SUMMER ECOLOGY OF OCEANIC BIRDS OFF SOUTHERN NEW ENGLAND

BY MALCOLM S. GORDON

BETWEEN June 13 and August 27, 1953, I spent a total of twenty-six days at sea off southern New England on the research vessel *Blue Dolphin*. Some notes on the distribution and ecology of the oceanic birds observed during this period are presented here. Indications of quantitative correlations between hydrographic conditions, food supply, as plankton populations, and bird abundance were found.

More than 95 per cent of the bird observations used in this paper were made by the author. The remainder were made by Dr. Richard H. Backus, of the Woods Hole Oceanographic Institution, and by various members of the ship's company, to whom sincere appreciation is here expressed.

Thanks are also due to David C. Nutt, master of the *Blue Dolphin*, Drs. John C. Ayers, LaMont C. Cole, J. Brackett Hersey, Robert C. Murphy, and Charles G. Sibley, and Messrs. John T. Nichols and Charles F. Powers, all of whom have aided in various ways.

This paper is Contribution Number 742 from the Woods Hole Oceanographic Institution and is part of a thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts with Honors in Zoology at Cornell University.

Observations.—The ship worked fairly intensively in two areas, an inshore area hereafter called Area I and an offshore area called Area III. The intervening sea is called Area II. These areas, shown in figure 1, are covered by U. S. Coast and Geodetic Survey Chart No. 1108.

The three areas were visited as follows, an observer being on deck at least 90 per cent of the daylight periods. The numbers in parentheses are the column numbers in table 1 which include observations made on the dates indicated.

Area I: traversed June 13 (1); all day July 11 and 12(2); traversed July 28(3); all day August 4(4); all day August 6(5); late afternoon August 11(6); morning August 12(6); and all day August 13(6).

Area II: parts B and C traversed July 16(1); B and C traversed July 18(2); A, B, and C traversed July 28(3); C traversed July 30(4); C traversed August 7(5); and A and B traversed August 27(6).

Area III: area less than ten miles to the eastward traversed June 29(1); all day July 16 and 17(2); morning and early afternoon July 18(2); all day July 29(3); morning and early afternoon July 30(3); morning and early afternoon August 7(4); and all day each day August 18 through 26(5).

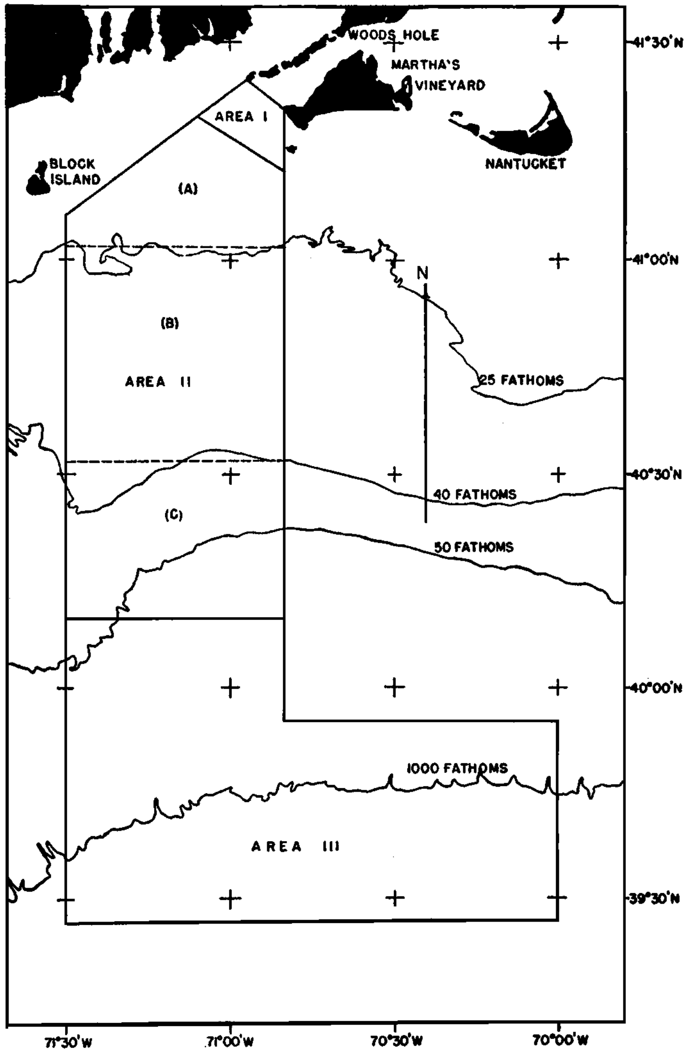

Figure 1. Bird Observation Areas.

