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SEABIRDS AND FISHING VESSELS: CO-OCCURRENCE AND ATTRACTION

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Seabirds in many areas of the world feed on fish, crustaceans and other organic matter discarded from fishing vessels working over continental shelves or other fishing grounds (Rees 1963, Grindley 1967, Jenkins 1971, Bartle 1974, Jehl 1974, Summerhayes et al. 1974). Our observations off the coast of Washington (Wahl 1975) have enabled us to quantitatively examine such behavior in terms of the effect of fisheries discards on the dispersion of different seabird species, and the relative importance of different types of vessels to different species. In this paper we compare and evaluate the relative abundances of several species recorded in the vicinity of fishing vessels with those recorded, on the same day, away from fishing vessels. The results of these analyses are discussed in relation to our observations of the feeding behavior of the different species at fishing vessels.

METHODS

Wahl (1975) conducted 46 one-day censuses of seabirds off Grays Harbor, Washington during April–October from 1971 to 1977. The area censused extends from Westport out to the continental shelf break and along the sides of Grays Canyon. We traveled an average of 12 km/h between fishing vessels and/or bird flocks and divided each census into observation periods of 30 to 120 min with Wahl and one other observer estimating the number of each species seen during each period. The types of fishing vessels encountered within 5 km of the census track line during each period were also recorded. The number of birds at fishing vessels or in natural feeding flocks was estimated by approaching to within 100 m, and remaining in the area until all birds were counted. We selected species for statistical analysis from a pool of users or potential users of discarded matter from fishing vessels. Data from the 10 most abundant species offshore are analyzed: Black-footed Albatross (*Diomedea nigripes*), Northern Fulmar (*Fulmarus glacialis*), Pink-footed Shearwater (*Puffinus creatopus*), Buller's (=New Zealand) Shearwater (*P. bulleri*), Sooty Shearwater (*P. griseus*), Fork-tailed Storm-Petrel (*Oceanodroma furcata*), Glaucous-winged Gull (*Larus glaucescens*), Western Gull (*L. occidentalis*), California Gull (*L. californicus*), and Sabine's Gull (*Xema sabini*). Data for Glaucous-winged and Western gulls are combined because we found a high incidence of intergradation between them. Pomarine and Parasitic jaegers (*Stercorarius pomarinus* and *S. parasiticus*) were common enough to permit analysis together but not separately. The uncommon Flesh-footed Shearwater (*Puffinus carneipes*) is included because it was recorded at fishing vessels more consistently than any other species.

On our censuses 95% of all fishing vessels encountered were in water of 40 to 400 m in depth. We excluded the bird data taken outside that depth range from the analysis because such birds cannot be distributing themselves with respect to fishing vessels. Data from eight censuses conducted in poor observation conditions were not used. Numbers of each species seen within each period were standardized to individuals per 30 min, the most common observation period. The periods within each census were grouped by presence or absence of potential attractants (trawlers and long-line fishing vessels or our vessel when we chummed [threw beef suet or popcorn overboard] to attract birds). The mean numbers of each species detected in periods with potential attractants present and in periods with potential attractants absent were computed for each census.

If a species' distribution is independent of the distribution of potential attractants, then its mean abundance in the presence of potential attractants will not be significantly different from its mean abundance in the absence of potential attractants. We have operationally defined "in the presence of" to mean within approximately 6 km (the product of our average speed and the most common observation period length); thus, by "in the absence of" we mean beyond 6 km. We use the mean abundance near potential attractants minus the mean abundance away from potential attractants as a measure of the degree of spatial overlap or co-occurrence. We tested the one-tailed null hypothesis that there was no co-occurrence ($P < 0.05$) by a paired t-test. Next we divided the periods within each census by the following attractant types and computed mean abundances for each type and census: foreign or long-line trawlers, domestic bottom or shrimp trawlers, and our vessel when we chummed. The mean abundances in the absence of potential attractants remained the same. These means were compared by one-way Analysis of Variance (ANOVA) and the Student-Newman-Kuels (SNK) multiple comparison test (Sokal and Rohlf 1969). We transformed the data by adding one and taking natural logarithms to correct for non-normality and non-homogeneity of variances. As we were unable to meet the requirement of independence for the ANOVA, we set the significance level for the SNK test conservatively at 0.025.

RESULTS

The mean abundance of all species was greater near potential attractants than away from potential attractants (Table 1). We arranged the species in three groups: (I) those that did not show co-occurrence ($P > 0.10$) with attractants; (II) those that showed a moderately significant degree of co-occurrence ($0.001 < P < 0.05$); and (III) those

TABLE 1. Mean abundances (birds/30 min) with and without potential attractants.

