Losses of seabirds in gill nets in the North Pacific

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Abstract

Existing knowledge on high-seas and coastal gillnet fisheries known to kill seabirds in the North Pacific is summarized. Recent estimates suggest that high-seas gillnet fisheries may have taken more than 500 000 seabirds in 1990. The majority of birds taken in those fisheries were Sooty *Puffinus griseus* or Short-tailed *P. tenuirostris* shearwaters. A recent analysis of impacts of those fisheries suggests that both shearwater populations may be declining slightly, although overall populations remain large. Impacts on seabirds of gillnet fishing in coastal waters are poorly known, except in California. Incidental mortality of seabirds in coastal gillnet fisheries may be adding additional stress to populations already compromised by habitat destruction and oil spills. Local populations of Marbled Murrelets *Brachyramphus marmoratus*, Common Murres *Uria aalge*, and Japanese Murrelets *Synthliboramphus wumizusume* may be particularly vulnerable to coastal gillnet fisheries. United Nations General Assembly Resolution 44/225 called for a moratorium on high-seas gillnet fishing by 30 June 1992. Japan has complied and Korea and Taiwan will comply with the moratorium.

Résumé

L'étude résume l'information existante sur les pertes d'oiseaux marins dues à la pêche au filet maillant, en haute mer et le long des côtes, dans le Pacifique Nord. Selon les estimations récentes, les pêcheurs hauturiers auraient capturé plus de 500 000 oiseaux marins dans leurs filets maillants, en 1990. La plupart de ces oiseaux étaient des Puffins fuligineux *Puffinus griseus* et des Puffins à bec mince *P. tenuirostris*. Une analyse récente des effets de la pêche indique un léger affaissement des populations affectées, qui demeurent néanmoins imposantes. Sauf pour la Californie, on connaît peu les effets de la pêche au filet maillant sur les oiseaux marins, dans les eaux littorales. Les prises fortuites dans les filets maillants constituent peut-être un stress supplémentaire que doivent subir les populations d'oiseaux marins, déjà éprouvées par la destruction de l'habitat et les déversements d'hydrocarbures. Les populations locales d'Alques marbrées *Brachyramphus marmoratus*, de Marmettes de Troïl *Uria aalge* et d'Alques du Japon *Synthliboramphus wumizusume* sont probablement très vulnérables à la pêche au filet maillant, dans les eaux littorales. La résolution n° 44/225 de l'Assemblée générale des Nations Unies prévoit un moratoire de la pêche au filet maillant en haute mer, à partir du 30 juin 1992. Le Japon a respecté et la Corée et Taiwan respecteront ce moratoire.

1. Introduction

Mortality of seabirds in coastal and high-seas gillnet fisheries has been one of the most pressing conservation problems affecting marine birds. Because many of the gillnet fisheries that have been identified as killing marine birds have changed frequently in size, we provide a current overview of the problem, and review the status of the coastal and offshore fisheries known to kill marine birds in the North Pacific.

2. High-seas gillnet fisheries

In fall 1991, the Japanese agreed to cease drift gillnet fishing on the high seas by the end of 1992. Korea and Taiwan, which also operate large drift gillnet fisheries in the North Pacific, promised to follow suit. Despite the termination of these fisheries, it is important to document them in this account, as they represent important case histories of substantial waste of wildlife resources.

2.1. Japanese mothership salmon fishery

The Japanese mothership fishery for salmon has operated in the North Pacific Ocean since 1952. The fishery began with three motherships and 57 catcherboats, peaked in size in 1959 with 16 motherships and 460 catcherboats, and decreased to a present fleet size of one mothership and about 56 catcherboats. The fishing area of the mothership fleet has fluctuated in size since the fishery's inception. Before 1978, the fleet fished in a large, irregularly shaped area between 46°N and 60°N, encompassing most of the western Aleutian Islands. The area open to the mothership fleet was reduced in 1978 to a narrow band north of 46°N between 165°E and 175°E but still extending east to 175°W in international waters in the Bering Sea (Jones and DeGange 1988). Most fishing occurred within the U.S. Exclusive Economic Zone (U.S. EEZ), particularly in waters southeast of the westernmost Aleutian Islands (DeGange et al. 1985). The mothership fleet was excluded from fishing in the U.S. EEZ in 1988 because of the inability of the Japanese to obtain a permit to incidentally take marine mammals in the course of their fishing operations. Most recently it operated in international waters south of the western Aleutian Islands, and in international waters in the Bering Sea.

