

BREEDING DISTRIBUTION, HISTORY, AND POPULATIONS OF NORTH PACIFIC ALBATROSSES

DALE W. RICE AND KARL W. KENYON

ALBATROSSES, the largest and most spectacular sea birds, have received little intensive long-range study, chiefly because they nest on remote, uninhabited oceanic islands. Much of our knowledge of the life history of these birds comes from the classic studies of L. E. Richdale (1950, 1952) on the Royal Albatross (*Diomedea epomophora*) in New Zealand. In order to gain knowledge of the habits of albatrosses that interfered with aircraft operations at Midway Atoll, the U.S. Navy financed a study of these birds. Rice spent from 17 November 1956 to 21 July 1958, and Kenyon from 29 December 1956 to 26 June 1957, in the Leeward Hawaiian Islands. In this period we made an intensive study of the Laysan Albatross (*D. immutabilis*) and a less intensive study of the Black-footed Albatross (*D. nigripes*) on Midway Atoll, and surveyed all known breeding colonies throughout the Leeward Chain. This report traces the historical records of population fluctuations and summarizes our data on the present populations of these two species. The breeding cycle and distribution at sea will be treated in later publications. The history of the third species of North Pacific albatross, the Short-tailed Albatross (*D. albatrus*), was reviewed by Austin (1949); during the 1958–1959 season the entire world population included 18 nesting pairs, all on Tori Shima (Fauna Preservation Society, 1960).

METHODS

We determined the size of nesting albatross populations by (1) aerial surveys, and (2) ground counts.

1. Aerial surveys were conducted at all the Leeward Hawaiian Islands during the incubation period (late November and December). The aircraft were Navy UF-1 Grumman Albatross amphibians. A series of passes was made over each island at an altitude of 60 to 150 meters, at a speed of 220 km per hour. During each run, an overlapping series of oblique photographs was taken from the side hatch with an F-56 Fairchild camera, which exposed 17.5×17.5 cm negatives.

A contact print was made from each negative. Each series of photographs was oriented by means of landmarks, and areas of overlapping coverage were blocked out. Each photograph was examined under a magnifying lens, or a $10\times$ binocular microscope. As each albatross was counted it was pricked with a pin, to avoid duplication or omission.

In most cases it was impossible to distinguish between incubating and unemployed birds. Ground counts made at Midway, a few days prior to

the aerial surveys, indicated that 25 per cent of the albatrosses visible on the photographs were unemployed. Therefore, we reduced our counts by 25 per cent to estimate the number of nests.

On certain areas complete counts were impossible because many birds were hidden by vegetation. Here we estimated numbers by comparing the photographs with photographs of comparable terrain on Eastern Island where the number of nests per unit of area had been determined by ground counts.

On all islands nearly complete counts of Black-footed Albatrosses were possible because they inhabit open terrain.

2. Ground counts were conducted in two ways. Where practicable, all nests were counted. Where Laysan Albatross nests were highly concentrated, duplication and omission were avoided by marking each incubating bird on the breast with a spot of red dye. The dye was applied from a bottle having a cotton wick inserted through a small hole in the cap; the bottle was attached to the end of a meter-long stick. Deserted nests containing eggs were also counted. A Veeder-Root hand tally was used to prevent errors in counting.

Where complete counts were impractical, sample plots were counted, and an estimate for the total area was extrapolated. Details are given below under the accounts for each island.

RESULTS

The known and probable breeding distribution, within historical times, of the three species of *Diomedea* occurring in (and endemic to) the North Pacific is summarized in Table 1. The authorities for the inclusion of each island or atoll within the range of *D. immutabilis* and *D. nigripes* are cited below. The range of *D. albatrus*, presented for comparison, is summarized from Austin's (1949) account. The breeding distribution of each species is plotted on the accompanying map (Figure 1).

Our estimates of present breeding populations, expressed as number of occupied nests at the beginning of the nesting season, are summarized in Table 2. Estimates have been rounded to the nearest two significant digits, as the accuracy of the census methods does not justify more precise figures.

The five outer atolls (Kure, Midway, Pearl and Hermes, Lisianski, and Laysan) of the Leeward Chain were surveyed both years; the inner four islands of the Leeward Chain, and Kaula of the main group, were surveyed only in the 1957-1958 season.

The number following the name of each island refers to the map (Figure 1).

Hawaiian Islands

Kure Atoll (1). Green Island is the only albatross breeding ground on this

westernmost atoll of the Hawaiian Island chain. Wetmore obtained observations on Kure from 17 to 22 April 1923. Of the Black-footed Albatross he says (*in litt.*): "300 pairs, in small colonies on sandspits and small areas of beach. Many dead adult birds seen, cause of mortality unknown."

TABLE 1
SUMMARY OF DISTRIBUTION OF NORTH PACIFIC ALBATROSSES¹

<i>Island or atoll</i>	<i>Diomedea albatrus</i>	<i>Diomedea nigripes</i>	<i>Diomedea immutabilis</i>
1. Hawaiian Islands: Kure Atoll		X	X
2. " " Midway Atoll		X	X
3. " " Pearl and Hermes Reef		X	X
4. " " Lisianski Is.		X	X
5. " " Laysan Is.		X	X
6. " " Gardner Pinnacles			X
7. " " French Frigate Shoals		X	X
8. " " Necker Is.		X	X
9. " " Nihoa Is.		X	X
10. " " Kaula Is.		X	
11. " " Niuhau Is.			X
12. " " Moku Manu			(X)
13. Johnston Island		(X)	(X)
14. Marshall Islands: Taongi Atoll		(X)	
15. Wake Island		(X)	(X)
16. Marcus Island		(X)	(X)
17. Izu Islands: Torishima	X	X	(X)
18. Bonin Islands: Kita-no-shima	(X)		
19. " " Muko-shima	(X)	(X)	
20. " " Yome-shima	(X)		
21. " " Nishi-no-shima	(X)		
22. Volcano Islands: Iwo Jima		(X)	
23. Daito Islands: Rasa Is.	(X)		
24. Ryu-kyu Islands: Kobisho	(X)		
25. " " Agincourt Is.	(X)		
26. Pescadores Islands: Byo-sho	(X)		

¹X = occurs; (X) = extirpated.

And, of the Laysan Albatross: "50 pairs, nesting on the beach around Green Island, alone, or in company with groups of *D. nigripes*. The small open area in the center of the island was a trap in which I found bodies of a dozen that had alighted there and then had not been able to take flight again." In 1957 we found several skeletons of albatrosses that had become entangled in the *Scaevola* thickets that surround the central open area, and had died of starvation. An effort was made by the Navy in 1959 to improve albatross nesting habitat on the island. With bulldozers, passages were cleared through the heavy growth of *Scaevola* to give albatrosses improved access to and from the ideal nesting sites in the island's interior.

During ground surveys, we counted 270 Laysan and 42 Black-foot chicks on 5 June 1957, and about 300 and 50, respectively, on 9 May 1958. Allowing for nest mortality, we estimate about 350 Laysan and 70 Black-foot nests at the beginning of each season (Kenyon and Rice, 1958).