The major weather disturbances during the period June 13 to August 27 were as follows: strong lows passed June 14–15 and 18–19; squall line July 3; lows passed July 12–13, 15, 21–22, 23–24, and August 3, 5, and 9; hurricane "Barbara" August 15; and a low on August 19.

Comparisons with Fuglister (1947) show that the sea-surface temperatures throughout the area were normal for the season. The temperature of the surface water in Area III rose from approximately 70° F. to 76° F. between June 29 and August 26.

The bird species observed were as follows: Sooty Shearwater (*Puffinus griseus*), Audubon's? Shearwater (*Puffinus ?lherminieri*), Greater Shearwater (*Puffinus gravis*), Cory's Shearwater (*Puffinus diomedea*), Leach's Petrel (*Oceanodroma leucorhoa*), Wilson's Petrel (*Oceanites oceanicus*), Frigate Petrel (*Pelagodroma marina hypoleuca*), Gannet (*Moris bassana*), and Pomarine Jaeger (*Stercorarius pomarinus*).

The identity of the small black and white shearwaters seen during the summer is uncertain. An examination of numbers of skins of Audubon's, Manx (*P. puffinus*), and Allied (*P. assimilis*) shearwaters (the subspecies which might be expected on the basis of distribution) in the American Museum of Natural History indicates that the color of the under tail coverts is not a reliable character for distinguishing these species from one another (see Peterson, 1947: 246). The color of the feet was not distinguishable on any bird seen during the present study. The color of the under tail coverts was observed on three birds; on two, the coverts were white, on the third, black. Thus, no definite statement may be made about the identity of all such shearwaters seen. It should be noted, though, that all these birds seen flew with very rapid wing beats and that, where such comparisons were possible, they appeared much smaller than Cory's Shearwaters. Dr. R. C. Murphy, in conversation, has likened the size relation between the Cory's and Audubon's shearwaters to that between a Rock Dove and a Robin, while that between the Cory's and Manx is similar to that between a Robin and a Catbird. Since the Allied Shearwater is only accidental in this area, I think the present birds were probably Audubon's Shearwaters.

The observations made are shown in Table 1.

For Area I: the shearwaters under column 6 were east of Area I proper—approximately over the twenty-fathom curve south of eastern Martha's Vineyard. The Audubon's Shearwater in column 5 was about four miles southwest of Gay Head.

For Area II: the letters following the numbers signify the subdivisions of the Area in which the birds were seen. (B, C) means that the birds were about equally numerous in B and C; (B-C) means that the birds were seen in northern C and southern B. The figures in column 2 are for one half the birds seen on July 18, either in III or IIC (but no distinction made in my notes).

For Area III: the column 2 figures include one half the birds seen on July 18 (see above).

The bird observations indicate the following pattern: oceanic birds were generally scarce in Area I; Wilson's Petrel, while not common,

TABLE 1

SUMMARY OF OBSERVATIONS ON BIRDS

Species	*Area*	*1*	*2*	*3*	*4*	*5*	*6*
Sooty	I	0	0	0	0	1–2	0
Shearwater	II	0	1(C)	0	0	0	0
	III	0	3–4	0	0	0	–
Audubon's	I	0	0	0	0	1	0
Shearwater	III	0	0	0	0	15	–
Greater	I	0	0	0	0	2–3	1
Shearwater	II	0	20–25(C)	3–4(B-C)	0	0	0
	III	20–25	60–70	2–3	0	5	–
Cory's	I	0	0	0	0	1–2	2
Shearwater	II	0	40–50(C)	4–5(B-C)	0	0	3(A)
	III	0	75–100	4–6	0	6	–
Leach's Petrel	III	0	2 prob.	0	0	4–5	–
Wilson's	I	0	5–7	0	0	2–3	3–4
Petrel	II	100–150 (B,C)	30–40(C)	3-4(B-C)	0	20–30(C)	10–15(B)
	III	abt. 100	300–380	40–50	0	1000–1400	–
Frigate Petrel	III	0	0	0	0	1[1]	–
Gannet	I	0	0	0	0	1	1
Pomarine	I	3	0	0	0	0	2
Jaeger	II	0	1	0	0	0	2
	III	1	1	0	0	2	–

[1] Collected August 18 at 39° 48′ N., 71° 02′ W. See Gordon (1955) for details.

being the most abundant. Areas IIA and B were rather barren, although occasionally Wilson's Petrels were moderately common in B. Area IIC occasionally had numbers of birds present in it but in general was quite barren, except for Wilson's Petrels. Area III usually had a fairly large population of birds. Wilson's Petrels were continuously common and became abundant in late August; Greater Shearwaters were the most abundant of the shearwaters in late June but lost this numerical dominance to Cory's Shearwater in the latter part of July. All of the larger shearwaters became quite scarce in late July and August, while Audubon's Shearwater became the most numerous form in late August. Jaegers were scarce, the only species seen in any of the areas being the Pomarine.