Species	Potential attractant: Present	Potential attractant: Absent	Significance[a]
Black-footed Albatross	5.15	1.14	***
Northern Fulmar	12.30	1.83	***
Pink-footed Shearwater	43.80	3.58	***
Flesh-footed Shearwater	0.37	0.03	***
Buller's Shearwater	56.60	13.40	*ns*
Sooty Shearwater	377.00	186.00	*ns*
Fork-tailed Storm-Petrel	4.72	3.15	*ns*
Pomarine and Parasitic jaegers	1.22	0.71	***
Western and Glaucous-winged gulls	18.50	5.27	***
California Gull	51.70	4.28	***
Sabine's Gull	2.45	0.92	**

[a] One-tailed t-test on the log transformed data (n = 38); where *ns* indicates not significant or $P > .05$; * $P < .05$; ** $P < .01$; and *** $P < .001$.

that showed a highly significant degree of co-occurrence ($P < 0.001$). Table 2 shows degrees of co-occurrence with different attractant types.

GROUP I: NO SIGNIFICANT CO-OCCURRENCE

Although we recorded 4.2 times as many Buller's Shearwaters near to potential attractants as away from them, the difference was not statistically significant (Table 1). They did not seem to be attracted to fishing vessels or to our chum, and we never saw them feeding on discarded matter. We suspect that this difference does reflect actual co-occurrence, but that it is not due to attraction. The species tends to occur in large flocks and we believe that the birds were probably not focussing on fishing vessels but rather on the same area that the vessels were working (see Fig. 1C).

Sooty Shearwaters occasionally fed on discarded matter, primarily from shrimp trawlers, and we noticed an increase in the frequency of this behavior since 1974. However, we could not measure a change in the degree of co-occurrence. In general, large concentrations were more common near domestic trawlers than near other potential attractants or away from potential attractants (Fig. 1D), although these flocks almost always represented a relatively small part of the total daily census of this abundant, widespread species. We suspect that the distribution of Sooty Shearwaters was primarily determined by the location of euphausid and anchovy concentrations.

We rarely saw Fork-tailed Storm-Petrels

TABLE 2. Mean abundances (birds/30 min) by period types and for those species that showed a significant degree of co-occurrence with potential attractants.

Species	Potential attractant: Present[a] FT 13[c]	DT 21	US 19	Absent 38	Order[b]			
Black-footed Albatross	8.57	5.77	2.62	1.14	FT	DT	US	AB
Northern Fulmar	23.60	8.10	1.81	1.83	FT	DT	AB	US
Pink-footed Shearwater	14.90	60.00	5.04	3.58	DT	FT	US	AB
Flesh-footed Shearwater	0.30	0.46	0.22	0.03	DT	FT	US	AB
Pomarine and Parasitic jaegers	1.51	1.36	0.89	0.71	FT	DT	US	AB
Western and Glaucous-winged gulls	8.81	18.60	12.30	5.27	DT	US	FT	AB
California Gull	132.00	59.20	17.20	4.28	FT	DT	US	AB
Sabine's Gull	8.18	1.89	2.01	0.92	FT	US	DT	AB

[a] Potential attractant types are: (FT) foreign fishing vessels; (DT) domestic fishing vessels; (US) ourselves when we chummed; and (AB) the absence of potential attractants.
[b] Potential attractant types listed from left to right in ascending order by mean abundance associated with each. Not significantly different subsets ($P > .025$; SNK multiple comparison test on the log transformed data) are underlined.
[c] Sample size (number of censuses with at least one period of the given type).

