only a few of each of the introduced species existed, but at least five of the adventive species were common. *Fimbristylis* sp. grew over most of the island and was the most dominant species. *Spergularis marina* was widespread, and small plants of *Sesuvium portulacastrum* were scattered about. *Eleusine indica* was fairly abundant in a few small areas. Two patches of *Cynodon dactylon*, one about 30 feet in diameter, grew in a slight depression on the north-central portion of the island (POBSP, 1967b). Similar plant distribution existed in November 1973.

Hikina Island: Only 14 species of vascular plants have been recorded from Hikina Island (Table 3). All are known from at least one of the other three islands; three are known from seed only.

The island was completed in 1964 and by September 1967 five species of growing plants and seeds of three species were recorded. Two of the five growing species were represented by one specimen each; both were obvious introductions. *Fimbristylis* sp. was the dominant plant and occurred scattered on almost the entire island. *Sesuvium portulacastrum* was the second most abundant species and grew in clumps, the largest of which was 6 by 9 feet. *Spergularia marina*, the third ranking species, was widely scattered over the island, but most plants appeared to be dead. The three seeds were all on the beach (POBSP, 1967b).

The island was revisited in February 1969 and two additional species of grass were recorded. The flora looked about as it did in September 1967, except that the *Fimbristylis* was more evenly spread, although little changed in density (POBSP, 1969). The flora was the same in November 1973, except for a large *Pluchea* bush growing in the north-central portion.

Johnston Island: In 1923, as mentioned earlier, only three plant species were known (Christophersen, 1931). Wetmore's 1923 photographs show *Lepturus repens* as the dominant species. U.S. Navy aerial photographs taken in 1935 and 1939 (see Figs. 3 and 5) reveal vegetation growing over the entire island; another taken in May 1941 shows original vegetation everywhere except around the buildings on the northeast corner and in an area north to south across the center. By 1942, another aerial photograph (see Fig. 6) shows no vegetation at all and numerous buildings.

Twenty-seven plant species were recorded in 1946; these consisted mainly of obvious introductions and accidental weeds. No original vegetation remained; the whole island was occupied by runways and buildings with disturbed ground in the open places and along paths and roadsides (Fosberg, 1949).

In January 1954, Newhouse (1955) found 43 plant species; 20 were not under cultivation and 23 were under cultivation in dependents' homes and gardens. Three plant species recorded in 1949 were not observed in 1954.

By 1967, 111 plant species had been recorded from Johnston Island (Table 3). Of these 111, 3 were native, 61 were planted, 44 were adventive, and 3 of questionable status. In addition, 56 of the 111 were not known from the other three islands.

Continued disturbance on Johnston Island in 1967 prevented any meaningful development of vegetation except in a few scattered locations near the runway. *Pluchea carolinensis*, which at times has been kept trimmed, had developed conspicuous stands on the south side of the runway, especially northeast of the Weather Bureau building; nesting Red-tailed Tropicbirds were especially attracted to these stands. Only one other species, *Cenchrus echinatus* or sandbur, was considered to be fairly abundant on open disturbed areas. Other species ranged in number from individual plants to widely scattered, but not abundant plants (POBSP, 1967b).

In November 1968, most of the *Casuarina equisetifolia*, or ironwood trees, were removed from atop the underground hospital, thus destroying some of the prime White Tern roosting and nesting habitat (POBSP, 1968). By November 1973, *Casuarina* trees near the tennis courts were supporting nests of both White Terns and Black Noddies.

Sand Island: A total of 54 species of vascular plants has been recorded from Sand Island (Table 3): 3 were native species, 23 were planted, 26 were adventive, and 2 occur only as seeds. Nine species found here are not known from the other three islands.

Original: Three species--*Lepturus repens*, *Boerhavia repens*, and *Tribulus cistoides*--were recorded in 1923 (Christophersen, 1931). Ground-level photographs taken in 1923 by Wetmore reveal *L. repens* to be the dominant species. U.S. Navy aerial photographs taken during the mid-1930's (see Fig. 3) show the island completely covered by vegetation. The arrival of a permanent military station in 1939 (see Fig. 8) signaled destruction of the original flora; by March 1940 (see Fig. 9) vegetation remained only on the north peninsula.

POBSP personnel recorded 11 species of plants here in 1963. Some 80 percent, or approximately 400,000 square feet, of the original portion, was covered by vegetation. The five most dominant species (Fig. 30) were, in order of importance, *Lepturus repens*, *Tribulus cistoides*, *Sesuvium portulacastrum*, *Boerhavia repens*, and *Amaranthus viridis*. The first three species covered 84 percent of the vegetated area (*Lepturus* 50 percent, *Tribulus* 30 percent, and *Sesuvium* 4 percent). The eight other species filled the remaining 16 percent and were primarily scattered over bare soil and rock (POBSP, 1964).

Seasonal climatic conditions and human disturbance often affect the islands' flora. For example, in early February 1967 the vegetation appeared drier than it had in October 1966, although several species had spread noticeably during the winter. At least two species, *Boerhavia repens* and *Tribulus cistoides*, were reduced in numbers. Heavy rains in February and March brought the growth up to the October 1966 level; there was only a slight decline in greenness by early May. By late August and September, when the flora was usually at its lowest growth, the vegetation appeared at least as vigorous and green as in May, and much more so than at the same time in 1966.

By 1967, 25 plant species were known from the original portion of Sand Island (Table 3). Of these 25, 3 were native, 2 were planted, 18 were adventive, and 2 occurred as seeds. Plant distribution as of late 1967 (Fig. 31) and late 1968 was similar to that in late 1964 except that *Boerhavia* was more widespread on the eastern half (POBSP, 1967b, 1968). Sparse plants were observed in November 1973, most likely resulting from low spring rainfall coupled with large numbers of Sooty Terns.

Man-made: The man-made portion was started in late 1939 and by May 1941 was nearly completed. A U.S. Navy aerial photograph taken in February 1942 from a height of 600 feet reveals no vegetation.

POBSP personnel recorded 19 species of plants here in 1963; 9 of these 19 were not growing on the original portion (POBSP, 1964).

By 1967, 50 plant species had been recorded (Table 3). Of these 50, 23 were obviously introduced, and 27 were probably adventive. In addition, 29 of the 50 species were not growing on the original portion, and seven were not growing on the other three islands in the atoll.

In 1967, pioneer adventive species including *Fimbristylis*, *Conyza*, *Sonchus*, *Cenchrus*, and *Pluchea* were increasing on the newest coral, dredged in 1964. Other species, including *Cynodon*, *Sesuvium*, and *Euphorbia hirta*, were replacing the above first four on the older dredged portion. *Scaevola* continued to grow well around the buildings in 1968 and 1969, thus providing nesting habitat for Red-tailed Tropicbirds (POBSP, 1967b, 1968, and 1969). A similar distribution was found in November 1973.

Invertebrates

The invertebrate fauna of Johnston Atoll is not well-known and while scattered collections have been made, no extensive systematic sampling programs have been conducted. Most of the published lists appear to be spotty and the ecological aspects of the zoogeography have been largely neglected.

Published reports and museum collections center around the macro-invertebrates of the major phyla Cnidaria, Mollusca, Annelida, Arthropoda, and Echinodermata. Of these phyla, even the corals--the most conspicuous group of the atoll marine fauna--are not well studied.

There are little or no data available on other groups such as the sponges (Porifera), the acoelomate bilateria (*e.g.*, Platyhelminthes), the pseudocoelomates (*e.g.*, Aschelminthes), the minor coelomate protostomes (*e.g.*, Priapulida, Sipunculida, Echiurida), the lophophorate coelomates (*e.g.*, Phoronida, Ectoprocta, Brachiopoda), and the minor deuterstome phyla (*e.g.*, Pogonophora, Hemichorda).

The invertebrate fauna (especially the Mollusca) known from Johnston Atoll, however, indicates that Johnston may serve as a unique filter bridge between the south-central (Polynesian) and western (Micronesian) Pacific fauna and the Hawaiian fauna.

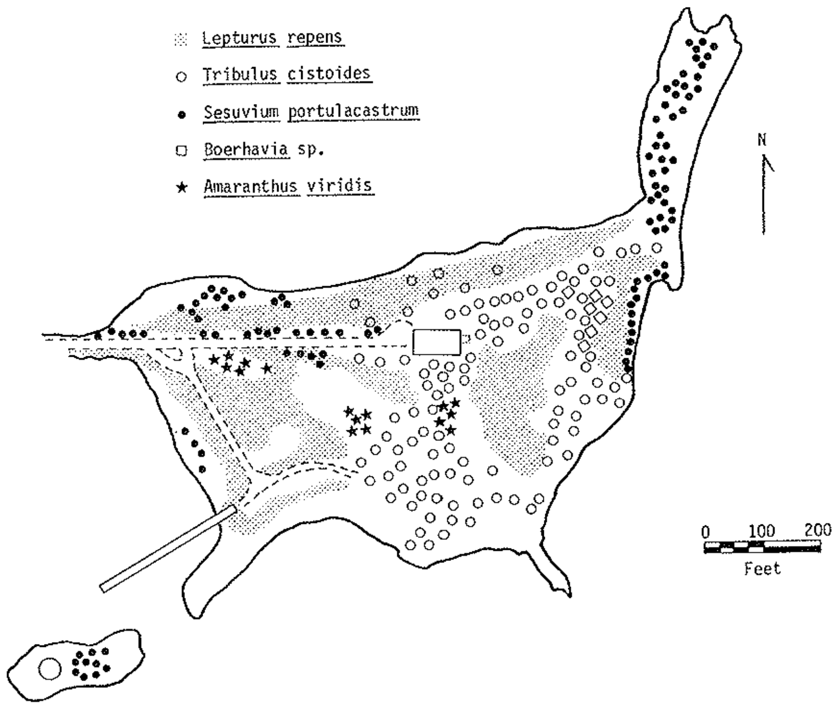


Figure 30. Distribution of the five most important plant species on the original portion of Sand Island, Johnston Atoll, July-August 1963.

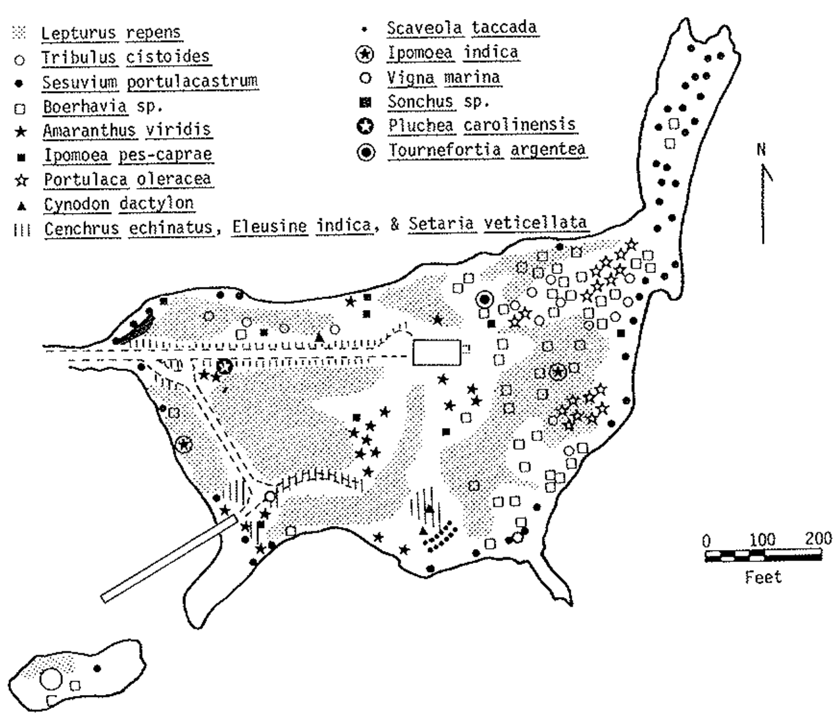


Figure 31. Distribution of dominant plant species on the original portion of Sand Island, Johnston Atoll, May 1967.

Cnidaria (Coelenterata)

Eighteen species in 11 genera of Cnidaria (hydras, jellyfish, sea anemones, and corals) are known from Johnston Atoll (Table 4).

The distribution and abundance of the seven genera of coral reported by Brock, *et al.* (1965, 1966) are presented in Table 5. Collection stations are shown in Figure 32. Two genera are quite restricted, occurring only in areas 1 and 2 near the marginal reef. The other five genera are distributed widely throughout the lagoon.

Dredging operations in 1964 destroyed over 1,100 acres of reef; dredging itself destroyed 700 acres of living coral while newly deposited "coral aggregate" destroyed more than 400 acres. In addition, over 7,000 acres of reef and lagoon were more or less seriously affected by silty water. The reduction in the percentage of living coral in these silty water areas varied from none to 40 percent, with 10 percent being roughly an average figure. A parallel reduction in the number of associated invertebrate species and fish species also occurred.

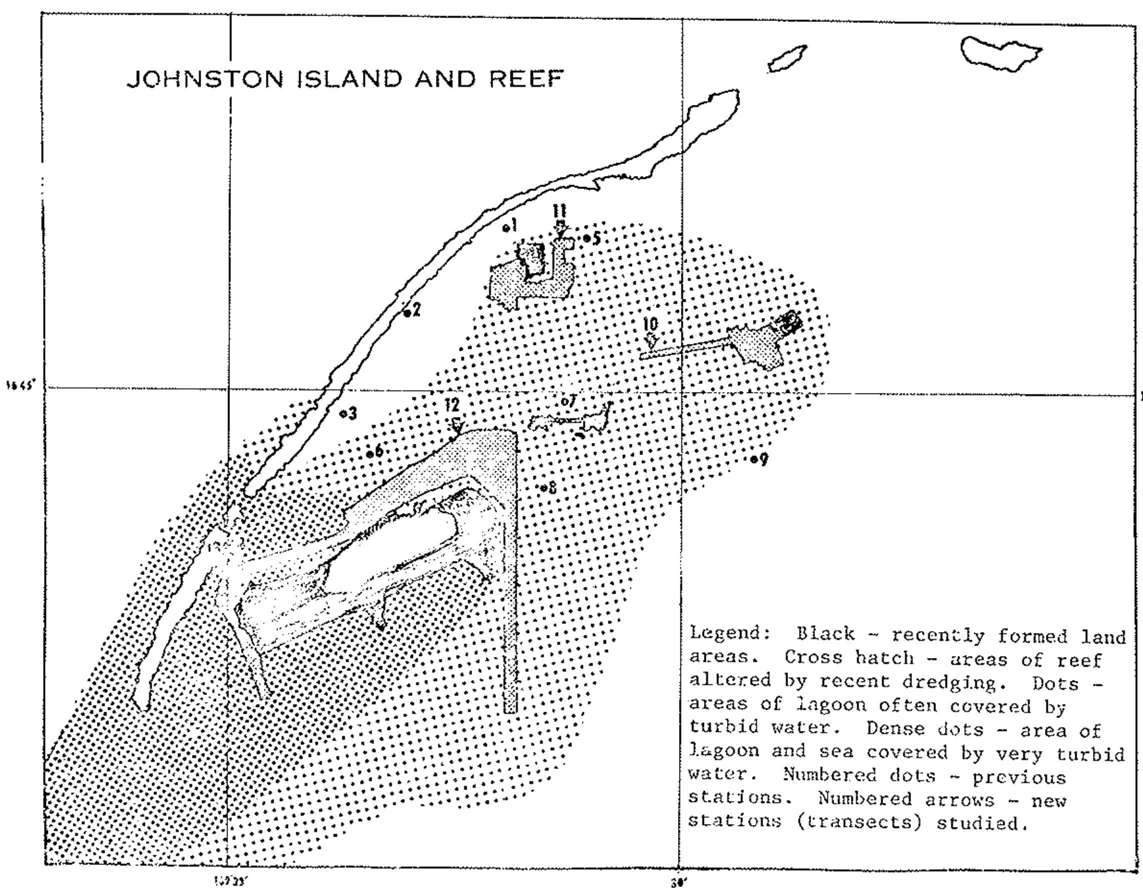


Figure 32. Johnston Atoll showing invertebrate and fish collection stations, dredged areas, and the extent of silt laden water (Brock, *et al.*, 1966).

Table 4. Cnidaria (Coelenterata) from Johnston Atoll*

Class Family Species	Wells 1934	Brock *et al.* 1965	Present Paper
Hydrozoa			
Milleporidae			
Millepora tenera	X		
Millepora sp.			X
Stylasterinidae			
Distichopora sp.	X		
Stylaster sp.			X
Anthozoa			
Pocilloporidae			
Pocillopora damicornis		X	
Pocillopora eydouxi	X		
Pocillopora meandrina		X	
Acroporidae			
Acropora humilis	X		
Acropora hyacinthus	X		
Acropora retusa	X		
Acropora tumida	X		
Montipora verrucosa	X		
Montipora sp.	X		
Agariciidae			
Leptastrea sp.	X		
Pavona variens		X	
Pavona sp.	X		
Fungiidae			
Fungia scutaria	X		
Poritidae			
Portites lutea	X		
Isopheliidae			
Telmatactis decora		?	X

*Taxonomic order follows Bayer, *et al.* (1956).

Table 5. Distribution and abundance of corals at Johnston Atoll, 1964-1965*

Areas	*Acropora* cespitose	vasiform	*Fungia*	*Millepora*	*Montipora*	*Pavona*	*Pocillopora*	*Porites*	Percent of living coral
1 (1964)	X	X	X		X	X	X	X	Mound tops 70 to 100% Lower sides 40 to 50%
2 (1964)	X	X		X	X	X	X	X	Ridge tops 99% Channel floor 1%
3 (1964)	X	X	X		X	X	X		80 to 90%
4 (1964)	X	X			X	X	X		20% or less
4 (1965)	X	X			X	X	X		10 to 20%
5 (1964)	X	X			X	X	X		90 to 95%
5 (1965)	X	X			X	X	X		50 to 75%
6 (1964)	X	X	X		X	X	X		50 to 75%
6 (1965)	X	X	X		X	X	X		50 to 70%
7 (1964)	X	X	X		X	X	X		20%
7 (1965)	X	X	X		X	X	X		15%
8 (1964)		X	X		X	X	X		20 to 30%
8 (1965)		X	X		X	X	X		15 to 20%
9 (1964)		X			X	X	X		50 to 60%
10 Reef**	X				X	X			10%
10 Cliff									0%
10 Bottom									0%
11 Reef	X	X			X	X	X		60 to 70%
11 Cliff									0%
11 Bottom						X			<0.1%
12 Reef					X	X			10 to 20%
12 Cliff									0%
12 Bottom									0%
13 Reef	X	X			X	X	X		10 to 15%
13 Cliff									0%
13 Bottom									0%
Number of X's	15	16	8	1	18	19	16	2	10%

*Adapted from Brock, *et al.* (1965, 1966).
**Areas 10 through 13, 1965 only.

Mollusca (by Harald A. Rehder)

The 58 species listed in Table 6 comprise only those mollusk species found in the collection of the National Museum of Natural History and by no means represent the complete fauna of this atoll. A thorough survey of the lagoon and a search of the reef and shores of both Sand and Johnston Islands for the smaller species would increase the list materially.

As might be expected, most of the species are widely distributed throughout the Indo-Pacific region. Six, however, are otherwise restricted to the Hawaiian Islands; these are *Trochus intextus*, *Turbo articulatus*, *Nerita picea*, *Cypraea granulata*, *Maculotriton* species, and *Peristernia crocea*. Two others, *Strombus maculatus* and *Cypraea schilderorum*, are found in Micronesia and Polynesia, as well as in the Hawaiian Islands, but not elsewhere.

On the other hand, 12 of the species listed are uncommon to rare in the Hawaiian Islands, and three--*Planaxis zonatus*, *Mitra columbelliformis*, *Parviperna dentifera*--have not as yet been recorded from Hawaii.

In brief, although the molluscan fauna of Johnston Atoll shows an affinity with that of the Hawaiian Islands, it is also closely related to the fauna of Micronesia and Polynesia. A more thorough survey of the mollusks of Johnston Atoll should help to clarify its biogeographical position.

Annelida

At present only 12 species belonging to eight families of Polychaeta are known from the lagoon waters at Johnston Atoll (Table 7). Edmondson, *et al.* (1925) listed six species collected during the 1923 TANAGER Expedition. Brock, *et al.* (1965) reported three species from 1963-1965 collections. The present paper lists six species found in the collections of the National Museum of Natural History and the Bernice P. Bishop Museum. Additional collecting will most likely result in an increased number of known species from the atoll.

Brock, *et al.* (1965, 1966) showed that dredging at Johnston slightly increased the number of polychaetes, but reduced their weight.

Arthropoda

Marine

The lagoon waters at Johnston Atoll support a total of 75 species belonging to 20 families of Crustacea (Table 8). Edmondson, *et al.* (1925) reported 59 species collected by the 1923 TANAGER Expedition, while Brock, *et al.* (1965, 1966) reported 12 species collected from 1963 through 1965. The present paper lists 61 species found in the collections of the National Museum of Natural History and the Bernice P. Bishop Museum. Further collecting at Johnston Atoll possibly would result in additional known species.

Table 6. Distribution and abundance* of Mollusca from Johnston Atoll

Gastropoda:	Marginal N.W. Reef	Johnston Island	Sand Island	Lagoon fill Sand Island
Trochidae				
Trochus intextux Reeve				U
Turbinidae				
Turbo articulatus Reeve	M			
Neritidae				
Nerita plicata Linnaeus		M	M	
Nerita polita Linnaeus			M	
Nerita albicilla Linnaeus			U	
Nerita picea Recluz		V	V	
Littorinidae				
Littorina pintado Wood		V	V	
Littorina undulata Gray		U		
Littorina coccinea (Gmelin)		U	M	
Planaxidae				
Planaxis zonatus A. Adams			U	
Modulidae				
Modulus tectum (Lamarck)				U
Cerithiidae				
Rhinoclavis sinensis (Gmelin)			U	
Rhinoclavis articulatus Adams & Reeve			U	
Cerithium mutatum Sowerby				U
Cerithium nesioticum Pilsbry & Vanatta				U
Hipponicidae				
Sabia conica (Schumacher)	U		U	
Strombidae				
Strombus maculatus Sowerby			U	U
Cypraeidae				
Cypraea granulata Pease				U
Cypraea helvola Linnaeus	U			M
Cypraea poraria Linnaeus	U			
Cypraea caputserpentis Linnaeus				U
Cypraea moneta Linnaeus	U			U
Cypraea maculifer (Schilder)				U

*V = Very abundant; M = Moderately abundant; U = uncommon.

Table 6. (continued)

Gastropoda (cont.):	Marginal N.W. Reef	Johnston Island	Sand Island	Lagoon fill Sand Island
Cypraeidae (cont.)				
Cypraea isabella Linnaeus				M
Cypraea carneola Linnaeus				U
Cypraea schilderorum (Iredale)	U			M
Naticidae				
Polinices (Mamilla) melanostoma (Gmelin)			U	
Cymatidae				
Cymatium (Septa) nicobaricum Röding				U
Cymatium (Septa) aquatile (Reeve)			U	U
Cymatium (Septa) gemmatum (Reeve)			U	
Cymatium (Ranularia) muricinum Röding			U	
Distorsio anus Linnaeus				U
Tonnidae				
Tonna (Quimalea) pomum (Linnaeus)				U
Muricidae				
Maculotriton species			U	
Drupa morum Röding	M			
Drupa ricinus (Linnaeus)	U		U	
Morula uva Röding	M		V	M
Morula granulata (Duclos)			M	
Drupella ochrostoma (Blainville)			U	
Nassa sertum Bruguière				M
Coralliophilidae				
Coralliophila violacea Kiener	M			
Quoyula madreporarum (Sowerby)	M			
Buccinidae				
Pisania ignea (Gmelin)	U			U
Nassariidae				
Nassarius (Reticunassa) dermestina (Gould)			U	
Fasciolariidae			M	
Peristernia crocea (Gray)				
Mitridae				
Mitra (Strigatella) columbelliformis Kiener				U

Table 6. (continued)

Gastropoda (cont.):	Marginal N.W. Reef	Johnston Island	Sand Island	Lagoon fill Sand Island
Turbinellidae				
Vasum turbinellus (Linnaeus)	U		U	U
Conidae				
Conus pulicarius Hwass	U			U
Conus nanus Sowerby	U			
Conus rattus Hwass	U			
Conus vitulinus Hwass	U			
Conus miles Linnaeus	U			
Conus flavidus Lamarck				U
Terebridae				
Terebra crenulata Linnaeus				U
Bivalvia:				
Isognomonidae				
Isognomon perna (Linnaeus)			M	
Parviperna dentifera (Krauss)			U	
Trapezidae				
Trapezium oblongum (Linnaeus)				U
Tellinidae				
Arcopagia (Scutarcopagia) scobinata (Linnaeus)				U

Table 7. Annelida from Johnston Atoll*

Class / Family / Species	Edmondson *et al.* 1925	Brock *et al.* 1965	Present Paper
Polychaeta			
Amphinomedae			
Eurythoe complanata (Pallus)			X
Eurythoe pacifica Kinberg	X		
Hermodice pinnata Treadwell	X		
Cirratulidae			
Cirratulus sp.	X		X
Eunicidae			
Eunice sp.			X
Polynoidae			
Hololepidella nigropunctata (Horst)			X
Phyllodocidae			
Phyllodoce stigmata Treadwell	X		X

Table 7. (continued)

Class Family Species	Edmondson *et al.* 1925	Brock *et al.* 1965	Present Paper
Nereidae			
Nereis kobiensis		X	
Perinereis helleri (Grube)	X		X
Leodicidae			
Lysidice fusca Treadwell	X		
Lysidice sp.		X	
Leodocidae			
Leodice sp.		X	

*Taxonomic order follows that in the Annelida collection of the National Museum of Natural History.

Table 8. Marine Arthropoda from Johnston Atoll*

Class Subclass Family Species	Edmondson *et al.* 1925	Brock *et al.* 1965, 1966	Present Paper
Crustacea			
Cirripedia			
Lepadidae			
Lepas anatifera Linnaeus			X
Malacostraca			
Squillidae [=Chloridelidae?]			
Pseudosquilla oculata (Brullé)	X		X
Palaemonidae			
Coralliocaris graminea (Dana)	X		X
Harpiliopsis depressus (Stimpson)	X	X	X
Jocaste lucina (Nobili)	X		X
Palaemonella tenuipes Dana	X		
Peridemenaeus tridentalus (Miers)	X		X
Gnathophyllidae			
Gnathophyllum americanum Guerin	X		X
Alpheidae			
Alpheus brevipes Stimpson		X	
Alpheus bucephalus Coutière	X		X
Alpheus clypeatus Coutière	X	X	X
Alpheus collumianus Stimpson	X		X
Alpheus crassimanus Heller	X		X
Alpheus diadema Dana	X		X
Alpheus gracilis Heller incl. subsp. *simplex* (Banner)	X		X
Alpheus leviusculus Dana	X		X

Appendix Table 8. (continued)

Class Subclass Family Species	Edmondson *et al.* 1925	Brock *et al.* 1965, 1966	Present Paper
Alpheidae (cont.)			
Alpheus lottini Guérin	X	X	
Alpheus paracrinitus Miers	X		X
Alpheus paragracilis Coutière	X		X
Synalpheus paraneomeris Coutière	X		X
Hippolytidae			
Lysmata paucidens (Rathbun)	X		X
Saron marmoratus (Olivier)	X		
Painuridae			
Panulirus marginatus (Quoy & Gaimard)			X
Panulirus pencillatus (Olivier)	X		X
Scyllaridae			
Parribacus antarcticus (Lund)	X		X
Axiidae			
Axiopsis johnstoni Edmondson	X		X
Galatheidae			
Galathea spinosorostris Dana		X	
Diogenidae			
Aniculus aniculus (Fabricius)	X		?
Calcinus elegans (N. Milne-Edwards)	X		X
Calcinus herbstii de Man	X		X
Calcinus latens (Randall)	X		X
Dardanus haanii Rathbun			X
Dardanus megistos (Herbst)			X
Dardanus punctulatus	X		
Dynomenidae			
Dynomene hispida Desmarest	X		X
Calappidae			
Calappa hepatica (Linnaeus)	X		
Leucosiidae			
Nucia speciosa Dana	X		
Majidae			
Perinea tumida Dana			X
Schizophrys hilensis Rathbun		X	
Portunidae			
Cataptrus inaequalis (Rathbun)	X		X
Portunus longispinosus (Dana)	X		X
Thalamita admete (Herbst)	X		X
Thalamitoides quidridens A. Milne-Edwards	X		X
Xanthidae			
Carpilius convexus (Forskal)	X		X
Chlorodiella asper Edmondson	X		X
Domecia hispida Eydoux & Souleyet	X	X	X
Etisus electra (Herbst)	X		X

Table 8. (continued)

Class Subclass Family Subspecies	Edmondson *et al.* 1925	Brock *et al.* 1965, 1966	Present Paper
Xanthidae (cont.)			
Leptodius sanguineus (H. Milne-Edwards)	X		X
Leptodius waialuanus Rathbun	X		
Liocarpilodes biunguis (Rathbun)	X		X
Liocarpilodes integerrimus (Dana)			X
Liomere bella (Dana)	X		X
Lophozozymus dodone (Herbst)			X
Phymodius laysani Rathbun	X		X
Phymodius nitidus (Dana)	X		X
Pilodius aberrans (Rathbun)	X		X
Pilodius areolata (H. Milne-Edwards)			X
Platypodia eydouxi (A. Milne-Edwards)	X		X
Pseudoliomera speciosa (Dana)	X	?	X
Tetralia glaberrima (Herbst)	X		
Tetralia spp.		X	
Trapezia cymodoce (Herbst)		X	
Trapezia digitalis Latreille	X	X	X
Trapezia ferruginea Latreille	X		X
Trapezia intermedia Miers	X		X
Trapezia maculata (MacLeay)		X	X
Trapezia rufopunctuta (Herbst)	X		
Trapezia speciosa	X		X
Ocypodidae			
Ocypode laevis Dana			X
Grapsidae			
Grapsus strigosus (Herbst)	X		X
Grapsus tenuicristatus (Herbst)	X		X
Pachygrapsus minutus A. Milne-Edwards	X		X
Pachygrapsus plicatus (H. Milne-Edwards)			X
Hapalocarcinidae			
Hapalocarcinus marsupialis Stimpson	X		X
Pseudocryptochirus crescentus (Edmundson)	X		X

*Taxonomic order follows Chase (pers. corres.).

Very little is known about the distribution and abundance of Johnston's marine arthropods. Brock, *et al.* (1965, 1966), in studying the effects of dredging, did reveal that dredging reduced the number and weight of xanthid crabs and alpheid shrimp inhabiting living cora. (vasiform *Acropora*) heads, but showed little change in crab and shrimp populations inhabiting living coralline (*Porolithion*) algae.

Terrestrial

Insects totaling 68 species of 35 families were known from the islands at Johnston Atoll by 1952 (Bryan, *et al.*, 1926; Chilson, 1953). These are listed in Table 9. POBSP personnel collected insects at Johnston from 1963 through 1969; these collections have not, as yet, been fully identified.

Table 9. Insects recorded from Johnston Atoll; adapted from Chilson (1953)

Orthoptera
  Blattidae
    Blattela liturícollis (Walker)
    Cutilia soror (Brunner)
    Periplaneta americana (Linnaeus)
    Pycnoscelus surinamensis (Linnaeus)
Dermaptera
  Labiduridae
    Anisolabis maritima (Gene)
    Euborellia annulipes (Lucas)
Mallophaga
  Menoponidae
    Austromenopon sternophilum (Ferris); on tern.
Thysanoptera
  Aeolothripidae
    Frankliniella sulfurea Schmutz
Hemiptera
  Lygaeidae
    Nysius terrestris Usinger
    Geocoris punctipes (Say)
  Reduviidae
    Zelus renardii Kolenati
  Nabidae
    Nabis capsiformis Germar
  Gerridae
    Halobates sericeus Eschscholtz
Homoptera
  Aphididae
    Aphis gossyppi Glover
    Aphis medicaginis Koch
  Margarodidae
    Icerya purchasi Maskell
  Pseudococcidae
    Pseudococcus (*citri* complex)
    Pseudococcus sp. perhaps *citri* (Risso)
    Ferrisiana virgata (Cockerell)

Table 9. (continued)

Homoptera (cont.)
  Coccidae
    Coccus sp.
    Coccus hesperidum Linnaeus
    Saissetia nigra (Nietner)
    Saissetia oleae (Bernard)
  Diaspididae
    Aspidiotus lataniae Signoret
    Chrysomphalus dictyospermi (Morgan)
    Pinnaspis sp.
    Pinnaspis strachani (Cooley) (of Ferris and Rao)
Neuroptera
  Hemerobiidae
    Sympherobius sp. may be *barberi* Banks
Lepidoptera
  Tineidae
    Tineola uterella Walsingham
    Ereunetis incerta Swezey
  Pterophoridae
    Trichoptilus oxydactylus (Walker)
  Phalaenidae
    Achaea janata (Linnaeus)
    Laphygma exempta (Walker)
Coleoptera
  Dermestidae
    Dermestes ater Degeer
  Histeridae
    Carcinops quattuordecimstriata (Stephens)
  Anobiidae
    Lasioderma serricorne (Fabricius)
  Tenebrionidae
    Alphitobius piceus (Oliver)
  Coccinellidae
    Coelophora inaequalis (Fabricius)
    Scymnus loewii Mulsant
    Scymnus notescens Blackburn
  Curculionidae
    Dryotribus mimeticus Horn
    Macrancylus immigrans (Perkins)
Hymenoptera
  Encyrtidae
    Aenasius advena Compere
    Leptomastix dactylopii Howard
  Formicidae
    Solenopsis geminata rufa (Jerdon)
    Monomorium pharaonis (Linnaeus)
    Cardiocondyla sp.
    Tetramorium guineense (Fabricius)
    Paratrechina (Nylanderia) sp.
    Paratrechina longicornis (Latreille)

Table 9. (continued)

Hymenoptera (cont.)
  Sphecidae
    Chalybion bengalense (Dahlbom)
  Vespidae
    Polistes fuscatus aurifer Saussure
  Megachilidae
    Megachile fullawayi Cockerell
Diptera
  Syrphidae
    Simosyrphus (*Xanthogramma*) *grandicornis* (Macquart)
    Xanthogramma scutellaris (Fabricius)
    Syrphus sp.
  Sarcophagidae
    Goniophyto bryani Lopes
    Sarcophaga sp.
    Sarcophaga dux Thomson
    Sarcophaga barbata Thomson
  Calliphoridae
    Phaenicia sp.
  Muscidae
    Musca domestica Linnaeus
    Musca domestica vicina Macquart
    Atherigona excisa (Thomson)
  Milichiidae
    Desmometopa sp.
  Agromyzidae
    Agromyze pusilla Meigen
  Hippoboscidae
    Olfersia spinifera (Leach); from frigate birds.

Medically Important Species: Medically important arthropods have, however, been studied (POBSP). These include 2 ticks, 5 chiggers, 2 nasal mites, 23 biting lice, and 2 louse flies. No fleas or mosquitoes are known from Johnston Atoll.

Ixodides: Two ticks, *Ornithodoros capensis* and *Ornithodoros denmarki* (family Argasidae), are known from Johnston Atoll. A third tick, *Ixodes laysanensis* (family Ixodidae), occurs on islands in the north-central Pacific, but has not been recorded from Johnston Atoll. It is expected, however, to eventually reach Johnston Atoll because of bird movement between islands in the north-central Pacific. Another tick, *Ixodes amersoni*, which occurs on islands in the south-central Pacific, is not expected to reach Johnston Atoll because of a lack of bird movement between islands in the north-central and south-central Pacific (Amerson, 1968).

Philip (1965) reported that two viral isolates were made from *Ornithodoros capensis* Neumann taken from Sooty Tern and Brown Noddy nests at Sand Island. He stated that this arbovirus may be related to "Hughes virus" which was isolated by Hughes, *et al.* (1964) from *Ornithodoros* *denmarki* taken in tern nests on Bush Key, Dry Tortugas, Florida. The arbovirus was later named "Johnston Atoll virus" by Clifford, *et al.* (1968), who noted that in addition there were also two unnamed viruses from seabird ticks taken at Sand Island, Johnston Atoll.

In order to obtain a better understanding of the relationship between *Ornithodoros capensis* and its hosts, a program was started in January of 1965 by the POBSP to monitor the tick population on Sand Island, Johnston Atoll, each month. Berlese samples were taken (using a 5" x 5" x 1" metal sampler) at random over the entire island which had been divided into sections (Fig. 33).

Berlese samples for 1965 totaled 515 for the entire island and 159 of these were positive for *O. capensis*; the infestation rate was 31 percent. Since the original part of Sand Island is the most important to the avifauna, 479 of the Berlese samples were taken from this part. The investation rate for the original part during 1965 was 33 percent and Table 10 presents the variation in each of the eight areas. The infestation rate was definitely highest (51 percent) on the northeast peninsula (Areas H and K) and diminishes gradually toward the western part of the island. This is shown in Figure 33 by the distribution of the positive samples in the different areas.

Table 10. Berlese sample data--*Ornithodoros capensis* infestation rates for Sand Island, Johnston Atoll, 1965.

	Areas								
	A	B	C	D	E	F	H	K	Total
No. samples negative	7	21	43	58	57	48	44	43	321
No. samples positive	4	4	4	5	16	35	46	44	158
Total samples	11	25	47	63	73	83	90	87	479
Percent positive	36%	16%	9%	8%	22%	42%	51%	51%	33%

This variation in infestation rates in the different areas could be due to several reasons: (1) ecological differences in the various areas, (2) bird distribution over the island, and (3) man's disturbance of the island. Ecological differences in the various areas are few since the vegetation and soil is similar throughout the island and the island itself is small. As will be shown later, the bird distribution, especially at the peak population, covers the entire original portion of the island. The USCG LORAN Station was built in 1960 and during construction all old buildings, etc., left from earlier activities, were bulldozed into the surrounding lagoon. This activity undoubtedly disrupted the soil and thus in turn may have destroyed any ticks which were present. The peninsula, being further away from the center of the disturbance, was not severely disrupted. This was verified when photographs taken in 1923 were compared with 1963 photographs. It is known that ticks were very numerous on Sand Island as early as 1923 (Wetmore, ms.a).

Bi-monthly infestation rates for Sand-Johnston (Table 11) reveal that there was an increase in the rate from January-February (32 percent) through

May-June (43 percent) and then a decrease through the fall months to a low of 17 percent in November-December. This seasonal fluctuation is shown in Figure 34 to be correlated with the seasonal population of all the breeding birds, mainly Sooty Terns, on the island. Briefly, the 1965 breeding cycle of the Sooty Terns was as follows: late October (1964)--few observed; November (1964)--sharp increase in night calls; December (1964)--increase in numbers, first roosting on 14th; late January (1965) --170,000 birds at night, only a few during day; February--thousands sitting on the island by the 10th, 25,000 incubating by the 15th, 40,000 by end of the month; mid-March--peak egg count of 140,000; April--82,000 chicks hatched by the 9th, but numbers dropped to 65,000 due to mortality; May--20,000 young were flying; June--well over 50 percent of young were flying and large numbers left the island, only 50 eggs remained; July--most of the young left the island; August--17,000 first half, 2,700 by end of month; September--few birds remained; October--one chick present, not over 10 adults a day; November--night calling increasing; December--by mid-month birds began setting down on the island, late month roosting totaled 50,000 birds. The area occupied by the Sooty Terns is shown bi-monthly in Figure 35.

Increase in the population and breeding activity of the Sooty Terns during the spring months directly influenced the tick population. The number of ticks per positive sample also increased during this period (Table 11) as follows: January, February--3.5; March, April--9.4; May, June--8.0. During the summer and fall months the number of ticks per positive sample showed a decrease and then an increase as follows: July, August--4.0; September, October--18.0; November, December--6.7. The increase in numbers during September and October is possibly due to low sample size (5) and the fact that samples were purposefully taken in places where ticks were plentiful (i.e., under rocks). The overall average for 1965 was seven ticks per positive sample.

The bi-monthly infestation rates for the three major areas (northeast peninsula, east half, and west half) of Sand Island are shown in Figure 33 and Table 11. These rates show that the tick populations in the different areas fluctuate similarly to that for the entire island (Fig. 34), as all three areas reach a peak in the May-June, July-August period. There is, however, a variation in the infestation rates in each area for each bi-monthly period. This again shows that the northeast peninsula area not only has a higher rate overall, but the rate was higher each bi-monthly period than the other areas. For instance, during May-June, the rate on the peninsula was 89 percent, while on the east portion it was 49 percent, and on the west portion it was 18 percent. As has already been pointed out (and shown in Figure 35), the Sooty Terns and other species utilize almost all of the available land areas during the spring and summer months, so the bi-monthly infestation rate variation for the different areas was not due completely to the number of birds using any particular area of the island.

The 515 Berlese samples taken on Sand-Johnston in 1965 are shown by host-source in Table 12 and demonstrate various nest infestation rates for *Ornithodoros capensis*. On Sand Island the highest nest infestation rates occur in the Brown Booby at 50 percent and the Brown Noddy at 49 percent.

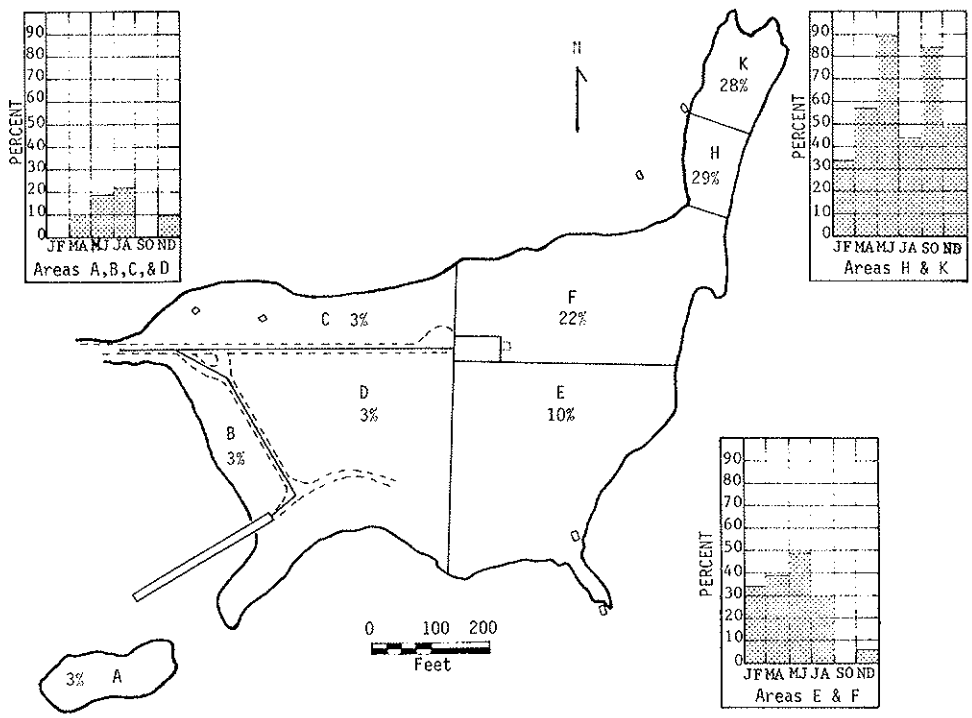


Figure 33. Distribution of positive samples of *Ornithodoros capensis* for 1965, Sand Island, Johnston Atoll. Inserts show bi-monthly infestation rates for the three major areas.

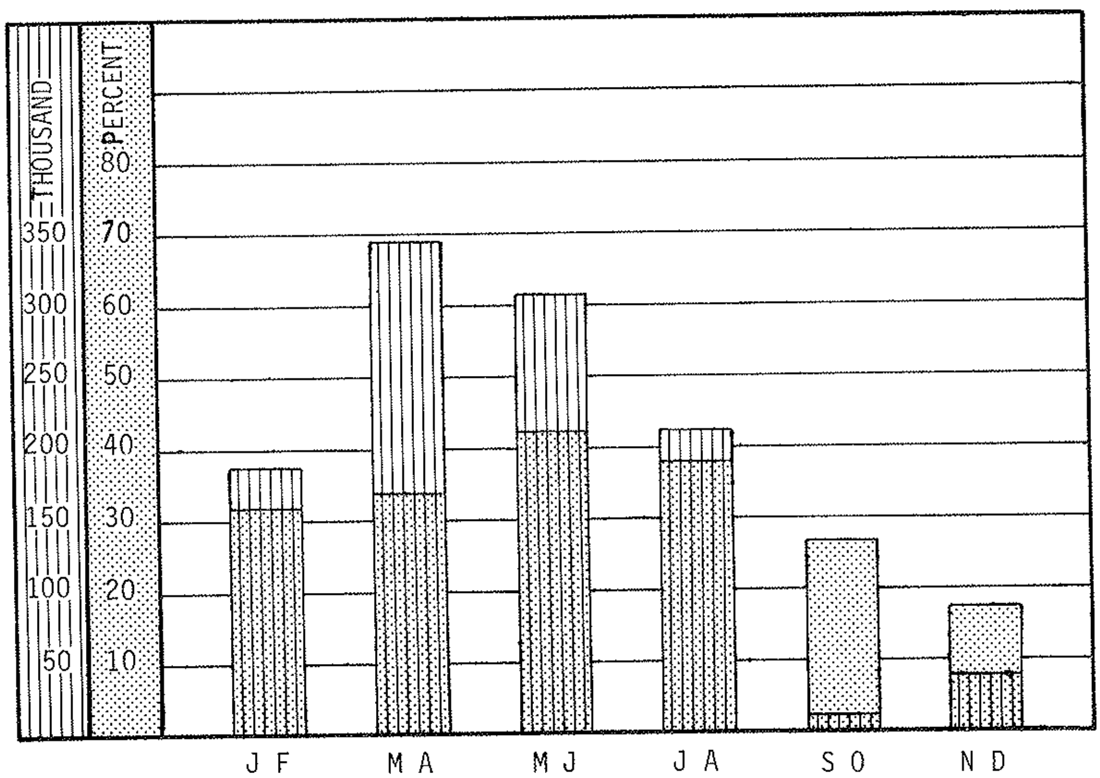


Figure 34. Bi-monthly tick infestation rates (stipples) compared with breeding bird population fluctuations (bars), Sand Island, Johnston Atoll, 1965.

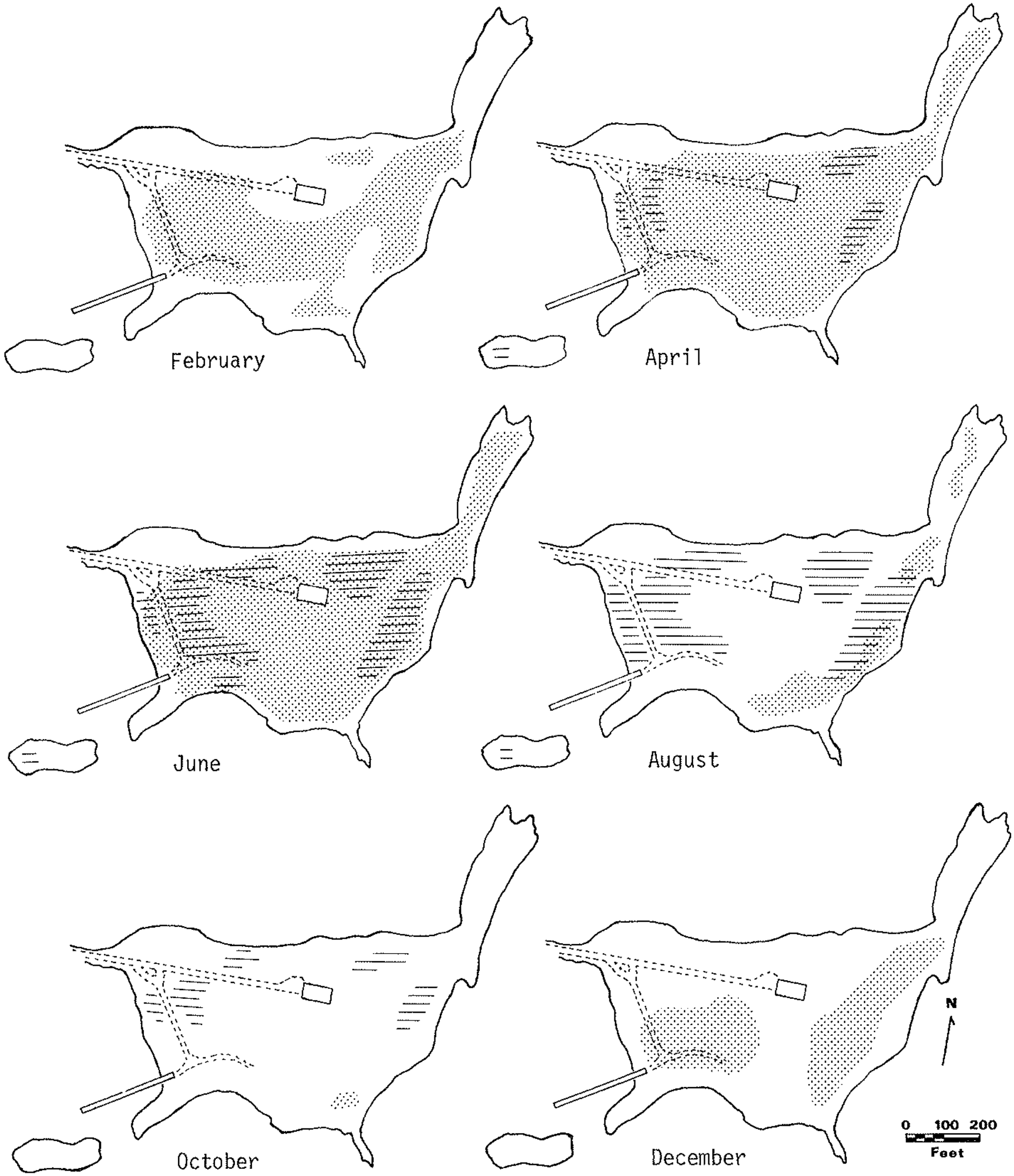


Figure 35. Areas used by Sooty Terns (stippled) and Wedge-tailed Shearwaters (barred) on Sand Island, Johnston Atoll, 1965.

The Sooty Tern, by comparison, has an infestation rate of only 26 percent; however, many of the samples labeled Miscellaneous Litter (rate 33 percent) probably should be listed under Sooty Tern nests since the species is so widespread over the island. The remaining infestation rates are as follows: Red-footed Booby 20 percent, Great Frigatebird 20 percent, Red-tailed Tropicbird 7 percent, and Wedge-tailed Shearwater 5 percent, with the rest being 0 percent. Comparative data from Green Island, Kure Atoll, northwestern Hawaiian Islands, are also shown in Table 12.

Table 11. Berlese sample data--bi-monthly *Ornithodoros capensis* infestation rates for Sand Island, Johnston Atoll, 1965.

	JF	MA	MJ	JA	SO	ND	Total
			Areas A, B, C, and D				
No. samples negative	1	20	42	7	10	49	129
No. samples positive	0	2	9	2	0	4	17
Total samples	1	22	51	9	10	53	146
Percent positive	0%	9%	18%	22%	0%	8%	12%
			Areas E and F				
No. samples negative	4	11	33	19	3	35	105
No. samples positive	2	7	32	8	0	2	51
Total samples	6	18	65	27	3	37	156
Percent positive	33%	39%	49%	30%	0%	5%	33%
			Areas H and K				
No. samples negative	21	8	2	43	1	12	87
No. samples positive	10	11	17	33	5	14	90
Total samples	31	19	19	76	6	26	176
Percent positive	32%	58%	89%	44%	83%	50%	51%
			All Areas				
No. samples negative	26	39	77	69	14	96	321
No. samples positive	12	20	58	43	5	20	158
Total samples	38	59	135	112	19	116	479
Percent positive	32%	34%	43%	38%	26%	17%	33%
No. of ticks per positive sample	3.5	9.4	8.0	4.0	18.0	6.7	7.0

Trombiculidae: Seven genera of 16 species of larval trombiculid mites, commonly referred to as chiggers, are known from POBSP collections in the central Pacific (Brennan, 1965; Brennan and Amerson, 1971). Five species taken off six host species have been recorded from Sand Island. *Neoschoengastia ewingi* was taken off Golden Plover and Brown Noddy, as well as from litter taken in the Sooty Tern nesting area. *Blankaartia amersoni* was recorded from the nasal cavities of Bulwer's Petrel, Red-tailed Tropicbird, Sooty Tern, and Brown Noddy. *Guntherana domrowi* was taken from Sooty Tern. *Guntherana* sp. was taken from a house mouse. *Womersia strandtmanni* was recorded off Sooty Terns. The first three species listed above are found both in the north- and south-central Pacific. *Guntherana* sp. is known only from Sand Island, Johnston Atoll. *Womersia strandtmanni* at Sand-Johnston is a first and only record from the Pacific; it is also known from the North American Gulf and Atlantic coasts.

Table 12. *Ornithodoros capensis* infestation rates from Berlese samples of hosts' nests

Host - Source	Green I., Kure Atoll 1964-1965			Sand I., Johnston Atoll 1965		
	Total Nests Examined	Total Nests Infested	Infestation Rate	Total Nests Examined	Total Nests Infested	Infestation Rate
Black-footed Albatross	25	2	8%	#	#	#
Laysan Albatross	61	9	15%	#	#	#
Wedge-tailed Shearwater	26	1	4%	37	2	5%
Christmas Shearwater	2	0	0%	3	0	0%
Bonin Petrel	13	0	0%	#	#	#
Bulwer's Petrel	0	0	0%	4	0	0%
Red-tailed Tropicbird	15	6	40%	14	1	7%
Blue-faced Booby	28	8	29%	#	#	#
Brown Booby	12	5	42%	16	8	50%
Red-footed Booby	6	0	0%	5	1	20%
Great Frigatebird	6	1	17%	10	2	20%
Sooty Tern	167	20	12%	82	21	26%
Noddy Tern	15	14	93%	76	37	49%
Black Noddy	0	0	0%	1	0	0%
Hawaiian Monk Seal	1*	0	0%	#	#	#
Polynesian Rat	9	0	0%	#	#	#
Misc. Litter	12	0	0%	267	87	33%
Totals	398	66	17%	515	159	31%

Do not occur.
* Resting area.

Rhinonyssidae: Amerson (1967) examined the nasal cavities of 460 adult and immature Sooty Terns taken throughout their 1965 breeding cycle on Sand Island, Johnston Atoll, for Rhinonyssidae, or nasal mites. Incidence of rhinonyssids of two genera, *Larinyssus* and *Sternostoma*, in adult terns increased during the egg-laying period and decreased (possibly due to feeding of young) after the eggs had hatched. Incidence in young Sooty Terns was low (2 percent) during their first 4 months, suggesting that transference of mites from adult tern to their young is not very efficient. During the 5th month, however, the incidence rose to 29 percent, suggesting that the mites were elsewhere in the host and they require time to travel to the nasal cavity.

Mallophaga: Chilson (1953) listed one species of Mallophaga, or biting lice, from terns at Johnston Atoll. Amerson and Emerson (1971) recorded 23 species of 11 genera and two families from POBSP collections (Table 13). Of the 12 bird hosts, all but two species were seabirds; the two were both shore birds. Five Mallophaga species were taken from the Wedge-tailed Shearwater, four species were taken from the Sooty Tern, and three species were from the Brown Noddy.

Hippoboscidae: Two species of hippoboscids, or louse flies, were recorded by POBSP personnel off five species of seabirds at Sand Island (Maa, 1968). *Olfersia aenescens* was taken from the Great Frigatebird, Sooty Tern, as well as from a Berlese sample containing litter. *Olfersia spinifera* was recorded from the Wedge-tailed Shearwater, Red-tailed Tropicbird, Great Frigatebird, and Brown Noddy. These two hippoboscid species are pantropical in the Pacific, Indian, and Atlantic Oceans.

Echinodermata

A total of 37 species belonging to 13 families of Echinodermata are presently known from the lagoon waters of Johnston Atoll (Table 14). Edmondson, *et al.* (1925) and Clark (1949), reporting primarily on material collected by the 1923 TANAGER Expedition, each recorded 24 species. Brock, *et al.* (1965, 1966) recorded six species from 1963-1965 collections. The present paper lists 26 species found in the collections of the National Museum of Natural History and the Bernice P. Bishop Museum.

Brock, *et al.* (1965, 1966) studied the distribution and abundance of conspicuous echinoderms at Johnston Atoll. Of nine species studied in 13 areas, *Tripneusten gratilla* was found in 12 areas and *Heterocentrotus mammillatus* was found in 10 areas. They concluded that dredging affected both distribution and abundance of echinoderms.

Vertebrates

The vertebrates of Johnston Atoll are well known. Extensive ecological studies have been made on the fishes, birds, and mammals. Although the species composition of reptiles is well known, very little is known about their populations.

Table 13. Mallophaga collected at Sand Island, Johnston Atoll by the POBSP; adapted from Amerson and Emerson (1971)

Suborder Family Species	Host
Ischnocera	
Philopteridae	
Halipeurus heraldicus	Phoenix Petrel
Halipeurus pacificus	Wedge-tailed Shearwater
Naubates harrisoni	Wedge-tailed Shearwater
Pectinopygus gracilicornis	Great Frigatebird
Pectinopygus sulae	Red-footed Booby
Quadraceps birostris	Sooty Tern
Quadraceps charadrii hospes	Black-bellied Plover
Quadraceps impar	Wandering Tattler
Quadraceps separatus	Brown Noddy
Quadraceps sp.	Gray-backed Tern
Saemundssonia albemarlensis	Sooty Tern
Saemundssonia hexagona	Red-tailed Tropicbird
Saemundssonia puellula	Wedge-tailed Shearwater
Trabeculus hexakon	Wedge-tailed Shearwater
Ablycera	
Menoponidae	
Actornithophilus incisus	Brown Noddy
Actornithophilus piceus piceus	Sooty Tern
Actornithophylus sp.	Brown Noddy
Austromenopon atrofulvum	Sooty Tern
Austromenopon squatarolae	Black-bellied Plover
Colpocephalum angulaticeps	Great Frigatebird
Eidmanniella albescens	Blue-faced Booby
Procellariphaga pailula	Wedge-tailed Shearwater
Procellariphaga sp.	Phoenix Petrel

Table 14. Echinodermata from Johnston Atoll*

Class Subclass Family Species	Edmondson *et al.* 1925	Clark 1949	Brock *et al.* 1965, 1966	Present Paper
Echinoidea				
Diadematidae				
Diadema sp.			X	
Echinothrix calamaris (Pallas)			X	
Echinothrix diadema (Linnaeus)	X	X		
Echinometridae				
Echinometra mathaei (de Blainville)	X	X		X
Echniometra oblonga (de Blainville)	X	X		X

Table 14. (continued)

Class Subclass Family Species	Edmondson *et al.* 1925	Clark 1949	Brock *et al.* 1965, 1966	Present Paper
Echinometridae (cont.)				
Echinostrephus aciculatus A. Agassiz	X	X		X
Echinostrephus molaris (de Blainville)		X		
Heterocentrotus mammillatus (Linnaeus)	X	X		X
Heterocentrotus trigonarius (Lamarck)	X	X		X
Toxopneustidae				
Tripneustes gratilla (Linnaeus)	X	X		X
Brissidae				
Brissus latecarinatus (Leske)	X			X
Holothuroidea				
Holothuriidae				
Actinopyga mauritiana (Quoy & Gaimard)	X	X		X
Actinopyga obesa (Selenka)	X	X		
Actinopyga sp.				X
Holothuria atra Jaeger	X	X		X
Holothuria difficilis Semper				X
Holuthuria hilla (Lesson)	X	X		X
Holothuria impatiens (Forskal)	X	X		X
Holothuria pardalis Selenka	X	X		X
Holuthuria parvula (Selenka)	X	X		X
Synaptidae				
Chiridota rigida Semper	X	X		X
Opheodesoma spectabilis Fisher			?	
Polyplectana kefersteinii (Selenka)	X	X		X
Stelleroidea				
Asteroidea				
Oreasteridae				
Culcita arenosa Perrier	X			
Culcita novaeguineae Muller & Torschel		X		X
Ophidiasteridae				
Linckia multifora (Lamarck)	X	X		X
Acanthasteridae				
Acanthaster planci (Linnaeus)	X	X		X
Mithrodiidae				
Mithrodia bradleyi Verrill	X			
Mithrodia fisheri Holly		X		X

Appendix Table 14. (continued)

Class Subclass Family Species	Edmondson *et al.* 1925	Clark 1949	Brock *et al.* 1965, 1966	Present Paper
Stelleroidea (cont.)				
Ophiuroidea				
Ophiactidae				
Ophiactis savignyi (Muller & Troschel)	X	X		X
Ophiocomidae				
Ophiocoma erinaceus Muller & Troschel	X	X		X
Ophiocoma pica (Muller & Troschel)	X	X		X
Ophiocoma sp.			X	
Ophiocomella clippertoni			X	
Ophiocomella sexradia (Duncan)				X
Ophiodermatidae				
Distichophis clarki			X	
Ophiopeza spinosa (Ljungman)				X

*Taxodermic order follows Hyman (1940), Durham, *et al.* (1966a, 1966b), and Beaver, *et al.* (1967).

Fishes

The fish fauna of Johnston Atoll is well known and is herein separated into two categories: pelagic fishes and inshore fishes.

In the interest of consistency, taxonomic order follows that used by Gosline (1955) and Brock, *et al.* (1965, 1966), whose identification and nomenclature follow Schultz, *et al.* (1953).

Pelagic Fishes

Numerous large pelagic fishes occur around Johnston Atoll. No extensive species list exists for this area, but fishes here include tuna (wahoo, skipjack, and yellowfin), barracuda, and sharks (Chapman, 1946; Halstead and Bunker, 1954a). Two sharks, not included in the inshore reef fauna but known from there, include the white-tipped shark, *Triaenodon obesus* (family Triakidae) and the grey sand shark, *Carcharhinus menisorrah* (family Carcharhinidae). Additional species of sharks are most likely to occur in the lagoon. Barracuda and tuna also are known from the lagoon waters (Brock, *et al.*, 1965, 1966).

Inshore Fishes

A total of 194 species of inshore fishes are known from Johnston Atoll (Table 15). Of these 194 species, 27 were reported by Smith and Swain (1882), of which five were described as new. Fowler and Ball (1925) listed 72 species collected in 1923 by the TANAGER Expedition; one of these was described as new. Nine species, three of them new, were reported by Schultz, *et al.* (1953). From collections taken in 1951, Halstead and Bunker (1954a) listed 60 species and Gosline (1955) recorded 111 species. Brock, *et al.* (1965, 1966) reported 143 species from collections taken during August 1963 through August 1965. As a matter of further historical interest, 109 species were known by 1954, 49 species not previously reported were added by 1955, and an additional 36 species were added by 1966.

Gosline (1955) suggested that the Johnston Atoll fish fauna is made up of four components: (1) endemics, (2) fish that have made Johnston a stopping point on their migrations north, (3) fish that have made Johnston a stopping point in their southward travels, and (4) the pelagic fish to whom Johnston is of little or no significance.

Only two species of Johnston fishes have not been taken elsewhere. These are *Centropyge nigriocellus* and *C. flammeus*, both butterfly-fishes; neither are abundant at Johnston (Gosline, 1955).

Since only two species are endemic, it would appear that Johnston is not isolated in the evolutionary sense. In contrast, according to Gosline, nearly one half of the Line Island inshore fishes do not occur in Johnston or Hawaiian waters. Because of the wide stretches of deep water between the northernmost Line Islands and Johnston, Johnston Atoll is comparatively isolated from the south. Johnston's fish fauna is much more closely allied to that of the Hawaiian Islands. This is seen in the fact that the majority of the tropical species present at Johnston are also found in Hawaii.

The present-day Hawaiian fish fauna is thought to have been derived from more tropical waters. Yet presence of many tropical species at Johnston that are now unknown from Hawaiian waters would seem to indicate that there is a limit to how many warm water species Hawaii can absorb. Eventually it is expected that more tropical species will establish themselves in Hawaiian waters. Gosline has suggested that Johnston Atoll was probably the original port of entry of Hawaii's inshore fish fauna.

Distribution and Abundance Within the Atoll

Halstead and Bunker (1954a) generalized the fish distribution at Johnston and divided the atoll into three zones: (1) northern (peripheral) reef area, (2) southern (shoal) reef area, and (3) bank (lagoon) shoals. The northern reef area was characterized by scombroid fishes, barracuda, sharks, and other pelagic species living on the seaward (open-water) side of the reef and eagle-rays, moray eels, butterfly, squirrel, surgeon, damsel, surmullet, puffer, and file fishes on the lagoon side. The southern reef area was not examined but a large shark population was thought to exist in the open water; fish species were believed to be fewer in number and variety here, compared to the northern reef area. The bank shoals or lagoon area was characterized by: moray eels, wrasse, parrot, coronet, surgeon, butterfly, squirrel, damsel, and puffer fishes in the patch reef portion; flounders, blennies, surmullet, pompano, puffers, pomacentrids, stingrays, and triggerfishes in the sandy areas; and trumpet, parrot, damsel, pompano, trigger, and butterfly fishes in the wreckage or dump area to the southwest of Johnston Island.

As part of an extensive study on the effects of dredging at Johnston, Brock, *et al.* (1965) studied the distribution and abundance of 75 species at nine localities within the lagoon during August 1963 to June 1964 (Fig. 36). Areas 1, 2, and 4 were near the marginal reef

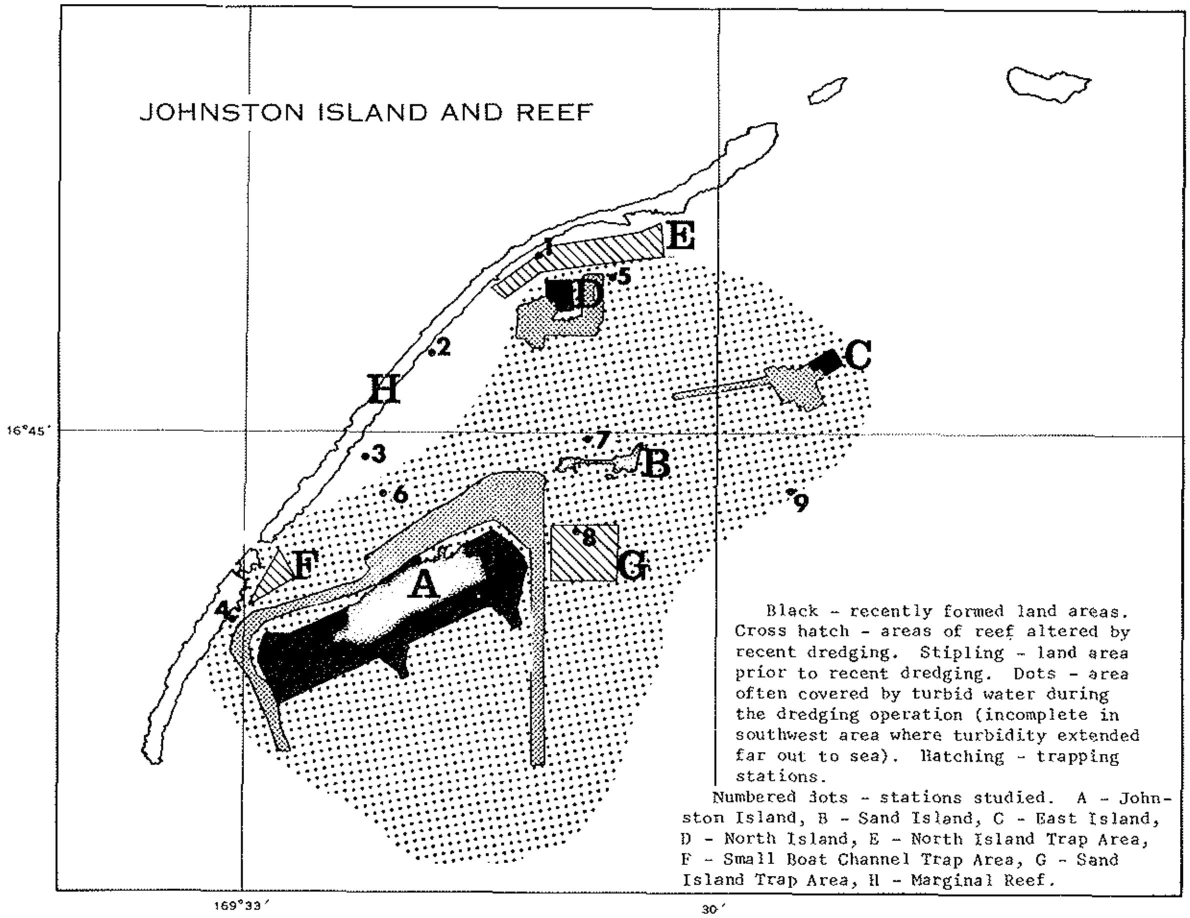


Figure 36. Fish collection stations, Johnston Atoll, 1963-1964 (Brock, *et al.*, 1965).

and each contained higher numbers of species, respectively 59, 45, and 43 species (mean = 49 species), than areas 3, 5, 6, 7, 8, and 9 in the lagoon proper. Numbers of species in the lagoon areas ranged from 28 to 39 species, with the mean being 33 species. Actual numbers of individuals were also highest in the marginal reef zone; however, ratios of numbers of species to numbers of individuals appear to be higher in general in the lagoon zone.

Commonness of species, based on the number of areas each were found in, show that of the 75 species, six species were found in all nine areas. The most abundant species was *Acanthus sandvicensis*; it was found in all areas and was dominant in five areas. The next three more abundant species, in order, were *Scarus sordidus*, *Ctenochaetus strigosus*, and *Acanthurus achilles*; each was dominant in three areas as well as found in all areas. Twelve species were found only in one area; these were considered rare in abundance.

Brock, *et al.* (1966) continued their distribution and abundance studies during August 1964 to August 1965. They added four new study stations (see areas 10, 11, 12, and 13, Fig. 32) and examined effects of recently completed dredging operations. They collected fishes in the bottom and sides (cliffs) of dredged areas, as well as non-disturbed reef areas. In general, the cliffs were barren of fish: two areas had no fish and two had three or nine species. Bottoms of three areas were also quite desolate: one had no species, one had three species, and the other had eight species. The remaining bottom area had 25 species, one more than the 24 species found in the adjacent reef. In general, the remaining non-dredged reef portion had fair numbers of species: 23, 19, and 14.

Effects of Dredging

Brock, *et al.* (1965) found no effects of dredging on fishes in their work through June 1964. But Brock, *et al.* (1966) did find the fish fauna adversely affected by dredging from August 1964 through August 1965.

By resurveying areas 4 through 8 they were able to compare numbers and abundance of species. The number of species of fish observed during 1965 was about 50 percent less than that observed during 1964 for stations 4 and 5, and about 10 percent less than stations 6, 7, and 8. From 2 to 13 species (mean = 7) new to each area were also found. If these were subtracted from the 1965 totals, then the difference between years would even be higher.

Brock, *et al.* (1966) also noted that the number of species rated as common or dominant was less for all stations (except one changing from common to dominant in station 8) for 1965 as compared to 1964. Their data suggest that while the total number of species observed for the two years changed very little for stations 6, 7, and 8, their abundance changed significantly.

Table 15. Inshore fishes recorded from Johnston Atoll

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	Brock, *et al.*, 1965 Dec. 1963– June 1965	Brock, *et al.* 1966 Aug. 1964– Aug. 1965
Myliobatidae (Eaglerays)					
Aetobatus narinari	X			X	X
Synodontidae (Lizardfishes)					
Saurida gracillis		X	X		
Synodus binotatus		X	X		
Synodus variegatus			X	X	
Congridae (Conger Eels)					
Conger marginatus (=*C. noordziekii*)		X			
Ophichthidae (Snake Eels)					
Brachysomophis sauropsis		X	X		
Leiuranus semicinctus	X	X	X		
Leptenchelys labialis		X			
Muraenchelys cookei		X	X		
Muraenichthys gymnotus		X			
Muraenichthys schultzei		X	X		
Myrichthys bleekeri	X	X			
Myrichthys maculosus	X	X	X		
Phyllophichthus xenodontus			X		
Schultzidia johnstonensis		X	X		
Xenocongridae (False Moray Eels)					
Kaupichthys diodontus			X		
Moringuidae (Worm Eels)					
Moringua macrochir		X	X		

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	Brock, *et al.*, 1965 Dec. 1963– June 1965	Brock, *et al.*, 1966 Aug. 1964– Aug. 1965
Muraenidae (Moray Eels)					
Anarchias allardicei		X	X		
Anarchias cantonensis		X			
Anarchias leucurus		X	X		
Echidna leucotaenia		X			
Echidna polyzona		X			
Echidna unicolor			X		
Echidna zebra		X			
Gymnothorax sp.			X		
Gymnothorax buroensis	X				
Gymnothorax eurostus		X	X	X	
Gymnothorax gracilicaudus		X	X		
Gymnothorax javanicus	X		X	X	X
Gymnothorax meleagris	X	X	X		
Gymnothorax molucsensis		X	X		
Gymnothorax pictus	X				
Gymnothorax undulatus		X	X		
Rabula fuscomaculata		X	X	X	
Uropterygius sp.				X	
Uropterygius fuscoguttatus		X	X		
Uropterygius knighti			X		
Uropterygius polyspilus		X			
Uropterygius supraforatus (=*U. dentatus*)		X	X		
Uropterygius tigrinus	X	X			
Belonidae (Needlefishes)					
Belone platyura	X	X			
Hemiramphidae (Halfbeaks)					
Hyporhamphus acutus		X	X		

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	 Dec. 1963– June 1965	Brock, *et al.*, 1966 Aug. 1964– Aug. 1965
Exocoetidae (Flyingfishes)					
Cypselurus peocilopterus	X				
Cypselurus simus	X				
Aulostomidae (Trumpetfishes)					
Aulostomus chinensis	X	X	X	X	X
Fistulariidae (Cornetfishes)					
Fistularia petimba	X	X	X	X	
Syngnathidae (Pipefishes)					
Doryrhamphus melanopleura			X		
Holocentridae (Soldierfishes or Squirrelfishes)					
Holocentrus lacteoguttatus	X	X	X		
Holocentrus microstomus	X				
Holocentrus sammara	X	X	X	X	X
Holocentrus spinifer	X	X	X	X	X
Holocentrus tiere	X	X	X	X	X
Holotrachys lima		X	X		
Myripristis argyromus	X	X	X	X	
Myripristis berndti	X		X		
Apogonidae (Cardinal Fishes)					
Apogon erythrinus		X	X		
Apogon manesemus		X	X	X	X
Apogon snyderi	X	X	X		
Apogon waikiki		X			
Pseudamiops gracilicaude		X	X		

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	 Dec. 1963- June 1965	Brock, *et al.*, 1966 Aug. 1964- Aug. 1965
Kuhliidae (Aholeholes)					
Kuhlia marginata	X	X			
Grammistidae (=Pseudo-chromidae)					
Pseudogramma polyacantha		X	X	X	
Priacanthidae (Big Eyes)					
Priacanthus cruentatus	X	X	X		
Serranidae (Sea Bass)					
Pristipomoides sieboldii	X				
Lutjanidae (Snappers)					
Aphareus furcatus			X		
Kyphosidae (Rudderfishes)					
Kyphosus bigibbus		X			
Kyphosus vaigiensis		X			
Mullidae (Sunmullets, Goat-fishes)					
Mulloidichthys auriflamma	X		X	X	X
Mulloidichthys samoensis	X	X	X	X	X
Parupeneus barberinus	X			X	X
Parupeneus bifasciatus	X	X		X	X
Parupeneus chryserydros	X			X	X
Perupeneus crassilabris	X			X	X
Parupeneus multifasciatus	X	X			
Parupeneus trifasciatus	X				

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965		Brock, *et al.*, 1966
			Aug. 1963	Dec. 1963- June 1963	Aug. 1964- Aug. 1965
Cirrhitidae (Hawkfishes)					
Amblycirrhites bimacula		X	X		
Cirrhitus alternatus			X	X	
Cirrhitus pinnulatus	X	X	X		
Paracirrhites arcatus			X	X	
Paracirrhites forsteri			X	X	
Carangidae (Pompano, Ulua, Papio)					
Carangoides ferdau	X	X		X	
Caranx ascensionis	X				
Caranx dasson	X				
Caranx gymnostethoides	X				
Caranx lugubris	X				
Caranx melampygus	X			X	X
C. (=*Gnathanodon*) *speciosis*					X
Scomberoides sancti-petri	X		X		
Trachurops crumenophthalmus		X			
Pomacentridae (Damselfishes)					
Abudefduf imparipennis	X	X		X	X
Abudefduf phoenixensis	X	X			
Abudefduf sordidus	X			X	X
Chromis leucurus	X	X	X	X	X
Chromis vanderbilti		X	X	X	X
Dascyllus albisella					
Dascyllus marginatus	X				X
Plectroglyphidodon johnstonianus	X	X	X	X	X

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965		Brock, *et al.*, 1966
			Aug. 1963	Dec. 1963–June 1963	Aug. 1964–Aug. 1965
Labridae (Wrasses)					
Bodianus bilunulatus	X			X	X
Cheilinus rhodochrous	X			X	X
Cheilio inermis			X	X	
Cheilio flauauittata					X
Coris gamimardi			X	X	X
Epibulus insidiator	X	X	X	X	X
Gomphosus varius (includes *G. tricolor*)	X	X	X	X	X
Halichoeres ornatissimus	X	X		X	
Labroides phthirophagus			X	X	X
Novaculichthys taeniourus		X			
Pseudocheilinus hexataenia	X				
Pseudocheilinus octotaenia		X		X	
Pseudocheilinus tetrataenia			X	X	
Stethojulis albovittata				X	X
Stethojulis axillaris		X	X	X	X
Thalassoma ballieui	X		X	X	X
Thalassoma fuscum			X		
Thalassoma duperreyi	X	X	X	X	X
Thalassoma lutescens	X	X	X	X	X
Thalassoma purpureum	X				X
Thalassoma quinquevittata		X	X	X	X
Thalassoma umbrostigma					X
Scaridae (Parrotfishes)					
Calotomus spinidens (=*C. sandvicensis*)		X	X		X
Scarus cyanogrammus	X				
Scarus dubius	X	X	X		X
Scarus duperreyi	X				

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	 Dec. 1963–June 1963	Brock, *et al.*, 1966 Aug. 1964–Aug. 1965
Scaridae (cont.)					
Scarus erythrodon	X				
Scarus forsteri	X				
Scarus perspicillatus	X	X	X	X	X
Scarus sordidus	X	X	X	X	X
Scarus sp. (grey)					X
Scarus sp. (blue-green)					X
Chaetodontidae (Butterfly-fishes)					
Centropyge flammeus	X	X		X	X
Centropyge nigriocellus	X		X		
Chaetodon auriga	X	X	X	X	X
Chaetodon citrinellus	X	X	X	X	X
Chaetodon ephippium	X	X	X	X	X
Chaetodon multicinctus	X	X	X	X	X
Chaetodon ornatissimus	X	X	X	X	X
Chaetodon quadrimaculatus	X	X	X	X	X
Chaetodon reticulatus			X	X	
Chaetodon trifasciatus	X		X	X	X
Chaetodon unimaculatus	X	X	X	X	X
Chaetodon eol				X	
Forcipiger longirostris			X	X	
Hermitaurichthys thompsoni			X	X	X
Megaprotodon strigangulus	X		X	X	X
Zanclidae (Moorish Idols)					
Zanclus cornutus	X	X		X	X
Acanthuridae (Surgeonfishes)					
Acanthurus achilles	X	X	X	X	X
Acanthurus glaucopareius			X	X	X

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965		Brock, *et al.*, 1966
			Aug. 1963	Dec. 1963- June 1963	Aug. 1964- Aug. 1965
Acanthuridae (cont.)					
Acanthurus guttatur				X	
Acanthurus mata					X
Acanthurus nigroris (=*A. elongatus*)	X	X	X	X	X
Acanthurus olivaceus	X	X		X	X
Acanthurus sandvicensis	X	X	X	X	X
Ctenochaetus cyanoguttatus					X
Ctenochaetus hawaiiensis				X	X
Ctenochaetus striatus	X				
Ctenochaetus strigosus	X	X	X	X	X
Naso lituratus	X	X	X	X	X
Naso unicornis	X	X	X		
Zebrasoma flavescens	X	X	X	X	X
Zebrasoma veliferum			X		
Eleotridae (Sleepers)					
Eviota viridis	X				
Gobiidae (Gobies)					
Bathygobius fuscus	X				
Gnatholepis anjerensis		X	X	X	
Hazeus unisquamis			X		
Zonogobius farcimen		X			
Blenniidae (Blennies)					
Cirripectes variolosus	X	X	X	X	
Exallias brevis		X	X		
Istiblennius gibbifrons (=*Salarias gibbifrons*)	X	X	X		

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	 Dec. 1963- June 1963	Brock, *et al.*, 1966 Aug. 1964- Aug. 1965
Brotulidae (Brotulids)					
Brotula townsendi		X			
Mugilidae (Mullets)					
Neomyxus chaptalii	X	X			
Sphyraenidae (Barracudas)					
Sphraena japonica	X				
Polynemidae (Threadfins)					
Polydactylus sexfilis	X				
Scorpaenidae (Scorpion Fishes)					
Scorpaena ballieui		X			
Scorpaena coniorta		X			
Scorpaenodes parvipinnis			X		
Bothidae (Flounder or Flatfishes)					
Bothus mancus	X	X		X	X
Echeneidae (Renoras)					
Remora remora		X			
Balistidae (Triggerfishes)					
Balistes bursa			X		
Melichthys buniva	X	X	X	X	X
Melichthys ringens	X				
Melichthys vidua	X	X		X	X
Rhinecanthus aculeatus	X	X	X	X	X

Table 15. (continued)

	Smith and Swain 1882 Fowler and Ball 1925 Halstead and Bunker 1954	Gosline 1955	Brock, *et al.*, 1965 Aug. 1963	Brock, *et al.*, 1965 Dec. 1963– June 1963	Brock, *et al.*, 1966 Aug. 1964– Aug. 1965
Monacanthidae (Filefishes)					
Alutera scripta			X	X	
Amanses carolae	X				X
Amanses sandwichiensis	X	X	X	X	
Pervagor melanocephalus	X	X	X	X	
Pervagor spilosoma					X
Ostraciontidae (Trunkfishes)					
Kentrocarpus hexagonus	X				
Ostracion cubicus	X				
Ostracion lentiginosus	X	X	X	X	X
Ostracion meleagris	X				
Ostracion solorensis	X		X		X
Tetraodontidae (Puffers)					
Arothron meleagris	X	X	X	X	X
Canthigasteridae (Sharp-nosed Puffers)					
Canthigaster jactator	X	X	X	X	X
Diodontidae (Box Fishes)					
Diodon hystrix	X				
Total Species	109	111	115	85	73
New to Atoll	109	49	29	1	5
Old Species Not Seen	0	46	71	101	120

Ciguateric Fishes

The first identified cases of ciguatera-type fish poisoning occurred at Johnston Atoll in 1950. According to Halstead and Bunker (1954a), there were about 20 cases of ciguatera poisoning between May 1950 and May 1951. Fishes thought by island workers to be dangerous to eat included: puffers (Tetraocontidae), triggerfish (Balistidae), saboti (Kuhliidae), ulua (Carangidae), "tuna" (probably *Euthynnus yaito*, a skipjack), "red or blue toothless snapper" (?), moray eels (Muraenidae), and surmullet (Mullidae).

Following this 1950 poison outbreak, Halstead and Bunker (1954a) studied the ciguatera problem at Johnston Atoll. They collected fishes in May, October and November 1951. They found that of 60 species (211 specimens) of 21 families tested, 47 species (78 percent), and 98 specimens (46 percent) were toxic (Table 16). Both the musculature and viscera of specimens were found to be toxic. Although the bioassay method used in this 1954 study was later found to be of questionable value (Banner, *et al.*, 1960), numerous species of inshore fishes were toxic as evidenced by the numerous cases of ciguatera poisoning reported (Banner and Helfrich, 1964; Brock, *et al.*, 1965).

By 1963, however, the poison problem appeared to have subsided (Banner and Helfrich, 1964). In August 1963, 21 species (224 specimens) of 11 families were examined for poison (Table 16) by Brock, *et al.*, (1965). Of these 21 species, only two (10 percent) were toxic: the white-tipped reef shark *Triaenodon obesus* (11 percent) and the large moray eel *Gymnothorax javanicus* (80 percent). By interviewing island construction workers (mostly from Hawaii), they also discovered that many varieties of lagoon fishes were eaten locally. Most "expressed a willingness to eat any of the Johnston...fishes except black ulua, moray eels, and sharks."

Brock, *et al.* (1965: 23) described the situation at Johnston Atoll as "...what might be expected near the termination of a period of occurrence of ciguatera poisoning in fishes. Such a period would become first evident by the herbivorous species becoming toxic. Following the initial stage both herbivorous and carnivorous species would be toxic, the latter through predation of the herbivores. This period may last for a number of years. Its termination would be marked first by the absence of young toxic herbivores, followed by the absence of young toxic carnivores. The residual effects would be evident through the occurrence of ciguatera toxin only in the large, long lived predators. Once a fish becomes toxic it appears to remain so for long periods of time even though it does not continue to consume toxic prey. However, the toxin locked up in the bodies of the larger predators can recycle back into other predators either large or small upon the occasion of their death from old age or disease or some other cause."

Randall (1958) suggested that the toxin responsible for ciguatera was produced by algae, possibly a blue-green algae, which occurred early and abundantly during the successional invasion of a newly denuded substrate by algae. The algae would be eaten by herbivorous animals and these, in turn, by carnivorous animals. Brock, *et al.* (1965) noted that if Randall's hypothesis was valid, a substantial increase in the number and species of toxic fish, beginning with the herbivorous species, should follow the dredging operations at Johnston which began in August 1963. At the beginning of this dredging, none of these herbivorous species was found to be toxic; only the larger predacious sharks and eels were toxic.

Ciguatera poison cases, in fact, did continue (Brock, *et al.*, 1966). Several poisonings (one serious, the others mild) were reported in May 1964 involving a predacious black ulua *Caranx melampygus*. In addition, two rather serious cases occurred in August 1965, with several species of reef fishes involved.

Likewise, a slight increase in numbers of toxic fishes occurred (Brock, *et al.*, 1966). Of 38 species examined during August 1964 to August 1965 (number of specimens unknown), six species of five families (16 percent) were toxic. As in the 1963 study, the moray eel *Gymnothorax javanicus* was most toxic at 48 percent, with the white-tipped reef shark *Triaenodon obesus* second at 19 percent toxic (Table 16). Another shark species--the grey sand shark *Carcharhinus menisorrah*--was also found to be toxic (11 percent); this species was not toxic in the 1963 tests. Three other species--all herbivorous--not toxic in 1963 were also toxic in the 1964-1965 tests. They were *Ctenochaetus strigosus*, a surgeon fish, and *Melichthys buniva* and *M. vidua*, both triggerfishes; all three fed mainly on algae. Furthermore, in some of the dredged areas thick algal mats developed over the whole bottom, with the blue-green algae *Lyngbya majescula* being the dominant species.

From these data, Brock, *et al.* (1966) suggested that a new cycle in the production of ciguateric fishes at Johnston may be in an initial stage. These data also support Randall's 1958 hypothesis discussed earlier for indeed following dredging (1) the blue-green algae increased, (2) the number of toxic herbivorous fish species increased, and (3) the number of ciguatera poisonings increased.

Published Johnston Atoll toxin data from 1966 through 1973 has been very limited, but does suggest that little change in toxicity levels has occurred. Brock (1972) found that ciguatera toxin in the moray eel *Gymnothorax javanicus* has not statistically changed in level from 1963 to 1970; these data are presented in a later section.

It is not known whether seabirds are affected by ciguatera poisoning; however, Halstead and Bunker (1954b) discovered that experimental chickens are apparently unaffected by the less virulent fish poisons. Most seabirds at Johnston and elsewhere in the central Pacific, moreover, do not feed on inshore lagoon fishes. At Johnston, only Brown Boobies have been observed feeding in the lagoon and this species, White Terns, and Black Noddies normally feed offshore near the atoll; the remaining species usually feed well at sea (King, 1967).

Table 16. Toxicity of fish species tested for ciguatera at Johnston Atoll

	Halstead and Bunker, 1954			Brock, *et al.*, 1965			Brock, *et al.*, 1966*		
	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic
Triaenodon obesus				20	2	11.1	26	5	19.2
Carcharhinus menisorrah				1	0	0	35	4	11.4
Aetobatus narinari	1	1	100.0						
Gymnothorax buroensis	5	1	20.0						
Gymnothorax javanicus	2	1	50.0	66	53	80.3	121	58	47.9
Gymnothorax meleagris	2	1	50.0	1	0	0			
Belone platyura	1	1	100.0						
Aulostomus chinensis	5	3	60.0						
Holocentrus lacteoguttatus	2	2	100.0						
Holocentrus sammara	1	0	0	18	0	0			
Holocentrus spinifer	7	2	28.6	1	0	0			
Holocentrus tiere	3	0	0						
Myripristis argyromus	3	2	66.7	16	0	0			
Myripristis berndti	1	1	100.0						
Apogon menesemus	2	2	100.0						
Priacanthus cruentatus	2	1	50.0						

Table 16. (continued)

	Halstead and Bunker, 1954 No. Tested	No. Toxic	% Toxic	Brock, *et al.*, 1965 No. Tested	No. Toxic	% Toxic	Brock, *et al.*, 1966 No. Tested	No. Toxic	% Toxic
Kyphosus bigibbus	1	0	0						
Molloidichthys auriflamma	2	1	50.0	17	0	0			
Mulloidichthys samoensis	7	2	28.6	1	0	0			
Parupeneus bifasciatus	3	1	33.3						
Parupeneus chryserydros	2	2	100.0						
Parupeneus crassilabris	1	0	0						
Paurpeneus trifasciatus	4	3	75.0						
Carangoides ferdau	5	1	20.0	1	0	0			
Caranx lugubris	5	2	40.0						
Caranx melampygus	4	2	50.0	1	0	0			
Abudefduf sordidus	7	6	85.7						
Dascyllus albisella				7	0	0			
Dascyllus marginatus	4	3	75.0						
Plectroglyphidodon johnstonianus	1	1	100.0	1	0	0			
Cheilinus rhodochrous	5	1	20.0						
Epibulus insidiator	4	2	50.0	6	0	0			

Table 16. (continued)

	Halstead and Bunker, 1954			Brock, *et al.*, 1965			Brock, *et al.*, 1966		
	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic
Thalassoma duperreyi	1	1	100.0						
Scarus cyanogrammus	1	0	0						
Scarus dubius	1	0	0						
Scarus duperreyi	1	0	0						
Scarus forsteri	1	0	0						
Scarus perspicillatus	12	2	16.7						
Scarus sordidus	7	0	0						
Chaetodon auriga	7	3	42.9						
Chaetodon citrinellus	1	1	100.0						
Chaetodon ephippium	2	2	100.0						
Chaetodon multicinctus	2	1	50.0						
Chaetodon ornatissimus	5	1	20.0						
Megaprotodon strigangulus	1	0	0						
Zanclus cornutus	1	1	100.0						
Acanthurus achilles	4	1	25.0	5	0	0			
Acanthurus nigroris	13	8	61.5	10	0	0			

Table 16. (continued)

	Halstead and Bunker, 1954			Brock, *et al.*, 1965			Brock, *et al.*, 1966		
	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic
Acanthurus olivaceus	6	2	33.3						
Acanthurus sandvicensis	5	2	40.0	16	0	0			
Ctenochaetus hawaiiensis				2	0	0			
Ctenochaetus striatus	7	5	71.4						
Ctenochaetus strigosus				5	0	0			
Naso lituratus	7	3	42.9						
Zebrasoma flavescens	1	1	100.0						
Botus mancus	2	0	0						
Melichthys buniva				3	0	0			
Melichthys ringens	11	4	36.4						
Melichthys vidua	2	2	100.0						
Rhinecanthus aculeatus	3	1	33.3						
Amanses carolae	2	0	0						
Amanses sandwichiensis	1	1	100.0						
Kentrocarpus hexagonus	1	0	0						
Ostracion cubicus	1	1	100.0						

Table 16. (continued)

	Halstead and Bunker, 1954			Brock, *et al.*, 1965			Brock, *et al.*, 1966		
	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic	No. Tested	No. Toxic	% Toxic
Ostracion meleagris	9	9	100.0						
Arothron meleagris				26	0	0			
Canthigaster jactator	1	1	100.0						
Number of Specimens	211	98	46.4	224	55	20.1	182	67+	36.7
Number of Species	60	47	78.3	21	2	9.5	38	6	15.7

*Thirty-two other species in addition to the six listed were tested for toxin; all were negative but their names were not given.

Species Accounts

Although the fish fauna of Johnston Atoll is well known, very little is known about the biology of individual species occurring there. Only one species, a moray eel, and one family have been studied extensively.

MORAY EEL *Gymnothorax javanicus*

Status

Abundant breeding species; present year-round throughout the lagoon and reef waters. Breeds during the summer months. Highest of all fishes toxic to man at Johnston; up to 80 percent are toxic.

Ecological Distribution

Halstead and Bunker (1954a) first collected two specimens of *Gymnothorax javanicus* from Johnston Atoll in 1951. Additional observations and collections were reported by Brock, *et al.* (1965, 1966) during 1963 through 1965. Brock (1972) found it to be very abundant from 1963 to 1971. In all, 1,165 specimens were taken at Johnston by the Marine Toxins Program of the Hawaii Institute of Marine Biology, University of Hawaii.

This species is a coral reef dweller, is very cryptic in color, and hides in reef crevices. At Johnston, it has been found throughout the lagoon and reef waters. It has been found under rubble in extensively dredged areas, but is more commonly encountered in areas of dense coral growth. Its vertical range is unknown, but has been collected at Johnston at depths ranging from 0.3 to 17 meters.

Populations

Although Brock, *et al.* (1965, 1966) found *G. javanicus* rare in their studies, Brock (1972) found fair numbers (6 to 164, mean = 50) in a sample of 648 eels collected at 13 stations throughout the lagoon. Additional population estimates or studies are lacking.

This species--perhaps the largest of the Indo-Pacific morays--probably lives to be older than 20 years. The only eel predators of significance at Johnston appear to be sharks (Brock, 1972).

Annual Cycle

Gymnothorax javanicus occurs at Johnston Atoll throughout the year, although breeding occurs only in June, July, and August. Females release about 188,000 to 291,000 eggs per spawning. Males mature at 3.4 kg and females at 4.6 kg in weight. Males, however, attain a larger size than females.

This species feeds chiefly crepuscularly and nocturnally; however, attempted diurnal feeding has been observed. The variety of food items indicates it is an opportunistic predator; 89 percent consisted of fishes. Gut content analysis revealed, however, that this species feeds infrequently (Brock, 1972).

Ciguatera

Halstead and Bunker (1954a) first documented ciguatera at Johnston in 1950 and noted that toxin occurred in one of two *Gymnothorax javanicus* specimens examined. Brock (1972) examined 887 eels of this species taken at Johnston and found no statistically significant differences between the levels of toxicity from 1963 through 1970.

Analysis of the distribution of toxicity showed no significant differences in the levels of toxicity among the 14 habitat areas; however, there was a significant correlation of toxicity with depth. This further suggests that there is more toxin in the food of *G. javanicus* at depths of 6 to 12 meters, compared to depths of 0 to 6 meters. This species also displayed a significant increase in toxicity with increasing body size. No significant difference in the toxicity of the flesh from males and females existed, however. Up to 80 percent of all specimens examined were toxic (Brock, 1972).

Movement

Mark and recapture methods, as well as indirect observations, suggested that on a short-term basis (less than one year) *Gymnothorax javanicus* has a definite home range and its migration is restricted (Brock, 1972).

SURGEONFISHES Acanthuridae

Jones (1968) studied ecological relationships between 13 species of surgeonfishes, family Acanthuridae, found on Johnston Atoll in an attempt to determine habitat separation and feeding habits.

He concluded that although there appeared to be unlimited food available for all species, the fishes were separable on ecological grounds. He recognized four species groups by habitat (mid-water, sand patch, subsurge reef, and surge zones); three different ways of feeding (zooplankton feeders, grazers, and browsers); and at least four different categories of foods eaten (zooplankton, interstitial material, coarse algae, and filamentous algae). He also described numerous modifications of the alimentary canal which suggested interspecific differences in food handling. He hypothesized that there must be infrequent periods of food shortage during which selection pressure was high enough to favor adaptations that would tend to reduce interspecific competition.

Reptiles

Two reptile species--"one long brown species and one shorter grey species"--were recorded by E.H. Bryan, Jr. (ms.) in July 1923 when the first scientific visit was made to Johnston Atoll. He indicated that these were then abundant. Five species of reptiles are now known from the Atoll. All but one species, the Black Sea Turtle, were probably introduced by man. They are all known from various islands throughout the central Pacific.

Of the five species, two species occur only on Johnston Island and two species occur on Sand Island. Only one species occurs on both islands. As of 1969, none was known from Akau and Hikina Islands.

Species Accounts

There are no general references that illustrate the reptiles of Johnston Atoll. Taxonomy of the turtles follows Carr (1972) and Amerson (1971). Order of listing for lizards follows Brown (1957).

BLACK SEA TURTLE *Chelonia agassizi*

Status

Regular uncommon visitor; known from the lagoon, offshore Johnston Island, and Sand Island.

Observations

Brooke (ms.), who visited Johnston Atoll in March 1859, commented about the lack of turtles: "The reefs are covered with fish of various kinds. Mullet abound, but there are no turtles." Wetmore (ms. a and b), likewise, recorded no turtles at Johnston Atoll in July 1923.

POBSP personnel recorded sea turtles in the shallow marginal reef area west of Johnston Island in July 1963. An adult (USNM 163581) was collected 20 November 1966 on the beach of Sand Island. Island personnel in 1973 reported seeing 10 to 12 turtles offshore of Johnston Island throughout the year. A longtime resident estimated harvesting 12 to 15 per year.

Annual Cycle

The Black Sea Turtle apparently visits Johnston Atoll year-round. No records exist of it breeding on the atoll, although perhaps it did in small numbers prior to inhabitation by man. This species breeds during the summer in the northwestern Hawaiian Islands, especially at French Frigate Shoals (Amerson, 1971).

HOUSE GECKO *Hemidactylus frenatus*

Status

Common introduced breeder; occurs only on Sand Island.

Observations

It is not known when House Geckos were introduced to Johnston Atoll. POBSP personnel collected two specimens from Sand Island in May 1964 (USNM 154207-208) and two more in May and March 1966 (USNM 163579-580).

FOX GECKO *Hemidactylus garnotii*

Status

Uncommon introduced breeder; occurs on Johnston and Sand Islands.

Observations

POBSP personnel collected a Fox Gecko from Johnston Island 2 July 1966 (USNM 166825). Another was collected at Sand Island 22 August 1968 (USNM 166863).

MOURNING GECKO *Lepidodactylus lugubris*

Status

Uncommon introduced breeder; occurs only on Johnston Island.

Observations

A Mourning Gecko was collected (USNM 156990) from Johnston Island 28 October 1964 by POBSP personnel.

SNAKE-EYED SKINK *Ablepharus boutonii poecilopleurus*

Status

Uncommon introduced breeder; occurs only on Johnston Island; present status unknown.

Observations

Thirteen specimens of this species were collected by E.H. Bryan, Jr., on Johnston Island in July 1923 (USNM 66810-22). None has been recorded since.