In Area III, the late July decrease in numbers of Greater Shearwaters and the mid-July increase of Cory's Shearwaters were probably due to a completion of the northward migration and to completion of nesting activities and start of post-breeding season wandering, respectively. Similar conclusions were reached by Wynne-Edwards (1935).

The late July and August scarcity of all species of the larger shearwaters is not explained. There was no significant change in the surface temperature of the water covering the area during the summer. It seems unlikely that the small change observed could have been the cause of the great change in population makeup. It is also unlikely that hurricane "Barbara" caused the change, for it apparently began at least three weeks before the hurricane.

The marked increase in Wilson's Petrels and the appearance of many Audubon's Shearwaters in late August seem at least partially explicable by observation. Sargassum weed had earlier been virtually absent from the area. In late August, however, as usual in this region, it became very abundant, carrying with it its usual large community of small animals (shrimp, crabs, fishes, isopods, etc.). The food habits of Audubon's Shearwater and of Wilson's Petrel (Murphy, 1936, and Bent, 1922) make it appear likely that this influx of sargassum was the direct cause of both phenomena. This increase, however, further obscures the cause of the scarcity of the larger shearwaters (especially Cory's), for the food habits of these birds, as described by Bent (1922), are such that one would expect an increase in sargassum to attract them.

A consideration of the variations in abundance and distribution of birds follows. This is made on the basis of two major assumptions:

1. No birds were seen twice. This assumption is considered reasonable due to the wide-ranging habits of the birds involved. Though watched carefully, no shearwaters were ever observed to follow the ship. Wilson's Petrels followed the vessel for varying lengths of time, but never for as long as an entire day. The numbers of petrels recorded daily contain an estimated correction for this duplication.

2. The total number of birds seen in each area is proportional to the total population of birds present in that area at the time. No other assumption in this regard seems justified.

Table 2 summarizes the total bird numbers observed in the various areas during the summer. Column 4 of this table was calculated as follows: Column 2 (observed number) is the sum of all the numbers of shearwaters and petrels observed in each area (see Table 1), using the mid-point of the range when a range of numbers was recorded. Column 4 gives estimates of the numbers of birds that would have been seen in Areas I and III if six days only had been spent in these areas. These numbers were calculated by multiplying the Area I number by 6/7, and taking a random sample of six days from the time spent in Area III (numbering the days from 1–16, the days used were

1, 4, 7, 10, 13, 16—substantially the same results were obtained using other random samples of six days). Differences between the records for the three areas resulting from differing lengths of observing time are thus at least partially compensated for; I believe the "observing effort per unit time" was the same in all areas. The time-corrected numbers bear to one another the relation 1:18:45; the ratio between Areas II and III is 2:2.6.

TABLE 2

NUMBERS OF OCEANIC BIRDS

Area	*Observed number*	*Observing time (day)*	*6-day time-corrected number*
I	19	7	16
II	280	6	280
III	1910	16	717

"Land shyness" of the oceanic birds may have been responsible for the paucity of birds in Area I (the other areas are completely out of sight of land). It is therefore omitted from further consideration.

The time equalization in Table 2 also roughly equalizes the sea-surface areas observed in each Area. As a first order approximation, the *Blue Dolphin* may be considered to have steamed at a constant speed throughout each of the twelve days involved in Areas II and III. Since, on the basis of the vessel's tracks, about the same amount of overlap of observed areas appears to have occurred in each area, approximately equal areas of sea-surface were observed. The 1: 2.6 ratio between Areas II and III thus appears to be the best estimate of the "true" ratio available.

It should be pointed out that approximately one-third of IIC is covered by water of greater than fifty fathoms depth, hence rightfully belongs in the Slope Water area (Area III—see Miller, 1950). The above treatment of the data and the roughness of the known time-distribution of the records do not allow any reasonably simple correction of the bird ratio for this effect. Suffice it to say that the ratio would be somewhat increased by any such correction.

Why such a distribution exists now becomes a question. The uniformity of the birds' immediate aerial environment makes it seem likely that something in the sea is responsible, probably food supply.

