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MORTALITY OF SEABIRDS IN THE JAPANESE LAND-BASED GILLNET FISHERY FOR SALMON[1]

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Abstract. Mortality rates of seabirds in the Japanese land-based drift gillnet fishery for salmon were assessed from 413 gillnet sets made by Japanese research vessels in offshore areas used by the commercial fleet. Sixteen species of seabirds were recorded in nets. Shearwaters, primarily Short-tailed Shearwaters (*Puffinus tenuirostris*), and to a lesser extent Sooty Shearwaters (*P. griseus*), predominated in the catches, followed by lesser numbers of Tufted Puffins (*Fratercula cirrhata*) and Thick-billed Murres (*Uria lomvia*). Catch-rates of seabirds varied by oceanographic zone, with most being caught in oceanic waters north of the Subarctic Front. Approximately 151,000 seabirds were killed in the offshore component of the land-based fishery in 1977. Mortality was reduced to about 57,000 seabirds in 1987 because of a reduction in fishing effort. No estimates are available of seabird mortality in the nearshore component of the fishery. Mortality of seabirds in the land-based fishery is discussed with respect to other major drift gillnet fisheries in the North Pacific.

Key words: North Pacific Ocean; seabirds; drift gill nets; high-seas; entanglement; mortality.

INTRODUCTION

Drift gill nets used in fishing operations are known to kill a variety of non-target organisms, including various non-commercial fishes, seabirds, marine mammals, and sea turtles. Diving seabirds are particularly vulnerable to entanglement in fishing gear (Ainley et al. 1981, Carter and Sealy 1984, King 1984, Ogi 1984, Piatt and Reddin 1984, Piatt and Nettleship 1987, Atkins and Heneman 1987). Since 1952, two large drift gillnet fisheries for salmon have operated in the North Pacific Ocean: the Japanese mothership fishery and the Japanese land-based salmon fishery (Fredin et al. 1977). An estimated 95,000–250,000 seabirds were killed annually in the mothership fishery (Jones and DeGange 1988), but the magnitude of mortality in the land-based salmon fishery is not clear. In the early and mid 1980s, reported fishing effort by vessels of 40–90 metric tons in the land-based fishery was approximately equal to fishing effort in the mothership fishery (Shima 1985). Therefore, we suspected that seabird mortality in the land-based fishery would also be high. From a limited sample, Sano (1978) estimated that more than 160,000 seabirds may be killed annually in this fishery. Given the lack of information concerning mortality of seabirds in this fishery, we summarize data collected by both American and Japanese observers aboard Japanese research vessels that operated within the land-based fishery zone between 1977 and 1987.

DESCRIPTION OF THE FISHERY

The Japanese land-based salmon fleet operates within an irregular-shaped area in the northwestern North Pacific (Fig. 1). It is bounded on the east by 175°E, on the north by 44°N, on the west by Japan and the Japan Sea, and on the south by 38°N. The fishery begins each year in mid-May and extends until mid-July. Two categories of vessels make up the land-based salmon fleet: those vessels <7 metric tons and those 40–90 metric tons. The smaller vessels are restricted to fishing west of 153°E and make only 1–2 day trips from port. Little is known about seabird mortality in this component of the fishery. The larger vessels fish east of 153°E and make trips lasting from two weeks to one month (Fredin et al. 1977).

