

SOME BIOMETRIC STUDIES ON THE ALBATROSSES OF MIDWAY ATOLL

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Few species of birds have been subjected to such intensive observation as have the Black-footed Albatross (*Diomedea nigripes*) and the Laysan Albatross (*D. immutabilis*) which come to Sand and Eastern islands at Midway Atoll to breed. The result has been the accumulation of a large body of information about their behavior. Yet little of this is quantitative, so that precise information about most phases of their life is lacking. While studying the acoustical behavior of these birds from October 25 until December 14, 1958, we were able, at the same time, to make some quantitative studies of populations and to obtain some biometric data. These do not represent a unified set of observations nor are they part of any overall plan, but they do supply some much needed basic information on the birds.

ARRIVAL OF ALBATROSSES AT MIDWAY ATOLL

The albatrosses come each year from their wanderings over the Pacific Ocean to Midway for breeding in late October and early November. They remain until the following July or August, and then they and their offspring leave. While this general pattern has been well documented and some quantitative data on incubation periods are available, few exact data exist concerning dates of arrival, egg laying, or departure. Bailey (1952, 1956), Hadden (1941) and Chisholm (1937) give some information on time of arrival of the birds, but mostly they refer to "first" arrivals, with only scattered references to population increase. None of the information is quantitative.

To study the course of arrival of the albatrosses at Midway, we censused the birds in selected areas on Sand Island from October 31 until December 8, 1958. Before October 31, there were only scattered sightings. By December 8, the populations had been stable for more than two weeks.

The first Black-footed Albatross was sighted on October 15 and the first Laysan Albatross on October 27. These dates should be reliable, for the men stationed on the island wager on the first sightings, and thus they keep a close watch. On October 26, a survey showed only about 10 Black-foots on the island as a whole, and on the next day there were about 100. They had increased, by October 31, to about 400. Only 10 to 15 Laysans were present at that time.

For censusing we selected six areas, totalling 472,000 square feet, near the beaches where the Black-foots were known to nest regularly, and 22 areas, totalling 672,000 square feet, where Laysans were known to nest. For the Laysans, some areas were chosen especially to give data on the effects of human disturbances, such as earth movements or construction, on the populations. There were eleven areas that had been undisturbed for at least two years, and eleven which had been subjected to disturbances within the previous year. Of the so-called undisturbed areas, only one was not near houses or other buildings. The word undisturbed, therefore, does not mean that these areas had not been altered by man. Probably every square inch of surface on Sand Island had been disturbed in the last ten years.

To study the effects of type of ground cover on populations, seven areas were selected so as to include sections with scattered ironwood trees (*Casuarina equisetifolia*) and adjacent sections with no trees. In the "undisturbed" areas, the ground was covered with grasses, both under the trees and in open parts. In the "disturbed" areas, the grass was just returning after the disturbances and was usually sparse and scattered.

All the birds on the ground in these areas were counted, generally every day at ap-

proximately the same time (4 to 6 p.m.). Kenyon *et al.* (1958) studied the daily cycles of activity and found that flying was especially prevalent in the mornings, thus reducing ground counts. Our casual observations supported this. In a few cases, in which counting was attempted earlier than usual in the day, the counts were lower than usual.

Table 1 presents the data on population build-up for the two species.

TABLE 1

POPULATIONS OF BLACK-FOOTED AND LAYSAN ALBATROSSES IN SELECTED AREAS ON SAND ISLAND¹

Date	Black-footed	Laysan	Date	Black-footed	Laysan
Oct. 31	26		Nov. 20	666	1385
Nov. 1	233	2	Nov. 21	673	1397
Nov. 2	278	3	Nov. 22	687	1316
Nov. 3	259	4	Nov. 23		
Nov. 4	251	6	Nov. 24	619	1317
Nov. 5	369	8	Nov. 25	705	1521
Nov. 6	357	14	Nov. 26		1518
Nov. 7	419	90	Nov. 27		
Nov. 8	539	139	Nov. 28	631	1560
Nov. 9	496	171	Nov. 29		
Nov. 10	*	190	Nov. 30	603	1551
Nov. 11	428	348	Dec. 1		
Nov. 12	600	597	Dec. 2	541	1525
Nov. 13	519	752	Dec. 3	*	
Nov. 14	566	779	Dec. 4		
Nov. 15	559	894	Dec. 5	424	
Nov. 16		991	Dec. 6		
Nov. 17	499	1044	Dec. 7		
Nov. 18	482	1109	Dec. 8		1548
Nov. 19	648	1133			

¹Total census areas: Laysan, 672,000 sq. ft.; Black-footed, 472,000 sq. ft.