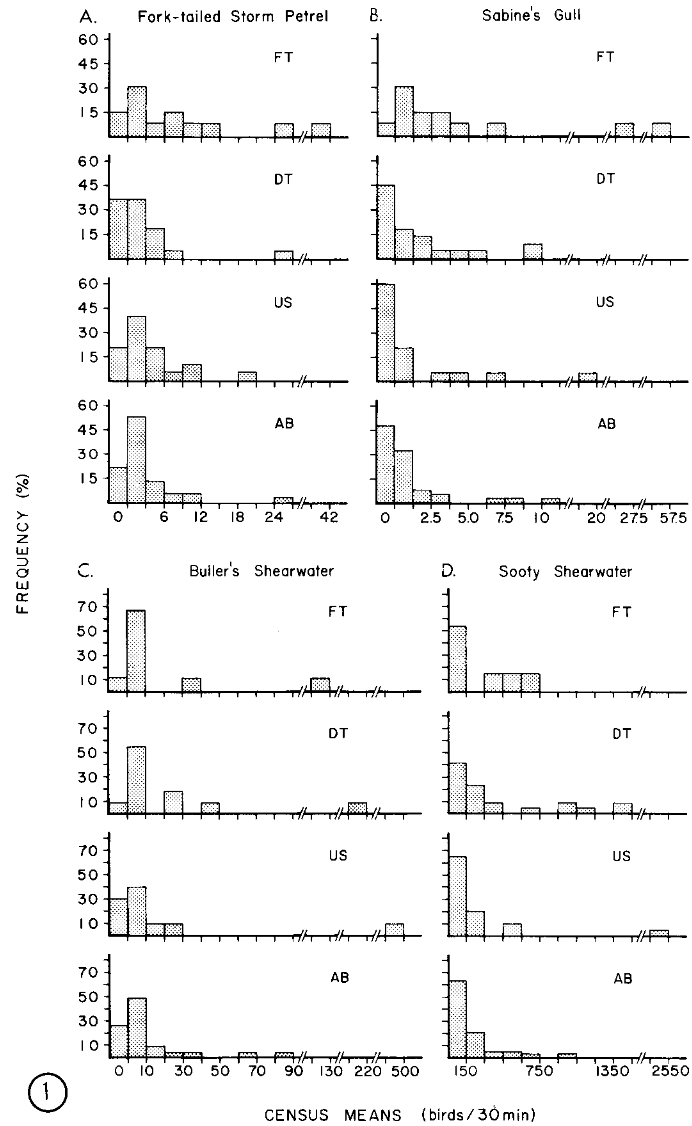

FIGURE 1. The pattern of abundance by period type for four species of seabirds near fishing vessels (see Table 2 for period type designations and sample sizes). Each panel shows the frequency distributions of census means, for each period type, by their magnitude. For example, in A, 30% of the censuses that had at least one period with foreign trawlers (FT) present recorded mean abundances of Fork-tailed Storm-Petrels of 0–3 birds per km^2. Note that the first bar in each graph shows the percent of censuses in which the species was absent from period of the given type; this bar is missing from the Sooty Shearwater histograms as this species was always present in at least one period of type in each census.

at domestic trawlers, probably because these trawlers discard large items (whole fish). Foreign trawlers discarded oil and solid processing wastes (offal) which are small enough for storm-petrels, but we only occasionally observed the birds feeding near vessels. Storm-petrels appear to be capable of navigation by olfaction (Grubb 1972, pers. observ.), and we attracted up to 250 Fork-tailed Storm-Petrels to our vessel with vegetable oil. Centers of storm-petrel abundance were usually over deeper water than that for trawlers, thus possibly explaining why the birds did not make more extensive use of foreign trawler by-products. Our use of oil as chum in areas where storm-petrels were seen occasionally had the effect of concentrating birds in what would otherwise have been low-abundance periods.