The dependence of sea-birds on planktonic food or plankton-dependent food has previously been pointed out by Jesperson (1924, and other papers). Wynne-Edwards (1935) considers Jesperson to have shown clearly that food supply is "the chief controlling factor in regulating local abundance of plankton-feeding birds." Off southern California, Miller (1936, 1940) has shown qualitatively a correlation between oceanic bird abundance and the edge of the Continental Shelf similar to that shown here. He considered it likely that plankton population sizes were significant in this. Redfield (1941) has also demonstrated an apparent direct qualitative correlation between plankton abundance and oceanic bird abundance (primarily for Wilson's Petrel) during the summer in the Gulf of Maine.

An analysis of plankton population figures for the areas studied here has been made. Two hypotheses, possibly alternatives, possibly supplementary to one another, have been developed. On the basis of present knowledge no indication of preference for one or the other seems justified.

First hypothesis: Hydrographic conditions in the water masses covering Areas II and III (the Continental Shelf and Continental Slope waters, respectively) are such that it would seem likely that Area III can maintain a larger total plankton population than Area II (Iselin, 1936; Miller, 1950; Riley *et al.*, 1949; Sverdrup *et al.*, 1942). Data showing that this actually is the case, in the summertime, are presented by Riley and Gorgy (1948).

Phytoplankton population figures (see table on p. 121 of Riley and Gorgy) are indicative of this but, unfortunately, are inconclusive. Figures for total zooplankton, based on observations made in the areas here being discussed, are as follows: From surface to near bottom on the Shelf, and for the upper 800 meters in the Slope area, "the averages for total zooplankton were of the order of 30 gm. wet weight per square meter of sea surface in the coastal zone . . . and upwards of 80 gm. in the slope water area" (Riley and Gorgy, p. 116). From these figures the zooplankton population ratio of coastal (Shelf) to Slope water is 1:2.7.

These figures become pertinent to the present hypothesis when the occurrence of "deep scattering layers" is noted in Area III (see Hersey, Johnson, and Davis, 1952, and various of the papers referred to in their bibliography). An at least partially similarly behaving phenomenon was observed fairly consistently in Area II in the course of the present work. In Area III during the months of July and August the fauna of the deep layers appears to be primarily copepods, amphipods, euphausian shrimps, and fishes (mostly small lanternfishes of the family Myctophidae).

Data on the food habits of the birds under consideration here (Murphy, 1936, and Bent, 1922) indicate that the shearwaters feed primarily on fish, squid, crustacea, and almost any reasonably edible oily substance. Both Wilson's and Leach's petrels feed primarily on crustacea—especially euphausians for Wilson's—small fish, and oily substances. Thus the birds eat exactly what occurs in the scattering layers.

However, the scattering layers are at the surface at night only. Do the birds feed at this time?

No reference to this problem has been found in any of the papers on oceanic birds consulted. However, from the fact that most of these birds are very active during the night while on their breeding grounds (Bent, 1922), also from my own observations of large amounts of nocturnal activity among Leach's Petrels at sea, it does seem reasonable to suppose that at least some feeding goes on in the dark.

There are usually casualties of the previous night's activities floating on the sea-surface (at least in Area III) in the morning, however. Many times during the course of the summer I observed dead squid (deep water forms possessing photophores) floating about. It may be that the birds do not feed at night but merely clean up the battleground after the war has retreated.

In addition, fairly extensive schools of small silvery fish were observed on several occasions during the daytime swimming near the surface in Area III. Schools of Round Herring (*Etrumeus teres*) were similarly observed in Area IIA. All these fishes are probably fed upon by the birds. The fishes in Area III were probably, the Round Herring almost definitely, feeding upon plankton.

Clarke (1940) supplies further evidence regarding this hypothesis, at first glance contradictory.

Clarke states that the Shelf water appears to support more plankton than the Slope water. This, however, is based upon a consideration of tows made throughout the year. When Clarke's summer data (between May 28 and September 3) alone are considered, essentially the same conclusion is reached as was reached by Riley and Gorgy (1948). Clarke's station 4 (apparently right over, or very near, the 100-fathom curve) is within the Slope area as defined in this paper; further, his Slope area tows went down to only 275 meters, hence only his night tows in this area sampled the entire significant population. Comparisons between summer night tows in the two areas give an average total plankton population ratio of 1:2.4.

Fairly strong evidence thus exists for a reasonably close quantitative correlation between bird population size and total plankton population size. A weakness exists in the above argument, however, which allows a somewhat different interpretation also to be made.