* Unauthorized killing in census areas; there was also disturbance in the areas with Black-foots from November 15 to 16.

In the Black-foots, the population increased slowly for the first two weeks, October 15 to 31. Thereafter, the increase was rapid but irregular until about November 8, after which there was a slow increase. The population was stable by about November 19. Twice during the time of arrival about 200 Black-foots were killed without authorization in two of the census areas, as indicated in table 1, and further harassments occurred in the areas on November 15 and 16. Thus, the date for final stability found here may be somewhat later than it would have been under untroubled conditions. However, there is no doubt that about one month elapsed between arrival of the first bird and stabilization of the population. This is a considerably longer time than the reports of Hadden (1941) and Bailey (1952) would lead one to suspect.

For the Laysan Albatrosses, likewise, the population increased only slowly at first, from first arrival on October 27 until about November 7. After this, the increase was rapid but irregular for about two weeks, followed by a slow increase. The population was relatively stable by about November 25. These data, again, show a much longer time of arrival than Bailey's (1952) statements suggest, but they agree with Hadden's estimates fairly well.

Hadden (1941) states that male Laysan Albatrosses return first and implies that the females arrive about one to two weeks later. He does not indicate how he distin-

gushed the sexes, but it is possible that he did this by observations on behavior. Bailey (1952) recounts Hadden's information but incorrectly states that the dates are for Black-foots, thus making it seem that, in both species, the males return first.

We had the opportunity to study this by determining the sexes of the birds that were accidentally killed by collision with objects on the island or by automobiles on the roads. There was no evidence, when we knew that both sexes were present in about equal numbers, that accidental deaths were more frequent in one sex than in the other. These samples, therefore, probably gave a good estimate of the relative numbers of males and females present.

For the Black-foots, there was no evidence that males arrived significantly before females. At all stages, except possibly before October 31, when only a small part of the population was present, males and females were found in about equal numbers. On the contrary, for the Laysans there was a striking preponderance of males over females between November 1 and November 15. After that the proportion of females rose, and after about November 20 the sexes were found in approximately equal numbers. Thus, Hadden's statement for the Laysans is confirmed, but the extension of this to Black-foots seems to be incorrect.

The general picture of arrival of the albatrosses at Midway would thus seem to be as follows. The Black-foots arrive about 10 to 14 days before the Laysans. The first Black-foot appears from October 15 to 20, and the first Laysan from October 25 to November 1. For 7 to 10 days after the arrival of the first bird, very few appear. After this, for 10 to 14 days, a rapid but irregular increase occurs, after which the rate of increase diminishes. Stable populations are reached 5 to 10 days thereafter. The Black-foots seem to be fully settled by November 15 to 20, the Laysans by November 23 to 27. For the Laysans, males arrive before females; approximate equality of the sexes in the population is achieved when the population has become almost stable. For the Black-foots, however, both sexes seem to arrive in about equal numbers throughout.

HABITAT PREFERENCES

It is well known that the Black-foots prefer open sandy areas usually near the sea for their nests, whereas the Laysans prefer sheltered areas with some growing vegetation. Most of the plants on Sand and Eastern islands of Midway Atoll are introduced species, and their distribution is determined chiefly by man's activities. Accordingly grasses and ironwood trees are maintained best near houses and other buildings. The Laysan Albatrosses, therefore, tend to congregate for nesting in the housing areas on Sand Island and at places on both islands where man's activities have resulted in the presence of grass and thin stands of trees.

The disturbances to which the islands have been subjected have had profound effects on the local populations of Laysan Albatrosses. This can be seen in table 2, in which the populations of Laysans, at the time of stability, are given for areas with different types of ground cover and histories. The terms, disturbed and undisturbed, were defined previously. The preference for partly tree-covered, grassy areas is obvious. It is interesting to note that trees in recently disturbed areas greatly increase the carrying capacity of these areas. The area described in table 2 as "dense thicket and dunes," was probably as nearly wild as could be found on Sand Island. This was landward of the dunes in an area little disturbed or traversed by man. The dominant plant was *Scaevola frutescens*, a native shrub forming dense thickets between which there were small sandy areas with scattered grass. It is clear that such a situation does not support as dense a population as does a grassy area with scattered trees. Man's predilection for grass and shade trees on these islands seems to have very definitely favored the Laysan Albatross.

