The Use of Food Samples from Sea Birds in the Study of Seasonal Variation in the Surface Fauna of Tropical Oceanic Areas

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ABSTRACT: Many parts of the tropical oceans appear to be relatively seasonless, but, because of the difficulty of sampling mobile and patchily distributed animals and the cost of oceanographic investigations, few data are available on the extent of seasonal changes. By regularly collecting regurgitations from sea birds, and identifying and measuring the food items, seasonal data could be obtained on the availability, size classes, and perhaps reproductive cycles of the fish and squid characteristic of the surface layer of tropical seas. Flying fish (Exocoetidae), juvenile tunas (Scombridae), and squid of the family Ommastrephidae are especially easily obtainable.

Experience gained during a recent study of the comparative feeding ecology of sea birds on Christmas Island (Pacific Ocean) makes it possible to assess the characteristics of bird species which affect their suitability for such study. Potentially useful species include terns (especially *Sterna fuscata, Anous stolidus, A. tenuirostris,* and *Gygis alba*) and boobies (especially *Sula sula*). Samples could be obtained from several bird species in the same period, and a program could include sampling of inshore waters with the neuston net and making basic oceanographic observations. Investigations of this kind could be carried out economically on any of a large number of tropical oceanic islands.

IN ASSESSING the results of a study of the feeding ecology of some sea birds of Christmas Island, in the central equatorial Pacific, we attempted to make use of published information concerning seasonal variations in the fauna of the surface layer of the sea in this region. It soon became evident, however, that this type of information is very sparse, and that those workers who have made seasonal comparisons have often had to depend on data collected in different areas, in different years, or by different methods (see, for instance, King and Demond, 1953; King and Hida, 1957; King and Iversen, 1962).

The absence of information on seasonal variation in many tropical oceanic areas results mainly from the expense of running oceanographic ships, and the conflicting demands on their time, which generally prevent adequate sampling in a single area over a period as long as a year. Only in a few areas where there are important commercial fisheries are good seasonal data available. Even in these areas, however, there are generally few data on changes in the abundance of the forage animals which form the food of most sea birds and of many fish used for human food. This is because nets used for routine plankton sampling do not catch many nekton animals, and even modern nets like Isaacs-Kidd trawls catch few fast-swimming animals near the surface (King and Iversen, 1962; Pearcy, 1965).

It would be of considerable interest to obtain more information on the extent to which seasonal fluctuations in physical and biological characteristics actually occur in those parts of the tropical oceans which appear to be more or less constant throughout the year. For instance, ornithologists working on tropical islands in several different areas have found that among the sea birds breeding on a single island (or group) some species have evolved regimes under which individuals breed at intervals of less than a year, suggesting that seasonal variation in the environment is not of great importance to them.

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But on the same islands other species have annual breeding regimes, indicating that for them seasonal influences are sufficiently strong to outweigh the selective advantages of breeding at shorter intervals (Ascension Island: papers in Ibis 103b, 1962–63; Christmas Island: Gallagher, 1960; Ashmole, 1965; Ashmole and Ashmole, 1967; Ashmole, in press; Galapagos Islands: Lévêque, 1964; Snow, 1965). Some advances are now being made in understanding the differences in feeding ecology which lead to dependence of different birds on different groups of prey species, but lack of knowledge of the importance of seasonal effects in populations of the various prey species prevents further progress. The reproductive cycles of oceanic fish and cephalopods in relatively seasonless areas are even less well understood, but are of both theoretical and practical importance.

The purpose of the present paper is to show that a very economical investigation of seasonal (and year-to-year) variation in the surface fauna of a tropical oceanic area could be carried out by making use of the sampling of the oceanic environment which is done by sea birds, and at the same time by collecting certain other data.

The method which we propose depends on the fact that tropical sea birds of many species are easy to catch and, when caught, will often regurgitate the whole or part of their latest meal. Regurgitations provide, on average, far more items in good condition than do stomachs of shot or netted birds and their collection does not appreciably affect the bird population. Regurgitations are stored in formalin and the individual food items identified and measured at leisure. Since the feeding methods of each species are reasonably constant, regular sampling on an adequate scale would permit detection of changes in the relative availability of different prey species. Furthermore, each of the bird species takes prey covering a considerable range in size, so that the data should reflect changes in the size-frequency distributions of the various prey species. Deductions could doubtless also be made about the timing of reproduction in some of the fish and squid species. The method could be used on almost any tropical island on which appropriate species of sea birds are available for a large part of the year, but the decision as to which bird species should be used for sampling depends on considerable knowledge of the ecology of the available species.