Birds

Several sources were used in assembling the common and scientific names of the birds occurring at Johnston Atoll (Table 17). The names used in the American Ornithologists' Union's *Check-list of North American Birds* (1957), as amended by Eisenmann, *et al.* (1973), were followed for species occurring in North America. In the interest of consistency, seabird names agree with those which appear in Watson's *Smithsonian Identification Manual: Seabirds of the Tropical Atlantic Ocean,* and King's *Smithsonian Identification Manual: Seabirds of the Tropical Pacific Ocean.* Taxonomic order follows that of Peter's *Check-list of Birds of the World,* volumes I, II, and III, with the exception of the Procellariiformes, which follow Alexander, *et al.* (1965), the Anseriformes, which follow Delacour (1954, 1959), and the Charadriiformes, which follow Bock (1958) and Jehl (1968).

Table 17. *Birds from Johnston Atoll***

Order Procellariiformes	
Family Diomedeidae	
*Diomedea nigripes**	Black-footed Albatross
*Diomedea immutabilis**	Laysan Albatross
Family Procellariidae	
*Pterodroma alba**	Phoenix Petrel
Bulweria bulwerii	Bulwer's Petrel
Puffinus pacificus	Wedge-tailed Shearwater
Puffinus nativitatis	Christmas Shearwater
*Puffinus puffinus newelli**	Newell's Shearwater
Family Hydrobatidae	
*Oceanodroma tristrami**	Sooty Storm Petrel
Order Pelecaniformes	
Family Phaethontidae	
*Phaethon aethereus**	Red-billed Tropicbird
Phaethon rubricauda	Red-tailed Tropicbird
*Phaethon lepturus**	White-tailed Tropicbird
Family Sulidae	
*Sula dactylatra**	Blue-faced Booby
Sula leucogaster	Brown Booby
Sula sula	Red-footed Booby
Family Fregatidae	
Fregata minor	Great Frigatebird
*Fregata ariel**	Lesser Frigatebird
Order Ciconiiformes	
Family Ardeidae	
*Bubulcus ibis**	Cattle Egret
Order Anseriformes	
Family Anatidae	
*Anas acuta**	Pintail
Anas [=*Mareca*] *americana**	American Wigeon
Anas [=*Spatula*] *clypeata**	Northern Shoveler

Table 17. (continued)

Order Galliformes	
Family Phasianidae	
Gallus gallus	Domestic Chicken
Order Falconiformes	
Family Falconidae	
*Falco peregrinus tundrius**	Peregrine Falcon
Order Charadriiformes	
Family Charadriidae	
*Pluvialis dominica**	American Golden Plover
Pluvialis [=*Squatarola*] *squatarola**	Black-bellied Plover
*Charadrius semipalmatus**	Semipalmated Plover
Family Scolopacidae	
*Numenius tahitiensis**	Bristle-thighed Curlew
Tringa [=*Totanus*] *flavipes**	Lesser Yellowlegs
*Actitis macularia**	Spotted Sandpiper
*Catoptrophorus semipalmatus**	Willet
Heteroscelus incanus [=*incanum*]*	Wandering Tattler
*Arenaria interpres**	Ruddy Turnstone
Limnodromus sp.*	Dowitcher species
Calidris [=*Crocethia*] *alba**	Sanderling
Calidris [=*Ereunetes*] *mauri**	Western Sandpiper
Calidris [=*Erolia*] *melanotos**	Pectoral Sandpiper
Calidris [=*Erolia*] *acuminata**	Sharp-tailed Sandpiper
*Tryngites subruficollis**	Buff-breasted Sandpiper
*Philomachus pugnax**	Ruff
Family Phalaropodidae	
*Steganopus tricolor**	Wilson's Phalarope
Family Laridae	
*Larus glaucescens**	Glaucous-winged Gull
*Larus argentatus**	Herring Gull
*Larus atricilla**	Laughing Gull
*Larus pipixcan**	Franklin's Gull
Larus spp.*	Gull species
Sterna lunata	Gray-backed Tern
Sterna fuscata	Sooty Tern
*Thalasseus elegans**	Elegant Tern
*Procelsterna cerulea**	Blue-gray Noddy
Anous stolidus	Brown Noddy
Anous tenuirostris	Black Noddy
Gygis alba	White Tern
Order Columbiformes	
Family Columbidae	
Columba livia	Rock Dove
Order Strigiformes	
Family Strigidae	
*Asio flammeus**	Short-eared Owl

Table 17. (continued)

Order Passeriformes	
Family Alaudae	
*Alauda arvensis**	Skylark
Family Zosteropidae	
*Zosterops japonica**	Japanese White-eye
Family Estrildidae	
Lonchura striata	Society Finch

**Resident birds are unmarked; non-resident birds are marked with an *.

Introduction

The 56 bird species recorded belong to 10 orders, 19 families, and 38 genera; 22 species are classes as seabirds, and 34 species are waterfowl, marsh, and land birds (Table 18).

Table 18. Status of birds on Johnston Atoll

	Akau	Hikina	Johnston	Sand Original	Sand Man-made
Seabirds:					
Breeders					
Bulwer's Petrel			b	B	B
Wedge-tailed Shearwater			B	B	B
Christmas Shearwater			b	B	
Red-tailed Tropicbird			B	B	B
Brown Booby	?	?	b	B	b
Red-footed Booby			b	B	b
Great Frigatebird	R	R	b	B	b
Gray-backed Tern	B*	B**	b	B	b
Sooty Tern			b	B	b
Brown Noddy	?	B*	bR	B	b
Black Noddy			B**	B	r
White Tern			B	R	R
Former Breeders					
Black-footed Albatross				bR	
Laysan Albatross			b	R	O
Blue-faced Booby			b	bR	r
Visitors					
Phoenix Petrel				R	
Newell's Shearwater				R	
Sooty Storm Petrel					R
Red-billed Tropicbird			R	r	
White-tailed Tropicbird	O		R	O	O
Lesser Frigatebird				R	
Blue-gray Noddy			r	R	

Table 18. (continued)

	Akau	Hikina	Johnston	Sand: Original	Sand: Man-made
Waterfowl, Marsh, and Land Birds:					
Regular Migrants					
Pintail			R	R	R
American Golden Plover	R	R	R	R	R
Bristle-thighed Curlew	R		R	R	R
Wandering Tattler	R	R	R	R	R
Ruddy Turnstone	R	R	R	R	R
Sanderling			R	R	R
Pectoral Sandpiper				R	R
Irregular Visitors					
American Wigeon				R	?
Northern Shoveler				R	?
Glaucous-winged Gull				R	?
Herring Gull			R		R
Laughing Gull			R	R	
Short-eared Owl	R	?	R	R	
Stragglers					
Cattle Egret				R	R
Franklin's Gull					R
Accidentals					
Peregrine Falcon			R	R	
Black-bellied Plover			R	R	R
Semipalmated Plover				R	R
Lesser Yellowlegs				R	
Spotted Sandpiper				R	R
Willet			R		
Dowitcher species				R	
Western Sandpiper					R
Sharp-tailed Sandpiper			R	R	R
Buff-breasted Sandpiper					R
Ruff				R	R
Wilson's Phalarope				R	
Gull species			R		
Elegant Tern				R	
Skylark			R		R
Japanese White-eye			R		R
Introductions					
Domestic Chicken			B**		
Rock Dove			B**		
Society Finch					R
Present Breeders	1*	2**	6	11	3
Former Breeders	0	0	10	2	6
Total species	8	6	35	44	35

B = Breeder; R = Recorded; O = Overflier. Capital letters indicate status 1963-1969; lower case letters indicate status 1923-1962, if different than at present.

* bred only in 1964
** bred only in 1973.

Seabirds

Of the 22 seabird species recorded at Johnston Atoll, 12 are breeders, three are former breeders, and seven are visitors (Table 18).

Breeders: All 12 resident breeding species nest in the Hawaiian Islands and other parts of the tropical Pacific. These 12 appear to have closer affinities with their respective northwestern Hawaiian populations than with those in the Line and Phoenix Islands. See also the Banding and Movement section.

Former Breeders: Three species formerly bred at Johnston Atoll. The Black-footed Albatross presently breeds only in the Hawaiian Islands and the Bonin-Volcano Islands area, while the Laysan Albatross presently breeds exclusively in the Hawaiian Islands. Both species normally range north of 10°N. The Blue-faced Booby breeds throughout the tropical Pacific.

Visitors: In the surrounding ocean one may find both seabird species that use or breed at Johnston Atoll and those that seldom occur there. These latter species (Table 18) include both breeders from the Hawaiian Islands and Line-Phoenix Islands, as well as breeders from other areas of the Pacific who migrate into or through the surrounding waters during their non-breeding season (POBSP, 1967a). Normally most of these 28 bird species stay at sea, but, because of sickness or bad weather, any could alight on the islands at Johnston Atoll.

The seven seabird visitors to Johnston Atoll come from the north, south, and east Pacific.

The Newell's Shearwater breeds exclusively in the main Hawaiian Islands, while the Sooty Storm Petrel breeds only in the Hawaiian Islands and the Bonin-Volcano Islands area. Although the White-tailed Tropicbird and Blue-gray Noddy breed throughout the tropical Pacific, those that visit Johnston are thought to breed primarily in the Hawaiian Islands.

Visitor seabirds from the south Pacific are the Phoenix Petrel and Lesser Frigatebird. Both are equatorial, south-central Pacific breeders. The Lesser Frigatebird has been recorded from the western

Pacific, Wake, and Kure, and may have a clockwise migration pattern that occasionally includes Johnston on the return to their southern Pacific breeding islands.

From the east Pacific comes the Red-billed Tropicbird which breeds on islands along the coast of Central and South America.

Waterfowl, Marsh, and Land Birds

The 34 species of waterfowl, marsh, and land birds recorded at Johnston Atoll (Table 18) are herein divided into regular migrants (seven species), irregular visitors (six species), stragglers (two species), accidentals (16 species), and introductions (three species).

Regular Migrants: One of the regular migrants is the Pintail which breeds in temperate North America, Europe, and Asia. The remaining six species are shore birds which are all arctic breeders. Of the seven species, three--the Pintail, Bristle-thighed Curlew, Pectoral Sandpiper, and Sanderling--are regular, but uncommon. The remainder are common.

These regular migrant shorebirds breed during the summer in the Northern Hemisphere and migrate south for the winter. Some use Johnston Atoll as a "wintering ground"; others, particularly first-year birds, spend the summer here.

Irregular Visitors: Whereas regular migrants have a set pattern to their movements, the six irregular visitors have no set pattern in their visits to Johnston. This group contains two ducks, both temperate breeders; three gulls, all subarctic and temperate breeders; and an owl, which breeds in the north-central Pacific and various temperate areas.

Stragglers: The two species in this group rarely visit Johnston, but the atoll is within their range. The Franklin's Gull breeds in northwestern North America, and the Cattle Egret has its closest breeding population in the main Hawaiian Islands.

Accidentals: The accidental species at Johnston are so classified because they are out of their normal range of occurrence. Fourteen species are arctic and temperate breeders. Two land bird species are introduced north-central Pacific breeders. The rain-water puddles on Johnston may attract accidental birds, especially shorebirds.

Introductions: Three species of birds have been introduced by man. The Rock Dove breeds and the Domestic Chicken probably breeds; both species are semi-tame. The Society Finch is caged.

Annual Cycles

Among the bird species at Johnston Atoll, annual breeding and population cycles vary.

Breeding Cycles: The seabirds breed during all seasons of the year (Fig. 37). Most have short, distinct breeding periods; some have extended breeding cycles. Based on peak breeding periods, the 12 present breeding seabird species are grouped as follows (Table 19): winter and spring breeders (one species), spring and summer breeders (nine species), summer breeders (one species), summer and fall breeders (one species); none is a fall and winter breeder. Two former breeding species were probably winter and spring breeders; another was most likely a spring and summer breeder.

Table 19. Peak breeding period of Johnston Atoll birds

Winter-Spring	Spring-Summer	Summer	Summer-Fall
Gray-backed Tern	Christmas Shearwater	Bulwer's Petrel	Wedge-tailed Shearwater
	Red-tailed Tropicbird		
	Brown Booby		
	Red-footed Booby		
	Great Frigatebird		
	Sooty Tern		
	Brown Noddy		
	Black Noddy		
	White Tern		

Winter and Spring: The single winter and spring breeder is the Gray-backed Tern. In the northwestern Hawaiian Islands, where space and nest site competition is no problem, this species is a spring and summer breeder. Apparently because of nest site competition with Sooty Terns on the reduced space available at Sand Island, the Gray-backed Terns have shifted their nesting cycle so that first eggs are laid by early or mid-winter. Last chicks fledge by late summer. The two former breeders, Black-footed Albatross and Laysan Albatross, were probably winter and spring breeders.

Spring and Summer: Of the nine species with a spring and summer peak breeding period, one is a procellariiform, four are pelecaniforms, and four are charadriiforms. Egg laying and fledging within this group varies. Only two species actually start laying eggs during the spring months: Christmas Shearwater and Black Noddy. Individual birds of the remaining seven species commence laying during the winter months--the Brown Noddy as early as December, the Red-tailed Tropicbird, Brown Booby, Great Frigatebird in January, and the Red-footed Booby, Sooty Tern, and White Tern in February. Of the nine spring-summer breeders, only the young of two species (Black Noddy and White Tern) completely fledge by the end of the summer months. The young of two species (Christmas Shearwater and Sooty Tern) normally commence fledging in the summer and extend into early fall. The Brown Noddy extends its fledging period to late fall. Fledging of the remaining four species (Red-tailed Tropicbird, Brown Booby, Red-footed Booby, and Great Frigatebird) extends into early winter. The Blue-faced Booby, a former breeder, probably had a spring and summer peak breeding season.

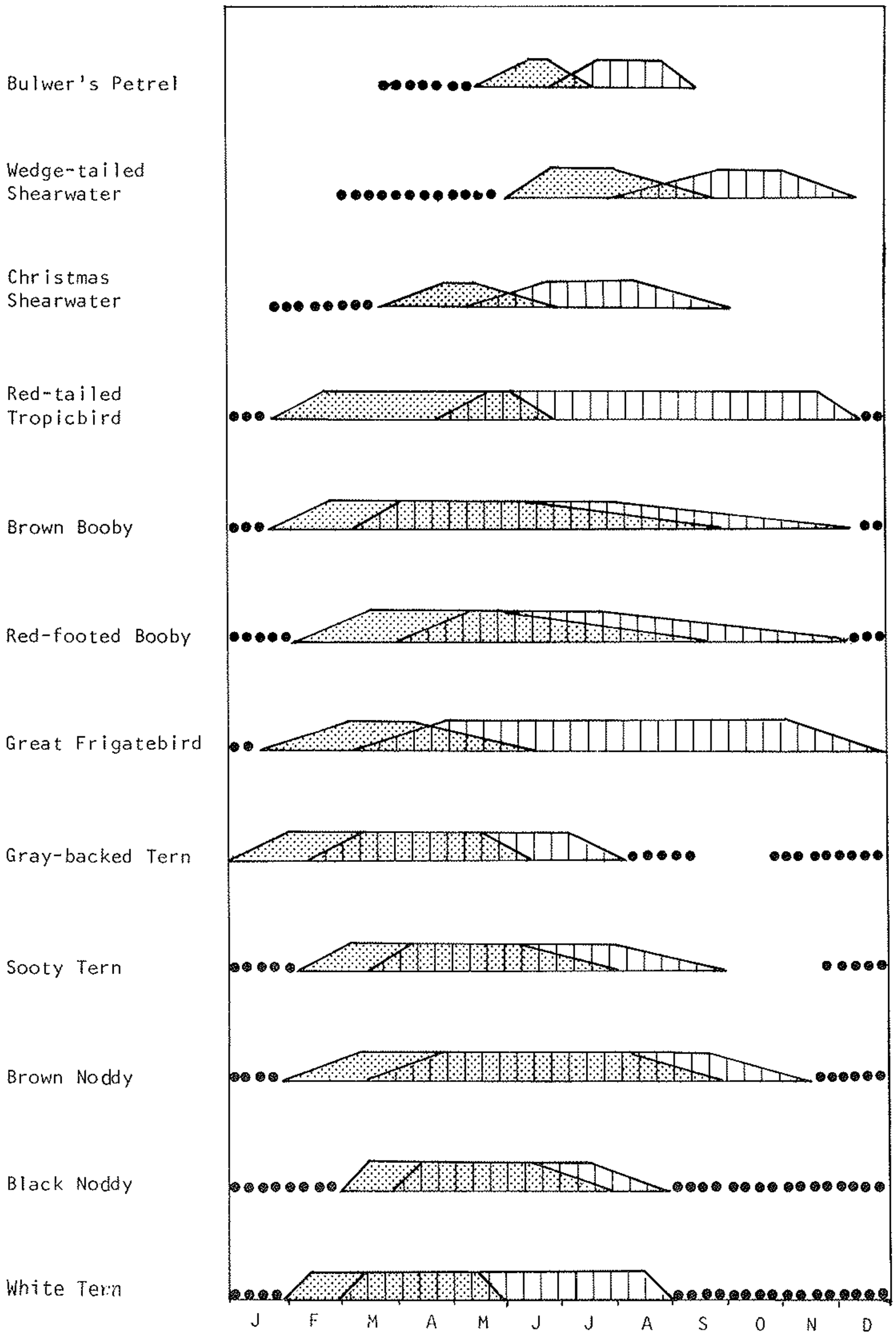


Figure 37. Breeding cycles of seabirds at Johnston Atoll; stippled area represents eggs, barred area young, and black dots non-breeding birds.

Summer: Only one species, Bulwer's Petrel, a procellariid, has a peak breeding season that is contained in a single three-month period. Actually this species could be considered as a spring and summer breeder since courtship begins in late March and first eggs are laid the last of May. Or it could be considered a summer and fall breeder because a few fledglings do not leave until early September. The cycle of this species in the northwestern Hawaiian Islands is in fact slightly later and is there considered to be a summer and fall breeder.

Summer and Fall: The Wedge-tailed Shearwater, a procellariiform, is the only species at Johnston Atoll that has a summer and fall peak breeding period. Eggs are laid in early June and young fledge by late fall or early winter.

Extended: Although all 12 breeding species have a peak breeding period, five species are considered to have an extended breeding season. These are the Red-tailed Tropicbird, Brown Booby, Red-footed Booby, Great Frigatebird, and Brown Noddy. In all of these species, the egg laying period and fledging period each extend at least over a three-season span.

Population Cycles: Many of the bird species using Johnston Atoll leave the Atoll during part of each year; others stay throughout the year (Fig. 37 and Table 20). Even so, all have a population buildup sometime during the year.

Breeding Seabirds: Although the breeding population consists of 12 species, five species are dominant both in total numbers and in their importance to the surrounding ocean (Fig. 38). The Sooty Tern, with a mean population of 300,000 to 310,000 breeding birds in March, April and May, makes up 95 percent or more of the total island population between February and July; perhaps as many as 600,000 Sooty Terns use Johnston Atoll annually.

Red-footed Boobies, whose mean population ranges up to 3,750 birds, ranks second in seabird numbers in winter and spring; most of these birds are transients for only a few young are produced each year. The Brown Noddy ranks third in mean population numbers, but ranks second in number of young (about 1,000) produced each year. The Wedge-tailed Shearwater ranks fourth in numbers of adults using the atoll and is present only from March to early December; it ranks third in numbers of young (up to 250) produced annually. The Great Frigatebird ranks fifth in population numbers (a mean peak of 750 in March and April), but only produces about 130 fledglings yearly. Mean monthly populations for all the other species, combined, never totals more than 600, nor lower than 300.

As is evident from Figure 38, bird population numbers are extremely high (up to 310,000) from mid-winter through summer. This coincides with the peak breeding periods. During the fall and early winter the total population usually is below 9,000 birds.

Table 20. Monthly occurrence of non-resident birds at Johnston Atoll

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black-footed Albatross			X								X	
Laysan Albatross							X				X	X
Phoenix Petrel									X			
Newell's Shearwater						X		X				
Sooty Storm Petrel												X
Red-billed Tropicbird				X	X	X						
White-tailed Tropicbird	X	X	X	X	X		X	X	X			X
Blue-faced Booby	X	X	X	X	X	X	X	X	X	X	X	X
Lesser Frigatebird			X					X				
Cattle Egret	X	X	X	X	X			X	X	X	X	X
Pintail	X	X	X	*	*	*	*	*	X	X	X	X
American Wigeon										X	X	
Northern Shoveler									X	X		
Peregrine Falcon											X	X
American Golden Plover	X	X	X	X	X	X	X	X	X	X	X	X
Black-bellied Plover	X						X				X	X
Semipalmated Plover								X	X	X		
Bristle-thighed Curlew	X	X	X	X	X	X		X	X	X	X	X
Lesser Yellowlegs								X				
Spotted Sandpiper								X	X			
Willet								X				
Wandering Tattler	X	X	X	X	X	X	X	X	X	X	X	X
Ruddy Turnstone	X	X	X	X	X	X	X	X	X	X	X	X
Dowitcher sp.									X	X		
Sanderling	X	X	X	X	X	X	X	X	X	X	X	X
Western Sandpiper									X			
Pectoral Sandpiper				X	X				X	X	X	
Sharp-tailed Sandpiper									X	X		
Buff-breasted Sandpiper									X			
Ruff			X									
Wilson's Phalarope								X				
Glaucous-winged Gull		X	X									
Herring Gull			X								X	X
Laughing Gull			X	X			X			X		
Franklin's Gull					X							
Gull sp.	X	X	X									X
Elegant Tern				X								
Blue-gray Noddy				X	X		X					
Short-eared Owl	X	X	X	X	X	X	X				X	X
Skylark											X	
Japanese White-eye	X				X					X	X	X

*In captivity.

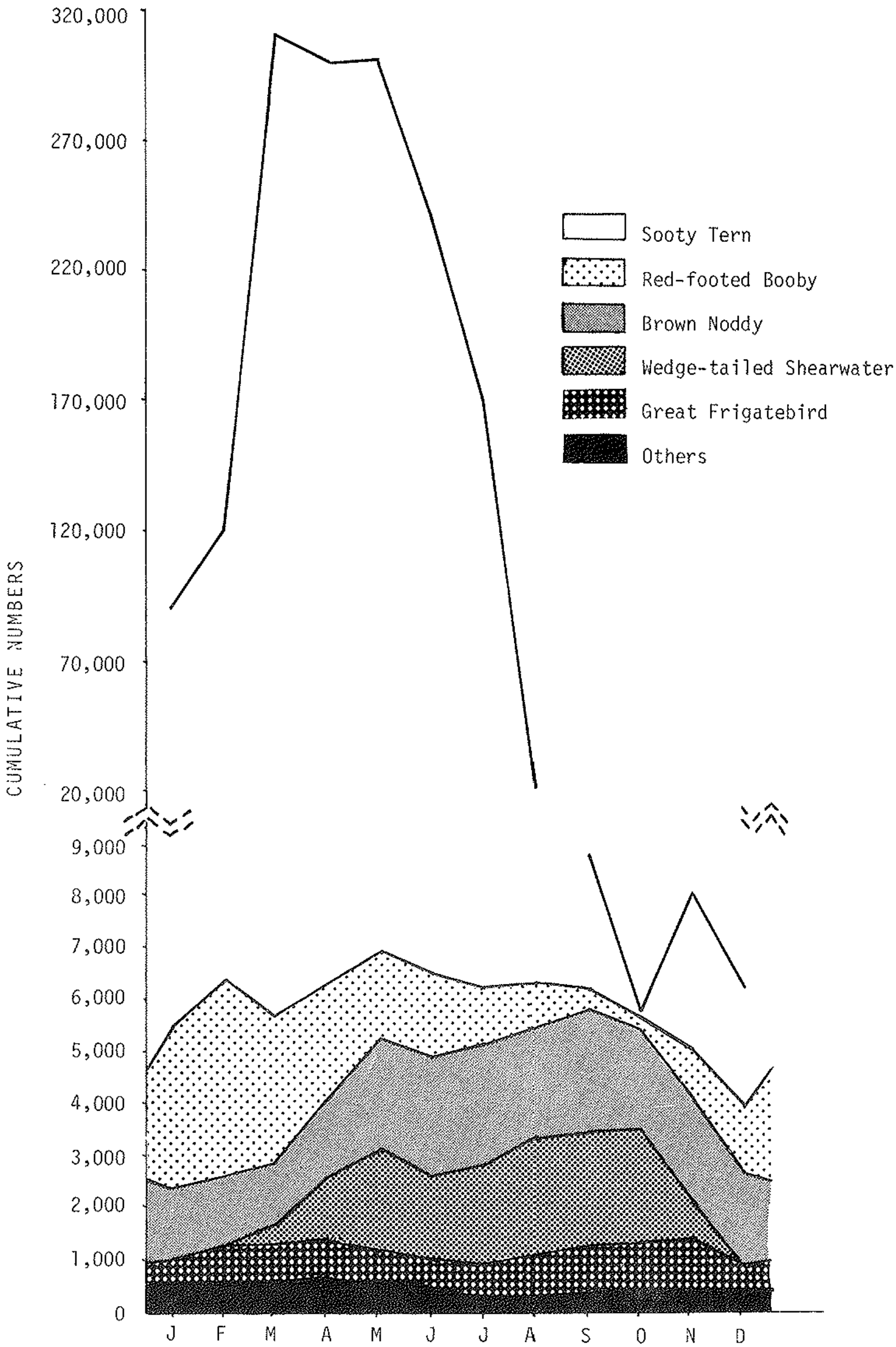


Figure 38. Monthly cummulative bird populations, Johnston Atoll 1963-1969.

Of the 12 breeding species, seven are present on the atoll throughout the year (Fig. 37). The remaining five species spend from 1 1/2 months to six months away from Johnston. Most of these probably leave the central Pacific and migrate to distant areas.

Former Breeding Seabirds: The Blue-faced Booby is present, though uncommon, throughout the year (Table 20). Black-footed Albatross have been recorded on Johnston Atoll in November, and March, while Laysan Albatross have been observed during November, December, and July; both albatrosses may occur offshore during late winter and early spring.

Regular Migrants: Of the seven regular migrants, three--American Golden Plover, Wandering Tattler, and Ruddy Turnstone--are known in all months (Fig. 39 and Table 20). Although the Wandering Tattler and Sanderling are found in low numbers throughout the year, American Golden Plovers and Ruddy Turnstones show peak population periods in fall and mid-winter and early spring; these peaks correspond to migrations from Arctic breeding areas in fall and migrations north in mid-winter and early spring. A slight population decline occurs in early winter; lowest populations occur during the summer months when only immatures remain on the atoll.

The Bristle-thighed Curlew is known from all months except July. The Pintail has been observed in most years from September through March; captive birds have been kept from April through August. The Pectoral Sandpiper has been recorded in most years in April and May and in September, October and November.

Irregular Visitors, Stragglers, and Accidental Birds: The monthly occurrence of the irregular visitors, stragglers, and accidental species is presented in Table 20.

As for the seven visiting seabirds, the White-tailed Tropicbird has been recorded from all months except for June, and October and November. The Red-billed Tropicbird, however, is known only from April, May, and June. Similarly, the Blue-gray Noddy is known from April, May, and July. The Lesser Frigatebird has been recorded during March and August. The Newell's Shearwater also has only occurred during two months--June and August. The Phoenix Petrel and Sooty Storm Petrel have been seen only one month, respectively September and December.

Of the six irregular gull visitors, the Laughing Gull has been recorded from four months, the Herring Gull from three months, and Glaucous-winged Gull from two months. The American Wigeon and Northern Shoveler are each known from two months. The Short-eared Owl, however, has been observed in all months except August, September, and October.

One of the two stragglers, the Cattle Egret, is known from all months except June and July, while the other, the Franklin's Gull, is known from only March.

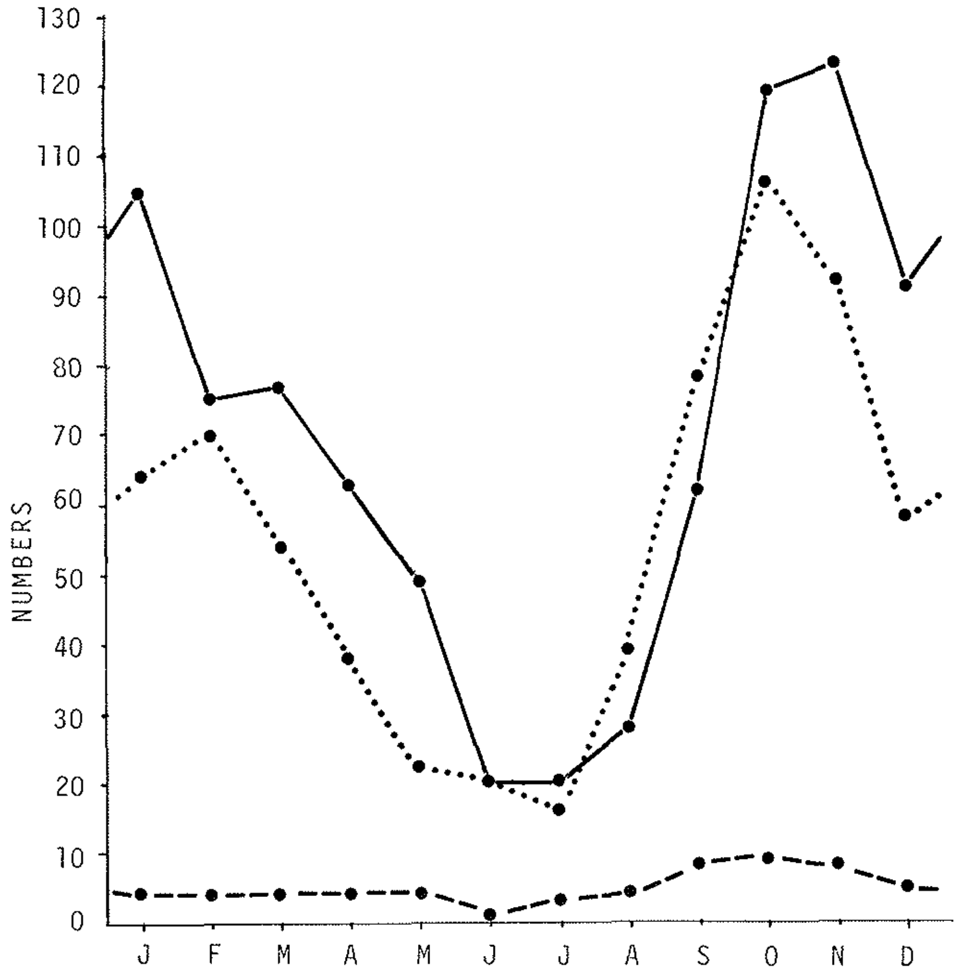


Figure 39. Monthly mean shorebird populations for Johnston Atoll, 1963-1969; Golden Plover (solid line), Ruddy Turnstone (dots), Wandering Tattler (dashes).

Of the 15 accidental waterfowl, marsh, and land birds, the Japanese White-eye is known from five months, the Black-bellied Plover from four months, the Semipalmated Plover and gull species from three months each, the Peregrine Falcon, Spotted Sandpiper, Dowitcher species and Sharp-tailed Sandpiper from two months each; the remaining eight species are known from one month each.

Introduced Birds: The three introduced bird species are known from all months. Furthermore, both breeding species probably breed year-round.

At-Sea Birds: In August 1963, a 50,000 square mile, rectangular, pelagic grid was established by the POBSP, centered approximately 175 miles southwest of Johnston Atoll. In all, 42 monthly survey cruises were conducted in this grid through February 1967. Birds, primarily seabirds, were observed along 22,898 miles of daytime travel and along

10,819 miles of night travel. Pelagic observations maintained for more than 2,500 hours in daytime and more than 1,150 hour at night recorded 33,261 birds of 41 species. Tables 21 and 22 show, respectively, monthly occurrences and area derivation of these species.

Figure 40 presents the monthly fluctuation in the number of birds within this grid. A definite 12-month diurnal cycle exists which has four basic features.

There is a population low from late December through early March and is primarily a reflection of the absence of Sooty Terns and Wedge-tailed Shearwaters. The major elements of the avifauna at this time are probably Johnston Atoll non-breeding species, although at least one north Pacific non-breeding species and two northwestern Hawaiian Islands breeding species regularly occur in small numbers.

A spring peak exists from late March through early May and is primarily the result of the arrival of Johnston Atoll breeding species in the area. In addition, the number of birds is augmented by the passage of migrants moving between distant areas, primarily from the south Pacific to the north Pacific.

There is a summer plateau from late May through August. Johnston Atoll breeding species predominate at this time. The numbers are, however, supplemented by sojourners from the south Pacific.

The cycle shows a fall migration peak--higher even than the spring peak--from September through early December. Migrating seabirds, moving from the north Pacific to the south Pacific, make up the bulk of the pelagic population at this time. Sooty Terns and Wedge-tailed Shearwaters, perhaps from the northwestern Hawaiian Islands and passing through on migration, also contribute to the September peak.

Figure 41 presents the monthly diurnal population fluctuation within the grid by species group. Two groups, the shearwater-petrel group and the tern group, account for over 90 percent of all birds present. The shearwater-petrel group accounts for 54 percent of all birds throughout the year; it is the most abundant of all groups from July through December. The tern group comprises 39 percent of all birds present throughout the year; it is the most abundant group from March through June. The tropicbird group accounts for two percent of all birds present year-round. The booby group accounts for only one percent of all birds present throughout the year, but is the most abundant group from January through February.

In all, 21 seabird species were recorded during the nocturnal observations. Because of the difficulty in observing most species, only Sooty Terns were counted with any degree of accuracy. The nocturnal annual cycle (Fig. 42), therefore, primarily reflects the Sooty Tern cycle rather than the total population. Nevertheless, two population peaks were prominent, one in February, and another in March.

Table 21. Occurrence of birds at sea in the grid 175 miles southwest of Johnston Atoll

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black-footed Albatross	X	X	X	X								X
Laysan Albatross		X										
Dark-rumped Petrel								X	X	X	X	X
Juan Fernandez Petrel	X	X	X	X	X	X	X	X	X	X	X	X
White-necked Petrel	X	X	X	X	X	X	X	X	X	X	X	X
Tahiti Petrel	X	X								X	X	
Phoenix Petrel	X	X								X	X	
Mottled Petrel				X	X					X	X	
Herald Petrel		X										
Kermadec Petrel	X	X			X	X	X	X	X	X	X	X
Bonin Petrel			X	X		X		X		X	X	
Black-winged Petrel	X	X	X	X	X	X	X	X	X	X	X	X
White-winged Petrel			X								X	
Collared Petrel										X		
Bulwer's Petrel			X	X	X		X	X	X	X	X	
Pale-footed Shearwater				X				X		X	X	
Sooty Shearwater				X	X	X			X	X	X	X
Slender-billed Shearwater				X	X	X			X	X	X	X
Wedge-tailed Shearwater (light)	X	X	X	X	X	X	X	X	X	X	X	X
(dark)				X	X	X	X	X	X	X	X	X
New Zealand Shearwater									X			
Christmas Shearwater		X	X	X		X	X	X	X	X	X	X
Newell's Shearwater					X	X	X	X	X		X	
Sooty Storm Petrel		X	X	X								
Leach's Storm Petrel	X	X	X	X	X	X		X		X	X	X
White-throated Storm Petrel								X				
Red-tailed Tropicbird	X	X	X	X	X	X	X	X	X	X	X	X
White-tailed Tropicbird	X	X		X	X	X	X	X	X	X	X	X
Blue-faced Booby	X	X	X	X	X					X	X	X
Brown Booby	X	X	X	X			X			X	X	X
Red-footed Booby	X	X	X	X		X				X	X	X
Great Frigatebird	X	X	X	X	X			X	X	X	X	X
Mallard									X			

Table 21. (continued)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Peregrine Falcon											X	
American Golden Plover										X	X	X
Ruddy Turnstone								X	X	X		
Red Phalarope				X								
Skua								X	X		X	
Pomarine Jaeger					X	X		X		X	X	X
Long-tailed Jaeger				X		X				X	X	X
Laughing Gull			X									
Gray-backed Tern					X			X		X		
Sooty Tern		X	X	X	X	X	X	X	X	X	X	X
Brown Noddy				X				X	X	X	X	X
White Tern	X	X	X	X	X	X	X	X	X	X	X	X
Short-eared Owl											X	

Table 22. Status* and area of derivation of birds observed at sea near Johnston Atoll

Species	Status	Area of Origin	
		Primary	Secondary
Black-footed Albatross	Breeder	Northwestern Hawaiian Islands	
Laysan Albatross	Breeder	Northwestern Hawaiian Islands	
Dark-rumped Petrel	Breeder	Main Hawaiian Islands	
Juan Fernandez Petrel	Sojourner	Juan Fernandez Islands	
White-necked Petrel	Migrant	Kermadec Islands	
Tahiti Petrel	Sojourner	Various south Pacific Islands	
Phoenix Petrel	Sojourner	Line and Phoenix Islands	Various south Pacific islands
Mottled Petrel	Transient	New Zealand	
Herald Petrel	Sojourner	Various south Pacific Islands	
Kermadec Petrel	Sojourner	Various south Pacific Islands	
Bonin Petrel	Breeder	Northwestern Hawaiian Islands	
Black-winged Petrel	Sojourner	Kermadec Islands	
White-winged Petrel	Sojourner	Juan Fernandez Islands	
Collared Petrel	Sojourner	New Hebrides Islands	New Caledonia, Fiji
Bulwer's Petrel	Breeder	Johnston Atoll	Hawaiian, Line and Phoenix Islands
Pale-footed Shearwater	Migrant	New Zealand	
Sooty Shearwater	Transient	New Zealand, Australia, Tasmania	southern South America
Slender-billed Shearwater	Transient	Australia, Tasmania	
Wedge-tailed Shearwater (light)	Breeder	Johnston Atoll	Hawaiian Islands
(dark)	Sojourner	Line and Phoenix Islands	south Pacific islands
New Zealand Shearwater	Migrant	New Zealand	
Christmas Shearwater	Breeder	Johnston Atoll	Hawaiian Islands
Newell's Shearwater	Breeder	Main Hawaiian Islands	
Sooty Storm Petrel	Breeder	Northwestern Hawaiian Islands	
Leach's Storm Petrel	Sojourner	Aleutians, Alaska	Kamachatka
White-throated Storm Petrel	Sojourner	Line and Phoenix Islands	Various south Pacific islands
Red-tailed Tropicbird	Breeder	Johnston	Hawaiian Islands, Line and Phoenix Islands
White-tailed Tropicbird	Breeder	Main Hawaiian Islands	Line and Phoenix Islands

Table 22. (continued)

Species	Status	Area of Origin: Primary	Area of Origin: Secondary
Blue-faced Booby	Breeder	Northwestern Hawaiian Islands	Line and Phoenix Islands
Brown Booby	Breeder	Johnston, Hawaiian Islands	Line and Phoenix Islands
Red-footed Booby	Breeder	Johnston, Hawaiian Islands	Line and Phoenix Islands
Great Frigatebird	Breeder	Johnston, Hawaiian Islands	Line and Phoenix Islands
Mallard	Sojourner	North America	
Peregrine Falcon	Sojourner	North America and Asia	
American Golden Plover	Migrant	Siberia, Alaska	
Ruddy Turnstone	Migrant	Siberia, Alaska	
Red Phalarope	Migrant	Siberia, Alaska	
Skua	Migrant	New Zealand	southern South America
Pomarine Jaeger	Sojourner	Siberia, Alaska	
Long-tailed Jaeger	Migrant	Siberia, Alaska	
Laughing Gull	Sojourner	North America	
Gray-backed Tern	Breeder	Johnston Atoll	Hawaiian Islands
Sooty Tern	Breeder	Johnston Atoll	Hawaiian Islands
Brown Noddy	Breeder	Johnston Atoll	Hawaiian Islands
Black Noddy	Breeder	Johnston Atoll	Hawaiian Islands
White Tern	Breeder	Johnston Atoll	Hawaiian Islands
Short-eared Owl	Sojourner	Main Hawaiian Islands	North America

*Breeder: breeds on nearby islands; Migrant: breeds elsewhere, but migrates to north-central Pacific; Sojourner: breeds elsewhere, feeds in north-central Pacific Ocean on way to distant "wintering" ground; Transients: breeds elsewhere, moves through (but does not feed) north-central Pacific Ocean on way to distant "wintering" ground.

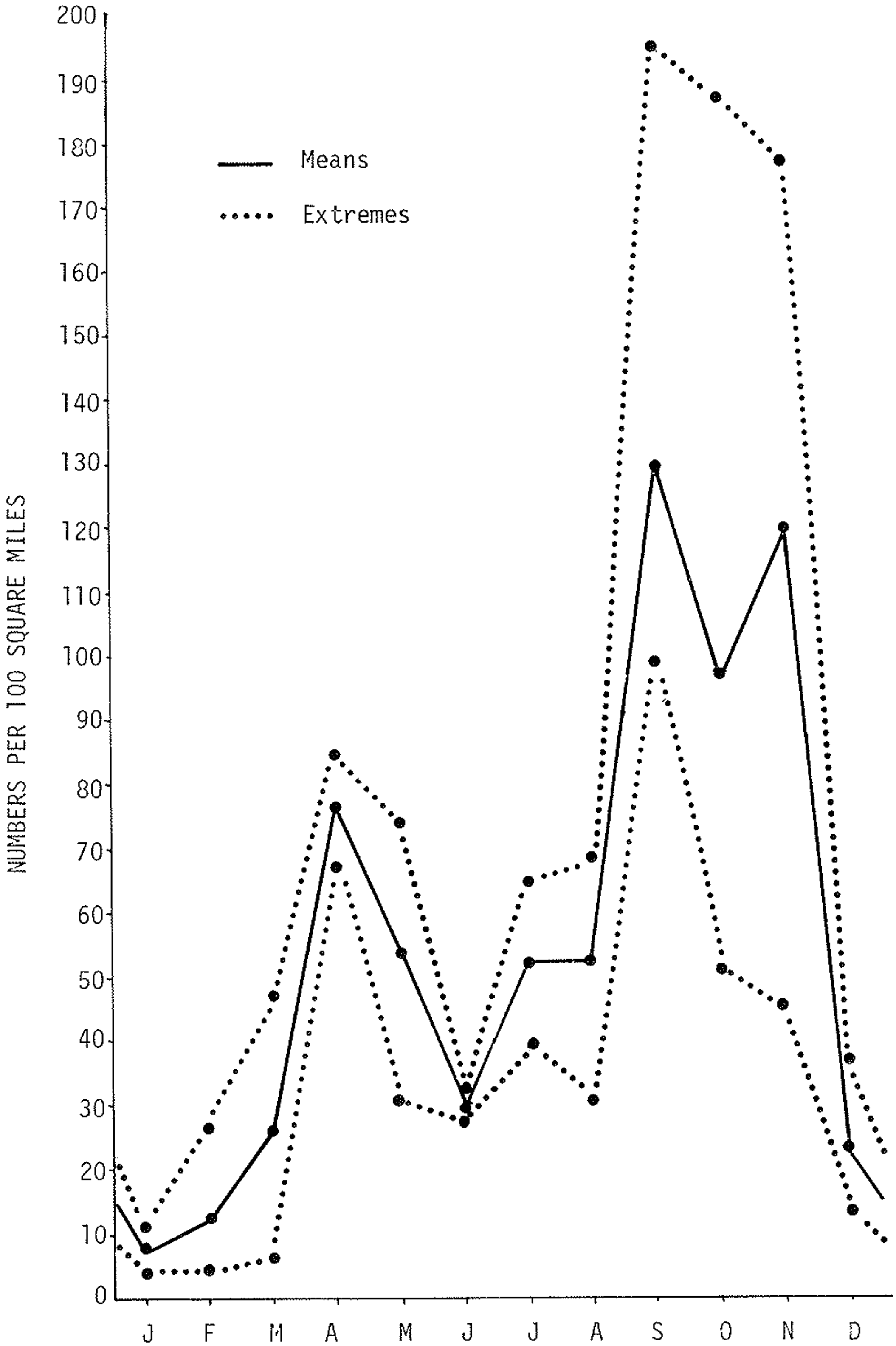


Figure 40. Diurnal bird populations at sea 175 miles southwest of Johnston Atoll, 1963-1967.

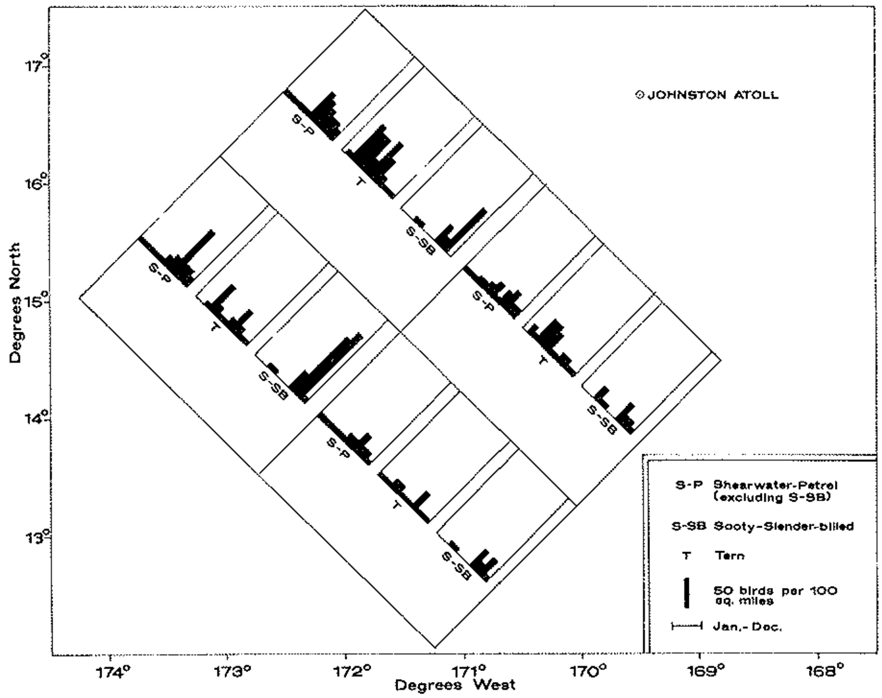


Figure 41. Monthly diurnal seabird population fluctuations by species group within the at-sea area 175 miles southwest of Johnston Atoll, 1963-1967.

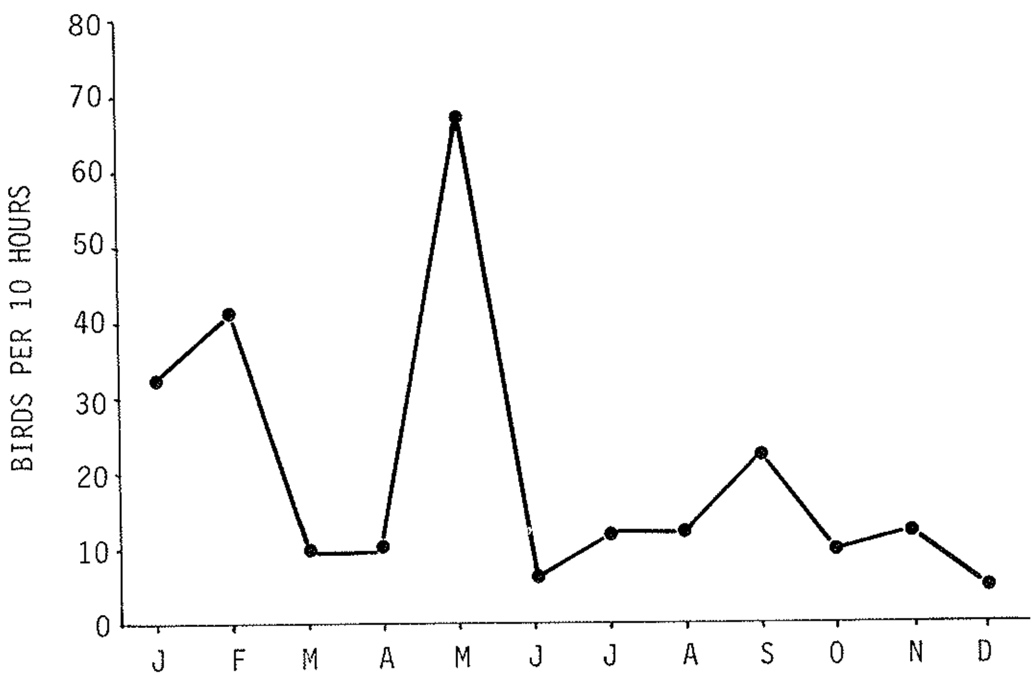


Figure 42. Total nocturnal bird sightings at sea 175 miles southwest of Johnston Atoll, 1963-1967.

Effects of Weather Patterns: The annual breeding and population cycles presented in the two preceding sections were based on data from normal weather patterns from 1963 through 1968. The 1969 weather pattern, however, was abnormal.

The 1969 season advanced normally until early February, when the weather pattern was disrupted by a series of low pressure disturbances moving across the area from the west. During this period winds shifted to the south, occasionally southwest, and for one brief period of strong winds and heavy rain, to the north. Heavy rains fell on several days during this time, particularly 3 and 8 February. The normal trade wind pattern was re-established in the last half of February, and no further weather disturbances occurred through the end of April.

Concurrent with these weather changes came a decline in numbers and changes in behavior of nearly all bird species on the Atoll. Most drastically influenced were the three major terns: Sooty Terns, Gray-backed Terns, and Brown Noddies, but Christmas Shearwaters, Red-tailed Tropicbirds, Brown Boobies, and Great Frigatebirds were noticeably affected.

The connecting factor between the weather pattern and changes in bird numbers remains obscure. Food availability may have decreased, making it necessary for the birds to stay at sea in order to fulfill their nutritional requirements, or perhaps the combination of changed wind patterns and heavy cloud cover affected the navigational procedures of the birds such that they were unable to find or return to the island.

The restoration of normal weather in late February was followed by increases in numbers and nesting activity in all breeding birds, but most were delayed in comparison with other years. Sooty Terns were about ten days behind their usual cycle, and Brown Noddies did not commence laying until over a month later than in former years.

There was evidence that unusually favorable feeding conditions prevailed in March and early April. Sooty Terns spread to occupy a greater area than ever before, and two-egg clutches, many of them identical in proportions and color pattern, were more common than in any other year. Brown Noddies accelerated laying so that, although the first eggs were not laid until 20 March, the total number laid by mid-April was three times the total produced by that date in 1968. Gray-backed Terns re-nested beginning in late March, and laid several times more eggs than they normally lay in the re-nesting attempt. Four Brown Booby pairs laid three-egg clutches, the first ever recorded for Johnston Atoll. The only outstandingly conflicting evidence comes from Christmas Shearwaters, which did not begin laying until early April, and produced only three eggs during April. Perhaps the shortage of food in February had a more drastic effect on these birds because of the larger size of their egg and consequent greater need for heavy feeding during its development. Shearwaters are thought to lay no replacement eggs, and the forced resorption of a partially developed egg might block further egg production in that year.

Ecological Distribution Within the Atoll

The four islands at Johnston Atoll differ in size, height, soil, vegetation, fresh-water supply, and degree of human disturbance. Major differences in avifaunal distribution, especially breeders, are found between disturbed and non-distrubed islands (Table 18).

Of the 56 bird species known from the atoll, 52 are known from Sand Island. Furthermore, 44 species are known from the original portion, while 35 are from the man-made part. In all, 35 species are known from Johnston Island, while eight are from Akau Island and five are recorded from Hikina Island.

Seabirds:

Breeding: Thirteen breeding seabird species are known from Sand Island; 11 species presently nest there (Table 18). Likewise 14 breeding species are known from Johnston Island; however, only three species currently nest there. One species has been known to nest in recent years on man-made Akau Island; two have nested on man-made Hikina Island.

Visitors: All seven seabird visitors are known from Sand Island, possibly attracted there by other seabird species; six are recorded from the original portion, while only two are from the man-made part (Table 18). Three species are known from Johnston Island. One species is known from Akau Island, none from Hikina Island.

Waterfowl, Marsh, and Land Birds:

Regular Migrants: All seven regular migrants are known from both original and man-made portions of Sand Island (Table 18). Likewise, all but one species--the Pectoral Sandpiper--are known from Johnston Island. Four species have been recorded from Akau Island; three species are from Hikina Island.

Irregular Visitors, Stragglers, and Accidentals: In all, 22 irregular visitor, straggler and accidental waterfowl, marsh and land bird species are known from Sand Island: 16 from the original portion and 12 from the man-made part. Ten species have been recorded from Johnston Island. Only one species is known from Akau Island; one is known from Hikina Island.

Introductions: Two of the introduced species are known from Johnston Island. One species has been recorded from Sand Island.

Island Accounts:

Avifaunal components of each island, listed alphabetically, are discussed in the following section.

Akau Island: Eight bird species have been recorded (Table 18). The island was built in 1964 and the low population and breeding numbers recorded since are due primarily to human disturbance.

Total daytime populations are extremely small; populations, especially of roosting shorebirds, probably increase at night.

Only one species--Gray-backed Tern--has nested on Akau. That occurred only in 1964 after the island was completed, but before building construction started. The nests were placed on bare sand but most were destroyed by construction; none has nested since. Great Frigatebirds roosted on various objects on the island, and Brown Boobies probably roost here occasionally. White-tailed Tropicbirds have also been seen flying over the island.

Four regular migrant shorebirds--American Golden Plover, Ruddy Turnstone, Bristle-thighed Curlew, and Wandering Tattler--have been observed on the beaches of Akau.

Only one irregular visitor--a land bird--has been recorded. Short-eared Owls sometimes roosted here when present on the atoll.

Because of human inhabitation (buildings, etc.), small size, and lack of nesting habitat, Akau Island attracted very few bird species. However, with the proposed reduced human activity after fall 1973, the island will no doubt attract additional bird species and perhaps even breeding seabird species.

Hikina Island: Since Hikina Island was built in 1964 only six species of birds have been recorded, primarily because of human disturbance (Table 18).

From 1964 through 1969 one seabird occasionally roosted here and three of the regular migrant shorebirds commonly feed on the beaches. Roosting shorebirds frequented the island at night.

Hikina Island has continued to attract small numbers of bird species because of human disturbance, the island's small size, and a lack of suitable nesting habitat. Two species of seabirds, however, did nest in 1973 because of reduced human disturbance. These two species and most likely others will continue to breed here as long as human disturbance is kept at a minimum.

Johnston Island: Birds totaling 35 species have been recorded from Johnston Island (Table 18). Of these 35 species, 17 were seabirds and 18 were waterfowl, marsh, and land birds.

Of the 17 species of seabirds, four presently breed and ten formerly bred on the island. Since 1963, only one of these ten former breeders has ever been recorded from Johnston Island. This decline in breeding species, as well as a correspondingly low bird population, can be directly attributed to human disturbance beginning in the late 1930's.

Presently White Terns utilize the tallest *Casuarina* trees and various man-made objects on which to roost and lay their eggs. Likewise, Black Noddies roost and nest in the tallest *Casuarina* trees. Red-tailed Tropicbirds nest under the larger bushes--particularly *Pluchea*--scattered about the island. Wedge-tailed Shearwaters nest under the denser bushes and have been known to nest under various buildings.

Sand Island: Fifty-two species of birds have been recorded from Sand Island (Table 18). Of these 52 species, 44 are known from the original portion and 35 are known from the man-made portion.

Of the 35 species known from the man-made portion, three species of seabirds presently breed. An additional six species of seabirds nested here while the island was uninhabited during the late 1940's and 1950's. Bulwer's Petrels presently nest in cavities formed by the rocks along the causeway. Red-tailed Tropicbirds and at times Wedge-tailed Shearwaters nest under the dense bushes, especially *Scaevola* and *Tournefortia*, growing around the buildings.

Of the 44 species recorded from the original portion, 11 species of seabirds presently breed. In addition, two breeding species of seabirds no longer nest either here or elsewhere on the atoll. The population cycles shown in Figure 38 are predominantly of birds on Sand Island. During the spring and summer, Sooty Terns nest on the bare ground over most of the island (Fig. 35) and are the most prominent species. The 1963 nesting areas for other species are shown in Figures 43 and 44. Nesting areas are also illustrated under individual species accounts. Brown Noddies nest on the ground around the periphery of the island. Black Noddies nest in the low *Amaranthus* bushes, when present. Gray-backed Terns nest on the ground on the northeast peninsula and the southwest islet. Red-tailed Tropicbirds nest under low vegetation, and various cement slabs and other objects, about the island. Wedge-tailed Shearwaters nest in burrows over much of the island; most burrows are placed so that vegetation roots help support the surrounding soil. Christmas Shearwaters, and at times Bulwer's Petrels, nest under cement slabs and various wooden timbers lying about on the surface of the island. Brown Boobies nest on the ground on the southeast hill, the south edge, the northeast peninsula, and the southwest islet. Red-footed Boobies build their nests on the east hill, on the *Tournefortia* bush northeast of the transmitter buildings, and on the various pilings around the island. Great Frigatebirds nest along the east hill and the south edge.

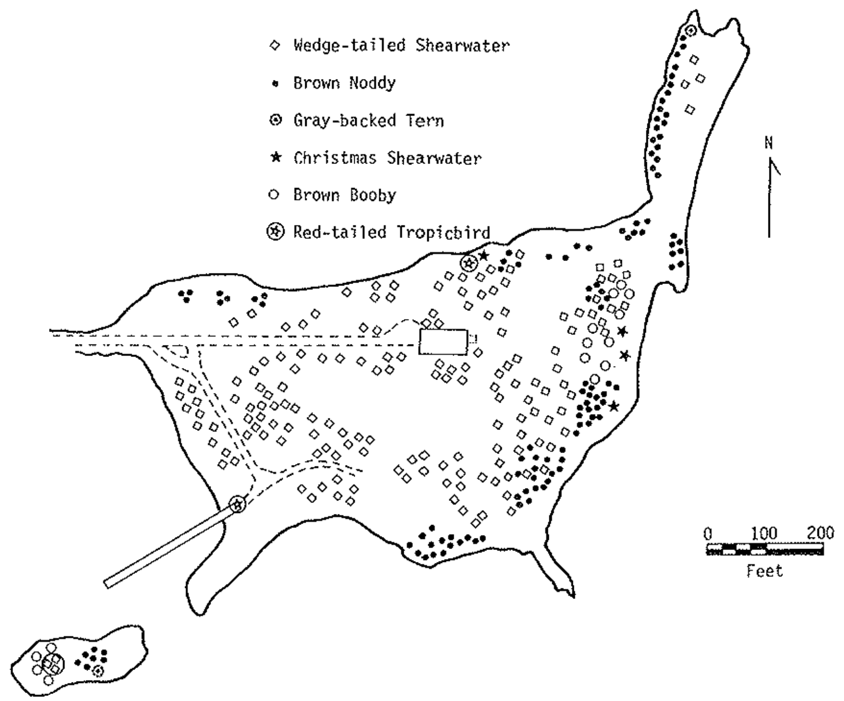


Figure 43. Nesting areas of ground nesting birds (except Sooty Terns) on the original portion of Sand Island, Johnston Atoll, 1963.

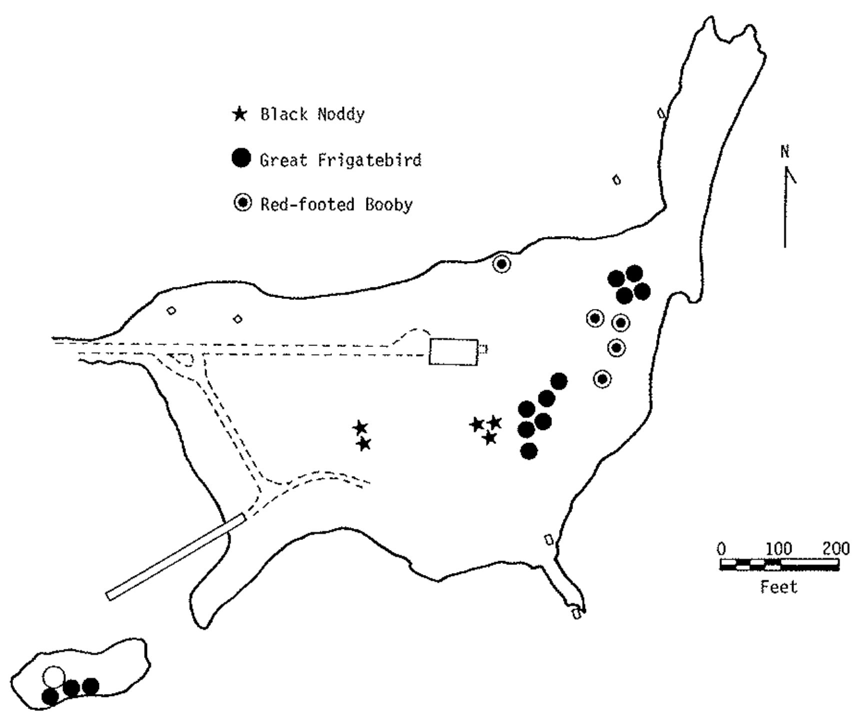


Figure 44. Nesting areas of birds which normally nest in low vegetation on the original portion of Sand Island, Johnston Atoll, 1963.

Mortality

The largest cause of mortality during the POBSP studies was the guywire system of the LORAN-C antenna on Sand Island. This system contained 24 top-loaded guywires which stretched from the top of the 625-foot tower to concrete anchors located in the lagoon in a circle around the island. In addition, three other sets of guywires stretched from part way up the tower to two sets of concrete anchors located on or near the island itself. One of these latter sets, stretched low across the southeast corner of the island, accounted for an abnormally high amount of mortality because it crossed a heavily-used bird area and was closer to the ground than the other guywires.

Table 23 shows monthly mortality of Sooty Terns from this guywire system recorded during five months of the breeding season in 1965. Since roughly 600,000 adult Sooty Terns use the island during the breeding season and about 60,000 young fledge annually, the 5,062 dead birds represent about 0.8 percent of the total population. Adult mortality is about 0.5 percent, while immature mortality is about 3.7 percent. Adult Sooty Tern losses were greatest just as egg laying began (March) when highest numbers swirled low over the island; chick losses were highest when they began to fly. Of the 5,062 dead birds 14.4 percent were banded (adults 9.2 percent, immatures 21.1 percent). There appeared to be a decline in numbers of adult Sooty Terns lost to the guywires during the last two years (1968 and 1969) of POBSP studies. Possibly the remaining birds were becoming wary of the wires as undoubtedly most adults had had close brushes with the wires and it is possible they could learn to avoid them.

Mortality records were also kept for other species during the five-month study. Although not as spectacular number-wise as for Sooty Terns, two other species actually had higher mortality rates. Surprisingly, shorebirds had the highest rate at 5.8 percent (nine dead). Great Frigatebirds were next at 1.8 percent (24 dead, 8.3 percent banded). Although no figures are available, a high percentage of the Great Frigatebirds that fledged each year broke their wings on these wires and died. The mortality rates for Brown Noddies (33 dead, 18.2 percent banded) and Wedge-tailed Shearwaters (25 dead, 44 percent banded) were the same--0.8 percent--as for Sooty Terns. Red-footed Boobies (nine dead, 11.1 percent banded) had 0.3 percent mortality, whereas Red-tailed Tropicbirds (one dead) had 0.5 percent mortality.

Dead birds from the guywires presented little disposal problem because of the presence of dermestid beetles (*Dermestes ater*). These insects were at their lowest numbers in mid-winter when returning Sooty Terns first began hitting the wires. The population quickly responded to the increase in food and by the time the terns reached their peak abundance, the dermestids could eliminate

Table 23. Sooty Tern mortality from guywire strikes, Sand Island, March - July 1965

	Adults			Immatures			Combined		
Month	Total Killed	No. Banded	Percent Banded	Total Killed	No. Banded	Percent Banded	Total Killed	No. Banded	Percent Banded
March	1,320	122	9.2				1,320	122	9.2
April	438	40	9.1				438	40	9.1
May	312	29	9.3	153	27	17.6	465	56	12.0
June	527	36	6.8	1,792	335	18.7	2,319	371	16.0
July	251	35	13.9	269	105	39.0	520	140	26.9
	2,848	262	9.2%	2,214	467	21.1%	5,062	729	14.4%

carcasses, even of frigatebirds and boobies, in little more than a day. This made it unnecessary, and even undesirable, to initiate any kind of dead bird removal program except where carcasses appeared near buildings.

Of lesser importance in cleaning carcasses were cockroaches, ants, and flies. Fly populations generally were low because dermestids devoured carcasses too quickly to allow fly larvae to develop--indeed any fly larvae on a carcass usually were devoured by the ants and dermestids.

Banding and Interisland Movement

The use of U.S. Fish and Wildlife Service bands is a widely accepted method for marking birds. By using these serially numbered, metal (usually aluminum), leg bands at Johnston Atoll, and throughout the central Pacific, the POBSP was able to (1) study bird migration, (2) obtain species longevity, (3) recognize individuals from their neighbors, and (4) estimate populations by the mark-and-recapture method. To facilitate sighting Johnston-banded birds at sea and on distant islands, most banded adults and young were also tagged with a blaze-orange, plastic, leg streamer.

Banding: N.P. Ashmole, then of the B.P. Bishop Museum, Honolulu, Hawaii, banded the first birds at Johnston Atoll in February 1963; he banded 72 seabirds of five species. Birds totaling 303,732 of 21 species were banded at Johnston Atoll by POBSP personnel from July 1963 through September 1969 (Table 24). The POBSP banded more birds here than anywhere else in the central Pacific. Amerson, then of the Smithsonian Institution, banded 97 birds of five species in November 1973.

From 1967 through 1969, primary emphasis turned to recapture of banded birds, but chicks of most species were banded in as large numbers as possible in order to continue to mark known-age birds for future studies.

By far the majority of these 303,901 birds was banded at Sand Island. Only a few of two species--Red-tailed Tropicbird and White Tern--were banded at Johnston Island. None was banded at Akau and Hikina Islands.

Of the total banded (Table 24) there were: 285,526 Sooty Terns, 7,979 Brown Noddies, and 6,517 Wedge-tailed Shearwaters, 1,047 Red-footed Boobies, and 1,005 Great Frigatebirds; the remaining 16 species only accounted for 1,827 banded birds.

Interisland Movement: In all, 18 species totaling 60,932 birds have been recaptured at Johnston Atoll since 1958 (Table 25). Of this total, 60,526 birds were originally banded on the atoll, while 406 were banded elsewhere.

Table 24. Birds banded at Johnston Atoll, 1963 to 1973

	1963	1964	1965	1966	1967	1968	1969	1973	Total
Laysan Albatross			1						1
Bulwer's Petrel		23	21	6	11	21	14		96
Wedge-tailed Shearwater	1,966	1,248	919	1,192	72	948	88	84	6,517
Christmas Shearwater	22*	14	7	8	9	14	9		83
Red-billed Tropicbird							1		1
Red-tailed Tropicbird	24	138	96	71	78	99	116	3	625
White-tailed Tropicbird							1		1
Blue-faced Booby	2	13	18	5	1		5		44
Brown Booby	41*	82	51	48	40	57	55	1	375
Red-footed Booby	29	46	200	348	135	57	231	1	1,047
Great Frigatebird	312*	31	147	160	78	103	166	8	1,005
Pintail			1			1	1		3
American Golden Plover	38	14	14	30		23			119
Wandering Tattler						3			3
Ruddy Turnstone	7	5	4				1		17
Gray-backed Tern		63	67	60	27	16	38		271
Sooty Tern	16,895*	44,208	54,153	118,300	13,899	15,200	22,871		285,526
Blue-gray Noddy							1		1
Brown Noddy	726*	1,370	1,485	1,212	680	1,700	806		7,979
Black Noddy	4	27	17	23	26	26	29		152
White Tern		5	13			12	5		35
Totals	20,066	47,287	57,214	121,463	15,056	18,280	24,438	97	303,901

*Totals include 2 Brown Boobies, 3 Christmas Shearwaters, 5 Great Frigatebirds, 17 Brown Noddies, and 45 Sooty Terns, all banded by N.P. Ashmole in February 1963.

Table 25. Yearly band return totals for Johnston Atoll

	1958	1963		1964		1965		1966		1967		1968	
	Other	JA	Other	JA	Other	JA	Other	JA	Other	JA	Other	JA	Other
Bulwer's Petrel						15		19		25		29	
Wedge-tailed Shearwater		2		263		697		1,051	2	200		383	
Christmas Shearwater				14		22		13		17		14	
Red-tailed Tropicbird				8		64		87		111		101	1
Blue-faced Booby				1	4	4	9		3	1	1		4
Brown Booby				13	1**	71		76		105		112	
Red-footed Booby				2		14	24	30	70	24	39	16	7
Great Frigatebird		6		11		63	2	146	4	39	3	34	10
Pintail	1												
American Golden Plover				2(2)		1		1		1			
Wandering Tattler													
Ruddy Turnstone									2				1
Gray-backed Tern						2		6		2		2	
Sooty Tern				799	1	3,173	6	10,799	16*	10,017	31	13,902	31
Elegant Tern													
Brown Noddy		4	2	51	3	103		194	1	96		278	1
Black Noddy		2		4	1	1			1		2	5	
White Tern											1		
Totals	1	14	2	1,148	10	4,230	41	12,422	99	10,638	77	14,876	55

Table 25. (continued)

	1969		1970		1971		1972		1973		Total	
	JA	Other	JA	Other	JA	Other	JA	Other	JA	Other	JA	Other
Bulwer's Petrel	40										128	0
Wedge-tailed Shearwater	72		2		4				9		2,683	2
Christmas Shearwater	19										99	0
Red-tailed Tropicbird	129	3	2		2						504	4
Blue-faced Booby		2									6	23
Brown Booby	123	1	1		1+	1			1		503	3
Red-footed Booby	30	53				1					116	194
Great Frigatebird	47	9				1			2		348	29
Pintail											0	1
American Golden Plover	3(1)										8	0
Wandering Tattler	(1)										0	0
Ruddy Turnstone											0	3
Gray-backed Tern	11										23	0
Sooty Tern	6,846	10			9,554	37	15		121		55,206	132
Elegant Tern		1									0	1
Brown Noddy	145				4				7		882	7
Black Noddy	8	2									20	6
White Tern											0	1
Totals	7,473	81	5	0	9,565	40	15	0	140	0	60,526	406

*Does not include one Phoenix bird not accepted.

**One band found, actual date not known; not included in totals.

( )Numbers in parenthesis are sightings of streamered birds and are not included in totals.

The 406 captures of birds from other localities involve 13 species, but represent only 388 birds as some were captured more than once. These birds were originally banded at 15 localities (Table 26). The majority came from the northwestern Hawaiian Islands with the most from French Frigate Shoals (127 birds, or 33 percent). Laysan Island was second at 51 birds (13 percent) and Kure Atoll third at 40 birds (10 percent). Wake Atoll, however, was second overall with 60 birds (15 percent) moving to Johnston. Only five birds, three being questionable records, possibly moved to Johnston Atoll from islands to the south.

In addition to birds coming to the Atoll, 345 birds of 12 species originally banded at Johnston Atoll were captured on 20 other atolls or island groups and from 13 at-sea localities (Table 26). Of these 345 banded birds, 273 (79 percent) went to the Hawaiian Islands and Wake, while 50 (17 percent) moved to the west and southwest Pacific. Twelve banded birds (most questionable records) possibly moved to the Phoenix Islands.

The number of individual banded birds involved in interisland movement, both to and from the atoll, totals 733. French Frigate Shoals (232 birds), Laysan Island (92 birds), Kure Atoll (75 birds) and Wake Atoll (73 birds), in that order, are the atolls most frequently involved.

The overall POBSP banding and recapture program in the central Pacific has shown that bird movement between the Line and Phoenix Islands area and the Hawaiian Islands and Johnston area was virtually nil (Amerson, 1968). Movements between islands within each of these areas was much larger, and the number of birds returning to their island of banding was still greater. Banded birds from both areas, however, were recaptured in the far western Pacific.

Banding data seem to indicate that Johnston Atoll is a major focal point for interisland movements in the north-central Pacific. Movements to and from Johnston Atoll are highest among all the islands in this area. This may simply result from full-time POBSP personnel coverage at Johnston, or it may actually reflect a high degree of movement to and from the atoll (POBSP, 1967b).

Avifaunal Affinities

The Johnston Atoll avifauna shows clear affinities with the Hawaiian Islands, both taxonomically and in movement patterns. These are, of course, the closest islands to Johnston.

Particularly significant are movements of breeding species: Red-footed Boobies, Great Frigatebirds, Blue-faced Boobies, Brown Noddies, Wedge-tailed Shearwaters, and Black Noddies (list is in descending order of numbers of interisland movements from Table 26), in which most of the recorded movements involving Johnston are with the Hawaiian Islands. The major exceptions are Sooty Terns and Red-tailed Tropicbirds,

Table 26. Interisland movement of banded birds involving Johnston Atoll

To Johnston from:	Kauai	Oahu	French Frigate Shoals	Gardner Pinnacles	Laysan	Lisianski	P & H Reef	Midway	Kure	Wake	Marshalls
Wedge-tailed Shearwater		2	6								
Red-tailed Tropicbird							1	2		2	
Blue-faced Booby			12	1			1		2		
Brown Booby								1		1	
Red-footed Booby	19	16	61		38	5	8	6	26		
Great Frigatebird		1	23				3		1		
Pintail											
Ruddy Turnstone											
Sooty Tern		2	16		13	4	2	20	11	57	1
Elegant Tern											
Brown Noddy			4				2				1
Black Noddy			4			1					
White Tern			1								
Total (To)	19	21	127	1	51	13	17	29	40	60	2
From Johnston to:											
Laysan Albatross									(1)		
Wedge-tailed Shearwater			6								
Blue-faced Booby			3		5	4					
Brown Booby						1					
Red-footed Booby	1		44		13	24	2	3	15		
Great Frigatebird			6						4		4
Ruddy Turnstone											
Gray-backed Tern											
Sooty Tern		1	34		23	10	7	23	14	13	4
Brown Noddy		1	8				1				1
Black Noddy			3			1			1		
White Tern			1								
Total (From)	1	2	105		41	40	10	26	35	13	9
Grand Total	20	23	232	1	92	53	27	55	75	73	11

Table 26. (continued)

To Johnston from:	Carolines	Marianas	Philippines	Japan	New Guinea	Solomons	Nauru	Ellice	Phoenix	Line	At Sea	Alaska	California	Total
Wedge-tailed Shearwater														8
Red-tailed Tropicbird														5
Blue-faced Booby														19
Brown Booby														2
Red-footed Booby														179
Great Frigatebird														28
Pintail													1	1
Ruddy Turnstone												1		1
Sooty Tern									2+2*	1*				131
Elegant Tern													1	1
Brown Noddy														7
Black Noddy														5
White Tern														1
Total (To)									4	1		1	2	388
From Johnston to:														
Laysan Albatross														1
Wedge-tailed Shearwater											3			9
Blue-faced Booby														12
Brown Booby							1							2
Red-footed Booby														102
Great Frigatebird			1											15
Ruddy Turnstone												1		1
Gray-backed Tern					1									1
Sooty Tern	2	2	13	5				2	10*		9			172
Brown Noddy	2		2		1	4	1		2**		1			24
Black Noddy														5
White Tern														1
Total (From)	4	2	16	5	2	4	2	2	12		13	1		345
Grand Total	4	2	16	5	2	4	2	2	16	1	13	2	2	733

*Questionable; **One taken offshore; ( )Sighting only.

in which a disproportionately high number of movements are from Wake Island, which lies west of Johnston at a greater distance than any of the Hawaiian Islands.

Furthermore, those breeding species for which subspecies or color phases can be used to determine affinities, are allied with the northern islands: Wedge-tailed Shearwater, Red-footed Booby and Blue-gray Noddy are of the typical northern color phases (or subspecies in the case of the Blue-gray Noddy).

As for the non-breeding species, movements of birds not banded but collected, however, remain mostly from the Hawaiian Islands: Newell's Shearwater, Sooty Storm Petrel, White-tailed Tropicbird, Cattle Egret, Blue-gray Noddy, Short-eared Owl, and Japanese White-eye. There are a few recorded movements from the south and east. The Phoenix Petrel and Lesser Frigatebirds are equatorial breeders, although Lesser Frigates have been recorded from Wake and the northwestern Hawaiians, and may have a circular migration pattern that includes (occasionally) Johnston on the return to the equatorial breeding islands. From the eastern Pacific comes the Red-billed Tropicbird, and from the northeast, possibly via Hawaii, have come a number of accidentals: Glaucous-winged Gull, Laughing Gull, Franklin's Gull, Elegant Tern, and possibly Herring and Western Gulls.

Techniques

Although most of the study techniques used by the POBSP at Johnston Atoll were straight-forward and self-explanatory, a few comments on the accuracy and relative values of the results are necessary to clarify the meaning of the data, and to emphasize that in some cases, tables and discussion are carefully labelled to state what the figures actually represent, rather than what they ideally should represent.

For example, reported numbers of birds in the semimonthly reports ideally were to be the total number of birds using the atoll during the period in question. Clearly, this figure is unattainable for even the most conspicuous and easily enumerated species. It would require constant surveillance on the entire atoll for the entire period, with all new birds detectable. Thus the figure can mean no more than the number of individuals of a given species known to use the atoll during the period. In many cases figures reported really are not estimates of total numbers using the islands, but of maximum seen at one time, which is probably far lower in nearly every instance than the total number using the island during the period, because it is extremely unlikely that all would be present at any one time, even at night for roosting. Reported counts, then, should be regarded as indices to the numbers using the atoll, rather than accurate estimates, although in a few cases they may be fairly accurate.

In general, the fewer individuals and to a lesser extent, the larger and more conspicuous the bird, the more likely is the count to accurately represent the true number of individuals using the island. An extreme example is the Cattle Egret, which occurred no more than two at once, were comparatively large and conspicuous and were highly predictable in habits and habitat.

It is recognized that the capture-mark-recapture (or observe) calculations for populations do not meet the assumption of no turnover in the population between marking and observation. However, it is the only technique available in most cases and the estimates are presented in a few cases where no other objective estimates are available. They may even be used for estimating the rate of turnover, as for example in Sooty Terns, Black Noddies, and White Terns. Some indication of populations are thus possible.

Rapid turnover of personnel necessarily had a deleterious effect on data gathering, through studies being dropped or changed when personnel changed. However, a large body of reliable information was assembled in the field notes and semimonthly reports. Basically these species accounts will summarize in detail those aspects of the life histories and populations for which comparable data were obtained for all species of ecological equivalence.

Specimens

The first scientific bird specimens were collected by Kern in March 1859 when the U.S. Schooner FENIMORE COOPER visited Johnston Atoll (Brooke, ms.). What species were collected are not known; however, they were lost when the ship later burned and sank in Japan (Brooke, 1955).

Prior to the first POBSP in July 1963, 93 specimens of 16 bird species--all collected by Alexander Wetmore in July 1923--were known from Johnston Atoll. POBSP personnel collected 616 specimens of 41 species from 1963 through 1969. These 709 specimens of 41 species are all housed in the bird collection of the National Museum of Natural History (USNM), Washington, D.C.

Fifty-one new species distributional records--two first specimen records of species previously unknown for the central Pacific Ocean, one first specimen record of a species previously known only from a sight record in the north-central Pacific Ocean, 38 first specimen records for the atoll, and ten first sight records--and four new species breeding records are reported herein. Table 27 summarizes these specimen and distributional records. These records fall into two categories, one composed of species that regularly occur on islands in the north-central Pacific Ocean but which cannot be considered unusual, and the other group composed of species of uncommon or seldom-documented occurrence on islands in the north-central Pacific Ocean.

Table 27. Bird specimens and summary of new records from Johnston Atoll

Species	Collected Specimens Wetmore	POBSP	Total	New Records
Phoenix Petrel		1	1	sr
Bulwer's Petrel	9	1	10	sr, br
Wedge-tailed Shearwater	7	93	100	sr
Christmas Shearwater	10	1	11	sr, br
Newell's Shearwater		2	2	sr
Sooty Storm Petrel		1	1	sr
Red-tailed Tropicbird	5	24	29	sr
Blue-faced Booby	7	3	10	sr, br*
Brown Booby	5	9	14	sr
Red-footed Booby	8	21	29	sr
Great Frigatebird	6	61	67	sr
Lesser Frigatebird				r
Cattle Egret				r
Pintail		4	4	sr
American Wigeon		2	2	sr
Northern Shoveler		1	1	sr
Domestic Chicken				r
Peregrine Falcon		1	1	sr
American Golden Plover	1	18	19	sr
Black-bellied Plover		1	1	sr
Semipalmated Plover		2	2	sr
Bristle-thighed Curlew		5	5	sr
Lesser Yellowlegs		1	1	sr
Spotted Sandpiper		1	1	sr, SFR
Willet				r
Wandering Tattler	2	2	4	sr
Ruddy Turnstone	1	9	10	sr
Dowitcher species				r
Sanderling		1	1	sr
Western Sandpiper				r
Pectoral Sandpiper		8	8	sr
Sharp-tailed Sandpiper		2	2	sr
Buff-breasted Sandpiper		1	1	sr
Ruff		1	1	sr
Wilson's Phalarope		1	1	sr, SR
Glaucous-winged Gull		2	2	sr
Herring Gull				r
Laughing Gull		1	1	
Franklin's Gull		1	1	sr
Gull species		1**	1**	r
Gray-backed Tern	5	14	19	sr
Sooty Tern	12	224	236	sr
Elegant Tern		1	1	sr, SFR
Blue-gray Noddy	2	1	3	sr
Brown Noddy	6	78	84	sr
Black Noddy		6	6	sr

Table 27. (cont.)

Species	Collected Specimens Wetmore	POBSP	Total	New Records
White Tern	7	7	14	sr
Rock Dove				r, br
Skylark				r
Japanese White-eye		2	2	
Society Finch				r
Totals	93	616	709	

br=first breeding record; r=first sight record; sr=first specimen record; SR=first specimen confirmation of a species previously known only from a sight record in the north-central Pacific Ocean; SFR=first specimen record for a species previously unknown from the central Pacific Ocean.

*extirpated; **specimen lost.

Species Accounts

For descriptions and illustration of the 56 species of birds recorded herein, the reader is referred to the ornithological sources cited previously, especially King (1967).

BLACK-FOOTED ALBATROSS *Diomedea nigripes*

Status

Former uncommon breeding species; recent regular but scarce winter visitor at sea near Johnston Atoll; two questionable records of birds landing on Johnston and Sand Islands during the 1960's. Small numbers probably nested on the sandy portions of Sand Island, as well as on Johnston Island, prior to military occupancy.

Ecological Distribution

Johnston Island: One possible record exists. Sundell, a POBSP employee, wrote in his field notes 22 November 1963: "While on Johnston in the evening I talked with an engineer who claims to have seen a Black-footed Albatross over the island on November 17." No further confirmation of this record was obtained.

Sand Island: The only breeding record for the atoll was a sight record made by a member of Wetmore's 1923 party: "W.G. Anderson, of our party, who had come in November 1922, as navigator for a fishing sampan, informed me he saw one, with its egg, on the beach of Sand Island. None were present during our work in July 1923" (Wetmore, ms. b).

One recent sight record is questionable. On 11 March 1964 a Black-footed Albatross followed the USS ENERGY to within about 2.5 miles of Sand Island and departed just after a harbor tug came to assist the ship to port. Bratley, a POBSP employee who was on Sand at the time, reported in his field notes: "I could see the Energy at this time from Sand, but I could not see if there was any bird following it." On 12 March, Coast Guardsmen described to Bratley a bird seen sitting on the causeway of Sand and flying around over Johnston that may have been the Black-footed Albatross that had followed the ship in the day before. No further confirmation could be made of this record.

Populations

The occurrence of albatross on Johnston Atoll in the past is poorly recorded. During the 1800's there were no scientific visits and no known observations reliable enough to determine the species composition of the atoll's avifauna. Brooke (ms.) reported "an albatross" as being collected on 15 March 1859. A guano prospector, Le Grand Brown, listed "the Gooney" as being present in 1905 (U.S. Nat. Archives, R.G. 59, guano letters), but no quantitative significance can be attached to this record. In addition to Anderson's breeding sight record in November 1922 (Wetmore, ms. b), he (Anderson, 1954) reported seeing a Black-footed Albatross there in 1929, but this may have been an erroneous listing of the bird he saw in 1922.

Rice and Kenyon (1962) interpreted Wetmore's observations, including the absence of albatross bones in the piles of bones left by feather hunters shortly before Wetmore's visit, as evidence that albatross were extirpated [prior to the time of said feather hunters]. It is equally likely that the albatross population never exceeded a few birds, even before the first feather poachers arrived. Johnston Atoll is the southernmost known breeding island for Black-footed Albatross, unless the record (Rice and Kenyon, 1962) for Taongi Atoll (14°35'N) in the northern Marshalls is valid. Amerson (1969), however, found no evidence to substantiate this Taongi breeding record.

An elderly Polynesian construction worker on the islands in the late 1930's told Amerson of the POBSP in 1964 that albatrosses of both species were on the island when construction work began, and that they were shot by marines. Whether they were shot for lack of better entertainment, or whether there was an official effort to rid the islands of these birds because of the hazard to aircraft, is not known.

An article in the New Yorker magazine (Anon., 1945) listed the Black-footed Albatross as occurring on Johnston Atoll, but this listing was "based in part on the British Admiralty Sailing Directions, and in part on information supplied by U.S. Navy personnel who had been stationed on the island...." (Hutchinson, 1950: 186), and is of little value in determining the status of the species on the atoll.

Even if man left Johnston Atoll it is doubtful if Black-footed Albatross would return to its islands to breed because of their strong tendency to nest on their place of hatching. Those that may have survived the feather hunters and early military construction have probably long since gone elsewhere, or most likely have died.

Annual Cycle

The sight record of an egg in November 1922 by Anderson (Wetmore, ms. b) falls within this species' breeding cycle in the northwestern Hawaiian Islands. There, adults arrive during the last part of October, eggs are laid about mid-November, young hatch beginning late January, and adults and young leave by the end of July (Richardson, 1957).

Banding and Interisland Movement

No Black-footed Albatross were banded and no specimens were collected from the island by POBSP personnel. No interisland movements are known.

At-Sea Distribution

Brooke (ms.) saw "a black albatross" on 19 March 1859 while sailing west two days from Johnston Atoll.

Black-footed Albatross do occur at sea in the grid southwest of Johnston Atoll, where they have been found in small numbers from December through April (POBSP, 1967a). The POBSP collected three specimens at sea near Johnston Atoll (Appendix Table 7). They are seldom found below 10°N in the central Pacific (King, 1967).

LAYSAN ALBATROSS *Diomedia immutabilis*

Status

Former uncommon breeding species, presently a rare visitor; a regular but rare winter visitor at sea near Johnston Atoll. Small numbers nested on Johnston Island prior to military occupancy.

Ecological Distribution

Johnston Island: Wetmore (ms. b) recorded one young bird on the high barren areas of Johnston Island in July 1923. None was observed in late April or May 1928 by Thurston (1928), although this species may have been present in the late 1930's (see Black-footed Albatross account). A few visited here in 1949, probably November or December (Jensen, 1949).

Three were present in early winter 1957 (Manandic, pers. comm.). Manandic, former SSgt., USAF, stationed on Johnston in 1957, knew the birds of the atoll quite well and used the term "albatross" not "gooney" to describe the birds in question. He described them as large white birds, with hooked beaks, a description that could hardly have fit any other species.

Sand Island: One adult with a bare brood patch landed on the road to the transmitter building on 10 December 1965. It was banded, photographed, and ectoparasites collected before being released by POBSP personnel. Another adult was seen soaring over the western portion of Sand for at least ten minutes on 26 December 1966 by POBSP personnel.

Populations

For the Laysan Albatross, as for the Black-footed Albatross, Johnston Atoll was previously the southernmost extreme of the breeding range. Small numbers bred on the atoll prior to military occupancy, but now the species is a rare visitor.

The discussion of the occurrence of albatrosses before 1923, and of Rice and Kenyon's (1962) interpretations of Wetmore's observations, are included in the Black-footed Albatross account and apply equally to the Laysan Albatross.

It is also unlikely that this species will return to Johnston Atoll to breed, even if man decides to abandon the atoll in the future.

Annual Cycle

Wetmore (ms. b) wrote of the one young bird, nearly ready to fly in July 1923, as: "This should not be taken as indicative of the rarity of the species, since by July--most members of this species had left their breeding grounds [in the northwestern Hawaiian Islands], and were at sea." The annual cycle of the Laysan Albatross in the Hawaiians is similar to that described for the Black-footed Albatross, but the cycle is about two weeks later (Richardson, 1957).

Banding and Interisland Movement

The only Laysan Albatross banded by POBSP personnel on the atoll, an adult banded on Sand 10 December 1965, was seen and identified by its orange, plastic, leg-streamer over Kure Atoll, nearly 1,000 miles to the northwest, three days later, 13 December, by POBSP personnel (Woodward, 1972).

At-Sea Distribution

Laysan Albatross have been observed only during one month--February--in the grid southwest of Johnston Atoll (POBSP, 1967a). This species seldom is found below 15°N in the central Pacific (King, 1967).

PHOENIX PETREL *Pterodroma alba*

Status

Accidental; one specimen record from Sand Island.

Observations

The only Phoenix Petrel recorded from Johnston Atoll was an adult female Kepler and Lehner collected after it landed "in a *Tribulus* bush in the Wedge-tailed Shearwater colony..." on 18 September 1964. The bird appeared to be in good health and was kept alive for a few days before it was killed and preserved.

Phoenix Petrels breed in the summer in the Line and Phoenix Islands (Clapp, pers. comm.) and occur south to about 24°S latitude in the central Pacific (Murphy and Pennoyer, 1952). Small numbers occur at sea north to the Hawaiian Islands (King, 1967) but may only rarely alight on islands in this area. POBSP (1967a) personnel recorded Phoenix Petrels at sea in low numbers in the grid southwest of Johnston Atoll only during October, November, January, and February.

Specimens

The Phoenix Petrel noted above is a new specimen record for Johnston Atoll. Furthermore, it has never been recorded on land in the Hawaiian Islands.

BULWER'S PETREL *Bulweria bulwerii*

Status

Uncommon breeding species, present from March to early September. Nests in rock crevices along the causeway, on the east and west shores, and on the southwest islet of Sand Island; previously nested on Johnston Island. About half of the 40 to 50 adults that return each year attempt to breed, and at least five to ten young are produced yearly. Adults return in March, lay in May or June, and depart just ahead of the chicks which hatch in late June or early July and fledge in late August or early September. Nests are in rock crevices mainly along the man-made causeway of Sand Island.

Ecological Distribution

Johnston Island: Wetmore (ms. b) in July 1923 found about 400 nesting in crevices in the rock ledges of Johnston Island with young ranging from a week old to those partly covered with contour feathers. Wetmore's field notes (ms. a) reveal something of their habits and habitats:

Common, nesting in the rock ledges along the beach where I hear their barking calls day and night. They are more advanced in their breeding here than farther north as they have young from a week old to those growing contour feathers. The small young are as usual in petrels very fluffy with heavy down about the head that almost hides the eyes. Young beginning to molt into first plumage appear much larger than the adult and in reality are heavier because of the heavy layer of greasy fat that covers the entire body. They remain hidden in the ledges during the day, but at night come out into the open shuffling about on the breast. At day they seek shelter when exposed to light.

The larger ones resent handling and attempt to bite as do adults when handled at this season. The young utter a low whistling wheeze somewhat similar to the note of a squab.

Adults delight to rest a few inches apart and with extended head and swelling throat utter their comical little barking call, a note common to both sexes. When quiet they rest prostrate on the breast and moving merely shuffle along barely raising the body free of the sand and dropping back at once.

About 400 on Johnston Island.

None has been recorded on Johnston Island since, most likely because the natural rock crevices where Wetmore found them in 1923 have all been destroyed by military activities.

Sand Island: Wetmore (ms. b) saw none on Sand in July 1923. Because of their nocturnal and secretive habits, Bulwer's Petrels were completely overlooked by POBSP personnel in 1963 but were, however, recorded as nesting from 1964 to 1969.

Bulwer's Petrels were seldom found except in the rock crevices where they nested (Figs. 45 and 46). The distribution of these sites is shown in Figure 47. Most nests were along the causeway, where angular rocks and blocks of concrete form deep crevices in which the birds lay their eggs on a thin mat of grass stems. There were also a few sites under chunks of concrete on the east and west shores of the original portion of the island, some of the same ones used by Christmas Shearwaters. The sizes of cavities required by these two species appear to be sufficiently different to prevent competition between them for sites. On the southwest islet a bird was heard calling in 1967 but could not be reached or seen in the crevices, several feet deep, between concrete chunks used to build the bunker. In 1969 a chick almost ready to fledge was caught there. Nesting probably occurred there in other years as well. In 1967 one bird was found among rocks along the south shore, but no nests were ever discovered there.

Figure 45. Bulwer's Petrel chick, about 2 months old, in front of rock crevice nest site along causeway, Sand Island, Johnston Atoll, 25 August 1966 (POBSP photo by P. C. Shelton).

Figure 46. Concrete slabs on east shore, at base of northeast peninsula, Sand Island, Johnston Atoll, 8 May 1967. Christmas Shearwaters nested regularly under the large slabs at left. and Bulwer's Petrels attempted to nest at least once under the slabs in center of photo. Brown Noddies nested in the edge of the *Sesuvium* growing just above the storm beach (POBSP photo by P. C. Shelton).

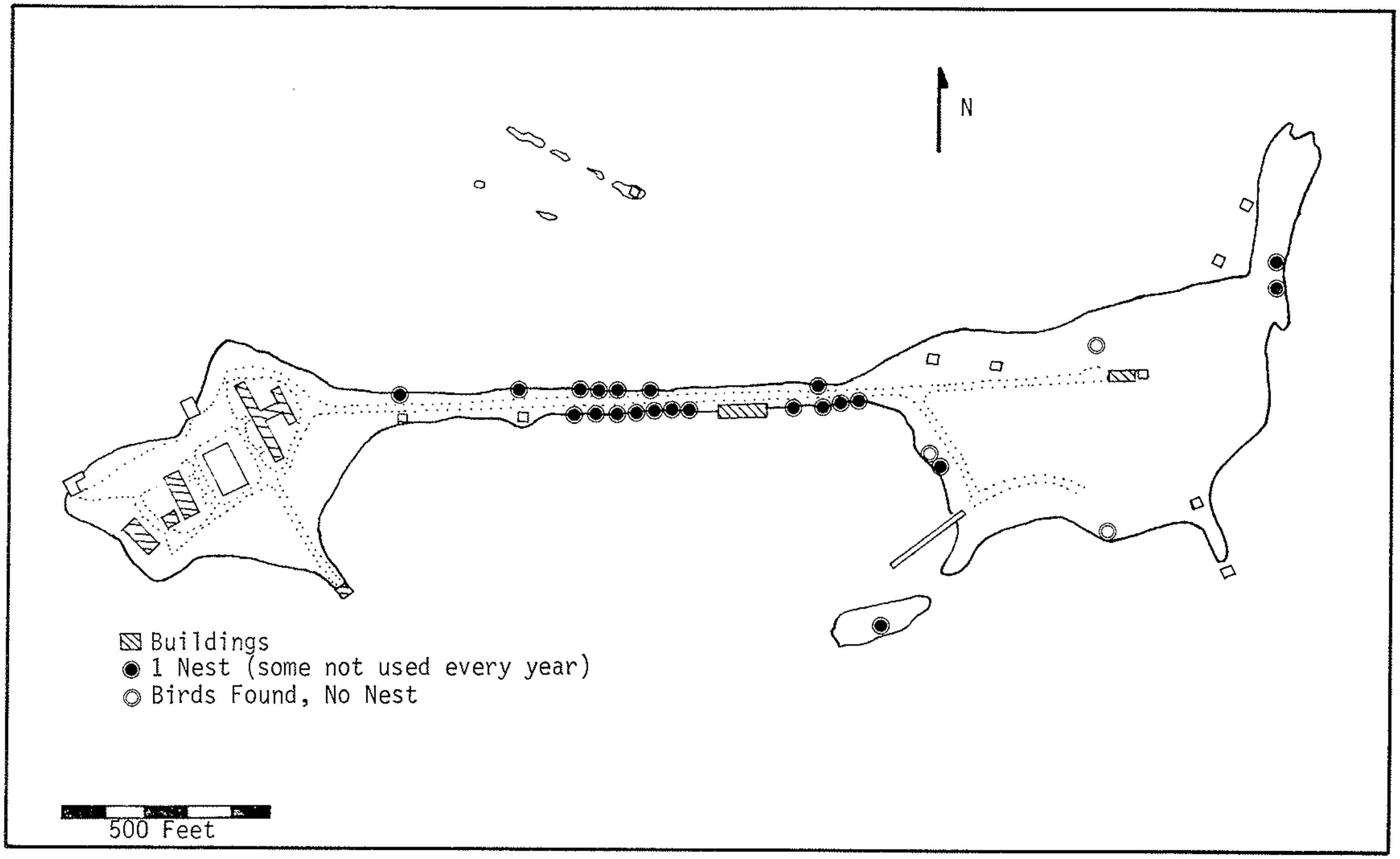


Figure 47. Distribution of Bulwer's Petrel nest sites, Sand Island, Johnston Atoll, 1964-1969.

Rarely were Bulwer's Petrels found in the open, away from rocky cover. One of the 1965 chicks that returned in 1969 was first found sitting in the road on the causeway but it was found later in 1969 in a cavity on the causeway. On 3 August 1966 a lone calling bird with a bare brood patch was found on open ground north of the transmitter building among Sooty Terns. Almost exactly three years later, 2 August 1969, the same bird appeared in the same place, again sitting alone among Sooty Terns and calling. Possibly this bird was hatched, or had formerly nested, at a now destroyed site under a rock on concrete slab near where it appeared in these two years.

Populations

These nocturnal and secretive petrels are among the most difficult to census of the less common birds using the island. They were completely overlooked in 1963. Semimonthly estimates by different observers varied, resulting in a wide spread in the ranges for estimates shown in Figure 48. The mean of these estimates for each period probably represents the true numbers fairly well, although the spring buildup may be steeper than shown.

