

tained during late spring-early summer towards the end of the incubation period.

Fecundity values calculated from the relationships in Figure 2 range from 4,800 to 7,450 at 70 mm carapace length and from 25,400 to 38,300 at 125 mm. The relationship of Saila et al. (1969) gives the lowest values over the entire range of sizes considered. This relationship is suspect, however, since it is based on samples obtained from three widely separated areas. Over most of the size range considered the relationship for Placentia Bay gives higher estimates than those from the relationship derived by Saila et al. (1969) from Herrick's (1911) data, indicating that Herrick's data should not be discounted as Saila et al. (1969) suggested.

Definitive statistical comparisons of size-fecundity relationships for American lobsters from different areas would require large samples which adequately cover a wide range of sizes. Even with such samples comparisons could be somewhat confounded by geographic variation in size at first maturity, which, for certain areas, would preclude direct comparison of fecundity at smaller sizes. In addition, samples would have to be taken at approximately the same stage in the incubation period by the same method of capture and be subjected to similar handling and procedures for determining egg numbers. These requirements are unlikely to be met in the foreseeable future. However, as tenuous as the comparisons presented here may be, they do suggest substantial geographic variation in size-fecundity relationships for American lobsters.

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#### MORTALITY OF SEABIRDS IN HIGH-SEAS SALMON GILL NETS<sup>1</sup>

Since 1952, the Japanese have operated a large salmon driftnet fishery in the northern North Pacific Ocean and Bering Sea. This fishery is divided into two components: the high-seas mother-ship fleet, which consists of several processing ships and their numerous, smaller catcher boats that remain at sea during the entire fishing season, and the land-based fleet, which consists of independent fishing boats that catch and store their own fish and return to Japan at more fre-

<sup>1</sup>Contribution No. 224 of the Point Reyes Bird Observatory.

quent intervals (Sanger 1976; Fredin et al.<sup>2</sup>). A similar fishery in the North Atlantic between 1965 and 1976 was responsible for the deaths of large numbers of the thick-billed murre, *Uria lomvia*, and significant reductions in its breeding populations (Tull et al. 1972). Recent work in the North Pacific and Bering Sea by Sano (1978) and King et al. (1979) indicated that large numbers of seabirds are killed annually in the Japanese salmon fishery also.

Previous estimates of seabird mortality resulting from the Japanese high-seas and land-based gill net fisheries were based on data gathered from research nets only (e.g., Sano 1978; King et al. 1979). These nets include both smaller and larger mesh sizes than nets used in the commercial

fishery. We wished to investigate if mesh size influenced bird mortality rates, and if so, to reassess the impact of gill net fisheries on seabird mortality. Since previous estimates of the total bird catch were based on data averaged over broad regions, we also investigated the geographic variation in catch rates to determine whether in some areas they could potentially be having an important impact on local bird populations.

#### Methods

We participated in cruises aboard Japanese research vessels during 1978 and 1979 as shown in Figure 1. The *Oshoro Maru* and *Hokusei Maru* deployed research nets and the *Hoyo Maru No. 67* deployed a small series of research nets between two extensive spans of commercial nets. Research and commercial nets differ significantly only in the variety of mesh sizes used. In this study the mesh sizes in the research nets ranged 37 to 233

<sup>2</sup>Fredin, R. A., R. L. Major, R. G. Bakkala, and G. K. Tanonaka. 1977. Pacific salmon and the high seas salmon fisheries of Japan. Processed Rep., 324 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Boulevard E., Seattle, WA 98112.

