WINTER DISTRIBUTION OF JUVENILE AND OLDER RED-FOOTED BOOBIES FROM THE HAWAIIAN ISLANDS

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The Red-footed Booby (*Sula sula*), a pantropical seabird, varies geographically in the central Pacific. Almost all members of this species who breed in the Hawaiian Islands and at Johnston Atoll are white morphs; juveniles are darker, a dull gray-brown dorsally and dingy white below, but become lighter with age until adult plumage is attained after three to four years (Woodward 1972). Adult Red-footed Boobies from south-central Pacific islands (e.g., the Line and Phoenix islands) include small numbers of white morph birds, but most are easily identified, darker morphs. Immatures from these southern breeding islands, however, are not reliably separable from northern immatures in the field. This study reports on the different winter distributions of adult and immature Hawaiian Islands Red-footed Boobies found in the central Pacific. It is based on observations by personnel of the Pacific Ocean Biological Survey Program (POBSP, Smithsonian Institution) and published records.

METHODS

I analyzed banding data for the south Pacific and some field observations on islands. In addition, other POBSP personnel and I made seabird observations between 1963 and 1969. We conducted 16 surveys over 137 days during January and February, 1964–1968, between 10° and 26° North Latitude, and 148° to 175° West Longitude. Bird watches were normally made from dawn to dusk, and all sightings were logged on field record sheets with time to the nearest minute. Bird locations were later interpolated on the basis of sunrise, noon, and sunset positions of the survey ship, but are grouped in this report by noon ship positions. When possible, color morph, age and other information (see Gould 1974) were recorded for each bird seen; 65% of Red-footed Boobies sighted were identified as either adult or immature birds.

RESULTS

BANDING AND ISLAND STUDIES

Red-footed Boobies breed on many Hawaiian Islands, especially those in the northwest chain. Although breeding occurs in all months, most nests are built in spring and summer (table 1). At Johnston Atoll, south of the Hawaiian Islands, less than a dozen pairs breed (Amerson 1973, Amerson and Shelton 1976)—a population of inconsequential size with regard to this study.

POBSP banding results show that a higher proportion of immature than adult Red-footed Boobies travel south of their Hawaiian nesting islands after breeding. For example, 2.47% of the 607 nestlings banded at Kure Atoll moved to Johnston, but only 0.59% of 1011 adults moved (data from Woodward 1972), a significantly different frequency ($\chi^2 = 10.3$, $P < 0.01$). This difference was found despite the possibility that mortality may be higher in young birds. Similarly, for birds banded at French Frigate Shoals and Laysan Island, proportionately more immatures than adults move south after the breeding season. Within about a year after banding, immatures banded at these two islands were found to the south on 50 occasions and north on only 4; in contrast, adults were found to the south on 9 occasions and north on 11 (from Amerson 1971, Ely and Clapp 1973). This difference is also significant ($\chi^2 = 4.12$, $P < 0.05$).

The banding data show not only different frequencies of movement to Johnston Atoll that are related to age, but also a different timing (table 2). A portion of this seasonal difference is probably caused by adults leaving Johnston soon after January to return north to nesting islands, while at the same time many immatures remain at Johnston. However, relatively low numbers of young birds are caught in December–February after the breeding season, a time when relatively large numbers of adults are captured (table 2). This suggests that few young birds visit Johnston because most are at other islands, or remain at sea and do not visit or rarely visit any island. Woodward (1972) showed that young from Kure do not stay at the Hawaiian nesting islands in winter, reinforcing the notion that immatures remain at sea.

Red-footed Boobies do not develop complete adult plumage until they are three years old (Woodward 1972). Because precise aging of two- and three-year-olds is difficult in the field, I have also analyzed published north and south inter-island movements of birds (Woodward 1972, Amerson 1971, Ely and Clapp 1973) at least two years after the birds were banded as juveniles; the comparison does not show significantly different frequencies of north-south movement between immatures two years after their hatching and

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TABLE 1. Months of peak egg-laying by Red-footed Boobies at central Pacific islands.