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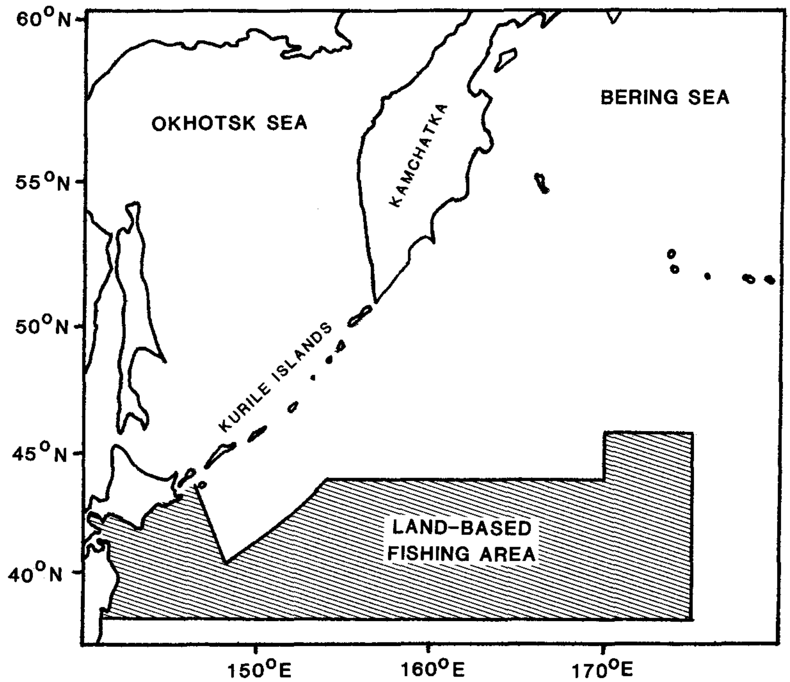

FIGURE 1. Area open to the Japanese land-based drift gillnet fleet for salmon.

The gear used by most of the larger vessels is a 15.0 km-long monofilament gill net made of 30, 37.5, or 47.5 m-long sections (tans). The tans are laced together to form a curtain that hangs from the surface to a depth of approximately 8 m. The dominant mesh size used is 115 mm (Fredin et al. 1977). Nets are set near dusk and retrieved near dawn. While fishing, the nets drift with the wind and currents and are located the following morning with the aid of attached lights, and radio and radar beacons.

The Japanese land-based salmon fleet differs from the Japanese mothership fleet in that each fishing vessel works independently and makes multiple trips to the fishing grounds from port. The mothership fleet, in contrast, stays at sea during the entire fishing season, and movements and fishing activity for the fleet are orchestrated by staff on the motherships.

METHODS

We summarize data on the incidental take of seabirds from 413 gillnet sets made by Japanese research vessels in the land-based fishing grounds between 1977 and 1987 (a set is defined as the deployment and retrieval of one gill net on one day). These data include 371 sets observed by Japanese biologists during 1977–1987 and 42 sets observed by U.S. biologists in 1979, 1984, and 1985. The largest subset of these data for any year is 295 sets in 1977. In contrast to commercial fishing vessels that used tans of unstandardized lengths, research vessels used nets made up of ≤130 tans (about 6.1 km) of 47.5 m each. Observers identified and tallied the number of birds caught in nets during retrievals. Nets on research vessels consisted of variable mesh-sizes, therefore, U.S. observers also quantified the amount of each mesh size fished at each station and the size of mesh in which birds were caught. We include here mortality data on nets of 24 mesh sizes ranging from 19–233 mm stretched diagonal mesh.

Seabirds caught incidentally in 23 gillnet sets in 1984 were sexed and aged. Sex was determined by examining the gonads, whereas aging criteria varied by species. Shearwaters with a bursa of Fabricius were classified as immature. Tufted Puffins were aged by plumage as adults, immatures and one-year-olds. Breeding status was determined by the presence or absence of incubation patches.

TABLE 1. Comparison of species-composition, catch-rates, and estimates of total mortality of seabirds killed in the Japanese land-based drift gillnet fishery.