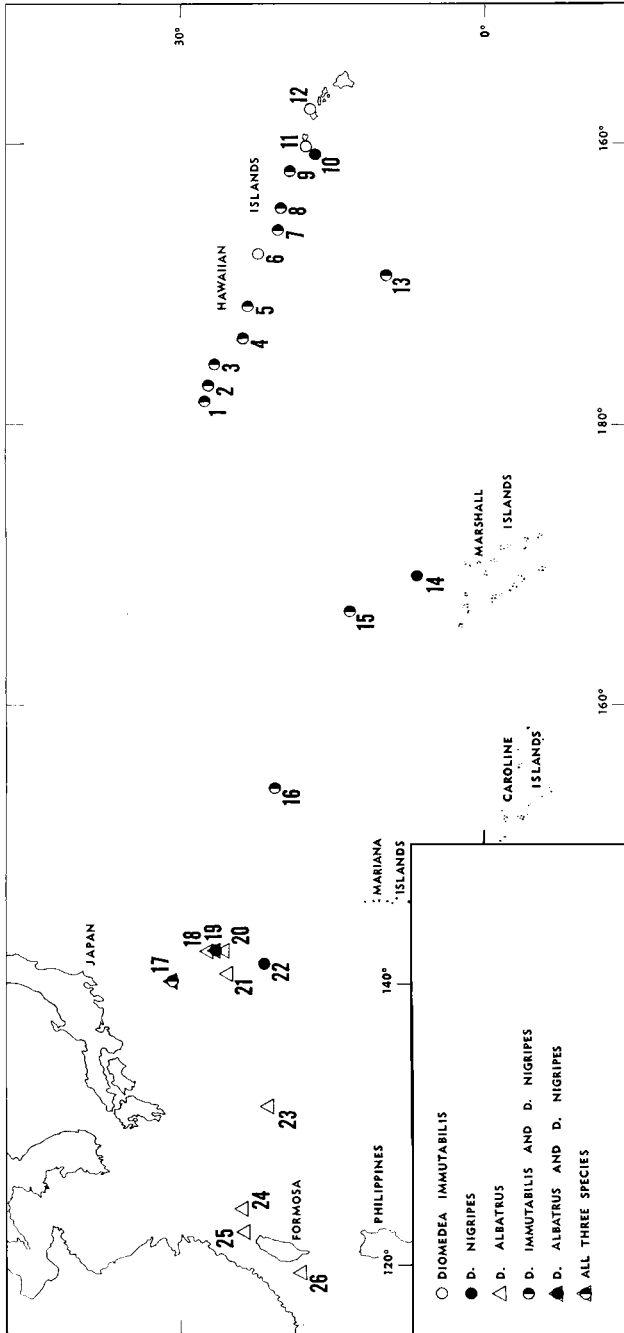


Figure 1. Map of the past and present breeding distribution of the three North Pacific species of *Diomedea*. See Table I for key to geographical locations.

TABLE 2
ESTIMATED NUMBER OF NESTING PAIRS OF ALBATROSSES IN THE HAWAIIAN ARCHIPELAGO DURING THE 1956-1957 AND 1957-1958 SEASONS

<i>Island</i>	<i>D. immutabilis</i>	<i>D. nigripes</i>
Kure Atoll		
Green Island	350	70
Midway Atoll		
Sand Island	60,000	6,300
Seal Islet	30	-
Rocky Islet	25	-
Eastern Island	40,000	2,400
Pearl and Hermes Reef		
Kittery Island	-	450
Seal Island	450	370
Grass Island	1,200	1,900
south sandspits	-	63
Southeast Island	14,000	2,300
north sandspits	-	120
North Island	2,100	1,900
Lisianski Island	30,000	2,700
Laysan Island	130,000	34,000
Gardner Pinnacles	2	-
French Frigate Shoals		
Tern Island	24	2
Trig Island	100	130
Whale Island	260	840
Round Island	-	12
East Island	200	170
Gin Island	-	3
Little Gin Island	-	340
Disappearing Island	-	2
Necker Island	2,500	370
Nihoa	500	50
Kaula	-	100
Niihau	500	-
Moku Manu	0	-
Total pairs	282,241	54,592
Rounded	280,000	55,000
Total nesting birds	560,000	110,000

In 1960 construction of a Coast Guard radio station on Kure was begun. *Midway Atoll* (2). Two large islands (Sand and Eastern), three small islets, several shifting sandspits, and a surrounding reef constitute the dry-land area of this atoll. Sand and Eastern islands are the only important bird-nesting islands. Up to the time of this study Midway was the only one of the Leeward Hawaiian group having a permanent human population. A cable station was established there in 1903, and Pan American Airways established a base there in 1935. The atoll has been under the jurisdiction of the Navy Department since 20 January 1903, and was made a national defense area on 14 February 1941. Much of the five square km of Sand and Eastern islands are now occupied by the U.S. Naval Station.

When Munro (1942) visited Sand Island in 1891, he wrote that it was

an "indescribably desolate, lonely isle. I . . . looked over the large expanse of white sand . . . broken only by a few green mounds of *Scaevola* bushes . . . the moans of the solitary petrel and the occasional harsh squawk of the tropic bird under the house, the total absence of other birds . . . was depressing."

Cable Company employees introduced earth, garden plants, shrubs, and trees. Mr. George Willett visited Sand Island on 14 March 1913, and recorded in his notes (Bailey, 1956) that "A few Laysan Albatrosses were nesting near the houses and on the beach at the opposite end of the island were small colonies of Black-footed Albatrosses." In the late 1930's Hadden (1941) stated: "There are over 2,000 [Laysan Albatrosses] in the P.A.A. compound by actual count." Munro (1943) observed: "The transformation of Sand Island of Midway from a desolate desert isle to a pleasant little countryside, and from a birdless island to one carrying an extraordinarily large bird population is largely due to the Commercial Pacific Cable Company and Mr. and Mrs. Daniel Morrison." More detailed historical information is given by Hadden (1941), Bryan (1942), Fisher and Baldwin (1946), Fisher (1949), and Bailey (1952). Wetmore was at Midway 23-24 April 1923. He estimated (*in litt.*) that on Eastern Island there were 1,000 pairs of Black-foots and "1,500+ pairs [of Laysans] that nested mainly in long openings in the brush cover. My notes state it was difficult to judge their numbers but there were certainly more than 1,500 pairs, all with well-grown young. (The total however could not have been more than 1,800 pairs, if that many.)" On Sand Island he estimated 1,000 pairs of Black-foots and 1,000+ pairs of Laysans.