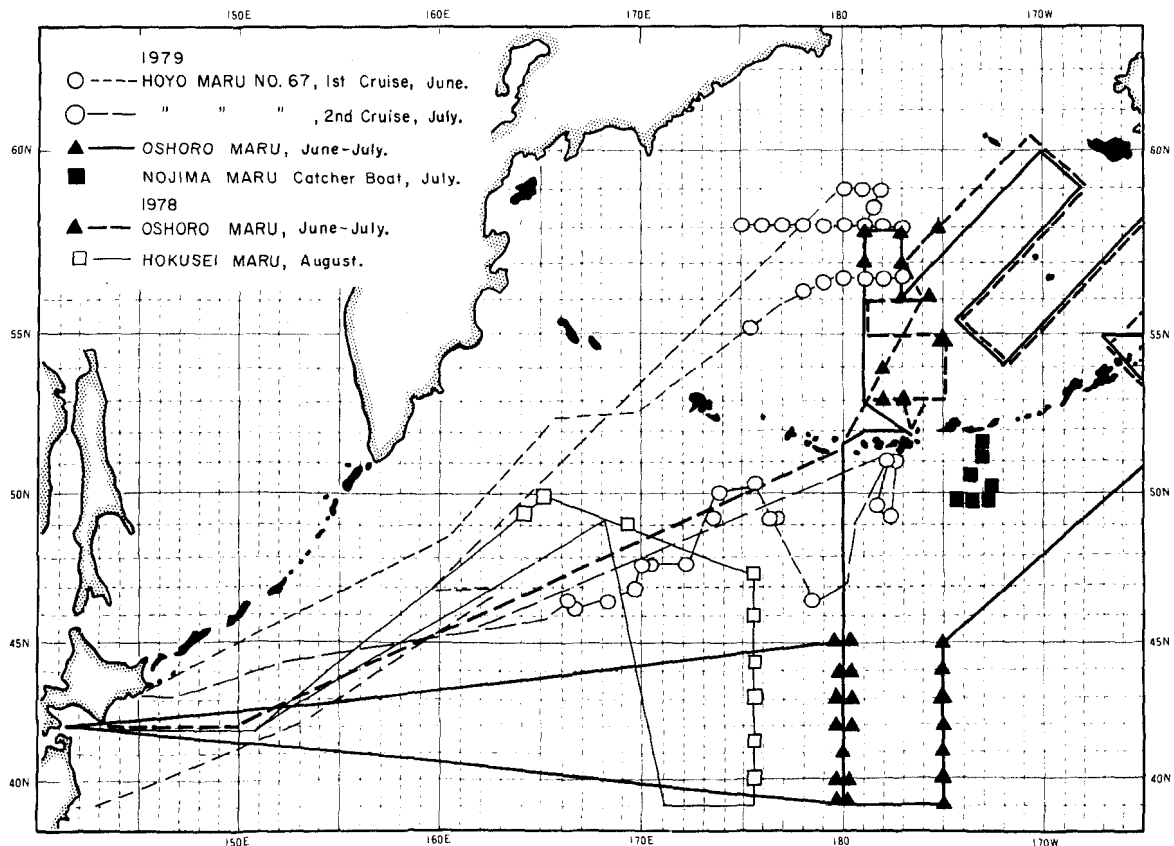


FIGURE 1.—Cruise tracks (lines) and net setting stations (symbols) where observations were made in 1978 and 1979.

mm but the commercial nets were limited to meshes ranging 110 to 130 mm. In 1979 we also obtained some data from commercial catcher boats of the mother ship *Nojima Maru*, but these were used only in determining geographical differences in catch rates. Nets were set at 16:30 h and hauled at 02:30 h on *Hoyo Maru No. 67*, similarly to commercial boats; on other cruises deployment and retrieval were at 18:00 h and 03:00 h. Nets consisted of panels, called tans, 50 m by 6 m deep that were sewn together in series, with floats attached to the topline and lead weights attached to the bottom line of each panel. The stretched mesh thus hung vertically like a curtain from the sea surface down to a depth of 6 m. A commercial net was usually about 15 km long, while those on our vessels were about 6.5 km (130 tans). A commercial fleet of 45 catcher boats (plus a mother ship) deployed its nets in parallel lines on a grid, each net about 5 nmi from neighboring ones. For several sets in the central Bering Sea, *Hoyo Maru No. 67* fished within the configuration of a commercial fleet. A complete review of the Japanese drift gill net fishery is contained in Fredin et al. (footnote 2).

On all cruises except that of the *Nojima Maru* catcher boats, we noted entangled birds as the nets were being retrieved. Carcasses from the first cruise of *Hoyo Maru No. 67* were saved by Jones, frozen, shipped to the United States, and, along with those from *Nojima Maru*, were later identified by Ainley; those from other cruises were identified immediately by Ainley and DeGange. On most sets the mesh size and the depth at which birds were entangled were recorded.