Species	Percent of total birds caught		Catch-rate[a]	Catch-rate[b]	Estimated number of birds killed[c]	Estimated number of birds killed[d]
	1977	All years	1977	All years	1977	1987
Laysan Albatross	0.7	0.6	0.0003 (0.0063)	0.0002 (0.0042)	921	231
Northern Fulmar	1.1	1.4	0.0005 (0.0105)	0.0006 (0.0126)	1,536	694
Sooty Shearwater	1.3	4.5	0.0006 (0.0126)	0.0019 (0.0400)	1,843	2,197
Short-tailed Shearwater	30.6	33.1	0.0149 (0.3137)	0.0142 (0.2989)	45,883	16,418
Flesh-footed Shearwater	0.0	0.1	0.0000 (0.0000)	0.0001 (0.0021)	0	116
Unidentified shearwater	21.7	17.9	0.0106 (0.2232)	0.0077 (0.1621)	32,646	8,903
Fork-tailed Storm-petrel	1.3	1.1	0.0006 (0.0126)	0.0005 (0.0105)	1,843	578
Pomarine Jaeger	0.1	0.1	0.0001 (0.0021)	0.0001 (0.0021)	307	116
Common Murre	1.5	1.3	0.0007 (0.0147)	0.0005 (0.0105)	2,150	578
Thick-billed Murre	11.4	9.4	0.0056 (0.1179)	0.0040 (0.0842)	17,245	4,625
Pigeon Guillemot	0.3	0.2	0.0001 (0.0021)	0.0001 (0.0021)	307	116
Ancient Murrelet	0.2	0.7	0.0001 (0.0021)	0.0001 (0.0021)	307	116
Parakeet Auklet	4.7	3.9	0.0023 (0.0484)	0.0017 (0.0358)	7,079	1,966
Crested Auklet	0.1	0.1	0.0001 (0.0021)	0.0001 (0.0021)	307	116
Rhinoceros Auklet	0.3	2.7	0.0016 (0.0337)	0.0012 (0.0253)	4,929	1,387
Tufted Puffin	20.9	19.1	0.0102 (0.2147)	0.0082 (0.1726)	31,403	9,481
Horned Puffin	0.8	0.9	0.0004 (0.0084)	0.0004 (0.0084)	1,229	462
Unidentified bird	0.0	3.5	0.0000 (0.0000)	0.0015 (0.0316)	0	1,734

[a] Birds/tan (birds/km).
[b] Birds/tan (birds/km); mean catch-rate (all years) was calculated by multiplying the percent of total birds caught for each species by 0.043 birds/tan, which represents the best estimate of catch-rates for the fishery.
[c] Mean catch-rate × 146,265 km fished in 1977.
[d] Mean catch-rate × 1,156,224 tans fished in 1987.

Catch-rates of seabirds were expressed as birds caught/tan of gear. To compare geographic differences in catch rates, we divided the land-based fishing grounds into three regions on the basis of oceanography: 1) Confluence waters, representing the large mixing area of the warm-water Kuroshio Current and the cold-water Oyashio Current, including all waters west of 155°E, 2) Frontal waters, represented by the broad Subarctic Frontal Zone east of 155°E and between 38°N and 42°N, and 3) Subarctic waters, which include cooler waters east of 155°E and north of 42°N (Favorite et al. 1976, Roden 1972). In addition, we compare catch rates of seabirds by whole latitude blocks (e.g., 42°N–43°N, 43°N–44°N) within the Subarctic region, the area in which most of the data were collected. To examine differences in catch-rates of various mesh-sizes, we divided catch-rate data for the 24 mesh sizes used on the research vessels into four groups of six and tested for significance among groups. We used a Kruskal-Wallis one-way analysis of variance (ANOVA) and a non-parametric multiple comparison test (Siegel and Castellan 1988) in these analyses. Estimates of mortality were calculated for 1987 by multiplying the number of standardized tans fished by the large vessels of the land-based fleet by a catch statistic derived from all data. Mortality in 1977, a year in which reported fishing effort was not standardized (i.e., unknown amounts of 30, 37.5, and 47.5 m-long tans), was estimated by calculating the mean number of birds killed/km of gear and multiplying that by the total estimated km fished in 1977. Total km fished in 1977 was estimated by multiplying the number of fishing operations by 15 km (the maximum allowable).

RESULTS

COMPOSITION OF THE INCIDENTAL CATCH OF SEABIRDS

A total of 2,204 seabirds of 16 species was killed in the 413 gillnet sets. Shearwaters, primarily Short-tailed Shearwaters, predominated in the catch in terms of percent of total birds killed and birds/tan for both 1977 and for the entire data set, followed by Tufted Puffins and Thick-billed Murres (Table 1). Some identifications made by untrained Japanese observers in 1977 were suspect and were grouped into general taxonomic categories where appropriate (e.g., shearwater spp., murre spp., etc.).