In the course of our study of the food of sea birds on Christmas Island during the period March 1963 to June 1964, we examined 800 samples (mainly regurgitations) from eight species of sea birds. We were mainly concerned with comparing the food of different species, and we did not have the opportunity to collect very large numbers of samples from any one species, so that our data are not suitable for detailed seasonal analysis. However, they do demonstrate the potentialities of the method. A complete account of the study is available in Ashmole and Ashmole (1967), and here we shall discuss only those aspects which are pertinent to the planning of a more general investigation, and in particular to the choice of bird species from which samples should be obtained.

The samples which we collected on Christmas Island consisted of entire or partially digested fish and squid, while two bird species also provided various invertebrates other than squid, mainly water striders (*Halobates*) and crustaceans. Nearly all the squid belonged to a single genus (*Symplectoteuthis*) of the family Ommastrephidae, but the fish were distributed among 33 families. The state of the samples varied considerably, but there were fairly consistent differences among the bird species (Table 1). These differences resulted partly from the fact that in some species it was easiest to obtain samples from young birds which had previously been fed by adults, while in others it was easy to catch adults. The best samples were those obtained as the birds arrived to feed their chicks, while those obtained from roosting adults were generally more digested and thus the items were more often unidentifiable. It would be important, therefore, to plan future work in such a way as to obtain the food items as soon as possible after they were caught by the birds.

The usefulness of a particular species would depend largely on the ease with which large numbers of identifiable fish could be obtained from it, so we have calculated (Table 1) the number of fish which we were able to identify (to family level) per 100 samples collected. In the following short accounts of the most promising bird species we have also commented on the abundance of each species, the ways in which it

may be caught, the methods and zones which it uses in feeding, and the size of the animals which it obtains.

EVALUATION OF THE BIRD SPECIES

Of the eight bird species whose food was sampled on Christmas Island (Table 1), four would not be very suitable for marine biological investigations. It is time consuming to obtain samples from the Christmas Island Shearwater, *Puffinus nativitatis* Streets, the Phoenix Petrel, *Pterodroma alba* (Gmelin), and the Red-tailed Tropic-bird, *Phaethon rubricauda* Boddaert, and the number of identifiable fish which can be expected in 100 samples (Table 1) is rather low for all these species. The Blue-grey Noddy, *Procelsterna cerulea* (F. D. Bennett), provides large numbers of items per sample, but the populations on many islands are rather small, and the species is not widely distributed. Furthermore, it feeds close inshore on very small items which could probably be sampled more efficiently with a neuston net (David, 1965) towed behind a small boat. The other four species studied—the Sooty Tern, *Sterna fuscata* Linnaeus, the Brown Noddy, *Anous stolidus* (Linnaeus), the Black or Lesser Noddy, *Anous tenuirostris* (Temminck), and the White or Fairy Tern, *Gygis alba* (Sparrman)—all have certain advantages for regular study. Salient numerical details are given in Table 1.

Sterna fuscata (Sooty Tern)

This is the most abundant of all tropical sea birds, breeding in enormous colonies on islands in the tropics around the world (see Ashmole, 1963 for details of its breeding distribution and breeding seasons). The eggs are laid on the ground in the open, and sometimes there are as many as five nests per square meter. The birds may desert whole areas if they are disturbed too much at the start of nesting, but later they sit tightly and may be caught with a hand net. However, incubating birds rarely regurgitate when caught, and the only way in which large numbers of samples can easily be collected is to catch adults (with a long-handled hand net, or mist nets) as they arrive to feed their chicks, especially in the late afternoon, or to catch chicks shortly after they have been fed. Before breeding starts, a few regurgitations can be obtained by catching birds at night when they are roosting on the ground, but the samples are generally small and largely digested. On most tropical islands the species has one fairly short breeding season, but on Christmas Island and a few other central Pacific islands there are two breeding seasons each year.

Sterna fuscata catches its prey either while flying or by plunging to the surface, but it probably hardly ever submerges completely. It has been recorded as feeding at night (Gould, in press), but this probably occurs only when the moon is nearly full. It is an oceanic species capable of feeding hundreds of miles from land, even when breeding. However, the actual distance traveled regularly probably varies considerably from colony to colony.