Using data from the *Hoyo Maru No. 67* and the *Nojima Maru* catcher boats (see Figure 1), we compared catch rates to distance south of the Aleutian Islands. Data from *Oshoro Maru* and *Hokusei Maru* were not used because they did not use commercial nets. However, a comparison of catch rates to the distance north of the Aleutians used data exclusively from *Oshoro Maru* because we had no data from commercial nets close enough to the islands. The shape of the regression curve would not be affected but the asymptotes would be displaced downward due to the low catch rates of the research nets used.

On two cruises in 1979, Ainley and DeGange censused seabirds that occurred within 300 m of one forequarter of the ship whenever we steamed at 9-12 kn during daylight; birds circling or following the ship were ignored. Distance traveled dur-

ing a given time period (a transect) multiplied by the 300 m transect width provided an estimate of ocean area surveyed. Area divided into the number of birds counted resulted in an index of bird density per square kilometer. For 16 sets on the July cruise of *Hoyo Maru No. 67* and 5 sets on the 1979 cruise of *Oshoro Maru*, densities of nettable seabird species (i.e., those caught during the cruises) were correlated to the number caught per tan (110-130 mm mesh only) at each set. Density indices at netting areas were averages of the counts immediately before arrival at and another after departure from the netting site. Only five of *Oshoro Maru's* sets were used because other studies took her far away from netting areas at very low speed before transits at cruising speeds began. We equilibrated our estimates of bird density based on simultaneous but independent counts made aboard *Oshoro Maru*, 25-27 July 1979.

In the following discussions oceanographic regions are approximate because they are based on geographic locality as shown in Favorite et al. (1976), and not on sophisticated oceanographic measurements taken at the time of bird observations. Hourly sea-surface temperatures, however, did aid somewhat in confirming the boundaries between certain domains.

## Results and Discussion

### Species Observed

We recorded 31 species of seabirds during our at-sea observations but only 15 of these were caught in the nets (Table 1). For certain species, their pelagic distribution was reflected in the gill net catch by statistically significant correlations ( $P < 0.05$ ) between density estimates and number of birds caught. For example, in the Bering Sea and in Western Subarctic waters south of the Aleutians, the short-tailed shearwater greatly outnumbered the sooty shearwater, both in density and in the gill nets, but farther south to just north of the Subarctic Front their numerical importance in the catch and in the censuses was reversed. Several other species also showed differences in their distributions, for example, ancient murrelet and crested auklet.

A bird's foraging methods influenced its susceptibility to being caught (Table 2). Of the 13 species we observed that feed beneath the sea surface by diving or pursuit plunging (see Ainley 1977 for

TABLE 1.—Density indices  $\pm$ SD and number caught per tan ( $\times 10^{-3}$ ) in parentheses for notable seabird species in different oceanographic areas; the number of  $\frac{1}{2}$ -h transects are shown below each area name.