Island	Location		Peak egg-laying months	Source
Johnston Atoll	16°40′N,	169°30′W	Feb.–Mar.	Amerson and Shelton 1976
Necker Island	23°30′N,	164°44′W	Mar.–Apr.	R. B. Clapp, pers. comm.
French Frigate Shoals	23°45′N,	166°10′W	Mar.–Apr.	Amerson 1971
Laysan Island	25°42′N,	171°44′W	Apr.–May	Ely and Clapp 1973
Lisianski Island	26°02′N,	174°00′W	Apr.–May?	Clapp and Wirtz 1975
Kure Atoll	28°25′N,	178°10′W	May–June	Woodward 1972

adults banded at the same time. The evidence from the small banding sample suggests that hatching-year and older Red-footed Boobies from the Hawaiian Islands tend to be caught in different months at Johnston Atoll, but this is not so for second-year and older birds.

Few Red-footed Boobies breed at Johnston Atoll. In winter and spring, however, many roost on support wires of a high radio transmitting tower. Although counts vary day to day, seasonal trends are pronounced. Counts are lowest in October (rarely exceeding 500), but by late November 1200 boobies may be present, only 10% of which are juveniles (V. M. Kleen, POBSP field notes). The increase continues until late February, when counts often exceed 3500 birds (Amerson 1973, Amerson and Shelton 1976).

The population build-up of Red-footed Boobies at Johnston Atoll in November and December is caused mostly by adults and subadults (immatures with partial adult plumage). During February and early March, numbers of juveniles (less than 1.5 years old on the basis of plumage) increase, and by late March they comprise 92% of the roosting birds (B. A. Harrington, POBSP field notes). These observations agree with banding results, i.e., that young birds appear at Johnston Atoll later than older birds.

The banding and other observations from Johnston show that virtually all of the Red-footed Boobies relevant to this study are from the Hawaiian Islands, with a few from Wake Island. The next most likely sources are the Line and Phoenix islands. However, more than 90% of birds from these islands are dark morphs, and only a few of these have been sighted in the area considered here. Also, the POBSP banded thousands of Red-footed Boobies in the Line and Phoenix islands, as well as at other south-central Pacific islands, and none have ever been captured at Johnston or other north-central Pacific islands. More than 1000 Red-footed Boobies that were banded at Johnston were marked with conspicuous orange streamers; these were seen commonly in the Hawaiian Islands, but almost never at islands south of Johnston. In short, there is little movement of Red-footed Boobies into the Johnston and Hawaiian islands area from more southern nesting islands.

OBSERVATIONS AT SEA

The January and February observations of Red-footed Boobies at sea, but near islands, confirm the results of island studies. Counts made within 100 nautical miles of Hawaiian Islands and within 100 nautical miles of Johnston Atoll produced significantly different

TABLE 2. Numbers of adult and hatching-year Red-footed Boobies banded during breeding seasons at Laysan Island and French Frigate Shoals, and recaptured within 18 months at Johnston Atoll (from Ely and Clapp 1973, Amerson 1971).

Age when banded	Number recaptured in:			
	Dec.–Feb.	Mar.–May	June–Aug.	Sept.–Nov.
Adult	30	3	1	0
Hatching-year[a]	11	37	12	1

[a] Hatching-year = banded as nestlings or immatures with juvenal plumage.

TABLE 3. Summary of counts of adults and immature Red-footed Boobies at sea in January and February within 100 nautical miles of Hawaiian Islands and Johnston Atoll.

Location	No. counts (days)	No. adults	No. adults per day	No. immatures	No. immatures per day	Percent immatures
Hawaiian Islands	24	181	7.5	21	0.9	10.4
Johnston Atoll	13	173	13.3	114	8.8	39.7

TABLE 4. Numbers of adult and immature Red-footed Boobies seen at different distances from Johnston Atoll in January–February, 1964–1968.

Nautical miles from atoll	No. counts (days)	No. adults	No. adults per day	No. immatures	No. immatures per day	Total birds	Percent immatures
1–100	13	173	13.3	114	8.8	287	40
101–200	22	28	1.3	97	4.4	125	78
201–300	20	8	0.4	51	2.6	59	86

proportions ($\chi^2 = 36.9$, $P < 0.001$) between age groups (table 3). Because the breeding population at Johnston is small, these results indicate that a higher proportion of immature than adult Red-footed Boobies move south from the Hawaiian Islands to the vicinity of Johnston.

The ratio of adult to immature Red-footed Boobies changes with distance from islands. For example, table 4 compares numbers seen at varying distances from Johnston Atoll in winter; adults occur less frequently than immatures at greater distances ($\chi^2 = 42.6$, $P < 0.001$). Insufficient observations prevent a similar analysis for other islands.