Our 242 samples were mostly from adults feeding chicks. They contained, on the average, 5.6 items each, of which 60% were fish, 40% squid. On the whole, the samples were in good condition, and 79% of the fish were identified to the family level. This means that about 266 identifiable fish could be expected per 100 samples. The identified fish belonged to 21 families, the ones which occurred most regularly being Exocoetidae and Scombridae, Gempylidae, Serranidae, and Emmelichthyidae. The identified squid were nearly all Ommastrephidae. Of the fish, 93% were between 2 and 10 cm in length (measured to the base of the tail), while 98% of the squid were between 2 and 8 cm in mantle length. We obtained sufficient data from this species to suggest that important seasonal changes exist in the availability of certain fish families, but a more intensive sampling program would be necessary to demonstrate such changes convincingly.

In summary, the advantages of this species are that it is available in great numbers, and samples can easily be obtained; the samples are often in good condition, and contain a high proportion of identifiable items; Scombridae are especially well represented in the samples; and the feeding range of the species is such that it provides samples from a large oceanic area. However, one cannot determine precisely the area from which each sample comes, and it is not easy to obtain many samples at times when the birds are not breeding.

TABLE 1

SUMMARY OF DATA ON THE FOOD OF EIGHT SPECIES OF SEA BIRDS ON CHRISTMAS ISLAND

ITEM	*Phaethon rubricauda*	*Puffinus nativitatis*	*Pterodroma alba*	*Sterna fuscata*	*Anous stolidus*	*Anous tenuirostris*	*Gygis alba**	*Procelsterna cerulea*
Mean weight of bird (gm)	665	324	269	173	173	90.9	101	45.4
Mean number of items per sample	3.8	10.5	4.4	5.6	5.1	18.3	1.3 4.3	41.8
% composition by number								
Fish	33	63	26	60	71	95	59	49
Squid	64	36	48	40	29	4	41	9
Other invertebrates	3	0.2	26	0.1	0	1	0.3	42
% of fish identified to family	55	20	1	79	67	27	87	38
% of squid identified to family**	100	62	24	88	100	71	100	74
Estimated number of fish identifiable to family per 100 samples	69	132	1	266	243	470	67 221	778

* When two figures are given for *Gygis alba* the upper refers to food samples carried in the bill and the lower to regurgitations.
** Some additional squid were tentatively identified.

Anous stolidus (Brown Noddy)

Anous stolidus breeds on many of the tropical islands where *Sterna fuscata* is found, but generally is less numerous. The birds are fairly easy to catch with a hand net at night, especially when there is no moon; mist nets could doubtless also be used, and unfledged young can be caught by hand. No general account of the breeding seasons of this species is available, but in many colonies breeding is probably less tightly synchronized than that of *S. fuscata,* while in some areas (including Christmas Island) individuals roost on the breeding islands even when they are not breeding.

A. stolidus uses feeding methods similar to those of *S. fuscata,* but sometimes also feeds while swimming on the surface; there is no evidence that it feeds at night. In contrast to *S. fuscata, A. stolidus* apparently does not normally feed more than about 50 miles from the colony, although the size of the zone utilized may be different in different areas.

Nearly all our 38 samples from *A. stolidus* were obtained from roosting adults early in the night, soon after they had returned from feeding. They contained, on the average, 5.1 items each, 71% of these items being fish, the remainder squid. Over half of the fish were identified to the family level, so that about 243 identifiable fish could be expected per 100 samples. The identified fish belonged to nine families, of which Exocoetidae, Scombridae, Holocentridae, and Gempylidae occurred most regularly. All the identified squid were Ommastrephidae. Of the fish, 94% were between 2 and 12 cm in length, while all but 1 of the 50 measurable squid had mantle lengths between 2 and 8 cm.

The advantages of *A. stolidus* as a sampler of the surface fauna of tropical seas are that the species is widely distributed, is available on some islands even outside the breeding season, and will often provide regurgitations when caught early in the night; its relatively limited feeding range means that animals obtained from it could normally be assumed to come from within 50 miles of the island. However, it is less abundant than *S. fuscata* and rather more difficult to catch.

Anous tenuirostris (Black Noddy)

This species (in which we include *Anous minutus*), although it breeds only on islands where bushes, trees, or cliffs are available to provide nest sites, often occurs in large colonies. Young birds often regurgitate when handled, but more consistent sampling can be carried out by catching roosting birds with a hand net early in the night, since on Christmas Island and many other islands some birds are present at all times of year.

A. tenuirostris feeds by the same methods as *A. stolidus* and *S. fuscata;* there is no conclusive evidence that it feeds at night. This species seems usually to feed even closer to its shore base than does *A. stolidus:* the Christmas Island birds fish very largely within 5 miles of the shore, but in some other areas (for instance Ascension Island, Atlantic Ocean) they go farther out to sea.