All 202 Short-tailed Shearwaters examined in 1984 were immature and the sex ratio was sig-

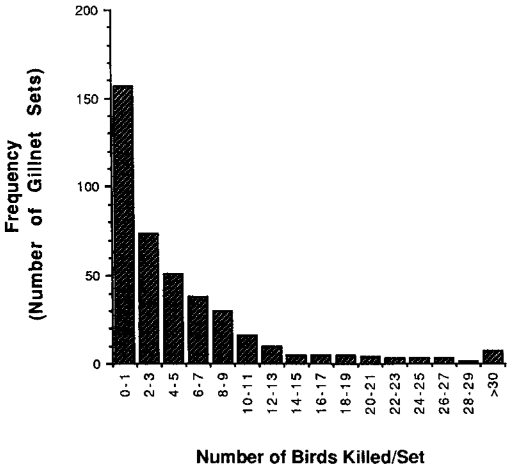

FIGURE 2. Number of seabirds killed per set in 413 gillnet sets made by Japanese research vessels in 1977–1987.

nificantly unbalanced: 132 (65%) were females and 69 (34%) were males (χ^2 = 20.28; df = 1; P < 0.05). Tufted Puffins taken in the land-based fishery were predominantly one-year old (67.8%) or sub-adults (28.6%) and only one of the 28 birds examined was an adult. Of 19 Tufted Puffins that were sexed, 12 were female and seven were male.

VARIATION IN THE CATCH-RATES OF SEABIRDS

The number of birds killed in each set ranged from 0 to 109, but 11 or fewer birds were caught in 88% of the sets (Fig. 2). Catch-rates of seabirds were highly variable, ranging from 0.00 to 0.83 birds/tan. For the 1977 data, an average of 0.05 birds/tan (1.03 birds/km) were killed (SD = 0.08; n = 295; CV = 161.78). Catch-rates for all years combined were similar ($\bar{x}$ = 0.04; SD = 0.76; n = 413; CV = 177.63, 0.91 birds/km).

Catch-rates for all species of seabirds combined differed among oceanographic regions (Kruskal-Wallis test; χ^2 = 29.47, df = 2, P < 0.001) and were significantly higher in Subarctic waters than in either Confluence waters or Frontal waters (nonparametric multiple comparison test, P < 0.05; Fig. 3). Catch-rates of individual species of seabirds also varied by oceanographic region. For example, catch-rates of Tufted Puffins were higher in Subarctic waters than either Confluence or Frontal waters (Kruskal-Wallis test; χ^2 = 27.14; df = 2; P < 0.001; nonparametric multiple comparison test, P < 0.05). Murres were caught only in Subarctic waters. Catch-rates of Short-tailed Shearwaters also tended to be higher in Subarctic waters but not significantly so (Kruskal-Wallis test; χ^2 = 3.71; df = 2; P = 0.160). In contrast, catch-rates of Sooty Shearwaters (*P. griseus*) were higher in Frontal waters and Confluence waters than in Subarctic waters (Kruskal-Wallis test; χ^2 = 12.91; df = 2; P = 0.002; nonparametric multiple comparison test, P < 0.05). In Subarctic waters, where most of the data were collected, catch-rates of seabirds tended to increase with latitude (Kruskal-Wallis test; χ^2 = 16.87; df = 5; P = 0.005; Fig. 4). Temporal differences in catch-rates were not observed.

Mean catch-rates of seabirds in nets of research vessels varied with mesh size (Table 2), as suggested by Ainley et al. (1981). Catch-rates were higher in meshes 91–121 mm than in those smaller and larger (Kruskall-Wallis test; χ^2 = 12.91, df = 3, P < 0.005, nonparametric multiple comparison test). Table 2 suggests that catch-rates of seabirds began to increase in meshes of 72 mm and 82 mm. The range of mesh-sizes with the highest catch-rates included 115 mm, which is the predominant mesh-size used in the commercial land-based fishery (Fredin et al. 1977).