In the late 1930's Hadden estimated the albatross population on Midway (presumably Sand Island only) at 20,000 Laysan and 30,000 Black-footed albatrosses. As vegetation spread, the more adaptable Laysan continued to increase. The Black-foot population apparently reached a maximum of nearly 20,000 pairs in the early 1940's, after which it declined. Whether the decline was the result of wartime activity or a result of ecological conditions is a moot question. We suspect that the early stages of vegetation growth, between 1903 and the late 1930's, gave needed protection from blowing sand, causing a population increase. Maximum vegetation development during the 1940's and 1950's, however, destroyed the open areas preferred by the Black-foot. Wartime destruction of birds and decreased nesting habitat apparently combined to stabilize the population at about 5,000 to 6,000 nesting pairs in the late 1950's. It is beyond question that planting on Sand Island, which furnished shelter to nesting albatrosses, was directly responsible for the growth of the population, particularly of the Laysan Albatross, from a

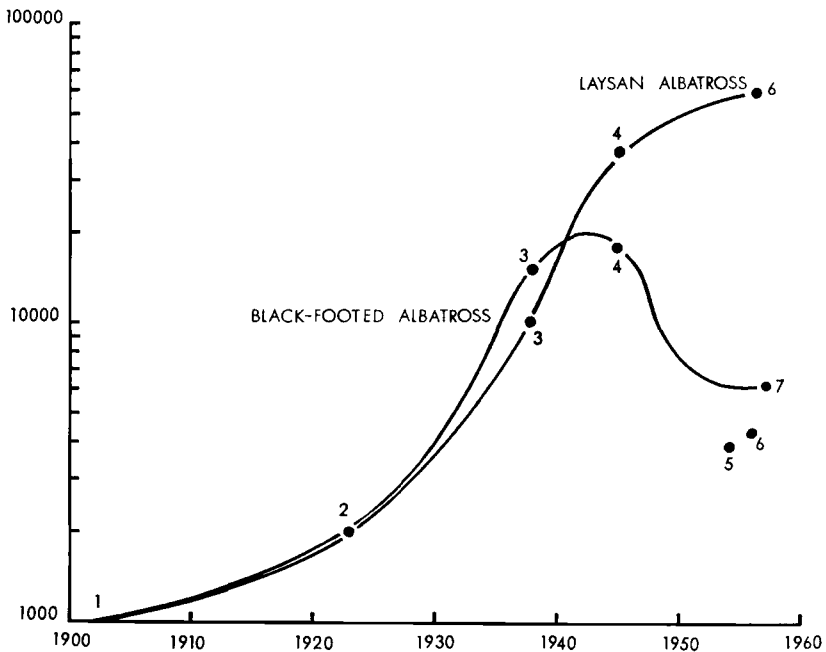


Figure 2. Dots represent estimates of nesting pairs of Laysan and Black-footed albatrosses on Sand Island, Midway Atoll. Estimates are few and were obtained by different means, but indicate a general order of magnitude of the two populations. The hypothetical population curves are drawn by eye. References are: (1) prior to 1903 (Munro, 1942); (2) 1923 (Wetmore, *in litt.*); (3) late 1930's (Hadden, 1941); (4) May, 1945 (Fisher and Baldwin, 1946); (5) Dumont and Neff (MS., 1955) estimate of December 1954; (6) our 1956-1957 estimates; the Black-footed Albatross nest estimate based on a late season count may have been inadequately corrected for early season nest mortality; (7) December 1957, total nest count.

negligible number prior to 1903 to about 100,000 nesting pairs by the late 1950's. Fisher (1949) points out that the few censuses of albatrosses at Midway were made at different seasons and by different methods. A rough order of magnitude, however, is indicated (Figure 2).

Our estimates of the total nesting populations of Laysan and Black-footed albatrosses at Midway are based on sample nest counts of Laysan Albatrosses and complete nest counts of Black-footed Albatrosses. Counting could not always be accomplished soon after egg laying was completed; therefore, correction factors based on sample nest mortality studies are applied to the field counts.

Black-footed Albatross: In late January and early February of 1957, counts of all existing nests were made on Sand and Eastern islands and a

correction factor applied to obtain an estimate of the total nests in early December 1956, after egg laying had been completed. On Sand Island 3,659 nests were counted. From one small colony a correction factor of 17 per cent for nest mortality to this time was obtained, giving a calculated total of 4,281 nests. On 27 February our Eastern Island nest count of 1,669 nests was corrected to an estimated total of 2,286 nests in the early season. The 1957-1958 season counts indicated a possible increase (or an inadequate correction factor in the previous year) in nests on Sand Island, where 6,188 were counted between 2 and 5 December 1957, and a stable condition on Eastern Island, where a count of 2,333 nests was obtained on 9 December 1957.

Laysan Albatross: Available time did not permit us to attempt complete counts of the great number of nests of this species at Midway. Randomly distributed 0.0809 hectare (0.2 acre) circular plots were located by consecutively numbering grid-line intersections on a map, and selecting grid intersections from a table of random numbers. On Sand Island (area 384 hectares) 48 plots were counted; on Eastern Island (area 135 hectares), 28 plots.

In mid-December a total of 604 nests were counted on the 48 plots on Sand Island, and an estimate of 59,699 nests calculated. On Eastern Island, between 19 January and 16 February 1957, counts of all nests on 52 per cent of the nesting area were completed for a total of 14,024 nests. These counts were applied to the remaining area on the basis of similar nest density per unit area (as obtained from ground surveys and examination of aerial photographs) for a total estimate of 39,582 nests extant during the counting period. A nest mortality rate of 6 per cent per month was obtained from sample areas, giving a calculated total (corrected to early December) of 44,332 nests. The population on Sand Island was not estimated during the 1957-1958 season because widespread construction and earth-moving operations disrupted nesting activity. On Eastern Island sample plots were counted in December of 1957, giving a calculated total of 42,625 nests.

Counts obtained on Rocky and Seal islets in 1957 are given in Table 2.

After construction activities have been terminated at Midway Atoll, it will be necessary to conduct further population studies. Much land available for nesting during the period of our studies is now covered by black-top and buildings.

Pearl and Hermes Reef (3). Five permanent islets and several semi-permanent sandspits are surrounded by dangerous shallows and reefs. Vegetation is sparse and low, so that aerial photographs reveal all nesting albatrosses (Figure 3A). Wetmore visited this atoll in 1923 and gives the following estimates from his field notes (*in litt.*): Black-footed Albatross