Our 110 samples, which were mostly regurgitations from roosting adults, contained on the average 18.3 items each. Of these items, 95% were fish, nearly all the remainder being squid. The regurgitations were often in the form of tightly-packed masses, many of the items being in a rather advanced state of digestion. We identified only 27% of the fish to the family level, partly because a large number of the fish were fry that we could not identify. Nevertheless, some 470 fish were identified per 100 samples. The identified fish belonged to 17 families, among which the most regularly represented were Exocoetidae, Gempylidae, Scombridae, Blenniidae, Holocentridae, and Emmelichthyidae. The few identified squid were all Ommastrephidae. Of the fish, 98% were less than 6 cm long, and 77% between 1 and 4 cm. Of the few squid, 83% were between 2 and 6 cm in mantle length.

A. tenuirostris was the only species which showed any dramatic differences in the diet at different seasons. In May 1963 and June 1964 we found in the diet a far higher proportion of fish less than 2 cm long than were present in our other sampling periods.

This species has the advantages that it is abundant, easily caught while roosting, and on some islands is available all the year round; the samples provide large numbers of fish, and these

are from inshore waters; the small size of its prey would make study of its food an excellent complement to that of one of the larger species, for instance *A. stolidus*. Its main disadvantage is the difficulty of identifying many of the fish fry.

Gygis alba (White or Fairy Tern)

Gygis alba, another widespread tropical species, generally is less abundant than the preceding three species, but many tropical islands have populations of a thousand or more birds. The nests are dispersed, either in forks or hollows in branches of trees, on the tops of coral blocks, or on cliff ledges where these are available. *G. alba* differs from the other species in that the adults rarely regurgitate, and they carry food for the young in their bills. Hence the technique for obtaining food samples is different. The birds usually come quite close to a human intruder, even when carrying food, and may often be caught with a long-handled net; the food items dropped by the birds as they are caught can then be retrieved from the ground. Our samples were mainly obtained from adults in this way, although we also collected regurgitations from juveniles and from adults.

On Christmas Island *G. alba* breeds at all times of year. In many other areas, however, breeding is more seasonal and, since the individuals leave the colonies when they have finished breeding, it would be impossible to obtain samples at all times of year.

This species catches most of its prey in flight, and there is some evidence that it feeds extensively in the half light at dawn. It sometimes feeds close inshore, and most of the prey carried back to the young in the bill are probably caught fairly close to the colony; however, the species sometimes ranges hundreds of miles from land.

Among our 152 samples, those carried in the bill contained, on the average, 1.3 items each, while regurgitations contained 4.3 items. Fish made up 59% of the items, the remainder being squid. The samples were generally in excellent condition, and 87% of the fish were identified to the family level. Collecting only food carried in the bill, one could expect to obtain approximately 67 fish identifiable to the family level per 100 samples. However, all of these would be in excellent condition, so that further identification would be much easier than in most of the other birds. The fish which we identified represented 22 families, 5 of which were not found in the food of any of the other bird species. Blenniidae occurred most regularly, followed by Exocoetidae, Myctophidae, Scombridae, Gempylidae, and Gonostomatidae. Squid of the families Ommastrephidae and Enoploteuthidae were identified. Of the fish, 96% were less than 8 cm in length; the samples carried in the bill contained a lower proportion of small fish than did the regurgitations. Of the squid, 93% were between 2 and 6 cm in mantle length.

This species ate far more squid during one of our sampling periods than at other times, and during this same period the squid taken included Enoploteuthidae (*Abralia* sp.) which were not found in samples obtained in the earlier part of the study.

The main advantages of this species are the excellent condition of the items carried in the bill and the fact that a wide variety of prey are eaten. However, it is difficult to obtain many samples, since usually the populations are not very large, and some of the birds are too wary to be caught when carrying fish, so that a quantitative study would probably have to depend primarily on other species.

Other Species

The species just discussed are those with which we have most experience, but other species also might be used for sampling, and we have tried to indicate some of the criteria which should be used in deciding whether a given species would be appropriate. The only large species included in our study was *Phaethon rubricauda* (weights are included in Table 1), which takes large prey, but from which it is generally not easy to obtain many samples. The obvious additional candidates, available on many tropical islands, are the various species of frigate birds, *Fregata* spp., and boobies, *Sula* spp. We would reject the frigate birds on the grounds that they obtain some of their food by piracy, which complicates interpretation, and also the food generally is in poor condition. Of the three widespread tropical boobies, the Brown Booby, *Sula leucogaster* (Boddaert), is mainly an inshore feeder, is rather difficult to catch, and

is not often available in large numbers. However, either the Red-footed Booby, *Sula sula* (Linnaeus), or the Masked (or Blue-faced, or White) Booby, *Sula dactylatra* Lesson, might be useful.