Species	Transitional Domain (27)	W. Subarctic Gyre (36)	Alaskan Stream (24)	Bering Gyre (97)	Bering Current (8)
Laysan albatross, <i>Diomedea immutabilis</i>	0.1 $\pm$ 0.1 (2.0)	0.1 $\pm$ 0.1 (1.0)	0.1 $\pm$ 0.1		0.1 $\pm$ 0.2
Northern fulmar, <i>Fulmarus glacialis</i>	3.2 $\pm$ 5.6	1.8 $\pm$ 1.4 (3.0)	.8 $\pm$ 0.4	.3 $\pm$ .3	.6 $\pm$ .3
Flesh-footed shearwater, <sup>1</sup> <i>Puffinus carneipes</i>	.1 (0.3)				
Sooty shearwater, <sup>1,2</sup> <i>P. griseus</i>	.4 $\pm$ .8 (18.0)	.1 (2.0)	(.2)		
Short-tailed shearwater, <sup>1,2</sup> <i>P. tenuirostris</i>	(0.6)	11.7 $\pm$ 15.6 (17.0)	10.0 $\pm$ 13.5 (66.)	.8 $\pm$ 1.2 (3.0)	5.5 $\pm$ 1.9 (60.0)
Fork-tailed storm-petrel, <i>Oceanodroma furcata</i>	1.9 $\pm$ 1.8	3.1 $\pm$ 2.8 (8.0)	2.6 $\pm$ 1.1	1.5 $\pm$ 1.0 (.6)	2.3 $\pm$ 1.2 (2.0)
Common murre, <sup>1</sup> <i>Uria aalge</i>		.1		.1 (.3)	
Thick-billed murre, <sup>1,2</sup> <i>U. lomvia</i>		.1 $\pm$ .2 (2.0)	.2 $\pm$ .4 (5.0)	.1 $\pm$ 0.2 (4.0)	.5 $\pm$ .2 (12.0)
Ancient murrelet, <sup>1</sup> <i>Synthliboramphus antiquus</i>				.1 $\pm$ .4 (1.0)	.8 $\pm$ .8 (2.0)
Parakeet auklet, <sup>1</sup> <i>Cyclorhynchus psittaculus</i>			.1 (0.2)	.1	
Cassin's auklet, <sup>1</sup> <i>Ptychoramphus aleuticus</i>			(.2)		
Least auklet, <sup>1</sup> <i>Aethia pusilla</i>		(1.0)	.2 $\pm$ .6	3.3 $\pm$ 4.3	1.2 $\pm$ 1.6
Crested auklet, <sup>1</sup> <i>A. cristatella</i>		(2.0)	.1 (1.0)	.7 $\pm$ 1.6	.7 $\pm$ .8
Rhinoceros auklet, <sup>1</sup> <i>Cerorhinca monocerata</i>	.1 $\pm$ .2		(0.2)		
Horned puffin, <sup>1</sup> <i>Fratercula corniculata</i>	.2 $\pm$ .2 (.6)	.4 $\pm$ .5 (5.0)	.3 $\pm$ .4 (3.0)	.4 $\pm$ .5 (2.0)	3.9 $\pm$ 2.4 (2.0)
Tufted puffin, <sup>1</sup> <i>Lunda cirrhata</i>	.2 $\pm$ .2 (3.0)	.4 $\pm$ .5 (8.0)	.3 $\pm$ .4 (18.0)	.4 $\pm$ .5 (7.0)	3.9 $\pm$ 2.4 (6.0)

<sup>1</sup>Species that feed principally beneath the sea surface by diving or pursuit plunging.

<sup>2</sup>For correlation between density index and catch rate,  $P < 0.05$ ; Spearman's rank correlation.

TABLE 2.—The number of individuals by species caught in net meshes of various sizes (stretched).<sup>1</sup>

Species	Mesh size (mm)																
	37	42	48	55	63	72	82	93	106	112-115	118-121	130	138	157	179	204	233
Laysan albatross		2								2	1						
Northern fulmar										9			1				
Flesh-footed shearwater																	1
Short-tailed shearwater			1			1		1	14	106	11	15					1
Sooty shearwater		1			1		3	4	2	23	12	4	3	3	2	2	
Fork-tailed storm-petrel							1			11							
Common murre										1							
Thick-billed murre							2		1	25	2	1	1	1	1		
Ancient murrelet							1	1			1						
Cassin's auklet								1									
Horned puffin							1			8				2			
Tufted puffin								4	2	42	4	1	3	1			2
Least auklet										1							
Crested auklet							1			2	1						
Total	0	3	1	0	1	1	9	11	19	230	32	21	10	7	3	4	0
Tans set	162	162	489	495	495	495	495	495	495	7,303	3,035	674	495	495	155	162	27
Birds/tans set	0.00	0.019	0.002	0.00	0.002	0.002	0.018	0.022	0.038	0.031	0.011	0.031	0.020	0.014	0.019	0.025	0.00
$\bar{X}$ catch rate			<sup>2</sup> 0.003				<sup>3</sup> 0.020				<sup>4</sup> 0.026				<sup>3</sup> 0.018		

<sup>1</sup>Does not include thick-billed murre of *Hoyo Maru* set 17 or ancient murrelets of set 20; net retrieval was not observed.

<sup>2</sup>Significantly fewer than the other three classes ( $P < 0.01$ ; Sokal and Rohlf 1969:608).