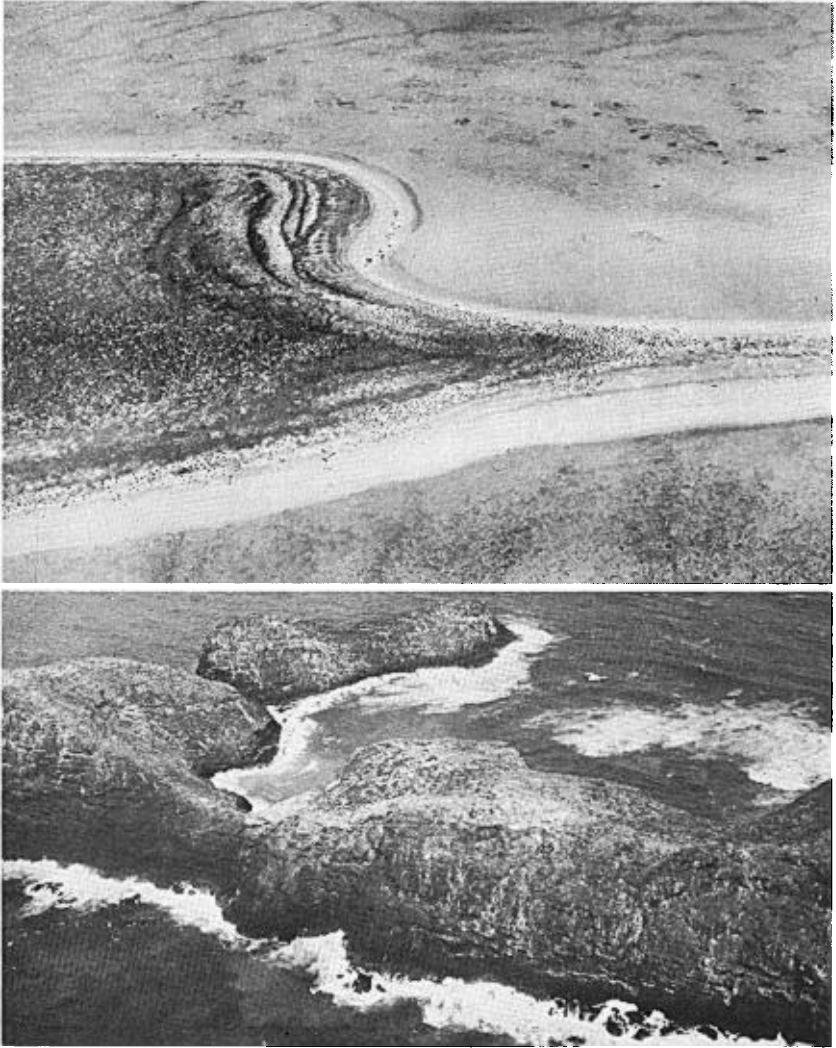


Figure 3. The two nesting habitat types occupied by Laysan and Black-footed albatrosses: (A—top) Portion of North Island in Pearl and Hermes Reef, a low coral atoll in the western part of the Leeward Chain. Black-footed Albatrosses nest on the nearly bare sand immediately above the beach; Laysan Albatrosses occupy the grassy interior. Monk seals (*Monachus schauinslandi*) and green turtles (*Chelonia mydas*) lie on the beach. 18 December 1957. (B—bottom) Necker Island, a high rocky island in the eastern part of the Leeward Chain. A mixed colony of Laysan and Black-footed albatrosses occupies the moderately sloping summit areas. Annexation Peak, at the left, is 75 meters in altitude. 28 December 1957. (U.S. Navy photographs.)

—"Southeast Island, April 26: 1,000 pairs, in groups on sandspits and along the beach. Not found in the grass-grown interior. Middle (or Grass) Island, April 27: 800 pairs; Western (or Seal) Island, April 27: 1,200 pairs"; total: 3,000 pairs. Laysan Albatross—"Southeast Island, April 26: 300 pairs, middle one of the two western islands (which I called Grass Island) April 27: 100 pairs; westernmost island (which I called Seal Island) April 27: 150 pairs"; total: 550 pairs.

Aerial photographic surveys were made over all the islets at Pearl and Hermes Reef on 10 December 1956 and 18 December 1957. The results are presented in Table 2. To allow for unemployed birds, 25 per cent has been subtracted, and the figures rounded to two significant digits. There was no significant change between 1956-1957 and 1957-1958.

Wetmore's estimates were made in late season, after unknown mortality had taken place. It is evident, however, that both species have increased since 1923.

Lisianski Island (4). Munro (1942) visited Lisianski in 1891 and noted that "Laysan albatrosses were over the whole island but not so thickly placed as on Laysan." In 1904 and again in 1910 (Bryan, 1942) Japanese feather hunters slaughtered large numbers of birds on Lisianski. Rabbits, probably introduced during this period, had devoured all vegetation and precipitated their own extermination by the early 1920's. In 1923 the USS *Tanager* expedition found the vegetation beginning to recover. Wetmore's population estimates obtained on 16-19 May 1923 (*in litt.*) are: Black-footed Albatross, 1,000 pairs and Laysan Albatross, "not more than 800 pairs."

Now much of the island's surface is covered by bunchgrass (*Eragrostis* sp.), which appears to inhibit albatross nesting. The birds are able to walk among the tall grass clumps, but are unable to take off when surrounded by them. We saw several Laysan Albatrosses making futile attempts to take wing from fields of bunchgrass when frightened by our low-flying aircraft. If the habitat were ideal, the surface area of this atoll could accommodate a much greater Laysan Albatross population than it now does.

Aerial photographic surveys of Lisianski were conducted on 7 January 1957 and 28 December 1957. We counted 3,665 Black-foots during the 1956-1957 season survey. Allowing 25 per cent for unemployed birds, we estimated 2,749 nests. During the 1957-1958 survey, 3,490 birds were counted, for an estimated 2,618 nests.

A complete count of Laysan Albatrosses could not be made from the photographs because of brushy vegetation. By comparison with photographs of areas of known nesting density on Eastern Island, we estimated

approximately 161 nests per hectare, or a total of 29,141 nests on the island's 181 hectares; certainly a tremendous increase since 1923.

Laysan Island (5). In 1891 when Munro (1942) visited Laysan he found Captain George Freeth, Governor of the Island, operating a guano works there, and the island was covered with vegetation. Mules, pigs, rabbits, and guinea pigs were brought to the island by the guano diggers. Rabbits and guinea pigs were liberated about 1903 (Dill and Bryan, 1912). Having no enemies, they increased, particularly the rabbits, to tremendous numbers, so that by 1923 when Wetmore (1925) visited Laysan he found it a desert waste and the rabbits starving. Those remaining were killed. Twenty-three feather poachers arrived in May 1909, and were removed by the U.S. Revenue Cutter *Thetis* in January of 1910. Henshaw (1912), who visited Laysan in 1911, estimated that the poachers had killed "upwards of 300,000" Laysan Albatrosses and in all "not far from a million" sea birds. Dill and Bryan (1912) estimated in 1911 that one sixth of the original Laysan Albatross colony was left. Between 24 April and 5 June 1911 they measured areas covered by nesting colonies and computed that there were 180,000 nesting Laysan Albatrosses (90,000 nests) and 85,000 Black-footed Albatrosses (42,500 nests). Bailey (1952) considered this estimate "over liberal," since his careful nest count between 22 December 1912 and 11 March 1913 revealed only 12,312 Laysan Albatross nests and 7,722 of the Black-foot. Wetmore visited Laysan 9-13 April and 2-14 May 1923. He recorded (*in litt.*) "4,700 pairs of Black-footed Albatrosses. During a severe blow at the end of April all of the adults left the island, leaving the young to fend for themselves. On May 3 I noted a one-third decrease in the number of adults over those noted April 9-13." His estimate of Laysan Albatrosses was 6,800 pairs. Considering that Wetmore's estimates were made after considerable chick mortality had taken place, they tend to confirm Bailey's work. In 1951, from sample field counts, Brock (1951) computed 103,900 (51,950 nesting pairs) of Laysan Albatrosses and 18,240 (9,120 nesting pairs) of the Black-footed.

Our count of Black-footed Albatrosses on aerial photographs taken on 7 January 1957 revealed a total of 42,837 birds, or (subtracting 25 per cent for unemployed birds) 32,128 nests. On 28 December 1957, the total count was 44,697, and the estimated nests 33,523.

Laysan Albatrosses could not be completely enumerated on the aerial photographs taken on the same dates because of vegetation and excessive obliqueness of camera angle. The photographs of Laysan Island were compared with photographs of Eastern Island where the number of nests per unit area was known from ground counts. On Laysan it was estimated that 304 hectares (750 acres) were occupied by a nest density of 432 nests per hectare, giving a calculated total of 131,328 nests.