ESTIMATES OF MORTALITY

Fishing effort for the larger vessels in the land-based fishery has decreased steadily from more than 19,000 vessel-days in 1965 to slightly more than 3,000 vessel-days in 1987 (Fig. 5). More than 6.9 × 10^6 tans of net (>295,000 km)/season were fished in the early 1960s compared with about 1.1 × 10^6 tans (52,250 km)/season in 1987. The number of vessels of more than 7 tons that held fishing permits also declined from more than 374 ships to 150 ships during the same period.

Estimating mortality of seabirds in the land-based fishery depends upon accurate reports of fishing effort. Before 1984, all data on fishing effort were in unstandardized tans, i.e., it was impossible to determine how many tans of 30.0, 37.5, or 47.5 m were fished. Therefore estimates of mortality, in this case 182,231 ± 33,471 (±95% CI), based on birds/tan (0.05) and total tans of effort for 1977 (3,719,000) were subject to error. We calculated an alternative estimate based on 1.03 birds/km and an estimate of 146,265 km of net fished in 1977. That estimate of 150,653 is lower than the other estimate of

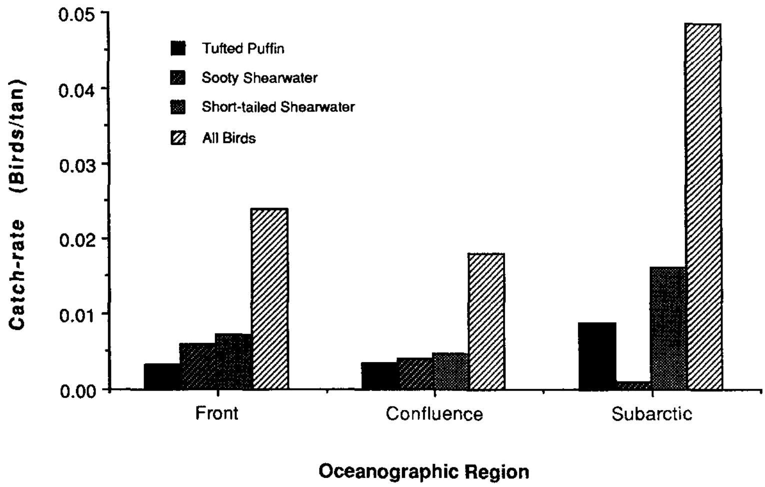

FIGURE 3. Mean catch-rates of seabirds by oceanographic region in 413 gillnet sets made by Japanese research vessels in 1977–1987.

182,231 but still within its 95% CI. Assuming that our overall mean catch-rate of 0.04 birds/tan (0.91 birds/km) is a reliable estimate of mortality in other years, then in 1987 when 1,156,224 standardized tans were fished, about 56,654 ± 10,400 seabirds were killed. Using the same general estimate of catch-rate suggests that more than 268,000 seabirds may have been killed in 1965 when more than 295,000 km of net were fished. Based on historical data on fishing effort and our estimates of catch-rates, we estimate that more than eight million seabirds have been killed in the large-vessel component of the land-based fishery since its inception in 1952.

We were unable to estimate seabird mortality in the small-vessel component of the fishery because effort data were unavailable. During the 1960s, 1,200–1,500 small vessels fished in the land-based fishing grounds but this number had decreased to 832 vessels by 1977 (Fredin et al. 1977).

DISCUSSION

Sano (1978) estimated that 167,000 seabirds were killed in the large-vessel component of the land-based fishery in 1977 but we do not know how Sano estimated fishing effort. This estimate falls within the 95% confidence interval of our estimate of mortality for the same year using unstandardized effort data.