TABLE 2

NUMBERS OF LAYSAN ALBATROSSES IN VARIOUS TYPES OF HABITATS IN SELECTED AREAS ON SAND ISLAND, NOVEMBER 26 TO 30, AND AVERAGE AREAS IN SQUARE FEET OCCUPIED BY EACH BIRD

Habitat types ¹	Areas	Nos.	Sq. ft./bird
Undisturbed			
Open, grassy	71,000	315	225
Tree-covered, grassy	95,000	746	127
Disturbed			
Open, scattered grass	447,000	309	1450
Tree-covered, scattered grass	45,000	152	296
Dense thicket and dunes	14,000	45	311

¹ "Disturbed" and "Undisturbed" refer to disturbance by construction or earth movement by man within 2 to 3 years.

The maximum populations of the Laysan Albatross found at Midway Atoll occurred on Eastern Island in particularly favorable areas, such as near the old terminal building. Here recent human interference was minor, and grassy ground cover and scattered trees and bushes remaining from former use by man created apparently optimal conditions for nesting. To learn how many Laysans might be accommodated under these conditions, the nests and the distances from each nest to its neighbors were measured.

The mean diameter to the outer edge of the "moat" around the nest for 63 individuals was 39 ± 0.26 inches (99 ± 0.66 cm.). The range in size was from 34 to 44 inches (86 to 112 cm.). The mean distance from edge to edge of neighbor's nests, based on 190 measurements, was 26 ± 1.3 inches (66 ± 3.3 cm.). The range was 0 to 72 inches (0 to 183 cm.), the median 21 inches (53 cm.). These figures give about 24 square feet per nesting pair (2.23 m.²) for the Laysans. The most densely populated area studied on Sand Island was that across from the Station Hospital, and here the area per bird was 70 square feet. Considering that trees and other objects made nesting impossible on about one-third of this area, one can consider it to be nearing the saturation point.

It is obvious from the data on populations in areas disturbed by man's activities that statements that the albatrosses at Midway are resisting man's encroachment are not true. As we have shown (Frings and Frings, 1959b), the populations of both Black-foots and Laysans on Sand Island are falling under man's harassment. The campaign under way to denude and level the dunes, while of questionable value in deterring flight over the runways, is certainly going to force many birds off the island. For the maintenance of the populations of these species at levels sufficient to forestall any danger of depletion, it would seem that improvements on Laysan and Lisianski islands to bring their carrying capacity nearer to the optimum than it is now are justified and indeed advisable. The present populations of these islands (Kenyon *et al.*, 1958; Rice, 1959) are far short of those that could be supported under even sub-optimal conditions (Frings and Frings, 1959b).

WEIGHTS OF ALBATROSSES

There are in the literature only scattered and non-quantitative references to the weights of these birds. To obtain information on this point, individuals that were killed accidentally on Sand Island were collected daily and were weighed and dissected for study of fat reserves and reproductive cycles. The data on weights are presented, in part, in table 3.

From November 12 to 16, most of the females still had eggs in the oviducts; from November 26 to December 3, most had laid eggs. The data presented thus allow comparison of the weights before and after egg laying. It is interesting to note that although

TABLE 3
WEIGHTS IN KILOGRAMS OF BLACK-FOOTED AND LAYSAN ALBATROSSES AT TWO TIMES
DURING NESTING AND EGG LAYING

	N	November 12 to 16 Range	Mean $\pm \sigma_m$	N	November 26 to December 3 Range	Mean $\pm \sigma_m$
Black-footed						
♂ ♂	123	2.6-4.3	3.40 \pm 0.032	45	2.3-3.6	3.12 \pm 0.036
♀ ♀	104	2.6-3.6	2.99 \pm 0.027	34	2.2-3.3	2.76 \pm 0.059
Laysan						
♂ ♂	152	2.7-4.1	3.31 \pm 0.023	81	2.4-3.9	3.08 \pm 0.032
♀ ♀	54	2.5-3.6	2.99 \pm 0.036	80	1.9-3.3	2.76 \pm 0.036

the males in each species are significantly heavier than the females, the differences between the weights of the same sexes of the two species are not significant. Earlier workers often implied, without quantitative data, that Black-foots are heavier than Laysans, and we found (Frings and Frings, 1959a) this to be the case for a few individuals which were sent to us in Pennsylvania in April, 1958.