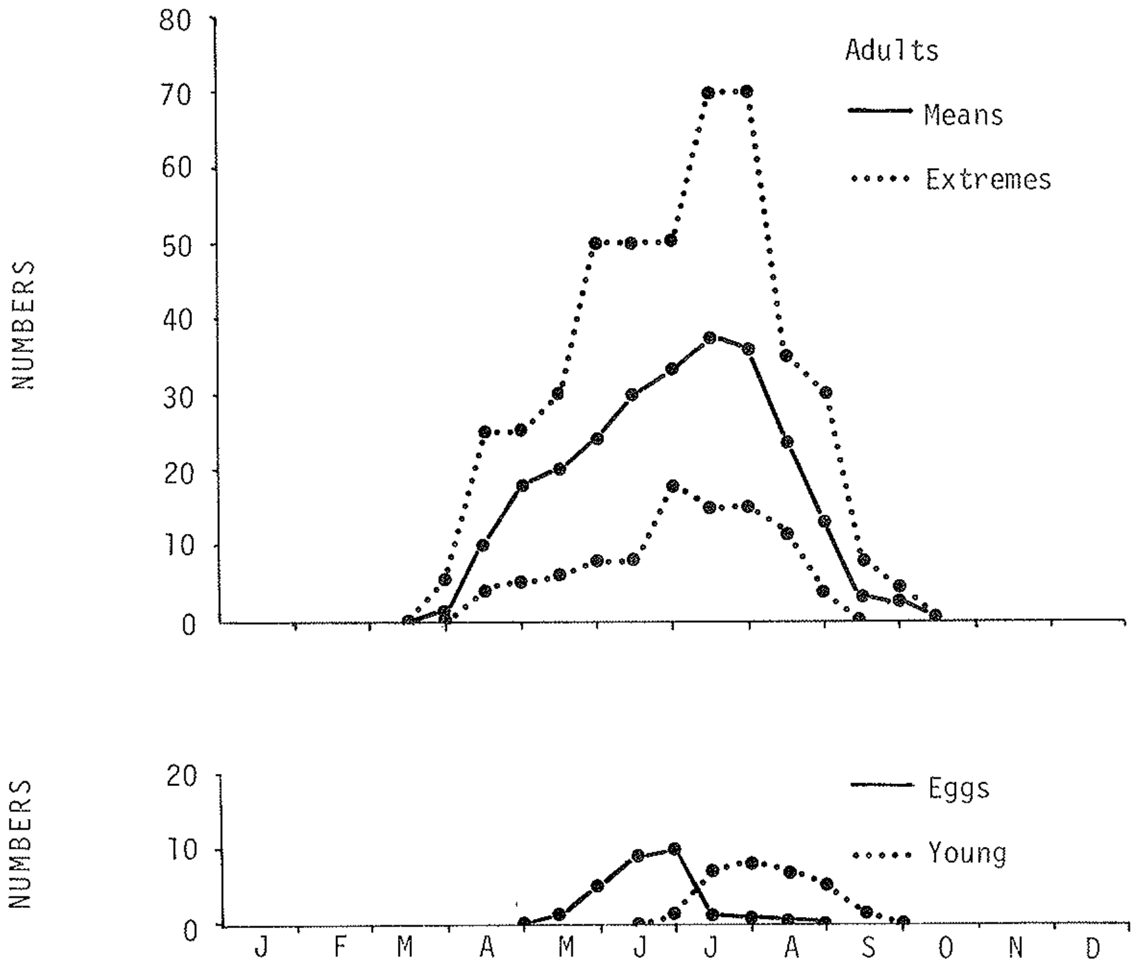


Figure 48. Means and extremes of semimonthly estimates of Bulwer's Petrel numbers, Sand Island, Johnston Atoll, 1964-1969.

The number of adults handled each year probably represents 75 to 90 percent of the returning birds on average, although it may have been no more than 50 percent in 1966. The upward trend in numbers handled each year at least partly resulted from an increase in birds present and was not entirely due to increased effort to catch them.

If one makes the reasonable assumption that Wetmore's 1923 visual estimate of 400 Bulwer's Petrels was slightly low, this species has been reduced by perhaps 90 percent since 1923. The natural rock crevices on Johnston Island where Wetmore found these birds in 1923 have all been destroyed. The birds using the atoll now depend completely upon the crevices on Sand Island between rocks and chunks of concrete used to build the causeway, and on space under slabs of concrete scattered around the island.

As in the case of Christmas Shearwaters, it is difficult to see where any Bulwer's Petrels would have been able to nest during the years of intensive military use of the two islands, and it is likely that during several years there was no successful nesting.

Under present conditions there probably are more available nest sites than are being used, and barring further disturbance the population should be able to increase to some extent.

Production of chicks was relatively high for this species and appeared to be increasing from 1964 through 1969 (Table 28). Losses were mainly of eggs rather than chicks, and most losses were attributed to flooding by high tides. If the adult population was about 50 in 1968 and 1969, then the number of chicks produced was about 20 percent of this number. Mortality rates for adults are unknown, but the apparent increase in total numbers indicates that there must be a net gain from year to year --more chicks are produced than adults lost. In 1968 the first known-age chicks returned to the island--the single chick banded in 1964 and one banded in 1965. Neither of these was recaptured in 1969, but three more of the six 1965 birds returned in 1969. Thus of seven chicks banded in 1964 and 1965, five survived long enough to return to the island, one at age three years and the others at four. None of these known-age birds was known to breed, but two of the 1965 chicks that returned in 1969 developed bare brood patches and engaged in courtship calling. All returned in late May or later, at least two months after established breeders return, and all returned to approximately the same section of the island where they had hatched.

Annual Cycle

Table 29 shows the available dates of major events in the annual cycle of Bulwer's Petrels on Sand Island during POBSP studies. Because the birds are secretive, returning to the island at dusk or after dark, and also returning at the time Sooty Terns are most abundant and most demanding of research time, observations were not as complete as for the more conspicuous species. Exact date of laying was not determined for any eggs, although dates of hatching and fledging were known for several.

Table 28. Productivity of Bulwer's Petrels on Sand Island, Johnston Atoll, 1964-1969*

		Chicks				
		Hatched		Fledged		
Year	Eggs	No.	Percent	No.	Percent of eggs	Percent of hatching
1964	6	3	50	3	50	100
1965	12	9	75	6	50	67
1966	10	6	60	5	50	83
1967	15	14	93	10	67	71
1968	13	11	85	11	85	100
1969	15	10	67	10	67	100
Totals	71	53	67	45	64	85

*All egg and chick figures are minima, considered to be about 90 percent complete [and the number of adults handled represents about 90 percent of the total].

Bulwer's Petrels were completely absent from the atoll for about six months, from late September to late March. The first birds probably returned to the island each year in the last week of March (see Figs. 37 and 48), although in some years none was seen until nearly mid-April. On arrival they come in at about dark and court in the nest sites through the night, leaving sometime in the early morning. They are most easily found at this time, for their courting calls can be easily heard. Many nest cavities are too deep for an observer to reach the birds, or in some cases even to see them, but at this season they can be called out readily by imitating their courting calls.

First eggs were found usually by the end of May, but it is likely that laying began by mid-May in most years. The latest known laying was about 5 July 1969. This egg, and the latest laid in other years, did not hatch, and probably was produced by young adults, laying for the first time. Exact incubation periods were not determined, but two 1968 eggs required at least 44 and 47 days. Earliest chicks appeared in late June and none was known to hatch after mid-July. The data are insufficient to draw definite conclusions, but apparently the successful nesters are closely synchronized. Egg laying may extend over six or seven weeks, but the latest eggs never survive; thus all the chicks hatch within about three weeks of each other.

Table 29. Extreme dates of significant events in the breeding cycle of Bulwer's Petrels on Sand Island, Johnston Atoll, 1964-1969*

Year	Adults present	Laying	Hatching	Fledging
1964	30 Mar.-late Sept.	by 20 May-?	*ca.* 10 July-?	?-late Sept.
1965	20 Mar.-*ca.* 10 Sept.	by mid-May-?	late June-early July	*ca.* 30 Aug.-*ca.* 15 Sept.
1966	11 Apr.-*ca.* 26 Aug.	late May-?	early July	*ca.* 30 Aug.-9 Sept.
1967	7 Apr.-late Aug.	by 15 May-?	?-?	late Aug.-mid-Sept.
1968	11 Apr.-early Sept.	late May-mid-June	*ca.* 1-15 July	*ca.* 1-18 Sept.
1969	25 Mar.-*ca.* 30 Aug.	by 15 May-*ca.* 5 July	by 29 June-5 July	*ca.* 26 Aug.-6 Sept.

*Precisely known dates are underlined; others are earliest or latest observed or estimated.

Fledging took place from the last week of August through mid-September. The period from hatching to fledging, determined for eight 1968 and 1969 birds, ranged from 57 to 67 days (mean = 62 days).

After the eggs were laid only one adult was found at a time at the nest, and after hatching the chicks were guarded only for the first few days. Nearly all five-day-old birds measured in 1969 were unattended, even at night. Apparently the deep, well-protected nest sites make parental protection unnecessary and the adults stay only long enough to feed their chicks, then immediately return to sea.

Pairs and single birds without eggs continued to return to the nest sites and court through early August when other birds were incubating or feeding chicks. Latest calling was heard 14 August in 1969. By the time the chicks are ready to fledge all adults are very scarce; not only do the non-breeders cease to come back but those with chicks abandon their offspring for several days before they fledge. No adults have been recorded after mid-September, and in most years none was found after the end of August.

Molt probably occurs entirely while the birds are away from the island. Only a few birds were examined carefully for molt, but all those examined in early spring had completely new plumage and none examined late in the breeding season had begun to molt.

Specimens

Appendix Table 7 lists the ten specimens of Bulwer's Petrel collected from Johnston Atoll. Wetmore collected nine (skins: 5 male, 4 female) and POBSP personnel collected one (skin: 1 male) in 1964; all are housed in the USNM. This is considered as a new specimen record, as well as a new breeding record.

Banding and Movements

Tables 24 and 30 show banding and recapture efforts on Bulwer's Petrels. These birds do not dig and consequently band wear was much less than on shearwaters. Thirteen of the 22 adults banded in 1964 were recaptured in 1969 and all bands were legible and in no immediate danger of being lost. None was rebanded.

A few birds may have changed mates or taken new ones when the former mate was lost, and a few birds changed nest sites, but generally pair and site bonds appeared to be very strong. Members of at least two pairs stayed together from 1964 through 1969, one pair definitely using the same nest site each year and the other using the same or another close by.

No interisland movements of Bulwer's Petrels to or from Johnston Atoll are known.

At-Sea Distribution

Bulwer's Petrels were found in the grid in all months except December, January, February, and June (Table 21 and Fig. 49). Since the grid population is too high to be accounted for by Johnston birds, and the peaks occur just before and after the breeding season, it is unlikely that Johnston based birds make more than a minor contribution to the grid population. The September peak in grid birds is certainly concurrent with the major southward migration from the Hawaiian chain (POBSP, 1967a).

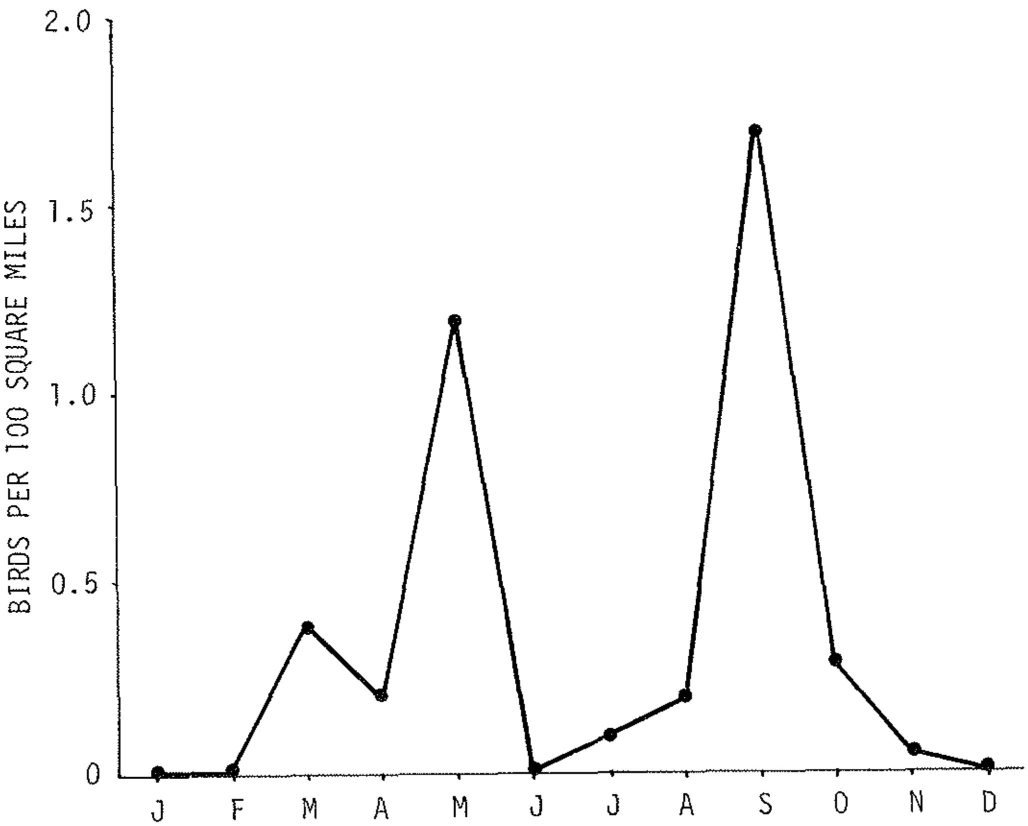


Figure 49. Diurnal occurrence of Bulwer's Petrels at sea 175 miles southwest of Johnston Atoll, 1963-1967.

Table 30. Banding and recaptures of Bulwer's Petrels, Sand Island, Johnston Atoll, 1964-1969

Year	Adults handled: New bandings	Adults handled: Returns*	Adults handled: Total	Young banded	Total new bandings
1964	22	0	22	1	23
1965	15	15	30	6	21
1966	3	19	22	3	6
1967	5	25	30	6	11
1968	11	29	40	10	21
1969	6	40	46	8	14
	62	128	190	34	96

*Each bird counted only once each year recaptured.

WEDGE-TAILED SHEARWATER *Puffinus pacificus*

Status

Abundant breeding species, present from March to early December. Nests in shallow to deep burrows, mainly in dense *Lepturus* on the west half of the original portion of Sand Island; a few nest on Johnston Island. Ranks third behind Sooty Terns and Brown Noddies in number of young produced each year (300 to 450), and fourth behind these two species and Red-footed Boobies in number of adults using the island (3,000). After an absence of about three months, adults return in March and immediately begin courtship and burrow digging, mainly in dense *Lepturus* on the west half of the original portion of Sand Island. Eggs are laid in late June and early July and most chicks hatch during the last three weeks of August. Fledging begins in November and the last chicks and adults usually leave in early December.

Ecological Distribution

Johnston Island: Brooke (ms.) described what most likely were Wedge-tailed Shearwaters from Johnston Island on 15 March 1859, as follows.

> The ground is undermined by petrels who live two together, and in walking over the island I came across many pairs sitting or lying cozily together at the entrance of their retreats, basking in the Sun and screened from the wind by

> the grass. They were quite noisy and many were billing and cooing. The people onshore call them diggers from the fact of their living in holes.

If these were Wedge-tailed Shearwaters--there are no records of Bonin Petrels from Johnston Atoll--their breeding cycle then was not in the same season as today.

Wetmore (ms. a and b) noted large numbers of Wedge-tailed Shearwaters on Johnston Island in July 1923. The island was honey-combed with burrows. Most were incubating in burrows up to four feet long; others were under little mats of vegetation above ground. Various other visitors noted this species on the island, including Thurston (1928) in April 1928, Clark (1945 a and b) in May 1945, and Fennell (1948) in 1948. POBSP personnel recorded a few wedge-tails each year during 1963-1969.

Johnston Island, where most of the original birds nested, probably became less suited to them throughout the war years. From 1963 to 1969 a few wedge-tails were atrracted to the fairly dense stand of *Vitex trifolia*, growing in loose gravelly sand on a point between the main street (Arthur Avenue) and the east taxiway. They dug shallow burrows there, or simply sat on the ground under the bushes; a few eggs were laid some years but no young were known to fledge. A few birds also used the crawl space under at least one building and burrowed under concrete slabs on top of an underground building.

Sand Island: Wetmore (ms. a and b) recorded this species on Sand in July 1923. He, as did Thurston (1928) in April 1928, noted the soil on the island was honey-combed with shearwater burrows. Moynihan (1957) found at least a few on the original part of Sand sitting on the ground in the open or just inside the mouths of their burrows during the daytime in April 1957. POBSP personnel recorded this species as very numerous on the original portion from 1963 through 1969. Amerson recorded them with almost fledged young in November 1973.

Figures 35, 43 and 50 show the distribution of Wedge-tailed Shearwaters on Sand Island. The preferred habitat from 1963 to 1973 was deep sand, stabilized by dense, undisturbed *Lepturus*, which was prominent only on the west half of the original portion (Figs. 51 and 52). Many burrows were dug in more open sandy areas, but without grass roots to hold the loose sand, heavy rains caused many of these burrows to cave in. They also burrowed under sidewalks around the transmitter building and the abandoned gun emplacement. The man-made end of Sand Island was too gravelly and hard-packed for the birds to burrow, but *Pluchea carolinensis* bushes growing southeast of the barracks were thick enough by 1969 to attract at least one bird for long enough to lay an egg.

The necessary element in all these habitats was shelter from the sun. Where this was obtained without digging, as in the gun emplacement or under buildings, the birds made no attempt to dig, but simply laid their eggs on the ground in a shallow cup formed of bits of grass, bones, and feathers. Burrows were lined similarly.

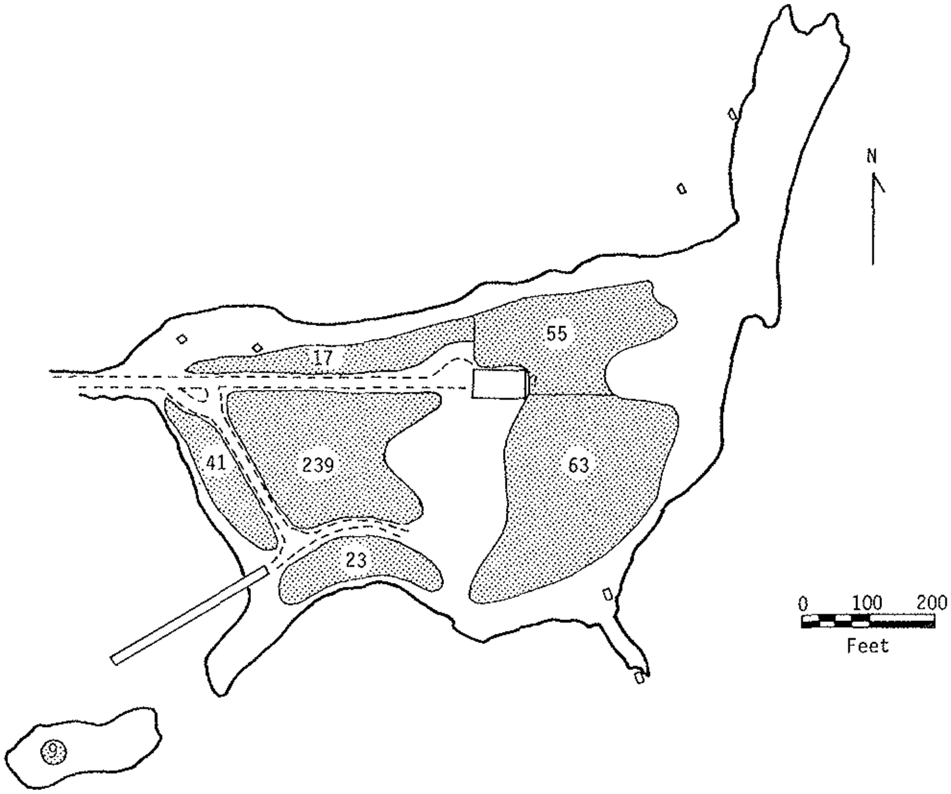


Figure 50. Distribution of Wedge-tailed Shearwater nest sites on Sand Island, Johnston Atoll, 1963-1969. Numbers indicate chicks banded in 1968.

Populations

The Wedge-tailed Shearwater population at Johnston Atoll consists predominantly of light phase individuals. Light phase populations also breed in the Hawaiian Islands and the northern Marshall Islands.

Figure 53 shows means and extremes of semimonthly estimates made by POBSP personnel from 1964 through 1969 of Wedge-tailed Shearwater numbers on Sand Island. These estimates were usually based on sample counts of birds above ground, plus a liberal allowance for birds in burrows and birds not returning to the island each night. Year to year variations in these estimates were small and more likely resulted from differences in estimating techniques than real variations in shearwater numbers. Hence, there is no evidence that the number of Wedge-tailed Shearwaters using the atoll varied during the years of POBSP studies.

On 30 September 1966 Shelton made a sample count on all parts of Sand Island and found that 57 percent of 150 Wedge-tails had fresh orange streamers put on some time that year. About 1,720 birds had been streamered in 1966, most of them in August and September. Although there was no way to determine an exact figure, streamer losses were thought to be less than

Figure 51. Wedge-tailed Shearwater chick in front of burrow under *Lepturus repens* clumps, Sand Island, Johnston Atoll, 2 September 1966 (POBSP photo by P. C. Shelton).

Figure 52. Wedge-tailed Shearwaters among *Tribulus, Boerhavia,* and *Lepturus* on southwest Sand Island, Johnston Atoll, mid-morning July 1963 (POBSP photo by A.B. Amerson, Jr.).

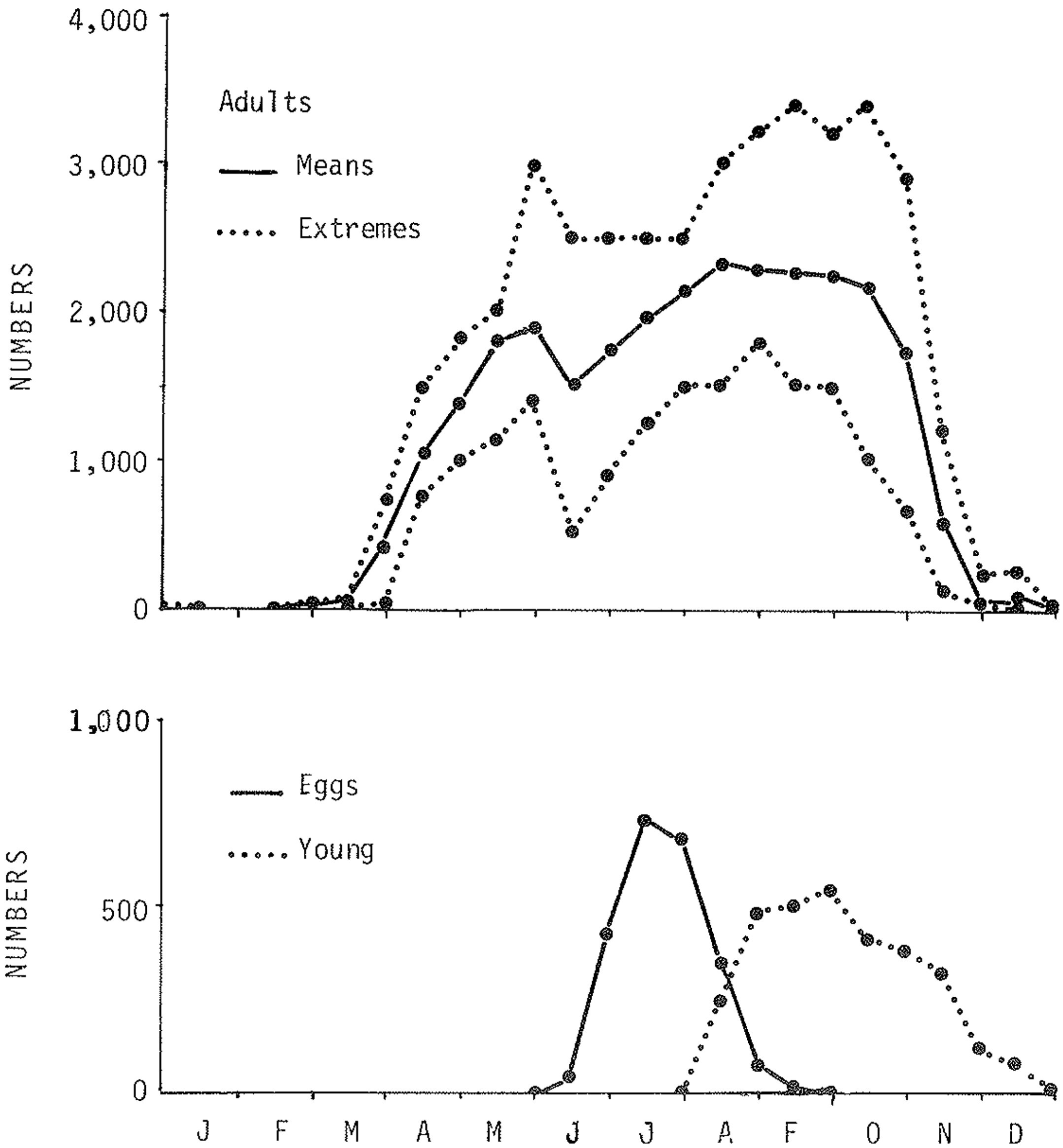


Figure 53. Means and extremes of semimonthly estimates of Wedge-tailed Shearwater numbers, Sand Island, Johnston Atoll, 1963-1969.

ten percent by 30 September. If there had been no streamer loss, then the 1,720 birds would represent approximately 57 percent of the total population using the island during that period:

1,720/0.57 = *ca.* 3,000.

If ten percent of the streamers had been lost by 30 September, then the total population would have been:

1,550/0.57 = *ca.* 2,700.

It is acknowledged that the assumptions underlying these calculations may not be fully met, but the data are presented as the best available estimate of wedge-tail numbers on Sand Island during this period. These figures are only about one-fourth larger than the mean of the semi-monthly estimates, which suggests that these estimates are a fairly good approximation of the numbers of wedge-tails using the island during the periods involved.

The only comparative data from pre-POBSP sources are from Wetmore's 1923 observations in which he estimated 2,500 wedge-tails on Johnston Island and 500 on Sand. Superficial comparison of these figures with POBSP estimates and calculations would indicate that the population of the atoll had not changed appreciably, but that the former population on Johnston Island had moved to Sand. But Wetmore's figure is a visual estimate, made over only a ten-day stay, in which Sand Island was not visited at night when maximum populations would have occurred. Visual estimates by the POBSP in mid-July averaged about 2,000 birds, or two-thirds Wetmore's estimate. Wetmore thought that a quarter of the several thousand birds he found killed by feather poachers were Wedge-tailed Shearwaters. Thus, his estimate of 3,000 must have been at least a thousand less than the original number.

Both Wetmore and Thurston stated that the entire surface of both islands was burrowed by wedge-tails. At that time at least five times as much dense *Lepturus* habitat was available as during the 1960's. If the pre-war density of burrows (and birds) was as great as the density during the 1960's, then the former population may have been several times that of the present. No comparative density data exist, but it is likely that many birds from Johnston have crowded on to Sand Island, resulting in greater density than occurred on the undistrubed islands.

In summary, then, it would appear that the original population of wedge-tails was at least 1.5 times that of the present, and may have been two or three times the 3,000 now thought to use the atoll.

Whatever may have been the magnitude of the decrease in population between Wetmore's visit and the 1960's, the cause is not difficult to determine. The original portion of Sand Island--less than ten acres--now has the only significant amount of natural habitat for this species. There probably were about 50 acres available to them on the two islands before military construction began. The ability of these birds to crowd together to adapt to artificial habitats, such as abandoned bunkers and crawl space under buildings, has not been great enough to allow them to maintain their original numbers.

It is not likely that enough wedge-tails were killed, either by feather poachers or military personnel, to lower permanently the population. Reduced nesting success during early years of military occupancy of the atoll probably gradually lowered the population to its present level. Johnston Island, where most of the birds originally nested, probably became less suited to them throughout the war years, but Clark's

(1945) and Fennell's (1948) notes indicate that more than the few dozen largely unsuccessful nesters found there in the 1960's were using Johnston until at least the late 1940's.

During POBSP studies the number of chicks produced each year averaged about ten percent of the adult population (Table 31). Figures in this table probably represent at least 90 percent of the chicks fledged in each year. Egg numbers were less reliable because many burrows were too deep to inspect. The two egg figures given are based on counts made over the entire island, with the ratio of eggs to burrows assumed to be the same for those that could not be inspected as for those that were examined. These counts were made in July or August, after an undetermined number of eggs had already been lost.

Table 31. Productivity of Wedge-tailed Shearwaters on Sand Island, Johnston Atoll, 1963-1968

Year	Eggs laid	Chicks banded*	Percent of eggs resulting in fledged chicks
1963		153	
1964		304	
1965		389	
1966	600	150	25
1967		(300)**	
1968	750	447	60
1969		0***	

*Number banded represents at least 90 percent of number fledged.

**Early September count. None banded.

***No counts were made in 1969. Numbers of eggs and chicks were estimated to be approximately equal to 1967 numbers.

Egg and chick losses resulted from several factors. Each year several dozen eggs were laid on top of the ground where there was no protection for the incubating birds. Some of these eggs were incubated for several weeks, but all were abandoned before they hatched. Eggs sometimes were broken in the burrows, possibly as a result of disputes over ownership of the burrows. Both these egg losses could be attributed to crowded conditions. Wedge-tails normally burrow under dense *Lepturus* and the burrows are fairly stable, even in heavy rains, because of the holding power of the grass roots, but much of Sand Island is now well vegetated and burrows in bare sand frequently cave in during heavy late summer rains. In 1966 a dry spring and summer coupled with disturbance from machinery in May when the LORAN-C transmitter tower was re-guyed and painted left little healthy vegetation and wedge-tail chick losses during August and September rains were greater that year than any other. Dogs killed at least 35 chicks in 1963 and at least 11 in 1964. The main culprit, a Coast Guard dog named "Jeffroe," was too aged to have much impact after those years although he survived until late 1968. Only a few chicks were killed by other dogs.

Adult mortality was very low and must not have been more than ten percent per year both on and away from the island, since an annual chick production of about this magnitude appeared to maintain the population.

Annual Cycle

Table 32 and Figure 37 shows inclusive dates for the major events in the annual cycle of Wedge-tailed Shearwaters on Johnston Atoll. The approximate numbers of adults, eggs, and chicks are shown on Figure 53.

Striking features of the wedge-tail's cycle are the uniformity from year to year and the shortness of the laying period. Among Johnston birds, this species holds the record on both counts. Wetmore's comment that most birds were incubating in mid-July 1923 indicates that the breeding cycle was the same then as now. In 1969, when egg laying was delayed in several other species, wedge-tails arrived on schedule. The unusual weather pattern thought to be responsible for the disruption of breeding in the other species occurred in early to mid-February and ended about three weeks before the wedge-tails returned. Other species did not regain normal status until after wedge-tails returned but wedge-tails, being the latest breeders on the atoll, apparently were not at a vulnerable stage in their cycle in the few weeks prior to returning to the islands.

The synchrony of egg laying in this species is remarkable. Virtually all the eggs appear to be laid within a month, and most in the last two weeks of June. Accurate dates for last egg laying are not available for most years, but in 1969 the southwest islet bunker was checked at least every other day through June and early July and all the 16 eggs were laid between 12 June and 1 July. Also, about three dozen eggs laid on top of the ground where they could be seen readily were laid between these dates. Close synchrony of laying in this species results partly from lack of relaying, which is also true of the other two breeding procellariiforms (Christmas Shearwaters and Bulwer's Petrels). Lack of chose synchrony in these two species may be related to their occurring in much smaller numbers than wedge-tails.

Wedge-tails began courtship and burrow digging almost immediately on arriving back on the island each year. For the first few days after they returned, they were present at night only, but soon small groups stayed through at least part of the day. Night numbers were always at least twice the daytime numbers. Numbers increased through late March and April, reaching a maximum in May when courtship was most intense and copulation occurred. The dip in early June (Fig. 49) resulted from females staying at sea to feed during development of the egg. From this time until after hatching began, observed numbers remained low. During incubation adults relieved one another at intervals of about eight days

Table 32. Extreme dates of significant events in the breeding cycle of Wedge-tailed Shearwaters, Sand Island, Johnston Atoll, 1963-1969

Year	Adults present	Egg laying	Hatching*	Fledging**
1963	?-1-15 Dec.	?	14-17 Aug.-?	?-1-15 Dec.
1964	11 Mar.-10 Dec.	15 June-?	4-5 Aug.-?	16-30 Nov.-*ca.* 14 Dec.
1965	11 Mar.-*ca.* 30 Nov	1-15 June-?	1 Aug-16-30 Sept.	1-15 Nov.-10-15 Dec.
1966	12 Mar.-2 Dec.	15 June-?	*ca.* 5 Aug.-3 Sept.	late Nov.-15 Dec.
1967	21 Mar.***-?	18 June-?	by 18 Aug.-10 Sept.	?-?
1968	20 Mar.-16-31 Dec.	16-30 June-?	*ca.* 10 Aug.-1-15 Sept.	early Nov.-3-16 Dec.
1969	14 Mar.-?	12 June- *ca.* 1 July	4 Aug.-24 Aug.	?-?

*Incubation period about 53 days; of six 1969 eggs, 3 hatched between 50 and 54 days, 2 between 52 and 54 days, and 1 in 53 or 54 days.

**Fledging period about three months; no exact data.

***One bird 23 Feb., no others until 21 Mar.

(mean = 7.75, range ≃ 4-12, n = 12, POBSP 1963 data). Few birds except those incubating remained through the day, but large numbers returned at night. Most of these appeared to be unoccupied birds--ones that did not lay or that lost their eggs.

During the first week after hatching chicks were usually tended by both parents at night but by only one during the day. Attendance became less regular as the chick's food demands increased and both parents spent more time feeding at sea, but returned frequently, possibly every night, to feed the chick.

Maximum numbers appeared in late August through September. Daytime numbers remained lower than during the spring courtship period, but at dusk hundreds streamed in to the island, mostly from the southwest, and remained through the night. Counts of 900 to 1,000 birds on the surface were made in August and September 1966. A few hundred more were under ground and not counted. Thus, each night approximately half the total number of birds using the island during the year returned during this period.

Those with chicks more than one or two weeks old apparently fed their offspring early in the evening and spent the reaminder of the night outside the burrows in large, loose roosting clubs, probably composed of these and unoccupied birds. Low intensity courtship accompanied by outbursts of moaning as enthusiastic as those of the pre-laying courtship period, continued through the early fall nights. By dawn, most birds had returned to sea to feed.

Numbers declined in October, probably because birds without chicks ceased returning. In November, adults with chicks began leaving and numbers declined sharply. The last adults ceased returning in early December. Chicks began leaving their burrows for short periods at night by October, and began to fledge in November shortly after their parents abandoned them. All were gone by mid-December.

Except for one bird found 23 February 1967, no Wedge-tailed Shearwaters were known to have been on Johnston Atoll between mid-December and mid-March--a period of four months. Presumably the birds spent this time at sea, feeding and molting.

The beginning of the post-nuptial molt has not been observed, but few birds were handled in late fall when it might have started. Adults have nearly completed their molt by the time they return in the spring. In five of 12 birds examined 13 April 1967 the distal primary was only about three-fourths grown on each wing. Body feathers of the returning birds have a frosted appearance which is soon lost by wear.

Specimens

Specimens of Wedge-tailed Shearwaters from Johnston Atoll are listed in Appendix Table 7. Wetmore collected seven specimens (4 males, 3 females) in July 1923. POBSP personnel collected 93 specimens from 1963 through 1969. All specimens are housed in the National Museum of Natural History.

This is a new published specimen record.

Banding and Interisland Movement

POBSP personnel and Amerson banded 6,517 individual Wedge-tailed Shearwaters (4,985 adults and 1,532 young) at Sand Island during 1963-1969, 1973 (Tables 24 and 33). Rapid wear and loss of aluminum bands made analysis difficult because 961 birds had to be rebanded. Beginning in 1968 most adults and all chicks were banded with Monel metal bands. Orange, plastic, leg-streamers were also put on most adults handled each year but these too were lost fairly rapidly; virtually none was found on returning birds at the beginning of each new breeding season. Of the 6,517 birds originally banded on the island, 3,635 were recaptured back there indicating strong ties to their breeding ground. Six birds, banded as young in 1968, were recaptured back on Sand Island in November 1973; these probably had returned to the island for the first time as they appeared to be going through pre-breeding courtship behavior similar to that observed in other Procellariformes. The Monel bands on these six showed little wear.

Nine Wedge-tailed Shearwaters banded as adults at Johnston Atoll were recaptured elsewhere: six at French Frigate Shoals and three at sea. One banded 19 September 1973 was recaptured 8 November 1965 at sea at 41°0'S and 174°20'E, which is west of Cook Strait, New Zealand. In addition, eight wedge-tails banded as adults elsewhere were captured at Johnston Atoll, six from French Frigate Shoals and two from Oahu.

At-Sea Distribution

Light phase Wedge-tailed Shearwaters--the phase most prevalent at Johnston Atoll and in the Hawaiian Islands--occurred at sea in the grid southwest of Johnston Atoll during all months but were at their highest in September and lowest during January, February, and March (Table 21 and Fig. 54). Year-to-year variations in density and rhythm were fairly small.

With the exception of an anomalously low grid density in June, the annual population cycles on Johnston Atoll and in the grid were similar from January through July (see Fig. 53). Major differences, however, existed between these two areas from August through December. In the grid, numbers continued to increase through September, decreased in October, and increased again through November and December. These were probably post-breeding and non-breeding birds concentrating prior to, or during migration. By October most, if not all, these birds had left the area. Increased numbers in the grid in November and December probably represent young birds leaving the islands and perhaps remaining at sea for a month or more, feeding and gathering strength for dispersal to the wintering area. Most of the birds observed in the grid in December and January were in apparent first year plumage.

No orange-streamered wedge-tails from Johnston were recorded within the grid. At least 25 orange-streamered birds were sighted, however, in the pelagic waters around Johnston Atoll. It is possible that a large part of the grid population consists of non-breeding birds that belong to the larger north-central Pacific population of which Johnston birds are only one group (POBSP, 1967a; King, 1974).

Figure 54. Diurnal occurrence of Wedge-tailed Shearwaters (light phase) at sea 175 miles southwest of Johnston Atoll, 1963-1967.

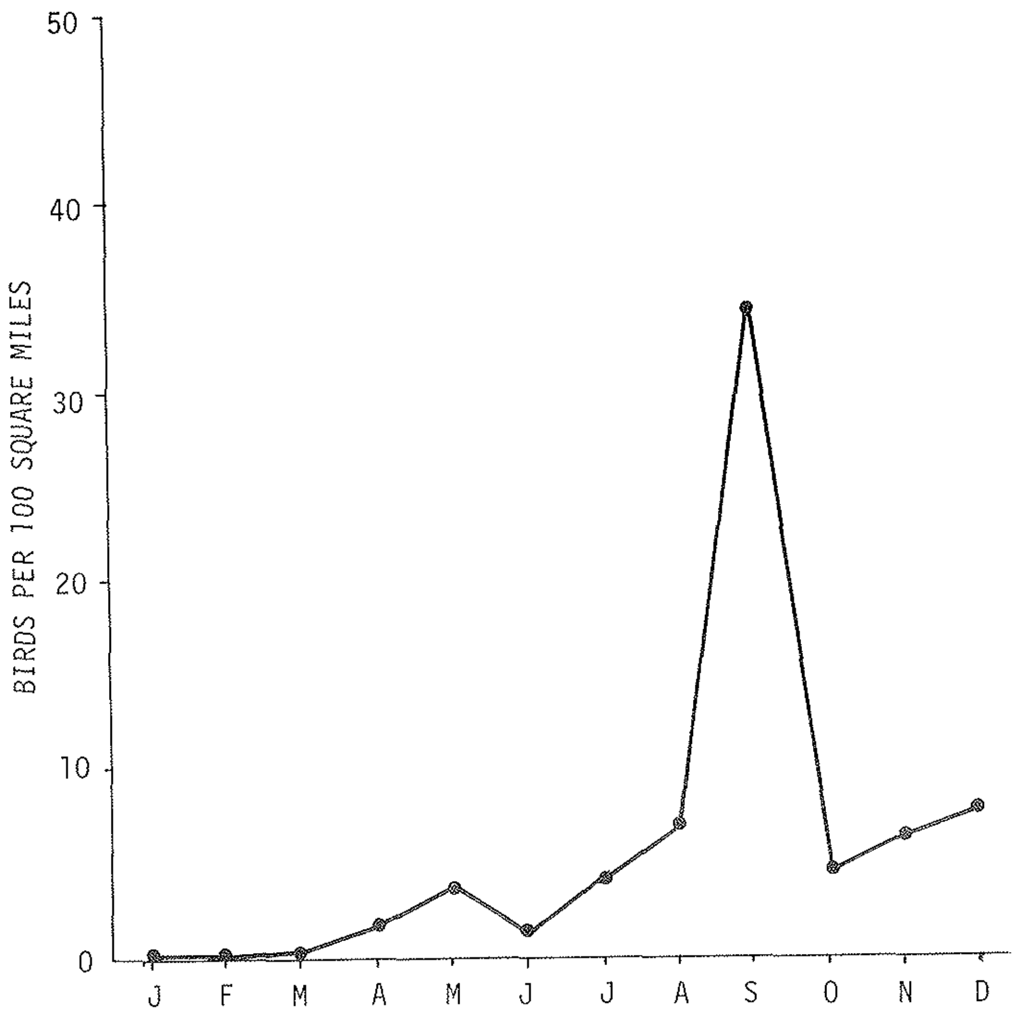


Table 33. Banding and recaptures of Wedge-tailed Shearwaters, Sand Island, Johnston Atoll, 1963-1973

Year	Adults					Young banded	Total Banded
	New banding	Returns	(Rebanded)	Recoveries*	Total handled		
1963	1,813	2		0	1,815	153	1,966
1964	939	234		29	1,202	309	1,248
1965	530	662	(113)**	35	1,227	389	919
1966	1,042	1,040	(447)	11	2,093	150	1,192
1967	72	196	(64)	4	272	0	72
1968	501	377	(319)	6	884	447	948
1969	88	71	(18)	1	160	0	88
1973	0	6	(6)	0	6	84	84
	4,985	2,588	(967)	86	7,659	1,532	6,517

*Dead birds.

**Numbers in parentheses are numbers rebanded.

CHRISTMAS SHEARWATER *Puffinus nativitatis*

Status

Uncommon breeding species, present from late January to late September. Nests on Sand Island; previously nested on Johnston Island. About 30 birds, half of which attempt to breed, returned each year during POBSP studies; three to ten eggs were laid and one to six chicks fledged each year. Adults returned to the island in January, laid from late March to early May, and left the island in August or September. Chicks usually hatched in May or June and fledged in August or September. Most successful nests were near the shore under boards, logs, and concrete slabs, or in an abandoned bunker. Attempts to nest in shallow trenches under *Lepturus* or *Boerhavia*, in the manner of birds nesting on undisturbed islands, usually were unsuccessful, probably because the best sites of this type were occupied by the larger and more aggressive Wedge-tailed Shearwaters.

Ecological Distribution

Johnston Island: Wetmore (ms. a) recorded about 400 Christmas Shearwaters here in July 1923 and described the colony as follows.

> There are two small colonies on the island, where these birds congregate amid the wedge-tailed shearwaters and have nests in holes dug to a shallow depth in the sandy soil. During the day all are hidden underground but at dark they creep out and remain active all night. Adults are calling and caressing one another though all have large young molting into first plumage. These squirm and bite when handled and utter a curious call cOO (given with expiration of breath) oo-oo (made as breath is inhated). The call is like that of the adult *P. cuneatus*. At dark the young creep out of their holes and remain in the open but seek shelter either in heavy grass or underground when the sun is high.
>
> Adults show some wear in plumage.
>
> The note of the adults is a curious crowing call coo-coo-oo-oo-Koo Koo Kaw, the first part drawn out and the last given rapidly. They are especially vociferous at daybreak in the morning and for an hour after.

Clark (1945b) again observed a few in May 1945. None has been recorded since.

Sand Island: Wetmore (ms. a) found about 100 adults with large young on Sand Island in July 1923. POBSP personnel recorded this species here in small numbers from 1963 to 1969. Kridler (BSFW, 1973) recorded four nests with eggs in May 1973.

Nesting habitat is discussed in detail in the Population section. In summary, they normally nest in shallow trenches under vegetation, usually *Lepturus*, but competition from Wedge-tailed Shearwaters appears to have driven them to the periphery of the island, where they use a variety of cavities under logs, boards, concrete slabs, and an abandoned bunker (Figs. 55 and 56). Attempts to nest under vegetation are less successful because the only vegetation available to this species is too sparse to provide adequate protection. Figures 43 and 57 show the distribution of the nesting sites used during POBSP studies.

Birds without nests were found in the same general area as the nesters. The east slope, where most of the unsuccessful nests were located, was a favored roosting place for birds without nests. A few were found at other sites scattered over the island, including the *Tournefortia* bush northeast of the transmitter, the unoccupied grass along the northwest shore, and the southwest islet bunker.

Populations

The mean and ranges of POBSP semimonthly population estimates during the years1964-1969 are shown in Figure 58. Year-to-year variations appear to be more likely due to variations in estimating techniques than to variations in actual numbers.

Nearly all Christmas Shearwaters returning to the island each year were handled at least once. Thus the number of new bandings, plus the number of previously banded birds caught, is a good estimate of the total number of birds using the island each year. This varied from 18 to 28 during the years 1963-1969 (see Tables 24 and 36). In all years except 1963, when observations by the POBSP did not begin until July, and 1966, when incomplete records were obtained, these figures probably represent at least 90 percent of the returning birds for the respective years. Loss of bands may have inflated the number of new bandings, which would compensate for birds missed. The total number of Christmas Shearwaters returning each year was 25 to 30. The mean of semimonthly estimates during the period of maximum abundance was about three-fourths this number, which probably is a good estimate of the number using the island during each semimonthly period.

Wetmore's estimate of 300 birds on Johnston and 100 on Sand in mid-July 1923 is over 20 times the number obtained from mid-July visual estimates during the 1960's. Loss of nesting habitat and crowding by Wedge-tailed Shearwaters appear to be the major causes of the decrease. Both shearwater species originally used similar habitat--sandy soil vegetated with *Lepturus*. Because both species are now crowded onto Sand Island and wedge-tails almost totally dominate available *Lepturus* stands, the smaller Christmas Shearwaters have declined to a much smaller fraction of their original numbers than have wedge-tails. During most intensive military use of Sand Island, there probably were years in which Christmas Shearwaters were unable to reproduce at all and the population may have dropped even lower than during the 1960's.

Figure 55. Christmas Shearwater chick, 2 and 1/2 months old, in shallow trench burrow under *Lepturus repens* clump on east shore of Sand Island, Johnston Atoll, 29 August 1966 (POBSP photo by P. C. Shelton).

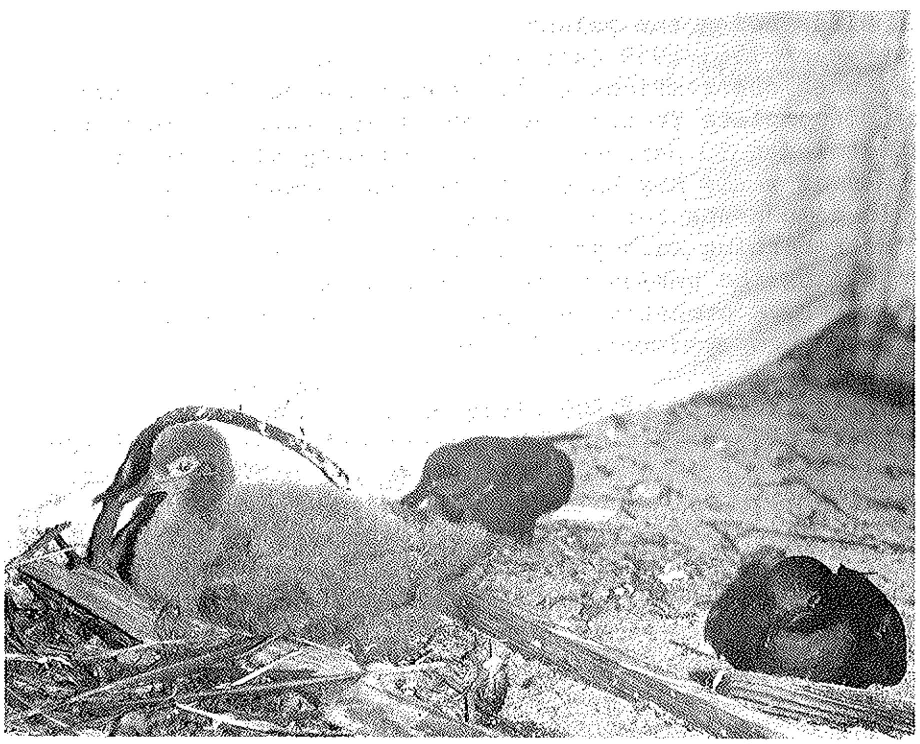


Figure 56. Christmas Shearwater chick, 2 months old, and adults in bunker on east shore, Sand Island, Johnston Atoll, 1 September 1966 (POBSP photo by P. C. Shelton).

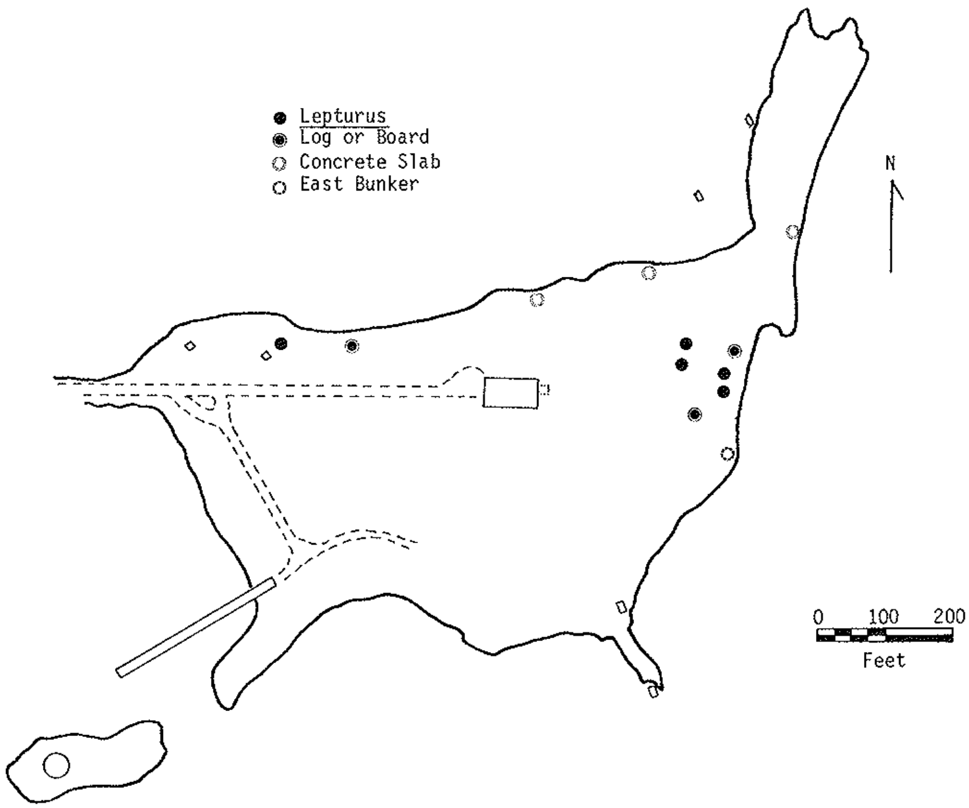


Figure 57. Distribution of Christmas Shearwater nest sites, Sand Island, Johnston Atoll, 1963–1969.

Fortunately, Christmas Shearwaters will nest closer to water than will wedge-tails. Cavities under concrete slabs, boards, logs, and an abandoned bunker, all close to the shoreline of Sand Island, were the sites of most successful breeding attempts during the 1960's (Table 34). Competition from Wedge-tailed Shearwaters restricted the Christmas Shearwaters that attempted to nest under vegetation to marginal sites under sparse cover where nests were exposed to rain, washing sand, and direct sunlight, as a result of which these nests were frequently abandoned.

Nesting success (Table 34) was low for all years except 1967 and 1968 when six and five young fledged. Low egg production in 1969 probably resulted from the weather pattern disturbance in February. Although the birds were only beginning courtship at the time, physiological changes must have been induced that prevented egg production in several birds.

Nearly all losses were of eggs rather than chicks, for only two chicks that hatched failed to fledge, both in 1965. One of these was killed by a dog just before it would have fledged; the other died much younger but the cause of its death was not recorded. Egg losses amounted to nearly half those laid; in a few cases the cause of loss was recorded. The two lost in 1964 were inundated by high tides; two

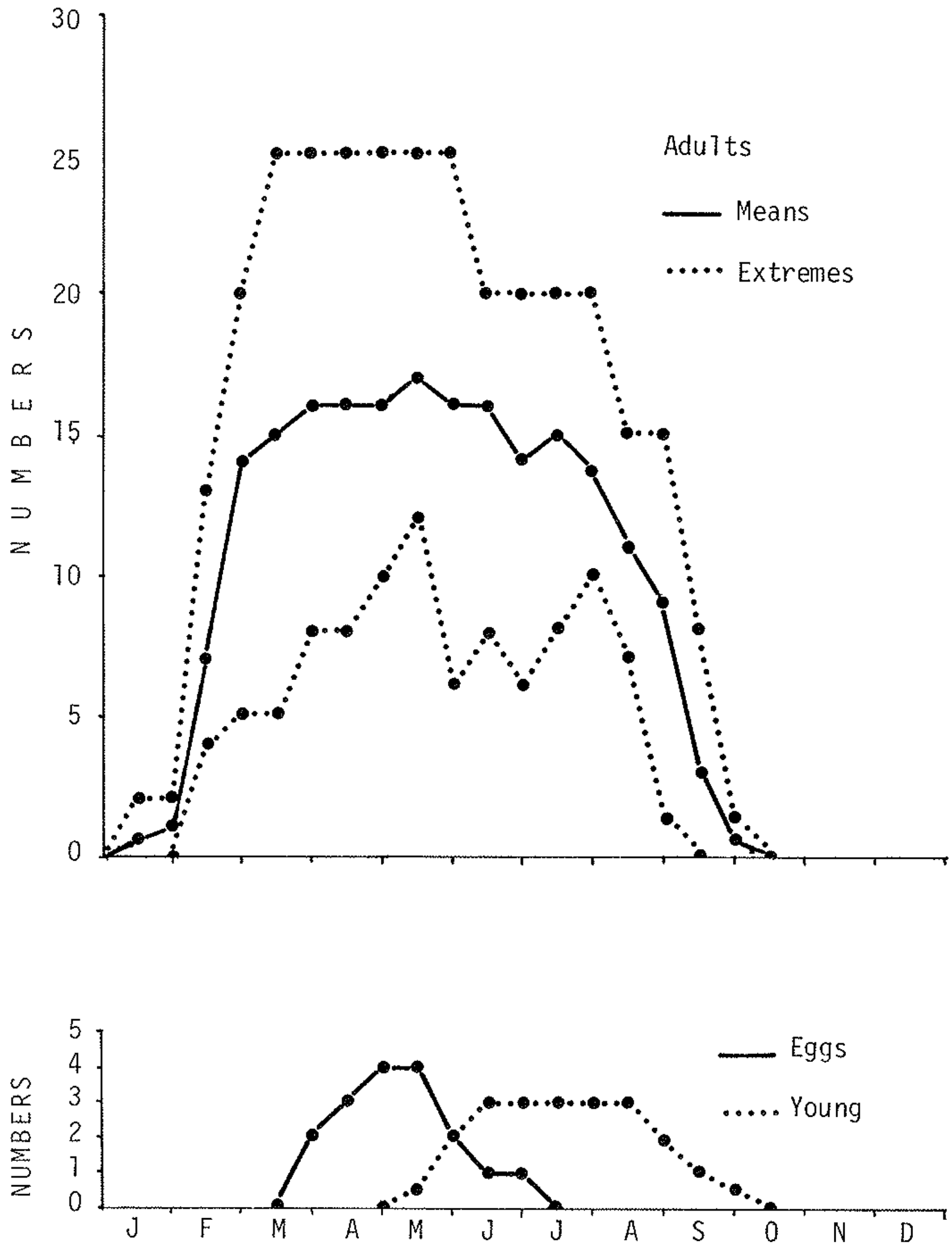


Figure 58. Means and extremes of semimonthly estimates of Christmas Shearwater numbers, Sand Island, Johnston Atoll, 1964-1969.

lost in 1968 were broken by Wedge-tailed Shearwaters; one 1968 egg was infertile; and one 1969 egg was abandoned when sand washed into the shallow nest cavity dug under loose *Boerhavia*.

Barring further disturbance of Sand Island, or further increase in wedge-tail numbers, Christmas Shearwaters should at least be able to hold their own, and might be able to increase slightly. On the northwest corner of Sand Island is a thin fringe of dense *Lepturus* that is not completely overrun by wedge-tails and this conceivably could be used by Christmas Shearwaters.

Table 34. Productivity of Christmas Shearwaters on Sand Island, Johnston Atoll, 1963-1969

Year	Number of Eggs Laid	Number of Chicks Hatched No.	Number of Chicks Hatched %	Number of Chicks Fledged No.	Percent of Eggs Laid	Percent of Chicks Hatched
1963				(2)*		
1964	4	2	50	2	50	100
1965	7	3	43	1	14	33
1966	6	2	33	2	33	100
1967	6	6	100	6	100	100
1968	10	5	50	5	50	100
1969	3	2	67	2	67	100
	36	20	56	18	50	90
All years:						
Cavities**	20	14	70	13	65	93
Natural Vegetation***	16	6	38	5	31	84

*Not included in totals.

**Under concrete slabs, logs, boards, or in abandoned bunker.

****Lepturus*, *Boerhavia*, or *Tribulus*.

Annual Cycle

From 1963 to 1969, after an absence of nearly four months, adults usually returned to the island in late January (Table 35 and Figs. 37 and 58). The first arrivals were usually seen soaring along the east shore at dusk; by dark they settled near the nest sites where they sat quietly most of the night, leaving by dawn. Numbers increased fairly rapidly during February as more birds returned each night and courtship began. Maximum numbers occurred in March when courtship was most intense. A few were sometimes present during the day at this time. Apparent numbers then declined slightly as those birds that would produce eggs spent more time feeding at sea. In 1969, pairs were observed copulating on 11 and 15 March. Eggs were laid by these birds 3 and 22 April, respectively. In both cases one bird returned to the nest less than half the nights during the two weeks before the eggs were laid. Other nights neither returned.

First eggs were laid in late March every year except 1969, when they were delayed until April. (In 1966 the first egg was discovered in April, but it had been laid sometime before that.) The delay in 1969 probably resulted from the disruption of the normal weather pattern in February; no Christmas Shearwaters appeared from 5 through 9 February, after at least three had returned regularly for several days in late January and early February.

Laying extended over a period of nearly seven weeks, slightly longer than for Wedge-tailed Shearwaters. If close synchrony in laying depended to any great extent upon social facilitation, then it would be expected that Christmas Shearwaters would be less synchronous than wedge-tails. The small numbers of Christmas Shearwaters nesting in scattered sites around the periphery of the island would have much less opportunity for social contact between pairs than would be the case with their more numerous relatives.

Exact dates of egg laying and hatching were obtained for only a few eggs; incubation averages about 52 days (range 51-54, n = 5) and fledging periods average about 96 days (range 88-103, n = 6).

One adult stayed with the chick during the day for the first week or so after hatching, and both parents usually returned at night for the first four to six weeks, after which only one usually returned. Chicks began to venture out of their nests at night when they are two-thirds grown, but they were quick to seek refuge if distrubed. Adults abandoned the chicks a few days before they fledged.

During the period of incubation and chick feeding, adults without eggs or chicks continued to return to the island at night. They arrived at dusk, soared along the east shore until about dark, then spent the night sitting in pairs or sometimes in groups of four or five near the beach on the east slope. Those that had lost eggs or had nested in former years usually returned to the site of their former nest or near the nesting birds. Low intensity courtship continued as long as these

Table 35. Extreme dates of significant events in the breeding cycle of Christmas Shearwaters, Sand Island, Johnston Atoll, 1963-1969

Year	Adults Present	Laying	Hatching	Fledging
1963	?-early Sept.			
1964	by early Feb.-*ca*. 20 Aug.	by 29 Mar.-1 Apr.	20-21 May	22-25 Aug.
1965	10 Jan.-*ca*. 1 Sept.	by 29 Mar.-30 Apr.	25 May-22 June	22 Aug.
1966	23 Jan.-30 Sept.	by 2 Apr.-*ca*. 10 May	*ca*. 12 June-*ca*. 1 July	8 Sept.-2 Oct.
1967	28 Jan.-*ca*. 25 Sept.	*ca*. 21 Mar.-6 May	13 May-*ca*. 29 June	*ca*. 13 Aug.-*ca*. 1 Oct.
1968	by early Feb.-26 Sept.	*ca*. 20 Mar.-7 May	*ca*. 5 May-19 June	4 Aug.-27 Sept.
1969	*ca*. 24 Jan.-*ca*. 15 Sept.	3 Apr.-22 Apr.	24 May-12 June	31 Aug.-*ca*. 20 Sept.

birds were present. At dawn they again soared over the east shore, occasionally calling as they flew, before heading out to sea for the day's feeding. These birds ceased returning to the island about the time the first chicks fledged.

Few birds were examined late in the breeding season, but two caught tending chicks in late August 1968 had started to replace their primaries. Thus the molt apparently begins shortly before the chicks fledge. Birds returning in January had completely new plumage.

Specimens

Eleven specimens are housed in the USNM (Appendix Table 7). This is considered to be a new published specimen record.

Banding and Interisland Movement

POBSP personnel banded 83 Christmas Shearwaters on Sand Island during 1963-1969 (Tables 24 and 36). Rapid band wear complicated analysis of the banding data. The aluminum bands used during the first five years of the study seldom lasted more than two years, so the birds had to be rebanded frequently. By 1969 several birds were wearing their fourth bands. Beginning in summer 1968 Monel metal bands were used to reband adults and to band all chicks. Recaptures of 1968 banded birds in 1969 showed little or no wear of the Monel metal bands.

Unfortunately, an undetermined, but hopefully small, number of birds lost bands without being rebanded, resulting in difficulties in tracing pair and site bonds and in inflation of the figure for total number of birds handled. The fragmentary data indicate that both pair and site bonds were strong--breeding birds almost always returned to the same site with the same mate year after year.

No birds banded as chicks were recaptured. Since these birds should not lose their bands until they return to the island and begin digging, it is unlikely that they returned and were not discovered. Each year a few unbanded birds appeared late in the breeding season and it is suspected that these were young birds, hatched before POBSP studies began, who were returning to the island for the first time.

No interisland movements of Christmas Shearwaters to or from Johnston Atoll were recorded.

At-sea Distribution

Christmas Shearwaters occur casually in the grid. They were observed there in every month except January and May (POBSP, 1967a).

Table 36. Banding and recaptures of Christmas Shearwaters, Sand Island, Johnston Atoll, 1963-1969*

	Adults			Young	
Year	New bandings	Returns** (rebanded)	Total Handled	Bandings	Total, new bandings
1963	20		20	2	22
1964	12	14(1)	26	2	14
1965	6	22(13)	28	1	7
1966	6	13(2)	19	2	8
1967	3	17(4)	20	6	9
1968	9	14(9)	23	5	14
1969	7	19(13)	26	2	9
	63	99(42)	162	20	83

*Includes three adults banded by N.P. Ashmole in February 1963; all other banding was by POBSP.

**Each bird counted only once each year.

NEWELL'S SHEARWATER *Puffinus puffinus newelli*

Status

Irregular summer visitor; two specimen records and one sighting on Sand Island.

Observations

The POBSP obtained three records of Newell's race of the Manx Shearwater from Sand Island. Amerson collected the first, an adult female, on 21 August 1963 from a group of 100 to 200 Wedge-tailed Shearwaters on the southeast slope. Harrington collected the second, an adult female, as it rested among Sooty Terns and Wedge-tailed Shearwaters in the southwest grass on 13 June 1967. The next night he saw another beside the transmitter building but did not collect it. All three were found at night.

Newell's Shearwaters are common at sea in the north-central Pacific from March to November (King and Gould, 1967), and a nesting ground was discovered on Kauai in 1967 (Sincock and Swedberg, 1969).

Specimens

The two specimens noted above and in Appendix Table 7 constitute a new specimen record for Johnston Atoll.

SOOTY STORM PETREL *Oceanodroma tristrami*

Status

Accidental; one specimen from Sand Island.

Observations

A Sooty Storm Petrel flew into the U.S. Air Force camera building on Sand Island shortly after midnight 21 December 1968, a night of high winds and intermittent rain. Brownell collected it. The bird was a female with a recently ruptured ovarian follicle, recently used oviduct, and a slightly vascularized bare brood patch, all indicating that it had laid shortly before arriving on Sand.

Sooty Storm Petrels breed from December through May throughout the northwestern Hawaiian Islands (Richardson, 1957; Clapp and Woodward, 1968; Amerson, Clapp, and Wirtz, in press). They normally occur at sea in the vicinity of their breeding grounds and probably disperse northward (King, 1967). Small numbers have been recorded only during February, March, and April in the grid southwest of Johnston Atoll (POBSP, 1967a).

Specimens

The specimen noted above and in Appendix Table 7 is a new specimen record for Johnston Atoll.

RED-BILLED TROPICBIRD *Phaethon athereus mesonauta*

Status

Rare visitor; three sight records from Johnston Island.

Observations

Three Red-billed Tropicbirds have been observed on Johnston Atoll, two of which were caught and released. Some sightings attributed to White-tailed Tropicbirds may have been Red-bills for the two are difficult to distinguish if seen only from below.

Moynihan (1957: 36) made the following comments on his survey of 6 to 10 April 1957:

> One individual of this species was present during every day of my stay. It flew back and forth in company with the Red-tailed Tropicbirds; but did not participate in

their displays. It did, however, come down to land with one of the Red-tails several times. A second Red-billed Tropicbird appeared on April 9. It also flew back and forth with the Red-tails; but the two Red-bills appeared to ignore one another.

This record seems to be a considerable extension of the known range of *P. athereus* (Joseph E. King, personal communication); but it is quite definite. I did not collect the two birds; but I got excellent views of both, even picking one of them up in my hands, and heard their shrill screaming calls (quite different from the rather hoarse croaking of the Red-tails).

On 11 April 1969 Shelton caught, banded, photographed, measured, and released an adult Red-billed Tropicbird on Johnston Island; he found it sitting under a dense *Pluchea* clump with nesting Red-tailed Tropicbirds. On 21 May Sgt. Browning, USAF, saw this same bird (the only tropicbird with a white tail and orange plastic leg streamer known to exist) flying over Johnston. On 7 June, Huber heard the bird calling and found it resting beside a Red-tailed Tropicbird chick under *Vitex* bushes about 200 yards from the site of its banding. On six of ten visits to this site from 7 through 28 June the Red-billed Tropicbird was found resting a few inches to a few feet from the red-tail chick. It was not found after 28 June. Only once was one of the parents of the chick present, and at this time all three birds rested quietly within a few feet of one another until the adult red-tail became restless, disturbing the red-bill, which then left the area. No time was available for detailed observations of this bird and its interactions with the red-tails. Most observations were during the middle of the day, but twice it was present in the evening and probably spent the night on the island.

Measurements of this bird (Bill: 62 mm; Wing: 303 mm; and Tarsus: 31 mm) best fit those of the eastern Pacific race, *Phaethon athereus mesonauta*, as described by Murphy (1936). This race breeds in the Caribbean, Atlantic, and in the eastern Pacific from the Gulf of California to Venezuela and on the Galapagos; it ranges from Southern California to Chile (AOU, 1957).

Another possible sighting of a Red-billed Tropicbird occurred 11 May 1969 when Sgt. Lewis, USAF, saw two tropicbirds with white tails, both without orange streamers, one nearly twice the size of the other, over Johnston Island. He thought the larger of these two birds may have landed on the roof of a building.

<u>Specimens</u>

No specimens exist for Johnston Atoll.

There are only two specimen records of the species from the central Pacific, one from Nihoa and one from French Frigate Shoals (Clapp and Woodward, 1968; Amerson, 1971).

RED-TAILED TROPICBIRD *Phaethon rubricauda*

Status

Common breeding species, present throughout the year. Nests on the ground usually under *Scaevola*, *Pluchea*, and *Tournefortia* bushes on both Johnston and Sand Islands. Red-tailed Tropicbirds were relatively scarce in 1923, but are now common breeders on both Sand and Johnston Islands. Thus they are among the few bird species that have benefitted from man's activities on Johnston Atoll. During POBSP studies numbers using the atoll each year increased from about 150 to about 200. Chick production increased more dramatically--from about 15 in 1964 to about 75 in 1969--as bushes growing on Sand Island provided a steadily increasing number of nest sites. Eggs have been laid in every month except November, but maximum populations and breeding occur during the spring.

Ecological Distribution

Johnston Island: Brooke (ms.) on 15 March 1859 while at Johnston Atoll wrote: "Kern and Thorburn returned at Sunset, bring off...a phaeton [sic.] with an egg...." The following day he noted: "One of the men onshore gave me a bunch of tropic bird feathers, red and very pretty." These observations no doubt refer to Red-tailed Tropicbirds.

Wetmore (ms. b) in July 1923 wrote: "A few pairs were found about the rock ledges of the shoreline. An egg ready to lay was taken from a female that I collected. Also secured one young bird not quite able to fly. Its notes resembled those of the adult....[There were] 8 on Johnston Island." Clark (1945a) observed a pair flying in May 1945, and Davis (1962) mentioned their presence in 1959-1960.

POBSP personnel found them nesting here from 1963 through 1969. Kridler (BSFW, 1973) and Amerson found them nesting in 1973. Nests were common under artificial edifices, but *Scaevola*, *Pluchea*, and *Tournefortia* bushes were also commonly used. Normal human activity disturbed them little; most nests were within a few feet of frequently traveled roads and walkways.

Sand Island: Wetmore (ms. b) reported four here in July 1923, and Moynihan (1957) observed it nesting under *Scaevola* in April 1957. POBSP personnel observed Red-tailed Tropicbirds nesting here during 1963-1969. Kridler (BSFW, 1973) and Amerson also found them nesting in 1973.

Figures 59, 60 and 61 show the locations of active nests of Red-tailed Tropicbirds on Sand Island in 1967 and 1969. Most of the increase from 1967 to 1969 was under bushes on the man-made portion of the island and on the northwest corner of the original portion where most new bush growth had occurred (Figs. 62 and 63).

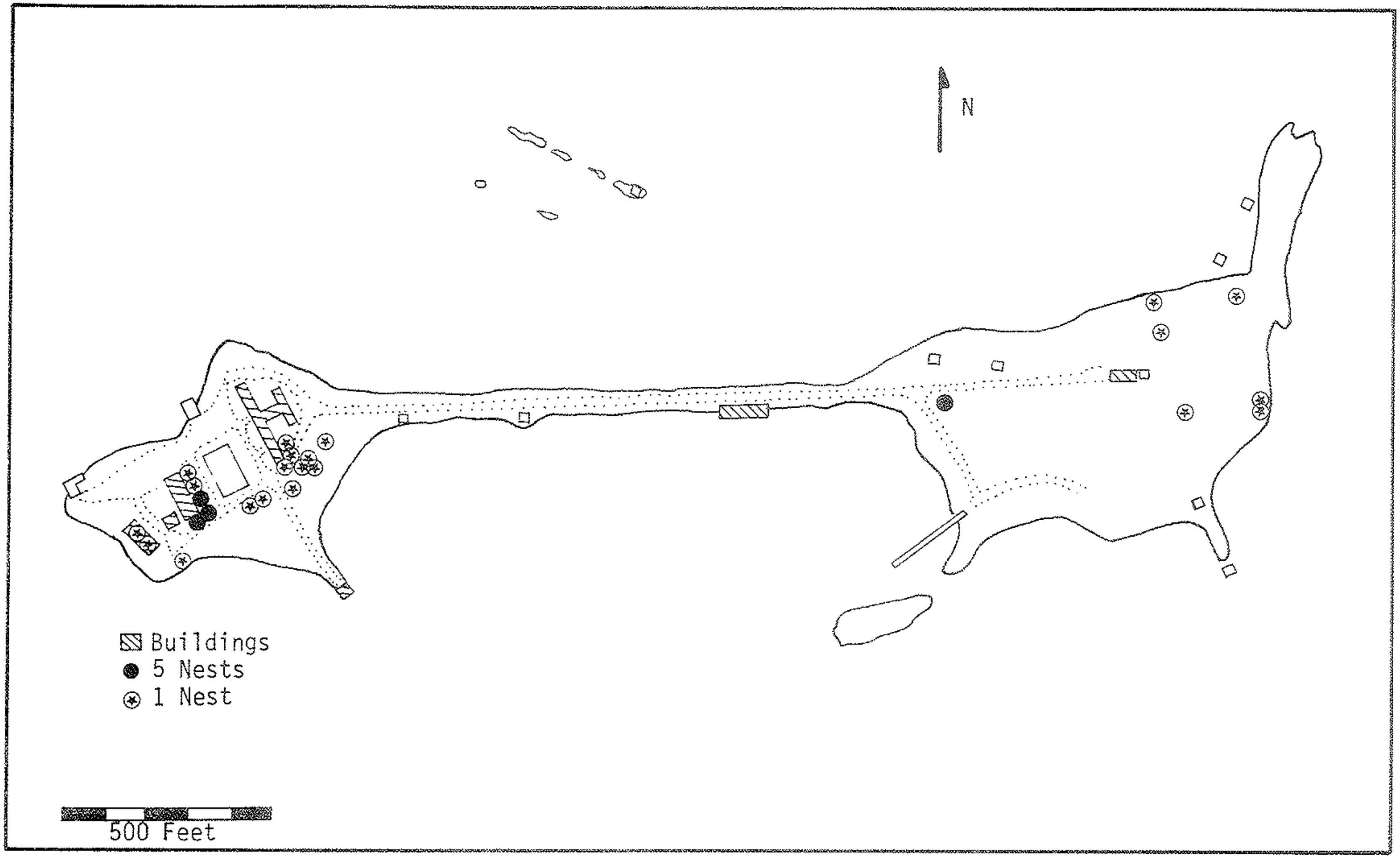


Figure 59. Distribution of Red-tailed Tropicbird nests on Sand Island, Johnston Atoll, 1967.

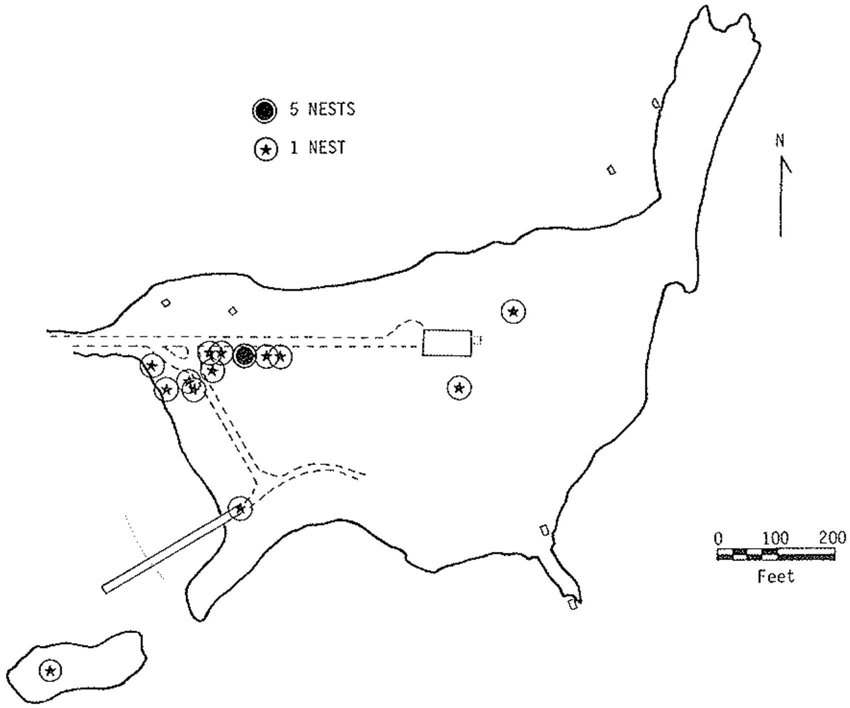


Figure 60. Distribution of Red-tailed Tropicbird nests on the original portion of Sand Island, Johnston Atoll, 1969.

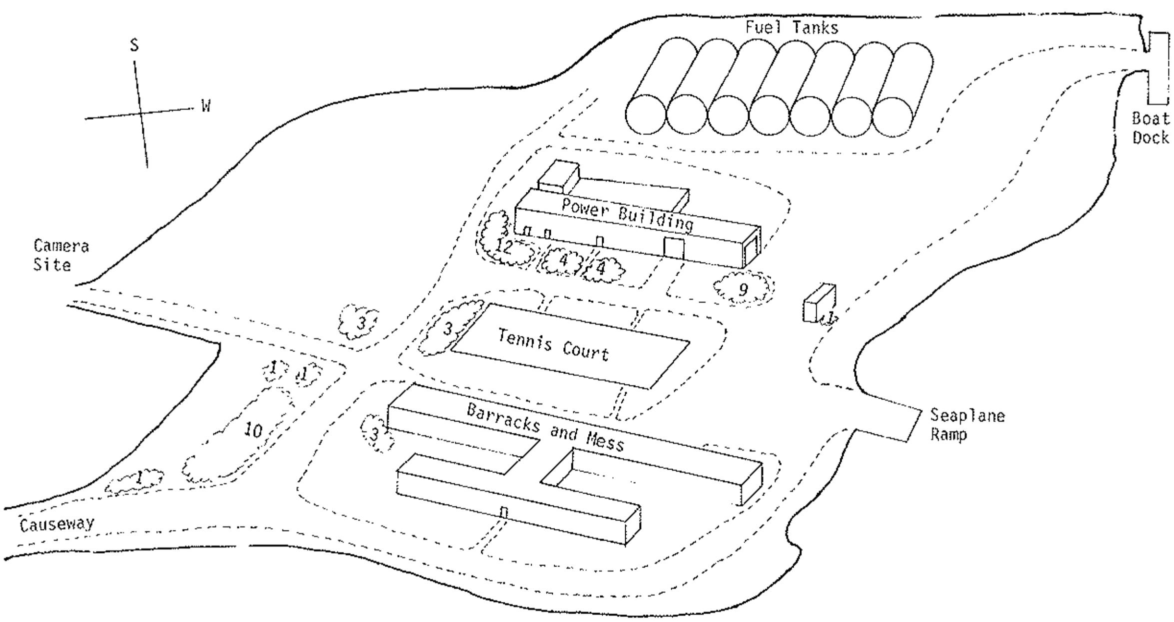


Figure 61. Distribution of Red-tailed Tropicbird nests on the man-made portion of Sand Island, Johnston Atoll, 1969.

Figure 62. Red-tailed Tropicbird on nest under *Tournefortia* bush northeast of transmitter building, Sand Island, Johnston Atoll, 25 February 1967 (POBSP photo by P. C. Shelton).

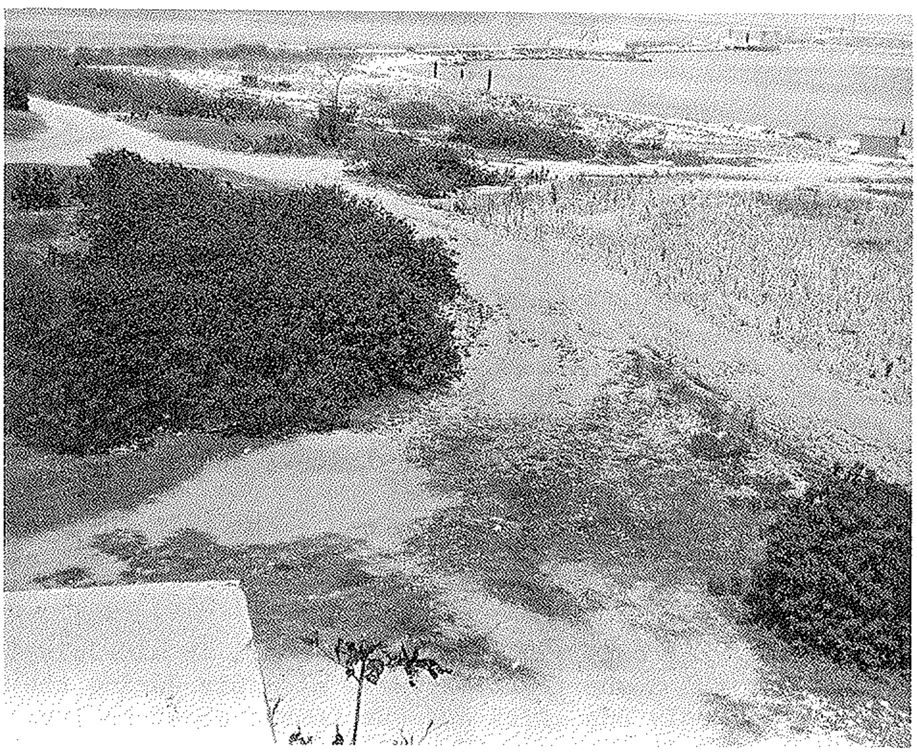


Figure 63. Looking east from top of power building, Sand Island, Johnston Atoll, 5 September 1969. Several Red-tailed Tropicbirds nested under these *Pluchea odorata* bushes (POBSP photo by P. C. Shelton).

Table 37 lists the distribution by plant species or other cover under which eggs were laid in 1967 to 1969. *Scaevola taccada*, *Pluchea odorata*, and *Tournefortia argentea* account for about 75 percent of the nest cover on Sand Island. On Johnston where there is a larger variety of habitats available, these three species still make up the bulk of the sites.

Shelter from the sun appears to be the most necessary feature for a tropicbird nest. *Scaevola* is denser than the other plants which may account for the higher rate of success in nests under it. *Lepturus* and *Amaranthus* provide the least cover among the plants used, because they are not only smaller and less dense than the woody species, but they are more ephemeral. An egg laid under *Amaranthus* in December 1969 was well-shaded at the time of laying, but by the time the chick was half grown the plant had dried away to nearly nothing, leaving the chick almost completely exposed. Had this happened earlier in the chick's development, it might not have survived.

Nests under artificial edifices were more common on Johnston than on Sand because there were more edifices and fewer bushes on Johnston. Normal human activity disturbed them little; most of the nests on both islands were within a few feet of frequently traveled roads and walkways. Birds returning to nests frequently startled workers by dropping silently out of the sky and shuffling awkwardly under a nearby bush within arm's reach of the onlooker.

No nesting material was used by Red-tailed Tropicbirds, but they usually formed a shallow depression for the egg by scraping away loose leaves or sand.

Populations

Figures 64 and 65 show POBSP semimonthly estimates of Red-tailed Tropicbirds on Sand and Johnston Islands.

The total number of adults handled each year (new bandings plus recaptures of previously banded birds) was about 130 in 1964 through 1966, but increased steadily thereafter to 174 in 1969. These figures probably represent 75 to 90 percent of the number returning to the islands each year. If this is true, then the total number returning was about 150 in 1964 through 1966, but increased to at least 200 by 1969.

Maximum semimonthly estimates usually ran about half this calculated annual total, and probably fairly accurately represented the actual population.

Wetmore's estimate of only 12 birds on the atoll in mid-July 1923 is only about a tenth the numbers estimated in mid-July during the late 1960's. Wetmore found only one chick and one female about to lay. In mid-July 1969 there were 11 eggs and 49 unfledged young on the atoll. Wetmore's figures may have been low if a few undiscovered tropicbirds nested in dense *Lepturus* as they did in the 1960's, but it is unlikely

Table 37. Distribution and nesting success of Red-tailed Tropicbirds by habitat type, Sand and Johnston Islands, 1967 to 1969

Habitat	Number of eggs laid and number and percent of fledged chicks											
	1967			1968			1969			Total		
	Laid	Fledged		Laid	Fledged		Laid	Fledged		Laid	Fledged	
Sand Island:	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
Scaevola taccada	17	13	77	27	18	67	29	24	83	73	55	75
Pluchea odorata	8	5	62	24	13	52	36	19	53	68	37	54
Tournefortia argentea	8	2	25	5	2	40	5	4	80	18	8	44
Lepturus repens	3	1	33				1	1	100	4	2	50
Amaranthus viridis				3	1	33				3	1	33
Misc. edifices*	6	1	17	2	2	100	4	1	25	12	4	33
	42	22	52	61	36	59	75	49	65	178	107	60
Johnston Island:												
Pluchea odorata							20	13	65			
Vitex trifolia							4	4	100			
Scaevola taccada							2	2	100			
Coccoloba uvifera							2	2	100			
Other bushes							2	0	0			
Misc. edifices*							6	4	67			
							36	25	70			

*Includes eggs laid under buildings, fuel tanks, concrete slabs, abandoned bunkers, base of old pier, triangulation stand, and beside walls.

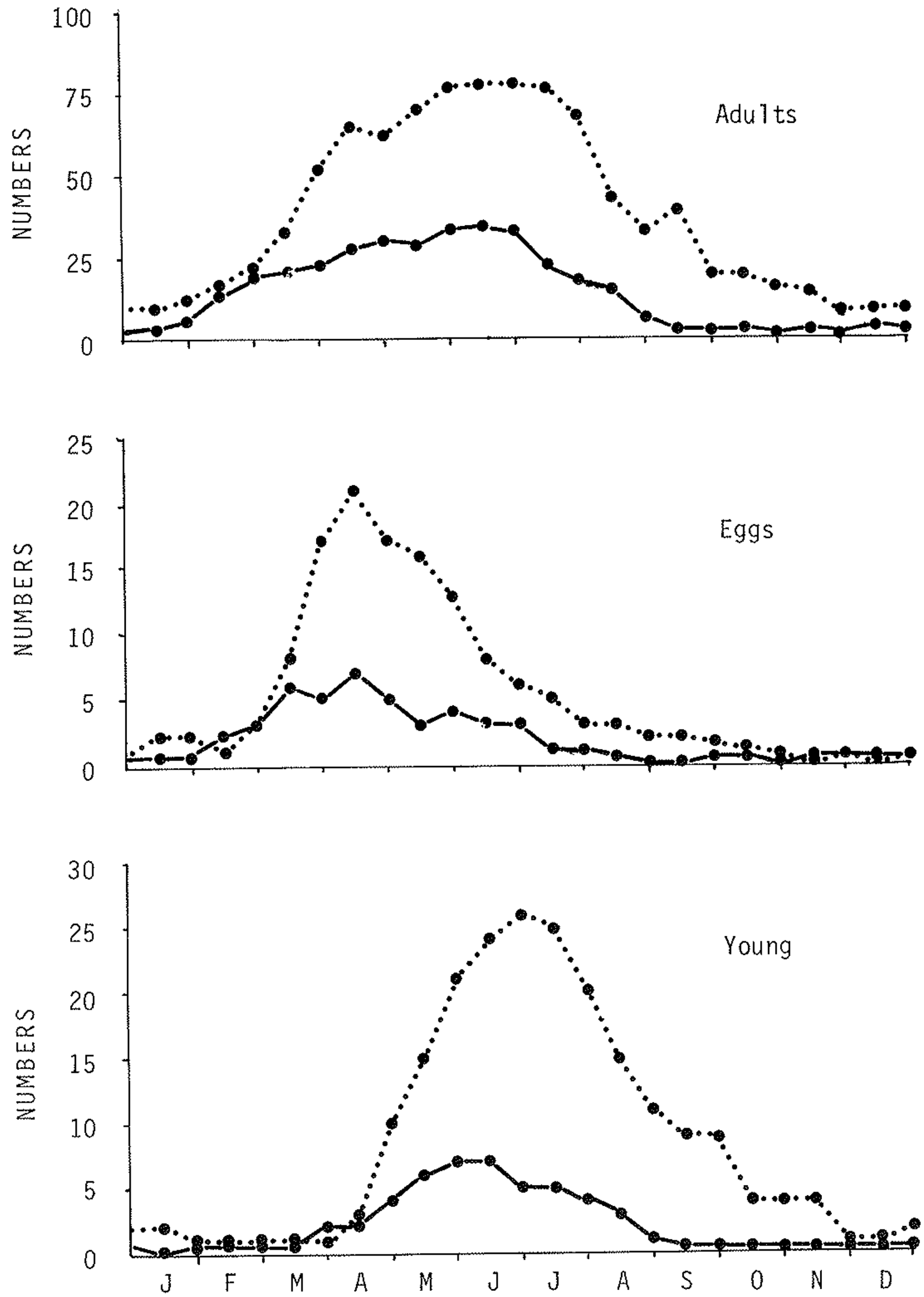


Figure 64. Means of semimonthly estimates of Red-tailed Tropicbird numbers, Sand Island, Johnston Atoll; 1964-1966 (solid line) compared with 1967-1969 (dots).

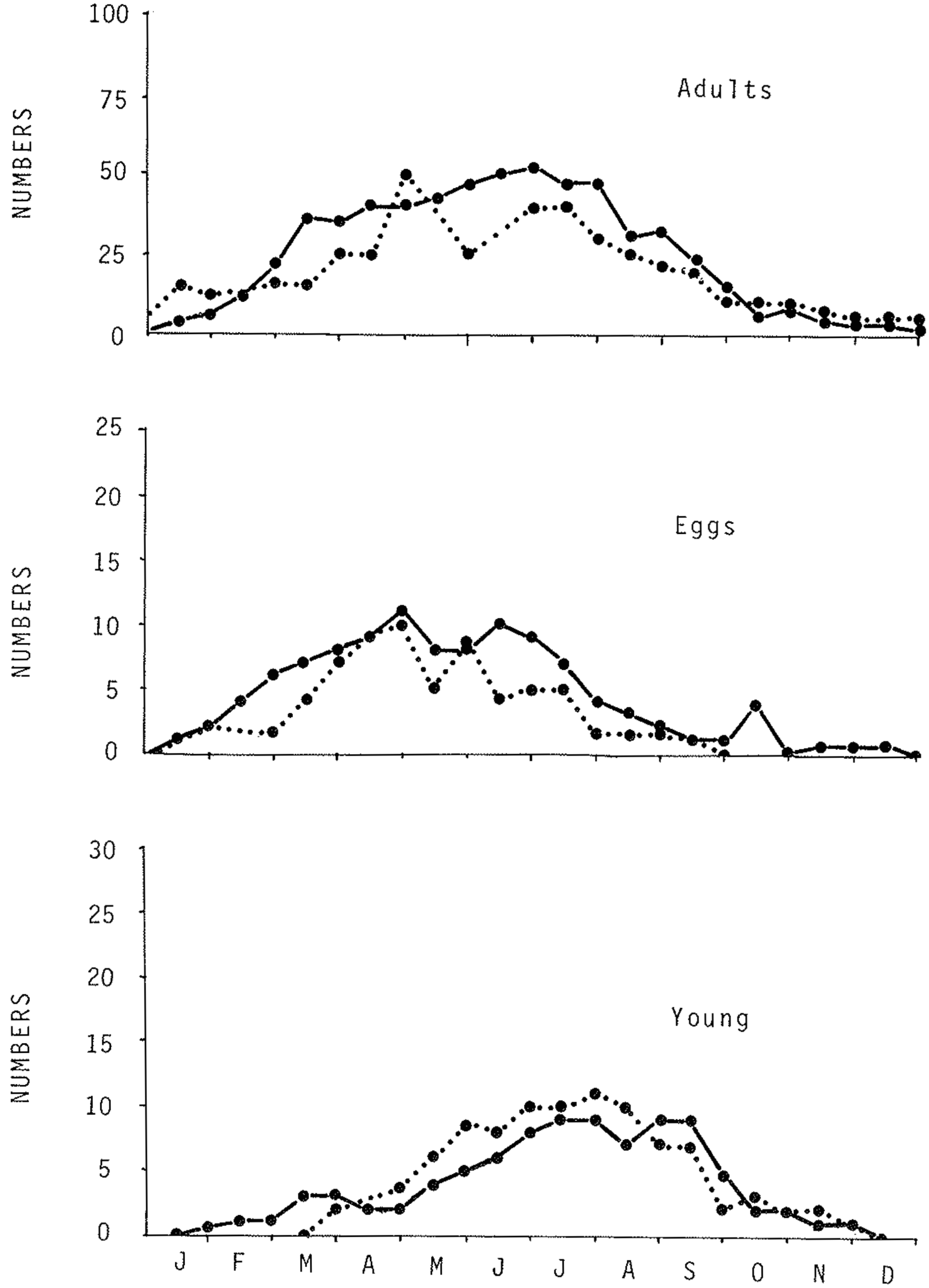


Figure 65. Means of semimonthly estimates of Red-tailed Tropicbird numbers, Johnston Island, Johnston Atoll; 1964-1966 (solid line) compared with 1967-1969 (dots).

that several biologists roaming the tiny islets for ten days could have missed more than a few tropicbirds. The rock ledges in which the birds nested in 1923 must have been marginal nesting habitat, sufficient for only a few pairs.

In early April 1957 Moynihan estimated 12 birds and found three eggs on Sand Island. He saw no tropicbirds on Johnston Island. By contrast, at the same time in 1969 there were 23 eggs, and an adult population estimated at 75 on Sand Island, and nine eggs and 25 birds on Johnston Island. This suggests that most of the increase in tropicbirds using Johnston Atoll has occurred in very recent years. Continued disturbance during the war years and for some time thereafter must have made it difficult for these birds to nest.

Table 38 shows productivity of eggs and young during POBSP studies. The 500 percent increase in fledged young--from about 15 in 1964 to about 75 in 1969--is considerably greater than the increase in adult birds returning to the island. This may indicate an excess of potential breeders which are prevented from breeding for lack of suitable habitat. As of 1969 there was no sign of this upward trend leveling off.

The survival rate of eggs and chicks is relatively high for a seabird. Productivity, figured as a function of the number of pairs nesting, is further increased by renesting. About a third of the pairs that lost eggs early in the season relaid a month or so later. In 1967 one pair laid three times before finally successfully rearing a chick. In 1968 at least ten pairs renested, resulting in four chicks, and in 1969 at least 11 pairs renested, rearing eight chicks.

Most nest losses occurred in the first week after laying and often appeared to result simply from abandonment of the eggs by the adults. In several cases only one adult was ever found at the nest. Presumably this was the female who deserted the egg after several days of vainly waiting to be relieved by her mate. A few presumably infertile eggs did not hatch even though well attended.

On Johnston Island, human disturbance, much of it unnecessary vandalism, accounted for a fairly large percentage of egg, chick, and even adult loss. On Sand Island a few chicks may have been killed by the always present dogs or cats, but these animals generally left tropicbirds alone. A 60-day old chick died after being drenched with insecticide in 1968. Wedge-tailed Shearwaters disrupted a few nests. Ants probably drove the adults away from at least one nest in 1967; and one egg laid under a concrete slab near shore was inundated by a high tide in 1967.

A few eggs on Sand were lost because of disturbance by other tropicbirds, probably in disputes over nest sites. In 1967 two eggs were so destroyed. In 1969 an adult was observed vigorously, and successfully, defending its nest and egg from an intruder. Also in 1969, an adult killed another in what appeared to be a struggle for a nest site, although neither bird had an egg or chick.

Table 38. Productivity of Red-tailed Tropicbirds on Johnston Atoll, 1964-1969*

Year	Pairs known to nest	Eggs Laid	Eggs Hatch	Eggs Percent	Chicks fledged Number	Chicks fledged % of eggs	Chicks fledged % of hatch	Chicks fledged % of pairs
Sand Island:								
1964	?	14	4	29	2	14	50	?
1965	?	19	14	74	12	63	86	?
1966	?	22	14	64	13	59	93	?
1967	36	42	26	62	22	52	85	61
1968	55	61	38	62	36	59	95	66
1969**	69	75	(53)	(71)	(49)	(65)	(92)	(71)
Mean	53	39	25	64	22	57	90	66
Johnston Island:								
1964	?	36	?	?	12	31	?	?
1965	?	30	?	?	19	63	?	?
1966	?	25	?	?	15	60	?	?
1967	?	38	?	?	11	29	?	?
1968	21	25	19	76	19	76	100	91
1969**	31	36	(26)	(73)	(25)	(70)	(96)	(81)
Mean	26	32	23	75	17	53	98	86
Totals for both islands:								
1964	?	50	?	?	14	28	?	?
1965	?	49	?	?	31	63	?	?
1966	?	47	?	?	28	60	?	?
1967	?	80	?	?	33	42	?	?
1968	76	86	57	66	55	64	97	72
1969**	100	111	(79)	(71)	(74)	(67)	(94)	74
Mean	88	71	68	69	39	56	96	73

*Figures are about 90 percent complete, except for 1967, 1968, and 1969 figures for Sand Island which are at least 98 percent complete.

**Parenthetical figures for 1969 are projected totals, assuming that the 29 large chicks (17 on Sand, 12 on Johnston) remaining 9 September fledged, and that the three eggs (two on Sand, one on Johnston) remaining 9 September hatched and the chicks fledged. Any losses that might have occurred in these eggs or chicks probably were offset by additional laying after 9 September.

This competition indicates that there may be a shortage of nest sites on Sand Island. Further evidence for such competition is the increase in nesting tropicbirds as the abundance of introduced bushes, mainly *Scaevola taccada*, *Pluchea odorata*, and *Tournefortia argentea*, increased. During the late 1960's there was a particularly rapid proliferation of *Pluchea odorata* on both the original and man-made portions of Sand Island. On Johnston Island, vegetation is seldom left undisturbed long enough for dense thickets to develop. Lower limbs of bushes frequently are trimmed, leaving little cover for tropicbirds. *Pluchea odorata* bushes growing along the south side of the runway on Johnston were removed in 1967 at the suggestion of POBSP personnel to prevent a possible hazard to aircraft if tropicbirds were attracted to these bushes.

The tropicbird population on Johnston Island remained stable during POBSP studies, but the increased numbers on Sand consisted partly of birds that had formerly used Johnston. In 1968 and 1969, 38 percent of the banded birds caught on Sand had been banded on Johnston. Only 11 percent of those caught on Johnston had been banded on Sand.

Annual Cycle

Although a few Red-tailed Tropicbirds may be found on the atoll at any time of year (Figs. 37, 64, and 65), the largest number appears during spring and early summer. Eggs were laid in every month except November, but 90 percent of the annual total was laid in the six months February through July.

In late December or early January there is an increase in the number of displaying birds over the islands as returning pre-breeders begin courtship. Maximum numbers are reached at midday; all leave well before dark, usually by 1500 hours. Shortly after returning to the island, pairs begin to spend time under bushes during the day. They stay over night only after they have eggs except for an occasional broody bird that incubates a rock for a few days. These may be males whose mates are at sea feeding while the egg develops.

Laying increases sharply beginning in February and reaches a maximum in late March, after which there is a steady decline through July. Incubation requires about 43 days (Table 39), during which time the adults relieve each other at intervals of about a week. When the chick hatches, the adults change off at least once every two or three days. After a week or ten days the chick is left alone most of the time but is fed regularly by both parents.

Young remain close to nest sites until they are nearly ready to fly. When they are fully feathered and over two months old they emerge from the bushes at dawn to exercise for an hour or so, return to sit quietly for the remainder of the day and night, and emerge again only the next morning. When chicks are about 75 days old adults cease to feed them. Fledging occurs at 80 to 90 days (Table 39). With one or two exceptions, chicks never returned to their nest sites after their first sustained flight.

Table 39. Incubation and fledging periods of Red-tailed Tropicbird eggs and chicks, Sand Island, Johnston Atoll, 1967-1969

	Mean	Range	Number
Incubation period	42.7	39-45	63
Fledging period	83.7	78-92*	65

*Not including one of 96 days, raised by one parent, and one of 103 days, probably raised by one parent.

Throughout the breeding season displaying birds were common over the islands during midday. Daily counts ranged from five to at least 15 on clear days during March and April, and still occasionally reached ten to 12 in July and August. Tradewind rain showers had no obvious effect on displaying tropicbirds, but on rare days of heavy overcast and steady rain none appeared.

In 1967 and 1969 virtually all nesting birds were fitted with orange plastic leg streamers as soon as they were found on eggs. Displaying birds seldom had streamers, indicating that birds with chicks or eggs did not usually take part in the display flights. The few displaying birds with streamers could have been accounted for by birds whose eggs had been lost. On the few occasions when incubating birds were observed relieving each other, the arriving bird flew directly to the nest and took over the egg after a noisy ceremony lasting ten to 15 minutes. The departing bird usually made a circle over the island, gaining altitude, then flew directly out to sea.