Second hypothesis: As was pointed out above, the large numbers of Wilson's Petrels observed in Area III in late August (which make up the greatest part of the birds observed in Area III) may well have been feeding upon the animals carried by the surface-drifting sargassum weed. These animals are certainly not considered in any of the plankton figures presented by either Clarke or Riley and Gorgy. One might, therefore, easily say that the correlation indicated above is merely fortuitous and, while interesting, has little significance. No way of correcting the present data for this effect is available. It might be pointed out, though, that Clarke (1940) gives figures for total plankton population in the upper twenty-five meters, for daytime hauls during the summer, that give an Area II: Area III ratio of 1:0.28.

It thus seems apparent to me that the critical observations regarding the relations of oceanic birds to their watery substratum are still to be made. Analyses of the stomach contents of petrels and shearwaters taken very shortly after sunrise and also at a variety of times of day in areas having abundant sargassum weed are needed before any reasonable approach to the difficulties mentioned may be made. That there is a correlation between food supply and bird abundance, however, seems quite clearly demonstrated.

Summary.—Observations of oceanic bird occurrence and distribution were made during the course of twenty-six days at sea off southern New England between June 13 and August 27, 1953. The areas covered and the observations made are described, and weather and sea-surface temperature data are presented.

Off southern New England in summer, oceanic birds appear to be more numerous, by a factor of 2.6, over Continental Slope water than they are over Continental Shelf water. The major mixing processes occurring in these water masses appear to supply more nutrients to the plankton of the Slope water than to that of the Shelf water. The ratio of total zooplankton populations of the Shelf water to those of the Slope water is 1:2.7. A consideration of "deep scattering layer" behavior and known feeding habits of the birds makes this appear to be something more than just an interesting parallel. However, deficiencies in our present knowledge, combined with complication of the food supply picture owing to the appearance of sargassum weed in the study area, do not allow definite conclusions to be reached. In any case, the general correlation between seabird abundance and food supply, first pointed out by Jesperson, seems strongly supported.

Temporal variations in species abundance of various of the birds

are also considered. Possible reasons for these variations are discussed. The field identification of the western North Atlantic species of small black and white shearwaters is considered, with the conclusion that sight indentifications are not trustworthy.

LITERATURE CITED

BENT, A. C. 1922. Life histories of North American petrels and pelicans and their allies. Bull. U. S. Nat. Mus. No. 121, 343 pp.

CLARKE, G. L. 1940. Comparative richness of zooplankton in coastal and offshore areas of the Atlantic. Biol. Bull. **78**: 226–55.

FUGLISTER, F. C. 1947. Average monthly sea surface temperatures of the western North Atlantic Ocean. Pap. Phys. Ocean. and Meteor. **10**(2): 1–25.

GORDON, M. S. 1955. A western North Atlantic record for the Frigate Petrel (*Pelagodroma marina hypoleuca*). Auk, **72**: 81–82.

HERSEY, J. B., H. R. JOHNSON, and L. C. DAVIS. 1952. Recent findings about the deep scattering layer. Jour. Mar. Res. **11**(1): 1–9.

ISELIN, C. O'D. 1936. A study of the circulation of the western North Atlantic. Pap. Phys. Ocean. and Meteor. **4**(4): 101 pp.

JESPERSON, P. 1924. The frequency of birds over the high Atlantic Ocean. Nature **114**: 281–3.

MILLER, A. R. 1950. A study of mixing processes over the edge of the continental shelf. Jour. Mar. Res. **9**(2): 145–60.

MILLER, L. 1936. Some maritime birds observed off San Diego, California. Condor **38**: 9–16.

MILLER, L. 1940. Observations on the Black-footed Albatross. Condor **42**: 229–38.

MURPHY, R. C. 1936. Oceanic birds of South America. Macmillan Co., N. Y. 2 vols., 1245 pp.

PETERSON, R. T. 1947. A field guide to the birds (2nd ed., revised). Houghton Mifflin Co., Boston, 290 pp. illus.

REDFIELD, A. C. 1941. The effect of the circulation of water on the distribution of the calanoid community in the Gulf of Maine. Biol. Bull. **80**: 86–110.

RILEY, G. A., and S. GORGY. 1948. Quantitative studies of summer plankton populations of the western North Atlantic. Jour. Mar. Res. **7**(2): 100–21.

RILEY, G. A., H. STOMMEL, and D. F. BUMPUS. 1949. Quantitative ecology of the plankton of the western North Atlantic. Bull. Bingham Ocean. Coll. **12**(3): 169 pp.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1942. The Oceans. Prentice-Hall Inc., N. Y., 1087 pp.

WYNNE-EDWARDS, V. C. 1935. On the habits and distribution of birds on the North Atlantic. Proc. Boston Soc. Nat. Hist. **40**(4): 233–346, pls. 3–5.

Department of Zoology, Yale University, New Haven, Connecticut,
February 2, 1955. (First submitted March 26, 1954.)