Between 27 May and 4 June 1958, 12 straight strip transects, 15.2 meters wide, were made between the lagoon and the ocean beach at nearly equal intervals around the island. We counted 2,884 Laysan Albatross chicks on 13.42 hectares of the island's 405 hectares (1,000 acres) of land area, for an estimated total of 87,036 chicks. Applying the nest mortality rate of 33 per cent, found on Eastern Island, Midway, we obtained a calculated total of 130,554 nests at the beginning of the nesting season. This estimate based on a ground count agrees very closely with the aerial photographic estimates made previously.

Gardner Pinnacles (6). Wetmore (*in litt.*) found two pairs of Laysan Albatrosses occupying Gardner Pinnacles on 22 May 1923. No Black-foots were noted.

On 28 December 1957 three Laysan Albatrosses were observed from the air, two on the pinnacle, one soaring nearby. Nesting could not be ascertained. The islet is too steep and tiny to accommodate more than a few pairs.

The *A.O.U. Check-list* (American Ornithologists' Union, 1957) includes Gardner Pinnacles in the breeding range of the Laysan Albatross, on the basis of Wetmore's observation. We have found no other published references to albatrosses on Gardner.

French Frigate Shoals (7). La Perouse Rock and 10 small coral sand islets compose this atoll. One of these, Tern Island, is completely taken up by an air strip and buildings of a U.S. Coast Guard Loran Station. In 1958, 13 men and a dog occupied Tern Island. During his visit, 22-26 June 1923, Wetmore (*in litt.*) recorded: Black-footed Albatross: "East Island, 75 well grown young; other islets, 330 well grown young. Only a few adults were still present to care for their young. Most of the juveniles were learning to fly and were on their own." Laysan Albatross: "East Island, 100 pairs; other islands, 30 pairs." On 18 and 19 December 1953 Dr. Frank Richardson (1954) visited the area. On Tern Island he found six nests with eggs of the Black-footed Albatross and 28 of the Laysan Albatross. His estimate of the number of nests with eggs on Trig, Skate, Whale, East, Gin, and Little Gin islands were: Black-footed Albatross, 1,500-1,700; Laysan Albatross, 600-700. He also visited La Perouse Pinnacle, but found no albatrosses nesting there.

We made a complete aerial survey of French Frigate Shoals on 28 December 1957. Our counts from aerial photographs, reduced by 25 per cent to allow for unemployed birds, and rounded to two significant digits, are presented in Table 2.

Wetmore's 1923 observations were made after the period of greatest chick mortality. Nevertheless, it would appear that a population increase has taken place at French Frigate Shoals since 1923.

Necker Island (8). In 1902 Dr. Gilbert "estimated roughly that there might be from one to two thousand" Laysan Albatrosses on the island, and the Black-footed Albatross was seen "sparingly" (Fisher, 1906). During a visit, 17-21 June 1923, Wetmore (*in litt.*) estimated "about 100 nearly grown young" of the Black-footed Albatross, "no adults present." Of Laysan Albatrosses he estimated 600 pairs. Richardson (1957) lists the Laysan Albatross as occurring there in fair numbers and the Black-footed in small numbers.

We made an aerial photographic survey of Necker (Figure 3B) on 28 December 1957. On the photographs we counted 3,327 Laysans and 491 Black-foots. Allowing 25 per cent for unemployed birds, we have estimated 2,495 and 368 nests of Laysans and Black-foots, respectively.

Nihoa (9). Also called Moku Manu or Bird Island. Bryan (1942) states that in 1923 a colony of Black-footed Albatrosses occupied the summit of the 285-meter high, dome-shaped plateau, and Richardson (1957) found the Laysan Albatross breeding there "in small numbers." Wetmore (*in litt.*), however, gives more specific data. In the period 10-16 June 1923 he found "60 well grown young [Black-footed Albatrosses] on a small flat below the pinnacle point of Miller's Peak (about 850 feet above the sea). Only 3 adult birds seen." He saw only two Laysan Albatrosses.

We made an aerial survey of Nihoa on 28 December 1957. A complete count could not be made from the photographs because of the shrubby vegetation that covers much of the steep slopes, and because of the possibility of confusing albatrosses with boobies (*Sula* sp.). A rough estimate of 500 Laysan and 50 Black-foot nests was made with 7 × 50 binoculars from the open hatch of the aircraft.

Kaula (10). The *A.O.U. Check-list* (American Ornithologists' Union, 1957) includes Kaula in the breeding range of the Black-footed Albatross on the basis of Wetmore's observations in 1923 (Wetmore, *in litt.*). We have found no other published references to albatrosses on Kaula.

We made an aerial survey of Kaula on 28 December 1957. Turbulent air currents prevented a close approach. The steep upper slopes are nearly bare; there appeared to be about 50 Black-footed Albatrosses on them.

Niihau (11). Nesting of Laysan Albatrosses on the island of Niihau was reported by Fisher (1951) in 1947, but no data on numbers were presented, as he was there during the late summer when the birds were absent. Aylmer F. Robinson (*in litt.*) of Makaweli, Kauai, one of the owners of Niihau, has generously furnished the following account of the history of the species on this island:

The Laysan Albatross is not new to Niihau. The fact that it has a Hawaiian name (*Moli*) is in itself proof that the bird has been known to the Hawaiians since early

times. The only new feature is that the birds are present in greater numbers than heretofore, and that they now come every winter for nesting on the island, whereas formerly it was to a degree intermittent. This change took place largely during the war years [1940-1945]

The albatross nesting on the island are mostly on the sand dunes or flat sandy land above the sea-coast, although some nestings in volcanic ash areas have occurred. While most are on the north end of the island, some are scattered along the southerly coasts wherever the soft, sand conditions are right for nesting.

No attempt has been made to count the number of albatross nests in any season, and it would be difficult to do so as they are intermittent over miles of sand dune and beach areas, and under small trees and shrubs where protection from the weather can be had. However in years of heavy nesting they must run into at least several hundred of nests. There appears to be no difficulty in raising the young birds; [some of] the nests have been destroyed at the egg stage by wild pigs. Presumably however the greater part of the nestings are successful in raising their young. The birds come mostly in the late fall or early winter and leave in the early spring. They are present again this year [1957-1958], although whether in the same numbers as some years I have not yet had time to observe. Such protection as is possible has always been accorded to these birds by us, simply as a matter of interest in maintaining the varied bird life of the place.

The black or brown albatross [*D. nigripes*], although present in flight in the channel between Niihau and Kauai, I have not observed nesting on the island.

Our rough estimate of 500 nests (Table 2) is based on this information.

Moku Manu (12). The first known nesting of Laysan Albatrosses on Moku Manu, a small islet off the Mokapu Peninsula of the island of Oahu, occurred in the 1946-1947 season, when one pair successfully raised a chick. In the 1947-1948 season a deserted egg was found at the same site on 11 January 1948 (Fisher, 1948; Richardson and Fisher, 1950). One adult bird was seen on the islet in December 1955 (Hawaii Audubon Society, 1956), and three in December 1956 (Hawaii Audubon Society, 1957).