All the birds, up to the time of our leaving Midway had extensive deposits of fat. It is possible that the weight of this excess fat, which was being consumed as incubation progressed, masked any difference in weight between the two species. At any rate, from the time of arrival until mid-December, the two species had similar weights; in both species, the males were about 0.4 kg. heavier than the females.

DETERMINING THE SEXES OF THE ALBATROSSES

The sexes in these species are almost identical externally. Actually, except for fortunate observations during critical behavior periods, it is almost impossible to distinguish the sexes of living individuals with certainty. Hadden (1941) implied that he could distinguish between the sexes, but he gave no hint as to how he did this.

In general, as shown in table 3, the males are heavier than the females, and Loomis (1918) found, for Black-foots, that males are larger, as determined by length, depth, and width of bill and length of tail, wing and tarsus. These, however, were not suggested as means for distinguishing sexes in the field.

Starting with a suggestion that the heads of males looked "flatter" ("as if with a 'crew-cut'") than those of females, we used the dead albatrosses, which could be sexed by dissection, to measure the width, depth and length of the head and the length and depth of the beak. All of these showed a sex difference, the males being larger. However, measuring the length and depth of the head and the depth of the bill proved to be difficult to do consistently, and the measurements of males and females overlapped considerably. We shall, therefore, omit consideration of these here. Measurements of head width and bill length afforded the required tool for sexing, and the data on these will be presented.

The head width was measured, using dividers and ruler, on the dorsal side at the widest point, just behind the eyes. At this point on each side, the skull has a blunt angle which is easily palpated. We found it best to have one person make all the measurements, for the skin can be variably compressed by different persons. The length of the bill was measured from the angle of the mouth to the tip. Again, variations in pressing back the feathers at the base resulted in some variation in measurements among different persons, and so only one person performed all the measurements. The absolute values

TABLE 4
HEAD WIDTHS OF BLACK-FOOTED AND LAYSAN ALBATROSSES AND THE RATIOS OF
MALES TO FEMALES WITH HEAD WIDTHS THE SAME

Head width (mm.)	Black-footed			Laysan		
	♂ ♂	♀ ♀	Ratio ♂ / ♀	♂ ♂	♀ ♀	Ratio ♂ / ♀
53					1	
54		1			6	
55		5			22	
56		10		3	32	1/11
57		18		8	32	1/4
58	2	28	1/14	30	12	2.5/1
59	7	23	1/3	33	4	8/1
60	13	7	2/1	28	3	9/1
61	18	1	18/1	21		
62	24			2		
63	12			3		
64	2			1		
65	1					
Totals	79	93		129	112	
Means	61.3	57.8		59.3	56.4	
σ_m	0.16	0.15		0.13	0.13	
*d/SE _d		15			16	

* d/SE_d = difference between means of males and females divided by the standard errors of the differences.

in tables 4 and 5, therefore, should not be used directly by anyone else. It is necessary, if the differences between males and females are to be determined accurately, to develop one's own standard procedures. When this is done, these measurements allow one to determine the sexes of living Black-footed and Laysan albatrosses with a high degree of certainty. The sex differences for each species in these measurements are obvious: the males are consistently larger. Black-foots have significantly wider heads than the corresponding sexes of Laysans; Laysans have longer beaks.

Using these data, one can construct tables of measurements for determining sexes of the birds. Thus, for Black-foots, all individuals with head widths of 57 mm. or less are females, and all with head widths of 62 mm. or over are males. On these bases, 42 per cent of the birds can be assigned to the correct sex with certainty. Between 58 and 61 mm., one can set up probabilities, as indicated in table 4. At 58 mm., the chances are 14:1 that the individual is a female, and at 61 mm., 18:1 a male. These figures may be considered as indicating a high degree of probability, and thus give another 29 per cent at high probability, a total of 70 per cent of the population. For the Laysans, 23 per cent can be sexed with certainty from head widths and a total of 69 per cent can be sexed with probabilities of 8:1 or better. Correspondingly, for bill length in Black-foots, 52 per cent have lengths of 93 mm. or less and are thus females, and those with lengths of 100 mm. or more are thus males; another 18 per cent have measurements of 94 to 95 mm. and are thus indicated to be females at probabilities of 11:1 or better. Similarly for Laysans, one can determine 40 per cent certainly and a total of 75 per cent at odds of 25:1 or better.