Data on the incidental take of seabirds in gill nets of the mothership fishery were gathered by U.S. observers from 1981 through 1987, when about 6% of the gillnet sets made in the U.S. EEZ each year were monitored.

Twenty-three species of seabirds are known to have been killed in gill nets of the mothership fishery (DeGange et

Table 1
Most recent data from high seas drift gillnet fisheries in the North Pacific

Fishery	Fishing effort, km/yr	Catch rate, birds/km	Estimated annual mortality	Major species affected[a]
Japanese mothership				
1981–1987[b]	58 300–137 000	0.60–2.30	32 000–250 000	STSH, TUPU, HOPU
1989[c]	15 823	0.60–1.10[d]	9500–17 400	CRAU, TBMU
Japanese land-based				
large vessel – 1987	52 250	0.80	56 000[e]	STSH, TUPU, TBMU
small vessel	Unknown	Unknown	18 000–60 000[f]	Unknown
Squid drift gill net	2 850 000	0.01–0.20	875 000[g]	SOSH, STSH, TUPU, HOPU, LAAL
Large mesh gill net	Unknown	Unknown	Unknown	Unknown
Canadian exp. gill net	504–4417	0.09	[h]	SOSH, RHAU

[a] STSH=Short-tailed Shearwater, SOSH=Sooty Shearwater, TUPU=Tufted Puffin, HOPU=Horned Puffin, TBMU=Thick-billed Murre, RHAU=Rhinoceros Auklet, CRAU=Crested Auklet, LAAL=Laysan Albatross.
[b] Four motherships and 172 catcherboats fished in 1981–1986; three motherships and 126 catcherboats fished in 1987. Estimates from DeGange et al. (1985) and Mendenhall (unpubl. data).
[c] One mothership and 56 catcherboats fished in 1989.
[d] Calculated from six sets made south of the U.S. EEZ in 1982 and eight sets made south of the U.S. EEZ in 1984 (DeGange et al. 1985).
[e] From DeGange and Day (1991).
[f] Estimated by Sano (1978) for 1977 fishing season.
[g] From Anonymous (1989).
[h] Estimate of mortality not calculated because no commercial fishery took place (see Jamieson and Heritage 1987, 1988).

al. 1985; Jones and DeGange 1988). Short-tailed Shearwaters *Puffinus tenuirostris* made up more than 50% of the incidental catch of seabirds during most years and in 1983 made up over 70% of the incidental catch (DeGange et al. 1985). Tufted Puffins *Fratercula cirrhata* averaged slightly more than 20% of the total take, followed by Horned Puffins *F. corniculata*, Crested Auklets *Aethia cristatella*, and Thick-billed Murres *Uria lomvia*. Most of the alcids taken in the offshore portion of the fishery were juveniles or subadults. Catches of breeding alcids were highest when catcherboats fished close to the Aleutian Islands. Of all the breeding seabirds, only Tufted Puffins and Crested Auklets were caught regularly.