GROUP II: SIGNIFICANT CO-OCCURRENCE

Although we occasionally saw Sabine's Gulls feeding or at least searching behind

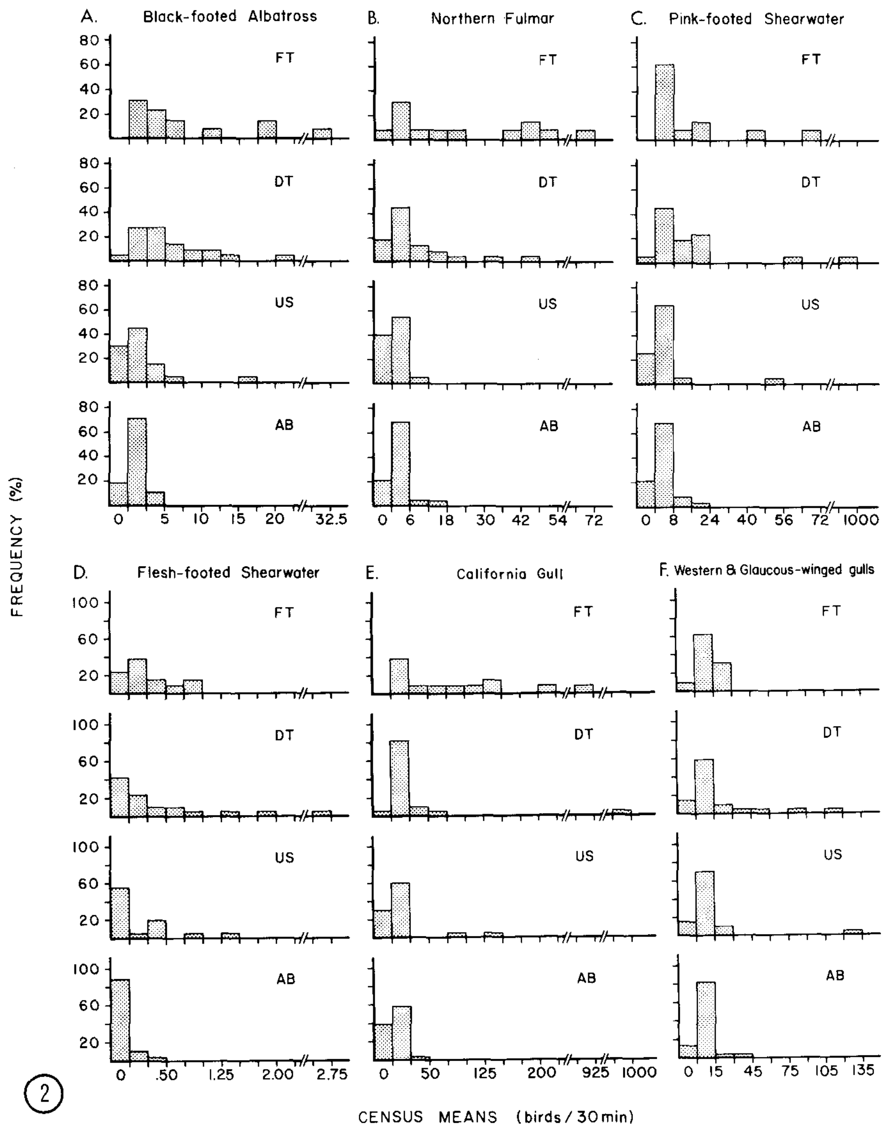

FIGURE 2. The pattern of abundance for six other species. See Figure 1 for explanation.

fishing vessels (Fig. 1B), we could not always tell whether they foraged upon waste material or upon some natural prey. The species' significant co-occurrence (Table 1) may have been due to both the gulls and fishing vessels being attracted to areas of high productivity and the tendency of Sabine's Gulls to investigate the feeding activity of other species. Interference from larger gulls and fulmars may have restricted this species' use of discards. However, significantly more individuals were found when we were near foreign trawlers than during any of the other periods (Table 2).

GROUP III: HIGHLY SIGNIFICANT CO-OCCURRENCE

Nearly all the individuals of species of this group seen during periods with potential attractants were feeding on offal at the ship or loafing nearby (usually within 500 m of the ship). This indicates that the co-occurrence is primarily due to the attraction of the birds to the fishing vessels.

We rarely saw flocks of Black-footed Albatrosses except at attractants. We recorded maximum concentrations of 250 at a foreign trawler, 60 at a domestic trawler, and 25 at one of our chums (Fig. 2A). The mean abundances near trawlers (foreign or domestic) were significantly greater than those near our chums or away from potential attractants (Table 2).

Large concentrations of Northern Fulmars were found most consistently near foreign trawlers, although equally large concentrations (up to 220) occasionally occurred near domestic trawlers; large concentrations were never found near our chums or away from potential attractants (Table 2).

Prior to 1976 we recorded 74 Flesh-footed Shearwaters, none of which were seen away from potential attractants. Since then we have seen 16 more, 3 of which were recorded away from potential attractants (Fig. 2D). There were only two concentrations greater than three birds, each at a domestic trawler. The mean abundances were significantly greater near to than away from potential attractants, but the differences among the mean abundances near the three different potential attractants were not significant (Table 2). Because it is difficult to detect single, dark shearwaters at sea, or in a mass of other shearwaters, we may have underestimated the abundance of this uncommon species both away from and near attractants.

In the fall, California Gulls were the numerical dominant at virtually every foreign fishing vessel. The mean abundance near foreign trawlers was much higher than any species other than that of the Sooty Shearwater (Table 2), and most of the Sooty Shearwaters were not associated with the trawlers. We recorded a high of about 10,000 of these gulls around several Russian trawlers in October 1972. While the species was present during over 75% of the periods near trawlers, it was present during less than 50% of the other periods (Fig. 2E).