The pelagic distributions of adult and immature Red-footed Boobies also differed on an east-to-west basis between 10° and 20° North Latitude, the only region we surveyed sufficiently and that had enough birds in January and February for an east-west analysis. A comparison of ages found east of longitude 169° (156 adults, 154 immatures) and west of 170° (26 adults, 117 immatures) shows statistically different frequencies ($\chi^2 = 16.9$, $P < 0.001$); within the same area, however, the north-to-south frequencies are not significantly different ($P > 0.05$). The area between 169° and 170° is not included in this tally because most survey in this zone was close to Johnston Atoll.

DISCUSSION

The reasons for differing distribution of adults and immatures of a number of seabird species are not completely understood. Similar reports exist for a variety of temperate gulls (Gross 1940, Drury 1963, Coulson 1966, Sanger 1973, Harrington 1975). Some species show different north-to-south distribution of adults and immatures, and others exhibit differences related to distance from shore (Sanger 1973, Harrington 1975) or other factors. Robertson (1969) found that Sooty Terns (*Sterna fuscata*) from Florida apparently spend their first few years in the eastern tropical Atlantic and later years in the Caribbean and western tropical Atlantic. First-year Gannets (*Sula bassana*) also tend to move farther south than adults (Thomson 1974).

Apparently, the distribution of the Red-footed Booby near Johnston Atoll is influenced directly by the atoll and especially by a radio tower erected early in the 1960's, which is now used by up to 6000 boobies as a roosting site. Historically, the numbers of Red-footed Boobies that used Johnston Atoll were much lower than in the late 1960's. Wetmore (1923) counted only 250 during July, whereas, currently over 2000, mostly immatures, may be counted in the same month. In April, Moynihan (1957) saw about 100 Red-footed Boobies at Johnston (mostly breeders); recently, 2000 often roost in the same month (mostly immatures).

Johnston Atoll has been, and still is, a poor nesting island for Red-footed Boobies, apparently because of the scarcity of woody vegetation that is preferred for nesting (Nelson 1970). A similar situation exists at Howland Island in the Phoenix group, where large numbers of Red-footed Boobies roost in dead Cordia trees, but few breed on the island, apparently because there are no live, woody bushes or trees.

Some evidence suggests that the numbers of adults and immature Red-footed Boobies at sea near Johnston have changed (increased) in the same manner as at the atoll. Except during unusually windy weather, I regularly saw lines of boobies flying to the atoll after sunset, apparently commuting from nearby fishing areas. These birds roost on the radio tower, an activity not possible before erection of the tower in 1963. In November 90% of these commuters were adults (V. M. Kleen, POBSP field notes), but as the fall and winter proceed, an increasing percentage are immatures (Amerson and Shelton 1976). The pattern we found in a pelagic area more than 100 miles southwest of Johnston Atoll was quite different because the proportion of adults was consistently low; apparently most adults remained closer to Johnston Atoll

(table 4). But the number of immatures in the pelagic area southwest of Johnston increased from October until February, and then began to decline. Meanwhile their numbers increased at the atoll. By April, when 2000 immatures were roosting at Johnston, few were seen in the pelagic survey area. Therefore, it seems as though the distribution of young shifted closer to Johnston between October and April. Possibly most juveniles arriving in this part of the Pacific Ocean in the autumn do not know of the roost at Johnston Atoll, and therefore do not use the atoll in October and November. Once they find the island their pelagic distribution must shift closer to the atoll, and the boobies commute to foraging grounds instead of remaining at sea at night. Perhaps they continue this routine in later years. This would explain the disproportionately high numbers of adults near the atoll in the autumn (for example 90% of the birds in November) at a time when high numbers of young birds are found at sea. If correct, this would also indicate that historical changes of numbers of Red-footed Boobies at the atoll have been accompanied by changes in the way the surrounding ocean is used.

These deductions prompt the question of whether learning is a proximate factor affecting the winter distribution of Red-footed Boobies in the central Pacific. The need for time and opportunity to learn best explains the different east-to-west and island-oriented distributions which I found between experienced adults and inexperienced immatures. However, differences in north-to-south distribution may occur because of seasonal and individual variations of breeding schedules of adults in the Hawaiian Islands.

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