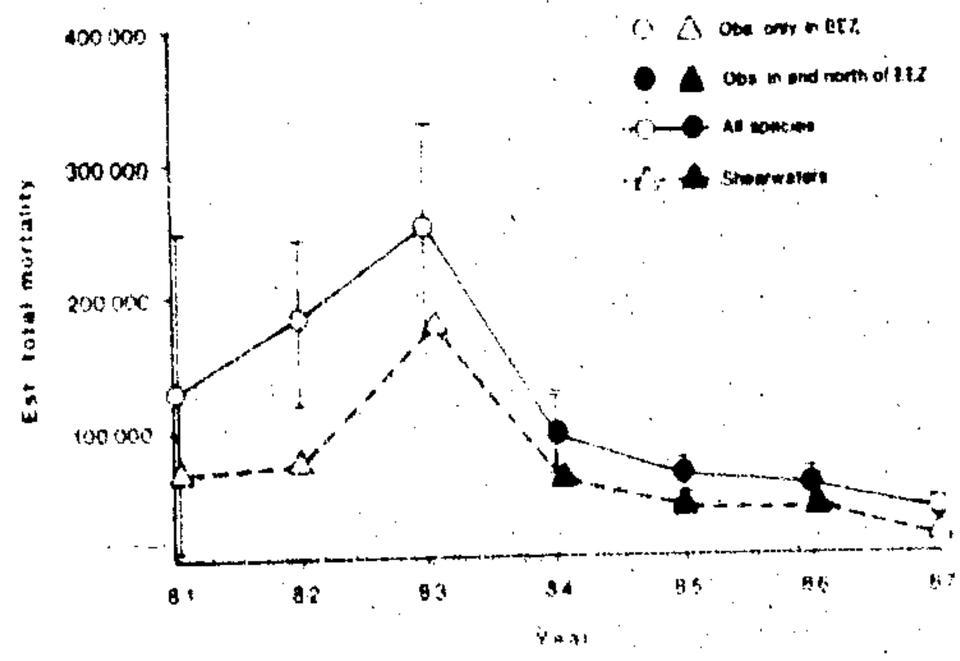
The number of seabirds killed per set ranged from 0 to 457, but most gill nets caught only a few birds. Mean catch rates were highly variable, both among years and among geographic areas. Catch rates for all birds caught in the U.S. EEZ were as high as 30.5 birds/km for individual sets and averaged from 0.6 birds/km in 1987 to 2.3 birds/km in 1983 (Table 1). The high total mortality in 1983 was the result of an unusually high catch rate of Short-tailed Shearwaters (Fig. 1). Catch rates also varied geographically, being highest within the U.S. EEZ south of the Aleutian Islands and lowest in the deep Bering Sea basin.

Total mortality of seabirds varied with year and effort. For the period 1977–1981, when four motherships and 172 catcherboats were in operation, estimates of mortality based on data from Japanese research vessels varied from 128 000–188 000 seabirds (Ogi 1984) to 266 500 (Ainley et al. 1981). In 1981–1984, estimated mortality based on data from U.S. observers varied from about 99 000 to 250 000 seabirds and declined thereafter to 32 000 seabirds in 1987 (Fig. 1), a year of comparatively little fishing effort. Because of further reductions in fishing effort in 1988 and 1989, seabird mortality was reduced even lower, perhaps to 17 000 or fewer seabirds (DeGange, unpubl. data). Ogi et al. (in press) estimate that 12 225 seabirds were killed in this fishery in 1990. The mothership fishery ceased operation in 1991.

2.2. Japanese land-based fishery for salmon

The Japanese land-based fishery for salmon is less well known than the mothership salmon fishery, but both have operated in the North Pacific since 1952. The land-based

Figure 1
Mortality of seabirds in the Japanese mothership salmon fishery, 1981–198



fishery operates in an irregularly shaped region bounded by 174°E, 44°N, 38°N, and Japan and the Japan Sea.

The only information available on the land-based fishery comes from 413 gillnet sets made from Japanese research vessels between 1977 and 1987 (DeGange and Day 1991). Sixteen species of seabirds were recovered. Short-tailed Shearwaters were most frequently taken and constituted 33% of the recorded mortality. Tufted Puffins and Thick-billed Murres, and Sooty Shearwaters *Puffinus griseus*, constituted 20% and 9% of the total, respectively.