The resident species of large gulls (Western and Glaucous-winged gulls) seem to be attracted equally to any food source (except oil) or feeding activity (Table 1). The larger mean abundance near domestic trawlers (Table 2) was numerically due to all but one of the largest concentrations of gulls being near domestic trawlers (Fig. 2F). We feel this occurred because both domestic trawlers and these two gulls were generally found closer inshore than were foreign trawlers or our chums, not because of differences in the degree of attraction.

Although rarely found in large numbers (only 15% of the periods had more than five birds), Pomarine and Parasitic jaegers were recorded during a similar proportion of the periods as most other species. We suspect that the decrease in mean abundances going from periods with foreign trawlers to periods without attractants (Table 2) reflects attraction to different types of fishing vessels (actually to the accompanying bird flocks) at different rates. Most birds did not stay more than 15 to 20 min at any potential attractant; this contrasts with most of the other Group III species which stayed hours or, possibly, days. The jaegers we saw were migrating, and they may have been attracted only if they happened to be passing close by a ship.

A few uncommon species were occasionally seen feeding upon discards, but insufficient data precluded parametric testing. We employed chi-square tests on data for Long-tailed Jaegers (*Stercorarius longicaudus*), Skuas (*Catharacta skua*), Herring Gulls (*Larus argentatus*), and Black-legged Kittiwakes (*Rissa tridactyla*). We tabulated the number of periods in which a species was present or absent and partitioned these values by the presence and absence of potential attractants to give a 2 × 2 contingency table.

Neither Long-tailed Jaegers nor Skuas showed a significant degree of co-occurrence ($P > .05$). However, both species were present in periods with chums appreciably more frequently than during other periods (Table 3); for Skuas, the difference between periods of chumming and absence was significant ($P < .05$). Herring Gulls are primarily winter visitors and few were seen on our censuses but they were present more often in periods with potential attractants (especially near chums; Table 3), and they showed a highly significant degree of co-occurrence. Black-legged Kittiwakes were also present more often near than away from potential attractants ($P < .05$). As was the case with the Group III species, we feel that the co-occurrence demonstrated for Herring Gull ($P < .01$) and Black-legged Kittiwake ($P < .001$) is because these birds are attracted to discards. None of the other species recorded on these censuses (see Wahl 1975) was concentrated at fishing vessels or seen feeding on discarded matter.

DISCUSSION

ATTRACTANT PREFERENCES OF GROUP III SPECIES

The number of birds consuming discards at a given fishing vessel should be a function of the rate at which they are attracted, the rate at which they leave, and the length of time that the offal has been available (persistence). The rates of attraction and departure should depend on the amount and type of discards available (volume), and the number and types of birds present (advertisement and interference). Important characteristics of the discarded matter are size, condition (whole or processed), sinking rate, and perhaps species. Competition for space behind the fishing vessel, competition for discards, and kleptoparasitism are important interactions between species that restrict the number of birds at a fishing ves-

TABLE 3. The pattern of presence for four uncommon species in each of the four period types for all censuses (fishing vessel designations as in Table 2).

	Potential attractant				
	Present				Absent
Species	FT 37[a]	DT 72	US 39	Combined 148	188
Long-tailed Jaeger	.11 (2.5)[b]	.10 (1.9)	.15 (1.5)	.11 (1.9)	.10 (1.2)[c]
Skua	.14 (1.0)	.11 (1.0)	.36 (1.9)	.18 (1.5)	.19 (1.4)
Herring Gull	.19 (2.6)	.14 (4.9)[d]	.42 (1.6)[e]	.23 (2.8)[f]	.08 (4.2)
Black-legged Kittiwake	.14 (2.0)	.18 (2.2)	.13 (1.2)[g]	.16 (2.0)[h]	.07 (2.2)

[a] Sample size (number of periods).
[b] The proportion of periods of the given type in which the species was observed, with the mean number of individuals per 30 min in periods in which the species was present in parentheses.
[c] With one atypical period included, values become .11 (3.9).
[d] With one atypical period included, values become .15 (14.0).
[e] With two atypical periods included, values become .44 (50.0).
[f] With three atypical periods included, values become .24 (29.0).
[g] With one atypical period included, values become .15 (109.0).
[h] With one atypical period included, values become .16 (29.0).

sel. However, the more birds present and the greater the percentage of highly visible species, the more conspicuous the feeding flock. This should increase the attraction rate. Foreign trawlers are much larger and more visible than domestic trawlers; they discard much more and for longer periods of time, and they work at sea almost continuously while domestic trawlers return to port frequently. In addition, foreign trawlers often occur in fleets of four to seven ships, one or two of which are processing at any given time; domestic trawlers are often alone and do not process at sea. These differences between vessel types in the volume and persistence of offal lead us to predict that mean abundances of birds attracted to the discards should increase in the following order for periods: (1) away from potential attractants; (2) near our chums; (3) near domestic trawlers; and (4) near foreign trawlers. None of the species adhered strictly to this ordering, but where differences between mean abundances were significant, the differences were all in agreement with this ordering (Table 2).