S. sula nests in colonies in bushes or trees, and regurgitates readily, at least when with young. The birds roost on many islands throughout the year; on Christmas Island, where the species nests on the main island, there is some breeding at all times of year. *S. sula* catches some of its prey below the surface by diving from a height, but has also been recorded catching flying fish in the air; it is thought sometimes to fish at night (Murphy, 1936). *S. sula* probably fishes mainly within a hundred miles of its home island (Murphy, 1936; Royce and Otsu, 1955, who almost certainly mistook *S. sula* for *S. dactylatra*). In a small series of samples from Oahu, Hawaii (Ashmole and Ashmole, in press) we found an average of nine items per sample, of which 64% were fish, 36% squid. Nearly 75% of the fish were identified, so that about 400 identifiable fish could be expected per 100 samples from this species. The fish found most frequently were Exocoetidae and Gempylidae, while all the identified squid were Ommastrephidae. Half of the fish were between 8 and 12 cm long, while there were appreciable numbers in the 12–16 and 16–20 cm groups; however, only a few squid with mantle length of more than 8 cm were present in our samples. The main advantages of this species are that it is available in some places throughout the year, and takes fish (and perhaps also squid) larger than any taken by the terns previously discussed.

We have had little experience with *S. dactylatra,* but relevant data have been presented by Dorward (1962). It would have advantages similar to *S. sula,* but probably ranges even farther from its breeding colonies.

DISCUSSION

It is clear that the use of analysis of the food of each of these bird species has certain merits, but also certain disadvantages. We suggest that valuable data could be obtained by making use of a group of bird species selected for the particular problem under investigation. For instance, to investigate the effects of seasons in the ocean around Christmas Island, it would probably be best to obtain a series of regurgitations, perhaps twice each month, from the three species *Anous tenuirostris, A. stolidus,* and *S. sula.* These samples would include animals ranging in size from less than 1 cm to at least 20 cm. The regurgitations from *A. tenuirostris* probably would represent sampling largely within 5 miles of the island, those from *A. stolidus* sampling largely within 50 miles, and those from *S. sula* might have been obtained as much as 100 miles away. On the other hand, for a long-term study concerned primarily with the detection of differences in the fauna of an oceanic area at the same season in a series of successive years, it would probably be most economical to collect samples from *Sterna fuscata,* choosing those months when this species has young. In any study, collection of samples from *Gygis alba* would be useful in providing animals in excellent condition and wide variety, to form the basis of a reference collection of the fish and squid available at the surface in the area.

If one is to use sea birds as samplers of their marine environment, it is important to have some understanding of the part which they play in the ecology of the surface layer of the sea. All the terns (including "noddies") considered here obtain their food within a few centimeters of the surface of the sea; boobies, *Sula* spp., tropic birds, *Phaethon* spp., and some shearwaters (*Puffinus* spp.), can penetrate a little deeper. Thus the terns should be sampling the fauna characteristic of the surface film, or "neuston." In fact, only one of the species for which we have data—the Blue-grey Noddy, *Procelsterna cerulea*—has a diet with a composition conspicuously similar to hauls made with the "neuston net" in the Indian Ocean (David, 1965): both contain large proportions of water striders (*Halobates*), pontellid copepods, and very small fish larvae. Among the other terns, only *A. tenuirostris* sometimes took many small fish larvae; and small crustaceans and *Halobates* were absent from the diet of all the larger species. Although there is little information available as to how many larger animals are normally present within a few centimeters of the surface during the day, observations suggest that, except for *Procelsterna cerulea* (and per-

haps *Gygis alba* feeding at dawn on animals which visit the surface during the night), all the terns studied are dependent on schools of tuna and other predatory fish to drive fish and squid to the surface: many of the prey animals are caught by the birds while they are actually jumping out of the water in efforts to escape the predators below. The larger birds like *Phaethon rubricauda* and *S. sula,* which can penetrate the water to a depth of at least 1 meter, may be able to catch prey which are not disturbed by other predators, and so may be partially independent of the presence of predatory fish.