Johnston Island (13)

Both Laysan and Black-footed albatrosses formerly nested on Johnston Island (American Ornithologists' Union, 1957), but there is little historical record, and they were extirpated at an early date by feather hunters. On a visit, 10-18 July 1923, Wetmore (*in litt.*) found evidence of recent feather hunting on the island, but no albatross remains were found among the bones, indicating an early elimination of these species from the island. However, he did find "one young [Laysan Albatross] nearly ready to fly," indicating that this species was attempting to recolonize the island at that time. He found no Black-footed Albatrosses but states that "W. G. Anderson, a member of my party had been here in November 1922, and saw one bird with an egg." In April 1957 Moynihan (1957; and *in litt.*) found no albatrosses on Johnston Island; they are undoubtedly extirpated, as an airstrip now occupies almost the entire area of this small island.

Marshall Islands (14)

According to Dall (1874), the Black-footed Albatross was "said by Capt. Geo. Holder to nest on the coral island of Gaspar Rico, near the equator, in the winter season." This island is believed to be Taongi Atoll (also called Pokak), the northernmost of the Marshall Islands (Aldrich, *in litt.*), and is so listed in the *A.O.U. Check-list* (American Ornithologists' Union, 1957). Albatrosses have not been found there since that time. In 1952, Fosberg (*in litt.*) found no sign of albatrosses on the island.

Wake Island (15)

The following information on the history of albatrosses on Wake has been compiled by John W. Aldrich.

Titian R. Peale (1848: 290) describes the albatrosses found nesting on Wake Island on the 20th of December [1841] under the name *Diomedea brachyura* and called them 'short-tailed albatross.' . . . This description appears to refer to both the Black-footed and Laysan Albatrosses which he thought were different age plumages of the Short-tailed Albatross. On page 337 of this same report is listed a specimen of the albatross with number 745. U.S. National Museum specimen 15552 is a *Diomedea nigripes* marked Wake's Island, U.S. Exploring Expedition, field number 745. This is the only skin of either *nigripes* or *immutabilis* cataloged in the U.S. National Museum from the U.S. Exploring Expedition. Inquiry of the Philadelphia Academy of Natural Sciences determined that there were no specimens of albatrosses taken on Wake Island by this expedition in that institution.

In the egg collections of the U.S. National Museum is a single badly broken and patched albatross egg without any number, but marked on the shell *Diomedea brachyura*, Wakes I. Dec. 20, T. R. Peale. From its size and shape this egg appears to be that of the Laysan Albatross. It is smaller than the Black-footed Albatross eggs in the collection. In color it is indeterminable.

Dr. Alexander Wetmore (in conversation) tells of his visit to Wake Island, from July 27 to August 7, 1923. Wake Atoll is comprised of a large island and two smaller ones which consist of a mixture of large chunks of coral and sand, low in elevation so that storm waves occasionally sweep entire areas of land. Dense vegetation covers some areas, with some of tree size. Wetmore found evidence of extensive plume hunting operations by the Japanese. The buildings and equipment gave evidence of a fairly permanent and recently operated skinning plant. The pile of bird bones indicated great destruction of bird life over the years. The species identified from the bones were frigate birds, boobies, and terns (no albatrosses). The time of year, July 27 to August 7, when Wetmore was on Wake was the off-season for albatross nesting, so the lack . . . of living [albatrosses] might not have been significant. However, the lack of dead birds and bones would indicate that the species of albatross found on Wake by Peale must have disappeared before 1923, and the fact that they were not among recent bones left by plume hunters indicates extermination long before 1923.

Information supplied by several observers who were on Wake from 1935 until the Japanese occupation in 1942 confirmed the absence of albatrosses on the island during this period.

Oliver L. Austin, Jr. writes (*in litt.*, 28 July 1959) "I was unable to get any information on the Japanese experiences with the gooneys on Wake. Nothing on the

subject had found its way into the Japanese literature by 1951, and I was unable to find any Japanese who had been there." Yoshimaro Yamashina (*in litt.*, 17 August 1959) could not find anyone in Japan who had any knowledge of the former status of albatrosses on Wake I. Nagahisa Kuroda (*in litt.*, 27 March 1960), although conversant with activities of plume hunters on Marcus had no information on similar activities on Wake.

Thus the only concrete evidence that any species of albatross ever nested on Wake Island is the skin of the Black-footed and the egg of the Laysan Albatross in the U.S. National Museum, together with Peale's recognizable description of the birds he found nesting there. There is no evidence that the Short-tailed Albatross nested there.

It is probable that the Black-footed and Laysan albatrosses found nesting on Wake, by Peale in the early part of the 19th century, were completely wiped out by the Japanese feather-hunting industry which was very active in the North Pacific around the turn of the century and which has been well documented for Marcus Island by Kuroda (1954). As at Marcus the more desirable albatross feathers may have caused these species to be exterminated first, so that complete elimination of both Black-footed and Laysan albatrosses was accomplished at an early date. This probably accounts for the lack of albatross bones in the remains left by plume hunters, examined by Dr. Wetmore on Wake in 1923.

U.S. Navy personnel who visited Wake in 1957 and 1958 told us that albatrosses do not now occur on the island.

Marcus Island (16)

Both Laysan and Black-footed albatrosses nested on Marcus Island; the population was originally estimated to be at least 1,000,000 birds (Bryan, 1902; Namiye, 1905; Kuroda, 1954). They were extirpated by a feather-hunting company between 1896 and 1902 (Bryan, *op. cit.*). U.S. Navy Personnel who have visited Marcus in recent years have told us that there are no albatrosses present.

Seven Islands of Izu (17)

In the Izu Islands, Black-footed Albatrosses nested only on Tori Shima. According to Hattori (1889), who was on the island from April to July 1889, the Black-footed Albatross was less common than the Short-tailed Albatross; it nested near the shore and never mixed with the larger species. A colony of about 200 was found in April 1932, but only a few birds were present in April 1933 (Yamashina, 1942). The last Black-foots apparently were killed by feather hunters in 1933 (Austin, 1949). On 25 January 1955, Black-footed Albatrosses (number not stated) were found nesting on Tori Shima, indicating a reoccupation of the island (Ono, 1955). No later information is available.

Laysan Albatrosses colonized Tori Shima about 1918; by 1930 the population had built up to about 50, but decreased to only a couple of birds in 1933. All three species were extirpated in the latter year (Austin, 1949; Austin and Kuroda, 1953).

Bonin Islands (19)

In the Bonin Islands the occurrence and nesting of Black-footed Albatrosses on Muko Shima was recorded prior to 1930 (Seebohm, 1890; Momiyama, 1930; Okabe, 1930). No data on abundance are available. No albatrosses were present in the Bonin Islands in March and April 1949 (Austin, 1949; Austin and Kuroda, 1953).

Volcano Islands (22)

Black-footed Albatrosses were reported nesting in large numbers on Iwo Jima by Seebohm (1891). No information is available concerning their status in subsequent years. The species no longer occurs in the Volcano Islands (Austin and Kuroda, 1953).

DISCUSSION

About 560,000 Laysan Albatrosses and 110,000 Black-footed Albatrosses nest each year in the Hawaiian Archipelago. All adults do not nest every year. Under average rates of nesting failure, about 33 per cent of the pairs nesting during the 1956-1957 season failed to return the following year (Rice and Kenyon, ms). If we estimate 8.6 per cent for mortality of adult birds during the year (see below), this means that for every 67 nesting pairs there are 24.4 (33 minus 8.6) adult pairs that failed to nest that year. This indicates that the total number of adults is 36.4 per cent (24.4/67) greater than the number that nest in any given year. In other words, about 73 per cent (100/136.4) of the adults nest each year. Therefore, the total adult populations include about 760,000 Laysan Albatrosses and 150,000 Black-footed Albatrosses.