Unbanded adults continued to appear in low numbers in spring and higher numbers in summer throughout the years of POBSP studies. Many caught in spring were later found nesting, while most caught in summer failed to nest despite frequent observations of display in the air and under bushes. Many, however, returned to nest in subsequent years, nearly always in the later part of the breeding season. These observations suggest that many of these unbanded birds were young adults, returning for the first time a year or so before breeding. Perhaps they had hatched before POBSP studies began.

Nearly all chicks fledged from 1963 through 1969 were banded, and ten of these were subsequently recaptured:

Age	Number Returning	Remarks
2 years	2	No breeding attempted; one struck guywire.
3 years	4	One bred successfully; one struck guywire.
4 years	4	Two bred successfully; another attempted but failed (see next entry).

Age	Number Returning	Remarks
5 years	1	Bred successfully after an unsuccessful attempt as a 4 year old.

Three of these birds returned to the islands on which they had hatched--one to Johnston, two to Sand; however, five which hatched on Johnston returned to Sand, while only two which hatched on Sand returned to Johnston. The two birds that struck guywires probably were returning to the islands for the first time and were unfamiliar with these obstacles.

After they abandon their chicks, adults apparently do not revisit the islands for about six months until they return to begin a new breeding cycle. Molt probably occurs during this time.

Specimens

Appendix Table 7 presents data on the 29 Red-tailed Tropicbirds collected from Johnston Atoll. This is a new specimen record.

Banding and Interisland Movement

From 1963 through 1969 POBSP personnel banded 622 Red-tailed Tropicbirds at Johnston and Sand Islands; in 1973 Amerson banded three (Tables 29 and 40). Of these, 500 have been recaptured back on the atoll. None banded on the atoll has been recaptured on other islands; however, an orange-streamered adult from Johnston was seen, but not caught, at Kure Atoll. Four birds banded on other atolls--two from Midway and one each from Wake and Pearl and Hermes Reef--were captured on Johnston Atoll. All of these islands are west or northwest of Johnston, suggesting that east to west, or northwest to southwest (Wake, northwestern Hawaiians to Johnston) movements may be more frequent for this species than north to south (Johnston to Line, Phoenix) movements.

During the seven years of POBSP studies band wear was not a serious problem, but a few birds banded in 1963 and 1964 needed new bands by 1969. None was known to be lost during this time but some probably were. Greatest wear probably occurs when the birds return to their nest sites and scrape out shallow nest depressions with their feet.

At-Sea Distribution

The at-sea grid density cycle for Red-tailed Tropicbirds (Fig. 66 and Table 21) closely resembles the population cycle on Johnston Atoll (see Figs. 64 and 65) and at other breeding localities in the northwestern Hawaiian Islands.

Breeding birds apparently remain close to the nesting area during the breeding season and may then disperse at sea for the remaining months. The lack of orange-streamered sightings in the grid supports this, but may also indicate that breeding birds never use the grid area. The grid

Table 40. Banding and recapture of Red-tailed Tropicbirds, Sand and Johnston Islands, 1963-1973

	Adults										Young Banded			Total New Banding
	Recaptures				New Bandings			Total Handled						
Year	Sand	Johnston	Total	Interisland	Sand	Johnston	Total	Sand	Johnston	Total	Sand	Johnston	Total	
1963					19		19	19		19	5		5	24
1964	6	2	8		18	106	124	24	108	132	2	12	14	138
1965	29	35	64		32	33	65	61	68	129	13	18	31	96
1966	42	45	87		13	31	44	55	76	131	12	15	27	71
1967	57	54	111		23	23	46	80	77	157	22	10	32	78
1968	83	18	101	1	32	16	48	116	34	150	35	16	51	99
1969	101	28	129*	3	34	11	45	136	41	177	47	20	67	116
1973											3		3	3
	318	182	500	4	171	220	391	491	404	895	139	91	230	625

*Three on Sand, one on Johnston rebanded.

population might then be composed of pre- or non-breeders which visit the Atoll at irregular intervals and then only for short periods.

Year to year fluctuations in density appear to be very small and random (POBSP, 1967a; Gould, King and Sanger, 1974).

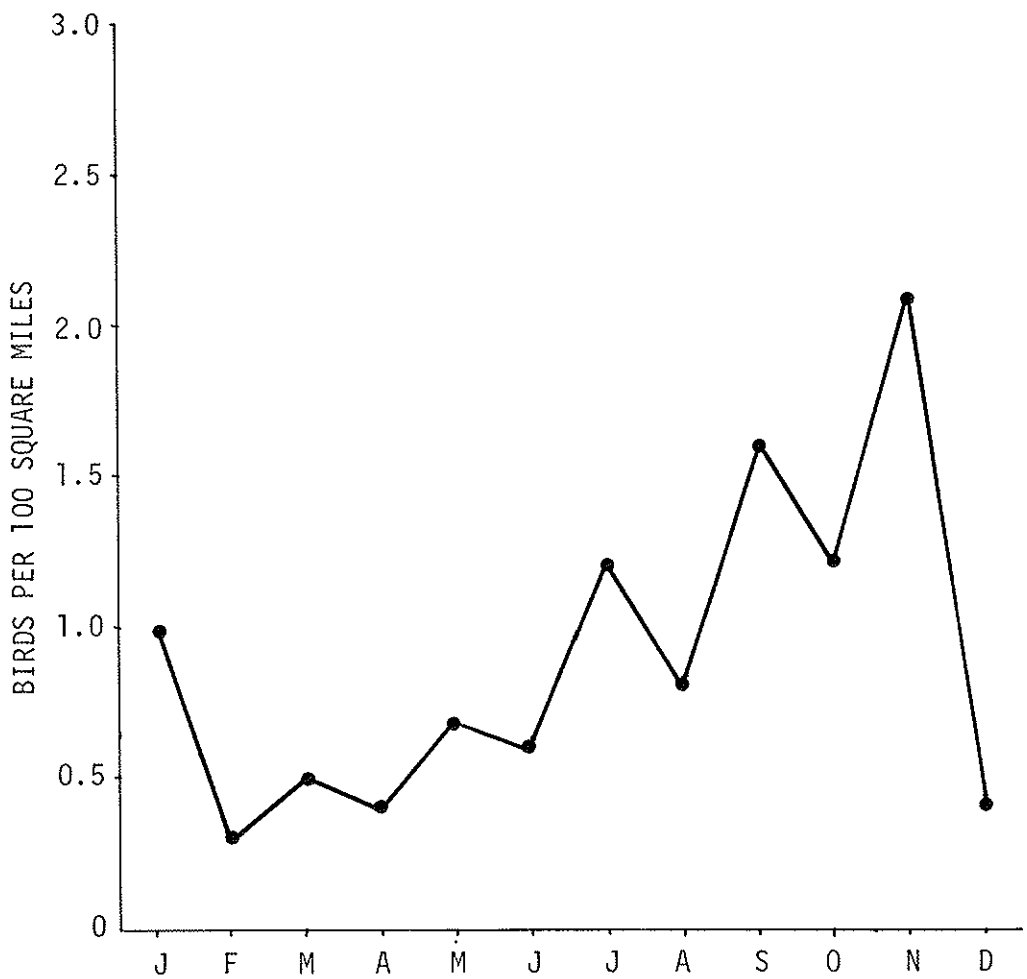


Figure 66. Diurnal occurrence of Red-tailed Tropicbirds at sea 175 miles southwest of Johnston Atoll, 1963-1967.

WHITE-TAILED TROPICBIRD *Phaethon lepturus*

Status

Regular visitor; most common at midday during winter, spring, and summer on Akau, Johnston, and Sand Islands.

Observations

Moynihan (1957) saw a White-tailed Tropicbird fly across Sand Island near midday on 7 and 8 April 1957.

White-tailed Tropicbirds are fairly regular midday visitors to Johnston Atoll during winter, spring, and summer, when Red-tailed Tropicbirds are displaying and nesting. None was known to land during POBSP studies, although several hovered low over the bushes on Sand Island, and a few hovered repeatedly in front of crevice-like openings between raised window shutters and the overhanging roof. In August 1973, Kridler (pers. comm.) recorded one on the ground under low vegetation near the garbage dump on Johnston Island.

From 1963 through 1969, POBSP observers listed 47 sightings (Table 41): 28 from Sand, 18 from Johnston, and 1 from Akau. Since the amount of time spent observing on Johnston was far less than on Sand, there must have been proportionately more birds visiting Johnston than Sand. In 1969, however, 15 of 19 sightings were on Sand, possibly reflecting a shift in activity to Sand similar to that described for Red-tailed Tropicbirds, and possibly related to the attraction of white-tails to displaying red-tails.

Most sightings were of single birds, but there were observations of two birds in early January 1964, on 18 and 22 July 1968, and on 13 April 1969. Three birds were seen on 28 July 1964 and 8 April 1969.

Reasons for the yearly population fluctuations shown in Table 41 are not known. No information is available from the nesting areas of these birds that could be correlated with these figures. The 1969 figures may be biased because after the first few sightings had been made, more notice was taken of displaying birds. The three birds seen 8 April 1969 stayed at least 400 feet high, and would not have been noticed had not their unusual calls been faintly heard. Before the fall of 1968, these calls would have been inaudible because of noise from the Coast Guard generators, now silenced as a result of the procurement of electric power from Johnston Island. There is no reason to suspect bias for any other year, especially 1966 when no birds were reported despite the presence of well-qualified observers during most of the season.

The seasonal pattern of occurrence shows maximum numbers from January through April and again from July through August. The early period corresponds with the early part of the breeding season on the northwestern Hawaiian Islands; these birds may be fishing in the Johnston area and are attracted to the island because of incipient broodiness. The July-August increase may result from wandering pre-breeders which are attracted to land areas slightly after the normal northern breeding season. The late fall low probably corresponds with the general decline in breeding activity of these birds at that time throughout their range when all stay at sea and are not attracted to land.

Table 41. Sightings* of White-tailed Tropicbirds on Johnston Atoll

	Month												
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1963	-	-	-	-	-	-	0	2	0	0	0	0	2
1964	3	2	0	0	0	0	3	2	1	1	0	0	12
1965	2	0	0	1	0	0	0	0	0	0	0	0	3
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	1	0	0	0	1	0	-	-	-	2
1968	-	0	1	0	1	0	4	2	0	1	0	0	9
1969	0	0	3	8	4	0	1	3	0	-	-	-	19
Total	5	2	4	10	5	0	8	10	1	2	0	0	47

*Numbers indicate number of birds seen.

Banding and Interisland Movement

Only one bird was handled at Johnston Atoll. At 1300 on 17 August 1969 one repeatedly circled the barracks and fenced antennas on Sand Island. It was netted on a low pass, banded, measured, photographed, and released. This was likely an immature bird, judging from its dark yellow bill. (Bill color was noted on three 1969 birds: one seen 9 March had an orange-red bill while one seen 28 July and the one caught 17 August had yellow bills.) There was no wing molt, but one central tail feather was less than one-fourth grown (75 mm). This new rectrix and parts of the body were pale pink, possibly indicating that body molt was in progress. Measurements were: Bill: 44 mm; Wing: 272 mm; Tail: 506 mm; Tarsus: 24 mm.

At-Sea Observations

White-tailed Tropicbirds were recorded casually in the grid southwest of Johnston Atoll in all months except March (POBSP, 1967a).

BLUE-FACED BOOBY *Sula dactylatra*

Status

Former common breeding species; recent regular but uncommon visitor to Sand Island through the year. About 200 previously nested on the sandy beaches of Johnston and Sand Islands. About seven birds visited Sand

Island each month during late winter and spring throughout POBSP studies; an average of one bird visited each month during the remainder of the year.

Ecological Distribution

Akau Island: This species was suspected of roosting at night on this man-made island during 1964-1969.

Hikina Island: Blue-faced Boobies probably roosted here at night during the late 1960's.

Johnston Island: Brooke (ms.) while on Johnston Island on 14 March 1859 referred to "a gannet" and on the 15th noted: "Some white boobies sat in the grass and put their snake like heads above it." These observations probably were of Blue-faced Boobies.

Wetmore (ms. a and b) found many on the beaches of Johnston Island in July 1923. He noted that the rock ledge on the eastern shore was used as a roosting spot with the birds standing flat-footed on level or rounded stones and not perching on sharp projections. None has been reported from the island since.

Sand Island: Wetmore (ms. a and b) noted small numbers on Sand Island in July 1923 (Figs. 67 and 68). Non-nesting birds were observed roosting during the day on the shore near the Brown Booby colony on the southern tip of the man-made end of Sand Island in April 1957 by Moynihan (1957). POBSP personnel found small numbers on the island from 1963 through 1969.

Blue-faced Boobies visiting Sand Island in recent years most commonly roosted on the LORAN-C antenna guywire bases. They also frequented the south shore (near or among nesting Great Frigatebirds), the east hill (among nesting Brown Boobies), the northeast peninsula and the southwest islet. Birds were seen a few times on the large anchor buoys between Johnston and Sand Islands.

Populations

Figure 69 shows semimonthly population estimates of Blue-faced Boobies on the atoll during POBSP observations. These estimates and Moynihan's (1957) figures show the present numbers are but a small fragment of the earlier 1923 population. Johnston Island is now never used by this species, and a few use Sand, particularly in mid-July, the time of Wetmore's 1923 observations.

The most likely cause of this decline was killing of birds and disturbance of nesting areas by military and construction personnel before and during World War II. It is probable that most, if not all, the nesting birds were killed, and none has successfully recolonized the atoll.

Moynihan's (1957) observations of up to a dozen birds present during the day indicates a larger population in 1957 than during the 1960's.

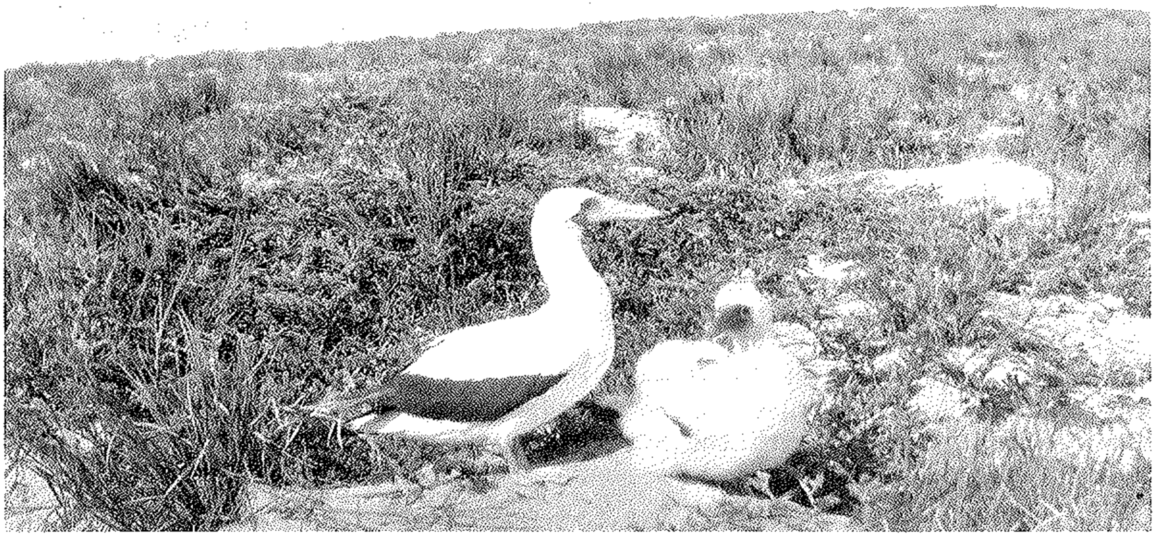


Figure 67. Blue-faced Booby adult and chick, Johnston Atoll, July 1923 (B. P. Bishop Museum photo).

Figure 68. A roosting club of Blue-faced Boobies on Sand Island, Johnston Atoll, 2 June 1941. Two immatures are in the center foreground (U. S. Nat. Archives, R. G. 80 photo).

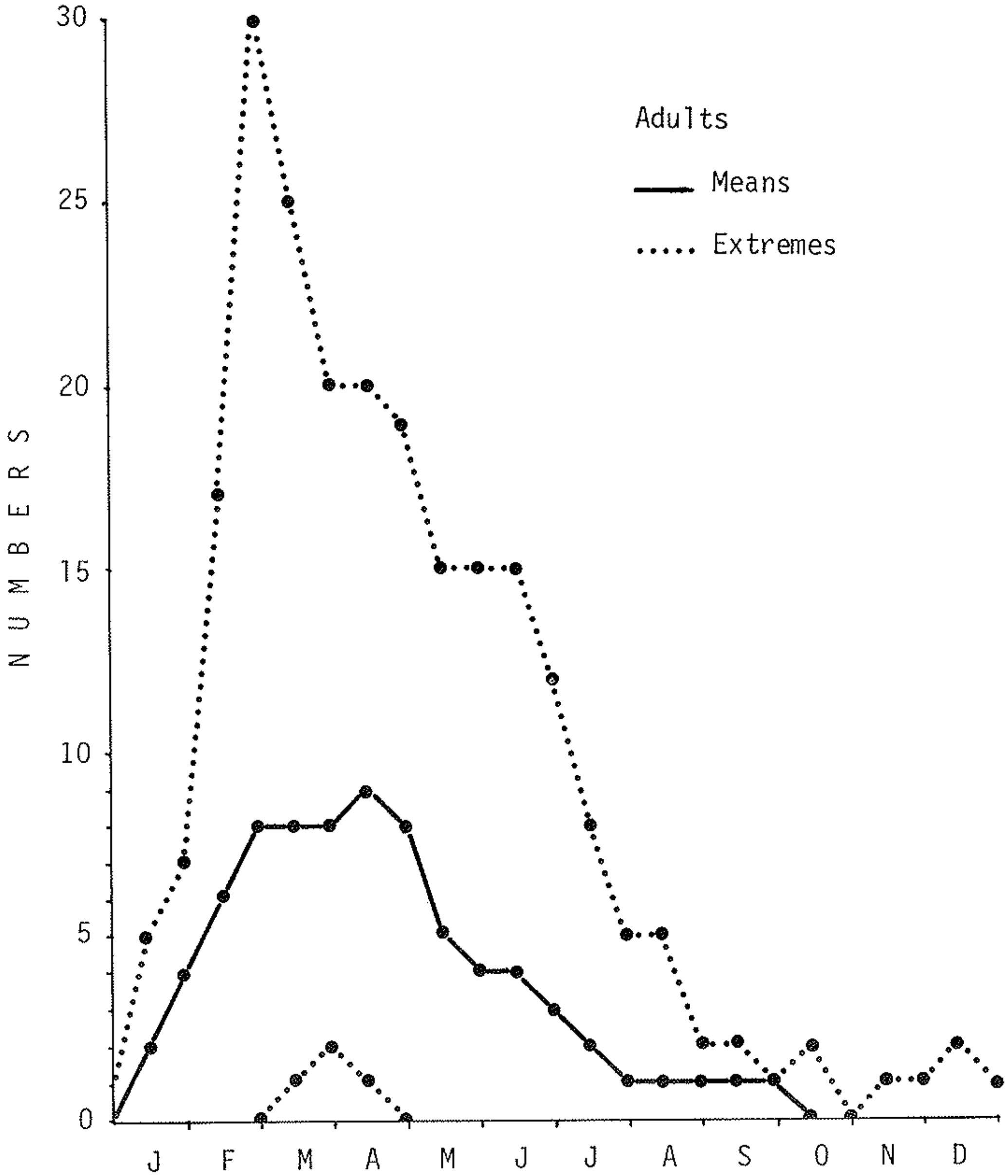


Figure 69. Means and extremes of semimonthly estimates of Blue-faced Booby numbers, Sand Island, Johnston Atoll, 1963-1969.

This many were sometimes present at night during POBSP studies, but there were never a dozen birds on the island during the day. Birds usually arrived within an hour before sunset and left by dawn. If present ratios of day populations to night populations were the same in 1957, then the 1957 population may have been several times larger than any recorded during the 1960's.

POBSP observations indicate a continuing decline in numbers using the atoll (Table 42). Maximum numbers in 1966 were only about half the maximum recorded in 1965, and the 1967 and 1968 maxima were less than a quarter of the 1966 maximum. There was only a slight increase in 1969 over 1968.

The reasons for this post-World War II decline are not definitely known. There are indications of a slight decline in young birds produced in the northwestern Hawaiian Islands, but the decline is not as great as the decline in birds coming to Johnston. No changes in habitat on Sand are known which would adversely affect the birds, and no changes in oceanographic or meterologic phenomena are known. Continued disturbance by people, including POBSP personnel, however, may have discouraged the birds from visiting the islands, or from staying if they do visit. In 1969 care was taken not to disturb roosting Blue-faced Boobies unless absolutely necessary for identification. After being handled once they were not flushed or otherwise disturbed. Several of these birds returned to the island nightly for over two months--much longer than any stayed in years when mass Sooty Tern banding greatly disturbed all ground roosting birds.

Barring further alteration of Sand itself or further disturbance by man, this species should be able to hold their own. If not, Blue-faced Boobies will become very rare in the Johnston Atoll avifauna. Thus, even if man left Johnston Atoll it would be many years, if not an impossibility, before this species would nest there again because of their strong tendency to breed on their place of hatching. There are probably no birds remaining that belong to what could be called a Johnston Atoll breeding population.

Annual Cycle

Wetmore's (ms. a and b) observations in mid-July 1923 that "A few (one or two pairs) had eggs and some downy young seen, but most [chicks] were well grown" indicated a spring-summer nesting cycle similar to that in the northwestern Hawaiian Islands. There adults are present all year, with eggs usually present from late January through mid-August, and fledglings from late June to November (Richardson, 1957; Amerson, 1971).

In recent years (see Fig. 69) Blue-faced Boobies have been present throughout the year, a similarity also of the Hawaiian population.

Specimens

Appendix Table 7 presents data on the ten Blue-faced Booby specimens known from Johnston Atoll. All are housed in the USNM. These constitute a new published specimen record, as well as an extirpated breeding record.

Banding and Interisland Movement

In all, 44 Blue-faced Boobies (two adult males, eight adult females, 14 unknown sex adults, 19 subadults and one immature) were banded by the POBSP on Sand Island (Tables 24 and 43). Of these 44 birds, only four were later recaptured on Sand, while five were taken as interisland

Table 42. Semimonthly population estimates of Blue-faced Boobies on Sand Island, Johnston Atoll, 1963-1969

Period		1963	1964	1965	1966	1967	1968	1969	Mean
January	1-15	-	3	5	0	2	-	0	2
	16-31	-	4	7	7	3	-	0	4
February	1-15	-	7	7	17	2	1	0	6
	16-28	-	7	30	6	3	1	0	8
March	1-15	-	7	25	9	2	1	2	8
	16-31	-	7	20	12	3	2	2	8
April	1-15	-	15	20	11	1	2	3	9
	16-30	-	19	16	7	1	0	4	8
May	1-15	-	15	8	2	1	0	4	5
	16-31	-	15	5	1	0	0	3	4
June	1-15	-	15	5	0	0	1	3	4
	16-30	-	12	1	0	0	1	3	3
July	1-15	-	8	0	1	0	1	2	2
	16-31	1	5	0	0	0	1	3	1
August	1-15	-	5	0	0	0	1	3	1
	16-31	2	2	0	0	0	0	2	1
September	1-15	2	1	0	0	1	0	1	1
	16-30	0	1	0	1	-	1	-	1
October	1-15	0	2	0	0	-	0	-	0
	16-31	0	0	0	0	-	0	-	0
November	1-15	0	0?	1	0	-	0	-	0
	16-30	0	0?	1	0	-	0	-	0
December	1-15	0	0?	2	0	-	0	-	0
	16-31	0	0?	0	1	-	1	-	0

recaptures on the northwestern Hawaiian Islands (Table 26). In addition 21 birds banded on other islands were caught on Sand through 1969.

The ages of the birds visiting the atoll indicate they were young birds from the northwestern Hawaiian Islands which visit the Johnston area during their pre-breeding-age wanderings. An unusually high 31 percent of the 65 different birds handled on the atoll was banded on other islands. None of these 21 interisland birds had been banded as adults, although in most cases as many adults or young were banded on the islands of origin. Although 24 of the 44 birds banded on Sand were listed as adults at the time of banding, it is likely that most were young adults which had not yet begun breeding. That only two of the 24 had acquired the distinctive adult male voice supports this hypothesis.

French Frigate Shoals was the island from which most of the inter-island recaptures came and to which most Johnston-banded birds went. This is the closest island to Johnston and has one of the largest nesting populations of Blue-faced Boobies in the Hawaiian chain.

At-Sea Distribution

Blue-faced Boobies were of casual occurrence at sea in the grid southeast of Johnston Atoll. They were observed in all months (see Table 21), except June through September (POBSP, 1967a).

Table 43. Blue-faced Boobies banded on Sand Island, Johnston Atoll, by the POBSP

Date of Banding		Adult males	Adult females	Adult, sex unknown	Subadults	Immatures	Total
1963	July	0	0	0	2	0	2
1964	January	0	1	0	0	0	1
	February	1	1	1	1	0	4
	March	0	1	0	2	0	3
	April	0	2	0	2	0	4
	June	0	0	1	0	0	1
1965	February	0	0	9	0	0	9
	March	0	0	3	0	0	3
	April	0	0	0	1	1	2
	May	0	1	0	0	0	1
	June	1	0	0	2	0	3
1966	February	0	1	0	0	0	1
	March	0	0	0	4	0	4
1967	February	0	1	0	0	0	1
1968	none banded						
1969	March	0	0	0	2	0	2
	April	0	0	0	1	0	1
	July	0	0	0	2	0	2
		2	8	14	19	1	44

BROWN BOOBY *Sula leucogaster*

Status

Common breeding species, present year-round. Nests are built on the ground on sites exposed to easterly winds at Sand Island; previously bred on Johnston Island. From 1964 through 1969 the breeding population increased from about 70 to about 140, and the chick productivity increased from 30 to 50. Thus the population returned to nearly its original numbers after a decline of unknown extent during the war years. Most adults probably stay close to the atoll year round but roost offshore on pilings and navigational aids except during the spring breeding season.

Ecological Distribution

Johnston Island: Wetmore (ms. a and b) observed many here in July 1923; a few nests--all on the ground--held chicks from two weeks old to nearly able to fly. Wetmore reported Brown Boobies nesting on the ground, and only on Johnston Island, in 1923. The specific location was not mentioned, but his description of the young climbing around on the rock ledges indicates that they were on well exposed sites. None has been recorded since.

Sand Island: In April 1957 Moynihan (1957) noted a small breeding colony with eggs to young of various ages in low grass and shrubbery on the southern tip of the western or man-made portion of Sand Island. In view of their preference for exposed slopes, it is difficult to see why the birds would have nested on this low-lying, somewhat protected area. Whatever the reason for this choice, the occupancy of the western end of Sand Island by the Coast Guard in the early 1960's necessitated the move to the present locations on the original, eastern portion of Sand Island.

Davis (1962) also found a small number of nesting pairs on Sand in 1959-1960. POBSP personnel recorded this species as nesting here from 1963 through 1969.

Figures 43 and 70 show locations of Brown Booby nests on Sand Island during POBSP studies. Little variation occurred during this period. Nests appeared to be placed more or less at random within the area, except that they were never closer together than about three feet. Individuals usually nested in the same general area, sometimes on almost exactly the same spot, in successive years. Ground cover apparently had little effect on nest site selection. Sites usually were situated to allow down-slope take-offs into the trade winds.

Nests were built on the ground (Figs. 71 and 72), and consisted of a deep cup formed of *Boerhavia*, *Lepturus*, *Sesuvium*, or *Tribulus*, relative amounts depending at least as much on availability as on preference. At least two nests were built on man-made objects in the lagoon. One in 1967 was located on a concrete antenna base and another in 1968 was located on one of the wooden navigation aids; military officials, however, discouraged such attempts.

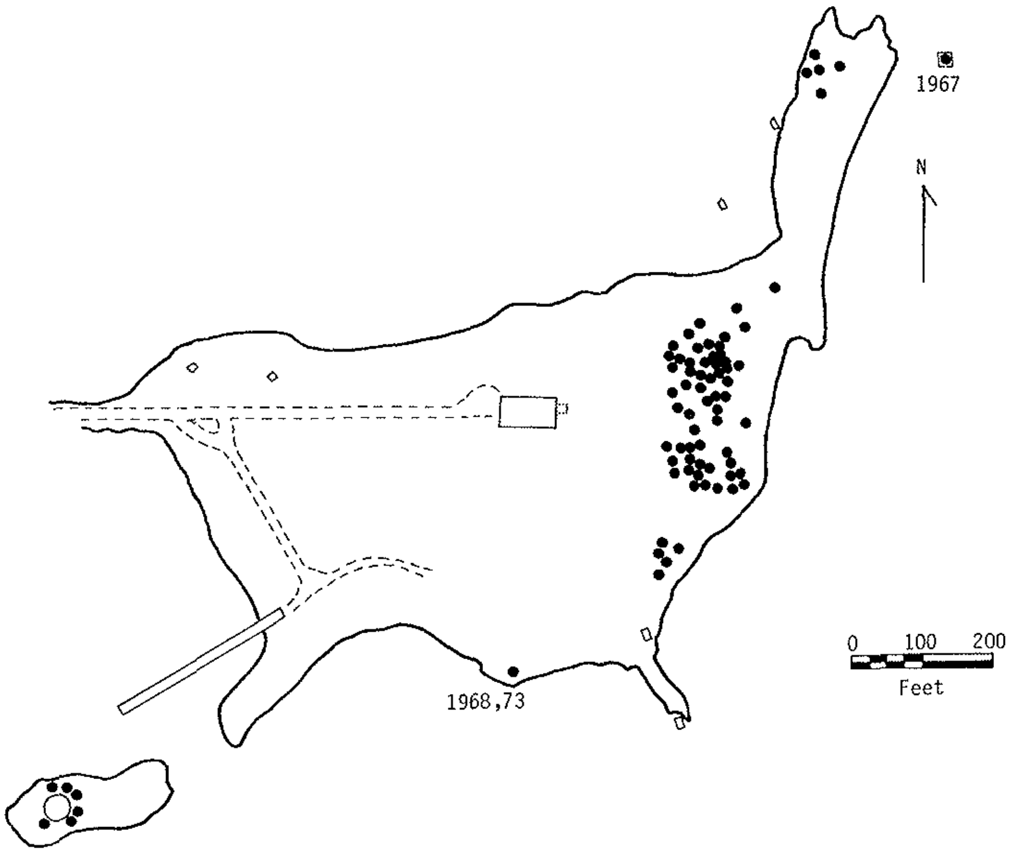


Figure 70. Distribution of Brown Booby nests on Sand Island, Johnston Atoll, 1969.

Except when they were courting, incubating, or tending chicks, nearly all adult Brown Boobies roosted on guywire bases and navigational aids in the lagoon, rather than on the island. A few did, however, roost on the rock ledge along the west side of the northeast peninsula.

Populations

Figure 73 shows the means of POBSP semimonthly population estimates for Brown Boobies at Sand Island based on 1964 to 1969 data. Estimates varied more between observers than between years; hence the mean is the best available representation of numbers present during any given semimonthly period.

The number of different birds handled each year doubled from 65 in 1964 to 129 in 1969 (see Table 24). Nearly all nesting birds were handled in all years, at least on the main east hill colony, and several one-year-old or older subadults were also caught each year. These figures probably represent 90 percent of the total number of birds using the atoll each year. If this is true, then the total number using the atoll increased from about 70 to about 140 from 1964 to 1969.

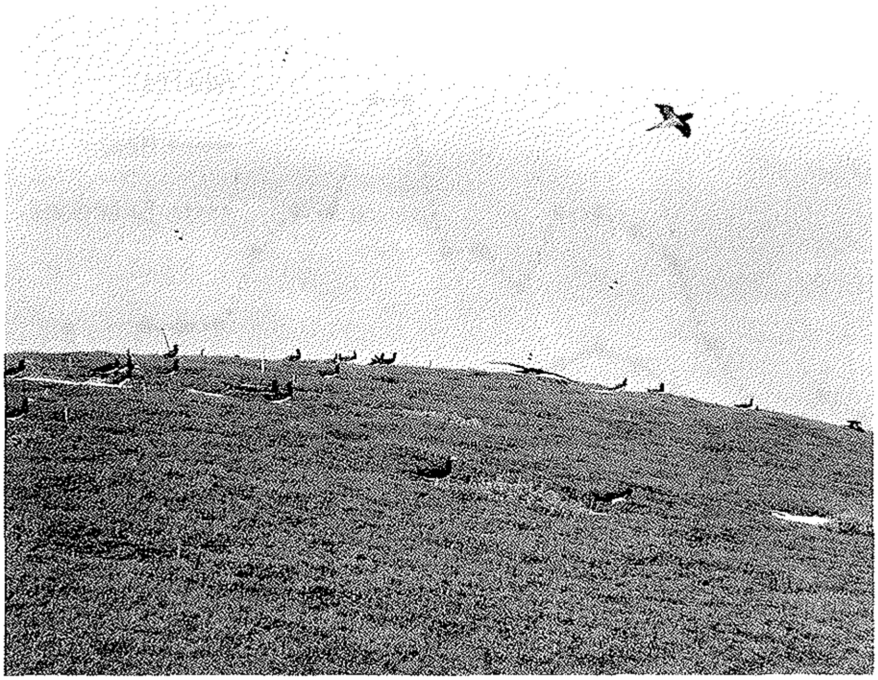


Figure 71. Brown Boobies in early stages of courtship and nest building, east hill of Sand Island, Johnston Atoll, 25 February 1969. Vegetation is mostly *Boerhavia* with scattered clumps of *Tribulus* (POBSP photo by P. C. Shelton).

Figure 72. Brown Booby adults and 31-day-old chick, west shore of northeast peninsula, Sand Island, Johnston Atoll, 9 July 1966. Brown Noddies roost and nest here also; Sooty Terns are in the background (POBSP photo by P. C. Shelton).

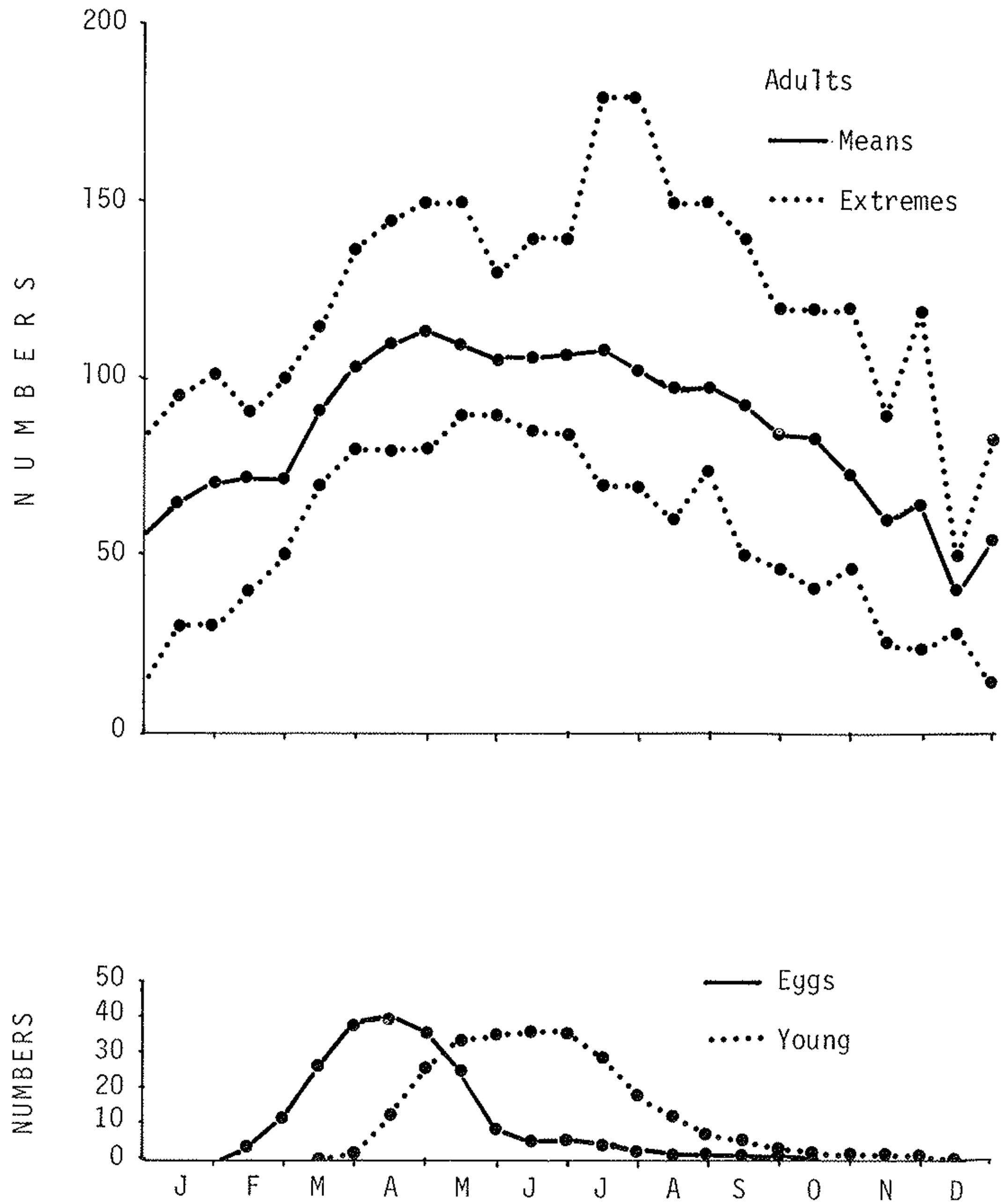


Figure 73. Means and extremes of semimonthly estimates of Brown Booby numbers, Sand Island, Johnston Atoll, 1963-1969.

Wetmore's observation of 75 birds on Johnston in July 1923 indicates a population nearly the same size as that found during POBSP studies, but the 18 pairs observed by Moynihan in 1957 were only about half the number of breeders observed during the 1960's. Thus, there appears to have been a decline in numbers of Brown Boobies during the war years and a subsequent increase which has not yet leveled off.

Production of young each year increased in almost exactly the same proportion as did the number of subadults handled (see Table 52). Except for the late nesters, hens normally laid two eggs each year which increased their chances of raising a chick. This, plus re-nesting, made the number of successful pairs fairly high, although the percentage of egg losses resulted from abandonment or infertility, rather than from outside disturbance. Chick losses were mostly of second chicks in two-egg clutches, discussed in more detail below.

Tables 44 through 48 show productivity in terms of clutch size, first, second, or third eggs in two- and three-egg clutches, re-nesting attempts, and the portion of the breeding season in which the nests were initiated. Most chicks resulted from the first egg of a two-egg clutch laid during the early part of the breeding season. But second eggs and re-nesting accounted for enough chicks to make the difference between a stable and an increasing population. Re-nesting would have been more frequent in some years if pairs where nests failed had not been given abandoned chicks from other nests. One-egg clutches had low success, but these were almost entirely laid by young birds nesting for the first time. Likewise late season nesting success was low, mainly because it was during this time that young birds made their first, usually unsuccessful, breeding attempts. Late season re-nesting by mature birds had a high success rate.

It would appear that since first eggs accounted for over 80 percent of chicks, and re-nesting success was unusually high, a more efficient strategy for mature birds would be to lay one egg, and to re-nest, again laying only one egg, if the first egg failed to produce a chick. It would be advantageous to lay two eggs in the first nest only if food conditions deteriorated before the second clutch could be laid. But the high rate of success of re-nesters, many of them beginning quite late in the season, indicates that food must be easily available for several months after maximum nesting occurs.

That the few three-egg clutches laid had a higher success rate than either one- or two-egg clutches indicates that pairs capable of laying three eggs were easily capable of rearing a chick. None of these clutches produced more than one chick, and in no known case did the chick come from the third egg.

The rare cases in which both chicks of a two-egg clutch survived appeared to result from lack of aggression toward the second chick by the first. Normally the first chicks hatches several days ahead of the second (the first egg is incubated immediately after being laid), and is therefore considerably larger than the second when the second hatches.

Table 44. Productivity of Brown Boobies, Sand Island, Johnston Atoll, 1963 through 1969

			Eggs			Chicks				
Year	Number Pairs	Number Nests	Number Laid	Number Hatched	% Hatched	Number Fledged	% of Eggs	% of Hatch	% of Nests	% of Pairs
1963	?	?	?	?	?	(20+)	?	?	?	?
1964	(36)	(38)	(78)	(48)	62	(24)*	31	50	63	67
1965	45	54	100	60	60	31	31	52	57	69
1966	50	55	(*ca.* 100)	(54+)	(54+)	35	(35)	(65)	64	70
1967	50	52	98	59	60	39	40	66	75	78
1968	58	64	128	90	70	46	36	51	72	79
1969	63	75	145	91	63	48	33	53	64	76
Totals	302	338	549**	348**	63**	223***	34**	54**	66	74

Numbers in parentheses are incomplete or approximate. Chicks reared by hand or by foster parents are not included.

*Six chicks fledged on southwest islet not included; total fledged = 30.

**Not including incomplete 1966 data.

***Not including 1963 data.

Table 45. Success rates of different clutch sizes of Brown Boobies, Sand Island, Johnston Atoll, 1964 through 1969

Year	1 Egg			2 Eggs							3 Eggs								
	No.	Success		No.	Success 1st egg		2nd egg		Total		No.	Success 1st egg		2nd egg		3rd egg		Total	
		No.	%		No.	%	No.	%	No.	%		No.	%	No.	%	No.	%	No.	%
1964*	1	0	0	35	?		?		23	66	2	?		?		?		1	50
1965*	8	0	0	41	23	56	3	7	26	63	2	1	50	1	50	0	0	2	100
1966*	6	2	33	37	?		?		31	84	2	?		?		?		2	100
1967	6	2	33	46	32	70	5	11	37	81	0								
1968	6	1	17	56	34*	68*	3*	6*	43	77	2	?		?		?		2	100
1969	9	0	0	62	38	61	7	11	45	72	4	1	25	2	50	0	0	3	75
	36	5	14	277	127	64**	18	9**	205	74	12	2	33***	3	50***	0	0	10	83

*Southwest Islet not included.

**1964 and 1966 not included.

***1965 and 1969 only.

Table 46. Percentages of Brown Booby chicks resulting from one, two, and three egg clutches, Sand Island, Johnston Atoll, 1964 through 1969

Year	% from one-egg clutch	Total Chicks	% from two-egg clutch 1st egg	% from two-egg clutch 2nd egg	Total Chicks	% from three-egg clutch 1st egg	% from three-egg clutch 2nd egg	% from three-egg clutch 3rd egg	Total Chicks
1964	0	24	?	?	96	?	?	0	4
1965	0	28	82	10	93	4	4	0	8
1966	6	35	?	?	89	?	?	?	6
1967	5	39	82	13	95				0
1968	0	40	85	8	93	?	?	?	5
1969	2	48	79	15	94	2	4	0	6
	2	214	82	12	93	2	3		5

Within a few days the first chick becomes antagonistic toward the second chick and pushes it out of the nest. Occasionally the parents retrieve the expelled chick, only to have it ejected again, or one parent may brood it outside the nest briefly. More commonly it is ignored and left to die, and in one case an adult male ate an ejected second chick. In no case was an expelled chick known to survive. In those cases where the second chick did survive with the first, there was no antagonistic behavior between the two. The parents appeared to make no distinction, and fed both regularly. In 1969, both chicks of the pair raised from the same nest were measured regularly. The older grew at about the average rate for single chicks and the younger was slightly below average. Both fledged in under 90 days which is at least as young as most single birds fledge. Thus it would appear that the parents had no difficulty feeding both chicks.

In summary, it appears that the reproductive strategy of Brown Boobies on Johnston Atoll retains characteristics developed under conditions significantly different from those existing at present around Johnston Atoll. The optimum brood size probably was one, whereas two could be reared more frequently on Johnston now if first chicks were less aggressive toward their younger brood-mates. Re-laying after failure of the first clutch must have been less efficient insurance than laying both eggs at approximately the same time. Thus it would appear that food must have been more scarce and available over a shorter period of time than under present Johnston conditions.

But at present the Johnston population is increasing, which indicates understocking. As the population becomes greater, food may be depleted more quickly, bringing about a return to conditions similar to those hypothesized to have existed some time earlier in the evolutionary history of Brown Boobies. Should this happen, the rate of success of renesters, and the incidence of two chicks being reared by one pair, will decline.

Table 49 summarizes breeding information on young birds returning to enter the breeding population. There is a steady increase in the number of birds attempting to nest through their fourth year, and there is also a steady increase in the rate of success of those that do attempt breeding. All breeding two-year-old birds were females, but by the fourth year there were as many males breeding as females. Birds up to four years old generally nested later than the older established breeders, but five- and six-year-old birds began nesting during or slightly ahead of the period of maximum nesting for the total population.

Annual Cycle

Brown Boobies use Johnston Atoll year round (Figs. 37 and 73), but apparent numbers fluctuate from a maximum of over 100 during the spring breeding season to a low of about 50 during the fall. Most of the breeders probably stay near the atoll year round, but do not return to roost on the island as regularly during the fall, which may account for the decline in numbers at that time.

Table 47. Renesting attempts, incidence of two chicks reared in one nest, and numbers of chicks raised by foster parents or by hand, Sand Island, Johnston Atoll, 1964 through 1969

	Renesting				
Year	Number of nests	% Success	% of Total chicks from renests	Number of nests where two chicks were reared	Number chicks reared by foster parents*
1964	2	50	4	1	0
1965	9	100	30	0	3
1966	5	?	?	1	1
1967	2	100	5	1	0
1968	6	100	15	0	8
1969	12	25	6	1	3
Totals	36	68**	12**	4	15

*All were second chicks ejected from nests by older chicks. All reared by Brown Booby pairs that had lost all their own eggs or chicks, except the three from 1969, which were hand-fed on Johnston Island.

**Not including 1966.

Table 50 presents the extreme dates for significant events in the Brown Booby breeding cycle during 1964 through 1969. Courtship has been observed by late November, but usually does not begin until January. During courtship, pairs spend most of the day on the nesting area, but leave in the evening to roost offshore. Egg laying has begun as early as late January, but normally began mid-February; eggs have been recorded as late as the end of September. Incubation required about 43 days (1969 data: range = 41 to 47 days; n = 80) and maximum hatching occurred in April. Chicks are closely guarded by the adults for about a month after hatching, although the chicks by this time are over half grown. The young fledge when about 90 days old (1969 data: range = *ca.* 80 to *ca.* 100 days; n = 20).

Table 51 shows the number of new nests established by semimonthly periods during 1964 through 1969. Although in 1965 and 1968 maximum laying occurred slightly earlier than in the immediately previous years, there was a general trend toward later nesting, discernible both in the date of first egg and the period of maximum laying. The variation was no more than a month over all years.

Table 48. Percent of Brown Booby chicks produced and success rates of nest by thirds of breeding seasons, Sand Island, Johnston Atoll, 1964 through 1969

	Percent of Chicks Produced				Percent of Nests Successful			
Year	First Third	Second Third	Third Third	Total	First Third	Second Third	Third Third	All
1964	42	29	29	100	77	58	54	63
1965	35	26	39	100	61	44	66	57
1966	?	?	?	-	?	?	?	63
1967	39	28	33	100	88	61	71	75
1968	33	39	28	100	72	82	62	72
1969	40	44	17	101	76	84	32	64
Totals	37	35	28	100	74	68	56	66

Table 49. Nesting success of known-age Brown Boobies, Sand Island, Johnston Atoll

	Year of Hatching	No. Banded	Age 2 No.	Age 2 Success	Age 3 No.	Age 3 Success	Age 4 No.	Age 4 Success	Age 5 No.	Age 5 Success	Age 6 No.	Age 6 Success
Females	1963		2	1	4	2	6	3	6	3	4	3
	1964				2	1	4	3	3	2		
	1965		1	0	5	2	5	4				
	1966				8	3						
	1967											
			3	1*	19	8	15	10	9	5	4	3
Males	1963				1	0	3	2	4	4	3	2
	1964				3	1	7	4	9	8		
	1965				3	2	4	1				
					7	3	14	7	13	12	3	2
Total	1963	20	2	1*	5	2	9	5	10	7	7	5
	1964	29			5	2	11	7	12	10		
	1965	35	1		8	4	9	5				
	1966	34			8	3						
	1967	39										
			3	1*	26	11	29	17	22	17	7	5
Summary Percent Successful:												
	Females			33*		42		67		56		75
	Males			0		43		50		92		67
				33*		42		59		77		72

*Questionable record.

Table 50. Extreme dates of significant events in the Brown Booby breeding cycle, Sand Island, Johnston Atoll, 1964-1969

Year	Laying	Hatching	Fledging
1964	23 Jan.-21 Apr.	10 Mar.-?	*ca.* 10 June-?
1965	*ca.* 15 Feb.-29 May	29 Mar.-10 July	30 June-21 Oct.
1966	11 Feb.-8 July	*ca.* 1 Apr.-1 Aug.	*ca.* 5 July-20 Oct.
1967	12-13 Feb.-12 July	25 Mar.-23 Aug.	*ca.* 25 June-*ca.* 25 Nov.
1968	20 Feb.-21 Aug.	4 Apr.-30 Sept.	27 June-*ca.* 10 Dec.
1969	19 Feb.-*ca.* 30 Sept.	2 Apr.-*ca.* 30 Sept.	3 July-*ca.* 5 Nov.

There was evidence that human disturbance may have delayed laying slightly. In 1967 and 1969, the first eggs were laid on the southwest islet, which is relatively rarely visited by people. Courting birds flush readily when approached to within several yards, and disturbance as little as two or three times a day by passing fishermen or biologists may prevent these birds from progressing as rapidly to laying as non-disturbed birds. Birds with eggs or young, by contrast, are docile and usually can be caught by hand with little difficulty.

The weather disruption in February 1969 had little effect on Brown Boobies. Nesting occurred later in 1969 than 1968, but not later than in 1967. Courting birds decreased from about 50 birds each day in late January to about 10 by the second week in February. By mid-February, numbers returned to the late January level, and laying began by the 19th, almost exactly the same time as in 1968. Laying progressed more slowly, however, and maximum laying occurred two weeks later in 1969 than in 1968. This delay is much less than that for several other species in 1969. Perhaps the tendency of Brown Boobies to feed closer to the island and in shallower water than any other breeding species accounts for their being less affected by the changed weather pattern than birds that feed farther at sea where food production may have been more drastically affected.

Another significant change in the pattern of nesting, evident on both Tables 50 and 51, is the increased variability to be expected from a larger population. However, if social facilitation is a significant factor in inducing breeding behavior in Brown Boobies, then the larger number of birds present in the later years may have stimulated more potential late nesters to lay.

Wetmore's description of the colony in July 1923 fits the stage found in July during the 1960's. Moynihan, however, found near-fledging chicks in early April 1957 about two months earlier than the earliest recorded fledging during POBSP studies. Perhaps the trend toward later nesting observed during the 1960's was a continuation of readjustment in the breeding cycle induced by disturbance during the war years.

Table 51. Numbers of Brown Booby nests established by semimonthly periods, Sand Island, Johnston Atoll, 1964 to 1969

Period	Year					
	1964	1965	1966	1967	1968	1969
Jan. 16-31	1					
Feb. 1-14	9		3	1		
15-28	6	16	7	5	15	2
Mar. 1-15	18 (1)*	14	17	8	27	15
16-31	2	12 (1)	13	18	12	29
Apr. 1-15	2 (1)	3 (1)	8 (1)	10 (1)	3	15 (1)
16-30		7 (5)	2 (1)	5		1
May 1-15		1 (1)	1	2		2 (2)
16-31		1 (1)	1	1	2 (2)	4 (2)
June 1-15			1 (1)	1	1	3 (3)
16-30			1 (1)			1 (1)
July 1-15			1 (1)	1 (1)	3 (3)	
16-31						
Aug. 1-15					1 (1)	2 (2)
16-31						
Sept. 1-15						
16-30						1 (1)
Totals	38 (2)	54 (9)	55 (5)	52 (2)	64 (6)	75 (12)

*Numbers in parentheses are of renests, and are included in total nests initiated.

During POBSP studies the maximum number of birds occurred in April, shortly after the laying peak, when most birds were incubating or tending small chicks. Incubation shifts occurred at least once and probably twice each day. In March 1968, Harrington found more females than males on nests in the early morning, with the percentage of males increasing throughout the day. Almost all incubation at night was done by males, and females apparently returned about dawn. Fairly frequently both members of a pair were at the nest during the day, but at night only those incubating remained on the island, while the mate roosted offshore on navigational aids or guywire bases, or possibly fed at sea. The frequent incubation shifts, and the occasional occurrence of both members of pairs at the nest, indicate that these birds feed fairly close to the island, perhaps within 25 miles most of the time, and that food is relatively easy for them to catch.

Soon after fledging the immatures begin roosting at night offshore on the guywire bases and navigational aids, but spend much time back on the island during the day, usually near their nest sites. On nights of unusually high winds they frequently roost on the ground. Some of these are still fed fairly regularly by their parents until at least December. About half the immatures from the previous season are on hand when the adults begin courting for the new breeding season. These young birds vigorously beg from the adults, who usually ignore the youngsters, and only rarely regurgitate food for them. The yearlings acquire their subadult plumage--typical adult pattern, except for scattered dark speckles on the breast and belly--from about 11 to 14 months of age. Facial colors begin to differentiate at this time also.

Breeding adults begin to molt before their chicks fledge. Four birds with large chicks or second nests examined in August 1969 had replaced most of their primaries. Replacement appeared to have begun simultaneously with primaries 1 and 6 and proceeded distally therefrom.

Specimens

Fourteen specimens of Brown Boobies have been collected at Johnston Atoll (Appendix Table 7); all are located in the USNM bird collection. These constitute a new published specimen record for the atoll.

Banding and Interisland Movement

In all, 375 Brown Boobies (114 adults and subadults, 261 young) have been banded at Sand Island (Tables 24 and 52). Nearly all nesting birds were banded and/or handled each year. The same birds returned each year, showing a strong attraction for the island. Individuals usually nested in the same general area, sometimes on almost exactly the same spot, in successive years.

Interisland movements of Brown Boobies have been few (Table 26). Four Johnston banded birds were recaptured or observed (identified by

Table 52. Banding and recaptures of Brown Boobies, Sand Island, Johnston Atoll, 1963-1969

Year	Recaptures Returns	Interisland	New Adult and Subadult Bandings	Total Adults and Subadults Handled	Young Banded	Total New Bandings
1963	0	0	21*	21	20	41
1964	13	(1)**	52	65	30	82
1965	71	0	16	87	35	51
1966	76	0	12	88	36	48
1967	105	0	2	107	38	40
1968	112	0	6	118	51	57
1969	123	1	5	129	50	55
1973	0	0	0	0	1	1
Totals	500	1	114	615	261	375

*2 banded by N.P. Ashmole, February 1963.

**1 old band found, no bird remains, not counted in total handled.

orange streamer) on other islands. An immature banded 12 July 1966 was captured alive and uninjured on Nauru Island, 0°20'S, 167°10'E, 2,000 statute miles from Johnston on 29 December 1966. An adult male, banded 26 April 1967, mated with a previously banded female and raised a chick which fledged about 9 August 1967 on Sand Island; on 1 September 1967, the male was caught on Lisianski Island. This probably was a Lisianski native, which happened to be on Johnston during the breeding season, but returned to Lisianski immediately thereafter. Brown Boobies with orange streamers were sighted on La Perouse Pinnacle, French Frigate Shoals, on 12 June 1967, and on Taka Atoll in the Marshall Islands (about 1,200 nm southwest of Johnston) 21 October 1964 (Amerson, 1969: 47).

There are two recorded movements of Brown Boobies to Johnston from other islands. On 30 June 1964 POBSP personnel found in the tunnel on the southwest islet of Sand Island a band which was put on a young Brown Booby on Eastern Island, Midway Atoll, by Dale Rice of the U.S. Fish and Wildlife Service 2 April 1958. This bird apparently died on Sand some time before POBSP studies began. An adult female banded 19 June 1966 on Wilkes Island, Wake Atoll, appeared in the east hill colony on Sand 20 May 1969, and laid an egg. No mate was ever seen with her or with the egg, and she abandoned the egg and disappeared after a few days.

At-Sea Distribution

Brown Boobies were observed in low numbers in the grid southwest of Johnston Atoll from October through April (Table 21). They were absent from May through September, except for July (POBSP, 1967a).

RED-FOOTED BOOBY *Sula sula*

Status

Uncommon breeding species, as well as an abundant, transient visitor; breeders present from February through August and probably are year-round residents, transients present throughout the year. Nests built primarily of *Tribulus* stems placed on the ground at Sand Island and on pilings, etc., around the periphery of the island; previously nested on Johnston Island. Transient visitors roost on antenna guywires, rock piles, pilings, and concrete blocks around Sand Island. During POBSP studies about a dozen pairs attempted to nest yearly, with one to six chicks fledging; transients numbered up to 3,000 or more at night.

Ecological Distribution

Johnston Island: About 250 were using Johnston Island in July 1923, but only six nests with eggs and a few with young from two weeks old to those nearly grown were there. Roosting birds used the low rock ledges along the beaches (Wetmore, ms. a and b). None has been recorded from the island since 1923.

Sand Island: Wetmore (ms. a) in July 1923 noted that "after three or four nights disturbance [on Johnston Island] however the majority moved to Sand Island." During April 1957, Moynihan (1957) saw approximately 100 on the western man-made portion. Some were immature birds; but most were adults, sitting on nests with eggs or fairly small chicks, on the same towers as the frigatebirds. POBSP personnel found them on Sand Island from 1963 to 1969.

The distribution of nesting sites used by Red-footed Boobies are shown in Figures 44 and 74. Changes in sites used during years of POBSP studies and in earlier years are discussed under the Population section. This species normally nests on bushes or trees, but these were completely lacking from the original flora of Johnston Atoll. Wetmore did not give details of nesting in 1923, but did mention one nest on the ground. Perhaps the comparatively small population of breeders--apparently not more than 50 or 60 in 1923--is a result of this lack of optimum habitat. Best conditions for red-foots may have occurred immediately after World War II, when abandoned towers and antennas on Sand Island provided raised nesting sites for perhaps 100 birds. The only raised sites available after the Coast Guard occupied Sand Island were pilings, concrete blocks, and rock piles around the periphery of the island, which the birds use willingly, but with little success because most of these are within reach of high tides and most eggs and nests are destroyed. Only the birds nesting on the east hill had even a fair degree of success.

There were a few bushes growing on the original end of Sand that were large enough to support nests by 1969, but they were not in areas frequently used by red-foots. The *Tournefortia* northwest of the transmitter building occasionally attracted roosting birds; by 1973 it supported at least one nester.

The favored nest building material during our studies was *Tribulus* stems which the birds gathered from growing plants. Red-footed Boobies are a major factor in the ecology of this plant species, for in years when its growth is not luxuriant, as in early 1967, the birds almost entirely strip the island of it. In 1967, the red-foot nests built in March were almost entirely of *Tribulus*, but by the end of the month, there was practically none left. The birds had pulled up all available stems, leaving only frayed and broken stubs above ground. When the second round of nests was built in late March and April, *Boerhavia* was the major material used, with a little *Sesuvium* in some cases. These materials are thinner and less durable than *Tribulus* and definitely were less desired by the birds. Vigorous sprouting from root crowns later in the year re-established *Tribulus* to its normal status. Its susceptibility to destruction in early 1967 may have resulted from the dry year of 1966, which most plants survived with reduced vigor. In 1969, when all plant species were unusually lush, following a year of above average rainfall, red-foots did little damage to *Tribulus*, and did not significantly decrease its abundance or vigor.

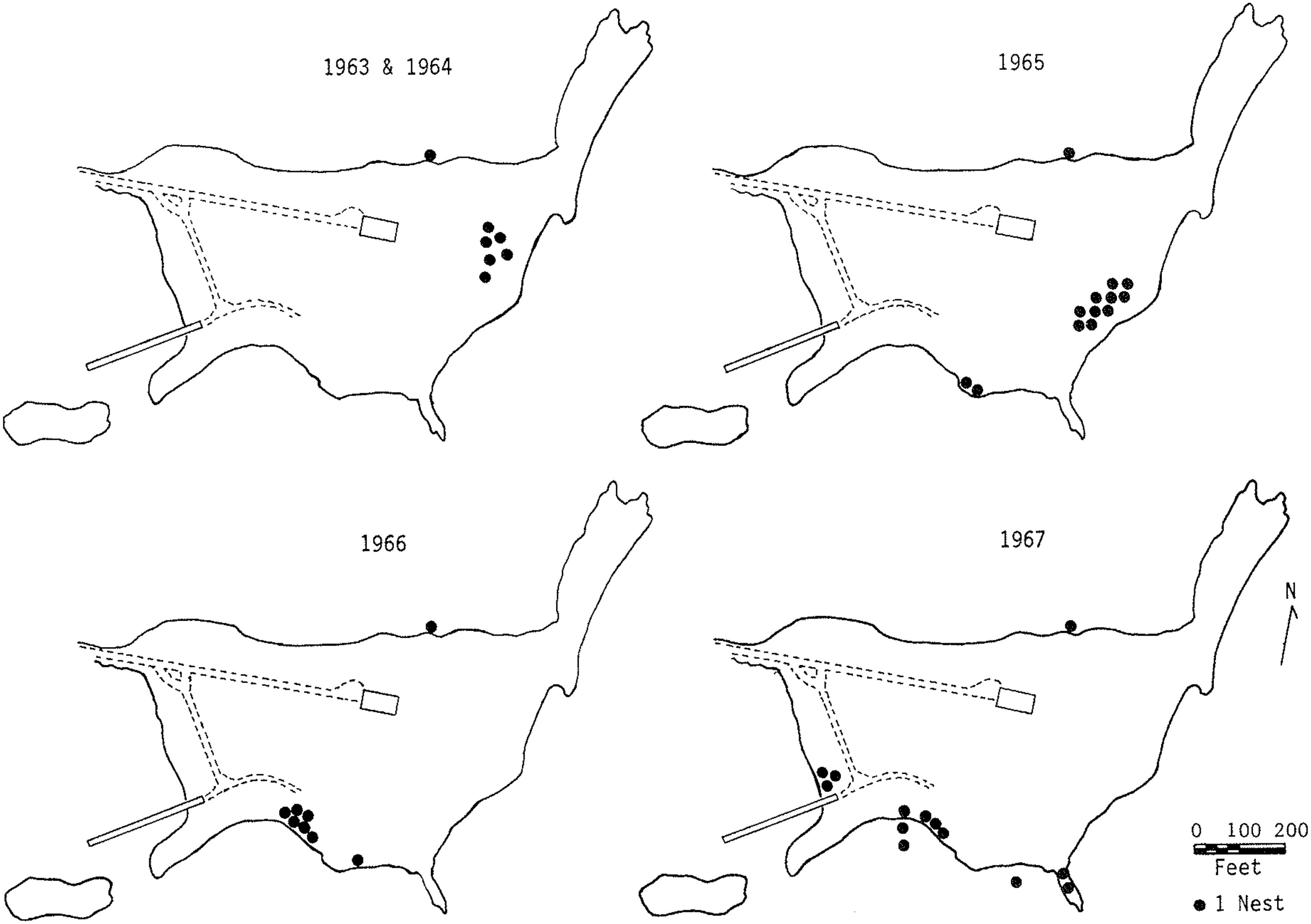


Figure 74. Distribution of Red-footed Booby nests, Sand Island, Johnston Atoll, 1963-1967.

The primary roosting habitat for Red-footed Boobies on Sand Island is the guywires of the LORAN-C antenna. Most preferred are the lower portions of those wires lying approximately perpendicular to the wind direction. Both Red-footed Boobies and Great Frigatebirds use the wires, but there is little mixing of the two species. In late 1966 Schreiber observed that Great Frigatebirds arrived earlier in the evening than Red-footed Boobies, and often landed on the lower parts of the wires. Later in the evening as red-foots arrived in increasing numbers, the boobies drove the frigates farther up the wires. In all cases of conflict observed, the frigatebird moved. Huber noted in June 1969 that Great Frigatebirds left the island earlier in the morning than red-foots. Schreiber also found some evidence that adult red-foots usurped the lower parts of the wires, forcing the younger birds to move higher.

Besides the guywires, roosting red-foots used rock piles, pilings and concrete blocks around the margins of the island. After the Coast Guard burned the planking from the old dock in August 1967, red-foots began roosting in numbers up to 200 to 300 on the exposed iron beams that remained.

Nesting birds attracted young non-breeders, and in the years 1963 through 1965 and again in 1969, subadults roosted on the east hill among the nesting birds. These numbered up to 100 or more in the early years, but no more than a few dozen in 1969, when only one pair nested on the hill. The south shore where Great Frigatebirds and a few red-foots nested was another favored roosting place for non-breeding red-foots.

Populations

Figure 75 shows the means and extremes of semimonthly population estimates of Red-footed Boobies from 1964 through 1969. The population is composed of two distinct elements: (1) resident breeding birds numbering no more than 2 or 3 dozen, which are the remnant of a formerly larger breeding population, and (2) transient birds, numbering upwards of 3,000 and mostly young pre-breeders from the northwestern Hawaiian Islands, that use Sand Island only as a roosting place while they are feeding or traveling in the Johnston area.

In contrast to the other two booby species, red-foots occur in relatively large numbers and nowhere near the total number visiting the island can be caught, or even accurately counted. Even the relatively few breeders were not handled in sufficiently large numbers to give more than a rough idea of their numbers. Maximum numbers of roosting birds occur only after dark and roost on the outer guywires, where they cannot be counted with less than perhaps a 25 percent margin of error, even by the most meticulous and experienced observers. Reported figures often fluctuated wildly from period to period, especially if personnel changed, and the new man made independent estimates based on his own interpretations of apparent numbers. For this reason, no purpose would be served by showing all semimonthly estimates. The graphed means probably represent a fair approximation of actual numbers present, and clearly shows the seasonal trends in numbers.

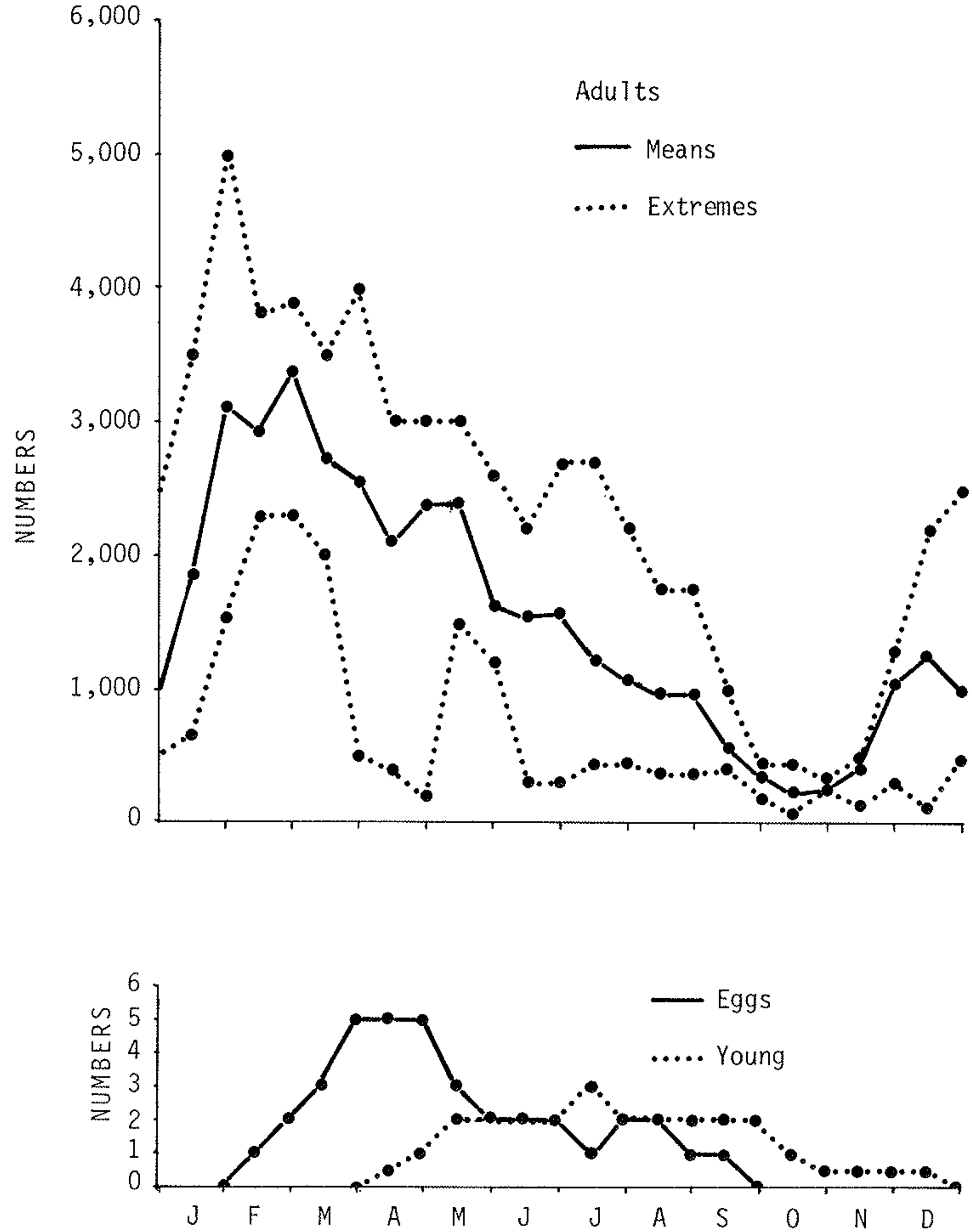


Figure 75. Means and extremes of semimonthly estimates of Red-footed Booby numbers, Sand Island, Johnston Atoll, 1964-1969.

The size of the original breeding population is unknown, but Wetmore's and Moynihan's observations indicated that it was substantially larger than that found during the 1960's. Wetmore's count of six nests with eggs, as well as young (number not given) from two weeks old to flying indicates at least twice as many breeders as during our studies, when no more than three eggs were found in July, and six was the maximum number of young produced in one year.

Moynihan (1957) did not count eggs or chicks, but his statement that most of the 100 birds he saw were on nests with eggs or small chicks indicates a population of breeders much larger than any noted since then, and possibly it was larger than it was before human occupation of the atoll. The brief period between Navy abandonment of Sand Island and its occupation by the Coast Guard may have been more favorable for Red-footed Boobies than any period before or since. The wrecked and abandoned towers and buildings may have provided enough elevated nest sites to attract a larger breeding population than was present before the war, and elimination of these sites by the Coast Guard no doubt decreased suitability of the island for red-foots considerably.

If the number of breeders in 1923 was as many as 50 pairs, then a substantial portion, perhaps half, of the first and second year birds Wetmore observed roosting on the island could have been young, Johnston-hatched birds. The others were most likely from other islands. Moynihan's observations do not indicate the presence of a substantial number of non-breeding birds. He did not, however, visit Sand Island except during the day, when roosting birds are at their lowest numbers. It does not seem likely, however, that anywhere near the number of roosting birds present during Aprils of POBSP studies (2,000 to 3,000) could have been using the atoll without his noticing them arriving at dusk. It therefore seems likely that the large number of roosting, non-breeding birds now using the island are attracted primarily to the guywires of the LORAN-C antenna and that much smaller numbers of these roosting birds used the island before the antenna was built.

Table 53 shows productivity figures for Red-footed Boobies for 1963 through 1969. These birds have the lowest rate of productivity, in terms of chicks produced per reproductive effort (eggs laid) and pairs breeding of any species now breeding on Johnston Atoll. Persistent renesting does not contribute significantly to productivity, for most successful eggs were the first laid by the pair in that year. In 1969, four pairs laid three eggs each without producing a chick.

The poor nesting success results primarily from lack of suitable nest sites (Figs. 76 and 77). In 1963, 1964, and 1965, most Red-footed Boobies nested in *Tribulus* clumps on the east hill, near the Brown Booby and Great Frigate colonies. A few nests were found in these years on concrete blocks and pilings around the island, but all the young came from the east hill. In 1966, 1967, and 1968, all nests were around the margins of the island, on pilings, rock piles, and the remains of an old boat. Increased activity of POBSP personnel was the most likely cause

Table 53. Productivity of Red-footed Boobies, Sand Island, Johnston Atoll, 1963-1969

		Eggs			Chicks			
Year	No. Pairs	No. Laid	No. Hatched	Percent Hatched	Fledged	Percent of Hatch	Percent of Eggs	Percent of Pairs
1963	?	(8)*	(3)	?	(3)	?	?	?
1964	?	(12)	(6)	(50)	6	?	?	?
1965	9	15	6	40	4	67	27	44
1966	?	(9)	2	?	1	50	?	?
1967	11	21	3	14	1	33	5	9
1968	(17)	27	6	22	4	67	15	?
1969	11	22	7	32	3	43	14	27
Mean	12	16.3	4.7	32	3.1	52	15	27

*Figures in parentheses are approximate.

of the birds failing to nest on the east hill. In 1966 particularly, Sooty Tern banding operations probably disturbed any pre-nesting birds on the east hill up to several times each night, which apparently was enough to discourage them from nesting there. In 1969 a pair that began courting on the east hill was carefully avoided until after they laid their eggs; they were successful in raising a chick.

Losses from the peripheral nest sites most commonly resulted from nests being washed away by high tides, usually the first spring tide after the nest was established. The nests frequently were precariously placed and high winds sometimes swept them off. The shallow cups formed by the nests did not insure the egg's safety, and flushed birds often kicked the egg off the nest platform as they flew. In 1969 a 19-day-old chick apparently fell off its nest on the old boat and drowned. Two infertile eggs, one each in 1968 and 1969, were incubated well beyond the normal incubation period.

Kleen constructed several platforms of old buckets and gratings on the pilings and derelict boat in late 1968, and one of the 1969 chicks fledged from one of these sites.

Red-footed Boobies mature relatively early, and may breed as three-year-olds (Table 54). Interestingly, one four-year-old bird successfully

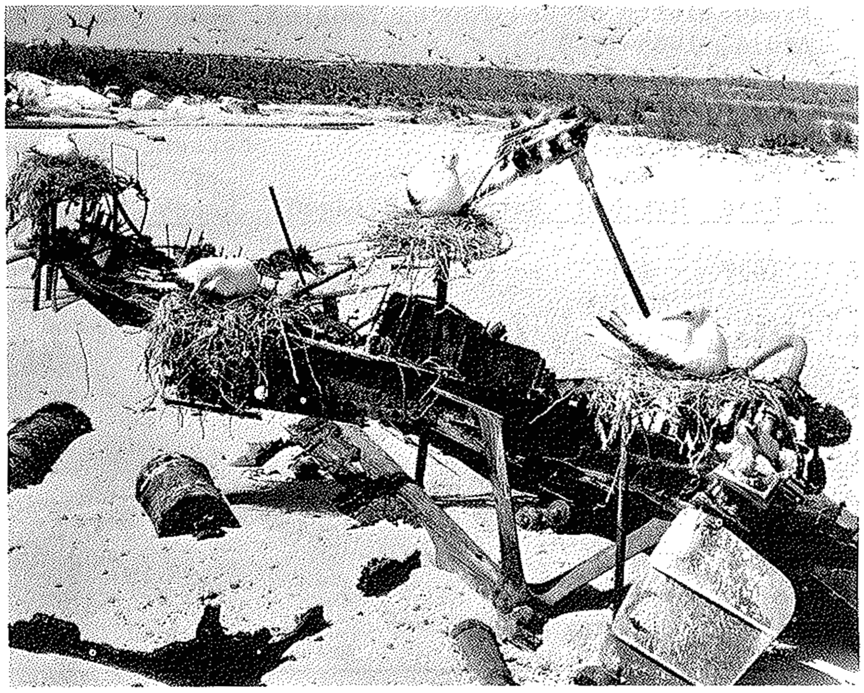


Figure 76. Four Red-footed Boobies nesting on artificial platforms (framework of an old boat) on the southwest beach of Sand Island, Johnston Atoll, 5 May 1969 (POBSP photo by P. C. Shelton).

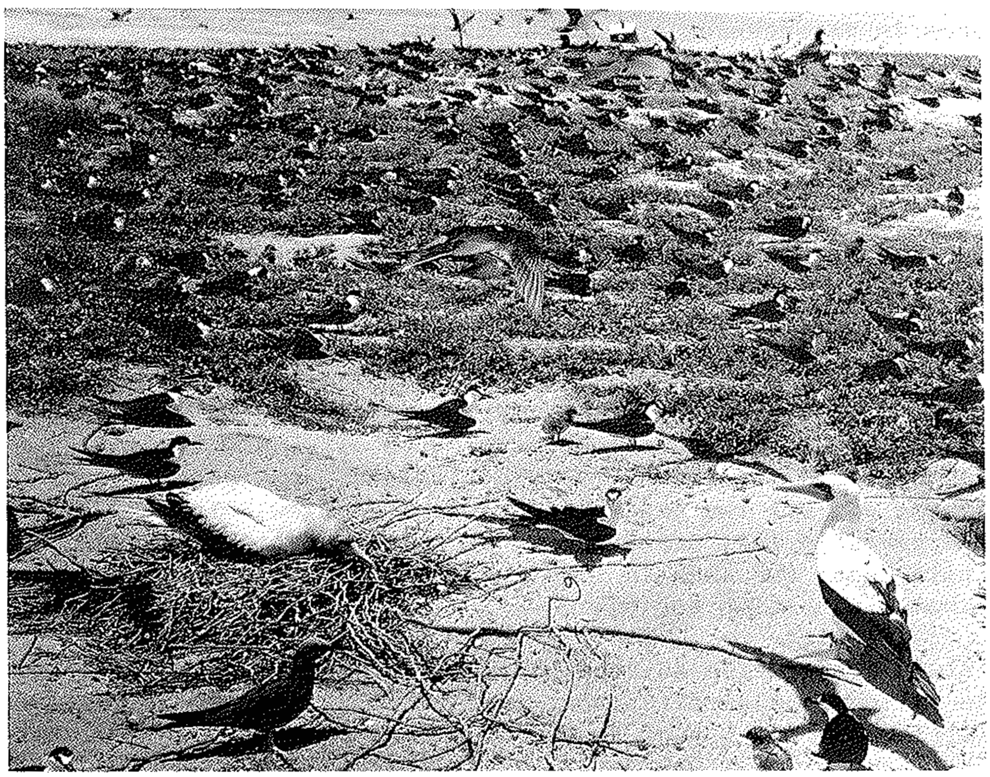


Figure 77. Red-footed Booby nest placed on ground on crest of hill east of transmitter building, Sand Island, Johnston Atoll, 4 May 1969. Sub-adult Blue-faced Booby roosting at lower right; Sooty Tern adults and chicks and Brown Noddy adult nearby (POBSP photo by P. C. Shelton).

raised a chick in 1969, which gave the known-age birds as high a rate of success as the general population. More known-age birds may have nested but were not caught, for only a little more than half the nesting birds were handled each year.

Table 54. Known-age Red-footed Booby nesting, Sand Island, Johnston Atoll, 1963-1969

		Found breeding as:					
		3-year-old		4-year-old		5-year old	
Year of Hatching	No. Fledged*	No.	%	No.	%	No.	%
1963	3					1	33
1964	6	2	33	1	17	2	33
1965	3	1	33	1**	33		
Total	12	3	33	2	25	3	33

*Less those known dead before maturity.

**Only known age bird known to raise a chick.

Annual Cycle

Breeders: The breeding birds probably are year-round residents on Johnston Atoll, and courtship has been observed in all months. But intensive courtship usually begins in January, when displaying adults are seen daily, and nest building begins. Laying normally begins in February and continues through the following four to six months (Table 55 and Figs. 37 and 75). Most eggs laid in April and later were by renesting birds that lost their first eggs. Relaying usually occurred about a month after the previous egg was lost.

The incubation period ranges from 44 to 46 days (mean = 45.4 days; n = 7). Chicks usually begin hatching in early April and may continue until late September. The fledging period ranges from 95 to 101 days (n = 4). Young birds are known to have fledged from early July to early December. These young birds remain near their nest sites for at least a few weeks after fledging, but soon begin roosting farther away.

Incubation shifts probably occurred fairly often--at least once a day--but may not have been as frequent as shifts in Brown Boobies. After hatching, chicks were attended closely for the first few weeks, but not as closely or as long as Brown Booby chicks. Unlike Brown Boobies, both Red-footed Booby adults rarely appeared together at the nest or with the chick. These observations possibly indicate that red-foots have more difficulty finding food than Brown Boobies, or at least that they travel farther from the island in search of food. The

Table 55. Extreme dates of significant events in the Red-footed Booby breeding cycle, Sand Island, Johnston Atoll, 1963-1969

Year	Laying	Hatching	Fledging
1963	? - 19 Aug.	? to 23 July	? to ? Sept.
1964	23 Feb. to by 3 July	11-14 Apr. to ?	? to ? Sept.
1965	by 17 Feb. to 16 July	7 Apr. to 2 Sept.	late July to 10 Oct.
1966	5 Feb. to late Apr.	Early May to early June	*ca.* 15 Aug. (only one bird fledged)
1967	8 Feb. to 1-4 Sept.	mid-May	15-25 Aug. (only one bird fledged)
1968	by 14 Feb. to 28 Aug.	*ca.* 9 Apr. to 23 Sept.	9 July to early Dec.
1969	19 Mar. to *ca.* 21 Aug.	4 May to *ca.* 25 Sept.	12 Aug. to 17 Aug.

comparatively large number of non-nesting red-foots--at least a few hundred at any time of year--might provide more competition for food than occurs in the smaller Brown Booby population. This comparison is not wholly pertinent if, as is suspected, Brown Boobies feed mostly inshore and red-foots over the open ocean, for the areas available to the two species would not then be of comparable size.

Throughout the breeding season, adult birds commonly roost on the pilings and rock piles where they nest. A few of these birds probably use these perches year-round. Whether or not there is a decline in numbers of breeding birds during the non-breeding months is not known, for these birds are not entirely separable from non-breeders, and during this season they are not easily caught for identification.

Non-breeders: The annual cycle in numbers shown on the population graph (Fig. 75) represents non-breeding birds almost entirely. Highest numbers occur in mid-winter months at about the beginning of the Johnston breeding season, followed by a slow decline through spring, summer, and early autumn, reaching a low in October. The sudden rise in numbers in late fall comes after the end of the breeding season on the northern islands.

In late fall and early winter, most of the birds are adults or older subadults, at least 1.5 years old, with white breasts and heads, but dark speckling on their backs and wings, typical of birds in their second and third years. Until late February, birds of the past breeding season--dark headed birds, with dark underparts or at least a dark breast band--are rare. Apparently these birds do not leave the nesting islands until after the adults and older subadults. But in late February the proportion of these dark young in the Johnston population increases and by late March they are the most numerous age-class present (Table 56).

Table 56. Plumage ratios of Red-footed Boobies, Sand Island, Johnston Atoll, 1967

Date	Adults and Subadults over 1 year old*	Subadults less than 1 year old**	Total Counted
27 Jan.	95%	5%	704
18 Feb.	95%	5%	54
21 Feb.	94%	6%	114
28 Feb.	88%	12%	69
23 Mar.	36%	63%	180
24 Mar. (night)	74%	26%	77
7 Apr.	49%	51%	67
12-28 June 1969 (hand caught and banded)	20%	80%	171

*Plumage white or mostly white.

**Plumage essentially gray-brown.

About the time the youngest birds reach maximum numbers on Sand Island, total numbers of roosting birds begin to decline, apparently as the adults return northward for their breeding season, and many of the older subadults follow. Throughout the remainder of the year, the approximately 1-year-old birds make up most of the non-breeding population, becoming, in late fall, the second year, white-breasted birds that make up the bulk of the population until the next crop of young arrives in late winter.

Where these 1-year-old-plus birds go in the summer and autumn, when the Johnston population is at its lowest, is uncertain. Many may return to the more northerly islands, but many more may remain at sea, possibly somewhere between Johnston and the northern islands, fishing in an area too far from land for them to return regularly.

Unfortunately, it is not possible to determine accurately the ratio of fully adult birds in the visiting population. It reaches a peak in mid-winter, but at this time it is difficult to distinguish these from the older subadults, which reach their maximum numbers at the same time. Fully mature birds probably never exceed 50 percent of the roosting population.

The movement pattern observed probably is correlated with feeding conditions at sea in the entire region. Food must be abundant within a day's flight from Johnston during mid-winter, but decreases through the spring, when heaviest demands by nearly all species are placed upon it. Minimal numbers of all species occur on Johnston in the fall, and food must be scarcest at this time. The sudden increase in Red-footed Boobies in late fall occurs at about the same time as Sooty Terns begin swirling near the islands, which would indicate that the food resources for these two species are either the same or at least follow similar cycles of abundance.

The effects of the guywires on Sand Island in drawing unusually large numbers of Red-footed Boobies was discussed earlier. Whether this causes an unnatural concentration of feeding effort by red-foots is not known. It may be that the birds fed in the vicinity of Johnston before the wires were present, but did not bother to come in to the island for lack of suitable roosting places.

Day-to-day numbers of roosting red-foots vary inversely with wind velocity and directly with cloud cover. Winds are more effective in determining numbers than cloud cover, and the effects of cloud cover are obscured by the more dramatic influences of winds. During periods of highest wind velocity, daytime numbers may drop to a few adults sitting on the more protected roosts on nesting sites, and nighttime roosting birds may number in the low hundreds. By contrast, when winds are light, daytime numbers of roosting birds may exceed the nighttime numbers during high winds, and nighttime numbers may range up to several thousand.

Reasons for the observed effects of clouds and winds on booby numbers are not well understood, but probably relate to energy requirements for flying and feeding. Energy output necessary for the birds to feed during calm, cloudy weather may be excessive, if they depend to any great extent upon upward deflected currents from wave-tops and thermal convection currents for sustaining flight while feeding. After several successive days of calm winds numbers begin to drop, which may indicate that the birds need to feed and leave to do so in spite of less than optimum flying conditions. It is also possible that the birds simply have difficulty roosting on the wires during high winds and find it easier to stay at sea than to return to the island. During storms with extremely high winds and heavy rains, large numbers of red-foots roost on the ground.

During each day, numbers of roosting red-foots on the island vary from a minimum at mid-day to a maximum well after dark which may be several times the minimum. The increase begins in late afternoon and reaches its maximum rate at about sunset, when flocks of up to a few dozen birds stream in from the sea to find roosting places on the outer guywires. Birds begin leaving before dawn, but fair numbers remain on the wires until an hour or more after sunup, especially on days with moderate or light winds. During this early morning period, large numbers of red-foots soar over the east hill, riding the upward deflected trade-winds. These birds often resettle for part of the day on the ground along the south shore and on the southwest rocks.

Turnover rates of the non-breeding birds probably is fairly slow. Although the number of birds handled was small in relation to the total numbers present, streamered birds remained conspicuous in the population for at least several weeks after periods of major banding effort. It would appear that during any particular season, birds return to the island at least every few nights, and many may return nightly.

Specimens

Appendix Table 7 presents data on the 29 specimens collected from Johnston Atoll. Of these 29, eight were collected by Wetmore in 1923 and 21 were collected by POBSP personnel; all are located in the USNM. This is a new specimen record.

Banding and Interisland Movement

In all, 1,047 Red-footed Boobies--180 adults, 844 subadults, and 23 young--were banded at Sand Island through the end of 1973 (Tables 24 and 57).

No interisland recaptures of Johnston-banded birds have been of known Johnston breeders or young hatched on Johnston. This is not surprising, for the Johnston area attracts hordes of birds from the Hawaiian Islands during the non-breeding season, presumably because food conditions are more favorable around Johnston, and it would be unusual if the residents regularly went elsewhere for food at that time. Only two known-age, banded birds hatched on Johnston have been caught back on the atoll during their second year, and none during their third year. But if the few young hatched there roosted on the guywires with the thousands of others the same age, their chances of being caught would be small. Nearly all the known-age birds caught in their fourth year, or older, were nesting. Thus, it is doubtful if any of the breeding birds, or their young, regularly leave the Johnston area during the non-breeding season.

Conversely, 281 red-foots have made interisland movements between Johnston Atoll and the Hawaiian Islands (Table 26). A total of 102 banded as non-breeding birds on Johnston have been recaptured to the north, while 179 banded elsewhere have been recaptured at Johnston.

Table 57. Banding and recaptures of Red-footed Boobies, Sand Island, Johnston Atoll, 1963-1973

	Adults				Subadults				Young	Total				
Year	New Bands	Returns	Recov-eries	Inter-Island	New Bands	Returns	Recov-eries	Inter-Island	New Bands	New Bands	Returns	Recov-eries	Island	Total Handled
1963	13	0	0	0	13	0	0	0	3	29	0	0	0	29
1964	8	2	0	0	32	0	0	0	6	46	2	0	0	48
1965	46	10	1	5	150	3	0	20	4	200	13	1	25	239
1966	63	10	2	18	284	16	2	49	1	348	26	4	67	445
1967	16	18	0	3	118	5	1	31	1	135	23	1	34	193
1968	5	16	0	0	48	0	0	6	4	57	16	0	6	79
1969	29	28	1	21	199	1	0	30	3	231	29	1	51	312
1973	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Total	180	84	4	47	844	25	3	136	23	1,047	109	7	183	1,346

At-Sea Distribution

Red-footed Boobies were absent from the grid southwest of Johnston from May through September (Table 21 and Fig. 78). This occurs from the last of the egg-laying period through the whole of the chick and fledging period on Johnston Atoll. Thus Johnston breeders are not using the grid area for food during most of their breeding season. The increase in birds from October through February occurs both in the grid and on Johnston. On the Atoll, however, numbers remained constant from February through at least April, whereas in the grid at this time there was a rapid decrease in numbers.

Three orange-streamered birds from Johnston were observed within the grid, two in December and one in January. Both of the December birds were subadults. On 30 January 1966, a banded immature from French Frigate Shoals was collected a few miles northeast of the grid. Since 84 percent of the grid population consisted of immature or subadult

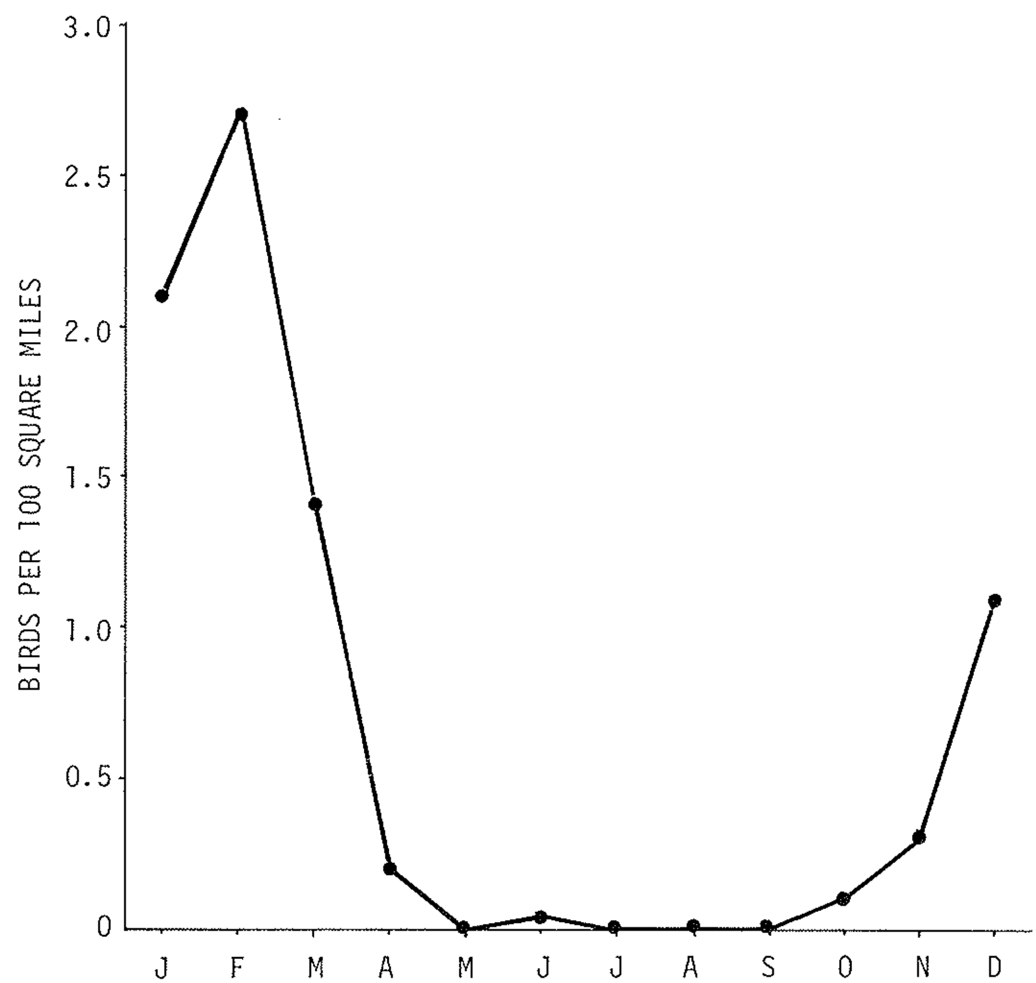


Figure 78. Diurnal occurrence of Red-footed Boobies at sea 175 miles southwest of Johnston Atoll, 1963-1967.

individuals it would appear that this area is composed mainly of highly mobile birds from both Johnston Atoll and the Hawaiian Islands (POBSP, 1967a).

Further analysis of the at-sea distribution of Red-footed Boobies is being conducted by Brian A. Harrington (in prep.).

GREAT FRIGATEBIRD *Fregata minor*

Status

Common breeding species, as well as a common, transient visitor; breeders present year-round but most active October through August; transients present throughout the year but most common in fall. Nests built of *Tribulus* on the ground or in grass clumps at Sand Island; previously nested at Johnston Island. Transient visitors roost on antenna guywires, and other raised sites. During POBSP studies several hundred pairs nested yearly, with up to 113 fledging; transients numbered up to 1,000 or more.

Ecological Distribution

Akau Island: POBSP personnel recorded Great Frigatebirds occasionally perching on towers here during the late 1960's.

Johnston Island: On 15 March 1859 while on Johnston Island, Brooke (ms.) reported: "...every now and then frigate birds would sweep with a roar over head. Perched on some fragments of coral were some frigate birds, some with flaming red pouches."

Wetmore (ms. a) found 800 here in July 1923 and described the colony as follows.

> Abundant. A few males are pairing and exhibit the inflated gular sac. Some few have eggs but the majority have young already on the wing. Birds able to fly are in many cases still fed by the parent. As the young bird sees the adult approach it spreads its wings and utters a begging call. The parent after circling past several times alights on the ground and opening the mouth regurgitates, while the young bird plunges its bill down the parent's throat to seize the food. After feeding, the old bird flies out over the water and swoops down to dip its bill and wash out its open mouth. A flock of the birds may be attracted easily by throwing small fish in the air when the great frigates swoop and circle about, often seizing the fish in the air. When one secures such a morsel, others pursue it and frequently snatch the fish from its bill. It usually happens that they wrangle until the fish falls into the water and is lost.
>
> I see them pursuing terns, Wedge-tailed Shearwaters, and boobies, often driving the unfortunates down into the water.

> At nightfall they gather in flocks to roost on the eroded ledges on the beach. They sleep with the head turned on the back but often spend an hour or more after dark in the care of their plumage. The adult female has a dull red rim around the eyelid. In the male this is black.
>
> Many are now molting extensively so that the beach is scattered with their feathers.
>
> The birds remain active at night and are continually overhead.

Four were seen in May 1945 (Clark, 1945 a and b); 100 were present in November 1949 but only a few in December 1949 (Jensen, 1949).

Some tried to nest in bushes along the south side of the runway near the northeast end in 1962, but construction work eliminated the bushes (Willis G. Morris, pers. comm.). POBSP personnel occasionally recorded Great Frigatebirds flying over Johnston Island in the 1960's, but no nesting attempts were observed.

Although the population in 1923 was almost entirely on Johnston Island, it has been exclusively on Sand since 1962, and it is unlikely that successful breeding occurred on Johnston for several years before that--perhaps not since before World War II.

Unfortunately, none of the old photos from Johnston Island shows frigatebird nests, but several show young birds sitting on the ground between *Lepturus* clumps. These all appear to be either along the top of the bank above the shoreline, or near the top of the 40-foot hill. These sites probably are those from which the adults can most readily take flight, since they would have difficulty rising from level ground, especially from between clumps of *Lepturus*.

Sand Island: Wetmore (ms. a and b) observed 100 here in July 1923. Moynihan (1957: 36) in April 1957 recorded the following.

> Frigate birds were the second most abundant species on Sand Island. There were at least 900 adult birds nesting on the girders of four overturned and partly collapsed radio towers on the western islet. A few of these were still incubating but most of them were sitting on chicks, some of which were half grown. There were also many birds in juvenal plumage flying overhead or resting on the same four towers, another collapsed tower a few yards away, and a few low bushes on the same islet. I would guess that the total number of Frigatebirds in the area was not less than 2000. (It might be noted, incidentally, that none of them ever landed on the bushes, trees, or houses of the eastern islet.)

POBSP personnel found Great Frigatebirds as common nesters and transients from 1963 through 1969. They were also present in November 1973.

Nesting areas used by Great Frigatebirds on Sand Island during POBSP studies are shown in Figures 44 and 79. Reasons for changes from site to site are not clear, but probably the knoll site was preferred. Intensive disturbance there by POBSP personnel in 1963-1964 may have caused the move to the south shore. Why more birds did not nest on the southwest islet, which presents what appears to be the best raised sites on the island, is not clear. Possibly competition with Brown Boobies nesting there is responsible.

During POBSP studies, a few Great Frigatebirds attempted to nest on navigational aids and guywire bases in the lagoon, but the few eggs laid were lost before hatching.

Because of the almost total lack of bushes, at least in the areas that are far enough from human disturbance for frigates to be attracted to them, the birds on Sand Island are forced to nest entirely on the ground (Figs. 80 and 81). Since the original vegetation of the atoll contained no shrubs or trees, frigates have never had anything but the ground or *Lepturus* clumps on which to nest. Exceptions to this occurred during the late 1950's after the Navy abandoned Sand Island when frigates nested on overturned towers and during the early 1960's when they nested on bushes on Johnston Island. That the Johnston Atoll birds would readily nest on raised sites is shown by their use of these girders and towers in 1957 (Moynihan, 1957), and by their attempts to use the bushes on Johnston in 1962.