The number of birds killed in each set varied between 0 and 109. Catch rates over the 10-year period ranged from 0 to 16 birds/km and averaged 0.8 birds/km (Table 1). Catch rates of seabirds for all species combined varied by oceanographic region and were significantly higher in subarctic waters north of 42°N than in subarctic front waters (38°N–42°N) or waters in the Oyashio Current–Kuroshio Current confluence (DeGange and Day 1991). Catch rates of individual species also varied with oceanographic region. For example, catch rates of Tufted Puffins were highest in subarctic waters, whereas catch rates of Sooty Shearwaters were highest in frontal waters (DeGange and Day 1991).

Both the size of the fleet and fishing effort of the large-vessel component of the land-based fishery peaked in the mid-1960s at 374 vessels, and more than 295 000 km of gear was fished. In 1989, the last year for which we have data, 156 vessels fished about 39 060 km of gear. Based on catch statistics and fishing effort, DeGange and Day (1991) estimated that in the mid-1960s more than 260 000 seabirds were killed annually. In contrast, mortality in 1989 was about 31 250 seabirds, reflecting reduced fishing effort. Sano (1978) estimated that seabird mortality in the small-vessel component of the fishery was 18 000–60 000 seabirds in 1977. Ogi et al. (in press) estimate that the large- and small-vessel components of the fishery took 57 232 and 53 155 seabirds, respectively, in 1990.

2.3. Large-mesh driftnet fishery

The large-mesh driftnet fishery of Japan dates back to 1905 when a fleet of sailing vessels fished for bluefin tuna *Thunnus thynnus* off Hokkaido. The fleet grew to 258 vessels by 1929 and disappeared by 1940 with decline of the bluefin tuna stock (Anonymous 1989). The fishery was revived following World War II and increased rapidly in size and area fished. During the 1970s and early 1980s, the Japanese large-mesh fishery continued expanding from coastal Japan to the central and eastern North Pacific. During the 1970s, the principal targets of the fishery were striped marlin *Tetrapterus audax* and broadbill swordfish *Xiphias gladius*. As the fishery expanded, it increasingly targeted on albacore *T. alalunga*. In 1975, the Fisheries Agency of Japan established restrictions on the length of net and mesh sizes for vessels greater than 10 t. Currently, the monofilament nets are a maximum of 12 km long and no more than 10 m deep. The size of the fleet peaked in 1982 at 717 vessels and declined by 1988 to 459 vessels. Currently only 70 vessels are licensed to fish (Nakano et al., in press).

There are limited data on the incidental take of seabirds in large-mesh driftnets. Ogi et al. (in press) report that 3563 seabirds of 13 species were taken in the Japanese fishery during the 1990–91 season. Most prominent of the species were the Black-footed Albatross *Diomedea nigripes*, Laysan Albatross *D. immutabilis*, Northern Fulmar *Fulmarus glacialis*, and Sooty Shearwater. Johnson et al. (in press) estimate that 5639 seabirds were taken in the same fishery. Ogi et al. (in press) also report that the Taiwanese large-mesh fishery took 1592 seabirds during the 1990 fishing season. The large mesh sizes used in this fishery may limit the take of seabirds (Ainley et al. 1981; DeGange and Day 1991).