To determine the total population, including both nesting and non-nesting birds, additional estimates must be made for two categories of the population: (1) unemployed birds (this includes all birds that visit the breeding grounds at one time or other during the breeding season, but do not nest; included are many of the nonbreeding adults, as well as some innubile birds); and (2) innubile birds that remain at sea throughout the breeding season.

(1) *Unemployed birds.* We have data from two experiments to determine the ratio of unemployed birds to nesting birds. During the 1957-1958 season, a 40-hectare section of Sand Island, Midway Atoll, located between an aircraft runway and the beach, was selected by the Navy as an experimental control area. During the incubation period, 5,365 Laysan Albatross nests, representing 10,730 breeding birds, were counted in this area (see Methods). Between 15 January and 7 March 29,764 Laysan Albatrosses were killed on this area. Nearly all nesting birds were killed; about 100-400 (based on an estimate of 100-200 chicks that survived until June) escaped the kill. This means that at least 19,000 un-

TABLE 3
1956-1958 ESTIMATE OF LAYSAN AND BLACK-FOOTED ALBATROSSES ORIGINATING IN THE
HAWAIIAN ARCHIPELAGO

	<i>Laysan</i> <i>Albatrosses</i>	<i>Black-footed</i> <i>Albatrosses</i> ¹
Adults nesting yearly	560,000	110,000
Unemployed birds	650,000-1,120,000	130,000-220,000
Innubile at sea ²	130,000- 376,000	25,000- 74,000
Total	1,340,000-2,056,000	265,000-404,000
Rounded	1,300,000-2,100,000	260,000-400,000

¹ Studies of non-nesting population segments were made only for Laysan Albatrosses. To obtain a total population estimate it is assumed that the data may be applied to the Black-footed Albatrosses.

² One- and two-year-old birds only.

employed birds were killed. Very few unemployed birds remained in this area after the kill. Most unemployed birds are as firmly attached to a particular site as are nesting birds (Rice and Kenyon, ms). There was no decrease in the number of unemployed birds in areas contiguous to the experimental area. Other unemployed birds that utilized this area only earlier or later in the season may have escaped the kill. Therefore, the 19,000 birds that were killed represent the minimum number of unemployed birds in this population. This indicates a ratio of almost two unemployed birds to each nesting bird, if unemployed birds of all age classes are strictly attached to a particular area.

Another study of unemployed birds was conducted from 1 April to 16 June 1957. The purpose was to ascertain what fraction of the population of unemployed birds might be observed on shore at any particular time. An area of approximately 150 m², easily accessible to our living quarters, was selected. All unemployed birds found visiting it were captured; an identifying number was painted, with a pressure spray can, on the white breast of each bird. The study plot and surrounding area were checked two or three times daily, and all marked unemployed birds were recorded. Methods are described in Kenyon *et al.* (1958). A total of 68 birds was marked. These spent 436 bird-days, from a possible total of 3,128 bird-days, on or near the study plot, indicating that an average of about 14 per cent (or about 1/7) of the total of unemployed birds are on shore during any one day at this season. From sample counts it was ascertained that the average ratio of unemployed birds on the ground to incubating birds was 1 to 3.

Each incubating bird represents a breeding pair. If X equals the number of incubating birds, 2X equals the number of breeding birds. The number of unemployed birds may be calculated as 7X/3. This gives a ratio of unemployed birds to nesting birds of (7X/3) : (2X), or about 1.17 : 1 (Table 3).

(2) *Innubile birds at sea.* Little quantitative data are available to indi-

cate the number of innubile birds that remain at sea. We know neither the proportion of each age group that returns to the islands, nor the mortality rates during the first few years at sea. A large-scale banding program (Rice and Kenyon, ms) has indicated that no appreciable number of innubile birds return until at least the third season following hatching. This means that at least the two youngest age groups are unrepresented in the census figures.

In the 1938–1939 season Hadden banded 127 adult Laysan Albatrosses on Sand Island, adjacent to Pan American Airlines' Gooneyville Lodge. During the 1956–1957 and 1957–1958 seasons we examined all birds on this area several times during the incubation period. At least 25 of these original banded birds were still alive during the 1956–1957 season. Therefore, the mean annual mortality was not greater than 8.6 per cent. If the population is stable or increasing, each year an average of at least 17.2 per cent of the breeding pairs must produce a young bird that survives to breeding age. Since only 73 per cent of the adult birds nest each year (see above), at least 23.6 per cent ($17.2/0.73$) of the eggs must produce birds that survive to breeding age. Survival of young Laysan and Black-footed albatrosses from egg laying to fledging on Sand and Eastern islands varied from 42 to 67 per cent (Rice, 1959). Therefore, the size of the one- and two-year age groups probably lies between 23.6 and 67 per cent of the number of eggs laid annually—or between 47.2 and 134 per cent for the two age groups combined.

These population estimates have been summarized in Table 3. We consider the lower figure an absolute minimum; the upper figure may be too low, because we have made no allowance for any unknown per cent of the birds older than two years that fail to visit the island during the breeding season.

The above data indicate that the total population of albatrosses is at least three times the number nesting during any one season. World populations may be conservatively estimated at 1,500,000 Laysan Albatrosses and 300,000 Black-footed Albatrosses.

ACKNOWLEDGMENTS

J. W. Aldrich gave much assistance in library research, and with P. T. Burtis, F. W. Landers, J. A. Neff, C. S. Robbins, W. C. Royall, Jr., R. T. Takahashi, and R. E. Warner assisted in various phases of the field work. The U.S. Naval Station, Midway Islands, furnished facilities for work on Midway, and provided aircraft and crews for the aerial surveys. The U.S. Coast Guard provided surface transportation to Laysan Island. O. L. Austin, Jr., H. I. Fisher, F. W. Fosberg, J. T. Marshall, Jr., M. H. Moynihan, G. C. Munro, A. F. Robinson, and A. Wetmore generously

supplied unpublished information on the status of albatrosses on several islands.

SUMMARY

Laysan and Black-footed albatrosses formerly nested on 19 islands and atolls in the central and western North Pacific Ocean between 14° and 31° N latitude. Many breeding colonies were extirpated, chiefly by feather hunters, during the latter half of the 19th century. The two species now breed on only 11 islands and atolls of the Hawaiian Archipelago (except for a few Black-footed Albatrosses on Tori Shima in the Izu Islands). During the 1956-1957 and 1957-1958 seasons there were 280,000 nesting pairs of Laysan, and 55,000 nesting pairs of Black-footed albatrosses, in the Hawaiian Islands. Computations derived from data on the Laysan Albatross (and presumed to be applicable to the Black-foot also) indicate that 73 per cent of the adult pairs are believed to nest each year; therefore, the total number of adult pairs is estimated at 380,000 Laysan and 75,000 Black-footed albatrosses. On the breeding grounds unemployed birds (nonbreeding adults and innubiles) outnumber nesting birds by a ratio of 1.17 : 1 to 2 : 1. Mean annual mortality among 127 adult Laysan Albatrosses during 18 years was not greater than 8.6 per cent. One- and two-year-old birds were not found on the breeding grounds. The world populations are conservatively estimated at 1,500,000 Laysan Albatrosses and 300,000 Black-footed Albatrosses.