Tuna schools are by no means randomly distributed over the tropical oceans, but occur largely in those areas where the animals on which they feed are most concentrated. In an earlier paper (Ashmole and Ashmole, 1967) we have discussed the evidence that in the open ocean convergence at "fronts" produces local concentrations of plankton and nekton, even in areas where the overall density of organisms is very low, and that these concentrations attract tuna schools. The existence of large populations of sea birds—like *Sterna fuscata*—which can range great distances from their islands even when breeding, probably depends on the presence of rich feeding areas of this kind. Clearly a knowledge of the areas where the wide-ranging species are feeding will help in interpreting the data obtained by the analysis of their food. The inshore-feeding sea birds, on the other hand, make use of the concentrations of prey animals, and of surface-feeding tunas, which are often present in the lee of islands.

Thinking that there might be a close correspondence between the food of surface-caught tunas and the food of the birds, we studied records of stomach contents of Yellowfin Tuna, *Neothunnus macropterus* (Temminck and Schlegel), kindly made available by the Honolulu Biological Laboratory of the U.S. Fish and Wildlife Service. The data used were for Yellowfin caught at the surface within 10 miles of Christmas Island and neighboring islands, but in different years from our sampling of the food of the birds. We found that there were striking differences between the diets of the tunas and of the birds, even if the comparison was restricted to the birds which fed close inshore. The tunas took a far higher proportion of reef-originating fish than did any of the birds, and presumably this reflects the fact that tunas can quickly and easily change from feeding right at the surface to feeding at considerable depths or around reefs, while the birds must wait for their prey to come to the surface. After they have completed larval life, typical reef-inhabiting fish such as Acanthuridae evidently do not often come to the surface even when pursued, and so are rarely eaten by birds; however, they were eaten by the tunas in considerable numbers. (The pelagic larvae were also eaten by tunas; they may also sometimes be taken by birds, and it must be remembered that we were able to identify only a small proportion of the partly digested larval fish found in samples from *A. tenuirostris* at certain times of year.) In contrast, Exocoetidae were unimportant in the diet of the tunas, but are of great importance in the diets of all the sea birds studied; probably the ability of these fish to escape submarine predators by flying renders them especially vulnerable to aerial predation by birds.

Attempts to sample forage animals near the surface of the central Pacific during the daytime, by means of oblique hauls with Isaacs-Kidd and other trawls, yielded so little material that they were abandoned in favor of night hauls, which produced catches containing far more organisms of generally larger size (King and Iversen, 1962). Although the greater number of organisms in night hauls partly reflects the movement to the surface layers at night of animals which are mesopelagic during the day, it is of interest that very few Exocoetidae, Scombridae, or Gempylidae, or squid of the family Ommastrephidae, were identified in either the day or night samples studied by King and Iversen. Since members of all these groups are commonly caught by birds feeding at the surface, it may be that they are such fast swimmers that they can generally dodge the nets (cf. Pearcy, 1965:266). Alternatively, they may be extremely patchily distributed, or so strictly confined to the surface that they are only rarely encountered by nets used in oblique hauls. In any case, it is clear that members of these groups are much more efficiently sampled by the birds.

In view of the commercial importance of tuna

fisheries, and consequent special interest in the biology of tunas, the effectiveness of tropical sea birds in catching juvenile tunas is worth emphasizing. King and Iversen (1962:301) said, "It was our hope that by means of midwater trawls we would capture juvenile tunas of lengths above 12 mm. which were able to elude the plankton nets. In 274 hauls made with the four midwater trawls described in this report we captured only six juvenile tunas, which ranged from 18 to 60 mm. in length." In contrast, in the 800 food samples which we obtained from birds on Christmas Island we found 247 young scombrids of which 166 were in 243 samples from *Sterna fuscata.* Of the latter group, 77 were examined in detail, and 69 proved to be Yellowfin Tuna. The scombrids from *S. fuscata* ranged from about 2 cm to 11 cm in length (measured to the base of the tail), but over 70% were between 4 and 8 cm. Those obtained in samples from *A. tenuirostris* included about a third which were less than 2 cm in length.

Since the birds eat mainly animals more than 0.5 cm in length, a program using birds to detect seasonal or longer-term changes in the environment could profitably be combined with other methods (such as use of the neuston net) of sampling the smaller organisms inhabiting the sea surface. If a version of this net could be arranged to fish clear of the bow wave of a small boat, it would permit quantitative sampling of the waters immediately around an oceanic island, to complement the sampling of larger animals, and a larger area, by the birds. The use of a small boat would of course also make it possible to obtain basic physical and chemical data requisite to an understanding of changes detected in the biota.

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