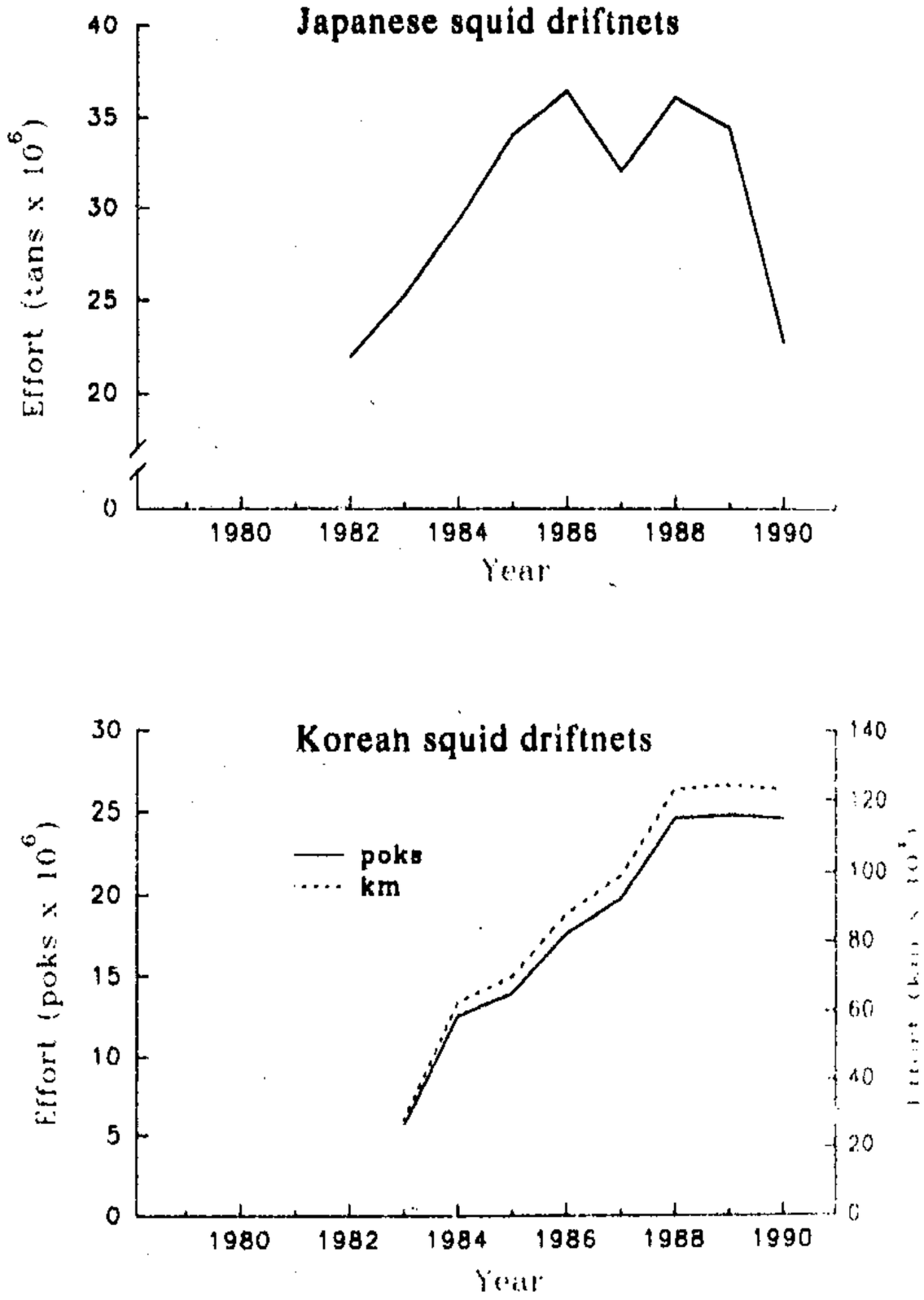
2.4. Squid driftnet fisheries of Japan, Korea, and Taiwan

The fishery for neon flying squid *Ommastrephes bartrami* refers to three fisheries in the subtropical, transitional, and frontal North Pacific, east of 170°E. The Japanese initiated the fishery in 1978 and during its brief unregulated phase it grew rapidly, to more than 1000 vessels by 1980 (Court 1981; Yatsu 1990). Korea and Taiwan began their own squid driftnet fisheries in 1979 and 1980, respectively (Gong et al. 1985; Yatsu 1990).