The Short-tailed Albatross, which formerly nested on perhaps nine islands in the western North Pacific, was reduced to 18 nesting pairs, all on Tori Shima, in the 1958-1959 nesting season (Fauna Preservation Society, 1960).

LITERATURE CITED

- AMERICAN ORNITHOLOGISTS' UNION. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union, Baltimore, Md. 691 pp.
- AUSTIN, O. L., JR. 1949. Status of Steller's Albatross. *Pacific Sci.*, **3**: 283-295.
- AUSTIN, O. L., JR., and N. KURODA. 1953. The birds of Japan, their status and distribution. *Bull. Mus. Comp. Zool.*, **109**: 280-637.
- BAILEY, A. M. 1952. Laysan and Black-footed albatrosses. *Museum Pictorial No.*, **6**: 1-78.
- BAILEY, A. M. 1956. Birds of Midway and Laysan islands. *Museum Pictorial No.*, **12**: 1-130.
- BROCK, V. E. 1951. Laysan Island bird census. *Elepaio*, **12**: 17-18.
- BRYAN, E. H., JR. 1942. *American Polynesia and the Hawaiian chain*. Tongg Publishing Co., Honolulu. 253 pp.
- BRYAN, W. A. 1902. A monograph of Marcus Island. *Bishop Mus. Occ. Papers*, **2**: 77-116.

- CASSIN, J. 1858. Mammalogy and ornithology. *In* United States exploring expedition. J. B. Lippincott and Co., Philadelphia. 466 pp.
- DALL, W. H. 1874. Notes on the avifauna of the Aleutian Islands, especially those west of Unalaska. *Proc. Calif. Acad. Sci.*, **5**: 270-281.
- DILL, H. R., and W. A. BRYAN. 1912. Report of an expedition to Laysan Island in 1911. U.S. Dept. of Agr. Biol. Survey Bull., **42**: 1-30.
- DUMONT, P. A., and J. A. NEFF. 1955. Report on Midway Islands—albatross study. Mimeographed memorandum to Lt. Gen. Joseph Smith, Military Air Transport Service, 8 pp.
- FAUNA PRESERVATION SOCIETY. 1960. The International Union for the Conservation of Nature and Natural Resources. *Oryx*, **5**: 379.
- FISHER, H. I. 1948. Laysan Albatross nesting on Moku Manu Islet off Oahu, T. H. Pacific Sci., **2**: 66.
- FISHER, H. I. 1949. Populations of birds on Midway and the man-made factors affecting them. *Pacific Sci.*, **3**: 103-110.
- FISHER, H. I. 1951. The avifauna of Niihau Island, Hawaiian Archipelago. *Condor*, **53**: 31-42.
- FISHER, H. I., and P. H. BALDWIN. 1946. War and the birds of Midway Atoll. *Condor*, **48**: 3-15.
- FISHER, W. K. 1906. Birds of Laysan and the Leeward Islands, Hawaiian group. *Bull. U.S. Fish Comm. for 1903*. pp. 769-807. Govt. Print. Off.
- HADDEN, F. C. 1941. Midway Islands. The Hawaiian planters' record, **45**: 179-221.
- HATTORI, T. 1889. [The story of the albatross of Torishima.] *Dobutsugaku Zasshi* **1**: 405-411. (In Japanese; original not seen.)
- HAWAII AUDUBON SOCIETY. 1956. Honolulu Christmas count. *Elepaio*, **16**: 38-41.
- HAWAII AUDUBON SOCIETY. 1957. Honolulu Christmas count. *Elepaio*, **17**: 55-57.
- HENSHAW, H. W. 1912. Our mid-Pacific bird reservation. *Year Book of Dept. of Agr. for 1911*, pp. 155-164.
- KENYON, K. W., and D. W. RICE. 1958. Birds of Kure Atoll, Hawaii. *Condor*, **60**: 188-190.
- KENYON, K. W., D. W. RICE, C. S. ROBBINS, and J. W. ALDRICH. 1958. Birds and aircraft on Midway Islands. November 1956-June 1957 investigations. U.S. Fish. Wildl. Serv. Spec. Sci. Rept.-Wildl., **38**: 51 pp.
- KURODA, N. 1954. Report on a trip to Marcus Island with notes on the birds. *Pac. Sci.*, **8**: 84-93.
- MOMIYAMA, T. 1930. [On the birds of the Bonin and Iwo Islands.] *In* Fauna of the Bonin Islands. Biographical Society of Japan, Tokyo. 226 pp. (In Japanese; original not seen.)
- MOYNIHAN, M. H. 1957. Notes on the sea-birds of Sand Island of the Johnston Island group. *Elepaio*, **18**: 35-37.
- MUNRO, G. C. 1941-43. Birds of Hawaii and adventures in bird study. *Elepaio*, **1-3**: 12 pts.
- NAMIYE, M. 1905. [Animals of Minami Torishima (birds).] *Dobutsugaku Zasshi* **17**: 219. (In Japanese; original not seen.)
- OKABE, M. 1930. [Information from the Bonin Islands.] *In* Data on birds and mammals. Ministry of Agriculture and Forestry, Tokyo, **6**: 264-273. (In Japanese; original not seen.)
- ONO, Y. 1955. Status of birds on Torishima; particularly of the Steller's Albatross. *Tori*, **14**: 25.

- PEALE, T. R. 1848. United States exploring expedition during the years 1838, 1839, 1840, 1841, 1842 under command of Charles Wilkes USN. Vol. III, Mammalia and Ornithology, Philadelphia, 338 pp.
- RICE, D. W. 1959. Birds and aircraft on Midway Islands 1957-1958 investigations. U.S. Dept. Interior, Fish and Wildl. Serv. Spec. Sci. Rept.-Wildl. 44, 49 pp.
- RICHARDSON, F. 1954. Notes on the birds of French Frigate Shoals. *Elepaio*, **14**: 73-75.
- RICHARDSON, F. 1957. The breeding cycles of Hawaiian sea birds. *Bernice P. Bishop Mus. Bull.*, **218**: 1-41.
- RICHARDSON, F., and H. I. FISHER. 1950. Birds of Moku Manu and Manana Islands off Oahu, Hawaii. *Auk*, **67**: 285-306.
- RICHDALE, L. E. 1950. The pre-egg stage in the albatross family. *Biol. Monographs* **3**: 1-92.
- RICHDALE, L. E. 1952. The post-egg period in albatrosses. *Biol. Monographs* **4**: 1-166.
- SEEBOHM, H. 1890. On the birds of the Bonin Islands. *Ibis*, **1890**: 95-108.
- SEEBOHM, H. 1891. On the birds of the Volcano Islands. *Ibis*, **1891**: 191.
- WETMORE, A. 1925. Bird life among lava rock and coral sand. *Nat. Geog. Mag., Wash.*, **48**: 77-108.
- YAMASHINA, Y. 1942. Birds of the Seven Islands of Izu. *Tori*, **11**: 191-270. (In Japanese; original not seen.)

U.S. Fish and Wildlife Service, Sand Point Naval Air Station, Bldg. 192, Seattle 15, Washington.