<sup>3</sup>No significant difference in catch rates ( $P > 0.05$ ).

<sup>4</sup>Significantly higher than the other three classes ( $P < 0.05$ ).

definitions), all were entangled at least once and were also entangled deeper in the nets than just the upper meter (Good and Ainley unpubl. data). Only 3 (17%) of the other 18 species we observed at sea were caught in the nets. Almost all of these

feed at the surface by scavenging, dipping, or by shallow plunges; the 3 caught were the most abundant scavengers of the area: laysan albatross, northern fulmar, and fork-tailed storm-petrel. Direct observations of their behavior and examina-

tion of their stomach contents (Good and Ainley unpubl. data) indicated that entanglement occurred as they attempted to eat fish caught in the net. A much smaller percentage (ca. 5%) of shearwaters (pursuit plungers) were caught while eating entangled fish, but probably none of the diving species (murre, puffins, etc.) scavenged from the nets (confirmed by stomach contents).

#### Rates of Entanglement

We tabulated birds by the mesh size in which they were entangled (Table 2). Catches in 112-115 mm meshes were combined as were those in 118-121 mm meshes. Not included were birds caught by commercial boats because we were not sure that all specimens reached us. Catch rates for six mesh sizes <82 mm were negligible, but rates for 106-138 mm meshes, including those used in the commercial salmon fishery (121-138 mm) (Fredin et al. footnote 2) were statistically greater than for the other categories. In 157-233 mm meshes, with or without the 233 mm mesh—no birds caught and only 27 tans set—the rate was similar to that for 82-93 mm meshes. Based on those results, we excluded from further analysis birds caught with  $\leq 82$  mm meshes.

The number of birds caught per tan was directly proportional to the density of nettable species present at the netting locality ( $r = 0.7154$ ,  $P < 0.01$ ,  $t$ -test). The correlation was improved ( $r = 0.7604$ ) when catch rates were adjusted for the actual amount of time the nets were deployed (i.e., birds/tan per hour deployed). The correlation would probably be improved even more if density indices were adjusted for the detectability of birds. For instance, tufted puffins on the water in the outer third of the 300 m count zone would probably not have been seen, especially in rough seas. The difficulty in detecting puffins might account for the lack of correlation between density indices and catch rates in Table 1, where significant correlations existed for more easily observed species.

The facts that bird densities differed geographically (or oceanographically; Table 1) and that catch rates were proportional to bird density led us to look for geographic differences in catch rates. In the northern North Pacific, the mean number of birds caught per tan increased with latitude. Rates were lowest, varying 0.00-0.03 bird/tan, between lat. 39° and 43° N (Subarctic Front and the Transitional Domain); were slightly higher, 0.03-0.08, between lat. 44° and 48° N (Western

Subarctic Domain); and were highest, 0.04-0.51, between lat. 49° and 51° N (Alaskan Stream). In that part of the Bering Sea sampled, the number of birds caught per tan increased with decreasing latitude. In the central Bering Sea (Bering Sea Gyre) catch rates were low, ranging 0.01-0.05, and were higher at the gyre periphery. Farther south in the extreme periphery of the gyre, the Bering Current, catch rates ranged 0.04-0.16. These rates were consistent with the relative differences in bird densities in these oceanographic regions (Table 1). Greater bird densities in the Alaskan Stream and Bering Current were due to the more productive waters there and to closer proximity to the Aleutian Islands where murre, puffins, and several other nettable species breed. In fact, as a direct function of distance, within 200 nmi of the Aleutians catch rates varied logarithmically ( $P < 0.01$ ; Figure 2). Rates were especially high within 50-75 nmi of the islands, where most of the murre and puffins in net samples were breeding adults (based on the presence of incubation patches). Most of those caught in the Bering and Western Subarctic Gyres and Transitional Domains were immature.