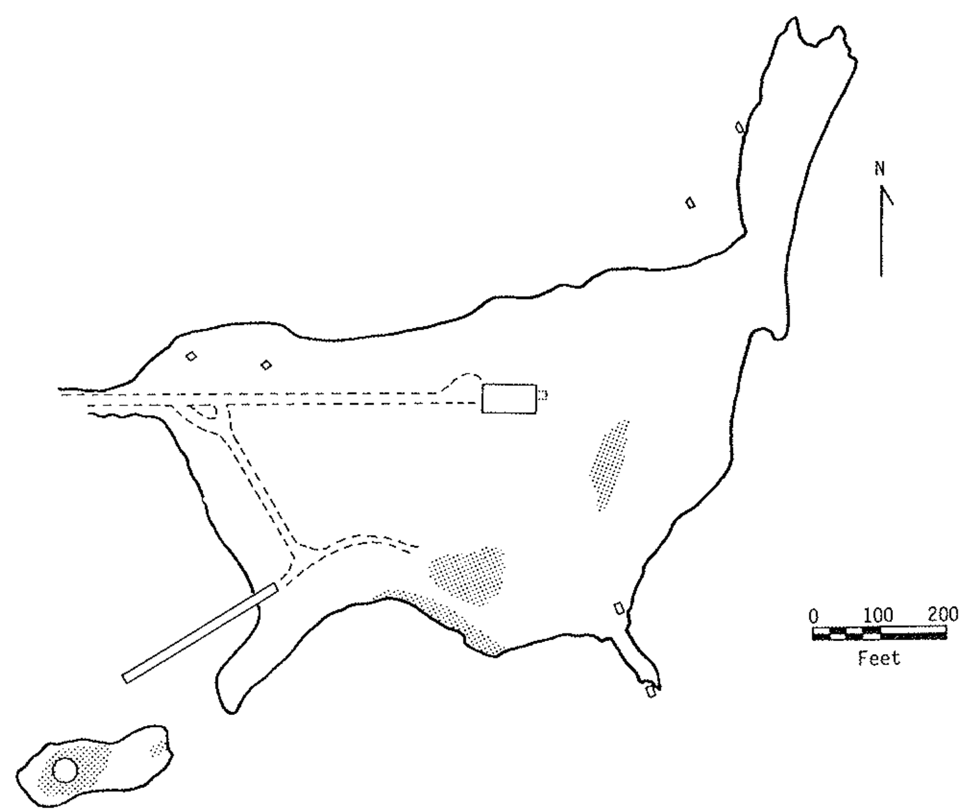


Figure 79. Great Frigatebird nesting areas, Sand Island, Johnston Atoll, 1963-1969.

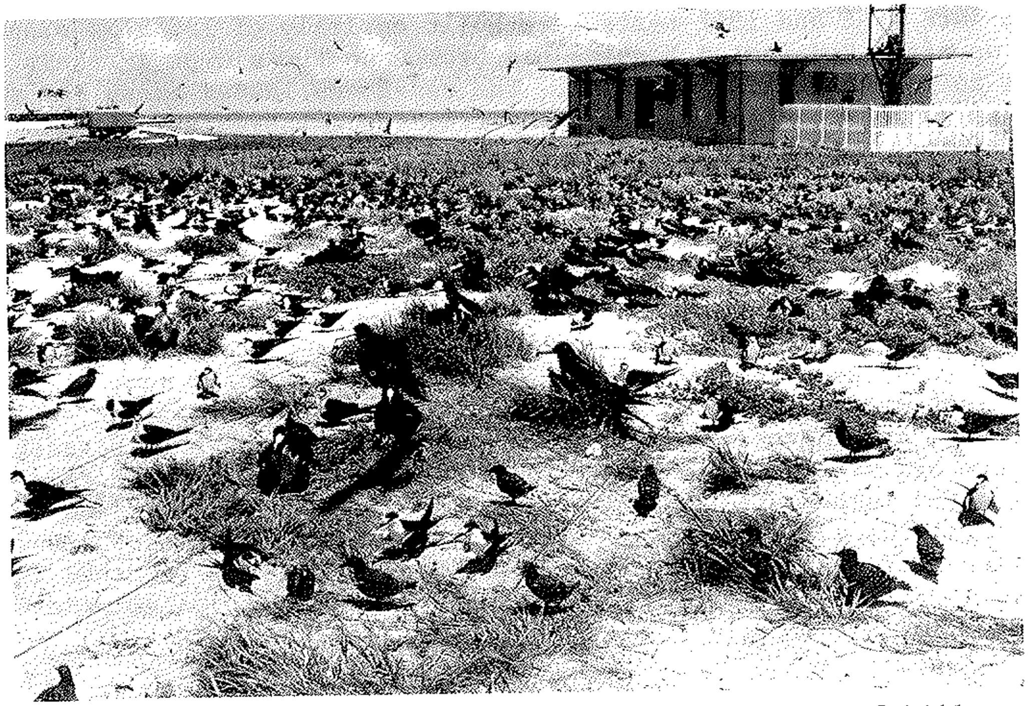


Figure 80. Great Frigatebirds nesting on ground on crest of hill east of transmitter building, Sand Island, Johnston Atoll, May or June 1964. Sooty Tern adults and chicks surround the colony (POBSP photo by A. B. Amerson, Jr.).

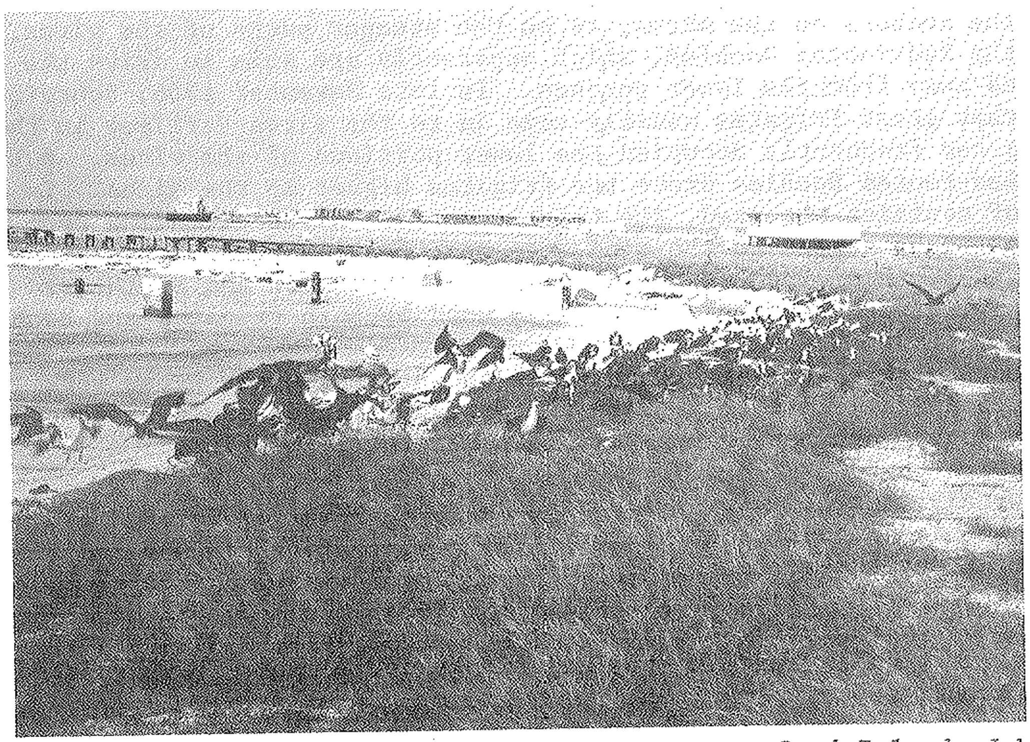


Figure 81. Great Frigatebird colony on south shore, Sand Island, Johnston Atoll, 26 February 1969 (POBSP photo by P. C. Shelton).

In late 1966 and 1967 nests were built entirely of *Tribulus* vines picked up after Red-footed Boobies had broken up the clumps in their efforts to gather nesting material. The red-foots landed among the vines and pulled them apart, while the frigates gathered the material on the wing, swooping down to pick up loose pieces left by the boobies. Nest material often was stolen from unattended Red-footed Booby nests, and was even stolen from red-foots carrying material, much like food material was stolen. Usually only male frigates gathered nest material, but at least once (26 February 1957) a female was seen gathering *Tribulus*.

Because of scarcity of material, many nests almost or completely lacked plant material. The nests of late breeders in the inland colony of 1967 were nothing more than depressions in the ground and in several cases, the egg was laid in the middle of *Lepturus* clumps, which raised the egg a few inches off the ground. By the time these late birds nested, *Tribulus* vines were practically non-existent because of removal by earlier nesting boobies and frigates. Boobies by this time had switched to *Boerhavia* for their nests; apparently the frigates made no attempt to use *Boerhavia*.

Non-breeding birds roost mainly on the guywires of the LORAN-C antenna, and in several other locations scattered around the island and lagoon (Fig. 82) which afford raised sites from which the birds can become airborne readily. Except for the guywires, most of these sites are used mainly during the day, and some only at low tide (North Antenna Rocks). On the guywires, frigates roost on the anchors or just above the anchors on the wires, or on the steeper parts of the wires, above the Red-footed Boobies, which apparently are able to drive the frigates away from the lower perches. In late November 1966, Schreiber noted that great frigates usually came in to the wires earliest in the evening and frequently occupied the lower portions of the wires. But later Red-footed Boobies drove the frigates higher up the wires. In all cases of conflict observed, the frigate moved. Wires extending from the tower at right angles to the wind were most heavily used. Thus those north and south of the tower, including the northeast and southeast inner wires, were usually most heavily used by both frigates and boobies.

Because they are larger and space themselves on the wires more widely, and are located higher on the wires, frigates could be counted in poor light much more accurately than Red-footed Boobies.

Two distinct behavior patterns occurred: sunning, and soaring. In the sunning behavior, the birds assumed ridiculous-looking positions with the wings outstretched and turned underside up, or with the body drooped across the wires as if they were dead. Usually they had their bills open, probably to help in cooling. Other aspects of the sunning postures, especially turning the underwings up, may have been related to the occurrence of parasites.

Soaring occurred on days with light winds and strong sunshine causing an updraft to form by air rising from the heated surface of

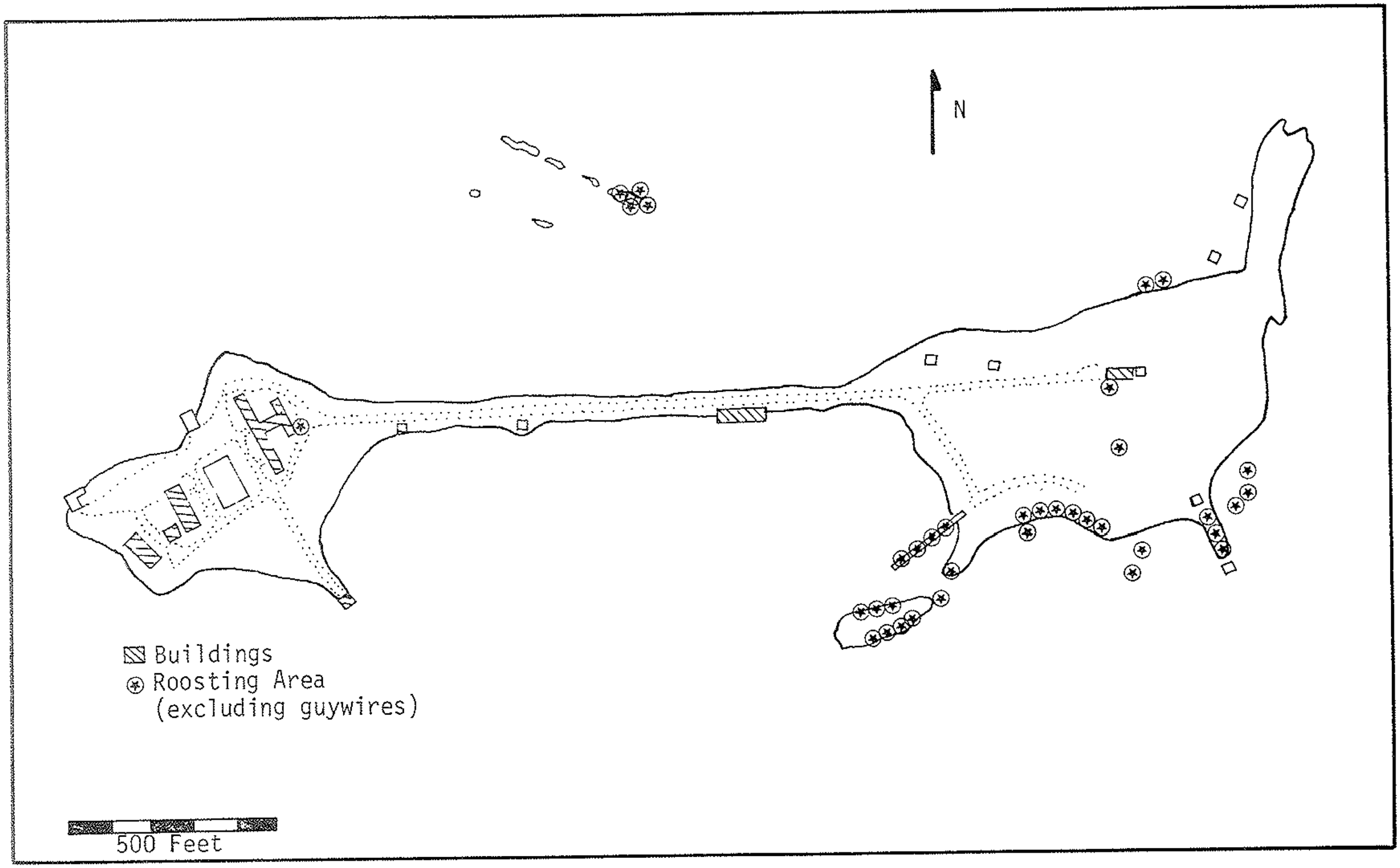


Figure 82. Great Frigatebird roosting areas, Sand Island, Johnston Atoll, 1963-1969.

the island. In normal (12-15 mph) or stronger winds, this updraft was either broken up or blown away from the island at such an angle that it was not usable by the birds. But with light winds the column drifted slowly away from the island, and it was invariably marked by several dozen frigates (and often other species as well, including Sooty Terns) circling motionless in the column, rising at least as high as the cloud bases, 1,500 to 2,000 feet up. Frigates could be observed flying (flapping) slowly from the roosting areas to this column of rising air, setting their wings and circling upward nearly to the cloud bases.

During normal trade winds, frigates spent a lot of time soaring over the east hill, where air forced over the rise afforded ample upward current to keep the birds aloft indefinitely.

Populations

Like Red-footed Boobies, Great Frigatebirds were difficult to census because most of them, especially non-breeders, roosted on the outer guywires and reach maximum numbers only after dark. Because they were larger, less numerous, and a greater proportion roosted on the ground, counts of frigates were somewhat more accurate than for red-foots, perhaps within a 10 percent margin of error.

Figure 83 shows means and extremes of POBSP semimonthly estimates of Great Frigatebirds on Sand Island, based primarily on roost counts made at late dusk or at night by moonlight. These figures represent maximum numbers present at one time during the period, rather than total birds using the atoll. There was no reliable basis for estimating the turnover rates in the roosting population, but it would be surprising if less than two or three times the maximum numbers recorded used the atoll each year.

In general there was much less seasonal fluctuation in Great Frigatebird numbers than for most other species on the atoll. The high of about 1,000 which occurs in early fall was only about twice the low of 400 to 500 which occurs during the winter. The graph of means of population estimates (Fig. 83) indicates two lows, one in December and January and the other in June and July, with broad highs between. The spring maximum appears to correlate with the breeding season on Johnston, while the fall maximum may be caused by an influx of transients.

Small period-to-period fluctuations in many cases resulted from differences in estimating techniques, or of inadequate counting. The number of birds present at any given time depends to a large extent upon the time of day, wind velocity, and cloud cover, and unless several counts are made during a semimonthly period, the maximum number of birds present during that period may be poorly estimated. Highest counts were made at night by moonlight when winds were minimal, but such conditions often did not occur during a given period. Use of a spotlight for night counts was not practical because the birds flushed when the light was turned on them.

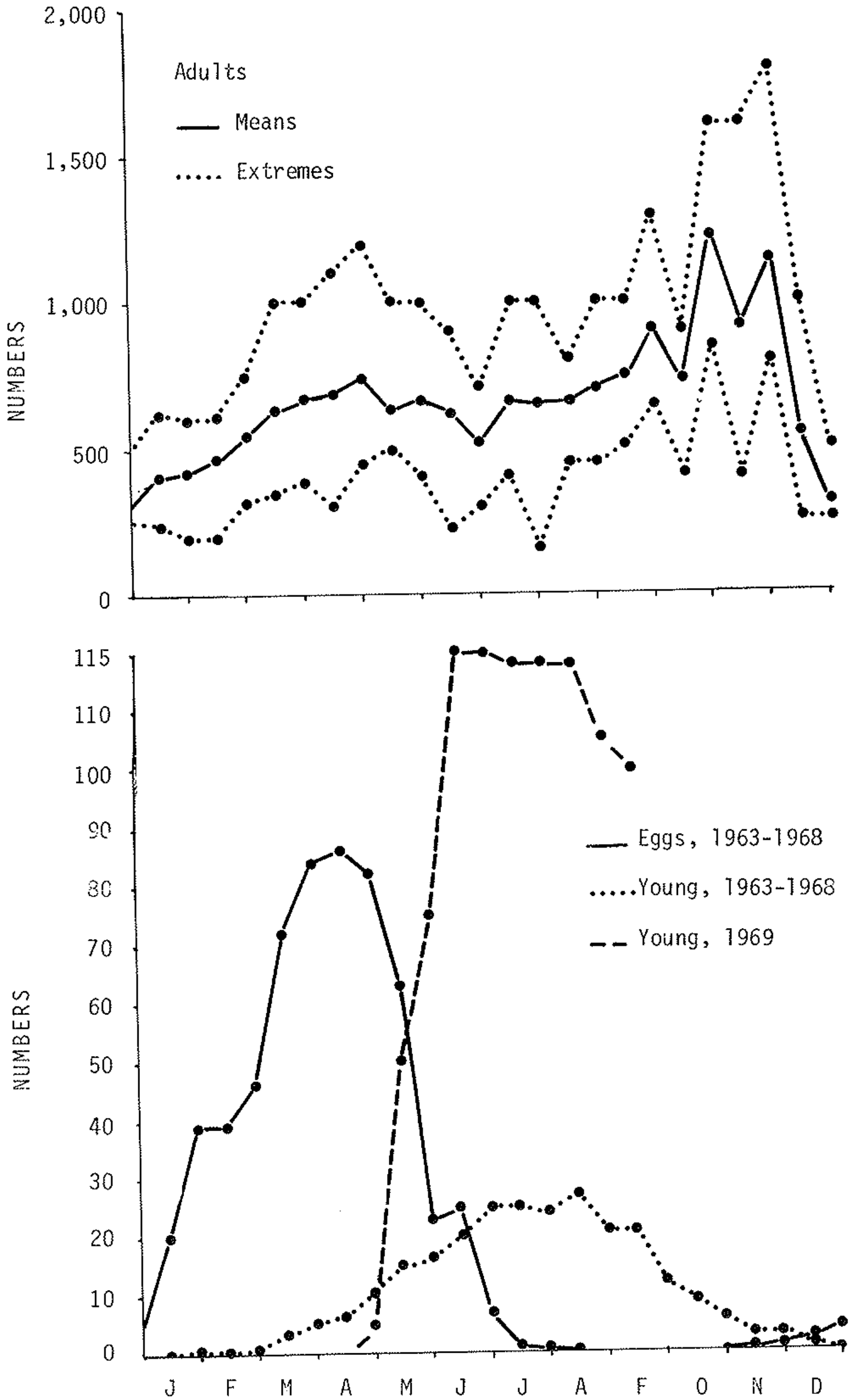


Figure 83. Means and extremes of semimonthly estimates of Great Frigatebird numbers, Sand Island, Johnston Atoll, 1963–1969.

Birds present in the breeding colonies varied from a low of a few to a few dozen birds present during late summer, increasing throughout the fall and winter, and spring as courtship activity increased, to a maximum of 250 to 350 during the period January through May. Before egg laying began, the number of birds decreased at night in the nesting areas, possibly because many of the birds roosted on the guywires, but later, the number remained constant day and night.

An exception to the above generality occurred in February, 1969, during the weather disturbance described elsewhere, when numbers in the colony fell from about 275 birds before the disturbance began to 48 birds on 18 February. This probably represented only those birds on eggs, but this could not be determined without disturbing the birds. By the end of February there were again over 250 birds in the colony each day.

There appears to have been some reduction in numbers between the times of the pre-POBSP estimates and the mid-1960's. Wetmore's estimate of nearly 1,000 birds in July 1923 is nearly twice the mean for July during POBSP studies, and Moynihan's estimate of 2,000 birds in April 1957 is nearly three times the April mean from POBSP figures. Although large numbers of great frigates roost on the LORAN-C guywires, their numbers did not appear to increase in response to the availability of these roosts as did Red-footed Boobies. Reasons for a decline in frigatebird numbers are not clear. Perhaps recruitment to the adult population was below normal because of missing age classes from years of intensive disturbance.

Productivity: Table 58 and Figure 83 list available data on productivity of Great Frigatebirds on Sand Island during POBSP studies. The spectacular increase in chicks fledged in 1969 resulted from our discontinuing all egg and chick counts in that year.

Detailed nesting studies were initiated at the beginning of the 1963-1964 nesting season, when eggs were counted daily in the nesting colonies. By mid-April 1964 it had become obvious that the daily disturbance was causing inordinately high losses of eggs and small chicks (mean fledglings for 1963 and 1964 = 9). At this time daily counts were discontinued, but eggs and chicks were counted semimonthly for the remainder of that season and throughout the nesting seasons of 1965 through 1968. Continued low productivity continued (mean fledglings for 1965 to 1968 = 26), however. This prompted Vernon M. Kleen to rope off the south shore nesting colony in late 1968. Throughout the nesting season of 1968-1969 we stayed far enough away (usually 20 to 30 feet) from the nesting frigates so that birds on eggs would not flush. Civilian and military personnel using the island cooperated excellently in this attempt to minimize disturbance. There were no more birds in the nesting colony in 1969 than in previous years, and as far as is known, no other factor changed in 1969 that could account for the increased survival of chicks. Productivity increased, resulting in 113 chicks fledged. Perhaps the increase would have been still more spectacular had not the weather disruption in February reduced the number of birds in the colony to about a fifth the usual number for one day. It is not known whether any eggs were abandoned during this period, but only one could be seen unattended in a photograph taken of the colony on 18 February, when birds were at their minimum.

Disturbance to nesting great frigates results in losses of both eggs and chicks. Adults incubating eggs or brooding small chicks apparently work the egg or chick up against their abdomen between their feet in such a way that the egg or chick is carried a few feet before falling free when the adult flushes. Even if not broken or killed, an egg or chick so treated is unlikely to be retrieved by the parent. In addition, small chicks left on the nest when the adult is flushed may be eaten by other frigates before the parent returns.

Table 58. Productivity of Great Frigatebirds, Sand Island, Johnston Atoll, 1963-1967*

	Colony Area									
	Knoll		So. shore		Islet		Inland		Total	
Year	Eggs	Young	Eggs	Young	Eggs	Young	Eggs	Young	Eggs	Young
1963	?	11	0	0	0	0	0	0	?	11
1964	400	6	0	0	61	0	0	0	460	6
1965	60	6	300	24	40	1	0	0	(400)**	31
1966	0	0	250	15	5	0	0	0	(255)	15
1967	0	0	250	16	0	0	50	10	(300)	26***

*Numbers of eggs counted daily only in 1964, and then only through part of season; number of young is number banded and not known to be lost within 90 days.

**Numbers in parentheses are approximate.

***Observations not made after mid-September; probably several of these were lost shortly after fledging. Most or all may have been killed by USCG personnel.

After the chicks become large enough to not be eaten or easily dislodged from their nests, mortality was relatively low until they fledged. At the time of fledging, mortality again became high, mostly because the inexperienced birds hit guywires, breaking their wings. Almost all the dead birds (destroyed and recovered) listed in Table 59 were birds that hit guywires.

If human disturbance continues, the breeding population will no doubt decline, but if disturbance is minimized the breeding population will probably increase.

Table 59. Fate of young Great Frigatebirds banded on Sand Island, Johnston Atoll, 1963-1967

Year	No. Banded	Dest.	Recov.	Tot. dead	Rep.	Ret.	No Data	Total possibly alive
1963	15	4	4	8	0	0	7	7
1964	6	0	1	1	2	0	3	5
1965	33	0	3	3	4	10	16	30
1966	19	4	2	6	0	3	10	13
1967	27	1	0	1	0	0	26	26*
Total	100	9	10	19	6	13	62	81

*Many of these killed by USCG personnel.
**Dest. = Destroyed, Recov. = Recovered, Rep. = Repeat, Ret. = Return.

Food Habits: Little is known of the feeding habits of Johnston Atoll frigatebirds except that they do commonly pirate food from Red-footed Boobies and Wedge-tailed Shearwaters, occasionally from Sooty Terns, as well as from one another, and rarely from Brown Noddies. No quantitative data as to the amount or proportion of food taken in this way are available.

An interesting aspect of food habits is the total lack of evidence that great frigates prey upon Sooty Tern chicks at Johnston Atoll, as has been noted from French Frigate Shoals (Amerson, 1971). The terns nest among the nesting frigates, and the young terns hatch during the time frigates are feeding their own young, which one would expect to be a time when any available food would be used. In 1967, Shelton even found several Sooty Tern chicks huddled under incubating and roosting frigatebirds near the south shore of Sand Island.

Annual Cycle

Breeders: The breeding season of Great Frigatebirds (Table 60 and Figs. 37 and 83) is one of the longest of any species on Johnston Atoll, both for individual birds and the colony as a whole. Normally seven to eight months elapse from the time a pair of adults begin displaying and nest building until their chick fledges, if they are successful. This includes a month of prelaying activity, about eight weeks of incubation (incubation period for one egg observed in 1964 was 56 days), and four or five months for growth of the chick. Although no positive evidence is available, birds that lose their first egg may relay, which would extend the period from displaying to fledging by at least another month.

Table 60. Extreme dates of significant events in the Great Frigatebird breeding cycles, Sand Island, Johnston Atoll, 1963-1969

Year	Earliest displaying males	Laying	Hatching	Fledging
1963-1964	?	27 Nov.-?	1-15 Mar.-?	(1-15 Oct.-1-15 Nov.)*
1964-1965	1-15 Oct.	1-15 Nov.-1-15 May	16-31 Mar.-1-15 July	16-31 Aug.-1-15 Dec.?
	E. hill:	(1-15 Apr.-1-15 May)	(1-15 June-1-15 Aug.)	16-31 Oct.-1-15 Dec.
1965-1966	?	1-15 Nov.-early May	18 Jan-16-30 June	1-15 Aug.-16-31 Dec.
1966-1967	?	4 Dec.-May?	23-28 Feb.-16-31 May	16-31 Aug.-?
	Inland:	(8 Apr.-May?)	16-31 May-16-31 July	?
1967-1968	?	?-May?	9-16 Apr.-1-7 July	27 Aug.-late Oct.
1968-1969	?	24 Nov.-?	by 31 Mar.-June	late Aug.-?

*Dates in parentheses are approximate.

Neither Wetmore's 1923 observations nor those of Moynihan in 1957 indicate significant variations in the nesting cycle from the pattern observed in the 1960's. During POBSP studies, the main colonies stayed on the same schedule year after year, but smaller groups varied from the larger ones by as much as three months.

Although an occasional male with an inflated gular pouch may be seen at any time of year, the first marked increase in displaying birds usually occurred in October. A few eggs were laid in early November of some years but there was not a significant number of eggs present until January. Displaying birds were common throughout the winter, and in 1965 and 1967 new nesting areas were occupied in early March, five months after the first nesters began their activities.

In 1963 and 1964 the earliest and largest nesting colony was on the east hill; in 1965 and subsequent years it was on the south shore. In mid-March 1965, birds began displaying in the 1963-1964 nesting area on the east hill, and by early April they had begun egg laying there, three months after the larger colony on the south shore began laying.

This east hill colony was not occupied in 1966 or 1967, but in March 1967 a secondary colony was established inland from the main south shore group, and these birds followed about the same chronology as the east hill colony in 1965.

Unfortunately, individual birds were not traced from colony to colony and year to year because banding and recapture operations were too disruptive to the colonies.

The chronology of nesting on the southwest islet in 1964, 1965, and 1966 closely followed that of the main colonies in those years.

Most hatching occurred in March and April in the main colonies, and in May and June in the late colonies of 1965 and 1967. Chicks in the main colonies were flying by late August, four to five months after hatching; young in the late colonies remained on the ground until December, after the first eggs of the next season had been laid in the larger colonies.

When the young become fully independent is not known, but birds up to a year old were seen being fed by an adult. If heavy or full dependence of young on their parents extends for more than a few months after fledging, it is extremely unlikely that these parents could breed again in the year after successfully raising a chick.

At least some of the young birds continue to use the atoll for several years. In 1967, several of the 1966 young were seen regularly, mostly roosting on pilings off the south and east shores. At least one 1965 bird (737-44933) was seen regularly near its hatching site on the east hill until early 1967. A 1965 bird (737-44932) was photographed while it roosted on a guywire in April 1967, and a 1963 bird (737-44213) was found partly decomposed (skeleton saved) on the east beach in March 1967 (see also Banding and Interisland Movement section).

The age at which the young begin breeding is not known, but it certainly is over five years. Known age five-year-old birds do not appear fully adult.

Non-breeders: The fall maximum in Great Frigatebird numbers (see Fig. 83) appears to be caused by an influx of transients, probably birds moving away from the northwestern Hawaiian Islands after the end of their breeding season. See also the Banding and Interisland Movement section for further details about transients.

Numbers of birds both on the wires and on terrestrial roosts varied inversely with wind velocity. Also, under any given wind velocity, there was a two-to-four fold increase in numbers during the night over those present during the day. Most of the increase occurred in the evening, and the birds thin out again in the early morning. During days of high winds there may be no birds on the wires, and only a few scattered individuals on the more solid roosts, while on days with little or no wind, up to 500 birds may be found on the wires and other roosts.

Table 61 shows several samples of ratios of the various recognizable sex and plumage categories at various locations on the island. The most serious shortcomings of these data are that they are too few, do not represent all the roosting locations on the atoll, and do not cover all possible times. Birds on the outer set of guywires were too far from shore to properly distinguish the plumage categories and no counts could be made at night.

There is insufficient evidence to conclude that the sex ratio of adults departs substantially from a 50-50 ratio.

The outstanding fact emerging from this set of figures is the preponderance of subadults and immatures in roosting areas (including all except the one count of 23 March 1967 in the breeding colony on the south shore). Since so few young are produced each year on Johnston Atoll, it is obvious that most of those roosting there are from other islands; presumably all are from the northwestern Hawaiian Islands, as indicated by the banding records.

What percentage of the adults roosting on the atoll are also from other islands is unknown, but there are several records of adults moving between the islands (see Banding and Interisland Movements).

Specimens

In all, 67 specimens of Great Frigatebirds have been collected at Johnston Atoll. Data for these are presented in Appendix Table 7. This constitutes a new specimen record.

Banding and Interisland Movement

From 1963 through 1969, POBSP personnel banded 997 Great Frigatebirds at Sand Island; Amerson banded eight in 1973 (Table 24). Of these 1,005, 348 have been recaptured back on the atoll (Table 25), and 14 have been recaptured elsewhere (Table 26). In addition, 29 birds originally banded on other islands were captured at Johnston.

Table 61. Plumage ratios of Great Frigatebirds, Sand Island, Johnston Atoll

Date and time	Location	AM	AF	AU	Sub-adult*	Imm.**	No.
24 Sept. 66 1855-1910 hrs.	NE & SE inner wires	20	23		36	22	165
29 Jan. 67 Evening	SE outer wires	21	52			27	163
Noon	SW islet			55		45	112
23 Mar. 57 1435	SW islet			32	15	52	40
1530	So. shore (breeding colony)			88	3	9	353
1630	SE inner wire			37	26	37	38
30 Apr. 67 1920-1940	NE and SE inner wires	33	20***		9	38	74
24 Feb. 69 1830	SE inner wire	3	12				43
29 May 69 1430	So. shore			258	1	1	260
	Inner wires & ground except So. shore			95	0	5	100
	Outer wires			76	0	8	84
6 Sept. 1945	NE inner wires			52		25	77

*Head mostly white, mottled with black

**Head white or white and red.

***Five birds had gray breasts.

The interisland birds (Table 26) show that most Great Frigatebird movements, if not all, involving Johnston are to and from the northwestern

Hawaiian Islands. In all, 23 from French Frigate Shoals, the closest island to Johnston, have been captured at Johnston. Curiously, six of these 23 were banded as chicks on the same day and same island: 13 June 1963, Whale-Skate Island. It is also noteworthy that two of these six birds were later retaken on their home island, and that an adult banded on Pearl and Hermes Reef made a similar round trip to Johnston and back to its original site. Three others from Pearl and Hermes Reef were also captured at Johnston. The 15 Johnston birds captured elsewhere were taken at: French Frigate Shoals (six birds), Kure Atoll (four), Marshall Islands (four) and Phillipine Islands (one).

At-Sea Distribution

Low grid densities for Great Frigatebirds from May through August (Fig. 84) correspond to the major breeding season on Johnston Atoll, while a somewhat higher density is maintained in the grid during the non-breeding season (November to March). The complete absence of frigatebirds in June and July may in part be due to the abundance of other bird species, especially boobies, near Johnston on which frigatebirds can parasitize (food robbing) without traveling all the way to the grid (POBSP, 1967a).

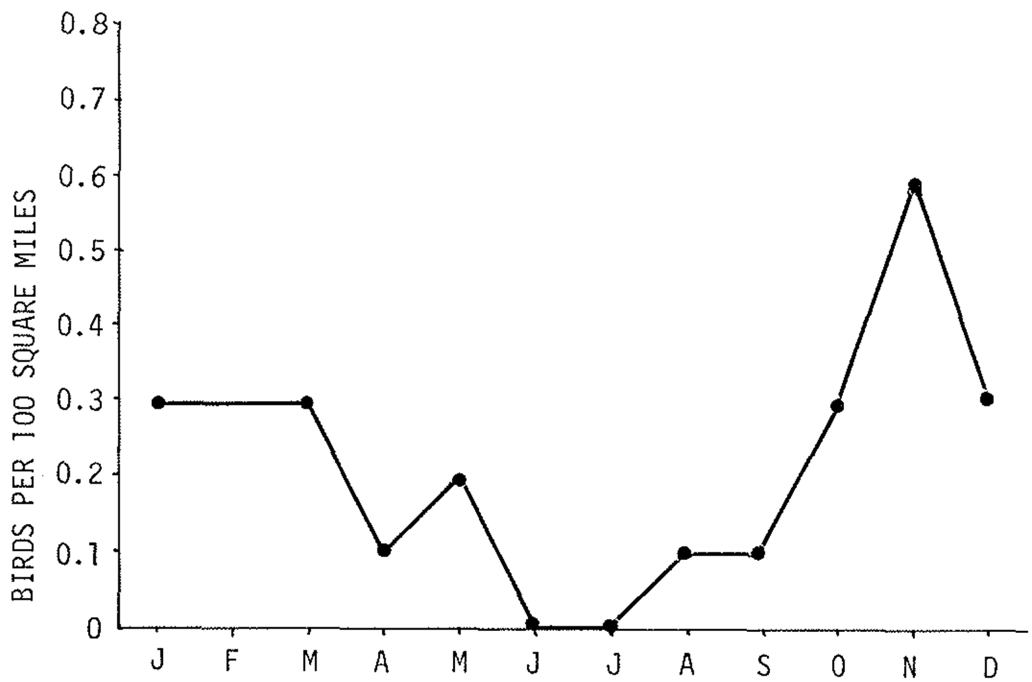


Figure 84. Diurnal occurrence of Great Frigatebirds at sea 175 miles southwest of Johnston Atoll, 1963-1967.

LESSER FRIGATEBIRD *Fregata ariel*

Status

Accidental; at least three sight records from Sand Island.

Observations

Harrington of the POBSP identified three adult male Lesser Frigatebirds over Sand Island on 31 March 1968. Eight others seen at the same time were thought to be this species, but were not observed well enough for positive identification. Shelton saw a frigate on 9 August 1969 that probably was an immature Lesser Frigatebird.

Lesser Frigatebirds breed on several islands in the Phoenix, Line, and Gilbert groups, and normally disperse westward across the western tropical Pacific (Sibley and Clapp, 1967; Amerson, 1969). Recent POBSP records from Kure (Woodward, 1972) and Wake Islands have extended the known non-breeding range in the central Pacific north-westward.

Specimens

These sightings constitute a new sight record for Johnston Atoll; no specimen record exists.

CATTLE EGRET *Bubulcus ibis*

Status

Straggler; six sight records on Sand Island; one sight record on Johnston Island.

Observations

Four Cattle Egrets were observed by the POBSP at Sand Island; one from 3 to 12 December 1966, one from 3 to 20 December 1966, one from 2 August to November 1967, one from 11 August 1968 to 29 May 1969. Kridler (BSFW, 1973) reported two on Sand Island in May 1973.

The first two POBSP birds appeared together following a night of strong southerly winds. One appeared weakened, with drooping wings, and disappeared after several days. The other remained until Schreiber scared it away in attempting to catch it. The other two birds appeared in August a year apart, and each remained for several months before disappearing for unknown reasons. No attempt was made to catch these birds, and unnecessary disturbance was avoided.

All four POBSP birds spent most of their time on Sand; no other part of the atoll supported sufficient populations of insects and mice to sustain them. The heavily grassed areas on Sand were their primary feeding places. The 1966 birds fed in the vegetation around the Coast Guard barracks, but the 1967 and later birds were never seen on the man-made end of the island. No shallow water feeding was seen. Most of their food must have been insects, but several times the egrets were seen eating mice.

During the daytime the egrets frequently roosted on raised perches, including the old dock, a sign near the dock, the fence around the LORAN-C transmitter, and an old triangulation stand northeast of the transmitter. At night, and also for extended periods during daylight, the birds roosted in sheltered spots on the southwest islet or along the south shore in the frigate colony. In 1969 the egret often appeared at dusk on the southeast outer guywire with Red-footed Boobies and may have spent the night there.

Mobbing by other birds, particularly Brown Noddies, Sooty Terns, and more rarely boobies, was fairly intense when the two August birds first arrived. Any time one of the egrets flew over the island, it was followed by up to a few dozen noddies and terns. No physical contact was made, and the mobbing did not appear greatly to disturb the egrets. However, the bird that arrived in August 1967 spent most of its time on Johnston Island for the first week, possibly because of intense mobbing by terns. After a few days the mobbing action waned, although it occasionally occurred during the day as long as there were noddies or sooties on the island. The 1966 birds were not bothered because virtually no terns were present during the day in December. In November 1968, when a Peregrine Falcon began roosting on the LORAN-C tower, the egret avoided Sand Island much of the time. Where it stayed was not discovered.

All four POBSP egrets were probably adults when they came to the atoll. All had yellow bills, which, especially in the case of the two August arrivals, probably means they could not have been hatched the same year in which they came to the island. The December birds could have been birds of that year which had just acquired the yellow bills. The only bird present during the spring acquired full breeding plumage by late March, with conspicuous buff on the crown and middle of the back and legs yellow to the feet. The bill and legs did not, however, turn noticeably reddish or orangish.

The closest breeding population of Cattle Egrets to Johnston Atoll is that which was introduced to Oahu in 1958. There is no evidence whether the Johnston birds came from there or from the eastern Pacific. A Cattle Egret has also been recorded from French Frigate Shoals (Amerson, 1971).

Specimens

These sightings constitute a new sight record for Johnston Atoll.

PINTAIL *Anas acuta*

Status

Regular fall migrant; four specimen records and many sight records from Johnston and Sand Islands.

Observations

Pintails were reported at least once each fall during POBSP studies except 1964. There were two spring records, and one bird stayed over the winter of 1966-1967 (Tables 20 and 62).

The largest influx of Pintails occurred in late October and early November 1966 when at least 30 arrived on the atoll. About a third of these were found dead, probably from exhaustion, and at least one was struck by an aircraft. The favored habitat on Johnston Island, where most of the birds were found, was rainpools along the runway. On Sand they most often stayed on the grassy west side of the original island. A few birds were seen in the lagoon near the islands.

Healthy birds usually departed a few days after arriving, but one female stayed on Sand Island from December 1966 until she died on 13 February 1967. She appeared normal and was fully capable of flight until a few hours before she died, when she was found suffering symptoms resembling those of botulism--greatly weakened, neck unable to support her head. She frequently fed on insects around piles of Sooty Terns killed on the guywires and may have been poisoned by a micro-organism or the product of a micro-organism picked up from the carcasses.

Specimens

The four Pintail specimens collected on Johnston Atoll by the POBSP are listed in Appendix Table 7 and constitute a new specimen record. Three of these had notched, juvenal rectrices, indicating that they were still in their first year. The fourth, the female taken in February 1967, would have acquired adult rectrices by the time she was collected, even if she had hatched the preceding year. Her oviduct was uncoiled, indicating that she had not bred, and therefore was probably less than a year old. A bird banded 31 August 1969 also had juvenal rectrices.

One of the males was well advanced in acquiring adult plumage, with many vermiculate body feathers, and well developed though still diffuse head and neck pattern. The other male, taken at nearly the same time of year, had only a few vermiculate feathers and no hint of the adult head pattern. The most striking characteristic of this bird was the bright rust color or virtually all the juvenal feathers. The few new feathers appeared to be normally colored.

Banding and Interisland Movement

U.S. Fish and Wildlife Service banding records include a Pintail banded in California 12 September 1957 which was recovered 10 October 1958 on Johnston Atoll. Three Pintails were banded by the POBSP on Johnston (Table 24), but none has as yet been recovered.

Pintails breed in the northern parts of North America, Europe, and Asia, and winter south into the tropics, including Hawaii (AOU, 1957), where they are the most abundant migrant duck from August to March (Medeiros, 1958). Pintails are frequent migrants to several of the northwestern Hawaiian Islands (Amerson, 1971) and the north Pacific (POBSP, 1964).

Table 62. Observations* of Pintails on Johnston Atoll

Date of Survey		Number of Birds	Age/Sex	Remarks
1958	10 Oct.	1		Banded 12 September, 1957, California.
1963	18 Oct.	1		Seen swimming by seaplane ramp, Sand I.
1965	31 Mar.	1	M	Described by Johnston I. resident; dead, not saved.
	15 Oct.	5		Flying over east end of Sand I., chased by Brown Noddies.
	16 Oct.	1	Juv. F	Collected, Sand I.
	17 Oct.	1	F	Banded and released, Johnston I.
	19 Oct.	9		Flying low over Sand I. Banded bird not present.
	29 Oct.	1	Juv. M	Collected Johnston I. Wings clipped; probably held captive before death.
	1 Nov.	1		Sight record.
1966	3 Oct.	1	F	S. shore, Sand I. (west end). Sight record on Johnston same day, possibly same bird.
	5 Oct.	2	F	Flushed from grass, NW side of Sand I.
		5		Reported from Johnston I.
	6 Oct.	1		Reported hit by aircraft, Johnston I.

Table 62. (continued)

Date of Survey		Number of Birds	Age/Sex	Remarks
1966	7 Oct.	1	M	Captured Johnston I.; died, not saved.
	14 Oct.	1		Reported on Johnston I.
	22 Oct.	4		On runway south of snack bar, Johnston I.
	29 Oct.	3		On lagoon near Sand I.
		2	F	Rainpools near runway, Johnston I.
	1-13 Nov.	2-9		Seen daily on Sand I.; maximum 9, 7 November. One juvenile male collected 7 Nov.
	1-15 Nov.	10+		Reported dead on Johnston I.
		7	F	Kept in pen, Johnston I. Captured weakened.
	5 Nov.	8	-	Rainpools along runway, Johnston I., one male in full breeding plumage.
	12 Nov.	5	-	Along runway, Johnston I.
	1-15 Dec.	12		Captured weakened, Johnston I.; kept in pen and all but one probably eaten (one still in pen through 1967).
1967	1 Dec.- 13 Feb.	1	AF	Present on Sand, probably visited Johnston also (see text). Died 13 February 1967.
	21-29 Mar.	1	F	Present on west side, original portion of Sand I. Probably moved on.
	23-28 Oct.	1	-	Present on Sand I., died, not saved.
1968	30 Sept.- 5 Oct.	1	F?	Caught and banded on Sand.
	31 Oct.- 16 Nov.	3+	-	Present on Johnston. Possibly captured, and held until 1969 (see below).
	12-13 Nov.	1	-	Present on Sand for one day.

Table 62. (continued)

Date of Survey		Number of Birds	Age/Sex	Remarks
1969	1 Jan.- 14 Aug.	3	F	In captivity on Johnston I., probably caught in November 1968. Moved to Sand I. *ca.* 16 February. Two died in June, third was released, and survived until 14 August.
	19 Aug.	1	-	Flew west past Sand I.
	29 Aug.- 3 Sept.	1	I	Regularly seen around tennis courts, Sand I. Banded 31 August. Thin, but healthy.
	8 Sept.	1	-	Reported along runway, Johnston I.

*All observations by POBSP except 10 October 1958 record.

AMERICAN WIGEON *Anas [=Mareca] americana*

Status

Uncommon fall visitor; two specimen records and several possible sight records from Sand Island.

Observations

Two American Wigeons were collected by POBSP personnel on Sand Island, the first on 23 October 1964 and the second on 29 October 1966. Both were first year males, as determined by the presence of juvenal rectrices. The 1966 bird had several vermiculated feathers on the sides, and several purplish-pink breast feathers, but the 1964 bird showed no signs of adult male plumage.

Two birds, probably of this species, were seen 15 October 1964, and unidentified ducks seen 13 October 1964, 5 September 1964, and 15 November 1965 could have been American Wigeons.

American Wigeons breed inland throughout most of western North America south to northeastern California, and winter south through Central America (AOU, 1957). Small numbers regularly visit the main Hawaiian Islands (Udvardy, 1961) and the POBSP has recorded several from the northwestern Hawaiians (Clapp and Woodward, 1968).

Specimens

The two collected specimens noted above and in Appendix Table 7 are the only verified records of this species for Johnston Atoll.

NORTHERN SHOVELER *Anas [=Spatula] clypeata*

Status

Uncommon fall visitor, one specimen record and at least one sight record from Sand Island.

Observations

One adult female was collected 26 October 1964 on Sand Island by POBSP personnel. A second record was a sighting by Kleen of a female on Sand Island 22 September 1968. Another seen by Kleen on 31 October 1968 could have been of the same bird.

Shovelers regularly migrate to the Hawaiian Islands (Medeiros, 1958). They breed across northern North America, Europe, and Asia and winter south from mid-temperate to tropical latitudes on these continents and Africa (AOU, 1957).

Specimens

The collected female noted above and in Appendix Table 7 is the first specimen record of a Shoveler for Johnston Atoll.

DOMESTIC CHICKEN *Gallus gallus*

Status

Introduced; probably breeds. Occurs in small numbers on Johnston Island only.

Observations

According to island personnel, a few fighting chickens were introduced to Johnston Island in early 1973. The cocks were reported to be caged in November 1973, but at least two hens were said to be running loose. It is not known if breeding occurs, but most likely it does. The chickens came from the main Hawaiian Islands.

This is a new sight record.

PEREGRINE FALCON *Falco peregrinus tundrius*

Status

Accidental, one specimen record from Sand Island, and a sight record, most likely the same bird, from Johnston Island.

Observations

A "hawk" was reported on Johnston Island 8 November 1968 and on 12 November a Peregrine Falcon appeared on Sand Island, no doubt the same bird. It remained on or near the atoll, returning at least every few days to roost 50 to 80 feet up on the LORAN-C transmitter tower, until 2 December when Kleen collected it.

During its stay on the island the Peregrine occasionally chased Great Frigatebirds, but apparently with no intent to kill. It did kill and eat young Brown Noddies and Wedge-tailed Shearwaters, and its presence affected the behavior of several other species. For example, the Cattle Egret, which had been seen regularly on Sand Island, disappeared to other parts of the atoll for long periods while the Peregrine was at large. Frigatebirds ceased roosting on the northeast inner guywire of the LORAN-C antenna, and did not resume normal use of the roosting area for one or two months after the Peregrine was shot.

Falco p. tundrius breeds on the arctic and subarctic tundra area of North America and winters from the southern United States to Argentina. *Falco p. pealei* breeds along the Pacific coast region to North America between about 50°N to 58°N and on the Aleutian Islands. A third race, *F. p. japonensis* breeds in northeastern Asia southward to Korea. It winters in Japan and on various western Pacific Islands (Vaurie, 1961; White, 1968).

A female identified by White as *F. p. pealei*, was collected at Kure Atoll on 7 March 1965 by POBSP personnel (Woodward, 1972). Sight records are also known from Midway Atoll, Lisianski Island, and the main Hawaiian Islands (Clapp and Woodward, 1968).

Specimens

The Johnston specimen, a female with heavy fat, was identified by Clayton M. White (pers. comm.) as *F. p. tundrius* on the basis of its morphology, measurements, and overall appearance. It is a new specimen record for the atoll. A male Peregrine Falcon collected at sea by the POBSP on 8 November 1963 at 14°10'N, 171°42'W, 200 miles southwest of Johnston, was provisionally assigned to this race by White (1968), but both could just as well have come from Asia as from North America.

AMERICAN GOLDEN PLOVER *Pluvialis dominica*

Status

Common migrant; found singly or in small groups inland and on beaches on all islands. Most abundant during spring, late summer, and fall; a few individuals present throughout the year.

Ecological Distribution

Akau Island: POBSP personnel found American Golden Plover on this man-made island from 1964 to 1969.

Johnston Island: Fennell (1948) saw a few "...at the end of the mat..." sometime in 1948.

POBSP personnel recorded them in the interior of the island and on the beaches from 1963 through 1969. Amerson also found it here in November 1973. American Golden Plovers, as well as other shorebird species, were especially attracted to Johnston Island during the 1964 construction period. Throughout the spring of that year coral was dredged and deposited on the island, resulting in a rich food source in the form of aquatic organisms (see also Population section). The decaying remains of these organisms in turn attracted flies and other insects, providing additional food.

Hikina Island: Small numbers were recorded here from 1964 through 1969 by POBSP personnel.

Sand Island: In 1923 Wetmore (ms. b) noted two American Golden Plovers and collected one on Sand Island.

POBSP personnel observed this species here during 1963-1969. Amerson also noted its presence in November 1973. American Golden Plovers showed less preference for specific habitat than any other shorebirds. They were almost equally abundant in the interior of the island and on the beaches. The original portion had the highest concentration, probably because of higher insect populations there as a result of denser vegetation and large numbers of other birds, including dead ones. They were seldom seen on rocky shorelines or other rough ground.

Populations and Annual Cycle

Figure 39 shows graphically the monthly mean population fluctuations recorded during POBSP studies. Figure 85 shows semimonthly population fluctuations by year, with irregularities smoothed by plotting the line from moving averages (i.e., each point is plotted at the average of the actual estimate for that point and the two adjacent points, resulting in smoothed lines which are more easily compared than lines plotted from the raw data).

Summer and winter numbers were fairly constant because the daily turnover of birds was small on the atoll as a whole, although there was movement between the islands. During the periods of migration in fall and spring, daily fluctuations were greater. The numbers shown for these seasons are no more than rough indices to the total number of birds passing through the atoll because they do not take into account daily turnover. The reported figures usually were estimates based on the largest count during the period in question, or in some cases

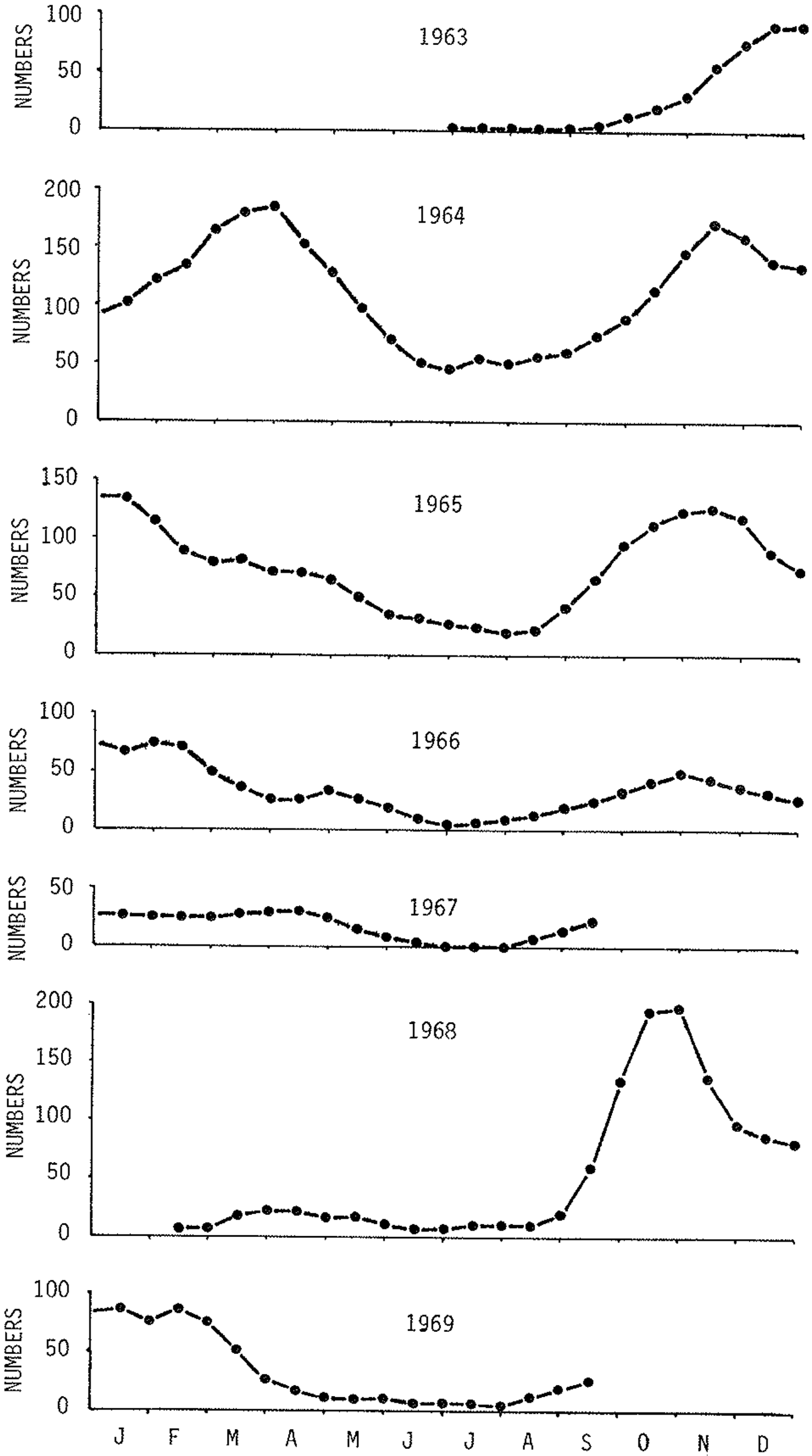


Figure 85. Moving averages of semimonthly estimates of Golden Plovers, Sand and Johnston Islands combined, 1963–1969.

only the last count made during the period, which in either case would result in a figure well below the actual number that had been on the atoll during the period. During the summer and winter, when populations were fairly constant, the reported figures probably were fairly close to the actual number present during the period.

The few former records given provide insufficient data to determine whether numbers of Golden Plovers visiting the atoll has changed significantly over the years. Wetmore's count of two birds in July 1923 is within the range of variability in Golden Plover numbers during POBSP studies, although it is below average.

From a July low which ranged from 50 in 1964 to none in 1967, numbers began to increase in late August, reaching a peak in late October or early November. As transients moved on and winter residents set up territories, numbers declined, then leveled off. During the spring there was a slight increase some years, but nothing as dramatic as the fall peak. It is likely, however, that as many birds moved through the area in spring as in fall, but that individuals spent less time on the atoll before moving on; thus the numbers recorded were not as high in spring as in fall.

An exception to this general pattern occurred in the spring of 1964 when numbers were far higher than in any other spring, and higher than most fall maxima. This unusual spring peak resulted from a rich food source in the form of aquatic organisms brought up in dredged coral. During this period 434 acres of land area was added to the atoll by dredging coral from the lagoon (Bauer, 1965). It was pumped onto the existing land as a slurry in large pipes, then bulldozed into place along the edge of the island, and out into the lagoon. Pools and slowly flowing sheets of water draining away from the solid material, and the solid material itself, contained abundant aquatic organisms; the decaying remains of these plants and animals attracted flies and other insects, all of which provided abundant food for shorebirds. It is unlikely that the number of birds visiting the island was significantly greater then than in other years, but the birds probably stayed longer. Rather than a constant flow of birds passing the atoll and staying no more than a day or so, large numbers stayed to feed and the daily counts were swelled greatly. This new land area quickly changed to solid barren coral which held little attraction for shorebirds.

Two new islands, Akau and Hikina, were built at the same time as the construction on Johnston Island; the scanty data show that the numbers of shorebirds found on these islands was greatest during the construction.

The only other unusual fluctuation occurred in fall 1968 when counts were as high as in spring 1964; there was no apparent reason for this unusual abundance. Weather patterns may have affected migration routes at sea or perhaps there was an unusually successful hatching year in the Arctic area where birds that migrate via Johnston Atoll breed.

By early October at least some plovers established territories on the islands, and fights between adjacent birds were common. Figure 86 shows the distribution of Golden Plovers on Sand Island 26 December 1965, at which time 35 territories could be distinguished. The clusters of twos and threes on the southwest and west sides of the island were probably birds without territories. Territories usually were maintained no later than January, at least on Sand, but the breakdown in territoriality probably was forced by the appearance at that time of hordes of pre-nesting Sooty Terns. In 1969 when Sooty Tern nesting was delayed until March a few Golden Plovers maintained territories until late February.

By late February a few birds had begun to molt into dark breeding plumage, and by April a third to half were in some stage of molt. As the breeding plumage developed, so apparently did the migratory urge and seldom did birds remain on Johnston until they had acquired their full breeding colors. Plovers remaining on Johnston through June, July, and August, presumably young of the previous year, sometimes showed at least a few dark feathers but never developed full breeding attire. Earliest fall migrants, arriving in late August, often showed remnants of breeding plumage, and birds with a few black belly feathers were found until October.

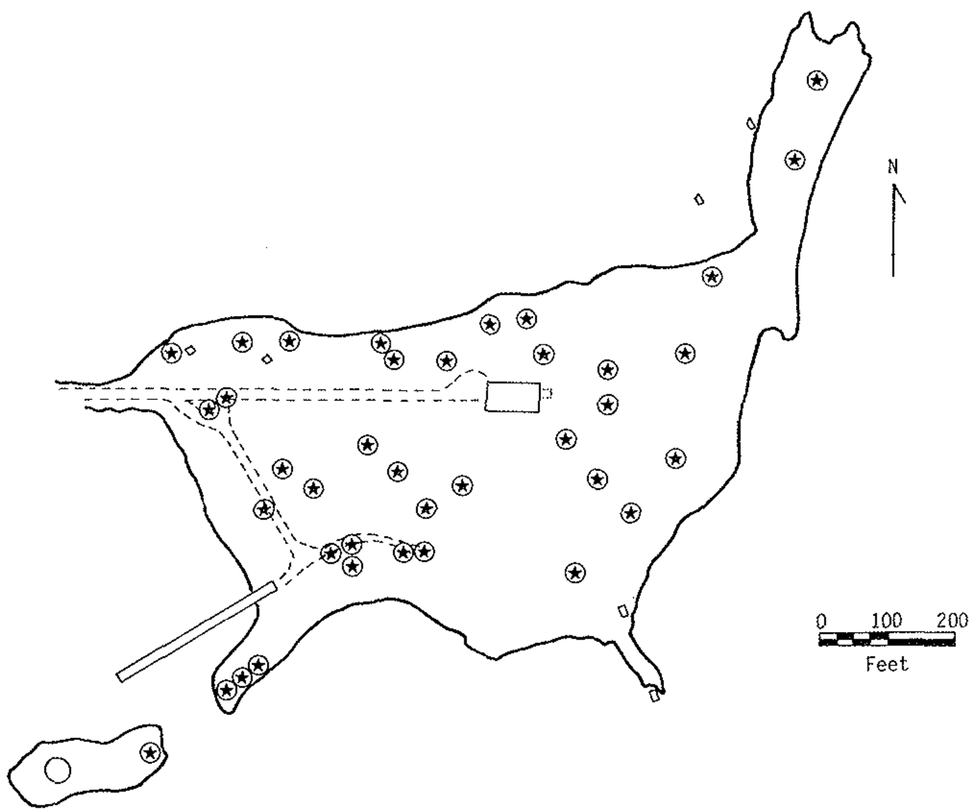


Figure 86. Distribution of Golden Plovers on Sand Island, Johnston Atoll, 26 December 1965.

Golden Plovers showed less preference for specific habitat than any other shorebirds. They were almost equally abundant in the interior of the islands and on the beaches. The original portion of Sand Island had the highest concentration of Golden Plovers, probably because of higher insect populations there as a result of denser vegetation and large numbers of other birds, including dead ones. Golden Plovers were seldom seen on rocky shorelines or other rough ground. Except when on territories these birds appeared to move freely between the islands of the atoll.

Although Golden Plovers frequently associated with Ruddy Turnstones, the two species probably were attracted to common feeding areas rather than to each other. Plovers were not as gregarious as turnstones and flocks of more than half a dozen were rare, even during the height of migration.

Over-winter mortality of Golden Plovers was fairly high, at least in some years. In 1964, 1966, and 1969 at least ten dead plovers were found during winter or early spring; lower numbers were reported in other years. Causes of mortality were not determined, but carcasses were widely scattered and definitely were not guywire strikes. Some fall birds appeared to be emaciated and may have been unable to recover from the stress of migration on the food available on Johnston. In 1964 and 1966, however, the deaths were most frequent in April, and involved apparently healthy birds. It is quite likely that the weekly spraying of the islands with insecticides was responsible for this mortality, but no chemical analysis of dead birds was attempted. Malathion and Vapono were heavily used on all islands of the atoll in an attempt to control cockroaches. Changes in metabolism associated with molt and preparation for migration may have rendered spring birds highly susceptible to insecticide poisoning.

Specimens

Wetmore collected one American Golden Plover at Johnston Atoll in 1923; POBSP personnel collected 18 specimens during 1963-1969 (Appendix Table 7). These constitute a new specimen record for the atoll.

Banding and Interisland Movement

A total of 119 American Golden Plovers were banded by POBSP personnel at Sand Island (Table 24). Most died on the island: a few shortly after banding, but two banded in early December 1963 were recaptured alive in March 1964; two banded in October 1964 were identified by their streamers in late December 1964 and one was recaptured alive in January 1965 and another was recovered, recently dead, in April 1966; one banded in November 1966 died on the island 23 April 1967; and one banded and streamered in 1968 remained on the island until about 20 March 1969, when it presumably migrated. These data indicated that individual wintering plovers may remain on the island for several months. They suggest, but do not prove, that plovers return to the same island in subsequent winters. No plovers banded elsewhere were recaptured on the atoll, and none banded on Sand Island has been recovered elsewhere.

At-Sea Distribution

American Golden Plovers were recorded as migrants in the at-sea grid southwest of Johnston only during October, November, and December (Table 21).

BLACK-BELLIED PLOVER *Pluvialis* [=*Squatarola*] *squatarola*

Status

Accidental; one collected and three reliable sight records from Johnston and Sand Islands.

Observations

Sundell and Wislocki closely observed, but were unable to collect, a Black-bellied Plover in winter plumage near the Coast Guard barracks on 27 November 1963. Two weeks later (11 December) they caught one in a mist net and collected it. It was also in winter plumage and may have been the same bird. Wislocki saw another on Johnston Island on 3 January 1964. The final record was Woodward's sighting of one Black-bellied Plover in partial breeding plumage on the original portion of Sand Island on 24 July 1965. All sight records, except that by Wislocki on 3 January 1964, were recorded in detail in field notes and could hardly be misidentifications.

Black-bellied Plovers are found infrequently in the northwestern Hawaiian Islands and have been recorded from Kure Atoll, Midway Atoll, Lisianski, and Laysan (Clapp and Woodward, 1968; Woodward, 1972), as well as in the main Hawaiians. This species breeds primarily on tundras of Eurasia and North America and migrates mainly along the coasts, from mid-temperate latitudes into the tropics (AOU, 1957).

Specimens

The collected specimen noted above and in Appendix Table 7 is a new specimen record for Johnston Atoll.

SEMIPALMATED PLOVER *Charadrius semipalmatus*

Status

Accidental; two specimen records from Sand Island.

Observations

Amerman saw one near the old pier on Sand Island each day from 30 August through 1 September 1963. He saw the same again or another 5 October, and Sundell collected one from the rocks northeast of the Coast Guard barracks on 15 October. All observations could have been of the same bird.

Kleen collected the second specimen 30 August 1968 after it had been run over by the Coast Guard jeep on the causeway.

Specimens

The two collected specimens, both immatures, noted above and in Appendix Table 7, constitute a new specimen record for Johnston Atoll.

The only other Semipalmated Plover specimen record from the north-central Pacific was taken at Midway Atoll. Sight records have been from Midway Atoll, French Frigate Shoals, Oahu, and Maui (Clapp, 1968a; Clapp and Woodward, 1968; Donaghho, 1969; Mull, 1969; and Amerson, 1971). Two specimens have been taken from Baker Island in the south-central Pacific (Clapp, 1968a). This species breeds in most of Alaska and eastward across Canada, and winters from central California and South Carolina south on both coasts to Patagonia, and the Galapagos (AOU, 1957).

BRISTLE-THIGHED CURLEW *Numenius tahitiensis*

Status

Uncommon migrant; found usually singly on Akau, Johnston, and Sand Islands. Fairly regular fall visitors, having been recorded every fall from 1963 through 1969, except 1966.

Ecological Distribution

Akau Island: A few were seen here by POBSP personnel.

Johnston Island: There were only three sightings on Johnston Island from 1963 through 1969.

Sand Island: Bristle-thighed Curlew favored habitat was the grassy areas within a few yards of shore on the original portion of Sand Island. Less often they wandered farther inland or used the man-made portion. The bird present in February and March of 1969 regularly flew to Akau Island each evening at sundown, returning to Sand each morning to feed throughout the day. It is likely that most curlews visited other parts of the atoll occasionally, for they often were absent from Sand.

Populations and Annual Cycle

From one to five Bristle-thighed Curlews were recorded every fall from 1963 through 1969, except 1966. Birds have been found in all months except April (Tables 20 and 63).

Table 63. Observations of Bristle-thighed Curlews on Sand Island, Johnston Atoll, 1963-1969

Date of Survey	Number of Birds	Remarks
1963		(Minimum number: 2; maximum: 6; probable: 4 or 5).
1 Aug.	1	Seen and heard several times during afternoon.
3 Sept.	1	Reported by several Coast Guardsmen.
13 Sept.	1	Seen at 1500 hours.
16, 17 Sept.	1	In puddle at west end of causeway.
28 Sept.	1	Found dead by dump, skeleton saved.
4, 5, Oct.	1	Reported by Coast Guardsmen.
1964		(Minimum number: 1; maximum: 3; probable: 1 or 2).
15 Sept.	1	On causeway, photographed by Lehner.
18 Sept.	1	By barracks, probing among coral rocks in afternoon.
6 Oct.	1	No data.
1965		(Minimum number: 6; maximum: 7-8; probable: 6).
2 Sept.	1	Collected.
14, 15 Sept.	1	No data.
16 Sept.	5	Seen together.
17 Sept.	1	Collected.
19-21 Sept.	1	One or more; no data.
1966	0	None observed.
1967		(Minimum number: 2; maximum: 3; probable: 2).
28, 31 Aug.	1	On west end of Sand I.

Table 63. (continued)

Date of Survey		Number of Birds	Remarks
1967	28, 31 Aug. 2 Sept.- mid-Oct.	1	Seen almost daily on west and southwest sides of east end of Sand I.; less often on causeway and west end. One collected in October by USCG.
1968			(Minimum number: 2; maximum: 4; probable: 4).
	14 May- 3 June	1	
	6, 7 Sept.	1	
	20-23 Sept.- 31 Dec.	2	One on Johnston I. 20 Sept., on Sand I. 21 Sept., joined by 2nd bird 23 Sept. Both present through end of year.
1969			(Minimum number: 3; maximum: 4; probable: 4).
	1 Jan.- *ca.* 20 Mar.	2	One died about 20 January., the other remained feeding on Sand I., roosting on Akau, until about 30 Mar.
	21 Aug.- 8 Sept.	2	Seen and heard intermittently on Sand I.
	9 Sept.	1	Heard on Johnston I.
	ca. 27 Aug.	1	John Gossett saw one with bad left leg on the northeast side of Johnston I.

Most of their food undoubtedly was insects, but three times curlews were seen attempting to eat mice. Kleen in October 1968 and Shelton in February 1969 saw a curlew slamming a mouse against rocks, apparently attempting to break it up enough to swallow it. Kleen was unable to determine if the mouse was eaten, but Shelton watched for 45 minutes during which time the mouse was slammed into the rocks several dozen times. The mouse was finally abandoned. The axial skeleton of the mouse, an adult female, was completely crushed and there were small breaks in the skin, but the Curlew apparently had been unable to swallow it. Brownell reported a curlew eating a mouse in January 1969, but gave no details.

Bristle-thighed Curlews were large and unusual enough to elicit a weak mobbing response from Brown Noddies--a response observed twice in 1965. In 1969, when the curlew flew from Sand to Akau at sunset, it passed through or under swirls of prebreeding Sooty Terns which briefly swarmed after it each evening.

Specimens

Bristle-thighed Curlews were not recorded at Johnston Atoll before POBSP studies began. The five specimens listed in Appendix Table 7 constitute a new specimen record for the atoll.

Banding and Interisland Movement

No curlews were banded on Johnston Atoll. No interisland movements involving Johnston are known.

Bristle-thighed Curlews breed in western Alaska and winter from the Marshall and Hawaiian Islands to Santa Cruz, Tonga, and Tuamotu Islands (AOU, 1957).

LESSER YELLOWLEGS *Tringa [=Totanus] flavipes*

Status

Accidental; one specimen record from Sand Island.

Observations

A slightly emaciated male Lesser Yellowlegs was collected by Amerson at Sand Island on 18 August 1963. For two days before being collected, this bird inhabited the original portion of the island where it ate insects from a pile of bird carcasses.

Specimens

The specimen noted above and in Appendix Table 7 is a new specimen record for the atoll.

Lesser Yellowlegs have been recorded from Kure Atoll, Midway Atoll, Laysan, Maui, and Oahu in the Hawaiian Islands (Clapp, 1968a; Clapp and Woodward, 1968; Woodward, 1972). This species breeds in northern Canada and Alaska and winters from southern North America to Argentina and Chile; most migration is inland (AOU, 1957).

SPOTTED SANDPIPER *Actitis macularia*

Status

Accidental; one specimen record and one sight record from Sand Island.

Observations

A Spotted Sandpiper in non-breeding plumage was collected by Kepler and Lehner near the barracks at Sand Island 1 September 1964. A sandpiper was seen repeatedly by Shelton along the causeway and on the rocky beaches from 28 August through 8 September 1969 probably was this species, although it could have been the smaller Common Sandpiper (*Tringa hypoleucos*) of the Old World.

Specimens

The single collected specimen noted above and in Appendix Table 7 is the only verified record of this species for Johnston Atoll, as well as for the entire central Pacific Ocean.

Other Pacific records are one collected at Taka Atoll in the Marshall Islands (Amerson, 1969) and a sighting of this or the Common Sandpiper on Enderbury Island in the Phoenix Islands (Clapp, 1968b). Spotted Sandpiper breed throughout most of the northern two-thirds of North America and winter from British Colombia, southern Texas, and South Carolina, south to Argentina (AOU, 1957).

WILLET *Catoptrophorus semipalmatus*

Status

Accidental visitor; one sight record on Johnston Island.

Observations

A large shorebird, 1.5 to 2 times the size of a Golden Plover, was observed by Capt. Douglas Boucher, USAF, on the northeast shore of Johnston Island 17 August 1969. It was dark above, with a distinct and conspicuous white wing bar. The size and wing bar make this bird most likely a Willet. The call was a distinct whistle, described as something like a killdeer, which roughly fits the "kay-ee" call of the Willet as given by Peterson (1961: 110). Captain Boucher was known to be an astute observer, and was quite familiar with Golden Plovers, with which he compared this bird's size.

Specimens

This is a new sight record for Johnston Atoll.

Only one other sight record of a Willet, a bird seen on Oahu (Pyle, 1968), exists for the central Pacific. This species breeds primarily along the border of Canada and the United States, and, locally, along the Atlantic and Gulf coasts; it winters from northern California, the Gulf of Mexico, and south Atlantic coasts of the United States south to northwestern Peru, Bolivia, and Brazil (AOU, 1957).

WANDERING TATTLER *Heteroscelus incanus*

Status

Common but scant migrant; found singly or in pairs on rocky shores of all islands. Maximum numbers occur during spring and fall migrations; few birds present in summer and winter.

Ecological Distribution

Akau Island: Few were present during POBSP studies.

Hikina Island: POBSP personnel found a few here from 1964 through 1969.

Johnston Island: Wetmore (ms. b) recorded two Wandering Tattlers in July 1923. POBSP personnel found them inhabiting rocky shores--never more than a few feet from water.

Sand Island: On Sand Island the favored habitat is the sides of the causeway which are composed almost entirely of large angular rocks. They most often feed solitarily, although pairs are common. During migration the largest aggregations were of only five or six birds.

Populations and Annual Cycle

Figures 39 and 87 show monthly mean population estimates and semimonthly estimates by year, respectively, based on actual counts of Wandering Tattlers on Sand and Johnston Islands during POBSP studies. These must be considered minimum figures because the other two islands, where one to three tattlers were usually found on the infrequent visits, were not included. These few birds would not greatly inflate the figures; it is likely that often birds were using all the islands of the atoll and counts of the two main islands probably took care of most if not all birds present. There is even the possibility of counting the same birds more than once on these two islands.

Major population variations occurred in the spring of 1964. The unusually large numbers of tattlers probably resulted from the abundance of food in the freshly dredged coral. Golden Plover and Ruddy Turnstone populations also increased then, probably for the same reason. The high number of tattlers present in fall 1968 also corresponded with an unusually high number of plovers and turnstones; there is no clue as to why these birds were more abundant than usual that year. Weather patterns may influence the number of shorebirds arriving on remote atolls, but no descriptions of such correlation are available.

Population numbers show slight dips during winter and summer, with highest numbers during the spring and fall migrations. There appear to be more tattlers present in the fall than in the spring, but, as in the case of Golden Plovers and Ruddy Turnstones, this may be only apparent because of shorter stays by spring migrants. Approximately half the

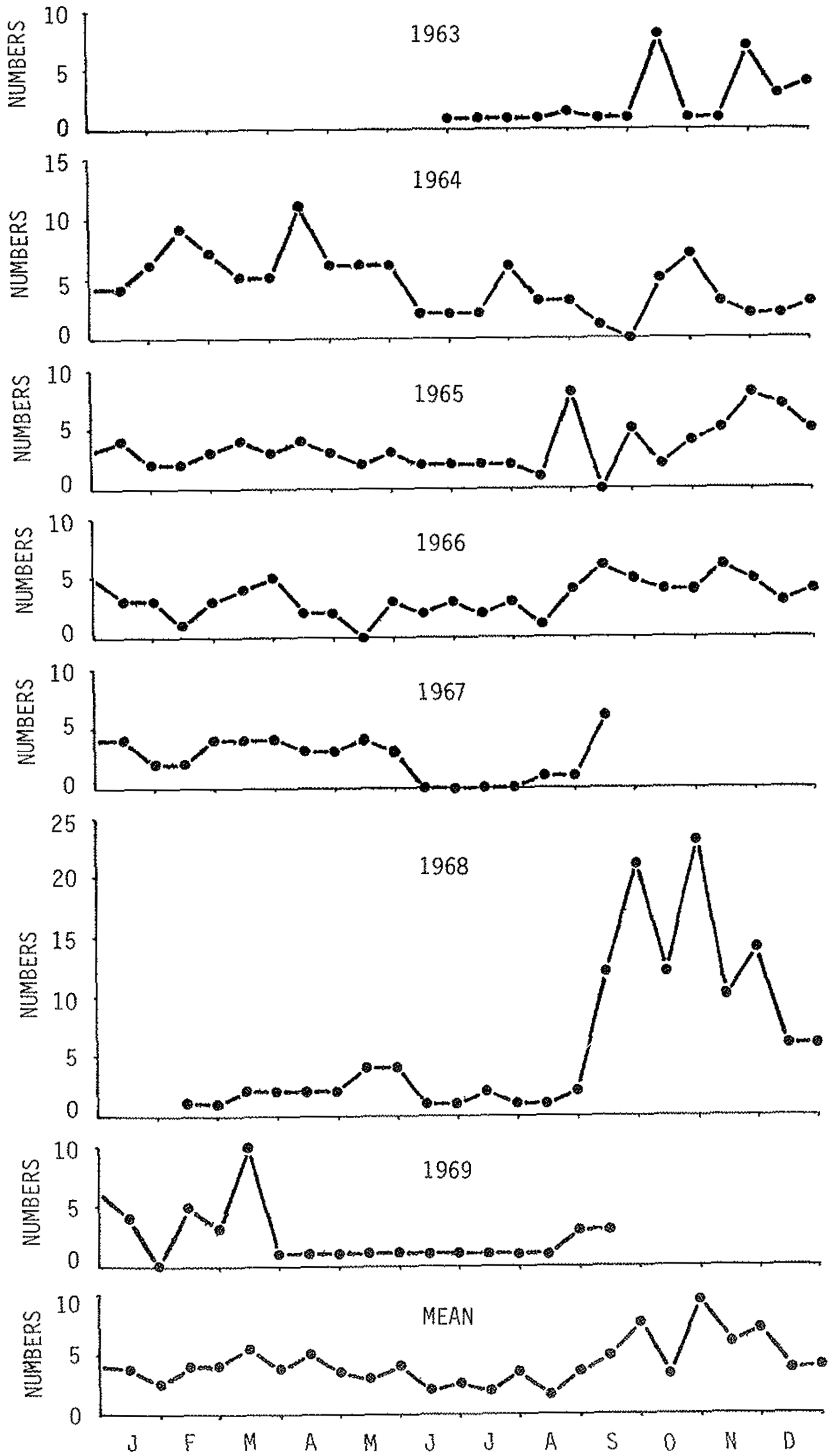


Figure 87. Moving averages of semimonthly estimates of Wandering Tattlers, Sand and Johnston Islands combined, 1963-1969.

tattlers passing through in March through May, and a smaller number of returning fall birds, showed some degree of barring on the breast; the rest were in typical unbarred non-breeding plumage. Summering birds probably were pre-breeding young that did not return north until they were nearly two years old.

Tattlers were more closely tied to shorelines than any other common shorebird visiting the atoll. They were practically never found more than a few feet from water, and generally inhabited the most rocky shores. On Sand Island the favored habitat was the sides of the causeway which were composed almost entirely of large angular rocks. They most often fed solitarily, although pairs were not uncommon. In migration the largest aggregations noted were of only five or six birds.

Specimens

Appendix Table 7 presents data from the four Wandering Tattlers collected on Johnston Atoll. These constitute a new specimen record.

Banding and Interisland Movement

Three Wandering Tattlers were banded and streamered in September and October 1968 by Kleen (Table 24); one was subsequently sighted in March 1969. Although it is possible that the bird was on the atoll throughout the intervening four months, it is more likely that it moved farther south for the winter and returned north via Johnston in March.

Wandering Tattlers breed above timberline in the mountains of Alaska and northwestern Canada, and possibly in Siberia. They winter along the west coast of North America and throughout most of the tropical Pacific Islands (AOU, 1957).

RUDDY TURNSTONE *Arenaria interpres*

Status

Common migrant; found in small flocks usually on gravelly areas along shores of all islands. Most abundant during spring and fall migrations; some birds present throughout the year.

Ecological Distribution

Akau Island: Ruddy Turnstones were recorded on the gravelly beaches at Akau from 1964 through 1969 by POBSP personnel. They probably roosted here at night.

Hikina Island: POBSP personnel recorded Ruddy Turnstones on the gravelly beaches at Hikina from 1964 from 1969. Although no night observations were made, it is likely that turnstones roosted here at night because of the quiet protected beaches.

Johnston Island: POBSP personnel observed this species here throughout its studies, especially in relatively open areas of coarse, gravelly coral. They were seen at one time or another on almost any open, gravelly part of Johnston Island, but largest concentrations were always on the wide, gravelly beach at the southwest corner, which was well protected from the surf. This same area was also probably used as a nightly roosting area.

Sand Island: Wetmore (ms. b) saw two Ruddy Turnstones on Sand in July 1923.

POBSP personnel found them here during 1963-1969. They were most frequently found on the newest coral, dredged in 1964, on the man-made end of the island or on beaches that were similar in texture. At night roosting flocks of turnstones were frequently flushed from the southwest islet, but only occasionally did they roost on the northeast peninsula.

Populations and Annual Cycle

Figure 39 shows monthly mean population estimates of Ruddy Turnstones recorded during POBSP studies. Figure 88 shows annual fluctuations; lines are smoothed by the moving averages method, as described in the Golden Plover account. Comments given in the Golden Plover account on the relationships between numbers reported in these tables and actual numbers of birds using the islands apply equally to Ruddy Turnstones.

The general form of the population curves for Ruddy Turnstones is the same as for Golden Plovers. The highest peaks occur in late fall, with a decline through winter, and a smaller, less distinct peak in spring. As with plovers, the actual number moving through in spring may be as high as in fall; individuals may have spent less time on the atoll during spring migration; therefore, observed numbers are lower.

Also like Golden Plovers, Ruddy Turnstones showed a higher population in spring 1964 than in any other spring, because of birds remaining to feed on freshly dredged coral. Unlike plovers, however, turnstones showed a similar but smaller increase in spring 1965. Apparently the new coral still contained abundant food for turnstones, but not for plovers. Turnstones reached unusually high numbers in fall 1968, as did plovers, and the reason is equally unapparent.

Some Ruddy Turnstones began to acquire their breeding plumage by late January, and by April and May most showed some degree of change although few, if any, completed the molt before leaving the atoll. From late June through August the few birds present were in non-breeding plumage, probably indicating that they were young birds that did not migrate to the northern breeding grounds. Early migrants arriving in late August and September sometimes showed part of their breeding colors, but these were soon lost.

Ruddy Turnstones tended to remain near shores more than did Golden Plovers, but they were often found inland, especially in relatively open

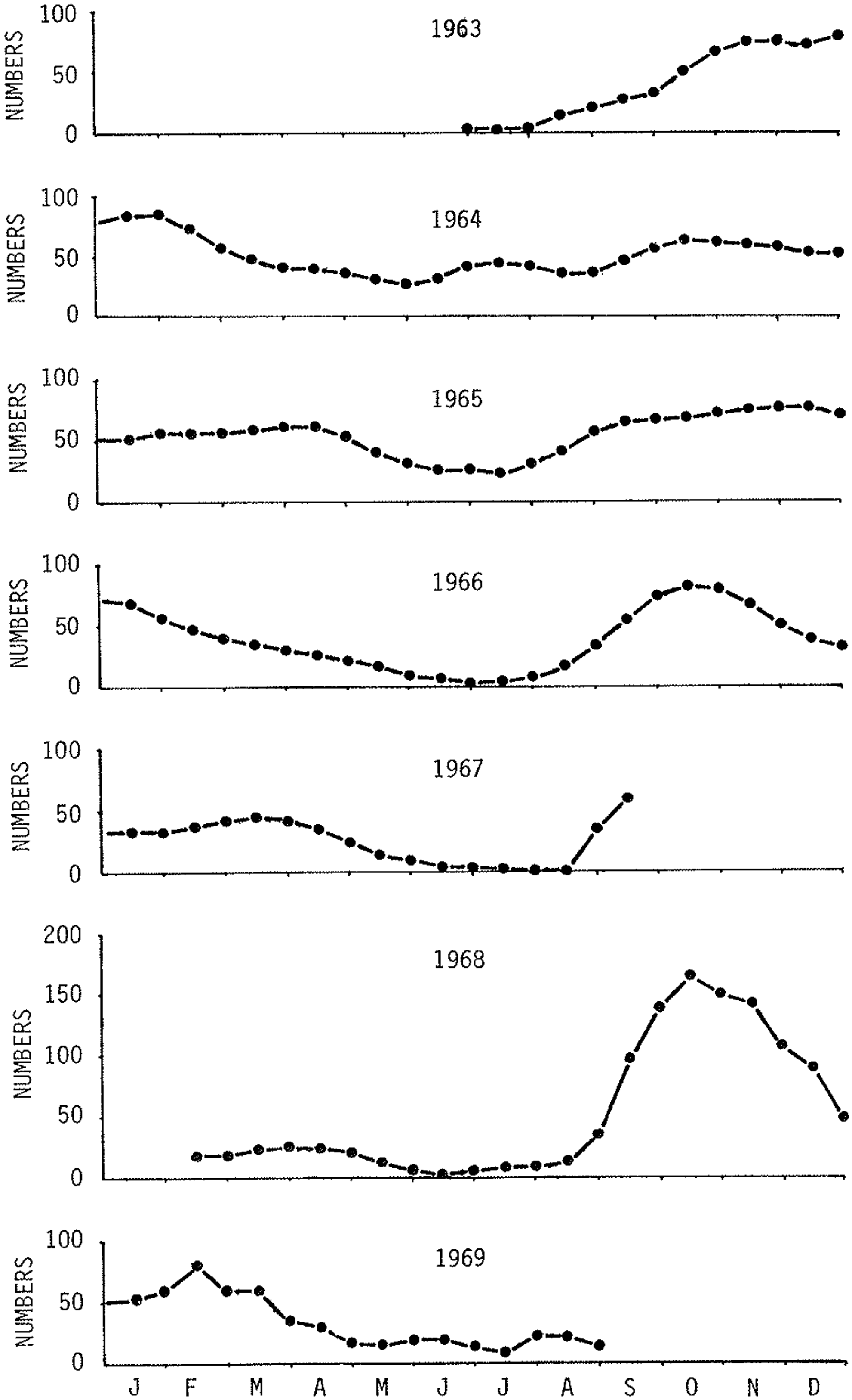


Figure 88. Moving averages of semimonthly estimates of Ruddy Turnstones, Sand Island, Johnston Atoll, 1963–1969.

areas of coarse gravelly coral. The tendency of turnstones to avoid vegetated areas may have saved them from the over-winter mortality described for Golden Plovers. If insecticides were responsible for Golden Plover mortality, then it would follow that turnstones might be less severely affected because spraying was primarily directed at vegetated areas. POBSP field notes and records mention only two dead turnstones being found: one in November 1965 and one in June 1966.

Feeding areas of plovers and turnstones were by no means mutually exclusive, and the two species frequently occurred together. The largest flocks of turnstones usually contained a few plovers, but this association appeared to be a mutual attraction to a feeding area rather than an attraction between the birds. Likewise most Sanderlings observed on Johnston Island were in the company of turnstones on the southwest beach, but the attraction for Sanderlings was more likely the beach than the turnstones.

Individual turnstones were rarely seen, and no territorial behavior was ever noted. Flock sizes ranged commonly from 3 to 20, but larger ones up to the 118 birds found 30 September 1968 on the southwest beach of Johnston Island were not unusual.

At night turnstones gathered to roost in larger groups on Sand Island. Counts were not possible, but estimates from calls and the absence of birds from other parts of the island at night indicated that at least all the birds feeding on Sand, and probably a good many from other islands in the atoll, were gathered in these roosting flocks. In November and December 1966 Schreiber noted that turnstones fed during the day in small flocks, but in late afternoon they gathered into larger groups on the man-made end of Sand Island where they continued feeding until dusk, when they all flew off toward Hikina Island. No night observations were made on Hikina or any other islands on the atoll, but it is likely that turnstone roosts occurred on islands other than Sand. Hikina, Akau, and the southwest beach of Johnston all would have provided quiet protected beaches similar to the southwest islet on Sand.

Specimens

Ten specimens of Ruddy Turnstones have been collected from Johnston Atoll (Appendix Table 7). These constitute a new specimen record.

Banding and Interisland Movement

The POBSP banded and streamered 17 Ruddy Turnstones on Sand Island (Table 24). Although marked birds were frequently seen on all the islands of the atoll, verifying suspected free movement among the islands, only one was recovered--a bird banded in October 1964 found dead in November 1965. Birds with streamers were seen in July and November 1965; the last banding that year had been done in March and April. These data indicate that turnstones may remain on the atoll for several months.

They suggest, but do not prove, that turnstones return to the same island in subsequent winters. One banded at Sand Island on 19 October 1964 was recaptured at St. George Island in the Pribilofs on 14 August 1966.

In 1966 Thompson and DeLong (1967) banded and marked (with red paint and green, plastic, leg streamers) 7,543 Ruddy Turnstones on St. George from a population of 15,000 to 20,000 birds. Two were later recaptured at Johnston: one was collected and one was caught alive and released. Records of marked birds in shorebird counts made from late September through early November 1966 on both Sand and Johnston Islands (Table 64) provided data from which crude calculations were made of the minimum proportion of Johnston Atoll birds that had been on St. George that year. Since Thompson and DeLong's figures do not account for turnover, 20,000 would seem to be a reasonable minimum figure for the population. Thus for each bird banded and marked on St. George, about two present were not banded. Assuming random mixing of marked and unmarked birds during migration, the number of turnstones on Johnston that had been on St. George was about three times the number of marked birds observed: 3.9 percent x 3 = 11.7 percent. Thus a minimum of about 12 percent of the Ruddy Turnstones on Johnston Atoll that fall had passed through the St. George Island staging area in the early part of their migration.

Table 64. Numbers and percentages of Ruddy Turnstones sighted on Johnston Atoll that were color marked on St. George Island, Pribilofs, fall 1966*

Period	Number sighted	Number marked	Percent marked
16-30 Sept.	387	17	5.9
1-15 Oct.	410	4	1.0
16-31 Oct.	401	21	5.2
1-15 Nov.	396	17	4.3
Totals	1,494	59	3.9

*Counts were made every day or every other day on Sand and once weekly on Johnston. Number of birds involved was far less than totals shown, because of duplication.

The actual number of marked birds in the population could not be determined because of duplication of counts and lack of turnover data for Johnston. The most seen at one time was four, but it is likely that at least two to four times this number visited Johnston Atoll.

The banding program on St. George extended from 1964 through 1968 and marked birds were observed in years other than 1966, but detailed ratios were not obtained. Another St. George bird was collected in 1968.

Thompson (1973) suggests a circular migration route for Ruddy Turnstones using islands in the Pacific Ocean. There is a southward movement through the central Pacific in fall and a northward migration in the western Pacific in spring through Japan and into Siberia and St. Lawrence Island, Alaska, to breed.

At-Sea Distribution

Ruddy Turnstones appeared as migrants in the at-sea grid southwest of Johnston Atoll only during August, September, and October (Table 21).

DOWITCHER species *Limnodromus* species

Status

Accidental; two fall sight records from Sand Island.

Observations

A dowitcher was observed and photographed on 8 September 1969 on the beach and a few yards inland in scattered grass at the southwest corner of the original portion of Sand Island. Mrs. R.C. Laybourne of the U.S. Fish and Wildlife Service Bird and Mammals Laboratories, National Museum of Natural History, tentatively identified this bird from Shelton's photographs (Fig. 89) as a Short-billed Dowitcher on the basis of spotting on the flank. Another dowitcher, possibly this species, was seen on Sand on 5 October 1964 by Kepler.

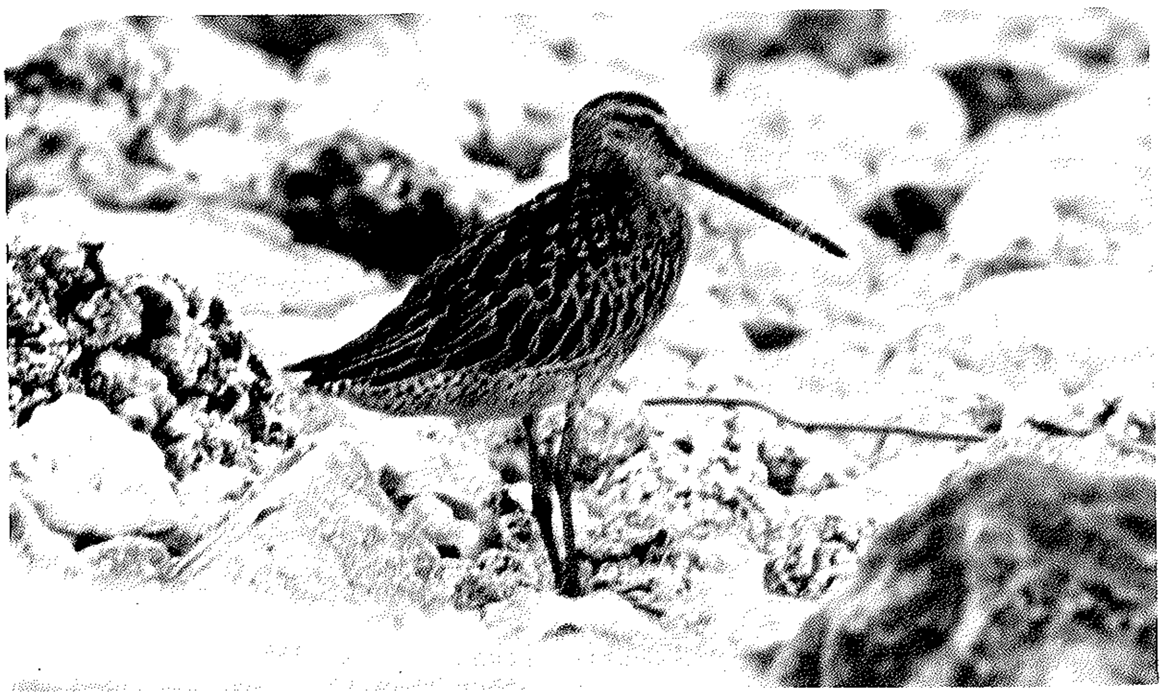


Figure 89. Dowitcher species photographed on Sand Island, Johnston Atoll, 8 September 1969 (POBSP photo by P. C. Shelton).

Since 1945, at least 15 sight records of dowitchers or Long-billed Dowitchers in the Hawaiian Islands have been published, but only two specimen records exist. A Long-billed Dowitcher was collected at Kure Atoll and a Short-billed Dowitcher was collected at Midway Atoll, the latter identified as *L. g. caurinus* (Clapp and Woodward, 1968; Woodward, 1972). Short-billed Dowitchers breed from southern Alaska, southern Mackenzie, and northern Alberta eastward across Canada, probably to the Ungava Peninsula. They normally winter from California, the Gulf Coast and South Carolina to Peru and Brazil. Long-billed Dowitchers breed from northeastern Siberia and northwestern Alaska to Mackenzie and normally migrate primarily through the western United States to Mexico and Guatemala (AOU, 1957).

This is a new sight record for Johnston Atoll.

SANDERLING *Crocethia alba*

Status

Uncommon migrant; usually found as singles on sandy beaches of Johnston and Sand Islands. Sporadic but regular visitor usually from late August through April.

Ecological Distribution

Johnston Island: Most Sanderlings were recorded here by the POBSP particularly on the sandy beach at the southwest corner. Most were loosely associated with flocks of Ruddy Turnstones and Golden Plovers.

Sand Island: POBSP personnel observed this species infrequently on Sand Island.

Populations and Annual Cycle

Sanderlings appeared most regularly from late August through April, but have been recorded in all months except June (Table 20 and Fig. 90). Highest numbers occurred in early 1964, when all shorebirds were unusually numerous because of abundant food from dredging operations (see Golden Plover and Ruddy Turnstone accounts), and in November 1966, at which time there was nothing unusual on the island to attract the birds.

Since most Sanderlings recorded were on Johnston Island and not on Sand Island, POBSP records do not reflect the true regularity of Sanderling occurrence on the atoll. In 1964, 1965, and 1966 Johnston was censused almost weekly, and figures from those years are more reliable than those from later years when there were long periods in which no complete shorebird censuses were made on Johnston. None was recorded from Akau or Hikina, but it is likely they occasionally visited these islands.

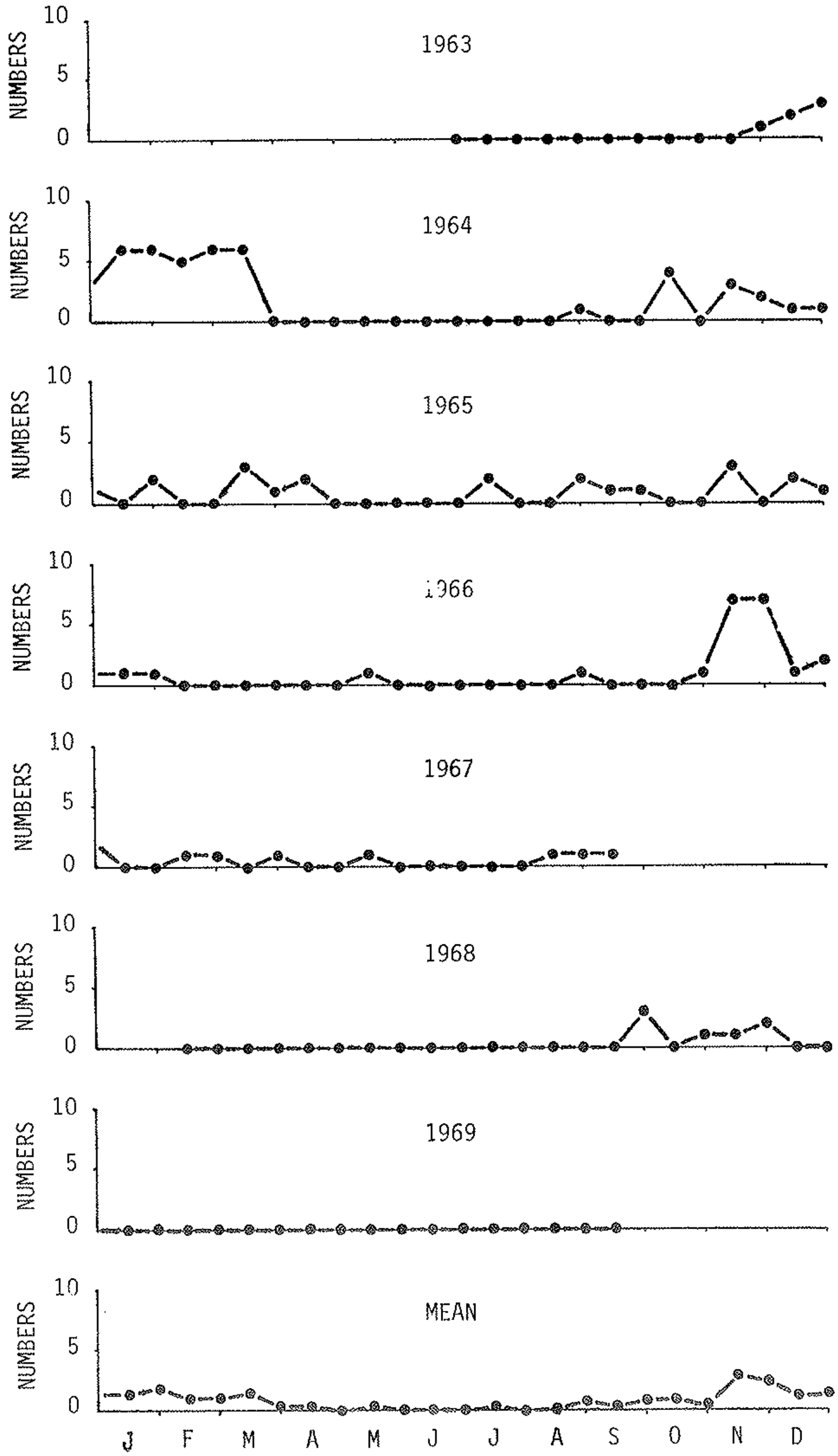


Figure 90. Moving averages of semimonthly estimates of Sanderlings, Sand and Johnston Islands, 1963–1969.