We recognize three factors which affect the accuracy of our estimates of mortality. First, the data are unstratified with respect to location and season. Densities of nettable species in the North Pacific vary markedly by season and with oceanographic conditions (Wahl 1978, Ainley et al. 1981, Hunt et al. 1981, Gould et al. 1982, Gould 1983, Day, unpub. data). In the Japanese mothership fishing zone, catch-rates of seabirds declined logarithmically with distance away from the Aleutian Islands and were positively correlated with densities of nettable species present in

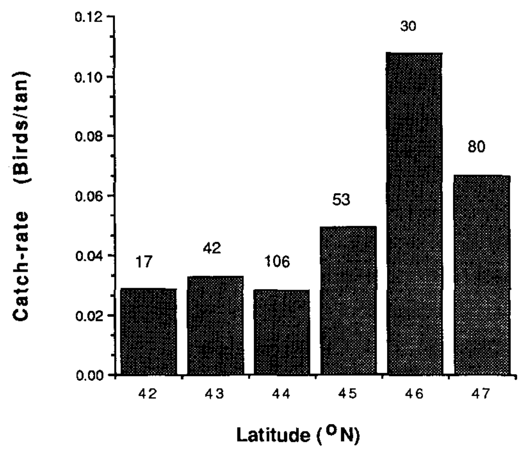

FIGURE 4. Mean catch-rates of seabirds by whole latitude block in the Oceanic region of the land-based fishing grounds. Numbers above columns are number of gillnet sets.

TABLE 2. Catch-rates of seabirds in nets of various mesh sizes.

	Mesh size (mm)	Number of tans fished	Number of birds caught	Mean catch-rate	
				(Birds/tan)	(Birds/tan/group)
Group 1	19	64	0	0	0.002
	22	64	0	0	
	25	78	0	0	
	29	204	0	0	
	33	257	2	0.008	
	39	359	0	0	
Group 2	42	232	3	0.013	0.018
	48	443	1	0.002	
	55	427	1	0.002	
	63	427	2	0.004	
	72	427	15	0.035	
	82	427	21	0.049	
Group 3	93	427	54	0.126	0.075**
	106	427	14	0.033	
	112	500	7	0.014	
	115	4,747	472	0.099	
	118	500	8	0.016	
	121	2,267	114	0.050	
Group 4	130	1,324	49	0.037	0.029
	138	419	16	0.038	
	157	419	10	0.024	
	179	338	5	0.015	
	204	338	5	0.015	
	233	75	0	0	

** Significantly different than other groups (Kruskal-Wallis test; $\chi^2 = 12.91$; df = 3; $P < 0.005$, nonparametric multiple comparison test, $P = 0.05$; Siegel and Castellan 1988).

the immediate area (Ainley et al. 1981). We found that catch-rates of seabirds were highest in Subarctic waters and within that region, catch-rates were highest in the northernmost latitude blocks, reflecting higher densities of nettable species. Ogi (1984) argued that estimating mortality using average catch-rates without accounting for seasonal effects will result in an overestimate of total mortality because catch-rates of seabirds will decrease on the fishing grounds as populations become depleted through fishing mortality. This argument assumes that seabird populations in the fishing area are static, which is unlikely. Although we did not observe temporal differences in catch-rates, they were observed in the mothership fishery, presumably as a result of changes in seabird numbers (DeGange, unpub. data).

Second, with the exception of the 45 gillnet sets observed by U.S. observers, these estimates of mortality do not account for seabirds that drop from the net prior to and during retrieval. Ainley et al. (1981) estimated that 5–13% of the seabirds caught in nets of research vessels drop out during retrieval. In contrast, usually less than 2% of the birds fall from the nets of commercial high-seas salmon gillnet vessels during retrieval (DeGange et al., unpub. data).

Third, our estimates of mortality do not account for higher catch-rates of seabirds in meshes used exclusively by commercial vessels. Our data indicate that catch-rates of seabirds in meshes 93–121 mm are approximately 0.06 birds/tan, which is about 13% higher than overall mean catch-rates from research vessels in the land-based fishing zone. Using a similar analysis, Ainley et al. (1981) suggested that catch-rates of seabirds from research vessels should be increased by 30% to account for higher catch-rates in commercial mesh-sizes. Our more conservative estimate of 13% would raise the 1987 estimate of mortality from 56,654 seabirds to 64,019 seabirds.