Different species seemed to prefer certain types of discarded matter: scraps and offal from foreign trawlers and processing ships; whole fish (large and small) discarded by domestic trawlers; or small fish or crustaceans that fell out of the net as it was being hauled in. However, it is difficult to determine preferences when factors such as volume and persistence are not constant among different fishing vessels. Also, it is impossible with these data to separate the effects of interference from other species (competition and kleptoparasitism) from the intrinsic properties of the food items. For instance, agile and maneuverable gulls (and occasionally Fork-tailed Storm-Petrels) usually took small items by aerial dipping as soon as they were discarded. However, these birds were occasionally displaced by Northern Fulmars, which are aggressive and agile when on the water. Fork-tailed Storm-Petrels are adept at picking up small items among much larger birds, though the storm-petrels appeared intimidated by dense flocks of aggressive gulls, shearwaters and fulmars. Items that sank more than one meter below the surface were taken only by Sooty Shearwaters, which dive readily. Sooty, Pink-footed and Flesh-footed shearwaters will take floating food items, but they often seemed to be beaten to them by the more aggressive Northern Fulmars or by gulls. Observations suggested also that shearwaters scavenged less effectively at chums after mid-summer when California Gulls became numerous and out-did shearwaters at retrieving floating items. Discards too large to be swallowed whole were taken by Black-footed Albatrosses (which also take items of any other size or shape), or if albatrosses were absent, by fulmars and large gulls.

SPATIAL DISTRIBUTION

The full extent of attraction of seabirds to fishing vessels cannot be measured until the distribution of both the vessels and birds over extensive areas (e.g., the entire continental shelf off Washington), the duration of fishing effort, and the food items discarded by the vessels and taken by the birds can be determined. However, we observed that birds were more numerous within 6 km of attractants, suggesting that birds were attracted from the surrounding area and, therefore, from distances greater than 6 km. When we were chumming, albatrosses often approached in direct, fast flight as late as 30 min after our "feed" was first advertised by gulls dropping to the surface (see Miller

1942). We feel that birds may be attracted to fishing vessels from at least 12 km away, with large vessels drawing birds from much greater distances.

We compared mean abundance (combining all periods) for each species for censuses in which no trawlers were encountered and those in which at least one was recorded. Black-footed Albatross, Pink-footed Shearwater and Flesh-footed Shearwater were significantly more abundant (t-test, $P < 0.05$) on days when ships were present. This suggests that fishing vessels were affecting the distributions of these species over an area at least the size of Grays Canyon (400 km^2). We feel that they were not just responding locally (concentrating on days when vessels were discarding, and dispersing within the same general area when discards were unavailable) but were following fishing vessels moving in or out of much larger areas. Thus, assuming equal availability of natural prey such as squid, summer concentrations of albatrosses might be expected to occur within range of foreign fishing vessels, whether these are operating off northern California, Oregon, Washington or British Columbia (see Robbins and Rice 1974).

FURTHER IMPLICATIONS

Beyond the quantitative measurement of co-occurrence of seabirds with fishing vessels, studies should attempt to quantitatively answer a number of questions. These include an investigation of the degree of "coincidental co-occurrence" in areas of high biological productivity, and the effects of fishing vessel discards on seabird populations. What are the net effects of competition between fisheries and seabirds, particularly in light of the recently increased fishing effort, particularly of industrial fishing and processing at sea? Do fishery discards enhance winter survival of seabirds, particularly pre-breeding age classes? What are the competitive advantages of bird species benefiting from discards (e.g., gulls) over species that do not (alcids)? Is discarded matter an important supplemental food source during periods when natural prey is scarce? And what are the interspecific, food-web implications to birds of the removal for human use of selected sizes or species of fish while leaving others?

SUMMARY

We observed 16 species of seabirds feeding on fishery discards over the continental shelf off Grays Harbor, Washington. Ten of these species were significantly more abundant within 6 km of fishing vessels than beyond this distance. For all but one of these species we concluded that the higher abundance near fishing vessels was primarily due to the attraction of the birds to the discards. Two other species were present more often within than beyond 6 km of fishing vessels, probably for the same reason.

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