Most Sanderlings were loosely associated with flocks of Ruddy Turnstones and Golden Plovers, which also were most abundant on the southwest corner of Johnston. Most were in typical light, non-breeding plumage, but a few fall arrivals still had part of their dark breeding dress.

Specimens

One specimen was collected by POBSP personnel (Appendix Table 7) and is a new specimen record for the atoll.

Banding and Interisland Movement

Only one bird was streamered, but was not banded because the bands were not small enough. No interisland movements are known.

Sanderlings are circumboreal breeders that winter on coasts and oceanic islands from mid-temperate northern to mid-temperate southern latitudes (AOU, 1957).

WESTERN SANDPIPER *Ereunetes mauri*

Status

Accidental; one sight record on Sand Island.

Observations

Kleen identified a bird on the causeway of Sand Island as a Western Sandpiper on 4 September 1968. It was not collected or seen again.

One Western Sandpiper has been collected at Kure Atoll and is the only record for the northwestern Hawaiian Islands (Clapp and Woodward, 1968; Woodward, 1972). This species breeds in Alaska and winters from California, the Gulf Coast and North Carolina south to Venezuela and Peru (AOU, 1957).

Specimens

This is a new sight record for Johnston Atoll; no confirmation specimen record exists, however.

PECTORAL SANDPIPER *Calidris [=Erolia] melanotus*

Status

Uncommon but regular fall migrant; eight specimen records and many sight records from Sand Island.

Observations

At least one Pectoral Sandpiper was seen each fall on Sand Island by POBSP personnel from 1963 through 1969 (Tables 20 and 65). There were at least 16 fall records, possibly more if birds seen on successive days were different; eight of these were verified by collecting. Only two spring records (April and May 1965) exist and these may have been of the same bird.

Most sightings were of single birds, not associated with other shorebirds. Habitat preference appeared to be similar to that of Golden Plovers; they were seen inland more often than along the shores. All observations were made on Sand Island.

Specimens

The eight Pectoral Sandpiper specimens noted above constitute a new specimen record for Johnston Atoll (Appendix Table 7).

Pectoral Sandpipers are regular visitors to the central Pacific as they have been recorded from Kure Atoll, Midway Atoll, Laysan, Oahu, and Hawaii (Clapp and Woodward, 1968; Woodward, 1972; and Ely and Clapp, 1973). They breed on the Arctic slopes of eastern Siberia and North America and winter primarily in South America, and casually to southern and western Pacific islands (AOU, 1957).

Table 65. Observations of Pectoral Sandpipers on Sand Island, Johnston Atoll, 1963-68

Date of Survey		Number of Birds	Remarks
1963	3 Oct.	1	Northeast peninsula, collected.
1964	25-26 Sept.	1	Observed first on 25th, collected 26th.
	19 Oct.	1	Observed near several Golden Plovers and Ruddy Turnstones; collected.
1965	29 Apr.	1	Seen clearly by two observers; not collected.
	6-7 May	1	Seen clearly by two observers; not collected. Possibly samd bird seen 29 April.
	14 Sept.	1	Collected.
	27 Sept.	2	Collected.
	28 Sept.	1	Sight record; no details.
	1-12 Oct.	1	Observed daily; probably same as seen 28 September.

Table 65. (continued)

Date of Survey		Number of Birds	Remarks
1965	19 Oct.	1	Sight record; possibly same as earlier in month.
	22-31 Oct.	2	Observed almost daily; one possibly same as seen earlier.
1966	12-25 Oct.	1	Seen almost daily, on north shore, east hill, south of transmitter, and by barracks, all open sandy sites.
1967			(No records; no observations after 12 September).
1968	30 Sept.	1	Collected.
	2 Oct.	1	Collected.
	2-10 Oct.	2	Present on Sand Island.
	11-17 Oct.	5	Up to five present daily.
	18-31 Oct.	4	Up to four present daily.
	4 Nov.	1	
	6 Nov.	1	
	12 Nov.	1	Found dead.

SHARP-TAILED SANDPIPER *Calidris* [=*Erolia*] *acuminata*

Status

Accidental; two specimen records and three sight records from Johnston and Sand Islands.

Observations

Immature females were collected by Lewis 29 October 1965 and by Kleen 30 September 1969. Schreiber and Shelton saw, but were unable to collect, one bird on Sand Island on 23 October 1966, and Kleen saw one 10 October 1968 on Sand and another, or the same bird, on Johnston Island on 16 October 1968. Pectoral Sandpipers, with which this species is easily confused, were present on the atoll at the times of all three of these sightings so comparisons could be made easily; hence these identifications are considered highly reliable.

Specimens

The two specimens noted above and in Appendix Table 7 constitute a new specimen record for Johnston Atoll.

Sharp-tailed Sandpipers have been infrequently recorded from Kure Atoll, Midway Atoll, Pearl and Hermes Reef, Laysan (Clapp and Woodward, 1968; Woodward, 1972; Amerson, Clapp, and Wirtz, in press) and the main Hawaiians. They breed in northern Siberia and winter primarily in the western Pacific. They occur rarely along the North American Pacific coast south to California (AOU, 1957).

BUFF-BREASTED SANDPIPER *Tryngites subrificollis*

Status

Accidental; one specimen record from Sand Island.

Observations

Kleen collected an immature Buff-breasted Sandpiper on the man-made portion of Sand Island on 14 September 1968.

Specimens

This specimen (see also Appendix Table 7) is a new specimen record for Johnston Atoll.

The only other known Pacific island records of Buff-breasted Sandpipers are from Eniwetok, in the Marshalls (Pearson and Knudsen, 1967; Amerson, 1969) and Oahu (Donaghho, 1970). This species breeds on the Arctic slope of North America and winters in Argentina, migrating primarily through central North America. They are of casual occurrence on the Pacific coasts of North America, Japan, and Siberia (AOU, 1957).

RUFF *Philomachus pugnax*

Status

Accidental; one specimen record from Sand Island.

Observations

A Ruff was seen on 10 March 1966 feeding with a small group of Ruddy Turnstones at the west end of the causeway on Sand Island. At dusk it roosted with a large flock of turnstones on the northeast peninsula where Tordoff collected it. The bird, a male, had its crop full of minute snails, but had no fat deposits.

Speicmens

This is a new specimen record for Johnston Atoll; see also Appendix Table 7.

Previous specimen records from the central Pacific are from Kure Atoll (Clapp and Woodward, 1968; Woodward, 1972) and Pearl and Hermes Reef (Amerson, Clapp, and Wirtz, in press). Kaigler (1971) reported a sighting from Maui.

Ruffs breed across northern Europe and Asia and winter in the southern parts of those continents and in Northern Africa. In addition to the above central Pacific records, there are casual and accidental records from the western Pacific and from eastern North America (AOU, 1957).

WILSON'S PHALAROPE *Steganopus tricolor*

Status

Accidental; one specimen record from Sand Island.

Observations

Kepler and Lehner collected an emaciated female Wilson's Phalarope in winter plumage on the original portion of Sand Island 16 August 1964.

Specimens

This collection is a new specimen record for Johnston Atoll (Appendix Table 7) and the central Pacific Ocean.

Four sight records of Wilson's Phalarope from Maui and Oahu in the main Hawaiian Islands (Kridler, 1966; Clapp and Pyle, 1968; Kaigler, 1971; and Mull, 1971) are the only other known records from the central Pacific. This species breeds across the interior of North America, in southern Canada and northern United States, and winters in southern South America (AOU, 1957).

GLAUCOUS-WINGED GULL *Larus glaucescens*

Status

Irregular winter visitor; two specimen records from Sand Island.

Observations

There are two late-winter POBSP records of Glaucous-winged Gulls from Sand Island. Harrington saw a second-year bird on 1 March 1968 and collected it 8 March; it proved to be a female with very light fat deposits and well worn flight feathers. Shelton found a badly decomposed immature on the southeast beach on 7 February 1969. A gull, probably this one, had been reported occasionally during the previous two weeks.

Specimens

The above two specimens constitute a new specimen record for Johnston Atoll (Appendix Table 7).

Glaucous-winged Gulls have been collected on most of the main Hawaiian Islands, where they are frequent visitors. There are infrequent records in the northwestern Hawaiians from Kure Atoll, Midway Atoll, Pearl and Hermes Reef, Lisianski, Laysan, French Frigate Shoals, and Necker (Clapp and Woodward, 1968; Amerson, 1971; Woodward, 1972; and Amerson, Clapp, and Wirtz, in press), and elsewhere in the central Pacific (Sibley and McFarlane, 1968).

Glaucous-winged Gulls breed from the Komandorskie, Pribilof, and Aleutian Islands to northwestern Washington, and winter south-westward to Japan, and from southeastern Alaska to Baja California. Non-breeders occur in summer south to California (AOU, 1957).

HERRING GULL *Larus argentatus*

Status

Rare visitor; various sight records of one bird from Johnston and Sand Islands.

Observations

A subadult (second-year) Herring Gull was seen by Kleen over Sand Island in late November and early December 1968 and at Johnston Island on 31 December 1968 (by Brownell) and 14 March 1969 (by Shelton). There was no opportunity to collect it.

Specimens

No specimens are known from Johnston Atoll; however, the sight record is considered new for the atoll.

At least 12 specimens of Herring Gulls have been collected in the northwestern Hawaiian Islands. All have been identified to the race *Larus argentatus vegae* (Clapp and Woodward, 1968) which breeds in Siberia and winters as far south on the Asiatic coast as central China and Formosa. It wanders casually to western Alaska, the Aleutians, and British Columbia (AOU, 1957).

LAUGHING GULL *Larus atricilla*

Status

Irregular winter visitor; one specimen record and three sightings from Johnston and Sand Islands.

Observations

The first Laughing Gull observed on the atoll landed on the southeast beach of Johnston Island 7 February 1964. It appeared to have just made its first landfall, for it flew only reluctantly and persistently put its head under its wing as if trying to sleep despite the presence of people. On 13 February it was still quite tame, but by March it had become more wary. During this time it remained in the same general area, feeding along the shore where dredging operations were underway. On 7 April it appeared on the northeast peninsula of Sand Island, possibly attracted by numerous dead fish from dynamiting operations. Amerson and Amerman collected it there; it proved to be a very fat immature male. The abundance of food from the dredged coral probably allowed this bird to maintain itself in good condition.

Second year Laughing Gulls were identified by Bratley and Lehner on 28 July 1964 and by Heryford and Bratley on 26 February 1965, both on Sand Island. The first flew over the island during the day, heading eastward. Sooty Terns harrassed it all the way across the island and it was not seen again. The second landed about midnight in a small group of roosting Blue-faced Boobies on the southwest islet. It could not be caught and was never seen again.

Kleen saw an adult Laughing Gull in non-breeding plumage fly along the causeway on Sand Island 28 October 1968.

Specimens

The specimen noted above is listed in Appendix Table 7. In addition to these records from the Atoll, Clapp collected an immature female 11 miles northwest of Johnston Atoll on 15 January 1965 (Sibley and McFarlane, 1968).

Most other records are to the south. Specimens are known from at sea (7 March 1964: 12°41'N, 171°28'W), Christmas Atoll, Palmyra Atoll, and Baker Island (Sibley and McFarlane, 1968; King, 1967). One specimen is known from Oahu (Berger, 1972).

Laughing Gulls breed along the Atlantic coast from Nova Scotia south through the Gulf of Mexico and Caribbean to northern Venezuela, and on the Pacific coasts of southern California and Mexico. They winter in the southern half of their breeding range and south to Brazil and Peru (AOU, 1957).

FRANKLIN'S GULL *Larus pipixcan*

Status

Straggler; one specimen record from Sand Island.

Observations

The only Franklin's Gull recorded from Johnston Atoll was a male in breeding plumage collected by Shelton on the causeway of Sand Island on 20 May 1969. When found it was almost dead, probably from starvation as it was thin and had no fat deposits. It was first sighted on Sand 19 May.

Specimens

This is a new specimen record for Johnston Atoll (Appendix Table 7).

Other records of this species from the central Pacific are from Maui, Oahu, offshore Kauai (King, 1959), French Frigate Shoals (Clapp and Woodward, 1968; Amerson, 1969), Palmyra, and Fanning (Sibley and McFarlane, 1968).

Franklin's Gulls breed from southeastern Alberta and eastern Oregon to Minnesota and Iowa; they winter along the Pacific coast from Guatemala to Chile, on the Galapagos Islands, and on the north coast of the Gulf of Mexico (AOU, 1957).

GULL species *Larus* spp.

Status

Accidental; one skeleton record (lost) and one sight record from Johnston Island.

Observations

A large gull, most likely a Western Gull in first winter plumage, appeared on Johnston Island about 25 January 1964. Despite futile efforts to collect it, the bird remained there at least through 9 March 1964.

Bratley first saw it lying on the beach on the south side of the island, during mid-afternoon. When approached to within about 25 feet it stood up, then flew out and lit on the water 200 yards offshore, only to return to shore within ten minutes. Attempts were made to collect the bird the next day, but it was more wary then, probably indicating some degree of recuperation from its journey to the atoll. On the 28th of January it was shot and wounded, but escaped by swimming out to sea. By about mid-February it was able to fly weakly, and it remained too wary to be collected. It was last seen 9 March. During the entire time it was on the island it stayed along the south beach.

A skeleton of a large dusky gull, possibly a Western Gull but not likely the same specimen, was found on Johnston Island 17 December 1965 (USNM field no. 25923). The skeleton, however, was later lost.

Specimens

The above records constitute a tentative new sight record for Johnston Atoll.

Western Gulls breed from northern Washington to Baja California and winter from southern British Columbia south through the breeding range (AOU, 1957). There appear to be no authenticated central Pacific records.

GRAY-BACKED TERN *Sterna lunata*

Status

Uncommon breeding species; present year-round. About 250 nest on Sand Island each year from December through July, but only a few dozen chicks are produced annually. Recent records of nesting on Akau and Hikina Islands. Previously nested on Johnston Island.

Ecological Distribution

Akau Island: Because high tides destroyed their eggs on Sand Island in late February 1964, about 200 Gray-backed Terns moved to the then newly constructed Akau Island in March and laid at least 85 eggs. Unfortunately, continued construction destroyed this new colony; only one chick hatched, which did not survive. None has been recorded since.

Hikina Island: Kridler (BSFW, 1973) recorded Gray-backed Terns nesting here in May 1973. A total of 35 nests was found, 12 of which contained very small downy chicks. About 80 adults were observed.

Johnston Island: Wetmore (ms. a) recorded 25 well-grown young, some of which were flying, here in July 1923. Because of human disturbance, none has been recorded since.

Sand Island: Wetmore (ms. a) also recorded 25 with young here in July 1923. In April 1957, Moynihan (1957: 37) observed "a small diffuse colony of Gray-backed Terns, including perhaps 200 birds, was stretched along both sides of the causeway between the islets. Most of the birds were incubating eggs in nests on the bare ground between boulders or patches of low vegetation."

From 1963 through 1969 POBSP personnel found Gray-backed Terns nesting in loose groups of from two up to 200 birds on rough, rocky ground around the periphery of the original island, including the southwest islet and (prior to 1968) on the abandoned pier (Figs. 43, 91 and 92). The maximum number of eggs present in 1967 in the various areas (Fig. 92) indicate approximate relative numbers of birds using these sites.

Eggs are deposited on the sand, with no prior preparation of site. Some incubating birds may gather in small stones within reach from the

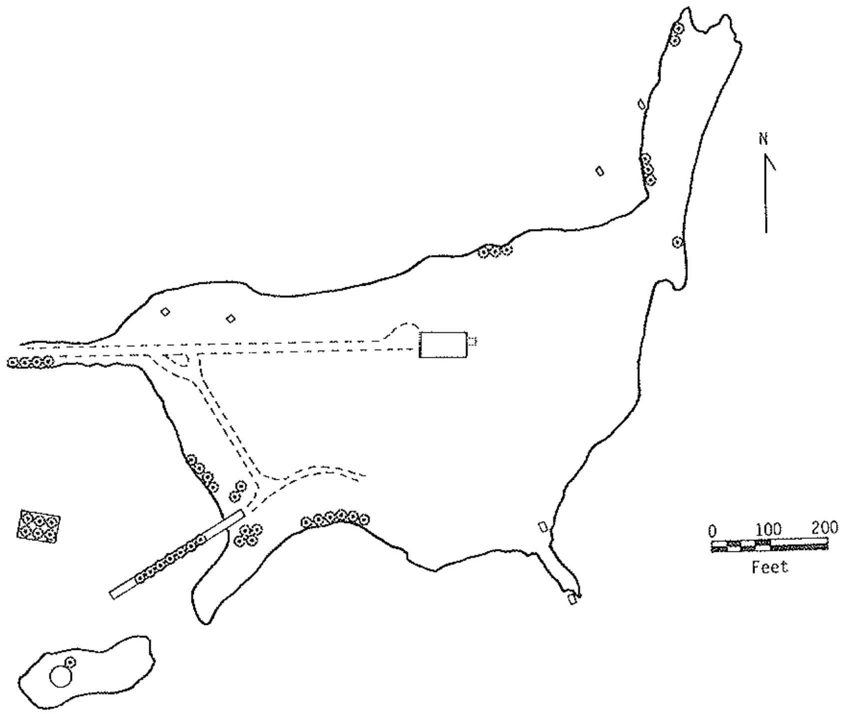


Figure 91. Distribution of Gray-backed Tern nest sites, Sand Island, Johnston Atoll, 1966.

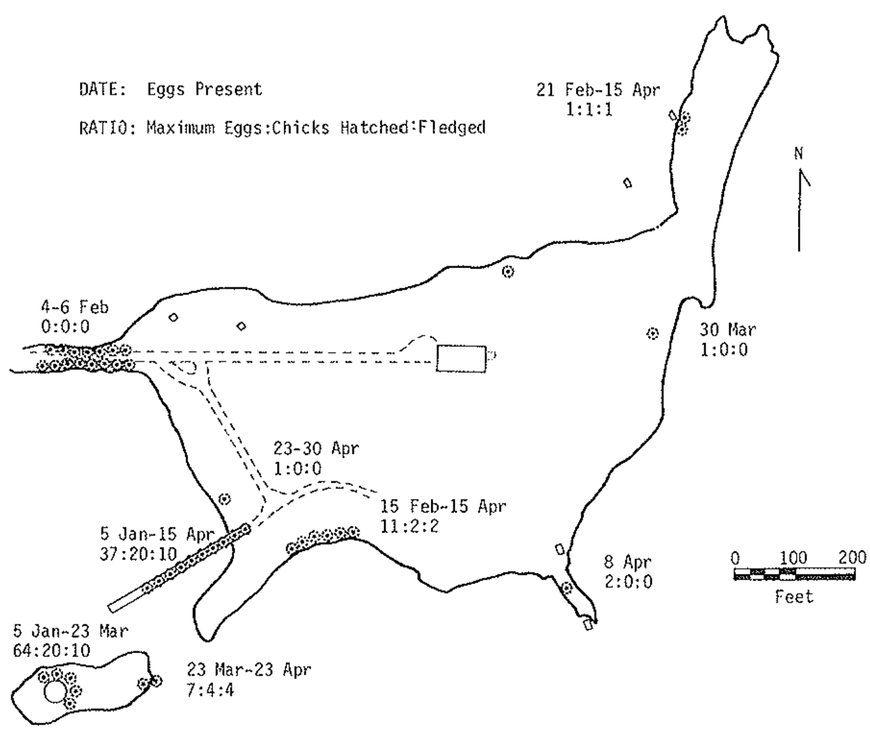


Figure 92. Distribution of Gray-backed Tern nest sites, Sand Island, Johnston Atoll, 1967.

egg, but usually there is no evidence of any attempt to build even the most rudimentary nest.

Apparently their choice of peripheral nesting areas and their beginning to nest before Sooty Terns are both adaptations to avoid competition for nesting space with that species. Prior to 1967, gray-backs usually began nesting on the old dock, which was perhaps the area most secure from competition with Sooty Terns. Unfortunately, most eggs and chicks were lost from the dock because it provided a poor base for eggs and practically no hiding places for chicks.

After heavy egg losses occurred on the dock, many birds attempted to renest on other parts of the island. Some of the second sites chosen were even poorer than the dock, and many eggs were lost to high tides (Figs. 93 and 94). In February 1967, two groups began nesting in areas that appeared to be far better than the dock--in the south-southwest rocks area, and on the west side of the northeast peninsula. Unfortunately, these areas were overrun by Sooty Terns in March before the gray-backs could successfully complete their nesting, and most of the eggs were lost or abandoned. The gray-backs stayed on their eggs after sooties moved into the area, but the numbers of eggs declined steadily with no increase in chicks. Behavioral observations were not made.

It would seem that if these birds began nesting here instead of on the old dock, they might be able to have chicks large enough by the time the Sooty Terns moved in and they would not be lost. It may be, however, that chicks, even up until just before they fledge, are highly susceptible to being killed by Sooty Terns, which descend in hordes and perhaps would kill any small tern within their territories.

In 1957, Moynihan found gray-backs nesting along the causeway well away from both groups of Sooty Terns that were also nesting then. Apparently at that time there was enough space so that the gray-backs could nest unmolested. Unfortunately, there are no records of the success of the colony then as compared to the period of POBSP studies.

Nesting gray-backs often served as foci for pre-breeding Sooty Terns when they settled on the island in the evenings. On 4 February 1966, one Sooty Tern incubated all day among Gray-backed Terns on the west shore; 14 more eggs were laid by early evening and on 5 February five were incubated a portion of the day; one persisted until 9 February, by which time no other had begun nesting. In February 1967 as the swirling sooties flew lower and lower over the southwest grassy portion of the island, they were attracted to the gray-backs nesting on the south-southwest shore, and on at least half the evenings, the first sooties to land did so among the gray-backs. The reactions of the gray-backs could not be determined. When the sooties began nesting, they did not do so near the nesting gray-backs; it was a few weeks before the gray-back nesting areas were taken in by the sooties, at which time the gray-back eggs began to decline steadily.

Figure 93. Gray-backed Tern on nest (center foreground) among Sooty Terns in *Ipomoea* and *Lepturus* on south shore of Sand Island, Johnston Atoll, 21 April 1969 (POBSP photo by P. C. Shelton).

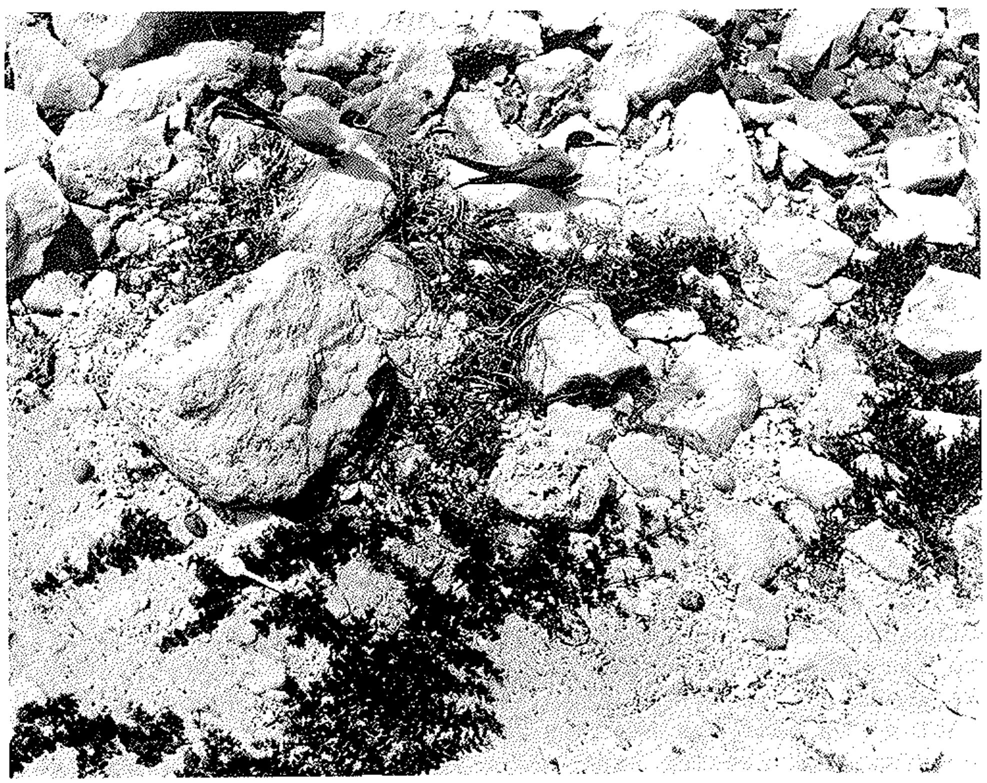


Figure 94. Gray-backed Tern nesting area on southwest islet, Sand Island, Johnston Atoll, 16 April 1969. Two adults, one chick, and four eggs are shown (POBSP photo by P. C. Shelton).

The peripheral areas used by nesting Gray-backed Terns are usually shared with Brown Noddies, but the noddies do not nest densely enough to cause any obvious conflicts with the gray-backs. Close behavi ›ral observations might reveal interactions that have gone unnoticed, ıowever.

Populations

Means and extremes of semimonthly estimates from 1963 through 1969 are shown in Figure 95. Year-to-year variation showed a slight decline from 1963 to 1969. The trend was evident both in adult and egg numbers, but was not reflected in number of chicks.

Comparison of both Wetmore's and Moynihan's figures with those from POBSP observations at the same time of year, however, indicate no detectable differences in total numbers on the atoll. The population that originally was divided between Johnston and Sand Island is now confined to Sand. Since this species occupies habitat marginal to Sooty Terns, and possibly Brown Noddies, there probably never was much nesting space available to them, and the population never exceeded a few hundred birds.

Mortality of both eggs and chicks was extremely high. An average of 101 eggs (range 63 to 155) was laid each year from 1964 through 1969, while only an average of 17 fledged (range 11 to 26). These figures do not show the actual difference, because many eggs were laid and lost without being reported in the counts. For example, in late February 1964, egg numbers increased to 155, but were reduced by losses to 86 by the end of the month. Also, on the old dock in 1965, about 118 eggs were laid, but no more than four young fledged. Without daily counts of new eggs, which were never made over the entire island through a complete nesting cycle, it is not possible to determine the total number produced each year. Most likely, however, at least 200 eggs were laid each year.

Numbers of young successfully fledged were not known precisely, but the figures for numbers banded, which probably were slightly higher than the number of young surviving to fledging, were: 11 for 1964, 15 for 1965, 13 for 1966, 24 (three of which were known to have died) for 1967, 15 for 1968, and 26 for 1969 (one died; one not banded). Thus, no more than five to ten percent of eggs laid resulted in fledged young.

Renesting appeared to be common in this species, but the second nest probably had even less success than the first.

The most dramatic example of renesting occurred in 1964, when about 200 birds--half the population--moved to the newly constructed Akau Island in March and laid at least 85 eggs, after high tides in late February destroyed about half the eggs present on Sand. Unfortunately, continued construction on Akau destroyed the new colony. Only one chick hatched, which did not survive. An adult found dead in this group had been banded and streamered earlier in the year on Sand, and several birds

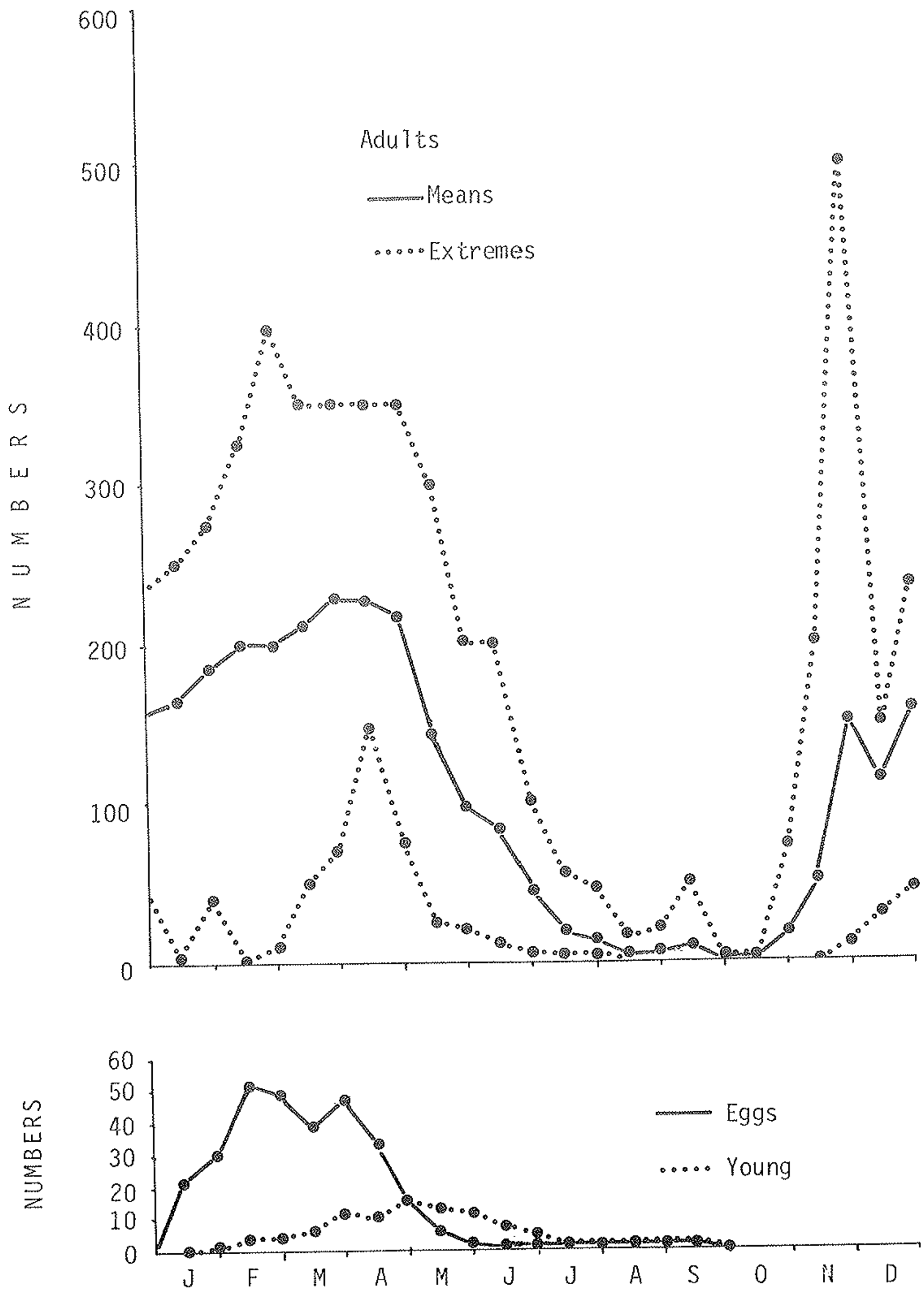


Figure 95. Means and extremes of semimonthly estimates of Gray-backed Tern numbers, Sand Island, Johnston Atoll, 1964-1969.

were seen with orange streamers. Streamered birds were also seen in late established nesting areas on Sand, indicating that these were birds from the first nesting areas rather than new birds just arriving on the atoll.

The ultimate cause of nesting failure in this species probably is competition with Sooty Terns for favorable nesting habitat (see also Ecological Distribution section).

Annual Cycles

Figures 37 and 95 show the annual cycle for Gray-backed Terns at Johnston Atoll from 1963 through 1969. Year-to-year variation (Table 66) was similar except for the 1967 and 1969 breeding seasons. For these two years the first egg laid was about one month early.

After an absence of two or three months, the first birds usually returned at night only about mid-November; often they were heard several nights or a few weeks before any were seen. Later they arrived at dusk and roosted. Arriving birds did not swirl over the island before landing, but flew directly to the roosting area, settled quickly and remained relatively quiet through the night. If disturbed, they flew up, calling, but quickly resettled if left alone.

Numbers present at night continued to build up as the breeding season approached, and continued to increase until after laying began. In 1966, the only year in which detailed descriptions of the sequence of events were made, three or four birds stayed on the dock during the day beginning ten days before the first egg was laid, and increased to about 40 by the time the first egg was laid. During this time birds arrived slightly earlier each evening, and courtship activity increased.

Normally first eggs appeared about mid-January. After laying began, and throughout the nesting period, no more than a third of the night population was present during the day; toward the end of the cycle when numbers began to decline, the day numbers declined more rapidly than night numbers.

Incubation required about 30 days (1969 data: mean = 30.2 days, range 29 to 32, n = 25 eggs). Eggs were pipped one day before hatching. Eggs normally hatched in late February and continued hatching into May and June. Fledging occurred from mid-March to September. By June, adults were very inconspicuous on the island, although a few invariably were present. The unfledged chicks stayed well hidden during the day, and were visited by the adults only at night. Usually adults tending chicks were accompanied by a few non-breeding birds, some of which appeared to be immatures hatched the same year. Others had adult-like plumage except for speckling on the crown, which may have indicated that they were subadults in their second year.

After the last chicks fledged, a few birds continued to visit the island at night for another month or so. These probably were the same birds that raised the last chicks.

Table 66. Extreme dates of significant events in the Gray-backed Tern breeding cycles, Sand Island, Johnston Atoll, 1963-1969

Event	Nesting season 1964	1965	1966	1967	1968	1969
Birds first returned to Island	1-15 Jan.	10 Nov. (1964)	14 Nov. (1965)	25 Nov. (1966)*	no dates	22 Oct. 1968
Eggs:						
First laid	16-31 Jan.	1-15 Jan.	21 Jan.	31 Dec. (1966)	--	Before 30 Nov. 1968
First period with 20 or more	1-15 Feb.	1-15 Feb.	16-31 Jan.	1-15 Jan.	--	1-15 Jan.
Maximum number present	16-28 Feb.	16-28 Feb.	1-15 Feb.	16-31 Jan.	?	1-15 Apr. (re-nesting)
Maximum number**	155	85	135	99	(72)	63
Chicks:						
First hatched	1-15 Mar.	16-28 Feb.	16-20 Feb.	*ca.* 30 Jan.	1-15 Feb.	7 Feb.
Last hatched	15 May	14 June	1-15 June	1-15 May	Apr.-May	19 May
First fledged	--	1-15 Apr.	11 Apr.	15 Mar.	--	*ca.* 1 June
Last fledged	16-31 July	1-15 July	16-31 July	10 Sept.	1-7 July	*ca.* 15 July
Number banded	11	15	13	24	15	26
Last birds seen on Island	1-15 Sept.	1-15 Aug.	16-31* July	After 12 Sept.	July	After 9 Sept.

*Except two present 23 Sept.-23 Nov.

**Maximum recorded at any one time; Total number each year estimated 200 or more.

In most years Gray-backed Terns were completely absent from the atoll or in very low numbers for two or three months--usually from August to mid-November. But in 1966, two birds arrived back on the atoll in late September, and continued to roost in the same area near the south-southeast shore until two days before the first new arrivals appeared on the old dock on 25 November. The breeding status of these two birds was unknown, but it seems fairly likely that they joined the new birds and began roosting with them on the dock. In August and early September 1969, however, several birds appeared on lagoon anchor buoys. An egg was laid on 9 September; the fate of this out-of-sequence population was not determined because POBSP personnel left the atoll and ended their six-year study.

Specimens

Nineteen specimens of Gray-backed Terns have been collected from Johnston Atoll (Appendix Table 7); these constitute a new published specimen record for the atoll.

Banding and Interisland Movement

The POBSP banded 271 Gray-backed Terns at Sand Island (Table 24); 23 of these have been recaptured back on the atoll (Table 25). One, banded as a fledgling on Sand 27 April 1965, was captured some 3,000 nautical miles to the southwest at Wuvulu Island, off the north coast of New Guinea, in August 1965. No foreign-banded Gray-backed Terns were recaptured on Johnston Atoll.

At-Sea Distribution

Gray-backed Terns were recorded at sea in the grid southwest of Johnston only during the months of May, August and October (POBSP, 1967a). These data suggest (1) that during the breeding season this species usually feeds close to Johnston, and (2) that during the non-breeding period either is at sea in this area or, more likely, travels through this area in August going to a distant "wintering ground" and again in October returning to Johnston.

SOOTY TERN *Sterna fuscata*

Status

Common breeding species; present from December through August. Breeds on Sand Island from February through July; previously bred on Johnston Island. Most abundant spring-summer breeder, numbering about 300,000 breeders producing up to 60,000 fledglings each year; at least 600,000 using the island annually.

Ecological Distribution

Johnston Island: Photographs from the 1923 TANAGER expedition (Wetmore, ms. a) show no distinct Sooty Tern nesting concentrations and none was mentioned in the reports (Appendix Table 8). There would be little reason to suspect concentrations, since the habitat was unusually uniform. Sooty Terns probably nested throughout the *Lepturus* on both islands, and non-breeding birds may have concentrated on the few more open areas such as the small guano digging area on Sand Island.

When the military took over the islands, construction work quickly destroyed much of the available habitat. Present and past numbers, however, show no indication that there was a decrease in birds, but they have had to crowd together much more for nesting, since now they have available only the original portion of Sand Island--about eight acres--as compared with the original total of about 50 acres for the two islands. The density of *Lepturus* on the original islands undoubtedly required wider spacing of nests than is now necessary on the relatively barren Sand Island, where vegetation is prevented from becoming too dense by repeated overrunning every few years by men and equipment and possibly also by the destructive effects of the now very crowded Sooty Terns.

Unfortunately, data from the war years are almost totally lacking, but it appears that Sooty Terns must have nested on Johnston Island through World War II, and afterwards, at least through the 1940's (Beckham, 1947; Fennell, 1948; Jensen, 1949) and probably until the mid-1950's (Benson, 1955). Apparently the move to Sand was complete by 1957, when Moynihan visited the atoll, for he found no Sooty Terns nesting on Johnston. The reason for the move to Sand Island likely was the wholesale destruction of eggs on Johnston.

Sand Island: Wetmore (ms. a and b) found Sooty Terns nesting here in July 1923 (Appendix Table 8). Few probably nested here during the war years (U.S. Nat. Archives, R.G. 80, U.S. Navy photographs), because several buildings were on the island and activity was intensive.

In 1957, Moynihan (1957) found Sooty Terns in two groups, one on each end of the island. The Coast Guard buildings on the western, man-made end eliminated most of the available habitat there, and repeated disturbance of the small area probably discouraged all nesting on that area. POBSP personnel found them nesting only on the original portion from 1963 through 1969. Harrington (1973 and 1974) also observed nesting here in spring 1971. Kridler (BSFW, 1973) again recorded them nesting in May 1973. Amerson saw and heard an occasional Sooty Tern flying at dusk in November 1973.

Sooty Terns lay a single egg on the ground without the utilization of any nesting material. POBSP personnel found Sooty Terns nesting on almost all the original portion of Sand Island (Fig. 96), with a maximum area occupied of about 330,000 square feet in 1966 and 1967 (Figs. 35 and 97). The only areas not used were the northwest section, where

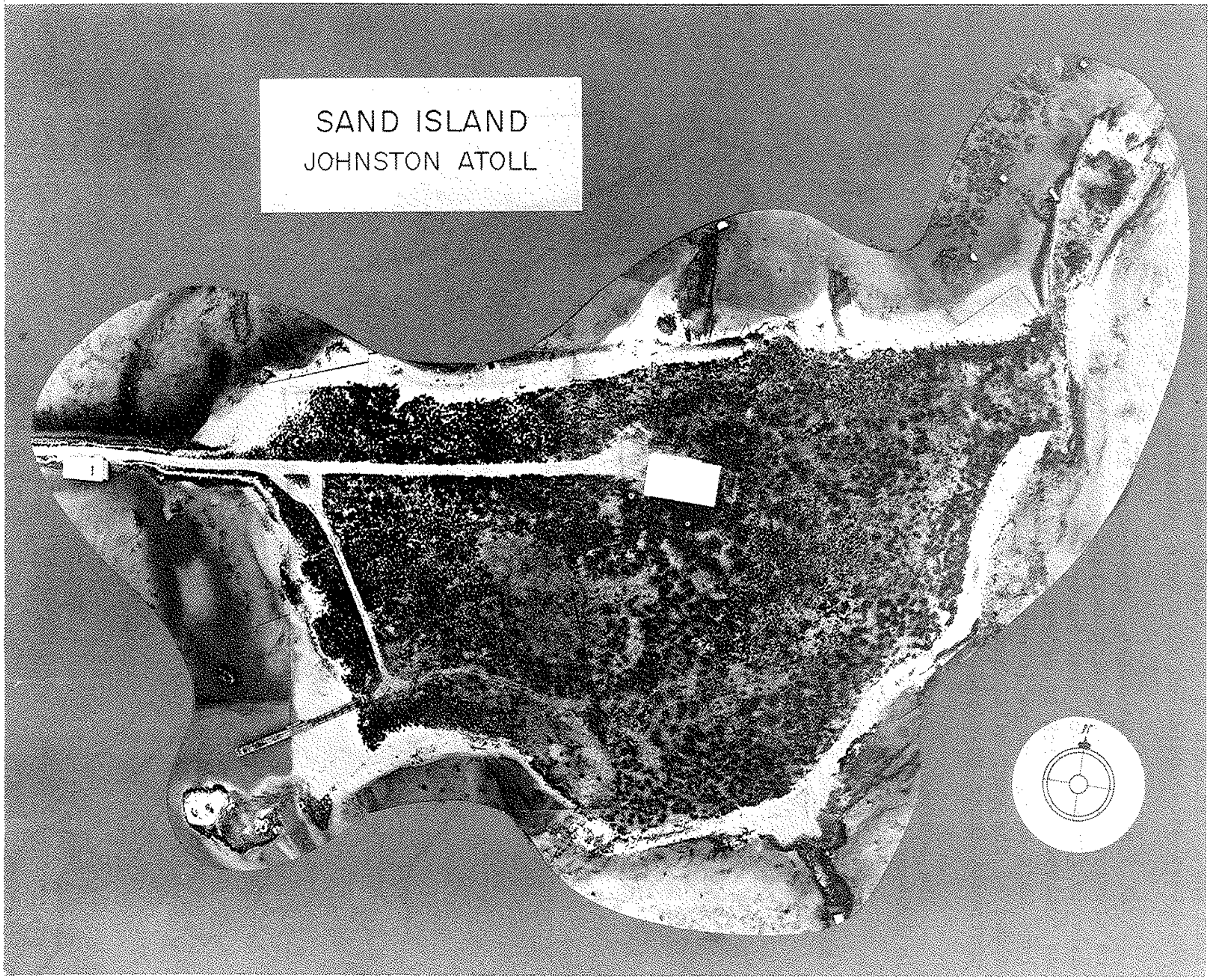


Figure 96. Sooty Terns (tiny dots) utilize almost all available ground nest sites on the original portion of Sand Island, Johnston Atoll, May 1964 (mosaic by A. B. Amerson, Jr. from POBSP photographs taken at the 620-foot tower level by R. W. Merrill).

possible reasons for their absence were the presence of heavy *Lepturus* (which may have been a result, not a cause, of the lack of Sooty Terns), or the presence of large numbers of ants in this area--possibly more than any other part of the island--may discourage nesting here. No objective ant population data were gathered, however.

At least in some years, there were areas too barren of vegetation to provide Sooty Terns with suitable means for nest orientation. Ashmole (1963) showed that Sooty Terns will not nest on smooth sand, with no features by which to orient themselves. The only such bare areas in 1967 were along the periphery of the northeast peninsula, the middle slope of the east hill, and a spot on the southeast slope under the southeast inner guywires.

The southwest islet had a few nesting birds in most years, but none in 1966 or 1967.

Harrington (1973) suggested that the heterogeneity of habitat features on Sand Island may increase nesting success.

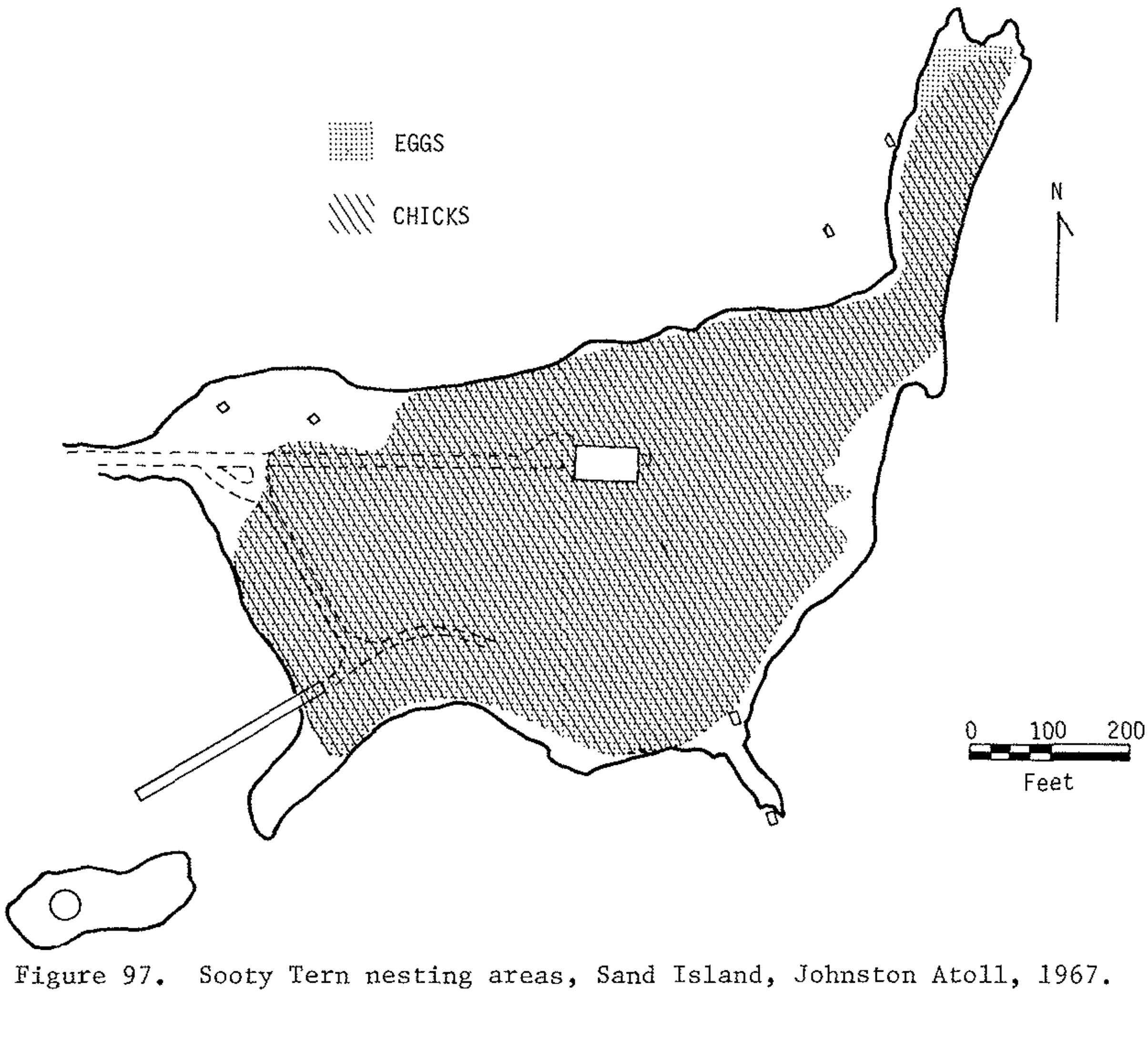


Figure 97. Sooty Tern nesting areas, Sand Island, Johnston Atoll, 1967.

Nesting density appeared to be highest in areas either bare or with light vegetation cover, and with enough microrelief in the form of rocks and other irregularities that the birds could find their nests, but where there was not enough vegetation to cause increased spacing of the birds. The only area on Sand where the latter conditions occur was in the dense *Lepturus* on the southwest portion of the island (Fig. 98). Otherwise, the spacing of birds appeared to be about as thick as they will tolerate. Pictures taken from a pole in the center of the island (Fig. 99) show the distribution of these nesting birds very well.

Sooty Terns are associated closely with several other nesting species on the island. The one with which there is a positive interaction is the Gray-backed Tern, which begins nesting before Sooty Terns, and in some cases serves as focal points for arriving sooties during the swirling, prebreeding phase of their cycle. In no known case have Sooty Terns actually begun nesting among nesting gray-backs, but the attraction is fairly well marked in birds settling in the evenings shortly before they begin nesting. It does not invariably occur, and the reasons for the variations, and for the gray-backs not being a nucleus for nesting sooties bear further study. The destructive effect of nesting sooties on nesting gray-backs was described in that species' account.

Sooty Terns and Brown Noddies occupy much of the same habitat, but little is known of their interrelationships. Noddies generally nest only around the periphery of the island, in rougher sites than sooties seem to prefer, but there is considerable overlap, especially on the east hill (see Figs. 97 and 106). There is some indication that numbers of Brown Noddy nests on the east hill increase after Sooty Terns thin out, but little reliable data exist. It may be that counts of noddy nests on the hill were more complete after the Sooty Terns left, rather than that they actually increased (see Brown Noddy account).

Sooty Terns also nest among nesting Brown Boobies on the east hill. Observations indicate that the sooties nested slightly farther from the boobies than from each other, but measurements were not taken. Several Brown Boobies stole Sooty Tern eggs and put them in their own nests. This probably occurred when boobies established nests near already established Sooty Tern nests, and the tern eggs were within their reach and were pulled into the nest by the boobies. In 1967 one mateless male booby used Sooty Tern eggs this way, breaking them all after a few days of incubation, because the tern eggs were not strong enough to withstand the trampling of the booby.

Along the south shore, and formerly on the east hill, Sooty Terns nest close to Great Frigatebirds. Also, formerly on the east hill they nested close to Red-footed Boobies. In 1967, when the inland great frigate colony formed, Sooty Terns were nesting densely in the area. Unfortunately, there are no data to indicate what, if any, reactions occurred between either the Red-footed Boobies or the Great Frigatebirds and Sooty Terns. On other islands (Christmas Island, Pacific Ocean,

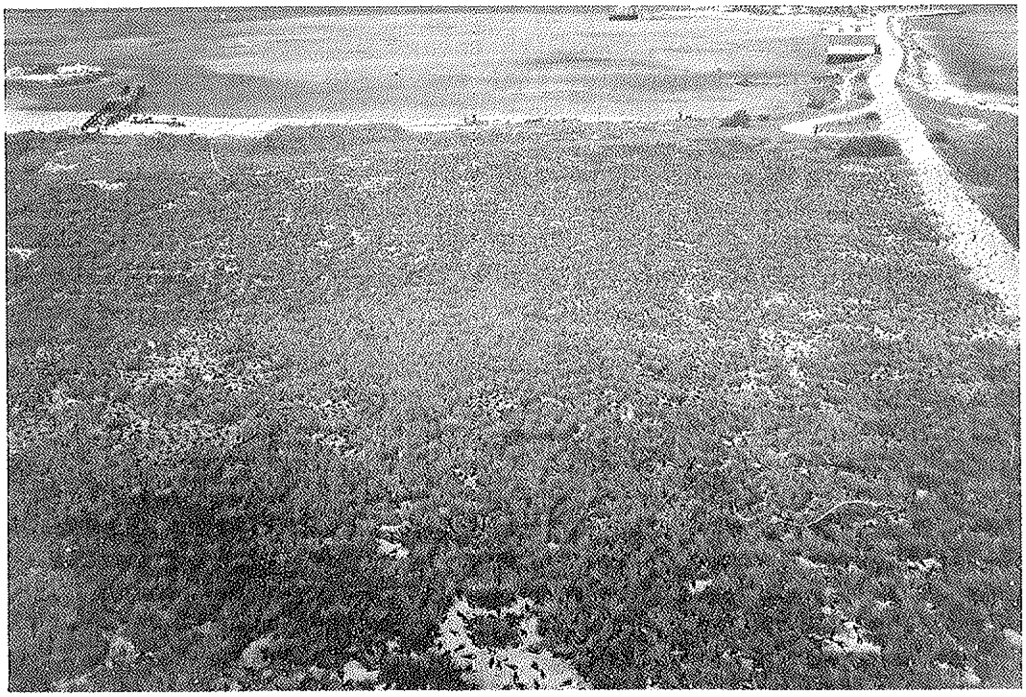


Figure 98. Nesting Sooty Terns cover virtually the entire southwest portion of Sand Island, Johnston Atoll, 14 April 1969. Most of the Wedge-tailed Shearwater burrows are under the *Lepturus* in this area. The southwest islet and old dock are visible at upper left (POBSP photo by P. C. Shelton).

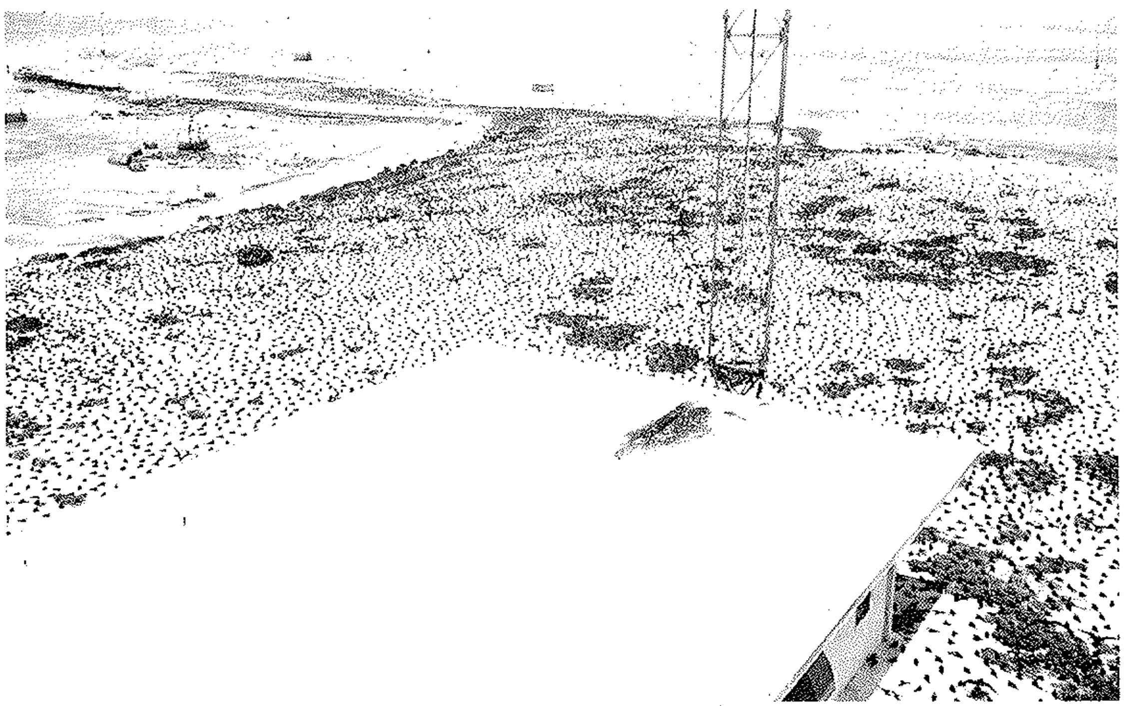


Figure 99. Nesting Sooty Terns northeast of the transmitter building and on the northeast peninsula, Sand Island, Johnston Atoll, 30 March 1967 (POBSP photo by P. C. Shelton).

Schreiber and Ashmole, 1970; and Ascension Island, Atlantic Ocean, Ashmole, 1963), frigatebirds eat large numbers of Sooty Tern chicks, but this has never been known to occur on Johnston Atoll. In 1967, downy Sooty Tern chicks were found huddled under incubating great frigates in the inland colony. In colonies where frigate feeding on tern chicks occurs, the behavior is conspicuous, as the frigates hover over the colony, picking up chicks from on the wing.

Populations

Figure 100 shows semimonthly POBSP population estimates for Sooty Terns during the years 1963-1969.

In general, maximum numbers present on Sand Island at one time is about 300,000, which occurs during the breeding peak in late March and April. Total numbers using the island, however, is at least 600,000 annually. Kridler (BSFW, 1973) estimated 400,000 adults with 192,000 nests in May 1973.

These estimates, however, show gross trends, and cannot be considered accurate within less than 25 percent; many may be in error by 100 percent. Sooty Tern numbers are practically impossible to determine accurately, and few of the personnel on the island were sufficiently experienced to make more than guesses at numbers present. Drastic changes during a given period are more apt to be caused by changes in personnel or in techniques used for estimation than to be actual changes in numbers of the magnitude shown.

The figures presented are supposed to be estimates of the total numbers of birds using the island during the period in question, based on numbers seen, day and night (night numbers almost always are greatest), on egg counts, chick-adult ratios, etc. In general, it appears that the maximum number ever present is around 300,000, which occurs during the breeding peak in late March and April.

Another technique used to estimate numbers using the atoll during the entire breeding season has been the calculation of total populations based on ratios of banded to unbanded birds in samples. Table 67 shows the results of these attempts.

In summary, it appears that the total number of Sooty Terns using Johnston Atoll is something over half a million, over half of which may be present at the peak nesting season in late March through April and May.

There are no previous estimates or calculations that can be regarded as anything more than guesses of the numbers present. Since all recent attempts to estimate numbers of this species that have been checked against more objectively calculated figures have been very low, it is doubted if early estimates for the Johnston population were anywhere near the actual numbers.

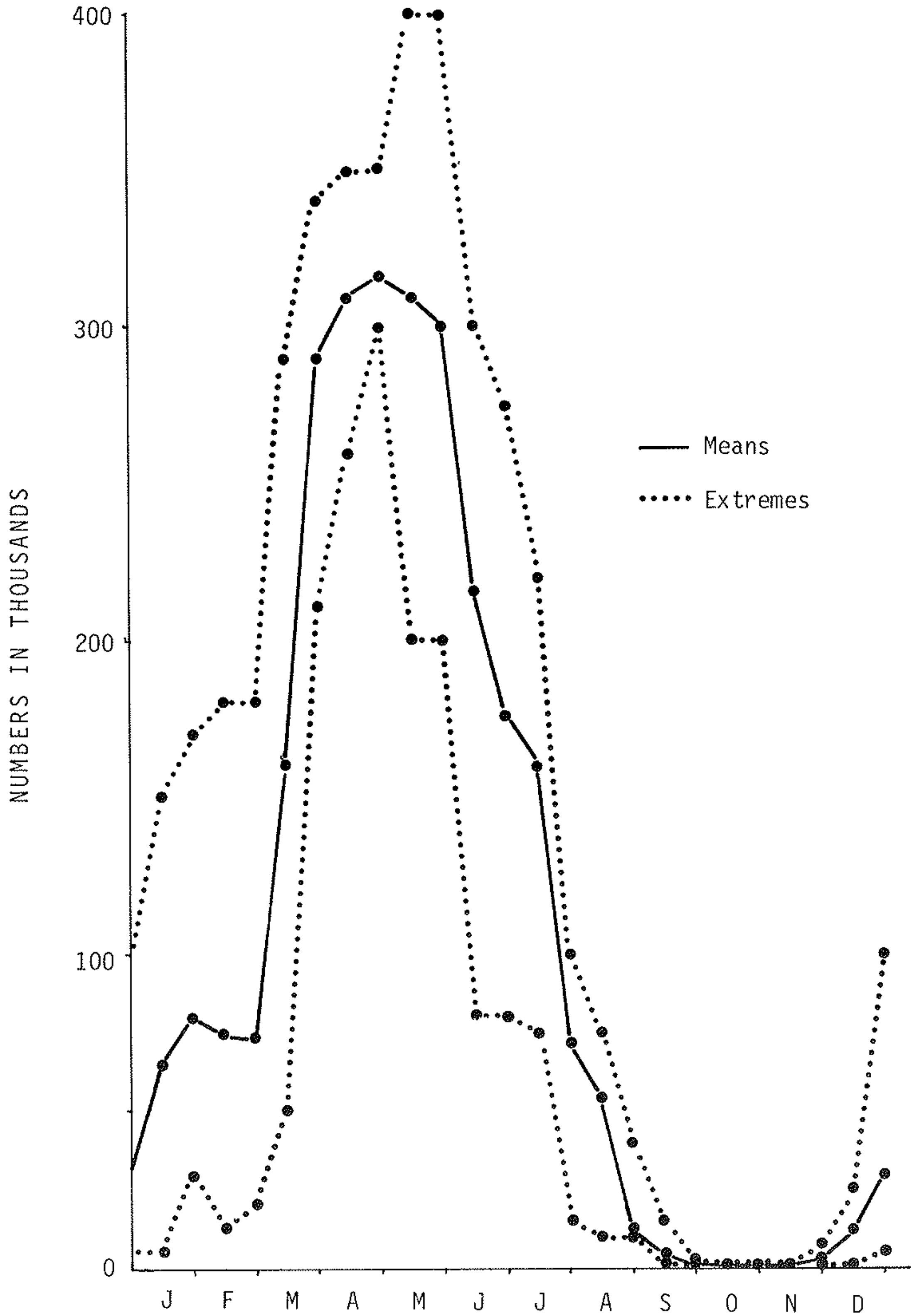


Figure 100. Means and extremes of semimonthly estimates of adult Sooty Tern numbers, Sand Island, Johnston Atoll, 1963-1969.

Table 67. Mark-release-capture calculations of Sooty Tern breeding populations, Sand Island, Johnston Atoll, based on February-April 1967 recaptures*

Manner of Recapture	No. Examined	No. Banded	% Banded	Calculated Population	95% C.L.
Netted from air	1,128	542	48	342,000	±31,000
Guywire strikes	1,193	502	42	388,000	±25,000
Ground counts	449	160	36	460,000	±58,000

*Calculations based on 163,655 adults banded through the end of 1966.

Wetmore's estimates for 1923, for example, indicate a total population of 5,500 (3,500 for Johnston and 2,000 for Sand). One photograph made on Sand Island during that period, however, shows over 1,200 birds. Since this picture probably did not include more than a fraction of the total, and the total using the island during the day is never more than a third or half the night population, the actual number using the island during July 1923 probably was similar to the numbers using the island during the same periods in the 1960's--15,000 or more.

One would expect that this species might have been reduced by the disturbance on the atoll, but there is no evidence for this either. The density of nesting birds is as great as in any colony known in the central Pacific. There are still small areas not occupied on Sand Island, however, that cannot be adequately explained in any other way than that they are not required by the birds. There appears to be an overfolding of subcolonies, after the initial peak of nesting has occurred, but this may be entirely renesting birds or late-breeding young birds that would not require more territory. During the initial buildup, there probably is more crowding than in most other colonies where they have room. There is, however, no evidence that the colony actually suffers from the amount of crowding imposed by the birds having to nest entirely on the east end of Sand Island. In 1957, Moynihan found them nesting in two widely separated groups, neither of which apparently completely covered the respective ends of the island on which they were found. His description indicates that less area may have been covered then than during POBSP studies, which may mean the population was reduced then and has increased greatly since 1957. Repeated destruction of eggs, young, and adults, that almost had to occur throughout the war years, probably reduced the populations considerably and they may still be increasing and readjusting to the more stable conditions now existing.

Sooty Tern colonies are almost universally unpopular with military personnel who have to live close to them, so there no doubt was much unrecorded harrassment of the population on Johnston, which has had to live closer to humans than any other known. That the colony now is as large as it is probably indicates a good ability to reproduce rapidly enough to repopulate the islands soon after afflicting disturbances were removed.

Nesting success in recent years has been quite high with up to 60,000 fledglings produced each year.

Annual Cycle

Chronology of the major events in the Sooty Tern annual cycle are shown in Figures 37, 100, 101, and Table 68.

The lowest numbers occur in October and November, when only a few individuals and small flocks visit the island briefly and irregularly. These wandering, non-breeding birds almost never land on the island; there are no data as to the origin of these birds; however, they are likely Johnston-based birds. Potential breeding birds are first attracted to the island in late November or December.

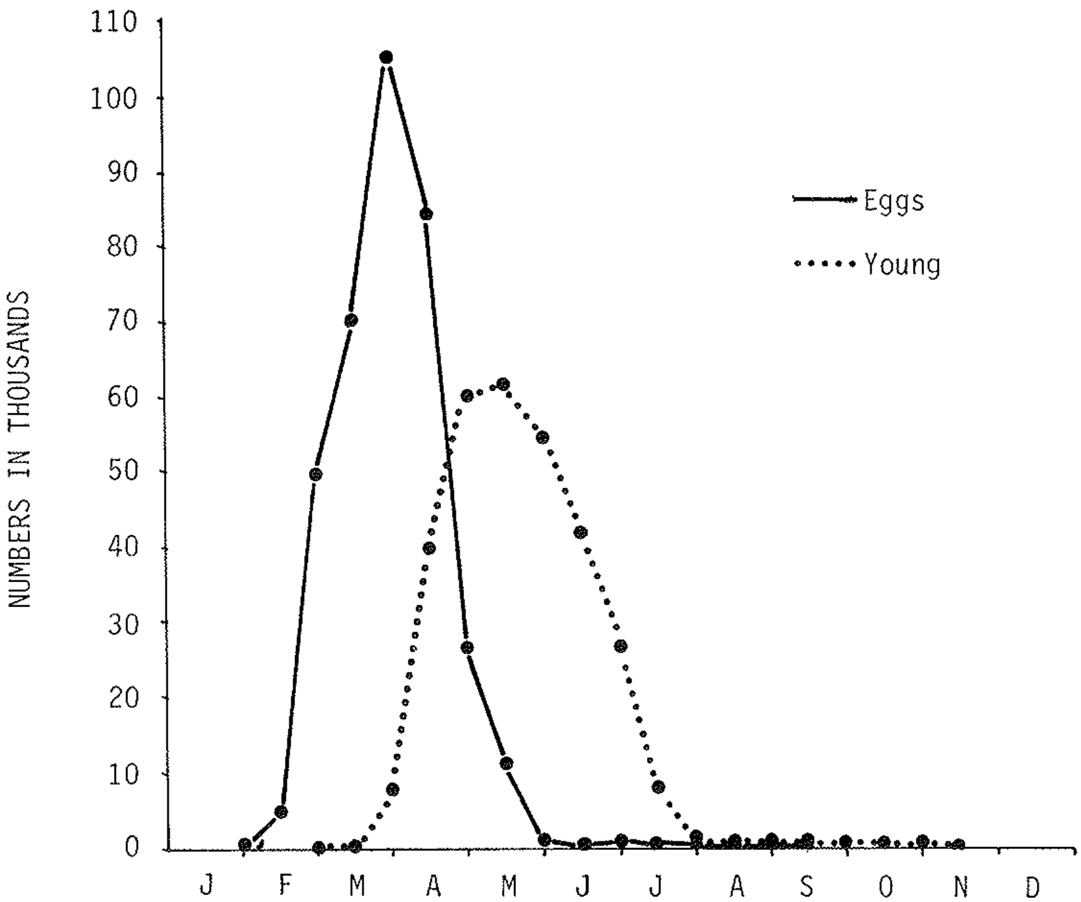


Figure 101. Means of semimonthly estimates of Sooty Tern eggs and young, Sand Island, Johnston Atoll, 1963-1969.

Table 68. Extreme dates of significant events in the breeding cycle of Sooty Terns, Sand Island, Johnston Atoll, 1963-1969

Year	First Swirls At Night	First Birds on Ground	First Eggs	First Eggs Incubated	Egg Peak	First Hatching	First Fledging	Last Eggs Present	Last Fledging
1963-4	16-31 Dec.	16-31 Dec.	1-15 Feb.	16-29 Feb.	16-31 Mar.	18 Mar.	1-15 May	16-31 Aug.	Oct.
1964-5	23 Nov.	14 Dec.	5 Feb.	10-15 Feb.	10-20 Mar.	14 Mar.	5 May	20 Sept.	16-30 Nov.
1965-6	23-27 Nov.	15 Dec.	28 Jan.	19-23 Feb.	1-15 Apr.	25 Mar.	16-31 May	31 Aug.	20-25 Sept.
1966-7	1-15 Dec.	31 Dec. (possibly 2-3 on 26th)	19 Feb.	23 Feb.	*ca.* 31 Mar.	25 Mar.	15 May	before 15 July	1-10 Sept.
1967-8	?	?	14 Feb.	17 Feb.	Apr.	14 Mar.	14 May	? Aug.	? Sept.
1968-9	mid-Nov.	?	27 Feb.	5 Mar.	10-11 Apr.	3 Apr.	26 May	19 Aug.	--

Sooty Terns at Johnston Atoll breed on an annual cycle. From 1964 through 1971 egg laying usually began in mid-February (± 15 days) and reached a peak in March. Laying usually continued into April and virtually ceased by mid-May. Sooty Terns have about a mean incubation period of 29 days (1969 data: range 27-32 days, 151 eggs) and about a 75-day fledging period. Thus first chicks usually appeared by mid-March and started fledging by mid-May. Once able to fly, young usually remain in the vicinity of the colony for about three weeks after which they departed with at least one parent. Most adults and fledglings leave by late July but last fledglings usually left by September; a few have remained into November.

During their nesting season--February through July--Sooty Terns make up about 97 percent of the bird population on the atoll; they are almost completely absent from September through November (Harrington, 1973).

Banding data have shown that youngest age of breeding is four years, but most individuals do not breed until ages six to eight, and a few probably do not breed until age ten. During their years prior to breeding, adolescents visit Sand Island, but not until they are at least two years old, and usually not until four or five years old. Most two-year-old birds return after adults have finished breeding, whereas non-breeding five- or six-year-old birds return earlier, about one to two months after most eggs have been laid. Because of very aggressive breeding older adults, the majority of these visiting adolescents remain flying over the colony. Some older birds do, however, land in non-breeding areas. Young adults nest later and in less desirable habitat than experienced breeders, tend to group with their own peers, and usually have similarly inexperienced mates (Harrington, 1973 and 1974).

Specimens

In all 236 Sooty Tern specimens have been taken at Johnston Atoll (Appendix Table 7); these constitute a new published specimen record.

Banding and Interisland Movement

In all, 285,526 Sooty Terns--164,798 adults and 120,728 young--were banded by the POBSP at Sand Island from 1963 through 1969 (Table 24). Of these birds, 55,206 were recaptured back on the atoll (Table 25) and 172 were captured elsewhere (Table 26). In addition, 132 banded elsewhere were captured at Sand Island.

Movement between Johnston Atoll, and the Line and Phoenix Islands has been recorded only 17 times. None of these records, however, has been substantiated by any collections, nor has there been even so much as a single orange-streamer sighting on land or at sea in that area. Furthermore, some of the records were obvious errors because of age discrepancies; others may have been because of band prefix number confusion by inexperienced banders. Thus few, if any, Sooty Terns from Johnston move to the Line and Phoenix Islands area.

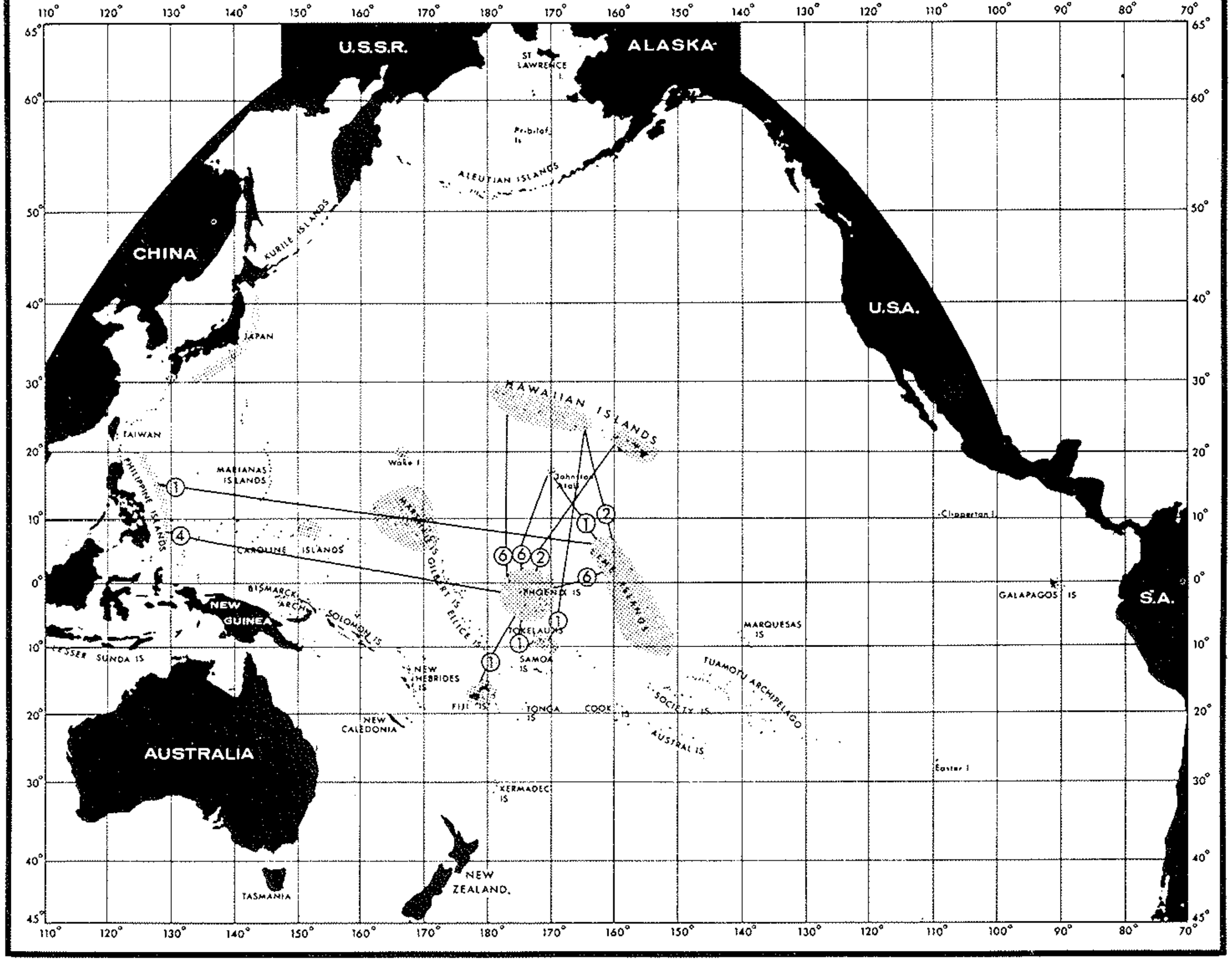


Figure 102. Interisland movement of Sooty Terns involving the Hawaiian Islands, Johnston Atoll, and Wake Atoll (Gould, 1974b).

The remaining Sooty Tern interisland movements have been between Johnston and (1) the main and northwestern Hawaiian Islands (68 birds to Johnston, 112 from), (2) the northern Marshall Islands and Wake (58 birds to Johnston, 17 from), and (3) the western Pacific (24 birds from Johnston).

Gould (1974b) has elaborated on Sooty Tern movement in the north-central Pacific. As of December 1968, he noted that the POBSP had processed 1,027 interisland and at-sea movements and 339 at-sea streamer sightings of Sooty Terns. These represent less than 0.01 percent of the total number banded. Figure 102 summarizes interisland movements of Sooty Terns involving Johnston Atoll. Unfortunately, few of these movements involve known status birds (e.g., breeding, non-breeding), or elapsed times less than the length of one breeding season. Thus he suggested that it was impossible to connect the islands of banding and recapture with meaningful directional arrows.

From recaptures made less than six months after time of banding, however, Gould found that Johnston-banded adult birds were captured in the northwestern Hawiian Islands only during June (one bird), July (three birds), and August (16 birds), and that Wake and northwestern Hawaiian-banded birds were captured at Johnston only during July and August (three birds each month). Thus during a given breeding season adult Sooty Terns were moving from island to island within the north-central Pacific only during the summer months, or the latter half of each breeding season. Furthermore, birds banded at Johnston, the northwestern Hawaiians, and Wake were captured in the western Pacific primarily during July (one immature), August (one immature), September (one adult and one immature), November (one adult), and December (one adult); only one immature was taken in March. This suggests that northcentral Pacific adult and immature Sooty Terns go to the western Pacific at the end of each breeding season.

Gould noted that of the 28 POBSP-banded birds (12 of which were banded at Johnston Atoll) captured in the western Pacific, 20 were probably driven there by typhoons and tropical storms. By analyzing the origin and pathways of these storme he was able to determine at least part of the Sooty Tern non-breeding range. This area was between 5° N and 20°N and between 170°E and the Philippines.

At-Sea Distribution

The Sooty Tern is the most abundant species in the northern grid, 175 miles southwest of Johnston. There are significant differences between the annual population curves of the grid and the breeding colony at Sand Island.

In the grid (Fig. 103), Sooty Terns arrive in January and build to high numbers in April and May; density then drops to a lower plateau until August, but peaks again in September. On Johnston (see Fig. 100), birds arrive in late December, build to high numbers during the breeding peak in late March and April, and maintain these high numbers during most of the summer. During the breeding peak most Johnston birds are laying and incubating eggs. This leaves half the breeding population, as well as the non-breeding population, free to travel relatively great distances (probably up to 300 miles) for food. The presence of spring peak numbers of orange-streamered birds (Table 69) within 50 miles of Johnston in March and in the grid during April (Fig. 104) support this. As the young hatch and grow, a greater and greater premium is placed on feeding nearer to the breeding island thus causing a decrease in grid numbers to the lower level from June through August. With the fledging of chicks in August, Sooty Tern numbers near Johnston decreased markedly especially in October. Immature birds were recorded within the grid from June through December, with greatest numbers present in September and October. Orange-streamered immature birds were recorded only during June, July, and August, with largest numbers in August.

Table 69. Orange-streamered Sooty Tern sightings within a 50-mile-radius of Johnston Atoll and in the at-sea grid 175 miles southwest of Johnston Atoll, 1964-1967

Month	50 Mile Radius from Johnston	Grid
January	0.18	0.00
February	0.00	0.00
March	0.96	0.13
April	0.26	0.81
May	0.76	0.53
June	0.83	0.57
July	0.05	0.52
August	5.18	0.36
September	0.66	0.00
October	0.00	0.00
November	0.00	0.00
December	0.00	0.00

The September grid peak was probably caused by a transient population moving through the area. This was supported by the fact that no orange-streamered birds were observed in September, and that only at this time were terns most abundant in the southwest half of the grid, which is farthest from Johnston. In addition, most birds were flying southwest (48 percent) and south or southeast (26 percent), and not toward Johnston.

The complete lack of diurnal Sooty Tern sightings (see Fig. 103) but high nocturnal numbers (Fig. 105) in January was a real and consistent phenomenon. Except for 1967, Sooty Terns were also virtually absent from the grid during the day in February, but were present in large numbers at night. At this time large numbers swirled around Sand Island at night, but disappeared during the day. Many of these were found within a 50-mile radius of the atoll, but not enough to account for the large nocturnal numbers over the island.

Food within the grid may not be available during the daytime in January, and perhaps only very irregularly in February. This was partially supported by the almost total absence of feeding flocks of any species at this time. Johnston-based birds may be feeding in other, as yet undetermined, distant areas and returning through the grid at night to join the nocturnal pre-breeding swirl over Sand Island. Just why no Sotty Terns pass through the grid during any part of the day, however, remains a mystery (POBSP, 1967a; Gould, 1974b).

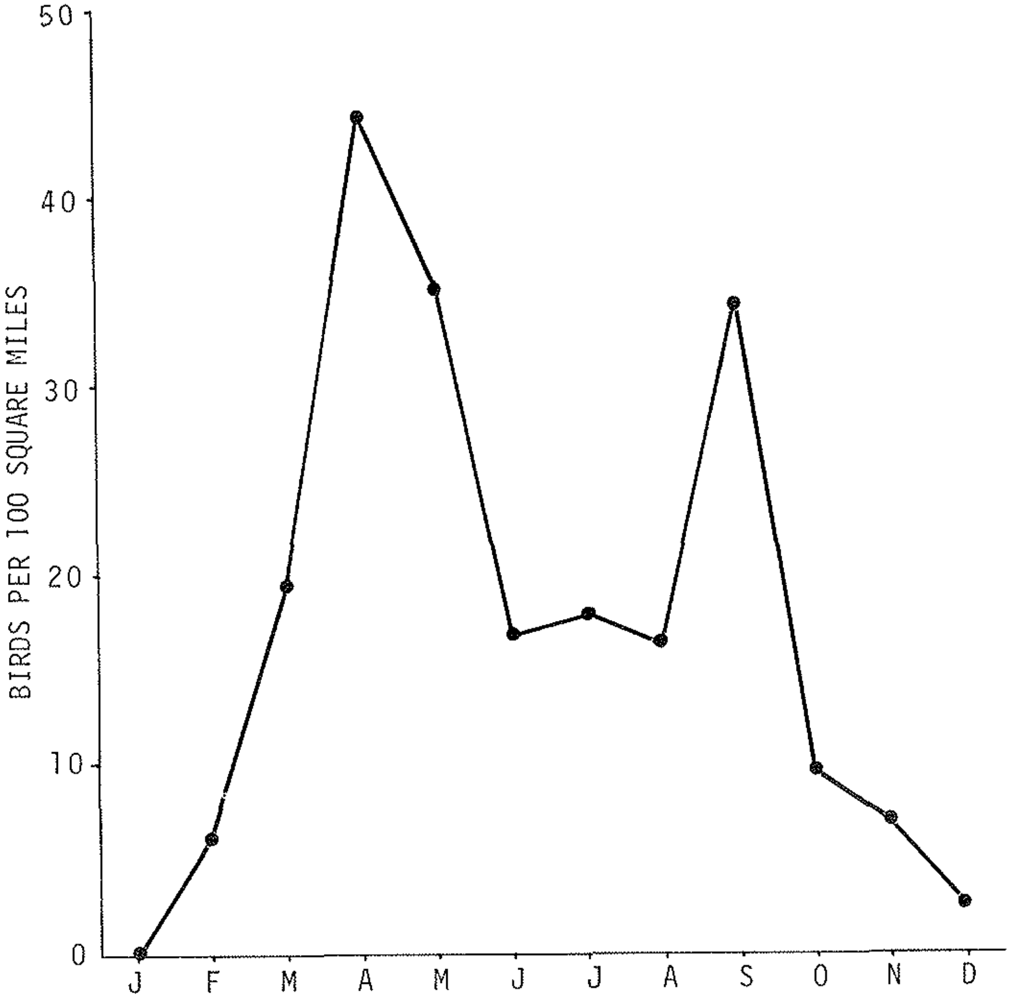


Figure 103. Diurnal occurrence of Sooty Terns at sea 175 miles southwest of Johnston Atoll, 1963-1967.

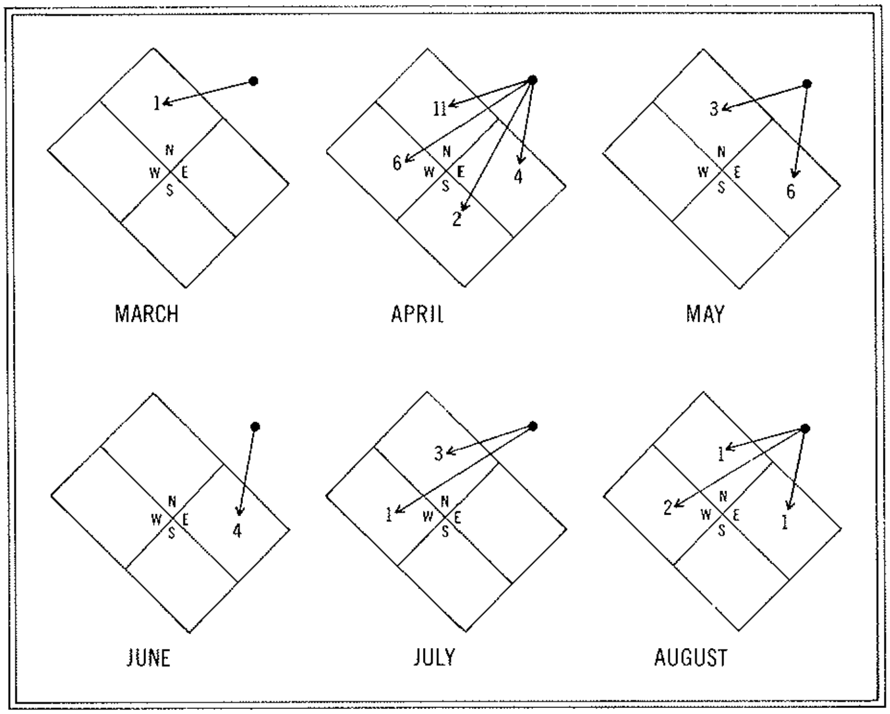


Figure 104. Orange-streamered Sooty Tern sightings at sea 175 miles southwest of Johnston Atoll, 1964-1967; dots: Johnston Atoll, numbers: actual sightings within each quadrant.

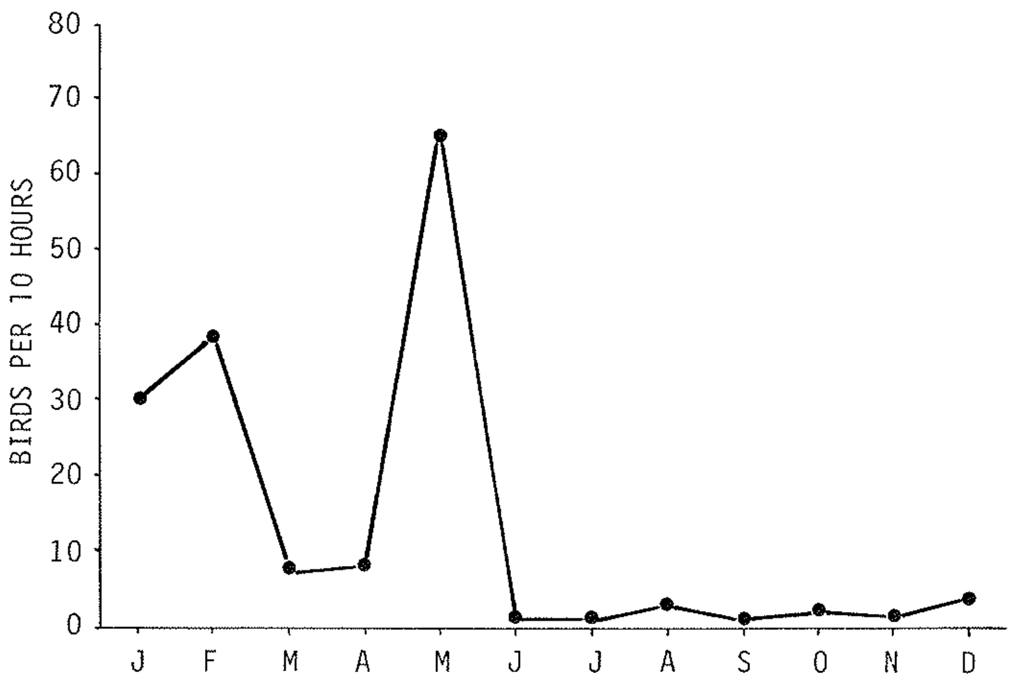


Figure 105. Nocturnal occurrence of Sooty Terns at sea 175 miles southwest of Johnston Atoll, 1963-1967.

ELEGANT TERN *Thalasseus elegans*

Status

Accidental; one specimen record from Sand Island.

Observations

Shelton collected an Elegant Tern at the edge of the Sooty Tern colony on the west beach of Sand Island 19 April 1969. The bird had been banded (USF&WS #963-34220) by Monte N. Kirven as a nestling 31 May 1966 at Chula Vista, California, almost 3,000 nautical miles east-northeast of Johnston. When collected, it was in winter plumage, but had almost completed a molt of its flight feathers (outer remiges were not quite full length). The presence of old ruptured follicles in the ovary and a convoluted oviduct indicated that the bird had bred previously. Although the bird was quite thin, its stomach contained a fish 103 mm long.

Specimens

This is a new specimen record for Johnston Atoll, as well as for the central Pacific Ocean.

Elegant Terns breed along the coast of Baja California and in the Gulf of California, wandering in fall north to central California, but wintering along the Pacific coasts of Peru and Chile (AOU, 1957). There are no other known records from the central Pacific.

BLUE-GRAY NODDY *Procelsterna cerulea*

Status

Uncommon visitor; three specimen records and one sight record from Johnston and Sand Islands.

Observations

Wetmore (ms. a) collected two non-breeding adult female Blue-Gray Noddies and saw a third 13 July 1923 "among clumps of grass below a low hill" on Johnston Island. He further noted (ms. b) that "both of those secured were nonbreeding birds, and I suppose that they had come in from the sea to rest." A third specimen, a male, was taken at sea about 50 miles west of Johnston (16°45'N, 170°20'W) on 20 July 1923 as the party was leaving for Wake Island.

There were no further records of this species from Johnston Atoll until 8 May 1967 when Shelton collected a young female as it roosted on a broken concrete bunker near the southwest islet.

Another bird appeared at dusk 12 April 1969 and returned to the island at least ten evenings from that date through 3 May, when it was last seen. For the first few nights it roosted on large rocks along the south shore, east of the Great Frigatebird colony, with Brown Noddies and a few Gray-backed Terns. Later it chose a large rock on the south side of the causeway east of the Signal Building, quite alone. For the last ten days it was seen only on the southwest islet where it may have roosted in ammunition slots in the old gun emplacement. Here it was caught, banded (652-49679), measured (Bill: 23mm; Wing; 171mm; Tail: 90mm; Tarsus: 27mm), and released on 24 April. It had no brood patch and was just beginning to replace its primaries and rectrices.

Specimens

The three Johnston Atoll specimens and the one at-sea specimen, noted above and in Appendix Table 7, are deposited in the USNM. These constitute a new specimen record for the atoll.

All three specimens, and the banded bird, belong to the light northern race, *P. c. saxatilis*, indicating that they came from high, rocky, northwestern Hawaiian Islands where they breed.

Banding and Interisland Movement

One Blue-Gray Noddy has been banded at Johnston Atoll (Table 24). No interisland movement of banded birds is known.

At-Sea Distribution

No Blue-gray Noddies were recorded in the grid southwest of Johnston Atoll. The species is, however, considered to be an uncommon visitor to the Johnston area. Wetmore's 1923 observations on the atoll and at sea, as noted above, and recent POBSP observations, suggest that Blue-gray Noddy visits may be less common now that Johnston is inhabited.

BROWN NODDY *Anous stolidus*

Status

Common breeding species; present year-round. Breeds on Sand Island from February through September; bred on Hikina Island for the first time in 1973; previously bred on Johnston Island. Second most abundant spring-summer breeder numbering about 3,000 maximum and producing about 1,000 fledglings each year. Nesting is primarily on the rougher areas, peripheral to the nesting Sooty Terns.

Ecological Distribution

Hikina Island: Brown Noddies nested here in May 1973 (BSFW, 1973); eight nests containing eggs and 40 adults were observed. Amerson reported two flocks of about 100 adults each roosting here in November 1973; two partially constructed nests, containing no eggs, were seen in *Sesuvium*.

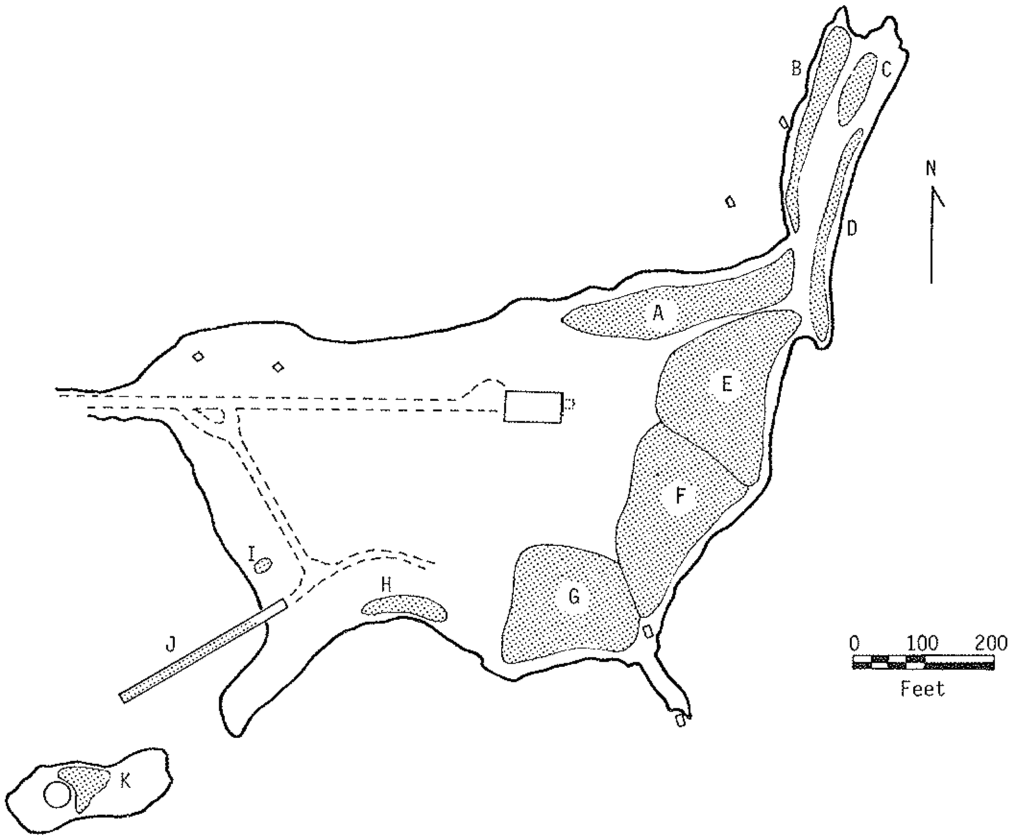
Johnston Island: About 1,500 Brown Noddies were observed nesting here in July 1923 by Wetmore (ms. b). Fennell (1948) saw a few at the end of the runway in 1948. None has been recorded since, most likely because of human disturbance.

Sand Island: Wetmore (ms. a) found about 800 here 10-17 July 1923 and described the colony as follows.

> About half have eggs; the rest young from newly hatched to grown. The newly hatched young are about evenly divided between light and dark.
>
> The nests of these birds are interesting. Some eggs are laid on bare sand or rock, others are deposited on a platform of grass with a slight central depression. Frequently the nest cavity contains ornaments in the form of entire shells, bits of larger shells, the calcareous opercula of cat's eye mollusks, bits of bone, a cranium or a mandible, or an odd shaped piece of wood. It is always of interest to look over the collection and before now I have been guilty of filching some pretty shells from the lot.
>
> Mating actions are of interest. The male with neck erect and bill pointing down patters rapidly off across the sand perhaps in a semicircle to pause finally and look down as though at a nest. He then returns to his mate and the two rise and swing off in erratic circles with a synchronism of movement that holds them always 15 or 18 inches one above the other.

Moynihan (1957) observed approximately 200, but only a few reproductive activities in April 1957; pairs held territories on either side of the causeway (alternating with Gray-backed Tern territories) and on the periphery of the Sooty Tern colony on the original portion. Davis (1962) saw relatively few on Sand Island in 1959-60, even though it was not inhabited by man at the time. He noted that they isolated themselves from the Sooty Terns. POBSP personnel found Brown Noddies to be common from 1963 through 1969. Amerson also found them here in November 1973.

Brown Noddies on Sand Island nest almost exclusively on the ground. The only exceptions were those few that nested on the old dock before it was burned in late 1967, and the occasional nest found on a concrete pillar in the intertidal zone of the south shore. Primary nesting areas were on the periphery of the island, in rougher, more rocky areas than Sooty Terns, and peripheral to them (Figs. 43 and 106).



PLOT	DATE	NUMBER OF ADULTS	EGGS	NESTLINGS	LOCALS	IMMATURES
A	8	15	9	0	0	0
	15	25	10	0	0	0
	23	25	14	0	0	0
	30	?	4	0	0	0
B	8	160	104	0	0	0
	15	150	104	11	0	0
	23	150	81	5	12	0
	30	?	50	15	22	0
C	8	26	18	0	0	0
	15	30	13	0	0	0
	23	30	17	0	0	0
	30	?	12	5	0	0
D	8	60	28	1	1	0
	15	75	31	0	2	0
	23	50	30	1	2	0
	30	?	21	3	2	1
E	8	40	14	0	0	0
	15	25	11	0	0	0
	23	40	15	0	0	0
	30	?	30	0	0	0
F	8	50	14	0	0	0
	15	60	18	0	0	0
	23	75	27	0	0	0
	30	?	30	0	0	0

PLOT	DATE	NUMBER OF ADULTS	EGGS	NESTLINGS	LOCALS	IMMATURES
G	8	60	38	0	0	0
	15	100	44	1	0	0
	23	100	56	1	1	0
	30	?	41	6	6	0
H	8	6	2	0	0	0
	15	1	1	0	0	0
	23	1	1	0	0	0
	30	?	0	1	0	0
I	8	1	1	0	0	0
	15	1	1	0	0	0
	23	1	1	0	0	0
	30	?	1	0	0	0
J	8	12	10	2	4	0
	15	15	11	2	4	0
	23	10	8	1	3	3
	30	?	7	0	3	3
K	8	100	80	0	3	0
	15	150	86	6	3	0
	23	150	114	7	8	1
	30	?	64	11	23	1

Figure 106. Brown Noddy nest distribution and abundance, Sand Island, Johnston Atoll, April 1967.

Nests were described by Wetmore in 1923. Then as now, the nests varied from nothing at all--egg laid on bare sand--to loose aggregations of vegetation, shells, and bird bones with a shallow central depression. Table 70 shows the composition of several 1968 nests. An interesting addition to the naturally occurring materials were the orange plastic streamers used by the POBSP for marking birds; these frequently occurred in the nests. Nests were placed on bare sand, in *Tribulus*, or *Boerhavia* clumps, or more rarely in the top of a *Lepturus* clump (Figs. 107 and 108).

Roosting Brown Noddies generally preferred exposed peripheral areas, including the southwest islet, northeast peninsula, and the east slope. In addition they roosted on the guywires, guywire anchors, and navigational aids throughout the lagoon. The latter habitat group was heavily used by non-nesting birds, including recently fledged young. During the winter, when breeding activity was minimal, roosting was restricted to the most exposed of these areas, especially the peninsula, islet, east-southeast slope, and guywires. At the onset of reproductive activity, more birds occupied the nesting areas themselves.

The relationship between Brown Noddies and Sooty Terns is poorly known. Noddies begin nesting earlier than sooties, and their first nesting areas almost invariably are the southwest islet, the old dock, and the northeast peninsula, indicating that the species has natural affinities for more isolated areas.

A photograph taken in 1923 shows Brown Noddies roosting thickly on the bare spot on Sand Island where guano was dug (near center of southwest area). No Brown Noddies were ever seen nesting this far inland during POBSP studies, but the area always was covered thickly with nesting Sooty Terns at that time of year (July). With Sooty Terns able to spread out more in 1923, Brown Noddies apparently also occupied areas (particularly in the interior) to which they do not now have access because of the density of Sooty Terns. Rough peripheral areas were used by the Brown Noddies in 1923, as indicated by Wetmore's notes. Relative numbers in the various areas were not precisely indicated.

There was only one instance of Sooty Terns being attracted to Noddies during the time sooties were swirling and first settling on the ground. On 31 December 1966 about 50 sooties landed among noddies roosting near the frigate colony along the south shore. Conflicts for nesting space did not occur until later in the season, when both species were near their breeding peak. In September 1967, Shelton observed an adult Brown Noddy thoroughly thrash an adult Sooty Tern, apparently in defense of a small noddy chick. Brown Noddies made at least a small part of their living pirating food from Sooty Terns and other birds. They were observed flying over the Sooty Tern colony looking for adults feeding young. The noddy then swooped low and pulled the fish or squid from the Sooty Tern. They have also been seen snatching food dropped by birds being chased by Great Frigatebirds.