It is difficult to assess the impact that the land-based fishery has on seabird populations in the North Pacific. Most of the larger vessels fish in a large geographic area far removed from land where catch-rates are relatively low. We agree with Ogi (1984) that the populations of many species of seabirds in the high-seas salmon fishing areas of the North Pacific probably originate from many colonies in the Pacific Rim, including Japan, the Soviet Union, and Alaska. Thus, impacts to seabirds from any one colony as a result of incidental take in the oceanic component of the fishery probably are negligible.

However, the Japanese operate three other driftnet fisheries on the high-seas of the North Pacific: the salmon mothership fishery operating north of the land-based zone which is now relatively small in size (Anonymous 1989, DeGange et al., in press), the squid driftnet fishery, which operates in the central North Pacific both north and south of the Subarctic Front (Shima 1985, Anonymous 1989), and the large mesh fishery for billfish and albacore (*Thunnus alalunga*) which broadly overlaps with the squid fishery (Anonymous 1989). Both Korea and Taiwan also operate large drift gillnet fisheries for squid in the North Pacific (Chen 1985, Gong 1985, Anonymous 1989) and the Taiwanese also operate a large mesh fishery for billfish and albacore (Anonymous 1989).

Collectively the fishing vessels in these fisheries deploy a staggering quantity of fishing gear each year. The combined squid fisheries alone set an estimated 2,850,000 km of net each year (DeGange et al., in press). There are no estimates of mortality of seabirds for the Japanese and Taiwanese large-mesh fisheries. In the early-mid 1980s the Japanese mothership fleet killed up to 250,000 seabirds each year (Jones and DeGange 1988). That fleet was excluded from fishing in the U.S. Exclusive Economic Zone in 1988 and the fleet was cut markedly in size, presumably reducing the number of seabirds killed each year. Losses of seabirds in the Japanese, Korean and Taiwanese squid fisheries are poorly known. Preliminary estimates of mortality, based on limited amounts of data, range from 875,000 to over 1,660,000 seabirds (Anonymous 1989, DeGange et al., in press). A joint U.S., Canadian, and Japanese observer program in the squid fisheries will better define the levels of mortality in coming years. Clearly, assessing the collective impacts to seabirds of all high-seas drift gillnet fisheries awaits more detailed information from the squid fleets.

The impacts of the nearshore, small-vessel component of the land-based fishery on populations of seabirds breeding on coastal islands of Japan and in the southern Kurile Islands are unknown, but potentially more serious than the large-vessel component. Coastal gillnet fisheries can be devastating to local seabird populations (Tull et al. 1972, Christensen and Lear 1977, Atkins and Heneman 1987, Piatt and Nettleship 1987, Takekawa et al., in press). Sano (1978) estimated that 18,000–60,000 seabirds were killed annually in nets set by small vessels in the Japanese land-based fishery. It is likely that many of the birds killed in this portion of the fishery were breeding adults from local colonies. In potential jeopardy are colonies of Common Murres (*Uria aalge*), Spectacled Guillemots (*Cepphus carbo*), Japanese Murrelets (*Synthliboramphus wumizusume*), Rhinoceros Auklets (*Cerorhinca monocerata*), and Tufted Puffins, some of which are already in decline (Hasegawa 1984). There are thousands of other small fishing vessels in coastal Japan that use gill nets to catch a variety of schooling fish (DeGange et al., in press). Mortality of seabirds in those fisheries are unquantified.

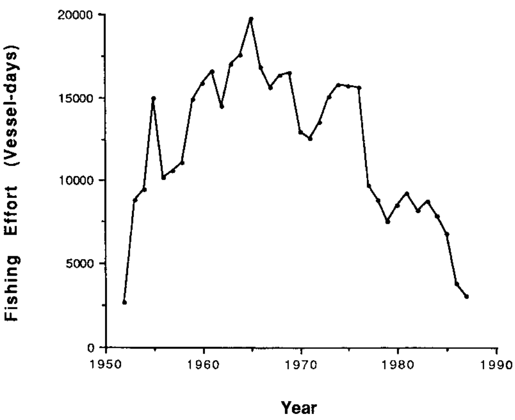

FIGURE 5. Changes in fishing effort since the inception of the large-vessel, offshore component of the Japanese land-based drift gillnet fishery for salmon.

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