The level of correlation between head width and bill length in individuals is sur-

TABLE 5
BILL LENGTHS OF BLACK-FOOTED AND LAYSAN ALBATROSSES AND RATIOS OF
MALES TO FEMALES WITH BILL LENGTHS THE SAME

Bill length (mm.)	Black-footed			Laysan		
	♂ ♂	♀ ♀	Ratio ♂/♀	♂ ♂	♀ ♀	Ratio ♂/♀
86-87		2				
88-89		6				
90-91		14				
92-93		26			1	
94-95	3	33	1/11		6	
96-97	11	23	1/2		7	
98-99	21	6	3.5/1		22	
100-101	21				23	
102-103	22			2	49	1/25
104-105	10			20	22	1/1
106-107	3			36	6	6/1
108-109				51	1	51/1
110-111				33		
112-113				23		
114-115				5		
116-117				2		
Totals	91	110		172	137	
Means	100.5	93.7		108.7	101.4	
σ_m	0.28	0.25		0.21	0.25	
d/SE _d	18			22		

prisingly low. For male Black-foots the correlation coefficient (r) is +0.14, and for females it is +0.21. For male Laysans it is -0.06, and for females it is +0.11. These two measurements should be useful almost independently, therefore, and so they proved to be. The following summary of determinations of sexes for 160 Black-foots and 240 Laysans confirms this point.

	Black-footed	Laysan
Sex certain (one of two measurements in certain range)	87 per cent	70 per cent
Sex determined with combined probability of 15:1 or better	9	17
Sex indeterminate, or with probability of 5:1 or less	4	13

When we had completed measuring about half of those ultimately measured, we constructed the tables and thereafter tested the data by predicting sexes from the measurements before dissection. We were able to be essentially certain of the sexes in about 90 per cent of these tests. In most cases of even small probability, the sex was correctly predicted from the measurements. In no case was the sex indicated to be certainly male or female by one measurement and the reverse by the other.

When we were able to determine sex in this way, we tried estimating sex from the general appearance of the heads: males with flatter appearing heads than females. When two individuals could be seen together, this was not difficult to do correctly. With just one bird, however, it was much more difficult and subject to error. There were some individuals which were so obviously male or female, on the basis of head shape, that they were easy to determine, but many others were not so clear-cut. In general, one could use this sight method for a preliminary estimate of sex, and if this could be sup-

ported by some behavioral observations it might prove valid enough, but it would be best to check by measuring.

SEXES OF DANCING ALBATROSSES

The dancing (ecstatic ritual) of these birds has excited considerable interest, but the interpretation of this behavior is still obscure. While presumably a courtship performance, it is not usual in the colony before egg laying. Earlier workers seem to have tacitly assumed that the dancing individuals—usually two, but by no means always so—were of opposite sex. Unfortunately, these workers gave no reasons for their belief, nor did they indicate how they determined the sexes.

Using head widths and bill lengths, we were able to study this. It was easy to capture both members of a dancing pair. They were measured and released, and then the measurements were compared with the tables previously discussed. The results follow:

	Black-footed	Laysan
Sex of one member, at least, indeterminate	2	16
Dancers certainly of opposite sex	4	55 (66 per cent)
Dancers probably of opposite sex (one member certain; other of high probability)		18 (21 per cent)
Both dancers females		8 (9 per cent)
Both dancers males		3 (4 per cent)

Too few Black-foots were measured to draw any conclusions. It is obvious from the data on the Laysans that most of the dancing pairs, by far, consist of a male and female. However, pairs can be found consisting of members of the same sex. We shall not speculate on the significance of these data in understanding the dancing behavior. Dancing, however, seems to be predominantly a heterosexual performance.

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SUMMARY

The build-up of populations of the Black-footed Albatross (*Diomedea nigripes*) and Laysan Albatross (*D. immutabilis*) during their annual arrival at Midway Atoll for breeding was followed by daily censuses in selected areas. About one month passed from the date of first arrival in each species until the population was stable: Black-foots from October 15 until about November 19; Laysans from October 27 until about November 25. Black-foots prefer open, sandy beaches for nesting; Laysans prefer areas with grasses and scattered trees. Thus the Laysans seem to be favored by man's presence at Midway. Disturbances by man that resulted in reducing ground cover reduced the population of Laysans. During the period of arrival and egg laying, the weights of the two species were essentially the same. Males in each species were about 0.4 kg. heavier than females. By measuring head widths and bill lengths of individuals whose sex was determined by dissection, it was found that males were significantly larger than females in these two dimensions. These measurements could be used to determine the sex of living birds in about 90 per cent of the cases. Using this method for sexing, it was found that individuals performing the albatross dance as a pair were, in 85 per cent of the cases, of opposite sex.

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