As Sooty Terns abandoned the northeast peninsula, the east hill, and southeast slope in early September 1966, there was an apparent move of

Table 70. Nesting material used by Brown Noddies, Sand Island, Johnston Atoll; observations by B.A. Harrington, about 1 May 1968

Material	Nest sites: North shore of northeast section in *Boerhavia*	North shore of northeast section on top of *Lepturus* clump	West shore of peninsula on coral ridge	West shore of peninsula on coral ridge	West shore of peninsula on coral ridge	West shore of peninsula on coral ridge	Peninsula, on *Scaevola* patch	Peninsula, on *Scaevola* patch	Peninsula, base, east side on rocky beach next to patch of *Sesuvium*	Peninsula, base, east side on rocky beach	East slope, on bare sand	East-southeast slope, in *Tribulus*	East-southeast slope, in *Tribulus*	Occurrence
Tribulus	70%	20%	100%			100%			50%		100%	39%	100%	8
Lepturus		80%						10%						2
Sesuvium							100%							1
Boerhavia										100%		49%		2
Coral & Shell	25%				100%			90%	30%			10%		5
Bird bones,	1%											2%		2
crab leg,	1%													1
eggshell	3%													1
Plastic debris									20%					1
No Material				100%										

Figure 107. Brown Noddies and Sooty Terns on the southwest portion of Sand Island, Johnston Atoll, July 1923. Johnston Island is visible in the background (B. P. Bishop Museum photo by Chapman Grant).

Figure 108. Brown Noddies nesting and roosting on the southwest islet, Sand Island, Johnston Atoll, 9 May 1967 (POBSP photo by P. C Shelton).

roosting noddies from the guywires back to the ground in these same areas. Accurate before and after counts were not made, however, and in 1967 it did not appear that the change was as significant. Previous observers had noted an increase in noddy nests on the east hill after Sooty Terns left, but were unsure the increase was real or resulted from more accurate counts after the other birds thinned out. Also in early September 1966 there was an increase in Brown Noddy guywire strikes. In September, nine were killed while earlier in the summer no more than two per month were killed.

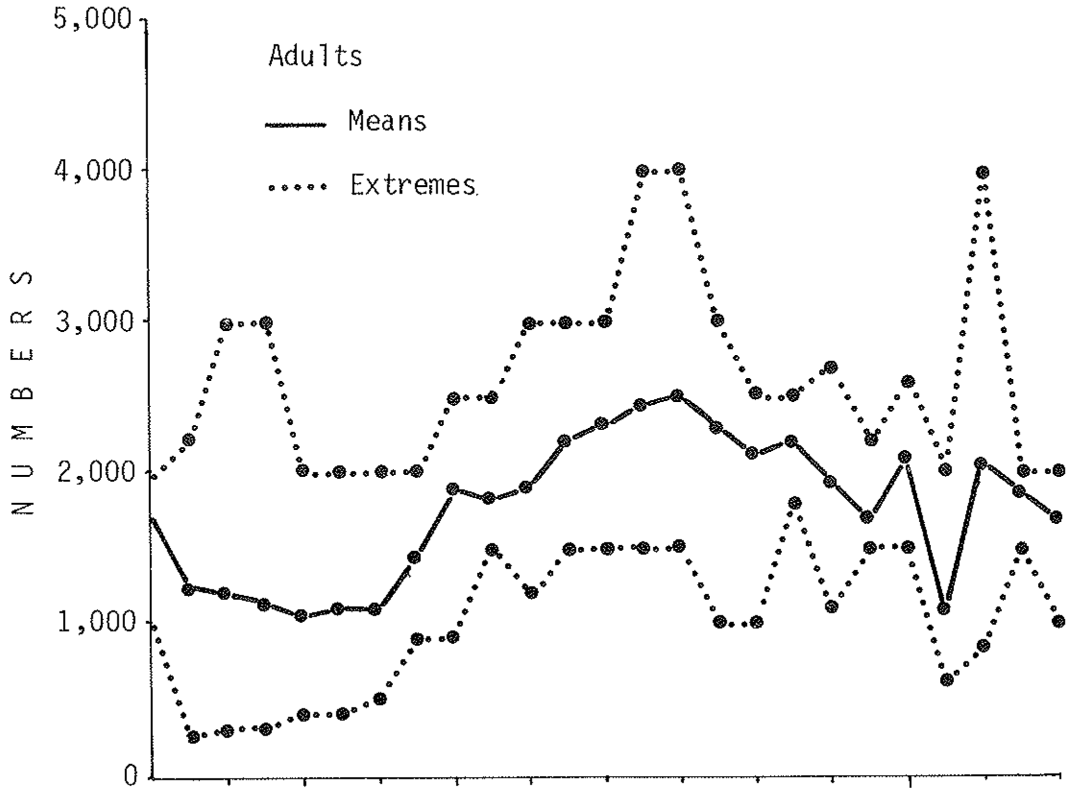
The relationship between Brown Noddies and Gray-backed Terns is also poorly known. In 1965 and 1966, Brown Noddies crowded Gray-backed Terns from the distal portion of the old dock, where the gray-backs had begun roosting and nesting before the build-up of noddies. In December 1966, gray-backs were roosting on the entire dock early in the evening, but noddies came in later, crowding the gray-backs to the proximal one-third of the dock. On the peninsula in 1965, at least, the two species apparently nested fairly close together without conflict.

Populations

Using the Brown Noddy population level that existed in 1923 as a norm, populations appear to have declined markedly during and after the war years, but seemed to have regained that level during the 1960's. Wetmore's estimates of 1,500 on Johnston and 800 on Sand Island agrees closely with POBSP estimates for July, except that all birds were on Sand Island. Moynihan's observation of 200 birds in 1957 and Davis' observations of "relatively few" in 1959-1960 indicate that the population must have been severely depleted, probably as a result of successive nesting failure during periods of intensive military activity on the islands. Recovery was rapid after this period, for by 1963-1964 the population had risen to over 2,000 birds, and to about 3,000 through 1969. This can only be attributed to the nearly non-disturbed condition that exists on the original portion of Sand Island.

Figure 109 shows mean semimonthly population estimates by POBSP from 1964 through 1969. Maximum numbers present at any one time was about 3,000 adults. Total numbers using the island annually was estimated to be between 6,000 and 12,000 birds. This species is never entirely absent from the atoll, and numbers drop significantly only in mid-winter, with relatively stable numbers throughout the rest of the year.

Variations between day and night numbers are significant, and differ between seasons. During the mid-winter low, most birds are present only at night, with only a few (mostly recently fledged young) on the island during the day. Adults (and presumably several-month-old young) arrive back on the island mostly within the period one half to one hour after sunset. These night roosting populations are difficult to estimate, and they may be larger than the figures indicate. It is possible, if not probable, that the number of Brown Noddies using the island does not decrease significantly during the winter, but that the length



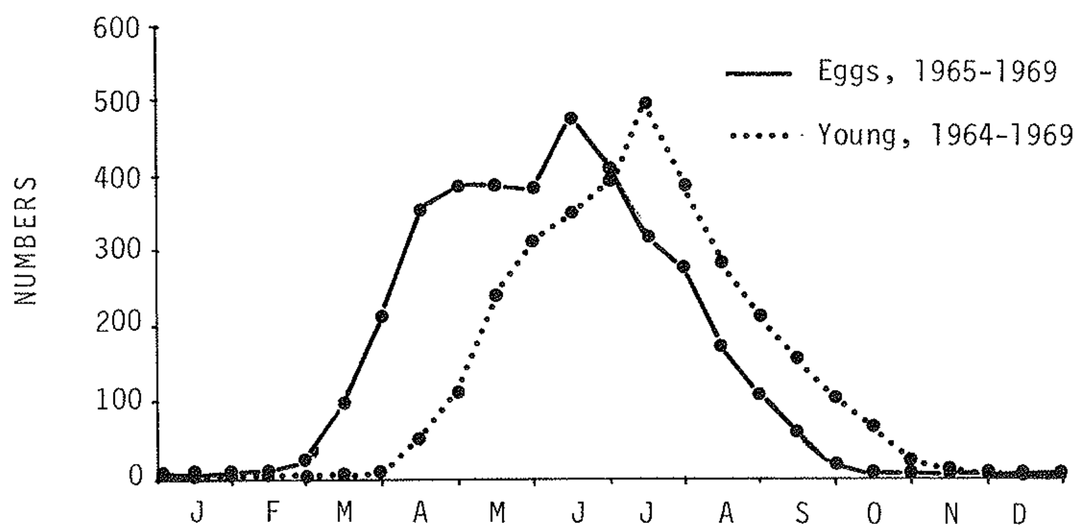


Figure 109. Means and extremes of semimonthly estimates of Brown Noddy numbers, Sand Island, Johnston Atoll, 1963–1969.

of time spent away from the island by individual birds increases. This gives the impression of fewer birds simply because there are fewer at any given time, although the total number has not decreased. As the nesting season approaches, the numbers present during the day increased markedly.

Estimates of the total number of birds using the island were crudely calculated from banding data.

In March 1967, two samples were counted to determine the proportion of birds on the population that was banded. On 7 March, 81 birds were counted on the peninsula and southwest islet, and of these 81, 27 birds (33 percent) were banded. A second sample on the islet only, made 23 March, showed 17 (34 percent) of 50 birds to be banded. Since the two samples were not mutually exclusive (parts or all of both were from the islet), they cannot be added together. Thus, the second, smaller sample from the islet alone, was deleted. Samples should have been taken all around the island, on the same day if possible, with the total number of birds counted at least several hundred.

Banding data show that young were seldom recaptured until they were three years old. Therefore the number of previously banded birds used for calculating a population estimate includes all adults banded through 1966 and all young banded through 1964, a total of 2,961 birds. The calculated population from these figures was 8,880 (±2,790) or 6,090 to 11,670.

There are, of course, serious limitations to these figures, chief among which are the following: (1) the actual rate of recruitment of young birds into the adult population was not known; (2) the samples were small (confidence limits wide) and were taken from only two areas on the island, which may not adequately represent the entire island population; (3) the turnover in adults through immigration, emigration, and deaths was not known; (4) banding was not uniform in the age groups represented.

The young produced before 1964 were either not banded at all (those hatched before 1963) or very lightly (1963). These birds would be treated as adults as they returned to the population, which they should have done. Even the 1963 birds should have been on the island in fair numbers in 1966, when adult banding was at about the same level it had been in earlier years. The 1964 cohort was banded more heavily than any other in this sample, and the presence of large numbers of these in the sample would inflate the percent banded, which would tend to make the estimate lower than reality.

In summary, the population of Brown Noddies on Johnston Atoll (Sand Island) probably possesses the following characteristics. Maximum number present at any one time: about 3,000 adults. Total number using the island 1963-1967: 6,000 to 12,000, plus 1,000 young produced each year in 1965 and 1966.

Productivity: Nesting success from 1964 through 1969 averaged about 1,000 young fledged each year. This is reflected in the number of young banded each year:

Year	Number Young Banded
1964	763
1965	1,071
1966	807
1967	650
1968	1,440
1969	806

The 1967 figure of 650 is minimal since no young were banded after early September. The 1969 figure of 806 is also minimal for 46 nestlings and 159 eggs remained in early September; the total number of young produced probably was about 1,000. In all, 2,222 eggs were laid from March 1969 through early September 1969, suggesting a nesting success of approximately 38 percent for that period.

Egg and chick mortality records were kept for a little over a month during the summer of 1964 on study plots on the south shore and northeast peninsula. These figures showed losses to be 15 to 20 percent of the 175 eggs present and about 25 percent of the 100 chicks studied being lost within the first month after hatching.

Other figures for egg and chick loss are not available, but this species probably has a lower rate of loss than most other birds on the atoll. Brown Noddies generally appear to be more aggressive in defense of their nests than most other species, and losses to abandonment and natural forces are considered low. Exceptionally high tides do, however, occasionally inundate nests near the water, especially on the islet and northeast peninsula. Guywire maintenance work for the LORAN-C tower was not particularly disruptive of this species in 1966, but they were said to suffer most in early June 1964. Quantitative data were not recorded either year. Predation by two cats disrupted two study plots in August 1964; again quantitative data on losses were not recorded.

Color Phases of Young: Brown Noddy young range in color from pure black to pure white. Whether discreet categories exist is debatable, and the genetic basis for the variations is totally unknown. Records kept in 1964, 1965, 1966, and 1967 show that of 573 chicks examined, 34 percent were white, 29 percent were gray, and 37 percent were black. Whether all observers used the same points to distinguish the categories is not known, but the data are fairly consistent from sample to sample. There was no evidence of seasonal or year-to-year changes in the ratios, and no evidence that it varied on different parts of the island. Incubation periods recorded in 1964 did not vary with the color phase of the chicks.

Annual Cycle

Figures 37 and 109, as well as Table 71, show the important aspects of the Brown Noddy cycle on Sand Island from 1963 through 1969. Brown Noddies have perhaps the longest breeding season of any species on the atoll. A few eggs or chicks may be found at any time, but the largest numbers occur from February through September. At other times, eggs occur irregularly and are widely scattered.

In most years courtship and nest site selection became noticeable by the end of January, and eggs were laid in February, only a few at first, but increasing to ten to 25 by the end of the month. Egg production increases through March and April; numbers hold fairly steady until July and decline through August and September, the latter being the last month in which more than a few scattered eggs are found.

The mean incubation period for 93 eggs was 35.6 days (range 30 to 41 days, 1964 data). Fledging required about six weeks. Extensive growth and development data were taken on this species in 1964, but these data have not been analyzed.

Daily egg laying, hatching, and losses were recorded for the end of the 1964 and 1966 breeding seasons on the northeast peninsula (Table 72). These data show that the number of new eggs, and new chicks per semi-monthly period, was about the same for these two years, indicating little annual variation in the breeding season.

Individual cycles have not been followed through the breeding season, but a few banded adults were recaptured on eggs or chicks at about the same time in successive years. Also, there were several examples of birds found on eggs at two different times during the same year, sometimes separated by more than the normal incubation time. These probably were birds renesting, but there was no evidence as to what happened to the first egg or chick in these cases. Two successful nestings in the same year cannot be ruled out on the basis of POBSP data, although this is considered unlikely. More careful work with individually marked birds needs to be done.

Several three- and four-year-old birds (banded as chicks in 1963 and 1964) nested in 1967. Table 73 shows that all of these were taken in the last half of the breeding season, although the numbers handled were small in all cases. Further data are needed.

In summary, present data are insufficient to show why the breeding season is extended; it could be because of renesting by birds that lost eggs or chicks, multiple nesting, nesting of younger birds, or even lack of nest space.

Table 71. Extreme dates of significant events in the Brown Noddy breeding cycles, Sand Island, Johnston Atoll, 1964-1969

	First Eggs	Egg Max.	First Hatching	First Fledging	Last Eggs Laid	Last Eggs Hatching	Last Fledging
1964	*ca.* 21 Feb.	15 Apr.- 15 May	1-15 Apr.	?	?	16-31 Oct.	?
1965	1-15 Feb.	16-31 May	16-31 Mar.	?	?	16-31 Oct.	?
1966	(1-15 Dec. 1965)* 16-28 Feb.	16-30 Apr.	16-31 Jan.	?	3 Nov.	13 Nov.	?
1967	before 31 Jan.	16-30 Apr.	before 15 Mar.	*ca.* mid-May	?	?	?
1968	*ca.* 1 Jan.	late June	*ca.* 1 Feb.	*ca.* mid-Apr.	?	16-31 Oct.	15-30 Nov.
1969	20 Mar.	mid-Apr.	24 Apr.	*ca.* 10 June	?	?	?

*First eggs (2) appeared 1-15 Dec. 1965; 1 to 3 eggs present through 15 Feb. 1966; first significant egg increase (21) appeared 16-28 Feb. 1966.

Table 72. Daily egg laying, hatching, and losses for Brown Noddies, Sand Island, Johnston Atoll, July-September, 1964 and 966

Period	1964 New eggs	1964 New chicks	1964 Eggs lost	1964 Eggs remaining	1966 New eggs	1966 New chicks	1966 Eggs lost	1966 Eggs remaining
July 1-15	27	41	10	72	26	52	?	*ca.* 60
16-31	13	29	12	44	18	16	*ca.* 20	*ca.* 42
Aug. 1-15	9	16	14	22	8	20	9	21
16-31	4	7	2	17	1	9	2	11
Sept. 1-15	1	10	2	6	0	7	2	2
16-30	0	3	3	0	0	2	0	0

Table 73. Known age Brown Noddy recaptures taken from eggs or chicks, Sand Island, Johnston Atoll, 1967

Date	Total handled	3-yr.-olds (1964 chicks: 763 banded) No.	Percent	4-yr.-olds (1963 chicks: 124 banded) No.	Percent
4-5 May	10	0	0	0	0
30 June	9	3	33	0	0
17-24 July	11	6	55	1	9
8 Sept.	7	1	14	2	29
	37	10	27%	3	8%

Banding data suggest that most adults return each year. An insufficient number of banded one- and two-year-old birds have been recaptured to determine how many of these birds remain on the island, but at least some do. They probably spend a greater portion of their time on inaccessible roosts, making their capture more difficult. Data presented earlier indicate that many, if not all, three-year-olds return to the island and nest, probably mostly late in the season.

Table 74 shows available data on primary molt in Brown Noddies on Sand Island. March and April birds, none of which was known to have eggs or chicks at the time, were nearly finished replacing their primaries, indicating that this occurs shortly before egg laying. Birds taken on eggs during June or later had, however, begun to replace their primaries before the chicks had hatched. The process apparently continues while the chick is growing and is completed shortly before egg laying in the next year. The consistency of occurrence of molt during incubation argues that this is not a phenomenon confined to renesting birds who lost eggs or chicks earlier in the year, but that it occurs in all incubating birds. Also, the young adults, hatched in 1964 and nesting in late 1967, all showed primary molt while they were incubating; it is virtually certain that these were not renesters.

Table 74. Primary molt scores of Brown Noddies, Sand Island, Johnston Atoll

Date	Status or Source	No. handled	Primary Molt score (Ashmole, 1962) Mean	Range
March 1967	Returns	6	82.5	56-100
	Guywire kills	5	100	100
Apr. 1967	Returns	3	99	96-100
	Guywire kills	3	100	100
June 1967	Returns, on eggs (1964 young)	3	10	6-12
	on chicks (banded as adults)	5	18	10-26
	all other	15	10.6	0-22
July 1967	Returns, on eggs (1963-64 young)	7	10.3	0-22
	(banded as adults)	3	24	18-32
	on chicks (banded as an adult)	1	24	?
1-15 Sept. 1966	Guywire strikes	4	25.5	6-36
16-30 Sept. 1966	Guywire strikes	5	40	26-52
21 Sept. 1966	Returns	2	17	2-32
Sept. 1967	Off eggs	11	24.6	3-41
	From air	6	24.7	1-38
		5	irregular or interrupted	

Specimens

The POBSP has collected 78 specimens of Brown Noddies from Sand Island. Wetmore took six skins from the islands in 1923 (Appendix Table 7). All these are in the National Museum of Natural History collections. These constitute a new published specimen record.

Banding and Interisland Movement

From 1963 through 1969, the POBSP banded 7,979 Brown Noddies on Sand Island (Table 24). Of these, 882 recaptures have been made back on the atoll (Table 25).

In all, there were 31 interisland movements of Brown Noddies involving Johnston Atoll (Table 26): 24 banded on Johnston have gone elsewhere and seven banded elsewhere have been captured on Johnston. Sixteen such movements were between the northwestern Hawaiian Islands and Johnston, while 15 moved in different directions, including islands in the western Pacific and islands near or south of the equator.

At-Sea Distribution

Within 100 miles of Johnston Atoll and compared with other Johnston breeding species, Brown Noddies were fifth in abundance during spring months. They were absent from at-sea observations from December through February, and July (POBSP, 1965). In the grid area 175 miles southwest of the atoll (Table 21), they were absent from January through July, excepting April (POBSP, 1967a).

BLACK NODDY *Anous tenuirostris*

Status

Uncommon breeding species; present year-round. A few pairs nest on *Amaranthus* bushes on Sand Island each spring and produce about three fledglings; up to 100 visiting non-breeding birds roost on antenna guywires. A few nested in *Casuarina* trees on Johnston Island in 1973.

Ecological Distribution

Johnston Island: Wetmore (ms. a) wrote in 1923: "19 July: One reported by Grant. I thought I heard one calling on first arrival here but was not certain." POBSP personnel observed three Black Noddies roosting here 23 June 1967. Amerson recorded eight adults, one flying immature, and three inactive nests in the *Casuarina* trees next to the tennis courts in November 1973.

Sand Island: Moynihan (1957) recorded 6-10 April 1957: "Some five or six Black Noddies spent considerable periods of time resting in two low bushes on the side of the causeway. They showed no reproductive behavior of any kind."

POBSP personnel found them nesting and roosting only on the original portion of Sand Island from 1963 through 1969. Amerson observed a few roosting at night in November 1973. All but one Black Noddy nest were placed in *Amaranthus* plants less than two feet high, growing in the areas southwest and southeast of the transmitter building (Figs. 44, 110, 111, and 112). One pair in 1967 nested in a high clump of *Lepturus* southeast of the transmitter, near other nests in *Amaranthus*. Nests seven to ten inches in diameter, with a shallow center cup about three inches in diameter, were constructed mainly of *Tribulus*, with small amounts of *Boerhavia* and *Lepturus*; excreta helped hold each nest together.

Most roosting birds used the northeast outer guywires, but others used such places as the northeast and southeast inner guywires, rockpiles, the old pier, the fence around the transmitter tower, the rocky west peninsula shore, and *Tournefortia* and *Amaranthus* bushes. No birds were ever reported from the west portion of Sand Island during POBSP studies. The presence of good roosts probably attracts more birds to the island than were present before military occupation.

In 1966 a few Black Noddies roosted on a dead *Amaranthus* bush near the old pier throughout July, but abandoned the perch in August when Sooty Terns stopped using the surrounding area. At all other roosting places Black Noddies were in company with large numbers of other species, mostly Brown Noddies.

Populations

Figure 113 shows the means the extremes of semimonthly population estimates of Black Noddies from 1963 through 1969. The population is composed of two elements: (1) a small resident breeding population numbering no more than 13 pairs, and (2) transient birds numbering about 150 which are probably non-breeders from the northwestern Hawaiian Islands.

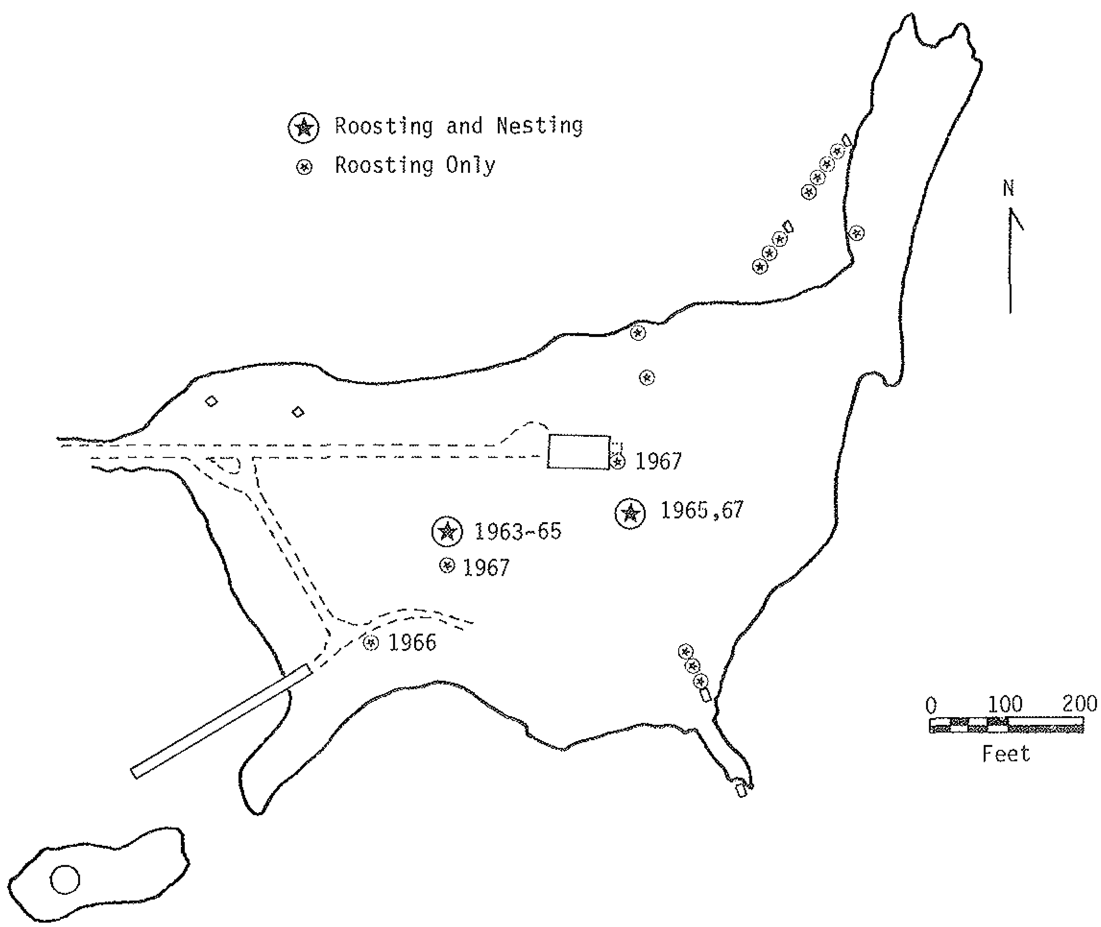


Figure 110. Black Noddy nesting and roosting areas, Sand Island, Johnston Atoll, 1963-1967.

Figure 111. Black Noddy nest in *Amaranthus* plants south of the transmitter building, Sand Island, Johnston Atoll, 7 May 1967. Sooty Tern adults and chicks nearby (POBSP photo by P. C. Shelton).

Figure 112. Black Noody nest with 12-day-old chick in *Amaranthus* plant south of the transmitter building, Sand Island, Johnston Atoll, 4 June 1969 (POBSP photo by P. C. Shelton).

Although neither Wetmore nor Moynihan found evidence of this species nesting in 1923 or 1957, it is possible that nesting occurred at least irregularly in those years. A successful breeding season could have been completed and most birds dispersed before Wetmore's July 1923 visit, and a breeding season could have begun after Moynihan's April 1957 visit. The ability of this species to nest in low vegetation, especially in *Lepturus*, here and elsewhere suggests that the lack of bushes or high vegetation before military occupancy would not necessarily have prevented breeding. The presence of more suitable bushes since military occupancy, however, appears to have increased the breeding population.

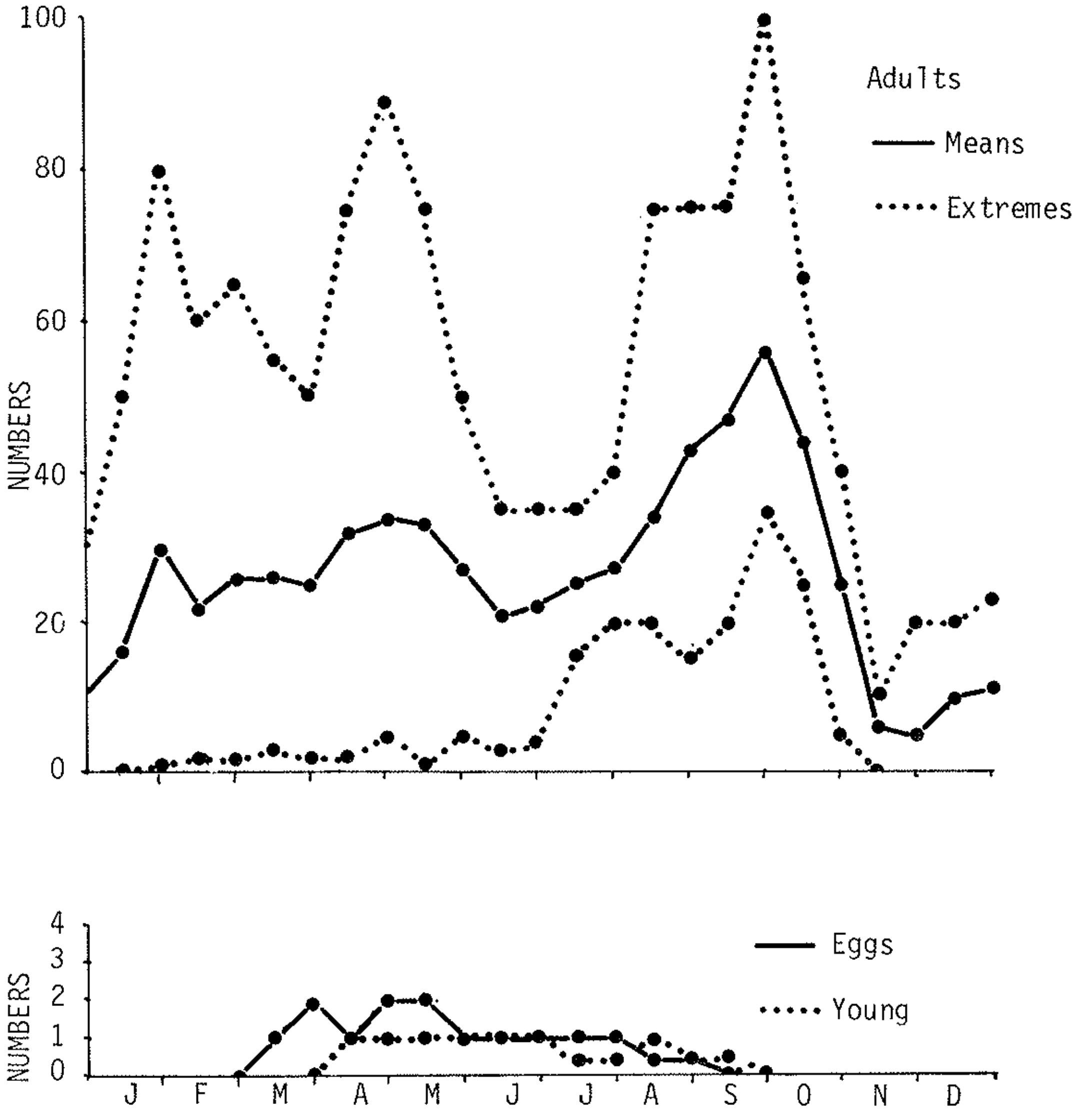


Figure 113. Means and extremes of semimonthly estimates of Black Noddy numbers, Sand Island, Johnston Atoll, 1964-1969.

From 1964 through 1969, excluding 1966 when none nested, an average of seven eggs (range three to 13) were laid each year (Table 75). An average of four eggs hatched (range three to seven); hatching success was 60 percent. An average of only three chicks (range two to six) fledged during these same years. Thus nesting success during that period was 46 percent.

Table 75. Nesting success of Black Noddies on Sand Island, Johnston Atoll, 1963-1969

		Eggs Hatched		Chicks Fledged		
Year	Eggs laid	No.	%	No.	% of eggs laid	% of eggs hatched
1963*	--	--	--	4	--	--
1964	13	7	54	6	46	86
1965	8	3	38	2	25	67
1966	0	0	--	0	--	--
1967	3	3	100	3	100	100
1968	7	5	71	3	60	43
1969	6	4	67	3	50	75
Totals**	37	22	60	17	46	77

*Data incomplete, observations began 7 July.

**Excluding 1963.

The maximum number of eggs laid in one year was 13 in 1964; if all these were first eggs (no renesting), then there would have been a maximum of 26 breeding birds that year. Whether more of the roosting birds, particularly those roosting on bushes rather than on guywires, were potential nesters which failed to nest for lack of suitable habitat is not known. Separate counts and closer observations should have been made on these birds.

POBSP population estimates of roosting Black Noddies were based on counts made in the various roosting areas, or of birds encountered during routine operations on the island. It is suspected that birds frequently were missed, especially at times of year when other birds were abundant and occupied most of the observer's time. Few birds came in to roost until heavy dusk, and maximum numbers were not present until well after dark. They could have been easily confused with Brown Noddies that roosted on many of the same locations.

Only in 1967 was there an attempt to determine how many birds may have used the island during the year. Table 76 shows calculations based on the number of streamered birds observed on the roosts. The slow gradual increase in calculated numbers present from 19 March through 16 April (when no additional birds were marked) indicates that the turnover rate was slow. Also, the figure for 27-29 August was not significantly different from those derived in March and April, although no birds had been handled since May. The presence in August and September 1967 of several birds with streamers put on before 1967 indicates that many of the same birds may return year after year.

Table 76. Calculations of numbers of Black Noddies using Sand Island, Johnston Atoll, 1967

Date	No. counted	No. marked	No. previously marked	Calculated population (95% of C.L.)
19 March	49	6	15	123±93
31 March	26	4	15	98±92
7 April	62	7	15	133±90
16 April	65	5	15	195±168
20 April	83	9	18	166±104
30 April	71	5	19	269±234
27-29 August	25	4	25	156±143

Although the confidence limits for the estimates in Table 76 are large, the consistency strengthens their validity. The conclusion drawn from these data is that the number of Black Noddies using Sand Island during a year is presently approximately 150 birds, which is about twice the highest number seen at any one time.

It is fairly likely that roosting Black Noddies have increased since 1923. Daytime populations are never more than a few birds, and it is not likely that Wetmore's party overlooked a roosting population which was present only at night. Moynihan did not visit Sand Island at night, when maximum numbers would have been present; thus it is possible that the 1957 population was as large as that found in the 1960's when daytime numbers also were seldom more than a few birds. It is possible that few birds used the island until military construction and subsequent abandonment increased available roosting habitat.

Nearly all birds roosting on guywires during POBSP observations were non-breeders. In February, March, and April 1967, 18 birds were handled: 17 from the northeast outer guywire and one from the shore of the peninsula. All of these birds were in some stage of primary molt, except for one bird which had all new feathers (Table 77). None had bare brood spots. Presumably most of these were from the northwestern Hawaiian Islands (one had been banded there).

Annual Cycle

The annual cycle of Black Noddies at Johnston Atoll is shown in Figures 37 and 113.

Breeders: The nesting cycle shifted slightly from 1964 through 1969 (Table 78). The cycles were similar in 1964 and 1965. In 1966 they did not nest at all. In 1967, first eggs were laid a month and a half later than in 1964 and 1965, while first eggs for 1968 and 1969 were laid a month later than in 1964 and 1965.

In 1964 and 1965, birds appeared on the nesting areas in February, and courted and built nests by the end of that month; first eggs, as well as the egg peak, occurred in the first half of March. First eggs appeared in late April in 1967 and in early April during 1968 and 1969. Eggs occurred usually through early July, but did extend through August in 1964. The few eggs laid later in the year--especially in 1964--may have been replacements for eggs lost earlier, but no data were obtained. The data from the end of the season in 1963 indicated that the cycle that year may have been about the same as in 1964 and 1965.

No eggs were known to have been laid in 1966. Only a few birds were present during the normal time of initiation of nesting, and they were seen only sporadically on the *Amaranthus* bushes on which nesting normally occurred. More intensive activity by POBSP personnel banding Sooty Terns may have, however, discouraged the Black Noddy nesters. Disturbance by the antenna maintenance crew in May would have discouraged only late nesters.

Individual breeding cycles of Black Noddies are among the shortest of any species on Johnston Atoll. Incubation of three 1965 eggs and seven 1969 eggs averaged 34.2 days (range 33 to 37 days), and fledging of two 1965 chicks and three 1969 chicks averaged 38 days (range 34 to 46 days). First chicks appeared in early April in 1964 and 1965, and late May in 1967, 1968, and 1969. Young were present normally into August, but have remained until early September. Young usually stayed around the nest area for at least a few weeks after fledging, but quickly became difficult to distinguish from adults.

One young bird, banded as a nestling in 1964, returned and nested in late April 1967. Thus young of this species may nest as early as three years old. More data would be necessary to determine if this is the normal age of first breeding.

Table 77. Primary molt scores of Black Noddies caught roosting on Sand Island, Johnston Atoll, February-April 1967

Month	No. handled	Primary Molt score (Ashmole, 1962) Mean	Range
February	11	62	18-100
March	3	47	14-70
April	4	64	49-82
Total	18	60	14-100

Table 78. Extreme dates of significant events in the Black Noddy breeding cycles, Sand Island, Johnston Atoll, 1964-1969

	First Eggs	Egg Max.	First Hatching	First Fledging	Last Eggs Laid	Last Eggs Hatched	Last Fledging
1964	1-15 Mar.	16-31 Mar.	1-15 Apr.	16-31 May	16-31 July	1-15 Aug.	*ca.* 1 Oct.
1965	6 Mar.	March-May	9 Apr.	25 May	16-30 June	16-31 July	27 May
1966	No eggs known to have been laid in 1966						
1967	16-31 Apr.	Late Apr.	16-31 May	1-15 July	1-15 July	16-31 July	Late Sept.
1968	8 Apr.	Late Apr.	20 May	24 June	25 June	28 July	2 Sept.
1969	2 Apr.	Late Apr.	22 May	2 July	2 June	6 July	28 July

Non-breeders: The seasonal fluctuation in numbers of roosting birds is difficult to discern, but there appears to be a low peak in spring, probably correlated with the breeding season on Johnston Atoll, and a slightly higher peak in fall, probably correlated with the post-nesting dispersal of birds from the northwestern Hawaiian Islands. These fluctuations are not entirely predictable from year to year. Periods of complete absence occurred only in November and December of 1965, 1966 and 1968. Personnel on the island during these times were familiar with the Black Noddy roosting areas, and checked them fairly regularly; therefore, it is not doubted that the birds were absent from the island during these two periods. The low number present during the first half of 1966 is not understood. Here also, the observers present were familiar with roosting and nesting areas, and would not have missed birds if more were present.

Specimens

POBSP personnel collected six Black Noddy specimens at Johnston Atoll (Appendix Table 7). This constitutes a new specimen record for the atoll.

Banding and Interisland Movement

The POBSP banded 152 Black Noddies on Sand Island from 1963 through 1969 (Table 24). Of these 152, 20 have been captured back on the island (Table 25) and five have been captured elsewhere (Table 26): French Frigate Shoals (three birds), and Lisianski Island and Kure Atoll (one each). In addition, five birds banded elsewhere have been taken on Sand Island; they are from French Frigate Shoals (four birds) and Lisianski (one). Thus many of the non-breeding birds are presumably from the northwestern Hawaiian Islands.

At-Sea Distribution

Black Noddies were never observed in the POBSP grid centered approximately 175 miles southwest of Johnston Atoll (POBSP, 1967a). They were, however, sighted within 100 miles of Johnston Atoll during April and May (POBSP, 1965). These data suggest that Black Noddies at Johnston Atoll do not go far from the Atoll to feed.

WHITE TERN *Gygis alba*

Status

Uncommon breeding species; present year-round on Johnston Island. During spring and summer small numbers attempt to nest in trees, on buildings, or antennas, but few are successful. Previously bred on Sand Island, but presently only an occasional visitor.

Ecological Distribution

Johnston Island: Brooke (ms.) observed White Terns on Johnston Island on 16 March 1859: "As I returned to the Captains hut I saw a beautiful white bird perched under the edge of a low cliff. Creeping cautiously up I took it in my hand. It was very beautiful, a species of tern, with blue bill black eyes and snow white plumage."

Wetmore (ms. b) in July 1923 observed "About 40 frequented the larger, higher rock ledges along the beaches of Johnston Island, where they nested in two small colonies. Nests held eggs or newly hatched young." These are shown in Figure 114.

During or before World War II construction destroyed all of this rocky habitat. These birds, however, have readily adapted to man-made structures and tree-nesting. Clark (1945b) recorded a few in May 1945 and Davis (1962) found an egg and a chick on a *Casuarina* branch in 1959-1960.

All POBSP observations of nesting were under eaves of buildings, on water towers, or on antennas until 1969. Birds were most frequently found roosting in *Casuarina* trees, especially the ones on the dispensary, northeast of the control tower, and to a lesser extent by the tennis courts. In February and March 1967, pairs were seen in and around *Coccoloba* trees on Johnston Island and hovering over a large *Tournefortia* bush on Sand Island, possibly looking for nest sites.

In 1969, Shelton recorded White Tern nest sites located on the large dish antenna stored on the south side of the taxiway (Fig. 115), in the *Casuarina* north of the post office, in the *Casuarina* and *Tournefortia* north of the tennis courts, and in the *Coccoloba* east of the control tower. Amerson found a few roosting in these same localities in November 1973.

Remains of White Terns that cats may have killed were found twice on Johnston Island (March 1965 and February 1967). Cats could prevent nesting in trees, and certainly would eat any young birds found on the ground.

Sand Island: Moynihan (1957) found five pairs breeding on the original portion in trees or on abandoned houses in April 1957. From 1963 through 1969 POBSP observers recorded only occasional birds visiting Sand Island; none nested here. Few birds actually roosted; roosting spots included the LORAN-A antenna, the LORAN-C antenna and fence, and the *Casuarina* near the barracks. Amerson recorded a pair roosting in the *Casuarina* east of the barracks in November 1973.

Populations

There is no evidence for a change in numbers of White Terns using Johnston Atoll from 1923 to the present. The 40 reported by Wetmore

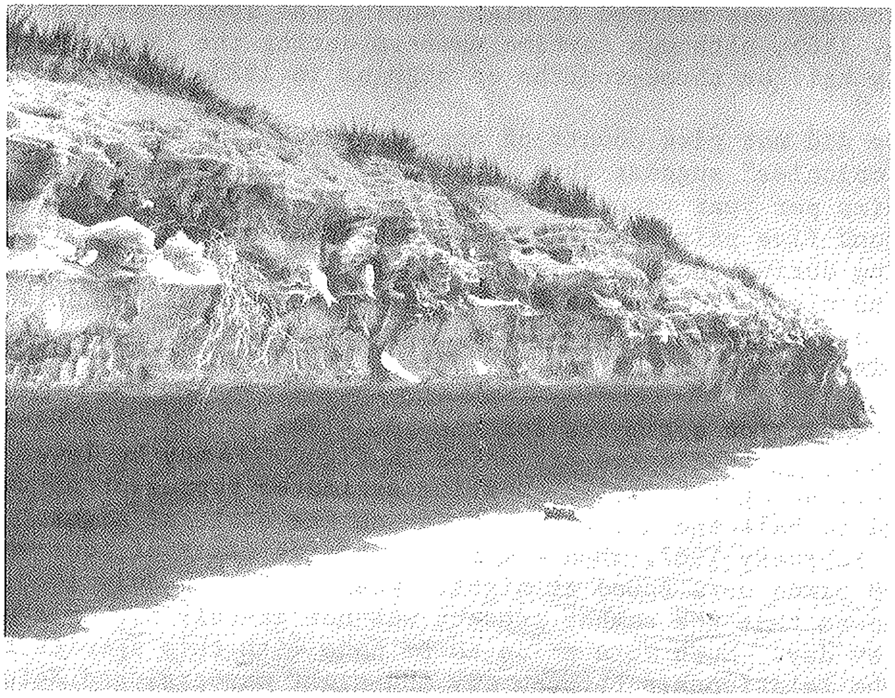


Figure 114. White Terns roosting on undercut beach rock on shore of Johnston Island, Johnston Atoll, July 1923 (B. P. Bishop Museum photo).

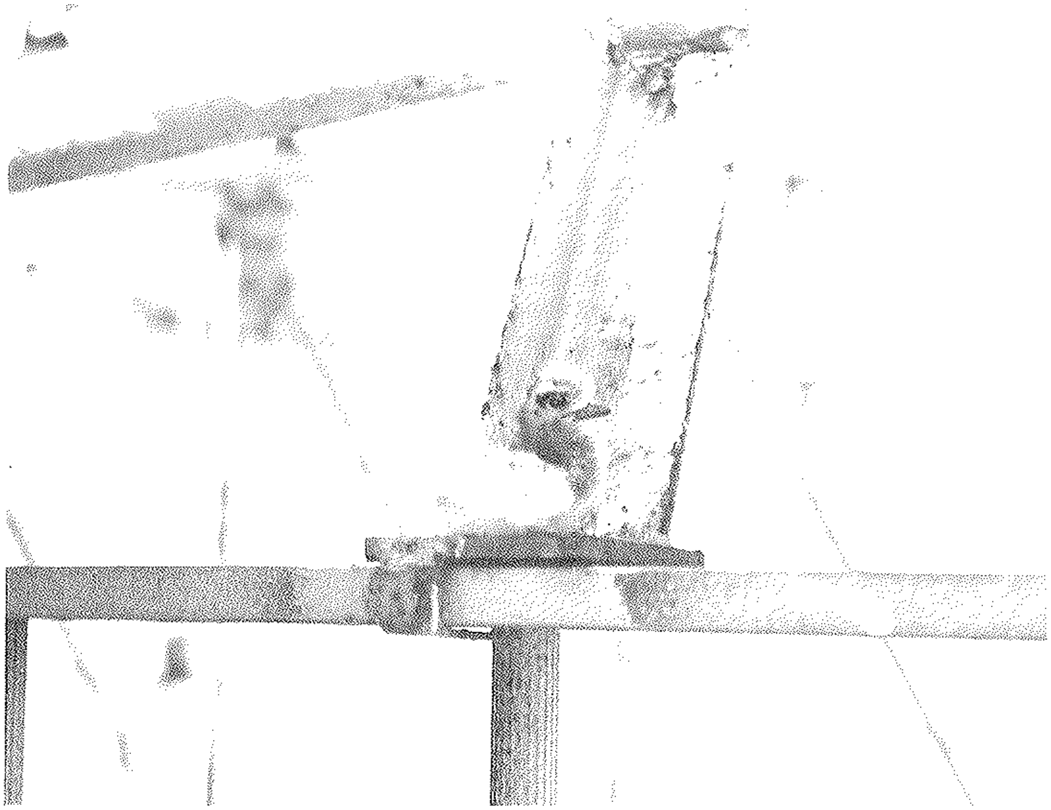


Figure 115. White Tern chick hatched on framework of old radio telescope, Johnston Island, Johnston Atoll, 19 June 1969 (POBSP photo by P. C. Shelton).

for 1923 probably was matched at night during the 1963-1969 POBSP study period (Fig. 116), although daytime numbers during the 1960's were usually only half or three-fourths as high as in 1923.

Wetmore did not give counts of eggs or chicks in 1923, but his "two small colonies" suggest that more birds nested then than the two or three pairs per year recorded during most POBSP years. In 1957 Moynihan found five pairs incubating. This is also more than ever found nesting during POBSP studies except for 1969 when 11 pairs nested. There were no clear indications that populations were higher during 1923, 1957, and 1969; it may be simply that more were able to breed because of less human disturbance.

Since population estimates for the 1963-1969 period were based on daytime counts, the estimates presented in Figure 116 may be lower than actual numbers using the atoll. Daytime estimates represent no more than a third to half the numbers roosting on the atoll at night. For example, in February 1967, when a maximum daytime count of four was recorded, 59 birds were found at night. Dusk counts in July 1966, however, showed that the number present was not greatly higher than those seen by day. Much more needs to be done with this species to determine the relationship between day and night numbers, and actual population fluctuations through the year.

Annual Cycle

Figures 37 and 116 show the annual cycle for White Terns at Johnston Atoll from 1963 through 1969.

The few known eggs during the 1963-1969 period were all found from February through May, and all chicks fledged by September. In 1969 at least 11 eggs were laid and six chicks probably fledged. Moynihan's observations of eggs and almost fully grown young in early April 1957 suggest that egg laying must have occurred by January at the latest. The presence of eggs in July 1923 extends the nesting season well into the summer. White Terns at Johnston have a longer breeding period than their counterparts in the northwestern Hawaiian Islands. There, eggs are known primarily from April through July, and chicks from May to November.

The mean numbers indicate a broad maximum in mid-summer and a low in mid-winter; maximum numbers were about four times the lowest numbers counted. The maximum was roughly correlated with the nesting season, or followed it by one or two weeks.

Banding was insufficient to yield good information on population turnover, but suggests that the rate may be rapid. In 1965, when 13 birds were banded and streamered in April, May and June, only one of 20 birds counted in early July had an orange streamer.

Specimens

Fourteen White Tern specimens have been taken from Johnston Atoll (Appendix Table 7). Six adults and one downy chick were preserved as

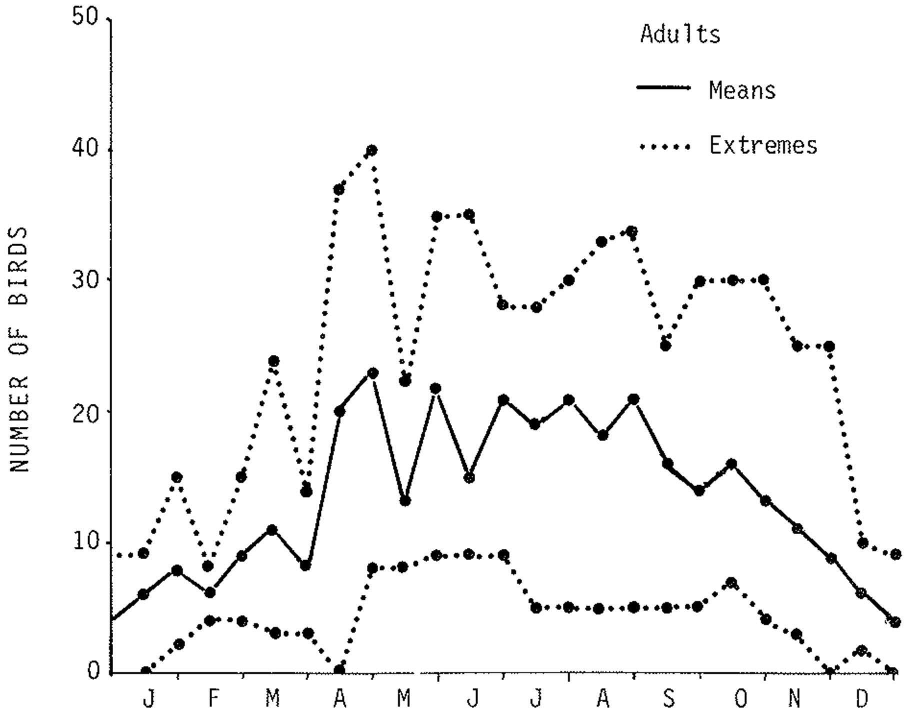


Figure 116. Means and extremes of semimonthly estimates of diurnal White Tern numbers, Johnston Atoll, 1963-1969.

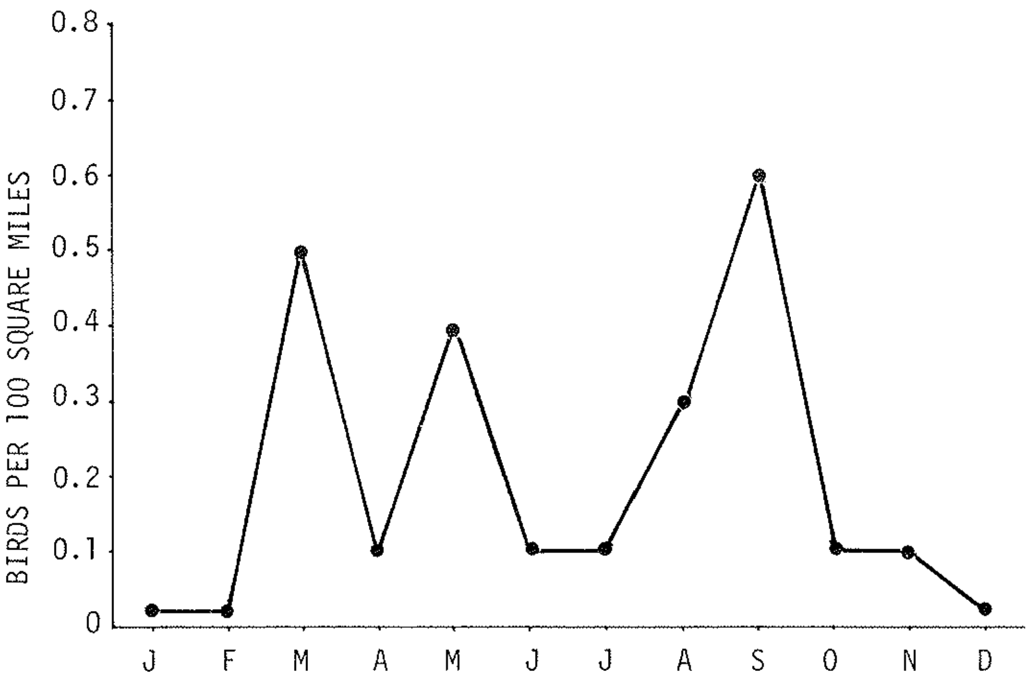


Figure 117. Diurnal occurrence of White Terns at sea 175 miles southwest of Johnston Atoll, 1963-1967.

skins taken by Wetmore in 1923. Six adult skins and one skeleton were taken by the POBSP. All specimens are in the National Museum of Natural History. These constitute a new published specimen record for the atoll.

Banding and Interisland Movement

The POBSP banded 35 White Terns on Johnston Island (Table 24). One of these, banded 29 May 1965, was captured on Tern Island, French Frigate Shoals--450 nautical miles to the north-northeast--on 6 July 1966. Another banded on French Frigate Shoals 4 August 1965 was found dead on Johnston Island 14 February 1967. There were no other inter-island recaptures, and, other than the one streamer observation cited above, no recaptures back on Johnston Atoll.

At-Sea Distribution

A few White Terns were present in the grid southwest of Johnston Atoll throughout the year (Fig. 117). Greatest density occurred in August and September, just after completion of their breeding season on Johnston Island. A small peak occurred in May at the beginning of the breeding season. A high March observation was considered to be a sampling error. Lowest density occurred during the non-breeding season (December through February), while another low density plateau occurred during the breeding season (June and July).

It was apparent that more birds utilize the grid than actually nest at Johnston. Many of these are probably pelagically-oriented non-breeders from the northwestern Hawaiian Islands, who may also occasionally roost on Johnston at night (POBSP, 1967a).

ROCK DOVE *Columba livia*

Status

Introduced breeder. Occurs in relatively small numbers on Johnston Island only.

Observations

According to island personnel, three pairs of Rock Doves, or Domestic Pigeons, were introduced from the main Hawaiian Islands to Johnston Island in 1972. By mid-1973 numbers had increased to about 100 birds. Because they were a nuisance around the military facilities, the population was reduced drastically. None was seen by Kridler (BSFW, 1973) in May and August 1973. As of November 1973 about 30 birds remained. At that time several flocks of various-colored birds were seen about the island, with the largest flock containing 12 birds.

The birds breed on Johnston Island and the young are eaten by island personnel. None is known from the other three islands.

Specimens

The above observations are considered to be a new sight record for this species at Johnston Atoll, as well as a new breeding record.

SHORT-EARED OWL *Asio flammeus*

Status

Occasional visitor; four to six sight records from Akau, Hikina, Johnston, and Sand Islands.

Observations

Moynihan (1957) recorded a Short-eared Owl at Johnston Island in April 1957. POBSP records (Table 79) involve four to possibly six different birds unless observations several months apart were of the same bird.

Intensive observations were made only on the owl present in late 1966 and early 1967 (Schreiber, 1967). From 3 November until the end of 1966 this bird visited Sand Island fairly regularly. When flushed, it usually flew toward Johnston or Hikina Island, suggesting that it roosted on one of these islands when not on Sand. From early January until 24 February it roosted on Sand each day under a *Lepturus* clump about 200 feet southwest of the transmitter building. By mid-January Sooty Terns were landing at night around the owl's roost. The owl left its roost each evening just as the sooties settled; encroaching darkness prevented further observations of its behavior. In late February Sooty Terns began staying on the island all day. The owl roosted in its usual place through the 24th, when the nearest terns were 100 feet away, but abandoned the site on the 25th, when the expanding Sooty Tern horde engulfed it. Through March and April the owl appeared fairly regularly at dusk along the road at the northwest corner of the original portion of Sand Island. During this time it roosted by day on an antenna on the north side of Akau Island. This owl was last seen on the afternoon of 27 April being chased by Sooty Terns over the lagoon west of Sand Island.

From November 1966 through March 1967 owl-eaten carcasses of three Golden Plovers, four Ruddy Turnstones, 13 Sooty Terns, and 15 Brown Noddies were found. The noddies were mostly young birds, recently or not yet fledged. Eight pellets, containing bones of birds and house mice, were also found during this period. Mice were abundant while the owl was present and probably made up a large portion of its diet.

This owl was never seen hunting or eating during the day; freshly eaten carcasses were found only in the mornings, indicating that the bird fed only at night.

Table 79. Observations of Short-eared Owls on Johnston Atoll

Date of Observations		Remarks and References
1957	6-10 Apr.	"One Short-eared Owl...flew out of a small patch of grass one evening" on Johnston I. (Moynihan, 1957: 35).
1964	24 Nov.	One bird flushed from a Wedge-tailed Shearwater burrow on Sand I., circled island and disappeared from sight.
	10 Dec.	One bird, probably the one seen 24 November, flushed from grass near old pier on Sand I. and flew to Johnston I.
1966	19 June-25 July	One bird roosted regularly during day in *Casuarina* tree on Johnston I., and visited Sand irregularly at night.
1967	3 Nov.-27 Apr.	One bird, possibly the one present earlier in 1966, appeared regularly on Sand I. from Nov. until its roosting place was overrun by Sooty Terns in late Feb. Thereafter is apparently stayed on Akau I. most of time, but visited Sand I. fairly regularly.
1969	25 May-July	Found on Sand I. only on 25 May, eating a Sooty Tern; reported on Johnston I. until at least early July.

Reactions of other birds to owls varied greatly. The owl seen 10 December 1964 was chased by frigatebirds and noddies. On Johnston Island in July 1966 White Terns avoided the tree in which the owl roosted, although they normally roosted there. In fall and winter 1966-1967, Red-footed Boobies and Great Frigatebirds roosting on the LORAN-C guy-wires took flight and circled close together when the owl circled above the wires. Frigates on nests flushed if the owl flew high over them, but if it was below about 30 feet the owl passed too quickly for the frigates to react. Shorebirds flushed, gave alarm calls, and joined in tight flocks when the owl was near. Brown Noddies and Sooty Terns only occasionally chased the owl as it flew; they usually ignored it. All these reactions were observed by day, when the owl was flushed and would not normally have been flying. No observations were obtained at night when the owl was hunting.

Specimens

No specimen records are known from Johnston Atoll.

There are resident populations of this circumboreal owl on both the Caroline Islands (*A. f. ponapensis*) and the Hawaiian Islands

(*A. f. sandwichensis*). The Hawaiian population is considerably closer to Johnston, and is the most likely source of the Johnston visitors. Owls have also been recorded from the northwestern Hawaiians. The Short-eared Owl collected on Kure fit measurements of neither the Caroline nor Hawaiian form and was considered most likely of the Holarctic race, *A. f. flammeus* (Clapp and Woodward, 1968; Woodward, 1972).

At-Sea Distribution

A Short-eared Owl was recorded in the at-sea grid about 130 miles west of Johnston Atoll on 16 November 1965 (POBSP, 1965).

SKYLARK *Alauda arvensis*

Status

Accidental visitor; two sight records on Johnston and Sand Islands.

Observations

On 18 November 1963, Sundell saw a bird on Sand Island which was most likely a Skylark. A Coast Guardsman first saw it flying eastward along the causeway in the early evening. Sundell immediately went with the Coast Guardsman and they flushed it "...from the ground in the bunch grass [of the original portion] just after leaving the causeway." His complete description follows: "It was the size of a large sparrow and predominantly brownish streaked on the back and wings and also on at least part of the breast (upper half). There were rather pronounced white patches along the outer edges of the tail and it is quite likely that the bird had a medium-sized crest. The bird flew with an undulating flight but was extremely wary and impossible to approach. When flushed the bird gave a single short, musical call note."

Nine days later, 27 November, U.S. Air Force personnel on Johnston Island reported a small bird of similar description that could have been the same one Sundell saw on Sand.

Specimens

No specimens are known from Johnston Atoll; however, the above observations constitute a new sight record.

Skylarks breed across Europe and Asia, and have been introduced in the main Hawaiian Islands (AOU, 1957). The Johnston Skylark was most likely from Hawaii. One collected on Kure Atoll, however, was identified as *A. a. pekinensis*, which breeds in northeastern Siberia, Kamchatka, and the Kuriles (Clapp and Woodward, 1968; Woodward, 1972).

JAPANESE WHITE-EYE *Zosterops japonica*

Status

Rare visitor; two specimen records and three sightings on Johnston and Sand Islands.

Observations

Records of Japanese White-eyes for Johnston Atoll include two specimens and three sightings of single birds. All records but one were made by POBSP personnel (Table 80).

All birds appeared to be healthy except the one taken 30 November 1965 which was so weak that it was caught by hand; it weighed only 7.9 grams. This bird appeared after four days of unusually strong northeast winds, which may have accounted for its poor condition. For comparison, the mean weight of five other POBSP-collected white-eyes--the other specimen from Johnston Atoll (10 grams) and four taken at sea between Johnston and Oahu (Ely, 1971)--was 10.4 grams (range 9 to 12.8 grams).

Specimens

The two specimens noted above and in Appendix Table 7 were previously reported by Ely (1971).

The white-eyes found on Johnston Atoll and the flocks observed at sea between Hawaii and Johnston presumably came from the population established on the main Hawaiian Islands. The occurrences of white-eyes at sea in October, November, and December, and on Johnston Atoll in October through March, coincide with the non-nesting season in Hawaii, where they breed from February through November (Hawaii Audubon Society, 1967). Although they are migratory only in the northern parts of their native range in Japan, all populations of Japanese White-eyes wander extensively after nesting (Austin and Kuroda, 1953).

Table 80. Records of Japanese White-eyes on Johnston Atoll

Date of Observations		Remarks and References
1964	11-14 Oct.	One bird seen 11, 13, and 14 Oct.; collected 14 Oct., Sand I. (Kepler and Stadel).
1965	29 Mar.	One bird flying about in shrubby trees on Johnston I. (Bratley).
	30 Nov.	One collected near docks, Johnston I. (Kepler).
	15 Dec.	One reported by Commanding Officer, Sand I.
1966	31 Jan.	One in bushes around barracks, Johnston I. (Tordoff).

SOCIETY FINCH *Lonchura striata*

Status

Introduced. Occurs as a caged bird on Sand Island.

Observations

According to Coast Guard personnel, two caged Society (or Bengalese) Finches were introduced on Sand Island in 1972. By November 1973, one was kept caged in the Coast Guard barracks building; the other had previously escaped and no doubt died. No breeding is known.

The Society Finch was probably introduced from the main Hawaiian Islands where it is commonly found in pet stores. The species is native to Southeast Asia.

Specimens

This is a new sight record for Johnston Atoll.

Mammals

There are no mammals native to Johnston Atoll, and none was recorded in the literature before POBSP studies began. A brief summary of the status of the atoll's mammals through 1964 was published (Kirkpatrick, 1966) and the following accounts are based on that publication, with additional notes from 1965 through 1973.

In addition to human occupants, six species of mammals were recorded through 1973 (Table 81). The two rodents probably arrived in ship or plane cargoes, while the dogs, cats, and rabbits were no doubt purposely introduced by military and civilian personnel; all, except for the rabbit, probably first appeared during World War II. The seals arrived from the resident population on the northwestern Hawaiian Islands.

Porpoises probably visit the atoll's lagoon waters, although none has been recorded. They have been reported by island boat operators as regularly occurring outside the main channel entrance.

Species Accounts

The introduced species are well known; however, a description and illustration of the seal can be found in *Mammals of Hawaii* (Tomich, 1969).

Table 81. Distribution and status* of mammals at Johnston Atoll

Species	Akau	Hikina	Johnston	Sand Original	Sand Man-made
House Mouse			B	B	B
Roof Rat			B		
Domestic Dog			R	R	R
Domestic Cat		R	B	R	R
Hawaiian Monk Seal	R	R	R	B	R
European Rabbit			R		R

*B = Breeding; R = Recorded.

HOUSE MOUSE *Mus musculus*

Status

Introduced breeder; abundant on Sand Island, smaller numbers on Johnston Island. Scant data suggest a mid-winter breeding peak; breeding may, however, be correlated with amount of vegetation.

Observations

No house mice had been recorded from Akau and Hikina Islands as of the end of 1969.

Johnston Island: House mice are found in small numbers on Johnston Island. The rodent and insect control program may have indirectly limited the mouse population size.

Sand Island: House mice were recorded as "very numerous" in 1963, and the population remained high throughout the POBSP study period. A live-trapping grid was established in 1964, first with 25 traps placed at five-foot intervals in a 20 by 20 grid. This was later expanded to 48 traps, then to 72 traps placed at intervals of 20 feet except for two rows separated by 50 feet through which passed the road to the LORAN-C transmitter. The final grid covered 27,260 square feet. This grid was trapped on the first seven nights of each month from May 1964 through May 1965. After that the grid was trapped intermittently and infrequently through 1967. Sherman live-traps baited with rolled oats were used.

During 7,329 trap nights from May 1964 through May 1965, trapping success ranged from 31 to 80 percent, and the population was considered to remain high throughout the period (Kirkpatrick, 1966). However, it seems likely that when the trapping success dropped to only 31 percent, there must have been a decline in the population. These data were obtained by or under the direction of Ralph D. Kirkpatrick, who is preparing them for publication.

In October 1966 and February 1967, trapping success in this grid as measured by number of mice caught per trap night was 73 and 74 percent. The calculated population sampled in February 1967 (Hayne, 1949) was about 185 mice, or one mouse per 148 square feet of the grid area. No attempt was made to correct these figures with buffer zones, compensations for trap-shyness or addiction, or any other factors. This area probably was as densely populated as any on the island.

The reproductive condition was analyzed in autopsied mice caught from October 1964 through March 1965, and external examination of breeding condition of animals judged to be adult in the October 1966 and February 1967 samples were made. The 1964-1965 data (Table 82) suggest mid-winter breeding for house mice on Johnston Atoll. However, the 1966-1967 data (Table 83) indicate that a peak in breeding had taken place shortly before October 1966, both because of the presence of lactating females and the high number of young animals that were born during the summer of early fall of 1966. The lack of obviously pregnant females in October suggested that breeding had stopped but pregnant and lactating females in February, as well as more young animals, indicated that breeding probably did not stop.

Table 82. Breeding condition of house mice autopsied, October 1964-March 1965

Date	Number of Females	Percent Pregnant	Mean No. of Embryos	Number of Males	Percent with C.E. Tubules*
October	2	0	-	0	-
November	23	0	-	29	0
December	21	4.8	4	24	37.5
January	19	26.3	5	23	52.0
February	27	3.7	5	17	17.6
March	23	0	-	23	8.7

*Cauda epididymus tubules macroscopically visible.

Table 83. Evidence of breeding condition in house mice live-trapped and released, October 1966 and February 1967

Date	Number Handled	Percent Adult	Sex ratio M:F	% Females Lactating	% Females Pregnant*	% Males with Scrotal Testes
October 1966	110	58	34:27	11	0	71
February 1967	172	65	58:53	8	min. 10	64

*Only those obviously heavily gravid were detected as being pregnant.

In summary, there are too little data to show if peaks in breeding occur, whether there are periods of non-breeding, or with what the fluctuations might be correlated. Subjective impressions indicate that mice are more abundant when the vegetation is more luxurious. For example, in mid-summer 1966, when the vegetation was at a low point in vigor, mice were less noticeable than in winter and spring 1967, when the vegetation was relatively lush.

Although house mice may be found nearly anywhere on Sand Island, they reach their greatest density in the heavy *Lepturus* on the eastern islet, including the area of the grid. Here cover and food are evidently optimum for these rodents. The density in and around the buildings is comparatively low, probably because the buildings are concrete and little if any food is available to them.

Another possible factor influencing mouse abundance may be the insecticides used against roaches. All parts of Johnston Island, and all but the eastern portion of Sand Island are sprayed once weekly with a strong insecticide. It may be more than coincidence that the highest density of mice is on the eastern, unsprayed portion of Sand Island. Mice could be secondarily affected by the chemicals through eating poisoned insects, or simply from contacting it on vegetation and the ground.

There are no indications that mice have any effect upon bird populations on the atoll, except in providing occasional food for three species occurring there--Bristle-thighed Curlews, Short-eared Owls, and Cattle Egrets. Also, dogs and cats prey on them. The food of house mice on Johnston Atoll probably consists mainly of seeds and insects, but no studies have been made.

Specimens

Twelve house mouse skins from Johnston Atoll are preserved in the National Museum of Natural History (USNM 360999-361010) and a large collection of skulls, to be deposited in the USNM, are being studied by Ralph D. Kirkpatrick of Ball State University, Muncie, Indiana. Preliminary study of these specimens by Kirkpatrick indicates that they are more nearly like Asiatic and Micronesian *Mus* in body weight than like North American or European animals. Molt has been studied by Brechner and Kirkpatrick, 1970.

ROOF RAT *Rattus rattus*

Status

Introduced breeder; present, but uncommon, on Johnston Island.

Observations

The roof rat is established on Johnston Island, but not on Akau, Hikina, and Sand Islands.

Johnston Island: Roof rats were reported from Johnston Island by 1962, but probably were introduced via ships or barges several years prior to that date.

Rats are most abundant in refuse dumps, along the pier, and in the warehouses and other buildings near the shipping wharfs. Rat control measures were initiated by military personnel in late 1964 and included snap-trapping and poisoning. The success of the program is not known, but reports of rats around the Navy pier in 1968 and 1969 indicate that they were not exterminated (Kirkpatrick, 1966).

Specimens

Seven specimens were secured from the control operation during September, October, and November 1964; all are in the National Museum of Natural History (USNM 360986-360992). One (USNM 360991) is melanistic. Reproductive data for the females were not recorded, but testes size and location in the three adult males indicate that they were in breeding condition.

DOMESTIC DOG *Canis familiaris*

Status

Introduced; breeding status unknown; present on Johnston and Sand Islands.

Observations

Johnston Island: Two dogs, at least one a female, were present from 1963 through 1965; from 1966 through 1969 numbers were higher.

Sand Island: Two male dogs were on Sand Island in 1963 (Kirkpatrick, 1966); numbers ranged from two to four through 1969. Two were present in November 1973. They were kept as pets, but were permitted to run loose.

At times dogs were destructive to nesting and roosting seabirds. Wedge-tailed Shearwaters were most affected: in November 1964 up to five nestlings a day were killed, but not eaten, by dogs. At least ten chicks were killed in October 1966. These chicks were most vulnerable in the last few weeks before they fledged. During that time adults were rarely present and no other birds were present in sufficient numbers to discourage the dogs. During the spring and summer, when adult Wedge-tailed Shearwaters, Sooty Terns, Brown Noddies, and Brown Boobies were numerous, the dogs appeared to be afraid to go into the colony. In early 1967 two Red-tailed Tropicbird chicks were killed on the western portion of Sand Island, possibly by dogs or cats. During 1968-1969 two newly introduced dogs never visited the bird colony unaccompanied and did not molest the birds.

DOMESTIC CAT *Felis catus*

Status

Introduced; breeds on Johnston Island, present on Hikina and Sand Islands.

Observations

Hikina Island: Two semi-tame cats lived here in February 1969.

Johnston Island: Domestic cats were numerous on Johnston Island, where a reproducing population existed through 1973. They were suspected of killing and eating White Terns (see White Tern account), but no evidence was obtained indicating that these animals bothered other birds. Unattended tropicbird chicks, or any weakened bird, would be likely victims.

Sand Island: A non-reproducing pair ran wild on the original portion until early 1964. They preyed on Sooty Terns and Gray-backed Terns. In 1964 they were lured to the man-made portion and kept as pets (Kirkpatrick, 1966). Two cats remained on the island through 1973; they did visit the bird colony and occasionally ate mice, but little evidence of bird predation was found.

HAWAIIAN MONK SEAL *Monachus schauinslandi*

Status

Visitor; one breeding record.

Observations

The first Hawaiian Monk Seals ever recorded outside the Hawaiian Islands appeared on Johnston Atoll in 1968 and 1969. The first, a young animal tagged as a pup in March 1968 on Laysan Island, 547 nautical miles to the north-northwest by U.S. Fish and Wildlife personnel, appeared on Johnston Atoll the last week of July 1968 and stayed until late December. During this time it was reported from nearly every part of the atoll, but it usually returned to sleep near the Navy docks on Johnston Island (Schreiber and Kridler, 1969). It reappeared during the last half of June 1969 and stayed at least to mid-August 1972.

On 29 January 1969 an untagged adult female hauled out on a protected beach on Sand Island and gave birth to a female pup. The two animals were tagged and remained on or near this beach until 3 March, when the adult disappeared. The pup remained and fed on snails and other marine invertebrates, as well as fish. It died in 1971 from a deep flesh wound, probably from a shark attack.

EUROPEAN RABBIT *Oryctolagus cuniculus*

Status

Introduced; occurs on Johnston and Sand Islands where it is kept caged.

Observations

Johnston Island: Rabbits were introduced onto Johnston Island during the early 1970's as a test animal for various chemical agents stored on the island. The animals are caged.

Sand Island: One rabbit was kept as a pet in a cage near the Coast Guard barracks in November 1973.

ECOLOGICAL SIGNIFICANCE

The conservation status of Johnston Atoll has been discussed by King (1973), but no ecological significance was given.

In order to assess the ecological significance of Johnston Atoll, four well-known ecologists in various fields were asked by Amerson (1973) to read the manuscript and evaluate the baseline findings. The following commentaries were obtained.

Ecological Values of Johnston Atoll
(by Ray Dasmann, International Union for Conservation of Nature)

Because of its small size, and extreme isolation Johnston Atoll was originally of considerable ecological interest as an area in which it would have been possible to follow the slow process of colonization and establishment of species on oceanic islands and to study over the years the processes that may have led to the development of new races or species in its limited biota. The opportunity was lost with the exploitation of the island and later with its development as a naval and air base. However, human occupancy of the island followed by the introduction and establishment of many new species of plants and animals has created an equally interesting ecological situation in which the interactions among its still limited biota could profitably be studied. Such situations, however, occur on many other isolated oceanic islands, and Johnston cannot be considered as particularly unusual or of outstanding interest from this point of view.

Considering the dry land area of Johnston Atoll, the greatest concentration of ecological interest is to be found on the remaining natural island, the ten acres of the eastern portion of Sand Island. This is the principal breeding area for seabirds and appears to support the most complex terrestrial biota. Sand Island is of major importance for its breeding population of Sooty Terns and of significant importance for breeding populations of Red-footed Boobies, Brown Noddies, Wedge-tailed Shearwaters and Great Frigatebirds. It is significant also as a wintering area for shorebirds, notably the Golden Plover and Ruddy Turnstone. Every effort should be made to minimize disturbance of this area in the future and to maintain it as a refuge for seabirds. With protection and freedom from disturbance its value as a seabird breeding center can be expected to increase, and it will achieve greater value as a site for ecological studies. By contrast, the ecological interest of the western, man-made portion of Sand Island, of Johnston Island, of Akau and of Hikina Islands, is slight at the present time, although if disturbance of these areas were to be greatly reduced in the future, they would no doubt be colonized in time by breeding populations of seabirds.

The marine area of Johnston Atoll can be considered of equal interest to the terrestrial area. Although the marine biota has not been thoroughly studied, the inshore fish population appears to be of considerable biological interest and it is likely that further studies will reveal a higher degree of endemism than is now reported, particularly among the marine invertebrates. Considerable damage to the marine fauna has resulted from past dredging and filling operations. Future activities of this nature, when necessary, should be conducted with greater precautions to minimize damage to reef and lagoon fauna.

Considering that Johnston Atoll may continue to be used for a variety of purposes in the future, it is recommended that particular attention be given to protection of the eastern portion of Sand Island for the purpose of maintaining the reef and lagoon biota in a healthy state, allowing for its recovery from past disturbance. Avoidance of pollution and siltation of the reef-lagoon complex should be given priority.

Johnston Atoll: Some Ecological Considerations
(by Robert E. Jenkins, The Nature Conservancy)

The report on the "Ecological Baseline Survey of Johnston Atoll, Central Pacific Ocean" presents a fascinating picture of what is unquestionably a unique, interesting, and important scrap of landscape. Johnston Atoll is unique to begin with because of its small size, extreme isolation, long (25 to 100,000,000 years) geological and evolutionary history, tremendous constancy of its oceanically buffered environment (remarkably small variation of landscape and practically all climatological variables), recent history of human disturbance and alteration, great changes in species composition resulting from colonization by introduced organisms, and, not least, by the amount of scientific research and data collection which has gone on there. Some of these values and potentials are considered in more detail below.

The Place of Johnston Atoll in the Natural Biosphere

Johnston Atoll is a focal point of biological activity in the midst of tremendous expanses of otherwise unbroken ocean. It served as a permanent home and habitat for a notably small number of terrestrial organisms in the past because of its isolation from other sites occupied by potential colonizers. However, the Atoll always has been and continues to be a vital link in the life cycles of a variety of pelagic organisms which retire there to breed (especially seabirds) or use it as a haven and way station along traditional routes of migrations or wandering. In addition to being the only pieces of dry land over thousands of square miles of ocean, the submerged platform of the atoll splits and deflects oceanic currents, causing eddies which produce turnover, upwelling, and nutrient enrichment. This makes the Atoll system a hot-spot of organic productivity supporting concentrations of fish and aquatic organisms and the seabirds which depend upon them for food.

The importance of atolls such as Johnston in determining the faunistic composition of a very large section of the ocean cannot be overestimated. Were Johnston physically (or ecologically) removed from its section of the globe, it would have measurable effects on the ecosystem over a very wide area. At present, habitats such as Johnston Atoll are particularly critical because they represent shrinking fragments of relatively predator- and harassment-free areas of a type becoming increasingly rare as pressure on the oceanic islands increases. In this capacity, Johnston serves as a reservoir for a diversity of species which are badly depleted or even endangered over much of the rest of their range.

In addition to acting as a temporary annual stopover for numbers of migrating species of birds and fish, Johnston Atoll has obviously served as an important stepping-stone in the longer time sequence of evolutionary events. Though this whole area of inquiry remains largely unelucidated at present, Johnston Atoll has clearly been an important focal point in the dynamic process of faunal exchange.

<u>The Importance of Johnston Atoll as a Scientific Laboratory</u>

Johnston Island has, over the years, attracted the attention of a large number of competent and even famous scientists who have visited the island, made their observations, and added to our store of knowledge about their disciplines and about Johnston Atoll specifically. Most of this information has been pulled together under the Smithsonian Institution's Pacific Ocean Biological Survey Program (POBSP). This program has also added a vast amount of new data of its own for comparison with the more fragmentary information published by past researchers. This collection of data will form the foundation of extensive new biological and environmental baselines which will assume an ever greater importance as we learn more of the Pacific ecosystems and as the effects of human activity increasingly influence those systems. The data collected in areas such as Johnston Atoll, when compared with later measurements in the same area, will be our only reliable yardsticks whereby we measure changes occurring in integrated ecological and life support systems. Without such comparisons, we will have no way of distinguishing between trivial environmental fluctuations and evidences of serious perturbation or trends of deterioration. Without them we would have no way to identify cyclical events and no way to extend our as yet rudimentary understanding of how natural systems function.

Of particular importance to Johnston Atoll is the recurring theme of its seabirds. In spite of all of the "reconstruction" which has severely changed the original natural environments in the area, there is still a tremendous seabird population using the near-shore feeding grounds or breeding--primarily on Sand Island. The information collected on these birds forms a truly impressive body of data. The monumental accomplishment of having banded over 300,000 individual birds in the course of six years has already added greatly to our knowledge of population dynamics, distribution, faunal exchange, site constancy, breeding systems, species composition, etc., and in the years ahead should add even more to our understanding of some important components of the oceanic system.

There have also been fairly extensive studies made on the effect of the dramatic and pervasive human alteration of Johnston Atoll. A continuation of these studies will give us new insight into the effect of dredging on the physical and biological environment of coral reefs, the effects of greatly enlarging the terrestrial mass in the area through the creation of entirely new superaquatic platforms from native materials, and the effects of stocking these (however haphazardly) with a large number of exotic species of plants and animals. The increase in the vascular plant flora from three species in 1923 to 127 in 1973 provides us with a very interesting case in point. In the last few years, the relatively young discipline of island biogeography has been yielding new insights on a number of ecological and evolutionary phenomena such as colonization, competition, extinction, community stability, genetic adaptation, ecological exclusion, niche dimensions, etc., and the Johnston Atoll situation represents a unique experiment in this field which could richly reward intense scrutiny. Aside from the population and community phenomena which are favorably isolated for investigation, the effects of the biota in modifying the raw, new substrates over time should be carefully observed and documented. Within the aquatic environment, the same processes of ecological recovery from the effects of dredging and filling provide us similar opportunities.

Another aspect of the past research which seems very worthy of protection and continuation is the baseline study on ciguatera-type fish poisoning. This has become a world-wide problem of growing dimensions, and the large amount of information, particularly that relating to the known-time variation in the prevalence of toxic episode and the fish species affected might eventually help us to unlock the riddle of what causes ciguatera poisoning and consequently the ways in which we can avoid or counteract it.

Future Potential

Because of its uniqueness, Johnston Atoll lends itself to so many different and important uses that a prime difficulty may be simply to determine--within the constraints imposed by the military, communication, transportation, physical research, and human habitat factors--which of the various additional uses should be given priority.

On the one hand, the Atoll area clearly represents a critical species reservoir. This function could undoubtedly be substantially enhanced without any significant interference in the "edificarian" uses of the island. The report observes, for example, that the Laysan and Black-footed

Albatrosses (both depleted species limited by long life cycles and the limited availability of nesting sites) are unlikely to re-establish themselves as breeders on Johnston Atoll through natural developments. However, we have an opportunity to assist by creating favorable conditions and otherwise promoting re-establishment. This would require something on the order of the procedures used to re-establish salmon in streams from which they have been eradicated. Such a project might include the hand rearing of nestling albatrosses on the island sites in question in the hopes of imprinting the young for later return at sexual maturity. Such activities have been undertaken in behalf of other endangered species by the Department of Interior which ironically still retains statutory responsibility for Johnston Atoll as a federal bird refuge.

On the other hand, parts of the islands might be used in quite different scientific experiments. The area's isolation offers a tremendous laboratory for the investigation of species dynamics as discussed above which could be enhanced through deliberate manipulation. Parts of the islands might be devoted to the intentional introduction of a large array of terrestrial biological species. Oceanic barriers would make control of the experimental design quite extraordinary and would protect against the sorts of deleterious consequences that frequently accompany exotic introductions in mainland areas. It would be possible to eradicate given species or even whole floras or faunas with relative ease if it became advisable. In this respect, Johnston Atoll may provide an absolutely unique opportunity to obtain information on maximum community diversity, competitive interactions in a large species array, etc., which could be arrived at by no other means. Of course, such uses would have to be controlled so as not to adversely affect the seabird colonies, but Akau and Hikina Islands appear to receive little or no use by seabirds and the same can be said of most of Johnston Island itself.

Ecological Significance of Johnston Atoll
(by Lee M. Talbot, Council on Environmental Quality)

The paper provides exactly what its title calls for, a survey of baseline ecological data for this important area. It is an extremely comprehensive job, and I believe an exceedingly valuable one. The detail provided varies greatly from species to species and from group to group, reflecting the variations in the data base of the survey. Birds, which were the focus of the Pacific Ocean Biological Survey Program on which the author was occupied originally, have been the focus of a greater amount of research than the other groups of organisms, and this is of course reflected in the detail presented in the paper.

Johnston Atoll has high ecological significance for two primary reasons. The first derives from its isolated location in the central Pacific Ocean. Study of the organisms found there can contribute significantly to the understanding of migration and distribution mechanisms and evolutionary ecology of a variety of types of organisms. The inshore fishes are exemplary of this in connection with the distribution, dispersion, and introduction of warm-water fishes.

Another allied source of ecological significance to this isolated Atoll derives from what studies based there can indicate about the migratory movements of birds, their parasites and pathogens, marine mammals, reptiles, and fishes. The bird studies have been the most extensive to date, of course, and the detail in this paper reflects that.

The other, and in my opinion more important, reason for its significance, derives from the history and nature of the Atoll. In its present form it is very largely man-made. Even those parts that have not literally been constructed by man have been very significantly modified. This history is well documented with scientific collections, descriptions, and maps and with extensive photographs. At the same time, it is a relatively simple ecosystem from the standpoint of topography and other physical aspects. A high percentage of the terrestrial organisms have been introduced by man (e.g., 124 out of 127 species of vascular plants, and all of the terrestrial mammals and reptiles). Since most of these introductions are of comparatively recent origin and many can be reasonably well dated, the Atoll provides an almost unique laboratory in which the mechanisms of dispersion, introduction, adaptation, and development of an ecosystem and its component species can be studied. The uniformity and simplicity of a substrate further facilitates study and comprehension of the mechanisms and isolation and understanding of the dynamic processes involved.

Beyond the basic mechanisms of introduction, dispersion, etc., of organisms in a new habitat, the Atoll provides opportunities for the study of the adaptation of species and communities to changed or new habitats. This derives from the extensive dredging and changes that have been made and continue to be made in portions of both the terrestrial and aquatic environment. Again a part of the significance here derives from the excellent documentation of the changes, including the photographs.

Further, the Atoll provides "control" study opportunities, for example, as between the dredged and undredged reef areas, and between the more or less natural and the recently man-made islands. A further opportunity is provided by the small cluster of different islands, each with its own well-documented history.

One of the types of study possible at the Atoll because of the conditions noted above is that of succession, or of developmental stages following the creation (through dredging, filling or clearance) of new and essentially sterile habitats. The opportunities here involve both the chance to document the types of succession that occur--and indeed whether there is a consistent succession or whether there is no consistent pattern--and the chance to study other processes associated with such a succession. An example of this is the ciguatera poison problem.

The Atoll offers the opportunity to study the relationship between ciguatera-type fish poisoning, and disturbance of the environment. Dredging operations beginning in 1963 provided an opportunity to test Randall's theory that the toxin responsible for the ciguatera was produced by algae which occurred early and abundantly during the successional invasion of a newly denuded substrate by algae.

In summary, Johnston Atoll is ecologically significant from the standpoint of its opportunities for ecological research which promises unique contributions to our knowledge of ecological processes. S me very useful ecological research has been accomplished there.

However, in my opinion, the potential of adding to our ecological understanding from dynamic study of this Atoll has only just been scratched. Realization of the research potential of this area requires the foundation of baseline data which this paper is intended to--and indeed well does--provide. Because of this, and because of the attention it focuses on this important area and opportunity, I believe that the paper is an exceedingly important and valuable contribution.

Johnston Atoll: Ecological Significance
(by George E. Watson, Curator of Birds, National Museum of Natural History)

Johnston Atoll constitutes the only exposed land in a vast area of the tropical Pacific Ocean. Although the total land area is about one square mile, only a small portion of this is available to birds for undisturbed resting, roosting, and breeding. Thus seabirds that inhabit many hundred thousands of square miles of open ocean concentrate on a small island. Likewise, shorebirds breeding on extensive northern continental areas migrate to the restricted insular ecosystem of Johnston Atoll.

The birds frequenting the atoll may be classified according to activity into breeders, offseason or prebreeding migrants, and vagrants. The ecological significance of the last is nil. The island does not play any role in the survival of the species and perhaps very little role in the long-term survival of the errant individual. Far and away the most important breeding bird is the Sooty Tern which produces about 60,000 chicks a year on Johnston Atoll. Lesser numbers of Brown Noddies and Wedge-tailed Shearwaters use the island for breeding as do relatively insignificant numbers of other species. None of these species is restricted to Johnston Atoll nor is the population on Johnston Atoll a significant fraction of the Pacific Ocean population of the species. There are no endemic landbirds or seabirds restricted to the islands.

The same is true of the five species of shorebirds that regularly visit the islands on migration. Most of these are wide-ranging and scatter from their largely arctic breeding grounds over much of the tropical oceans of the world. One species, the Bristle-thighed Curlew, is considered rare and endangered on its breeding grounds in Alaska. It disperses so extensively to islands in the tropical Pacific Ocean, however, that even if the Johnston Atoll birds were eliminated, the total species population would not be jeopardized.

The influence of long distance migrant arctic and subarctic shorebirds is probably slight at Johnston Atoll. Their numbers are not great and their dispersal even though over great distance is not concentrated in any given area. There has been little study of the food supply available to them and although no shorebirds breed on the islands, marking of individuals has demonstrated that tropical islands, including Johnston Atoll, serve as year-round tropical nurseries for first-year arctic shorebirds.

In spite of a massive bird-marking program centered on Johnston Atoll from 1963 to 1969, information on the movements of birds to and from the atoll is disappointingly meager, except for Sooty Terns. Marked individuals of that species have been observed at sea in all directions from the atoll at up to 481 miles distance and over an area of at least 300,000 square miles during the breeding season.

What still remains unknown is the importance of seabirds in the overall marine environment. Obviously in the waters near the island concentrations of birds can exert predation pressure on small fish, crustaceans and squid and thus limit populations in relatively infertile tropical waters. There is little feeding by seabirds in the lagoon or other waters near the atoll. Sooty Terns are probably feeding at up to a full day's flight away from the atoll. Some of the other species may also have great daily flight ranges. Nor is it known exactly where most of the individuals that breed on the island go during the period when they are not breeding. It is known that the island serves as resting or roosting ground for numbers of birds that breed elsewhere, particularly boobies from islands to the north in the tropical Pacific Ocean.

Individuals of most breeding species are present throughout the year although in nearly all cases the egg and chick stages occupy significantly less than 12 months. Because of staggered cycles, however, there is no month when some seabird is not engaged in some stage of breeding. The three main species, Sooty Tern, Wedge-tailed Shearwater and Brown Noddy, have eggs and chicks in every month save January and even during that month the terns and noddies are feeding in order to produce eggs.

The terrestrial insular ecosystem, however, is by no means a closed one, for on the one hand the seabirds concentrate nutrients on the island through the guano that they deposit and the rain and, probably to a lesser extent, wave action washes the nutrients back into the sea for recycling through the marine environment. There should be a tendency for the inshore waters of an oceanic island ecosystem to become increasingly richer with time. This should result in a change in species makeup from wide-ranging species that gather food far from an island to those whose feeding trips are short. Likewise, this could also produce a similar long term change in visitors that use the island for roosting.

Three species of seabirds, the Blue-faced Booby and Laysan and Black-footed Albatrosses, used to breed on Johnston in small numbers but no longer do so because of human disturbance. Several other species occur in smaller numbers than they ever did in 1923 when the island was subject to periodic visits by feather hunters. The atoll is at the southern limit of the albatrosses' at-sea feeding range and may be only marginally suitable for breeding under the best of circumstances, but several of the other species could well recover significantly if they were completely undisturbed.

SUMMARY

Johnston Atoll, located between the Hawaiian Islands and the Line and Phoenix Islands, is one of the most isolated coral atolls in the world. Military activity has greatly altered the atoll: two of the four islands are man-made and the original two have been greatly changed. Since World War II, the atoll has been a military base. The wildlife on the atoll is protected under a little-known 1926 Executive Order.

The flora of Johnston Atoll is well known. There are 67 species of benthic marine algae known from the lagoon. Increased silt from dredging activities in 1963 and 1964 decreased the number of algae species in the dredged areas. Three vascular plants occurred on the original two islands; man has apparently introduced 124 species since 1923.

The invertebrate fauna is not well known and dredging has further reduced or eliminated some species. The known groups are: 18 species of Cnidaria (Coelenterata), 58 species of Mollusca, 12 species of Annelida, 75 species of marine Arthropods, at least 87 species of terrestrial Arthropoda (including two tick species, five chiggers, two nasal mites, 23 biting lice, and two louse flies), and 37 species of Echinodermata.

The vertebrates are well known. There are at least two species of pelagic fishes and 194 species of inshore fishes. Dredging operations have drastically reduced the fish population in certain lagoon areas. Ciguatera is prevalent among the inshore fishes, with the moray eel, white-tipped reef shark and grey sand shark being most toxic. Five species of reptiles are known; all but one were introduced by man. Likewise, no mammals are native to the atoll. Of the six species known, man has introduced five species. Fifty-six species of birds, whose total population ranges upward to 600,000, are known from the atoll. Of the 22 seabird species, 12 species are breeders, three are former breeders, and seven are visitors. Of the 34 species of waterfowl, marsh, and land birds, seven species are regular migrants, six are irregular visitors, two are stragglers, 16 are accidentals, and three are introductions. Analysis of 60,932 returns of 303,901 birds comprising 21 species banded at Johnston Atoll reveals that the atoll is the major focal point for interisland movements in the north-central Pacific. A total of 733 individual banded birds have moved to or from Johnston Atoll; most inter-island movement involves the northwestern Hawaiian Islands.

Johnston Atoll is perhaps the most scientifically studied atoll in the central Pacific. Despite man's disturbance, the atoll is ecologically significant because of its isolation and from the standpoint of its opportunities for island ecological research. Although much ecological research has been accomplished, the potential of additional ecological understanding of the atoll is great.

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POBSP personnel who were involved in the Johnston studies are listed in Appendix Table 1, together with dates they worked on the Atoll. Although the lengths of time spent there varied greatly, it is not possible for us to single out individuals from this list for special thanks. All made significant contributions. Most of these people are mentioned in the text where specific contributions are discussed.

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ADDENDUM

The "Environmental Impact Statement" referred to on page 3 was made available in November 1974 to the Council on Environmental Quality by the U.S. Department of the Air Force (1974. Final environmental statement: Disposition of Orange herbicide by incineration, November 1974. Environmental Health Laboratory, Kelly Air Force Base, Texas. 137 pp + appendices). This Statement indicated that the Air Force planned to incinerate approximately 2.3 million gallons of Orange herbicide in a remote area of the Pacific Ocean downwind of Johnston Atoll. The Air Force proposed to use a specially designed vessel, the VULCANUS, to convert the Orange herbicide to its combustion products of carbon dioxide, hydrogen chloride, water, carbon, and carbon monoxide which would be released into the atmosphere. Environmentally insignificant amounts on unburned and pyrolyzates of the herbicide and its impurity 2,3,7, 8-tetrachlorodibenzo-p-dioxin (TCDD) may also be released into the atmosphere. The Statement concluded that "there will be no adverse effect on the environment caused by the incineration of Orange herbicide in a remote area of the Pacific."

The Statement further purposed that the principal alternative for incineration of the Orange herbicide was to be located on Johnston Island where "the environmental impact of the facility would be minimal." It further stated, however, that "the potential impact on the delicate ecosystem of Johnston Atoll and lengthy project duration make this alternative less desirable than the proposed [primary] action." Other alternative methods of disposition considered were: incineration in one of the 50 states, use of herbicide, return to manufacturer, deep well disposal, burial in underground nuclear test cavities, sludge burial, microbial reduction, fractionation, chlorinolysis, soil biodegradation, and no disposal action.

The Final Environmental Statement was accepted in March 1975 by the Council on Environmental Quality. The Air Force then sought an Ocean Dumping Permit from the Environmental Protection Agency (EPA); public hearings were held in Holululu and San Francisco in late April 1975. These meetings adjourned with the Air Force further evaluating the possibility of reformulating the herbicide as an alternative. The meetings are to reconvene in late summer or fall 1975. If at that time reformulation is considered unfeasible and if the EPA Administrator decides not to issue a dumping permit, the Air Force will pursue the principal alternative of incineration in a facility that would be constructed on Johnston Island. 12 May 1975.

Appendix Table 1. POBSP personnel participating in bird studies on Johnston Atoll, July 1963-September 1969

Name		Inclusive dates present on Johnston Atoll	Total Man-days
Amerman, Kenneth E.	1963	21 Jul.-12 Aug.	
		28 Aug.-22 Oct.	
	1964	24 Jan.-27 Apr.	
	1966	17 Jan.-17 May	
		3 Jun.-21 Jun.	309
Amerson, A. Binion, Jr.	1963	7 Jul.-29 Aug.	
	1964	12 Feb.-28 Feb.	
		22 Mar.-12 Jun.	
	1965	13 Jan.-20 Jan.	
	1966	11 Jul.-15 Jul.	162
Anderson, Alan H.	1965	3 May.-18 Jun.	46
Bratley, David A.	1963	22 Dec.-	
	1964	-24 Mar.	
		7 Jun.-10 Aug.	
	1965	17 Feb.-30 Apr.	229
Brownell, Robert L.	1968	16 Dec.-	
	1969	-11 Jan.	26
Bulmer, Walter	1967	14 Apr.-21 Apr.	7
Burkhalter, David L.	1967	17 Apr.-20 May	33
Elliott, R. Patrick	1963	21 Jul.-12 Aug.	22
Ely, Charles A.	1964	7 Jun.-12 Jun.	
	1965	13 May-18 May	
	1966	17 Feb.-22 Feb.	15
Harrington, Brian A.	1966	26 May- 7 Jul.	
	1967	18 May- 2 Jun.	
		13 Jun.-22 Aug.	
	1968	1 Mar.-28 May	
		4 Jun.-19 Jul.	261
Heryford, Norman H.	1965	13 Jan.- 7 Apr.	
		17 Jun.-30 Sept.	189
Huber, Lawrence N.	1969	2 Jun.-28 Jun.	26
Kepler, Cameron B.	1964	9 Aug.-19 Oct.	
	1965	6 Apr.-18 Jul.	
		8 Nov.-17 Dec.	213

Appendix Table 1. (Continued)

Name	Inclusive dates present on Johnston Atoll		Total Man-days
Kirkpatrick, Ralph D.	1964	18 Oct.-	
	1965	-14 Jan.	88
Kleen, Vernon M.	1968	10 May-6 Aug.	
		13 Aug.-3 Dec.	200
Lehner, Philip N.	1964	26 Jul.-28 Sep.	
		6 Dec.-	
	1965	-15 Feb.	135
Lewis, T. James	1965	27 Sep.-5 Nov.	39
Maze, Richard L.	1965	16 Dec.-	
	1966	- 22 Feb.	
		19 Apr.-31 May	110
Merrill, Richard W.	1964	29 Apr.-28 Jul.	90
Pyle, Robert L.	1966	16 Aug.-19 Aug.	3
Schreiber, Ralph W.	1966	20 Oct.-	
	1967	-10 Feb.	
	1968	13 Feb.-16 Feb.	
		26 Jul.-16 Aug.	137
Shelton, Philip C.	1966	30 Jun.-25 Oct.	
	1967	3 Feb.-9 May	
		25 Aug.-12 Sep.	
	1969	24 Jan.- 9 Sep.	458
Smith, Frank H., Jr.	1966	30 Jun.-30 Aug.	61
Stadel, Dennis L.	1964	9 Oct.-29 Nov.	51
Sundell, Robert A.	1963	27 Sep.-12 Dec.	76
Tordoff, Jeffery P.	1966	24 Feb.-16 Apr.	
	1968	13 Feb.- 1 Mar.	67
Wilz, Kenneth J.	1963	7 Jul.-29 Aug.	53
Wislocki, George S.	1963	20 Nov.-	
	1964	-22 Jan.	63
Woodward, Paul W.	1965	15 Jul.-31 Aug.	47
			3,216

Appendix Table 2. Annotated list* of vascular plant species recorded from Akau Island, Johnston Atoll

Polypodiaceae

Nephrolepis sp.

2 Sep. 1967: "Few plants growing from wooden foundation of building, in fairly well shaded area, close to plants that are watered regularly." (UH, ?).

Graminea

Cynodon dactylon Bermuda Grass

2 Sep. 1967: One patch about 30 feet in diameter, and a smaller one, both in a slight depression on the northcentral portion of the island. Stolons spreading in all directions. A few fruiting heads.