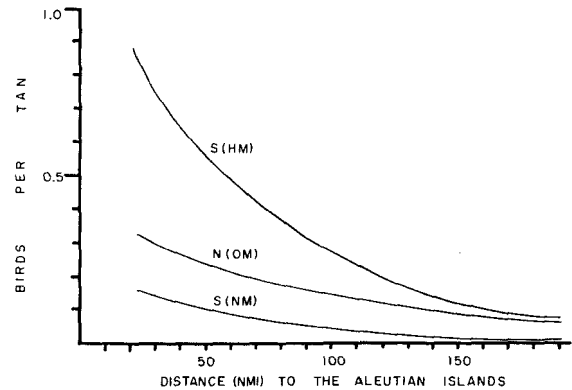


FIGURE 2.—Logarithmic relationships between bird catch rates and distance to the Aleutian Islands within 200 nmi, 1979: S(HM) = *Hoyo Maru* stations south of the islands ( $r = 0.9167$ ,  $P < 0.01$ ;  $y = 0.74 - 0.13 \ln x$ ), S(NM) = *Nojima Maru* stations south of the islands ( $r = 0.9186$ ,  $P < 0.01$ ;  $y = 0.36 - 0.07 \ln x$ ), and N(OM) = *Oshoro Maru* stations north of the islands ( $r = 0.9869$ ,  $P < 0.01$ ;  $y = 0.74 - 0.13 \ln x$ ); see Figure 1 for station localities.

#### Overall Seabird Mortality

The above estimates of catch rates, if applied to the commercial fishery, are minimal for two

reasons: most could be increased by >30% to account for the higher catch rates of nets with commercial size meshes (Table 2), and our estimates of commercial catch rates did not account for birds that dropped from the net before its retrieval. On the July cruise of *Hoyo Maru No. 67*, 3 shearwaters (of 6 caught) and 1 puffin (of 12 caught) dropped from the net when it was stretched taut in the retrieval process. On that cruise, 13% of the dead birds would not have been counted if only figures on the number of dead birds reaching the deck had been used as in other estimates of catch rates. Similarly, on cruises of the *Hokusei Maru* in 1978 and that part of the *Oshoro Maru* cruise south of the Aleutian Islands in 1979, 1 of 9 (11%) and 3 of 66 birds (5%), respectively, dropped out during net retrieval.

A valuable result of this study is the more realistic estimate of bird catch rates, compared with previous estimates (Sano 1978; King et al. 1979; Japanese Fishery Agency 1977 in DeGange<sup>3</sup>; DeGange footnote 3). Prior estimates agreed but were too low because they were based on research gear and the assumption that catch rates were the same regardless of mesh size, and they did not give enough attention to geographic differences in catch rates. They derived an overall mean value for birds caught per tan fished which dilutes considerably the high catch rates in certain areas. DeGange's (footnote 3) analysis, representative of earlier mortality estimates, derived a total of about 112,500 birds caught annually in the mothership fishery. We propose that a figure of 205,000, an increase of about 82%, is more realistic (Table 3). If our estimate were increased by an

additional 30% to adjust for the high catch rates of commercial meshes, the resultant figure of 266,500 birds is 136% higher.

The demonstration that bird catch rates increase logarithmically as distance to the Aleutian Islands decreases, and are generally higher in productive waters, is especially important. More observations are needed on catch rates in commercial nets to clarify the critical distance, but fishing at some distance within 50-75 nmi of the islands would severely reduce breeding populations of certain diving birds. This is precisely what happened when a salmon gill net fishery off Greenland was concentrated too near to murre breeding sites (Tull et al. 1972). In that fishery, 88% of the estimated 350,000-500,000 thick-billed murre caught per year were entangled in nets set <30 nmi from the coast. Other species, however, showed different distance-to-coast relationships; for example, 36% of the black guillemot, *Cepphus grylle*, were entangled <12 nmi from the coast, 80% of the greater shearwater, *Puffinus gravis*, were caught between 12 and 30 nmi, and 75% of the dovekie, *Plautus alle*, were caught between 12 and 60 nmi (50% at 30-60 nmi; Christensen and Lear (1976)).

In the North Pacific where the salmon driftnet fishery is much larger than the one in Greenland was, it is likely that gill netting has also been concentrated near bird breeding sites. In a sample of years for which data on the number of tans fished were available to us ( $n = 12$  during 1955-69 International North Pacific Fisheries Commission<sup>4</sup>), 44.4% of effort east of long. 170° E, or several million tans annually, was concentrated in the six 2° × 5° blocks (24 total blocks fished in that area) containing the western Aleutians. Such concentration of effort, coupled with marked geographic differences in bird catch rates, indicates the limitations in estimating the total seabird kill by using statistics averaged over broad areas as attempted by King et al. (1979). Their estimate of 5.0 million birds killed by the entire mothership fishery between 1952 and 1974, based on an average annual mortality of 250,000, is extremely low and should be at least doubled. After all, in the fishing area east of long. 170° E alone, we estimate that at least 4.1 million birds were killed in just the 12 yr mentioned above.

<sup>3</sup>DeGange, A. R. 1978. Observations on the mortality of seabirds in Japanese salmon gill nets made from the OSHORO MARU and HOKUSEI MARU, summer 1978. Unpubl. Rep., 37 p. U.S. Fish Wildl. Serv., Off. Biol. Serv., Anchorage, Alaska.

TABLE 3.—A comparison of bird catch in the 1978 mothership salmon fishery using two methods of catch rate estimation; the DeGange (text footnote 3) method is typical of all previous types of estimation.

2° N × 5° E Block	Tans fished <sup>1</sup>	Bird per tan		Total birds caught		
		DeGange	This report	DeGange	This report	Percent increase
50-165	34600	0.036	0.130	1,246	4,498	260
52-165	45800	.036	.130	1,649	5,954	260
48-170	250600	.040	.130	10,024	32,578	220
50-170	939500	.084	.130	78,918	122,135	60
52-170	281500	.053	.130	14,920	36,596	140
54-170	103400	.053	.038	5,480	3,929	-30
56-170	8900	.035	.038	312	338	10

<sup>1</sup>Source of data: International North Pacific Fisheries Commission (text footnote 4).

<sup>4</sup>International North Pacific Fisheries Commission. 1955-79. Catch statistics of Japanese mothership gillnet and land-based driftnet fisheries. Int. North Pac. Fish. Comm. Doc.

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## HISTOCHEMICAL INDICATIONS OF LIVER GLYCOGEN IN SAMPLES OF EMACIATED AND ROBUST LARVAE OF THE NORTHERN ANCHOVY, *ENGRAULIS MORDAX*

On the basis of histological criteria (O'Connell 1976), 8% of northern anchovy, *Engraulis mordax*, larvae from special net tows taken in the Southern California Bight in March 1977 were found to be in starving condition (O'Connell 1980). Almost three-quarters of the larvae that showed signs of starvation were concentrated in 4 of the 64 net tow samples. The present report compares the amount of glycogen in livers of additional larvae drawn from these four samples to that in the livers of larvae from samples taken in the same area, which contained robust larvae almost exclusively.

Glycogen, which is stored in the liver and transformed to glucose as needed to maintain an adequate blood sugar level, is the most immediately available of the three energy sources, glycogen, lipid, and protein (Love 1974). It is known to virtually disappear from the livers of many teleosts after only a few days of starvation (Black et al. 1966; Inui and Ohshima 1966; Bellamy 1968), but fish generally live long beyond the depletion of liver glycogen, maintaining the blood sugar level by gluconeogenesis (Love 1974; Cowey and Sargent 1979). However, there are also teleosts in which liver glycogen does not decline sharply at the onset of starvation, although gluconeogenesis does increase (Cowey and Sargent 1979). Thus abundance of liver glycogen cannot be considered a dependable indicator of starvation in teleosts, at least not for adult stages.

Postyolk-sac larval stages, which first exhibit stained liver glycogen about the time yolk is depleted, are more likely to show a drop in liver glycogen at onset of starvation. First feeding northern anchovy larvae die after only a few days of starvation (O'Connell 1976), indicating that reserves are limited. Lipid reserves, for example, are known to be negligible in early postyolk-sac herring and plaice larvae (Ehrlich 1974), and even at the relatively large size of 35 mm SL northern anchovy larvae survive starvation conditions for only 2 wk, on the average, during which time lipid reserves are severely depleted (Hunter 1976). Presumably liver glycogen declines sharply before lipid reserves are depleted in these early stages.

The estimates of glycogen reserves in the works cited above, and in many others, are derived from weight-based biochemical determinations, which