6 Sep. 1969: "...on watered lawn, on imported soil."

Dactyloctenium aegyptium Crowfoot Grass

2 Sep. 1967: One small patch near the south side of the island.

Eleusine indica Goosegrass

2 Sep. 1967: Fairly abundant in a few small areas, vigorous, fruiting. (UH, 1).

Eragrostis tenella Lovegrass

2 Sep. 1967: Few plants growing in partial shelter of building near plants watered regularly. (UH, 1).

Zea mays Corn

6 Sep. 1969: One 18 inch pale plant, with tassels, in plot.

Fimbristylis cymosa

2 Sep. 1967: Grows over most of the island, in about the same density as on Hikina. A worker who had been on the island 15 months said that these plants had become conspicuous only since his arrival.

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*Collections are shown by herbarium designation, followed by the number of specimens in each collection; UH = University of Hawaii. Data are taken from POBSP, 1967b and 1969.

Appendix Table 2. (Continued)

6 Sep. 1969:	Looks much like it did in 1967, possibly thicker. Fruiting profusely. Thick patch near north shore in a depression.

Palmae

Cocos nucifera Coconut Palm

2 Sep. 1967:	At least two plants about three feet high, near the dock; one fairly green, the other mostly dried up.
6 Sep. 1969:	About six trees, up to six feet; not doing too well.

Amaryllidaceae

Crinum or *Hymenocallis*

2 Sep. 1967:	One plant, not blooming.
6 Sep. 1969:	One small plant, and one six-foot plant with dried blooms.

Casuarinaceae

Casuarina equisetifolia Ironwood

6 Sep. 1969:	Two two-foot trees by buildings; heavily watered. Reportedly have grown five inches per month.

Polygonaceae

Coccoloba uvifera Sea-grape

2 Sep. 1967:	One small tree; no flowers or fruits.
6 Sep. 1969:	One tree, no flowers or fruits.

Amaranthaceae

Amaranthus viridis Pigweed

2 Sep. 1967:	A few small plants grew in area planted with several garden species, probably brought in soil with these plants.

Appendix Table 2. (Continued)

Nyctaginaceae

Boerhavia sp.

1-15 Jul. 1965:	"...there were approximately 20 small *Boerhavia* plants establishing themselves, and 4 *Boerhavia* plants had runner systems over 4 feet long. No *Boerhavia* was seen on 14 April [1965]. All these plants were in the southwest corner of the island."
6 Sep. 1969:	Two patches, green and fruiting, in depression, north side.

Aizoaceae

Sesuvium portulacastrum

1-15 Apr. 1965:	"Several small clumps...are growing in the southwest corner of the island--not cultivated."
1-15 Jul. 1965:	"One clump...was 2 feet in diameter, and many clumps were several inches across. There may be as many as 100 separate plants now established, most of them on the southwest corner of the island."
2 Sep. 1967:	Scattered small plants, no patch as large as that found on Hikina Island. No blooms noted, but no close examination was made.
6 Sep. 1969:	Scattered, blooming, not abundant.

Portulacaceae

Portulaca oleracea

2 Sep. 1967:	One small plant seen, near where the Orange was planted (near office buildings).

Caryophyllaceae

Spergularia marina

2 Sep. 1967:	Less abundant than on Hikina, but widespread over the island.
6 Sep. 1969:	Few scattered pads; blooming.

Appendix Table 2. (Continued)

Leguminosae

Acacia farnesiana Sweet Acacia

2 Sep. 1967: One six inch plant found growing from under wooden foundation of building.

Phaeseolus sp. Bean

2 Sep. 1967: Planted in rich soil and watered; production unknown.

6 Sep. 1969: Growing well in imported, watered soil.

Pisum sativum Pea

2 Sep. 1967: Planted in rich soil and watered; production unknown.

Vigna marina Beach Pea

6 Jul. 1965: Collected by POBSP. (UH, 1).

Ruthaceae

Citrus sinensis Orange

2 Sep. 1967: One plant about three inches high, apparently healthy, sprouted from seed. Another planted at the same time died.

6 Sep. 1969: Two or three small trees reported growing.

Euphorbiaceae

Codiaeum variegatum var. *pictum* Croton

2 Sep. 1969: One small shrub.

6 Sep. 1969: Several plants, no flowers.

Euphorbia glomerifera Spurge

2 Sep. 1967: Few plants found in the central portion of the island. (UH, 1).

6 Sep. 1969: Fairly abundant around buildings; blooming.

Appendix Table 2. (Continued)

Anacardiaceae

Mangifera indica Mango

6 Sep. 1969: Two planted trees reported.

Malvaceae

Hibiscus sp.

2 Sep. 1967: One plant; few red blooms.

6 Sep. 1969: Three or four plants; red blooms.

Guttiferae

Calophyllum inophyllum False Kamani

2 Sep. 1967: One small plant; no flowers.

6 Sep. 1969: One ten feet high; no flowers.

Apocynaceae

Plumeria rubra? Frangipani

2 Sep. 1967: One small plant; no flowers.

6 Sep. 1969: Two new plants; no flowers. Old one still there; no flowers.

Verbenaceae

Vitex ovata

2 Sep. 1967: Few plants; blooming profusely.

6 Sep. 1969: One plant seen; blooming profusely.

Solanaceae

Capsicum frutescens Pepper

2 Sep. 1967: Several plants (cultivated).

6 Sep. 1969: Two different kinds cultivated in plots.

Solanum lycopersicum

2 Sep. 1967: Few plants.

Appendix Table 2. (Continued)

Cucurbitaceae

Citrullus lanatus var. *vulgaris* — Watermelon

2 Sep. 1967: Few plants (cultivated).

Cucumis melo — Muskmelon

2 Sep. 1967: According to caretakers, these get about the size of oranges, ripen and fall off the vines.

Compositae

Conyza bonariensis

2 Sep. 1967: One plant, about 15 inches high with flowers and mature heads, near buildings.

6 Sep. 1969: Around dock; fruiting.

Pluchea indica

2 Sep. 1967: One plant about 15 inches high found on the west central portion of the island.

6 Sep. 1969: Few small plants, east southeast side.

Pluchea carolinensis

2 Sep. 1967: A few plants, none over one foot high, were found near buildings and among the cultivated plants.

Tagetes sp. — Marigold

6 Sep. 1969: Blooming (cultivated).

Zinnia elegans — Zinnia

2 Sep. 1967: Several plants; blooming profusely.

6 Sep. 1969: Blooming.

Appendix Table 3. Annotated list** of vascular plant species recorded from Hikina Island, Johnston Atoll

Graminea

*Eleusine indica** — Goose Grass

21 Feb. 1969: Very scarce. Collected from a small clump.

*Lepturus repens** — Bunch Grass

21 Feb. 1969: Collected from small clump--only one seen--at top of beach on east shore.

Cyperaceae

*Fimbristylis cymosa** — Sedge

2 Sep. 1967: The dominant plant on the island. It grows on almost the entire island, covering an estimated two to five percent of the surface. Viewed obliquely the ground almost appeared to be covered in some areas. Most of the plants were small tussocks, but there were a few clumps several inches in diameter, with eight to ten inch fruiting stalks.

21 Feb. 1969: More completely spread over island than in 1967. Estimated ten percent of ground covered. Nearly all in small, evenly spaced tussocks. Most with fruiting stalks. In spots with better moisture, for example where drainage concentrated water along the edges of concrete structures, there was fresh green growth.

Palmae

Cocos nucifera — Coconut Palm

21 Feb. 1969: Three trees, about 2.5-3 feet high, fairly recently planted, and apparently thriving well; two by dock and one by building.

Moraceae

*Ficus microcarpa** — Banyan

2 Sep. 1967: One 15 inch plant, south side of the island; probably planted.

**Collected specimens (marked *) are in the herbarium of the University of Hawaii. Data are from POBSP, 1967b and 1969.

Appendix Table 3. (Continued)

Aizoaceae

Sesuvium portulacastrum

? Jul. 1965: Several small clumps on the northeast corner of the island.

2 Sep. 1967: This was the second most abundant plant on the island. The largest clump was six by nine feet, in which the only blooms were found. Scattered, smaller non-blooming clumps occurred.

21 Feb. 1969: Small, widely scattered patches occurred, mostly around the perimeter of the island. A few blooms.

Portulaca probably *oleracea* Purslane

21 Feb. 1969: A few plants, with no blooms, by entrance to office.

Caryophyllaceae

*Spergularia marina**

2 Sep. 1967: Widely scattered over the island, but most plants appeared to be dead. A flat area of a few square yards, and a small mound of coral, both on the southwest corner near the dock, were almost covered with living plants, and there were a few blooms on the flat area. (UH, 1).

21 Feb. 1969: Scattered along the periphery; scarce. Large patch found in 1967 gone. Blooming.

Leguminosae

Mucuna sp.*

2 Sep. 1967: One seed found on east beach.

Euphorbiaceae

*Aleurites moluccana** Candlenut, Kukui

2 Sep. 1967: Several seeds found on east beach.

Appendix Table 3. (Continued)

Combretaceae

Terminalia catappa * Indian Almond, Kamani

2 Sep. 1967: Two seeds found on east beach. Note: Although this species grows on both Sand and Johnston, these islands are downwind and west of Hikina, and the seeds were all on the east beach. Therefore it seems likely that the seeds came from elsewhere.

Boraginaceae

Tournefortia argentea Tree Heliotrope

21 Feb. 1969: One plant, about a foot high, probably planted, about 100 feet east of entrance to office.

Solanaceae

Solanum lycopersicum Tomato

2 Sep. 1967: The one plant near the north shore had produced some fruit, according to the caretaker.

21 Feb. 1969: Plant(s?) on north shore spread to three or four feet in diameter; overmature. Several partly dried fruits hanging to vines.

Appendix Table 4. Annotated list* of vascular plant species recorded from Johnston Island, Johnston Atoll

Polypodiaceae — Ferns

Polypodium scolopendria

Apr. 1965:	Observed by C.H. Lamoureux, "growing in bath (?) house."

Araucariaceae

Araucaria heterophylla — Norfolk I. Pine

1952:	"Fosberg saw 3 growing in pots near terminal in 1952. Now growing in yard of Base Commander's house; one or two planted around buildings were nearly dead." (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, cultivated (escaped?) northern part of island. (UH, 1).
1967:	Two or three relatively small trees.

Pandancaceae

Pandanus tectorius — Screw-pine, Hala

Aug. 1944:	"Small, but healthy; about the size of a pineapple plant" (Bryan, 1944).
1950:	"In 1950 Fosberg observed one plant cultivated near a house. Now in the schoolhouse yard." (Doty and Newhouse, ms.).
Jan. 1954:	Observed by W.V. Newhouse. Cultivated.
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated. "Motor pool, and other parts."

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*Collections are shown by herbarium designation, followed by the number of specimens in each collection. BISH = B.P. Bishop Museum; UH = University of Hawaii; US = U.S. National Herbarium (Smithsonian Institution). Data for 1967 and 1969 are taken from POBSP, 1967b and 1969.

Appendix Table 4. (Continued)

Graminea

Cenchrus echinatus Sandbur

1 Nov. 1946:	"Abundant" (Fosberg, 1949). (BISH, 1).
Nov. 1953:	Collected by E.H. Walker, by building. (US, 1).
1954:	"Common" (Doty and Newhouse, ms).
Jan. 1958:	Collected by O. and I. Degener. "Very local." (BISH, 1).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Fairly abundant on open disturbed areas. Mature fruits found all year.

Chloris barbata Fingergrass

1 Nov. 1946:	"Abundant" (Fosberg, 1949). (BISH, 1).
1954:	"Common" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 2).

Cynodon dactylon Bermuda Grass

Aug. 1944:	"Small patches" (Bryan, 1944).
1 Nov. 1946:	"One small patch seen" (Fosberg, 1949). (BISH, 1).
1954:	"Now growing south of the main runway" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux. (UH, 1).
1967:	Scattered widely, but no well-developed stands found.

Dactyloctenium aegyptium Crowfoot grass

Apr. 1965:	Collected by C.H. Lamoureux, northern part of island.
1967:	Few plants scattered along runway. Mature heads in September. (UH, 1).

Appendix Table 4. (Continued)

Echinochloa crus-galli		Barnyard grass
Aug. 1944:	Collected by E.H. Bryan, Jr. (BISH, 1).	
Eleusine indica		Goose grass
1 Nov. 1946:	"Rare" (Fosberg, 1948). (BISH, 1).	
1950:	"Fosberg noted this to be abundant around edges of airstrip and along path in 1950." (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).	
1967:	Scattered, not abundant.	
Eragrostis tenella (incl. *amabilis*)		Lovegrass
1954:	"Common" (Doty and Newhouse, ms.).	
Jan. 1958:	Collected (as *E. amabilis* (L) Wight and Arn) by O. and I. Degener. (BISH, 1).	
Apr. 1965:	Collected by C.H. Lamoureux, sandy soil in north part of island. (UH, 1).	
Lepturus repens		Bunch grass
Jul. 1923:	"Growing in low, dry, brown bunches, forming a fairly dense, dominant stand" (Christophersen, 1931). (BISH, 1).	
6 Jun. 1942:	Collected by Ashley Browne. (BISH, 1).	
Aug. 1944:	Collected by E.H. Bryan, Jr. (BISH, 1).	
1 Nov. 1946:	"Abundant " (Fosberg, 1949). (BISH, 1).	
Nov. 1953:	Collected by E.H. Walker. (US, 1).	
1954:	"Common" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 3).	
1967:	A few bunches scattered along runway, south side.	

Appendix Table 4. (Continued)

Saccharum officinarum		Sugarcane
Apr. 1965:	Observed by C.H. Lamoureux. "Cultivated, a few plants only."	
Setaria verticillata		Bristlegrass
Aug. 1944:	Collected by E.H. Bryan, Jr. (BISH, 1).	
1 Nov. 1946:	"Common locally." (Fosberg, 1949). (BISH, 1).	
1950-1954:	"Occasional around the buildings in 1950 according to Fosberg and common around dependent's quarters at present" (Doty and Newhouse, ms.).	
Sporobolus virginicus		Dropseed
1954:	"Near quonset hut in officer's dependents quarters. This grass is a widespread grass of brackish beach shore areas and may become a good cover at Johnston" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island, on sand dune. (UH, 1).	
Cyperaceae		Sedges
Cyperus rotundus		
11 Sep. 1967:	Few scattered plants, open coral. (UH, 1).	
Fimbristylus cymosa?		
Jan. 1958:	Collected by O. and I. Degener, "common about airport." (Identified as *F. diphylla*). (BISH, 2).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 2).	
Cocos nucifera		Coconut palm
Aug. 1944:	"Small, windblown, no trunk" (Bryan, 1944).	
1 Nov. 1946:	"One seedling seen" (Fosberg, 1949).	
1951-1954:	"One coconut seedling was seen by Fosberg in 1951. Several are now present, e.g., in the schoolhouse yard and around the officer's dependents' quarters" (Doty and Newhouse, ms.).	

Appendix Table 4. (Continued)

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Araceae		
Anthurium andraanum		Anthurium
1954:	"Potted and growing in the house of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).	
Liliaceae		
Allium fistulosum		Welsh onion
1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).	
Allium sp.		Chives
1954:	"In the yard of Mr. E. English" (Doty and Newhouse, ms.).	
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Cordyline fruticosa		Cordyline
1954:	"In the yard of B.O.Q." (Doty and Newhouse, ms.).	
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Sansevieria trifaciata?		Bowstring Hemp
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Amaryllidaceae		
Crinum asiaticum		
Aug. 1944:	"A few plants" (Bryan, 1944).	
Crinum sp.		
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Hymenocallis littoralis		Spider Lily
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	

Appendix Table 4. (Continued)

Zingiberaceae

Alpina sp. Ginger

1954: "In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Musaceae

Helioconia humilis

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Strelitzia reginae Bird of Paradise

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Orchidaceae Orchids

Epidendrum sp.

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Vanda sp.

1954: "In the yard of Mr. Kahoiwai" (Doty and Newhouse, ms.).

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Casuarinaceae

Casuarina equisetifolia Ironwood

Aug. 1944: "Small, brown, windblown" (Bryan, 1944).

1 Nov. 1946: "Commonly planted" (Fosberg, 1949). (BISH, 1).

1951-1954: "Fosberg noted about 25 in the residential area in 1951. Several over 45 feet high are now doing well in the B.O.Q. area" (Doty and Newhouse, ms.).

Apr. 1965: Collected by C.H. Lamoureux, northern part of island. (UH, 1).

1967: At least eight to ten trees on the island, up to 20 feet high, all apparently healthy.

25 Jan. 1969: Trees on top of the hospital cut down to about ten foot stumps. Still alive.

Appendix Table 4. (Continued)

Moraceae		
Ficus microcarpa		Banyan
	Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
Polygonaceae		
Coccoloba uvifera		Sea-grape
	Aug. 1944:	"Small, but in good leaf" (Bryan, 1944).
	Nov. 1953:	Collected by E.H. Walker. (US, 1).
	1950-1954:	"Seen commonly planted near houses by Fosberg in 1950. Several trees seen during the present study" (Doty and Newhouse, ms.).
	Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
	1967:	Several trees, up to 15 feet high, fruiting profusely in September.
	25 Jan. 1969:	*Coccoloba* along bank next to runway are very dense and much larger than before.
Chenopodiaceae		
Chenopodium murale		Goosefoot, Pigweed
	1954:	"Found in the enlisted men's dependents quonset area" (Doty and Newhouse, ms.).
Amaranthaceae		Pigweeds
Amaranthus dubius		
	1954:	"Between quonset huts of enlisted men's dependents quarters" (Doty and Newhouse, ms.).
	Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 2).
Amaranthus spinosus		
	Aug. 1944:	"A few weeds" (Bryan, 1944). (BISH, 1).

Appendix Table 4. (Continued)

Amaranthus viridis

1 Nov. 1946:	"Common along fences" (Fosberg, 1949). (BISH, 1).
1950-1954:	"Fosberg reported this as common around airport buildings in 1950, between quonset huts at enlisted men's dependents quarters" (Doty and Newhouse, ms.).
Nov. 1953:	Collected by E.H. Walker; probably this species. (US, 1).
Apr. 1965:	Collected by C.H. Lamoureux from northern part of island. (UH, 1).

Nyctaginaceae

Boerhavia sp.

Jul. 1923:	"...most abundant at the east end of the island, on the seaward slopes of the highest hill; being sparingly found elsewhere" (Christophersen, 1931). (BISH, 1).
Jun. 1942:	Collected by Ashley Browne. (BISH, 1).
Aug. 1944:	Collected by E.H. Bryan, Jr. (BISH, 1).
1 Nov. 1946:	"Abundant, especially in places not walked too much" (Fosberg, 1949). (BISH, 1).
Nov. 1953:	Collected by E.H. Walker. (US, 1).
1954:	"Common in yards and along main runway" (Doty and Newhouse, ms.).
Jan. 1958:	Collected by O. and I. Degener. "Common along airport edge" (BISH, 1).
Apr. 1965:	Collected by C.H. Lamoureux, from northern part of island. (UH, 1).
1967:	Scarce, found only in one place.

Bougainvillea sp.

1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Appendix Table 4. (Continued)

Aizoaceae

Sesuvium portulacastrum

Aug. 1944:	"One plant seen" (Bryan, 1944). (BISH, 1).
Nov. 1953:	Collected by E.H. Walker, "along shore." (UH, 1).
1954:	"Common south of the main runway" (Doty and Newhouse, ms.).
Jan. 1958:	Collected by O. and I. Degener at "edge of airfield." (Bish, 1).
Apr. 1965:	Collected by C.H. Lamoureux from sand-covered bunker on northern part of island. (UH, 2).

Portulacaceae

Portulaca oleracea Purslane

Aug. 1944:	"Small patch in good leaf" (Bryan, 1944).
1 Nov. 1946:	"Common" (Fosberg, 1949). (BISH, 1).
1954:	[listed without comment](Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux from northern part of island. (UH, 1).

Caryophyllaceae

Spergularia marina

Apr. 1965:	Collected by C.H. Lamoureux from northern part of island. (UH, 1).
1967:	Scattered, not abundant.

Lauraceae

Persea americana Avocado

1954:	"Potted in the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.

Appendix Table 4. (Continued)

Cruciferae

Lobularia maritima Sweet Alyssum

1954: "In the yard of Mr. E. English" (Doty and Newhouse, ms.).

Leguminosae

Acacia farnesiana Sweet Acacia

Aug. 1944: "Small, very dry" (Bryan, 1944). (BISH, 1).

1954: "Only one plant seen. This growing on the west side of B.O.Q. building" (Doty and Newhouse, ms.).

Apr. 1965: Collected by C.H. Lamoureux from northern part of island. (UH, 1).

1967: One small shrub north of tennis courts, and a few on bank north of NCO club.

Crotalaria incana Rattlebox

Apr. 1965: Collected by C.H. Lamoureux from northern part of island. (UH, 1).

Leucaena latisiliqua

Apr. 1965: Collected by C.H. Lamoureux from northern part of island. (UH, 1).

Pithecellobium dulce Manila Tamarind

1 Nov. 1946: "Rare, planted" (Fosberg, 1949). (BISH, 1).

1954: "A small tree persisting under drought conditions." (Doty and Newhouse, ms.).

Prosopis pallida Algarobe, Kiawe

1 Nov. 1946: "Rare, planted" (Fosberg, 1949). (BISH, 1).

1954: [listed without comment] (Doty and Newhouse, ms.).

Appendix Table 4. (Continued)

Vigna marina		Beach Pea
	Apr. 1965:	Collected by C.H. Lamoureux from sand around bunker, northern part of island. (UH, 1).
	1967:	Growing on side of bunker near NCO club, blooming in May. (UH, 1).
Zygophyllaceae		
Tribulus cistoides		Puncture Vine
	Jul. 1923:	"...second in abundance, being scattered generally among the bunches of *Lepturus repens*." (Christophersen, 1931). (BISH, 1).
	6 Jun. 1942:	Collected by Ashley Brown. (BISH, 1).
	Aug. 1944:	Collected by E.H. Bryan, Jr. (BISH, 1).
	1 Nov. 1946:	"Abundant" (Fosberg, 1949). (BISH, 1).
	1954:	"Common" (Doty and Newhouse, ms.).
	Apr. 1965:	Collected by C.H. Lamoureux, from northern part of island. (UH, 1).
Rutaceae		
Citrus aurantifolia		Lime
	1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).
	Apr. 1965:	*Citrus* sp. observed by C.H. Lamoureux. Cultivated.
Euphorbiaceae		
Codiaeum variegatum var. *pictum*		Croton
	1954:	"Fosberg saw this in a pot at the terminal" (Doty and Newhouse, ms.).
	Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.
Euphorbia atoto?		Spurge
	12 Nov. 1953:	Collected by E.H. Walker, on sand along shore. (US, 1).

Appendix Table 4. (Continued)

Euphorbia prostrata		Spurge
Apr. 1965:	Collected by C.H. Lamoureux, from lawn in northern portion of island. (UH, 1).	
Euphorbia prob. *heterophylla*		Spurge
1 Nov. 1946:	"Abundant locally on small dune" (Fosberg, 1949). (BISH, 1).	
1954:	"Common" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux from northern part of island. (UH, 2).	
Euphorbia glomerifera		Spurge
1 Nov. 1946:	"Common along fences and edges of walks" (Fosberg, 1949). (BISH, 1).	
1951:	"Fosberg, in 1951, saw many plants of this species around the buildings" (Doty and Newhouse, ms.).	
1954:	"Common near chapel" (Doty and Newhouse, ms.).	
30 Jan. 1958:	Collected by O. and I. Degener, at edge of airfield. (BISH, 1).	
Apr. 1965:	Collected by C.H. Lamoureux from northern part of island. (UH, 1).	
1967:	Scattered along runway, in open coral. (UH, 1).	
Euphorbia hirta		Spurge
1954:	"Common at Johnston as in many other places" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).	
Euphorbia pulcherrima		Poinsettia
1954:	"Potted plants around dependent's quarters" (Doty and Newhouse, ms.).	
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	

Appendix Table 4. (Continued)

Pedilanthus tithymeloides		Slipper flower
1954:	Listed by Lamoureux, not in Doty and Newhouse (ms.).	
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Ricinus communis		Castor bean
Aug. 1944:	"Large and flourishing, as large as some of the trees" (Bryan, 1944).	
1 Nov. 1946:	"Common" (Fosberg, 1949). (BISH, 1).	
1954:	"Beside the path from PX to chapel" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).	
1967:	Many plants formerly (1966) growing near southwest end of barracks area apparently were removed during construction of swimming pool.	
Anacardiaceae		
Mangifera indica		Mango
1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).	
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Schinus terebinthifolius		Christmas Berry Tree
1 Nov. 1946:	Observed? [Not in Fosberg, 1949].	
1950:	"Fosberg in 1950 saw this planted near houses" (Doty and Newhouse, ms.).	
Tiliaceae		
Triumfetta procumbens		
Aug. 1944:	"Small, in good leaf" (Bryan, 1944).	

Appendix Table 4. (Continued)

Malvaceae

Hibiscus tiliaceus Hau

18 Jul. 1923:	"Planted 8 clips of hau (*Hibiscus tiliaceus*) on Johnston..." (Wetmore, ms. b).
1951:	"Fosberg in 1951 saw large trees of this around the base buildings which were then somewhat chlorotic" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Tree near NCO club blooming profusely in early September. (UH, 1).

Hibiscus sp.

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.

Thespesia populnea Milo tree, Portia-tree

Aug. 1944:	"Leaves were very small" (Bryan, 1944). (BISH, 1).
1 Nov. 1946:	"Commonly planted" (Fosberg, 1949). (BISH, 1).
1954:	"Around base buildings and in 1952 growing at the terminal" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Tree by NCO club with mature fruits in September. (UH, 1).

Sida sp.

Aug. 1944:	"A few plants, growing well" (Bryan, 1944).

Sterculiaceae

Waltheria indica

Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Few plants found between taxiway and runway, northeast end, and on south side of runway (UH, 1).

Appendix Table 4. (Continued)

Guttiferae

Calophyllum inophyllum False Kamani

Aug. 1944: "Small, shrubby" (Bryan, 1944).

1951-1954: "Fosberg reported this tree in 1951, to be 2-3 meters tall. Now along the north side of the street between the officer's dependent's quonsets and base commander's house" (Doty and Newhouse, ms.).

Apr. 1965: Collected by C.H. Lamoureux. Cultivated on northern part of island. (UH, 1).

Combretaceae

Terminalia catappa Indian Almond, Kamani

Aug. 1944: "Small, shrubby" (Bryan, 1944).

1 Nov. 1946: "Abundantly planted" (Fosberg, 1959). (BISH, 1).

1952-1954: "Fosberg observed that the large trees of this species around the base buildings were somewhat chlorotic. In 1952, he recorded one as growing in a pot at the terminal" (Doty and Newhouse, ms.).

Apr. 1965: Collected by C.H. Lamoureux, northern part of island. (UH, 1).

1967: Several trees with mature fruits in September.

Araliaceae

Brassaia actinophylla Octopus tree

1 Nov. 1946: Observed [Not in Fosberg, 1949].

1952: "Fosberg saw one in a pot at the terminal in 1952" (Doty and Newhouse, ms.).

1967: One plant found north of tennis courts.

Polyscias guilfoylei Wild coffee

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Appendix Table 4. (Continued)

Caricaceae

Carica papaya Papaya

1954: "In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Plumbaginaceae

Plumbago auriculata Plumbago, Leadwort

1954: "In the yard of Mr. E. English" (Doty and Newhouse, ms.).

Apocynaceae

Catharanthus roseus Madagascar Periwinkle

1954: "Sprawling shrub in schoolhouse yard" (Doty and Newhouse, ms.).

Nerium oleander Oleander

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Plumeria acuminata Frangipani

1954: "In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

1967: One blooming in September near base exchange; a few other small plants seen, not blooming.

Plumeria rubra Frangipani

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Thevetia peruviana var. *aurantica*

1 Nov. 1946: "Planted, not common" (Fosberg, 1949). (BISH, 1).

1954: Listed, no notes (Doty and Newhouse, ms.).

Thevetia peruviana (=nereifolia) Yellow Oleander

Aug. 1944: "Small, depauperate" (Bryan, 1944).

1953-1954: "At southwest corner of B.O.Q. building. This and *T. thevetioides* should be destroyed as they are very poisonous plants. One was removed in 1953 at E.H. Bryan's suggestion, and 11 may be gone now" (Doty and Newhouse, ms.).

Appendix Table 4. (Continued)

Convolvulaceae

Ipomoea pes-caprae — Beach Morning-glory

Aug. 1944:	"A few vines" (Bryan, 1944).
1954:	"On trellis work and fence, south side of commissary" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux on sand dune, northern part of island. (UH, 1).
1967:	Widely used for binding newly dredged coral; growing vigorously and blooming profusely in most locations all year.

Ipomoea macrantha — Wild Morning Glory

Aug. 1944:	"Probably this species" (Bryan, 1944).

Merremia tuberosa — Wood Rose

1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Hydrophyllaceae

Nama sandwicensis

1967:	On open coral between the northeast end of the taxiway and the main runway. (UH, 1).

Boraginaceae

Cordia subcordata — Kou

Aug. 1944:	"Small, probably this species" (Bryan, 1944).

Cordia sebestena — Kou, Geiger tree

1 Nov. 1946:	"Planted, rare" (Fosberg, 1949). (BISH, 1).
1954:	"In the schoolhouse yard" (Doty and Newhouse, ms.).
Apr. 1965:	Collected?

Appendix Table 4. (Continued)

Heliotropium curassavicum

Apr. 1965:	Collected by C.H. Lamoureux, from residential area. (UH, 1).
1967:	Widespread, but not abundant, blooming in September.

Tournefortia argentea Tree Heliotrope

Aug. 1944:	"Stunted, but in good leaf" (Bryan, 1944).
1 Nov. 1946:	"Planted, occasional" (Fosberg, 1949). (BISH, 1).
12 Nov. 1953:	Collected by E.H. Walker "along shore." (US, 1).
1954:	"Between base commander's house and officer's club" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Several trees, growing vigorously, blooming all year.

Verbenaceae

Stachytarpheta jamaicensis

1967:	Few scattered plants on open coral between the northeast end of the taxiway and the main runway. (UH, 1).

Vitex ovata

Aug. 1944:	"Small, but hardy" (Bryan, 1944). (BISH, 1).
1 Nov. 1946:	"Planted, occasional" (Fosberg, 1949). (BISH, 1).
1954:	"Across the street north of the infirmary and in the B.O.Q. yard" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Several large bushes on bank north of NCO club, and few on the south side of NCO club, used by nesting Red-tailed Tropicbirds. With blooms and fruits in September. (UH, 1).

Appendix Table 4. (Continued)

Solanaceae

Capsicum frutescens Pepper

1954: "In the yards of Mr. S.A. Kahoiwai and Mr. E. English" (Doty and Newhouse, ms.).

Nicotiana glauca

12 Nov. 1953: Collected by E.H. Walker by building. (US, 1).

1954: "...near tennis court opposite enlisted men's dependent's quarters" (Doty and Newhouse, ms.).

Apr. 1965: Collected by C.H. Lamoureux, northern part of island. (UH, 1).

Solanum lycopersicum Tomato

1954: "Cultivated near enlisted men's dependent's apartments. Only one plant seen" (Doty and Newhouse, ms.).

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Solanum melongena Eggplant

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Bignoniaceae

Tabebuia pentophylla West Indian Boxwood

Apr. 1965: Collected by C.H. Lamoureux. Cultivated, northern part of island. (UH, 1).

Rubiaceae

Gardenia sp.

1954: "In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Coprosoma sp.

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Appendix Table 4. (Continued)

Cucurbitaceae

Citrullus lanatus var. *vulgaris* Watermelon

1954:	"In the yard of Mr. S.A. Kahoiwai" (Doty and Newhouse, ms.).

Goodeniaceae

Scaevola taccada

Aug. 1944:	"Small, but sturdy" (Bryan, 1944).
1 Nov. 1946:	"Rare. Under *Messerschmidia* [*Tournefortia*] tree" (Fosberg, 1949). (BISH, 1).
12 Nov. 1953:	Collected by E.H. Walker. (US, 1).
1954:	"Near officer's club" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Scattered, not abundant, blooming in September.

Compositae

Bidens pilosa Bur-marigold

Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).

Conyza bonariensis

1954:	"South of the main runway" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Scattered in open area north of NCO club, mature heads in September.

Emilia sonchifolia

Apr. 1965:	Observed by C.H. Lamoureux. Weed.

Helianthus annuus Sunflower

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.

Appendix Table 4. (Continued)

Pluchea indica

Aug. 1944:	"Dry-looking, growing well" (Bryan, 1944). (BISH, 1).
1 Nov. 1946:	"Uncommon, five or six plants seen" (Fosberg, 1949). (BISH, 1).
12 Nov. 1953:	Collected by E.H. Walker. (US, 1).
1950-1951:	"Reported common around airport buildings in 1950 and noted again in 1951 as 'common' by Fosberg" (Doty and Newhouse, ms).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	"Scattered, not abundant, mature heads in September."

Pluchea carolinensis

1 Nov. 1946:	"Occasional (Fosberg, 1949). (BISH, 1).
12 Nov. 1953:	Collected by E.H. Walker.(US, 1).
1951-1954:	"In 1951 Fosberg found this less common than in 1946. It is still common now in 1954 south of the main runway" (Doty and Newhouse, ms.).
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).
1967:	Abundant on south side of runway, where it is attracting nesting Red-tailed Tropicbirds. Mature heads in September. POBSP recommended it be removed as a hazard to aircraft.
1969:	All bushes along south side of runway are gone. Most of those remaining in other areas are well trimmed and present poor habitat for tropicbirds.

Pluchea x *Fosbergii*

Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).

Appendix Table 4. (Continued)

Sonchus sp. *(oleraceus* x *asper)?*		Sow-thistle
1 Nov. 1946:	"Occasional" (Fosberg, 1949). (BISH, 1).	
1954:	"Common around dependent's quarters" (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, northern part of island. (UH, 1).	
	"The *Sonchus* on Johnston Atoll has previously been called *S. oleraceus* and *S. asper*. The collections I have seen are all ± intermediate between these two species" (Lamoureux, pers. comm.).	
1967:	Blooming in open area north of NCO club.	
Tagetes sp.		Marigold
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	
Vernonia cinerea		Ironweed
1 Nov. 1946:	(Not in Fosberg, 1949).	
1954:	[Listed without comment] (Doty and Newhouse, ms.).	
Apr. 1965:	Collected by C.H. Lamoureux, in shade of buildings near navy decks. (UH, 1).	
1967:	Scattered, open coral near barracks between NCO club and Base Exchange. (UH, 1).	
Zinnia elegans		Zinnia
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.	

Appendix Table 5. Annotated list* of vascular plant species recorded from the man-made portion of Sand Island, Johnston Atoll

Graminea

Cenchrus echinatus — Sandbur

Jul. 1963:	"Found around buildings and on causeway of man-made portion" (POBSP, 1964).
Apr. 1965:	Observed by Lamoureux?
1967:	In September the only healthy stands were around the fuel tanks on the west side of the man-made portion of the island, where continued disturbance seems to keep competitors out. Mature fruits were found on most plants in September.

Cynodon dactylon — Bermuda Grass

Jul. 1963:	"Found only around buildings on man-made portion" (POBSP, 1964).
Apr. 1965:	Observed by Lamoureux?
1967:	Spread during the winter (1966-1967) both from previously established plants and from one inch squares set around buildings by the Coast Guard in October 1966. Cessation of close mowing and weekly raking allowed new stolons to cover much of the bare sand around the buildings.
1969:	Spread greatly around buildings, probably because of better care by USCG--less frequent and higher mowing.

Dactyloctenium aegyptium — Crowfoot Grass

Apr. 1965:	Collected by C.H. Lamoureux, weed in *Cynodon* lawn. (UH, 1).
May 1967:	Collected by P.C. Shelton, open coral dredged about 1963. (UH, 1).

*Collections are shown by herbarium designation, followed by the number of specimens in each collection (UH = University of Hawaii). Data from 1967 and 1969 are taken from POBSP, 1967b and 1969.

Appendix Table 5. (Continued)

Digitaria sanguinalis? Crabgrass

Apr. 1965: Collected by C.H. Lamoureux, on causeway. (UH, 1).

Eleusine indica Goosegrass

Jul. 1963: "Scattered plants on man-made portion" (POBSP, 1964).

Apr. 1965: Observed by Lamoureux?

1967: There was no noticeable change in the scattered patches on the west portion.

Lepturus repens

Jul. 1963: "Found along causeway and scattered on man-made portion" (POBSP, 1964).

Apr. 1965: Observed by Lamoureux?

Seteria verticillata Bristlegrass

Jul. 1963: "Scattered plants on original and man-made portions, not common" (POBSP, 1964).

Cyperaceae

Fimbristylis cymosa? Sedge

Apr. 1965: Collected by C.H. Lamoureux, "rare, few in lawn and on road to photo shack." (UH, 1).

1967: Found only on the newest coral on the man-made (west) end of the island. All plants had mature heads in May and September. (UH, 1).

Palmae

Cocos nucifera Coconut Palm

Jul. 1963: "Planted around buildings only on man-made portion" (POBSP, 1964).

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Appendix Table 5. (Continued)

1967:	Two mature nuts were produced in early 1967 on the single 15 foot tree growing at the northwest corner of the tennis court. By September several new nuts had grown to two to three inches, but most of these fell off as they reached this size. The few seedlings planted in October 1966, all on the west portion, were alive through 1967, but none was growing vigorously.
1969:	Several small trees have been set, especially around the barracks buildings. The larger tree at the west corner of the tennis court has several nuts of various sizes, some probably mature, and others barely past the bloom stage. Tree has grown noticeably since 1967.

Liliaceae

Aloe sp.	Aloe
Jul. 1963:	"One plant on man-made portion; obvious introduction" (POBSP, 1964).
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.
1967:	The single plant in front of the Coast Guard office was still present, but not blooming or growing vigorously.
1969:	The single plant in front of the USCG office was blooming profusely in February.

Amaryllidaceae

Crinum sp. or *Hymenocallis*	
1967:	Several of these were planted in front of the Coast Guard office in October 1966; one bloomed in August 1967.
1969:	No trace now.

Bromeliaceae

Ananas comosus	Pineapple
Apr. 1965:	Observed by C.H. Lamoureux. "Two tops planted, unhealthy."

Appendix Table 5. (Continued)

Casuarinaceae

Casuarina equisetifolia Ironwood

Apr. 1965:	Observed by C.H. Lamoureux. "Cultivated, doing well."
1967:	One tree about ten feet high grows south of the Coast Guard office. It was transplanted from near the tennis courts in early 1967, and has grown little since.
1969:	The single tree south of the Coast Guard office is thriving, and has grown a little since 1967. Now looks much more healthy than just after being transplanted.

Moraceae

Ficus microcarpa Banyan

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.
1967:	One tree, about 15 feet high, west side of the man-made part of the island. In bloom in September 1967.
1969:	The tree by the tennis courts appears to be healthy.

Urticaceae

Pilea microphylla Artillery Plant

Apr. 1965:	Collected by C.H. Lamoureux, growing as weed in can with Poinsettia at signal building on causeway. (UH, 1).

Polygonaceae

Coccoloba uvifera Sea-grape

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.
1967:	One small tree in front of Coast Guard office.

Appendix Table 5. (Continued)

Chenopodiaceae

Chenopodium murale Goosefoot, Pigweed

Apr. 1965:	Collected by C.H. Lamoureux, sandy soil around signal building on causeway and as weed in *Cynodon* lawn near quarters and boat dock. (UH, 2).
1967:	A small patch grows between the fuel tanks and dock on the west side of the man-made part of the island. In bloom in September 1967.

Amaranthaceae Pigweeds

Amaranthus dubius

Apr. 1965:	Collected by Lamoureux, "in coral soil near signal building on causeway." (UH, 1).

Amaranthus viridis

Jul. 1963:	"Few scattered plants around buildings on man-made portion" (POBSP, 1964).
Apr. 1965:	Collected by Lamoureux in lawn around quarters. (UH, 1).

Nyctaginaceae

Boerhavia sp.

Jul. 1963:	"Scattered plants found on original and man-made portions" (POBSP, 1964).
Apr. 1965:	Observed by Lamoureux?

Bougainvillea sp.

Apr. 1965:	Observed by C.H. Lamoureux, "cultivated on trellis."

Aizoaceae

Tetragonia tetragonioides New Zealand Spinach

Apr. 1965:	Observed by C.H. Lamoureux, cultivated near dock.

Appendix Table 5. (Continued)

Sesuvium portulacastrum		
	Jul. 1963:	"...along causeway and around housing facilities of man-made portion" (POBSP, 1964).
	Apr. 1965:	Collected by C.H. Lamoureux near quarters. (UH, 1).
	1967:	Along the causeway and on the man-made portion of the island, seedlings of this species grew abundantly during September and October, forming a fine-textured, almost mold-like covering over the bare coral near clumps of mature plants.
Portulacaceae		
Portulaca oleracea		Purslane
	Jul. 1963:	"Occurs as scattered plants on original and man-made portions" (POBSP, 1964).
	Apr. 1965:	Observed by Lamoureux?
Caryophyllaceae		
Spergularia marina		
	Jul. 1963:	"Occurs only on man-made portion around buildings" (POBSP, 1964).
	Apr. 1965:	Collected by C.H. Lamoureux from coral sand on causeway and near quarters. (UH, 2).
	1967:	Comparatively rare on the west (man-made) part of the island, and it seems to be losing in competition with *Sesuvium*, *Cynodon*, and *Euphorbia*.
Lauraceae		
Persea americana		Avocado
	Apr. 1965:	Observed by C.H. Lamoureux. "Cultivated, unhealthy."

Appendix Table 5. (Continued)

Cruciferae

Lobularia maritima Sweet Alyssum

Apr. 1965: Collected by C.H. Lamoureux on causeway leading to old photo shack. (UH, 1).

Rosaceae

Eriobotrya japonica Loquat

Apr. 1965: Collected by C.H. Lamoureux; "cultivated on man-made part of island, but not surviving well." (UH, 1).

Leguminosae

Leucaena latisiliqua

Apr. 1965: Collected by C.H. Lamoureux, south of pump-house, in *Cynodon* lawn. (UH, 1).

Zygophyllaceae

Tribulus cistoides Puncture Vine

Jul. 1963: "Scattered plants found on man-made portion" (POBSP, 1964).

Apr. 1965: Observed by Lamoureux?

Euphorbiaceae

Codiaeum variegatum var. *pictum* Croton

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Euphorbia glomerifera Spurge

1967: Scattered in open new coral on the south side of the man-made part of the island. Blooming in May and September. (UH, 2).

Euphorbia hirta Spurge

Apr. 1965: Collected by C.H. Lamoureux, weed in *Cynodon* lawn near quarters. (UH, 1).

Appendix Table 5. (Continued)

1967: Dense patches in undisturbed areas around the buildings and tennis court on the man-made end of the island. In bloom in September. (UH, 1).

Euphorbia pulcherrima Poinsettia

Apr. 1965: Observed by C.H. Lamoureux. Cultivated.

Malvaceae

Hibiscus sp.

Apr. 1965: Observed by C.H. Lamoureux, "cultivated but unhealthy."

Combretaceae

Terminalia catappa Indian almond, Kamani

Apr. 1965: Observed by C.H. Lamoureux, cultivated.

Myrtaceae

Eucalyptus sp.

Jul. 1963: "One plant, found only on man-made portion" (POBSP, 1964).

Apocynaceae

Nerium oleander Oleander

Jul. 1963: "Found only around buildings on man-made portion of island. Definitely introduced" (POBSP, 1964).

Convolvulaceae

Ipomoea pes-caprae Beach Morning-glory

Apr. 1965: Observed by C.H. Lamoureux. "Cultivated around quarters."

1967: A small clump near the south side bloomed profusely in spring and summer.

Appendix Table 5. (Continued)

Boraginaceae

Cordia sebestena Kou, Geiger-tree

Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.

Heliotropium curassavicum

Jul. 1963:	"Occurs only on man-made portion" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, west end of causeway. (UH, 1).
1967:	Showed no change from 1966 through 1967. It was scarce, scattered around the outer parts of both portions of the island. All plants were blooming both in spring and late summer.

Tournefortia argentea Tree Heliotrope

Jul. 1963:	"One large plant and many very small plants on man-made portion" (POBSP, 1964).
Apr. 1965:	Observed by C.H. Lamoureux. Cultivated.
1967:	Planted around buildings on the man-made end of the island, bloomed and produced fruit profusely during the spring, summer, and fall.
1969:	Present.

Solanaceae

Solanum lycopersicum Tomato

1967:	One plant south of the tennis courts flowered and produced a few three-inch fruits in spring 1967. A few flowers were present in September.
1969:	Couldn't find the plant south of the tennis courts; the area is now covered with large *Pluchea odorata* bushes.

Appendix Table 5. (Continued)

Goodeniaceae

Scaevola taccada

Jul. 1963:	"Occurs only on man-made portion; appears to have been planted around buildings; less than a dozen plants" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, cultivated near maintenance building. (UH, 1).
1966:	*Scaevola* growing near the Coast Guard buildings on the west portion of the island bloomed and bore fruit throughout the summer and early fall.
1967:	On the man-made end of the island, *Scaevola* continued to grow well and provide most of the nesting habitat for Red-tailed Tropicbirds. Flowers were produced during the spring, and in September, both flowers and fruits were found.
1969:	Those around the Coast Guard power house have grown noticeably since 1967, and had fruits in February. Those planted along the west seawall, behind the fuel tanks, in October 1966, had spread laterally to three to five feet in diameter, but had not attained much vertical growth. They were green and vigorous.

Compositae

Conyza bonariensis

Apr. 1965:	Collected by C.H. Lamoureux, lawn west of tennis court. (UH, 1).
1967:	Scattered on the newest coral on the south side of the man-made end of the island. Plants that were blooming in the spring were mostly matured and partly dried up by September. (UH, 1).

Pluchea indica

Apr. 1965:	Collected by C.H. Lamoureux, west end of causeway, in coral sand. (UH, 1).

Appendix Table 5. (Continued)

1967:	A few plants occur on the southeast side of the man-made portion of the island; growing and spreading slowly, but none large enough to be conspicuous. Blooming in May.
1969:	The stand of this species growing on the eastern part of the area southeast of the barracks appears to have spread little since 1967, probably because of being crowded by *Pluchea odorata*, which is much more aggressive in this area. The plants, however, appear vigorous.

Pluchea carolinensis

Apr. 1965:	Collected by C.H. Lamoureux, coral sand at west end of causeway. (UH, 1).
1967:	"...appeared to have grown over the winter, but no quantitative data were obtained. During the summer of 1967 the plants on the south side of the west portion of the island grew and thickened rapidly, providing much more potential tropicbird nesting habitat."
1969:	Spectacular increase since 1967.

Sonchus sp. *(oleraceus* x *asper)?* Sow-thistle

Jul. 1963:	"Occurs only on man-made portion; scattered plants." (POBSP, 1964).
1967:	Occurred scattered around the buildings and open areas on the man-made end. In early spring it was in all stages of bloom and fruit, but by May most plants had mature fruits. By September many of the plants had partially dried up.
1969:	Scattered plants occur...along the causeway; also on other areas, especially near pump-house, etc.

Vernonia cinerea

Apr. 1965:	Collected by C.H. Lamoureux, "weed in *Cynodon* lawn near quarters...." (UH, 1).
1967:	Grew scattered around the tennis court, not abundant. Blooming in September. (UH, 1).

Appendix Table 6. Annotated list* of vascular plant species recorded from the original portion of Sand Island, Johnston Atoll

Graminae

Cenchrus echinatus — Sandbur

Jul. 1963:	"...found on original portion along road at junction of causeway. Plants clumped, sandspur type" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, original part of island, western part. (UH, 1).
1966:	Other grasses, including *Cenchrus echinatus*... which grow only along the road on the northeast corner of the island (original portion) were scarcely evident in July, but by October formed a lush cover over the area.
1967:	*Cenchrus echinatus* seems to be losing ground on the island. In the spring of 1967 it was scarce on the original portion of the island, most of the patches found last year having been crowded out by other grasses. In September only a few plants could be found on the northwest corner of the original portion....Mature fruits were found on most plants in September.

Cynodon dactylon — Bermuda grass

Apr. 1965:	Collected by C.H. Lamoureux, "mostly beside roads, not common." (UH, 1).
1966:	Other grasses, including...*Cynodon dactylon* ...which grow only along the road on the northeast corner of the island (original portion) were scarcely evident in July, but by October, they formed a lush cover over the area, with flowering plants.
1967:	The two patches on the original end of the island, one along the road to the transmitter and one on the south side of the island, showed little change from 1966 through 1967. All plants had mature heads in September 1967.

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*Collections are shown by herbarium designation, followed by the number of specimens in each collection (BISH= B.P. Bishop Museum; UH=University of Hawaii. Data from 1967 and 1969 are taken from POBSP, 1967b and 1969.

Appendix Table 6. (Continued)

1969:	On original portion, three patches growing and flowering during February, one on each side of the road nearly to the transmitter building, and one next to the northeast side of the concrete slab near the south shore. This last seems to be perhaps smaller than it was in 1967.

Dactyloctenium aegyptium Crowfoot grass

1967:	Other introduced grasses, including... *Dactyloctenium aegyptium*, were profusely flowering in late February and March, but by May had turned brown and were beaten down by birds on the east portion. However, they still afforded many times more ground cover than in summer 1966.
	Dactyloctenium aegyptium formerly had been found only on the man-made end of Sand Island, but in September 1967, at least two small clumps with mature fruits were found on the southeast side of the original part of the island.

Eleusine indica Goosegrass

Jul. 1963:	"Very few plants on original portion" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, in coral sand around transmitter building. (UH, 1).
1967:	Other introduced grasses, including *Eleusine indica*...were profusely flowering in late February and March, but by May had turned brown and were beaten down by birds on the east portion. However, they still afforded many times more ground cover than in summer 1966.
	"*Eleusine indica* appeared to be losing ground to the native *Lepturus* on the original part of the island."
1969:	Spread greatly, especially on areas previously almost barren along the old roads on the southwest corner of the island; healthy stands occur in several other parts of the original portion of the island, apparently occupying a position intermediate between *Lepturus* and *Boerhavia* in succession.

Appendix Table 6. (Continued)

Lepturus repens

Jul. 1923:	"...growing in low, dry, brown bunches, forming a fairly dense, dominant stand" (Christophersen, 1931). (BISH, 1).
Jul. 1963:	"Covers 50 percent vegetated area of original portion" (POBSP, 1964).
Apr. 1964:	Collected by C.H. Lamoureux, west part of original portion, and southwest islet. (UH, 2).
1966:	Dry and brown in July with no evidence of recent new growth. There was no evident difference between areas used by Sooty Terns and the small area north of the road to the transmitter building that was not used by terns. During August new growth of *Lepturus* became evident, and by October, green new growth overshadowed the dry, decadent old growth, giving a green appearance to the west portion of the original island. Most of the clumps were in flower by then as well.
1967:	Spread considerably from October 1966 to February 1967, but it was relatively dry and not flowering in February. By the end of March, it was at least as green as in October 1966 and covered much more area (see especially photos of Sooty Tern plot #3). It began blooming in April and May, although by early May its greenness had begun to decrease. In September it was green and lush, with blooms and fruits, even where it had been overrun by Sooty Terns all summer.
Mar. 1969:	Appeared to be less vigorous than other species, especially *Eleusine*, which was greener than *Lepturus*. In places, new blooming heads were seen, and in general the species appeared to have ended a period of growth. Isolated patches, apparently new, or at least recently becoming conspicuous, appear on the west side of the islet, and various places on the east half of the island. The stand along the east beach north of the east bunker is all but extinct, for no apparent reason. Christmas Shearwaters nesting there are now tunneling into

Appendix Table 6. (Continued)

and under dense *Boerhavia*. Could it be that *Boerhavia* actually squeezes out the *Lepturus*?

Setaria verticillata — Bristlegrass

Jul. 1963: "Scattered plants....not common" (POBSP, 1964).

Apr. 1965: Collected by C.H. Lamoureux, along road, western portion, original part of island. (UH,1).

1966: Other grasses, including...*Setaria*...which grow only along the road on the northeast corner of the island (original portion) were scarcely evident in July, but by October, they formed a lush cover over the area with flowering plants up to 2.5 feet high.

1967: Profusely flowering in late February and March, but by May had turned brown and were beaten down by birds on the east portion. However, they still afforded many times more ground cover than in summer 1966.

Also appeared to be losing in competition with *Lepturus* on the original part of the island.

1969: Little found.

Chenopodiaceae

Chenopodium murale — Goosefoot, Pigweed

Apr. 1965: Collected by C.H. Lamoureux, beside road, in coral sand. (UH, 1).

Amaranthaceae — Pigweeds

Amaranthus dubius

Apr. 1965: Collected by Lamoureux from "SW portion of original portion of island and west portion of original part of island." (UH,2).

Amaranthus viridis

Jul. 1963: "Found in the central and west area of the original portion " (POBSP, 1964).

Appendix Table 6. (Continued)

Apr. 1965:	Collected by C.H. Lamoureux from southwest and west portions. (UH, 2).
1966:	Sparse and low in July, but grew vigorously in several areas by September and October.
1967:	Grew vigorously and bloomed during spring 1967 in central area south-southwest of the transmitter. Patches along the northwest side of the island, especially along the road, had been crowded out by grasses. Black Noddies roosted on the two largest clumps (SSW and SE) in March, and in April three nests were built on the southeast clumps, all about a foot off the ground. By September only the major clumps were still intact, while seedlings that were growing around them during the spring had been destroyed by Sooty Tern trampling. Smaller clumps north of the transmitter and near the northwest side of the island were still intact, but not as vigorous as in 1966 because of more competition from other plants, especially grasses.
1969:	Appeared to have reached maturity and begun to dry up during February....At the beginning of the month, most plants were green, but by the first of March, had turned brown, and were shedding seeds profusely. Distribution little changed since 1967, but patch southeast of transmitter much reduced from 1967 levels. None there now is capable of supporting a Black Noddy nest. Also, that north of transmitter has further lost ground to grasses.
Nyctaginaceae	
Boerhavia sp.	
Jul. 1923:	"...more abundant than *Tribulus cistoides*, but neither begins to compare with the bunch grass in extent" (Christophersen, 1931). (BISH, 1).
Jul. 1963:	"Scattered plants found on original and man-made portions" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux from southwest islet and west part of island. (UH, 2).

Appendix Table 6. (Continued)

1966:	Green and blooming in July, indicating that drought was not a great factor in its status ....continued to grow and bloom vigorously throughout the summer and fall. During and after August...bore seeds abundantly.
1967:	Distribution was not significantly different from October 1966 to May 1967, but by late August 1967 it had spread tremendously, especially on the east half of the original portion of the island, including the northeast peninsula, and on the southwest islet. Large areas of previously bare sand were covered on the east hill. Blooming and fruiting were continuous through the spring and summer. Downy chicks, especially Brown Boobies, frequently had large numbers of seeds stuck to them. After the supply of *Tribulus* on the island was exhausted by early-nesting Red-footed Boobies, these birds used *Boerhvaia* for nest material. Most Brown Booby nests contained *Boerhavia* also.
1969:	This species is the most changed from the 1967 level of all plants on the island. It now carpets perhaps 80 to 90 percent of the east half of the original portion of the island, including nearly all areas that were barren in 1967. The diggings by the Coast Guardsmen for the hospital on the east hill are profusely covered, as is the ground over most of the rest of the east half of the island. On the east slope, Christmas Shearwaters are burrowing into the thick mat for their nest sites. This increase had started during the spring of 1967, and apparently has continued unabated. Thus this species seems to be an important pioneer, sand-holding species, at least on this island. It may be set back periodically by the tower maintenance and/or drought, but evidently there was sufficient rain during the last two years for it to thrive. During February most areas were in bloom, and mature fruits were also abundant, sticking to socks and to birds. It occurs in scattered clumps throughout the southwest area also, but does not appear to harm the *Lepturus* there.

Appendix Table 6. (Continued)

Aizoaceae

Sesuvium portulacastrum

Jul. 1963:	"Occurs on northeast peninsula, east shore, southwest islet and along roadway to transmitter building of the east portion...." (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux from southwest islet, west portion of original island. (UH, 2).
1966:	*Sesuvium portulacastrum* was least affected by the dry weather and disturbance of the early part of the summer. In July it was in bloom all along the fringes of the island, especially on the outer, undistrubed portion of the northeast peninsula. It continued to bloom and produce seed throughout the summer and early autumn.
1967:	*Sesuvium portulacastrum* underwent no noticeable change during the period of observation. In 1967 it was in bloom continuously except where it was badly trampled by Sooty Terns. Seedlings described in October 1966 did not survive, if indeed they were even of this species.
1969:	Continues to survive on the edges of the island, but has been crowded out of the central portion of the peninsula by *Boerhavia*. No really thrifty stands were found. A few blooms were noted.

Portulacaceae

Portulaca oleracea Purslane

Jul. 1963:	"Occurs as scattered plants on original and man-made portions" (POBSP, 1964).
Apr. 1965:	Observed by Lamoureux?
1966:	Occurred scattered around the island. These plants were inconspicuous until they began to spread and flower in September and October. By early October, seedlings were abundant on the nearly bare slope above the bunker on

Appendix Table 6. (Continued)

	the east shore. These probably grew from old seeds, or possibly from roots of destroyed plants, for few mature plants grew in this area.
1967:	Became fairly conspicuous on the east slope of the east portion of the island by early 1967, both on the slope above the east bunker where it was described in October 1966, and also on the northeast slope, where none was noticed at that time. By May 1967 all these plants were badly beaten down by Sooty Terns, and by September the areas were largely covered with *Boerhavia*. However, the few surviving *Portulaca* plants were larger than in May, and they were blooming more vigorously.
1969:	This species apparently lost out to *Boerhavia* on the northeast slope and above the east bunker, where the large patches that appeared in late 1966 were beaten down by terns and replaced by *Boerhavia* by May 1967. These areas are now densely covered by *Boerhavia*, and only a few scattered small *Portulaca* plants could be found. More thrifty patches were found near the shore northwest of the transmitter, and on the south side of the transmitter building.
Caryophyllaceae	
Spergularia marina	
Apr. 1965:	Collected by C.H. Lamoureux beside road on west part of original portion. (UH, 1).
Leguminosae	
Mucuna sp.	
Jul. 1923:	"A single kukui nut and a *Mucuna* seed were picked up on the south beach of Sand Island" (Christophersen, 1931).
Apr. 1965:	Observed by Lamoureux?
Vigna marina	Beach Pea
1967:	Plants were found in two places in early 1967: one near the old dock and one at the edge of the beach on the southeast corner of

Appendix Table 6. (Continued)

	the original part of the island. Both were small (one to two feet in diameter) and were badly trampled by Sooty Terns and Brown Noddies by May. The southwest plant (near the dock) could not be found in late summer. No blooms were found. (UH, 1).
1969:	The plant near the southeast inner guywire appeared to be about the same in size as in 1967, but one near the old dock could not be found. Leaves looked fresh on the plant found. On 9 March a very small plant was found on the east shore near the base of the peninsula, and on 24 March a very small plant was found on the south-southwest shore.

Zygophyllaceae

Tribulus cistoides	Puncture Vine
Jul. 1923:	"On Sand Island *Boerhavia diffusa* is more abundant than *Tribulus cistoides*, but neither begins to compare with the bunch grass in extent" (Christophersen, 1931).
Jul. 1963:	"Comprises 30 percent of the vegetated area of the original portion" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, southwest islet and west portion of original part of island. (UH,1).
1966:	Green and blooming in July, indicating that drought was not a great factor in its status. Continued to grow and bloom vigorously throughout the summer and fall. During and after August bore seeds abundantly.
1967:	One of the few plants showing any vigor during the dry summer of 1966, was all but wiped out over most of the island, especially the east hill, during January and February 1967 by nest-building Red-footed Boobies and Great Frigatebirds. Red-foots were most destructive because of their more vigorous efforts at pulling up the vines. Frigatebirds usually picked up only loose vines, often ones torn loose by boobies. By mid-March new booby nests were being constructed almost entirely of *Boerhavia*, and

Appendix Table 6. (Continued)

	frigatebirds were no longer building nests. A little *Tribulus* was found in Brown Booby nests, but most of it was gone before the Brown Boobies started building nests. By May *Tribulus* had made a strong comeback over most parts of the island, and was blooming, with a few green fully formed fruits on plants that boobies had reduced to scattered frayed stems in February. By September *Tribulus* was back at least to the level it attained in October 1966, and was blooming and fruiting profusely over the entire island.
1969:	This species appeared unusually healthy for this time of year, probably because Red-footed Boobies had not begun nesting and tearing it apart (this began about 4-5 March). Clumps were numerous and healthy. Many new blooms appeared during February. On the northeast slope, where several large clumps formerly occurred, there are large barren areas, which look as if the plants were over-exploited last year by boobies and frigates. Many dead or nearly dead roots are visible, but no growth. Brown Boobies are using this for nests (7 March) and Red-footed Boobies are increasing their use.
Euphorbiaceae	
Aleurites moluccana	Candlenut, Kukui
Jul. 1923:	"A single kukui nut...and a *Mucuna* were picked up on the south beach" (Christophersen, 1931).
Apr. 1965:	Observed by Lamoureux?
Combretaceae	
Terminalia catappa	Indian Almond, Kamani
Apr. 1965:	Observed by Lamoureux?
Convolvulaceae	
Ipomoea indica	
1967:	Found in two places on the original portion of the island in February 1967: one just back

Appendix Table 6. (Continued)

	of the crest of the east hill, east southeast of the transmitter, and one a few feet inland from the west beach about halfway from the road to the old dock. Both were small plants, with no blooms. Neither could be found in September. (UH,1).
1969:	Could find neither patch found in February 1967. That on the east hill is overgrown with *Boerhavia*, and *Lepturus* is thick on the southwest.
Ipomoea pes-caprae	
Jul. 1963:	"Found only on easter beach of original portion" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux in coral sand at top of beach on east end of original part of island. (UH, 1).
1966:	Grew in a few spots on the north and east sides of the island, was alive but decadent in July. During September and October these plants grew and spread, but no blooms were seen by 25 October.
1967:	Sent out long runners during the winter, but few blooms were found on the east portion of the island during the spring. In September the plants still looked vigorous, although they had not spread much during the spring and summer, and still were not blooming profusely.
1969:	Two large patches....which very nearly exclude all other plants, occur, one on the northwest corner of the island, and one northeast of the transmitter. Other plants around the island appear about the same as formerly.
Boraginaceae	
Heliotropium curassavicum	
Apr. 1965:	Collected by C.H. Lamoureux beside road, west portion, original part of island. (UH, 1).
1967:	"...showed no change from 1966 through 1967. It was scarce, scattered around the outer parts of both portions of the island. All plants seen were blooming both in spring and late summer."

Appendix Table 6. (Continued)

Tournefortia argentea	Tree Heliotrope
Jul. 1963:	"Only one small plant on original portion north of transmitter building" (POBSP, 1964).
Apr. 1965:	Collected by C.H. Lamoureux, north of transmitter building. (UH, 1).
1966:	The single *Messerschmidia argentea* growing north of the transmitter building was almost unrecognizable in July, having been run over by trucks during tower maintenance. By September it had produced abundant new leaves and had begun to bloom.
1967:	The single bush growing northeast of the transmitter was 2 1/2 to 3 feet high and 4 to 5 feet in diameter by March 1967--large enough for a Red-tailed Tropicbird to attempt to nest under it. By September it had grown slightly larger, and provided nightly roosts for 20 to 25 noddies of both species. Wedge-tailed Shearwaters burrowed at the base of the bush, which may reduce its vigor. This specimen, as well as all the larger ones planted around the buildings on the man-made end of the island bloomed and produced fruit profusely during the spring, summer, and fall.
1969:	Present.
Goodeniaceae	
Scaevola taccada	
1966:	Twelve *Scaevola* sp. plants up to about 6 inches high, brought from Hawaii by the U.S. Coast Guard, were planted near the south shore of the original portion of the island 21 October, following a heavy rain.
1967:	*Scaevola taccada* planted in October 1966 on the south side of the east end of the island were all alive and growing in February, but by May had suffered from trampling by Sooty Terns and Great Frigatebirds. Sooty Tern chicks used them for shelter from the sun. By September only 8 of the original 12 were still alive, but these had spread horizontally to a diameter of about

Appendix Table 6. (Continued)

	3 feet. Vertical growth was prevented by roosting terns and frigatebirds. A few flowers were produced by September.
1969:	Only 4 plants, one of which may be dead, remain of the 12 planted on the south side of the original portion of the island in October 1966. These are small, scarcely protruding above the surrounding grasses, but have spread laterally to perhaps three feet, and the leaves are green and fresh.
Compositae	
Pluchea carolinensis	
Apr. 1965:	Collected by C.H. Lamoureux, west part of original portion of island. (UH, 1).
1966:	*Pluchea* growing on the northwest corner of the original portion of the island (one bush) and scattered over the man-made portion, showed little effect of either the dry weather early in the summer or of the increased moisture in the fall. These grew comparatively little, and produced no new flowers.
1967:	The single large bush on the original end of the island and seedlings growing downwind from it are growing much more slowly than those on the man-made end, probably because of intensive competition, especially from *Lepturus*.
1969:	The bushes seeded from the original beside the road just past the turnaround on the way to the transmitter building have now grown to 4-6 feet in height, and as much in diameter, and now attract nest tropicbirds. These were no more than two feet high in 1967.
Sonchus sp.	Sow-thistle
Apr. 1965:	Collected by C.H. Lamoureux, west part of original portion of island. (UH, 1).
1967:	Grew abundantly on the northwest corner of the original part, where continuous disturbance of loose sand prevented establishment of competitors, and occurred scattered around the buildings and open areas on the man-made end. In early spring

Appendix Table 6. (Continued)

	it was in all stages of bloom and fruit, but by May most plants had mature fruits. By September many of the plants had partially dried up.
1969:	Now relatively scarce on the northwest side of the island. The area has been taken over by grasses, both *Lepturus* and *Eleusine*.

Appendix Table 7. Bird specimens* collected on Johnston Atoll

USNM No.	Date Collected	Age	Sex	Remarks
Black-footed Albatross				
493512**	12 Feb. 1964	A	M	14°46' N, 169°44'W, 120 mi. SSW of Johnston Atoll. Large brood patch
494144**	8 Mar. 1964	A	M	16°38'N, 169°38'W, 10 mi. SW of Johnston Atoll, in sight of islands
495791**	15 Jan. 1965			16°50'N, 169°50'W, *ca*. 20 mi. WNW of Johnston Atoll.
Phoenix Petrel				
494139	18 Sept. 1964	A	F	Kepler and Lehner
Bulwer's Petrel				
530877	16 July 1923	A	M	Wetmore
78	" " "	A	F	Wetmore
79	" " "	A	M	Wetmore
80	" " "	A	M	Wetmore
81	" " "	A	F	Wetmore
82	" " "	A	M	Wetmore
300808	11 July 1923	N	F	2/3 grown young; Wetmore
09	" " "	N	M	1/4 grown young; Wetmore
10	" " "	N	M	Less than 1 week old; Wetmore
493794	1 Aug. 1964	A	M	

*All specimens are skins collected by POBSP personnel on Sand Island, unless otherwise noted. All specimens are deposited in the National Museum of Natural History (USNM).

**Denotes selected specimens collected at sea near Johnston Atoll.

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
Wedge-tailed Shearwater				
300736	16 July 1923	A	M	Gray neck and breast; Wetmore
37	" " "	A	M	Gray neck and breast; Wetmore
38	18 July 1923	A	F	Light phase; Wetmore
39	13 July 1923	A	M	Dark phase; Wetmore
40	" " "	A	F	Dark phase; Wetmore
41	18 July 1923	A	F	Light phase; Wetmore
42	15 July 1923	A	F	Light phase; Wetmore
484252	20 Aug. 1963	A	M	Dark phase
492973	21 Aug. 1963	A	F	
493632	9 July 1964	A	F	
33	" " "	A	F	
34	" " "	A	F	
35	" " "	A	F	
495059	23 Aug. 1964			
60	14 Sept. 1964	A	M	
61	20 Oct. 1964			
62	22 Oct. 1964	A	F	
63	11 Sept. 1964	A	F	
64	16 Nov. 1964			
65	" " "	A	M	
66	" " "			
67	" " "			
495831	20 Apr. 1964	A	M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495839	9 Apr. 1965	A	F	
496233	14 Nov. 1965	A	M	
496322	20 Dec. 1965	A	M	
497473	25 Oct. 1965	A	F	
74	30 Sept. 1965	A	F	
75	11 Oct. 1965	A	F	
498323	30 July 1966	A	M	Skeleton
24	23 Aug. 1966	A	F	Skeleton
503356	17 Nov. 1965			Alcoholic
508107-508130	Fall 1963			Alcoholic
508136-508171	Fall 1963			Alcoholic
544146	1 Apr. 1966	A	M	
47	4 May 1966	A	M	
48	9 July 1966	A	F	
49	12 Sept. 1966	A	F	
50	2 Dec. 1966	A	M	
544393	25 Sept. 1968	A	M	
544596	30 Apr. 1967	A	M	
544600	13 June 1967	A	F	
Christmas Shearwater				
300701	16 July 1923	A		Wetmore
02	18 July 1923	A	F	Wetmore
03	16 July 1923	A		Wetmore

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
300704	18 July 1923	A	M	Wetmore
05	16 July 1923	A		Wetmore
06	" " "	A		Wetmore
07	14 July 1923	N	M	Large young, losing down on back and belly; Wetmore
08	" " "	N	F	Large young, losing down on back and belly; Wetmore
09	15 July 1923	A	F	Wetmore
10	" " "	A	M	Wetmore
496323	6 June 1965	N		Chick
Newell's Shearwater				
492973	21 Aug. 1963	A	F	Amerson
497980	" " "	A	F	Trunk skeleton of 492973
544600	13 June 1967	A	F	Ovary 10 x 8; L. ovum 2.0; Harrington
Sooty Storm Petrel				
544650	21 Dec. 1968	A	F	
Red-tailed Tropicbird				
300992	18 July 1923		M	
93	11 July 1923	A	F	
94	18 July 1923	A	M	
95	16 July 1923	N	M	Full grown, down-free young
96	15 July 1923	A	M	
493809	28 Apr. 1964		F	
10	21 July 1964		M	
495079	23 Oct. 1963	I	M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495989	1 July 1965		M	
496815	26 Feb. 1965		M	
16	10 Sept. 1966	A	M	On egg
497213	25 Mar. 1966			
497827	17 July 1966		F	
54	22 Dec. 1965		F	
55	" " "		F	
56	14 Jan. 1966		M	
57	16 Jan. 1966		F	
58	7 Feb. 1966		F	
59	16 Feb. 1966		F	
60	8 Apr. 1966		M	
61	13 May 1966		F	
62	22 Feb. 1967		F	
63	31 Mar. 1967		F	
64	16 Apr. 1967		F	
65	18 Mar. 1967		M	North I.
503030	Mar. 1964			Chick,alcoholic
31	Apr. 1964			Chick, alcoholic
544387	5 May 1965		M	
544398	6 Nov. 1968		M	
Blue-faced Booby				
300933	12 July 1923	S	F	Wetmore
34	" " "	A	F	Wetmore

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
300935	11 July 1923	A	F	Wetmore
36	12 July 1923		F	Wetmore
37	" " "	S	F	Wetmore
38	13 July 1923	S	F	Wetmore
39	11 July 1923	A	F	Wetmore
495787	29 Mar. 1965	S		Banded on Lisianski 21 Aug. 1964
496012	13 Apr. 1965		F	
498122	20 Jan. 1965			Skeleton
Brown Booby				
300860	12 July 1923	A	F	
61	" " "	A	M	
62	" " "	A	F	
63	" " "	A	?	
64	13 July 1923	I	F	First year plumage
495078	27 Sept. 1964		M	
496626	21 Dec. 1965			
27	15 May 1966		F	
28	24 May 1966	N	M	Chick
29	29 May 1966	N	M	Chick
497371	20 May 1965	N	M	Chick
72	22 Mar. 1967		F	
503373	23 Apr. 1965	N		Chick; alcoholic
74	30 Apr. 1965	N		Chick; alcoholic

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
Red-footed Booby				
300898	11 July 1923	A	F	
99	" " "	S	F	
900	" " "	S	?	
01	13 July 1923	A	F	
02	" " "	S	M	
03	11 July 1923	S	F	
04	" " "	I	F	Lead colored, young of year
05	" " "	S	F	
493473	13 Apr. 1964		F	
495797	19 Feb. 1965		F	
98	6 Mar. 1965		M	
496249	19 Feb. 1965			
50	4 June 1965		F	
89	12 Jan. 1966		M	
90	25 Jan. 1966		M	
91	12 Feb. 1966		F	
92	17 Feb. 1966		M	
93	20 Feb. 1966		M	
94	22 Feb. 1966		M	
95	25 Feb. 1966		M	
496648	4 Jan. 1966		F	
49	6 Jan. 1966		F	
50	23 Jan. 1966		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
497367	4 Jan. 1966		M	
68	27 Mar. 1967		F	
69	15 Apr. 1967		M	
498127	6 Mar. 1965			Skeleton
544691	1 Apr. 1969		F	USFW 757-37983
544692	11 Apr. 1969		F	USFW 767-53223
Great Frigatebird				
300972	13 July 1923	A	M	Wetmore
464442	11 July 1923	A	F	Wetmore
43	13 July 1923	A	M	Wetmore
44	" " "	A	M	Wetmore
465207	11 July 1923	A	F	Wetmore
465213	spr.-sum. 1923		F	Collected on French Frigate Shoals or Johnston, data lost; Wetmore.
493908	11 Oct. 1964		M	
495068	18 Sept. 1964			
69	2 Oct. 1964		M	
70	1 Oct. 1964			
71	8 Oct. 1964		M?	
72	14 Oct. 1964			
73	17 Aug. 1964			
74	13 Nov. 1964		F	
495809	15 Feb. 1965			
10	12 Mar. 1965		M	
11	18 Mar. 1965		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
496302	19 Aug. 1965		F	
03	20 Jan. 1966		M	
04	" " "		M	
05	" " "		M	
06	" " "		M	
07	" " "		F	
08	" " "		M	
09	" " "		M	
10	" " "		F	
498278	6 Aug. 1965		F	Skeleton
79	6 Aug. 1965		F	Skeleton
498413	24 Mar. 1969		F?	Skeleton, USFW 737-44221 banded Sand I., Johnston Atoll 10 July 1963 as N - U.
503043	Apr. 1964			Chick; alcoholic
44	" "			Chick; alcoholic
503322	20 Jan. 1966		F	Alcoholic
23	" " "		F	Alcoholic
24	" " "		F	Alcoholic
25	" " "		M	Alcoholic
26	" " "		M	Alcoholic
27	" " "		M	Alcoholic
28	" " "		M	Alcoholic
29	" " "		M	
33	" " "			Alcoholic

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
503334	24 May 1966		M	Alcoholic
35	20 Oct. 1966		M	Alcoholic
36	4 Nov. 1964			
37	16 Nov. 1965		M	Alcoholic
38	19 Nov. 1965			Alcoholic
77	15 July 1965			Alcoholic; chick
508094	21 Nov. 1963			Alcoholic
95	" " "			Alcoholic
543359	20 Dec. 1965		M	
60	20 Feb. 1966		M	
543361	20 Feb. 1966		F	
62	22 Feb. 1966		F	
63	5 Mar. 1966		F	
64	26 Mar. 1966		M	
65	" " "		F	
66	1 Apr. 1966		F	
67	28 May 1966		M	
68	18 July 1966		M	
69	18 Sept. 1966		M	
70	24 Oct. 1966		F	
71	17 Nov. 1966			
72	20 Dec. 1966		F	
73	25 Dec. 1966		M	
74	4 Jan. 1967		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
543375	15 Jan. 1967			Bisexual.
544396	9 Oct. 1968		M	
544986	1 Apr. 1968		F	
Pintail				
495973	16 Oct. 1965	J	F	
496775	29 Oct. 1965	J	M	Johnston Island, trunk skeleton saved
497795	13 Feb. 1967	A	F	
543175	7 Nov. 1966	J	M	Skeleton saved
American Wigeon				
495789	23 Oct. 1964	J	M	
543174	29 Oct. 1966	J	M	
Shoveler				
495075	26 Oct. 1964	A	F	
Peregrine Falcon				
493823**	8 Nov. 1963	A	M	200 mi. SW of Johnston, 14°10'N, 171°42'W
544948	2 Dec. 1968	J	F	
Golden Plover				
301051	15 July 1923		F	Wetmore
495054	12 Oct. 1964		F	
55	24 Oct. 1964		M	
56	10 Dec. 1964		M	
57	" " "		F	
58	13 Dec. 1964		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495724	31 Jan. 1965		F	
25	14 Apr. 1965		M	
495892	8 Apr. 1965		F	
496085	28 Oct. 1965		F	
86	31 Oct. 1965		F	
496211	11 Apr. 1964		M	
496685	19 Nov. 1965		F	
86	22 Apr. 1966		F	
87	2 May 1966		F	
498219	29 Mar. 1965			Skeleton
20	17 Nov. 1965		M	Skeleton
544565	22 Apr. 1969	A	M	Full breeding plumage
544649	13 Apr. 1966		F	
Black-bellied Plover				
493340	11 Dec. 1963			
Semipalmated Plover				
493853	15 Oct. 1963	I	?	
503671	30 Aug. 1968	I	?	Alcoholic
Bristle-thighed Curlew				
496054	2 Sept. 1965		M	
55	17 Sept. 1965		M	
498066	28 Sept. 1963			Skeleton
498412	24 Jan. 1969			Skeleton
544942	18 Oct. 1967		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
Lesser Yellowlegs				
493225	18 Aug. 1963		M	
Spotted Sandpiper				
493910	1 Sept. 1964		?	
Wandering Tattler				
301026	11 July 1923		F	At least partial breeding plumage
27	13 July 1923		M	Not in breeding condition
493223	18 Oct. 1963		M	Non-breeding plumage
544563	26 Sept. 1968	A	M	Partial breeding plumage
Ruddy Turnstone				
?	July 1923		?	Wetmore
495909	30 Apr. 1965		M	
10	2 May 1965		M	
11	1 May 1965		F	
496212	6 May 1964		F	
497276	10 Mar. 1966		F	
544397	29 Oct. 1968		F	
544539	3 May 1965			
544557	29 Sept. 1966		F	
58	16 May 1967		M	Johnston Island
Sanderling				
496210	25 Nov. 1965		F	Johnston Island

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
Pectoral Sandpiper				
493228	3 Oct. 1963		F	
495076	19 Oct. 1964		F	
77	26 Sept. 1964			
496068	14 Sept. 1965			
69	27 Sept. 1965		M	
544156	" " "		M	
545013	30 Sept. 1968			
544395	2 Oct. 1968		F	Ova minute (0.6 x 3 mm)
Sharp-tailed Sandpiper				
496071	29 Oct. 1965	I	F	Skull not ossified
544394	30 Sept. 1969	I	F	
Buff-breasted Sandpiper				
544935	14 Sept. 1968		F	
Ruff				
496600	10 Mar. 1966		M	
Wilson's Phalarope				
493870	16 Aug. 1964		F	
Glaucous-winged Gull				
544989	8 Mar. 1968	S	F	
?	7 Feb. 1969	S	?	F.N. 26396
Laughing Gull				
493503	7 Apr. 1964	I	M	Testis 5 x 2; Amerson and Amerman

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
494981**	15 Jan. 1965	I	F	Collected at sea 11 mi. NNW of Johnston, within sight of the islands; ovary 9 mm granular; Clapp
Franklin's Gull				
544936	19 May 1969		M	
Large unidentified gull				
?	17 Dec. 1965			Skeleton; F.N. 25923
Gray-backed Tern				
300637	13 July 1923	A	F	Wetmore
38	17 July 1923	I	F	Wetmore
39	" " "	A	F	Wetmore
40	" " "	A	M	Wetmore
41	" " "	A	M	Wetmore
495051	18 Jan. 1965		M	
52	" " "		F	
53	" " "	A	M	
495534	14 Apr. 1964		M	
497115	14 Feb. 1966		M	
543039	15 Mar. 1967		M	Chick
40	8 Apr. 1967		M	Chick
41	8 Mar. 1967		M	Chick
544388	20 Feb. 1965		U	
89	6 Apr. 1967		U	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
544566	23 Feb. 1967		M	
67	14 May 1967		M	
68	28 Feb. 1969		M	
69	7 Apr. 1969		F	
Sooty Tern				
300553	15 July 1923	A	M	Wetmore
54	" " "	A	F	Wetmore
55	" " "	A	M	Wetmore
56	" " "	A	F	Wetmore
57	" " "	A	U	Wetmore
58	" " "	A	F	Wetmore
59	" " "	I	F	Wetmore; fledged
60	" " "	I	M	Wetmore; fledged
61	" " "	I	F	Wetmore; fledged
62	" " "	I	M	Wetmore; fledged
63	" " "	I	M	Wetmore; fledged
64	" " "	I	F	Wetmore; fledged
493779	1 June 1964		M	
80	" " "		U	
81	" " "		U	
82	" " "		F	
83	" " "		M	
84	" " "		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
493865	15 Aug. 1964		F	
66	23 Aug. 1964		F	
67	6 Sept. 1964		M	
493871	17 Jul. 1964		F	
72	23 Jul. 1964		U	
73	" " "		F	
74	" " "		M	
75	" " "		F	
76	10 Aug. 1964		F	
77	11 Aug. 1964		F	
78	15 Aug. 1964		M	
79	" " "		M	
80	" " "		M	
81	19 Aug. 1964		M	
82	23 Aug. 1964		M	
83	24 Aug. 1964		F	
84	" " "		M	
85	26 Aug. 1964		M	
86	2 Sept. 1964		M	
87	8 Sept. 1964		F	
88	" " "		F	
89	" " "		M	
90	" " "		M	
91	" " "		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
493892	8 Sept. 1964		F	
93	" " "		M	
94	11 Sept. 1964		M	
493902	23 Jul. 1964		M	
03	" " "		M	
494983	" " "		F	
84	" " "		F	
85	17 July 1964		F	
86	23 July 1964		M	
87	" " "		F	
88	" " "		F	
89	25 Aug. 1964		M	
90	17 Aug. 1964		M	
91	15 Aug. 1964		F	
92	10 Aug. 1964		F	
93	1 Sept. 1964		M	
94	6 Sept. 1964		M	
95	17 July 1964		M	
96	9 Aug. 1964		F	
97	?		F	
98	17 July 1964		M	
99	" " "		M	
495000	23 July 1964		M	
01	" " "		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495002	23 July 1964		F	
03	17 July 1964		F	
04	23 July 1964		M	
05	" " "		F	
06	17 July 1964		F	
07	9 July 1964		F	
08	23 July 1964		M	
09	" " "		M	
10	17 July 1964		M	
11	23 July 1964		F	
12	" " "		F	
13	" " "		F	
14	" " "		F	
15	" " "		F	
16	" " "		F	
17	" " "		F	
18	" " "		F	
19	" " "		F	
20	" " "		F	
21	17 July 1964		F	
22	9 July 1964		F	
23	15 Dec. 1964		M	
24	16 Dec. 1964		F	
25	20 Dec. 1964		F	
26	21 Dec. 1964		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495027	23 Dec. 1964		F	
28	28 Dec. 1964		F	
29	" " "		M	
30	18 Jan 1964		M	
31	" " "		M	
32	" " "		M	
33	" " "		F	
34	" " "		F	
35	11 Aug. 1964		M	
36	2 Sept. 1964		M	
37	2 Sept. 1964		M	
495507	12 Feb. 1965		F	
08	12 Feb. 1965			
09	" " "		F	
10	" " "		F	
11	" " "		F	
12	" " "		M	
13	1 Mar. 1965		F	
14	9 Mar. 1965		M	
15	22 Mar. 1965		F	
495737	8 May 1964		M	
38	1 June 1964		M	
39	1 June 1964			
40	1 June 1964			

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495741	3 June 1974		M	
42	18 June 1964			
43	" " "			
44	23 June 1964			
45	2 July 1964			
46	8 July 1964		M	
47	9 July 1964		F	
48	17 July 1964		M	
49	27 July 1964			
50	9 Aug. 1964		M	
51	9 Aug. 1964		M	
52	9 Aug. 1964		M	
53	9 July 1964		F	
495872	2 June 1964		F	
73	8 June 1964		F	
82	25 Aug. 1964		M	
496368	26 Dec. 1965		M	
497085	23 Dec. 1965		F	
86	24 Dec. 1965		F	
87	13 Mar. 1966		M	
88	14 Mar. 1966		M	
89	" " "		F	
90	30 Mar. 1966		M	
91	" " "			
92	10 Apr. 1966		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
497093	11 Apr. 1966		F	
94	" " "		F	
95	15 Apr. 1966		M	
96	2 May 1966		M	
97	" " "		F	
98	9 May 1966		F	
99	" " "		F	
497100	" " "		F	
01	10 June 1966		M	
02	" " "		F	
03	" " "		M	
498086	23 July 1964		M	Skeleton
87	" " "		F	Skeleton
88	" " "		F	Skeleton
89	" " "		F	Skeleton
503045	23 Apr. 1964	N	U	Alcoholic
46	1964	N	U	Alcoholic
47	1964	N	U	Alcoholic
48	29 Apr. 1964	N	U	Alcoholic
49	1964	N	U	Alcoholic
50	Apr. 1964	N	U	Alcoholic
51	Apr. 1964	N	U	Alcoholic
503647	19 July 1969			Alcoholic

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
503648	28 July 1969			Alcoholic
49	3 Sept. 1969			Alcoholic
50	17 July 1969			Alcoholic
51	29 July 1969			Alcoholic
52	19 July 1969			Alcoholic
53	29 July 1969			Alcoholic
54	24 July 1969			Alcoholic
55	14 July 1969			Alcoholic
56	10 Aug. 1969			Alcoholic
57	31 July 1969			Alcoholic
58	9 Aug. 1969			Alcoholic
59	18 July 1969			Alcoholic
60	30 July 1969			Alcoholic
61	15 July 1969			Alcoholic
543001	22 Apr. 1965		F	
02	" " "		M	
03	" " "		F	
04	" " "		M	
05	" " "		F	
06	" " "		F	
07	" " "		F	
08	" " "		M	
09	" " "		F	
10	" " "		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
543011	22 Apr. 1965		M	
12	" " "		F	
13	27 Dec. 1965			
14	11 Mar. 1966		F	
15	13 Apr. 1966		F	
16	22 Apr. 1966		F	
17	24 June 1966		F	
18	25 Mar. 1967		M	
544076	12 July 1966		M	
77	" " "		M	
78	" " "		M	
79	" " "		M	
544244	23 Apr. 1967		F	
544390	10 Aug. 1968		M	
91	10 Sept. 1968		M	
92	13 Sept. 1968		M	
544454	26 June 1966		F	
55	25 May 1967		F	
56	9 Apr. 1968		M	
57	1 Apr. 1968		M	
58	17 July 1968		F	
544607	26 Dec. 1966			
08	1 Jan. 1967		M	
09	20 Jan. 1967		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
544610	20 Jan. 1967		F	
11	20 Feb. 1967			
12	6 Mar. 1967			
13	18 Mar. 1967			
14	22 Mar. 1967			
15	26 Mar. 1967			
16	5 Apr. 1967			
17	22 Apr. 1967		F	
18	8 May 1967			
19	1 Apr. 1967			
544620	15 Apr. 1967		M	
544626	10 Jan. 1967		F	
27	20 Feb. 1967		M	
28	27 Aug. 1967		M	
544638	2 Apr. 1968		M	
39	2 May 1968		F	
40	18 June 1968		M	
41	23 Mar. 1968		M	
42	1 Apr. 1968		M	
43	2 Apr. 1968		F	
44	26 Mar. 1968		M	
45	2 Apr. 1968		M	
46	25 Mar. 1968		F	
47	20 Mar. 1968		F	Five toes on right foot
48	26 June 1965		M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
Elegant Tern				
544937	19 Apr. 1969		F	
Blue-gray Noddy				
300368	13 July 1923	A	F	Wetmore
88	" " "	A	F	Wetmore
89**	20 July 1923		M	Taken at sea about 50 miles west of Johnston (16°45'N, 170° 20'W)
497694	8 May 1967	A	F	
Brown Noddy				
300652	15 July 1923	A	M	Wetmore
53	" " "	A	M	Wetmore
54	" " "	A	M	Wetmore
55	" " "	A	M	Wetmore
56	" " "	A	F	Wetmore
57	" " "	A	M	Wetmore
493756	20 July 1964		F	
57	20 June 1964		F	
58	" " "		?	
59	" " "		M	
60	" " "		?	
61	" " "		?	
62	20 July 1964		F	
63	" " "		M	
64	20 June 1964		?	
65	17 June 1964		?	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
493771	20 June 1974		?	
72	" " "		?	
73	" "" "		?	
74	" " "		?	
75	6 May 1964		F	
493895	18 Aug. 1964		F	
96	" " "		?	
97	" " "		?	
493915	" " "		?	
495039	11 Sept. 1964			
40	20 Aug. 1964		M	
41	18 Aug. 1964		M	
42	4 Oct. 1964		M	
43	5 Oct. 1964		M	
44	4 Sept. 1964		F	
45	20 Aug. 1964		F	
46	25 Aug. 1964		M	
47	20 Aug. 1964		M	
48	4 Sept. 1964		M	
49	7 Nov. 1964		M	
50	20 Aug. 1964		F	
495565	12 Feb. 1965			
66	" " "		M	
67	" " "		F	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
495568	12 Feb. 1965		F	
69	" " "		F	
495754	4 June 1964		F	
496045	11 June 1965		M	
496217	6 May 1964	N	U	Chick
496394	30 May 1965	N	M	Chick
497244	3 Jan. 1966		M	
45	14 Feb. 1966		F	
46	6 May 1966		M	
47	" " "		F	
497632	9 Feb. 1966		F	
33	1 Apr. 1966		F	
34	25 Feb. 1967		F	
35	1 Mar. 1967		M	
36	15 Apr. 1967		F	
37	21 Apr. 1967		F	
497673	18 July 1966		F	
74	20 Apr. 1967		M	
543151	3 Mar. 1966		M	
503054	Apr. 1964	N	U	Chick; alcoholic
55	1964	N	U	Chick; alcoholic
56	1964	N	U	Chick; alcoholic
503368	10 Nov. 1965			Alcoholic
69	29 Nov. 1965			Alcoholic
70	11 Dec. 1965			Alcoholic

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
503662	31 July 1969			Alcoholic
63	16 July 1969			Alcoholic
508172	21 Nov. 1963			Alcoholic
73	" " "			Alcoholic
74	" " "			Alcoholic
75	" " "			Alcoholic
76	" " "			Alcoholic
77	" " "			Alcoholic
78	" " "			Alcoholic
79	" " "			Alcoholic
80	" " "			Alcoholic
81	" " "			Alcoholic
544399	17 Nov. 1968		M	
544588	27 Apr. 1967		M	
89	2 May 1967		F	
544605	10 May 1967			
06	3 May 1967		F	
544651	26 June 1968		M	
52	2 May 1968		F	
Black Noddy				
495585	26 Jan. 1965	S	U	
86	" " "	S	U	
87	" " "	A	F	
88	" " "	S	F	
89	" " "	A	M	

Appendix Table 7. (Continued)

USNM No.	Date Collected	Age	Sex	Remarks
497671	17 Feb. 1967	S	M	
White Tern				
300409	16 July 1923	A	M	Wetmore
10	13 July 1923	A	F	Wetmore
11	16 July 1923	A	F	Wetmore
12	11 July 1923	A	M	Wetmore
13	12 July 1923	A	F	Wetmore
14	11 July 1923	A	F	Wetmore
27	" " "	N	F	Wetmore; downy young
493655	24 July 1964	U	M	Johnston
495900	26 May 1965	A	F	Johnston
497266	10 Sept. 1966	A	M	Johnston; Lg. testes, 5 x 3 mm
498128	29 Mar. 1965	U	U	Johnston; skeleton
503664	1 July 1969	N	u	Johnston Island; alcoholic; 3-5 day-old chick
65	" " "	A	U	Johnston Island; alcoholic
?	6 June 1969			Johnston Island; F.N. 26409
Japanese White-eye				
495080	14 Oct. 1964		?	
496214	30 Nov. 1965		?	Johnston Island

Appendix Table 8. Pre-POBSP observations of Sooty Terns on Johnston Atoll

Year	Month	Source	Remarks
1859	14-15 Mar.	John M. Brooke	(ms., see also Brook, 1955, and Findlay 1886: 1034). "Capt. Piper says that these birds keep close during the warm part of the day and go Seaward in the evening. In fact there are many flying round us in the moonlight this evening....The air was filled with birds screaming very loudly...."
1859	28 Aug.	Pendleton	(1859, *in* Ward, 1967: 433). "The islands are covered with a wilderness of birds, so that if one goes ashore he is shaded from the sun by them. About two months since, the ground was covered with eggs, so that it was difficult to walk without treading on them, but now the young birds are hatched and are running all over the island. When they get large enough to fly, all the birds of one kind will leave the island together and go to sea where they will remain several months, when they return again and commence laying."
1923	10-20 July	A. Wetmore	(ms. a and b). "Abundant. A few have eggs but the great majority have young on the wing or nearly ready to fly. Birds able to fly are still being fed by the parents and rest with them at night, the colony at such times being spaced off as when there are eggs in it. The call of the young is high-pitched. Those that I capture frequently regurgitate squid. One group that apparently have finished their breeding activities gather in a close flock on a stretch of open beach to sleep. The great

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			majority are adults but with them are a few young.
			Partly grown young are pugnacious and bite each other savagely.
			The main impressions left in the mind by these large colonies are number of birds and noise. The clattering calls are tittered incessantly day and night. About 2500 on Johnston Island, about 2000 on Sand Island.
			The birds are especially active and noisy during rains whether by day or night.
			The young when pursued by frigatebirds give up their fish without protest.
			With the Wedge-tailed Shearwaters these made the greater part of the bird population. I estimated those on Johnston Island at 3500, and on Sand at 2000. The majority of nests held fresh eggs. I saw a few young half grown and a few were able to fly, but usually did /not?/ attempt to take wing."
1928	April	L. Thurston	(1928: 4).
			"Din audible for half a mile," and "thousands of sea birds" probably both refer mainly to Sooty Terns. No numbers given.
1945-1946	June	Lowell Thomas *et al.*	Chapin (1954: 10-11).
			"My attention was drawn again to the Pacific by a film made by Lowell Thomas in June 1945 on Johnston Island, near lat. 16°45' North, in which a colony of Sooty

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			Terns was shown close to the airport. Correspondence with General B.E. Nowland and Captain A.S. Hill of the American Forces revealed that the terns were back again and nesting in the same month of 1946. There was a hint that some had returned to nest on the same island in November or December. That seemed curious, but no confirmation could be obtained."
1947	?	G.E. Beckham	(1947). In brochure introducing Johnston Atoll to incoming and transient personnel, a map shows "Gooney Bird Hill" in area on Johnston where the swimming pool was recently built. "Johnston Island has about 10,000 birds that live here during the migratory months. There are many kinds of birds, but are known to all the men as gooney birds. If you should step outside in front of the terminal and look toward the end of the island, you would probably see a small hill covered with them. This is known as "Gooney Bird Hill." From the description given, most of the birds on this hill must have been Sooty Terns.
1948	?	C. Fennell	(1948: 37). Letter from Seoul, Korea, after flight which stopped at Johnston on the way: His glasses were confiscated on landing, and most information was from asking residents. "The only important information I could gather from several fellows whom I asked about the birds was that they were a 'damned stinking nuisance,' and that they were destroying all their eggs in an effort to get

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			them to move across to Sand Island, a smaller strip of land about 1/4 mile distant. They all heartily regretted the fact that Johnston was designated as a bird sanctuary. One man named the species found there as noddy and sooty terns and moanin' birds."
1949	Dec.?	S. Jensen	(1949: 66). "At this season there are a great many Sooty Terns flying low over the south end of the island. They maintain an incessant and terrific clamor throughout the night. The birds fly very low at night, but during the day they are usually to be seen at a little distance off the island at an altitude of several hundred feet. They number about 2000, I believe."
1955	?	J. Benson	(1955). "To make matters worse, it is advisable to wear a hat at all times, because Johnson [sic] has been a bird sanctuary since 1926, by executive order of the late Pres. Coolidge. The birds occupy the entire western end of the island, and when we were there [date not given], the navy gathered up the eggs every day and threw them overboard in an effort to keep from being crowded off the island. Took them 2 1/2 hours to collect all the eggs, so you can see what they were up against."
1957	6-10 April	M. Moynihan	(1957) "This was the overwhelmingly dominant species on the island, in point of numbers. There must have

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			been at least 10,000 birds present, almost equally divided between two colonies, one on the bare ground and low grass in the center of the western islet, and the other in the grass on a low dune in the north-central part of the eastern islet (some distance away from a group of abandoned buildings and oil tanks). These birds all seemed to be in the later stages of the 'pairing phase' of the breeding cycle, *i.e.* at the stage, after Pair formation, when sexual behavior is most common and most vigorous, before the appearance of the first eggs."
1958	July and August	Holmes and Narver	Drawings and photographs.
			Engineering drawings of sprinkler system to protect birds from 1958 Atomic tests show probable approximate distribution of birds, presumably mostly Sooty Terns. The sprinkler was installed on approximately the west quarter of the man-made portion of the island (one picture shows a few birds scattered over this area, probably including Noddies, as well as sooties). The west third of the causeway was covered with the sprinkler, but there is no indication from pictures what birds may have been there. Approximately the north half of the original portion, with extensions to the south shore in one place, and all along the east shore was covered with the sprinkler system. The few pictures showing the areas around the buildings indicates that the area of the sprinkler system roughly corresponded to the area covered by Sooty Terns. Two pictures taken 22 July show several Sooty adults and young.

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			The young are all well grown, but several have short tails. There is not enough evidence to indicate any difference from present timing of the breeding cycle.
1959-1960	?	C.J. Davis	(1962). "The predominant 'nester' on Sand Island appeared to be the Sooty Tern (Fig. 5). The characteristic dull black upper body and the white forehead and underparts of wings and body differentiates it from other similar terns. The young bird in the foreground of fig. 6 blends very well with the dirt-like coral and sand. Unhatched eggs can be seen. Their density was about one per square foot. (Fig. 7) These are the 'wide-awakes'; observation reveals that they are active nearly 24 hours each day. It is of interest that their feathers are not waterproof, so they work hard for their food, snatching small fish and squid off the surface of the water and bringing it to the waiting young. Their harsh 'quank' and three-syllable 'ker-wacky-wack' warns the intruder that they are concerned over the single egg they have laid on the ground. Since they range throughout the tropical Pacific and are noted for their 'dis-appearance at sea', it was not unusual to find them nesting near remote Johnston Island."
1959-1960	?	U.S. Coast Guard	Photographs Photographs show Sooty Terns, all adults, some possibly on

Appendix Table 8. (Continued)

Year	Month	Source	Remarks
			eggs, on various parts of the original portion of the island. As best determined from the photos, the birds covered almost all the main portion of the original island, but were not on the northeast peninsula.
1961	23 May	U.S. Coast Guard	Photograph Photograph shows LORAN-C tower from near east end of causeway. Sooty Terns are over the entire island, except possibly the northeast peninsula, which cannot be seen well enough to tell if Sooty Terns are present or not. Numbers appear about the same as during the 1966-67 POBSP period.

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