Data on fishing effort are best known for the Japanese fishery (Yatsu et al., in press). Effort, in deployed tans[1] of gear, increased from a low of 21.9 million tans in 1982 to a high of 36.4 million tans in 1986; maximum effort occurred from 1985 to 1989 (Fig. 2). In 1989 and 1990 the fishing effort was

[1] High-seas gill nets are made up of smaller units of nets called tans; tans vary in length from 30 to 50 m.

Figure 2
Fishing effort in kilometres, tans, and poks (Korean equivalent of tans) for the Japanese and Korean squid drift gillnet fleets



standardized at 50 m per tan. In those years fishing effort was 1.72 million km and 1.14 million km, respectively (Yatsu et al., in press).

Data on fishing effort for the Taiwanese fleet are unavailable. However, the size of the fleet varied from 12 vessels in 1980 to 179 vessels in 1988. One hundred and thirty-eight vessels operated in 1990, the most recent year of data (Yeh and Tung, in press).

The Korean fleet varied in size from 14 vessels in 1980 to 157 vessels in 1989; fleet size was 142 vessels in 1990. Fishing effort from 1983 to 1990 varied from 281 700 km in 1983 to 1.24 million km in 1989 (Fig. 2) (Gong et al., in press).

Through 1987, data collected from research and commercial squid vessels produced seabird catch rates between 0.01 and 0.20 birds/km (Day and DeGange, unpubl. data). In comparison, an average of 0.80 birds/km were caught in the Japanese land-based salmon fishery and 0.6–2.3 birds/km were caught in the Japanese mothership fishery (Table 1). Based on this limited data set an estimate of annual mortality of seabirds in the combined squid driftnet fisheries of 875 000 seabirds has been proposed with nearly half of the estimated mortality being Sooty Shearwaters (Table 2). Short-tailed Shearwaters and Tufted Puffins also formed a large proportion of the estimated catch. Worst-case estimates of mortality exceeded 1.66 million seabirds annually, with Sooty Shearwaters accounting for 70% of the total (Day and DeGange, unpubl. data).

Table 2
Estimated annual mortality of seabirds in high-seas squid driftnets (from Day and DeGange, unpubl. data)

Species	Estimated total annual mortality
Black-footed Albatross	2 (00) ± 3 (00)
Laysan Albatross	53 (00) ± 58 (00)
Flesh-footed Shearwater	6 (00) ± 8 (00)
Buller's Shearwater	25 ± 49
Sooty Shearwater	427 (00) ± 312 (00)
Short-tailed Shearwater	100 (00) ± 10 (00)
Unidentified shearwater	45 (00) ± 54 (00)
Tufted Puffin	123 (00) ± 124 (00)
Horned Puffin	49 (00) ± 53 (00)
Unidentified birds	70 (00) ± 72 (00)
Total	875 (00) ± 786 (00)

Beginning in 1989, Canada, Japan, and the United States initiated a cooperative observer program, and in 1990 Korea, the United States, and Taiwan began cooperative observer programs (Fitzgerald et al., in press). These programs resulted in the refinement of mortality estimates in the squid fisheries. Johnson et al. (in press) estimate that 333 329, 69 319, and 8177 seabirds were taken in the Japanese, Korean, and Taiwanese fisheries in 1990, respectively. Dark shearwaters made up more than 90% of the total, and 95% of those identified shearwaters were Sooty Shearwater. Other species that constituted a noteworthy portion of the mortality were Laysan and Black-footed Albatrosses, Northern Fulmars, Buller's Shearwaters *P. bulleri*, and Fork-tailed Storm-Petrels *Oceanodroma furcata*. Ogi et al. (in press) estimate that the 1990 bycatches of seabirds in the Japanese, Korean, and Taiwanese fisheries were 294 946, 73 423, and 4056 seabirds, respectively. In all three fisheries, dark shearwaters, primarily *P. griseus*, predominated. Ogi et al. (in press) report that 1648 Ancient Murrelets *Synthliboramphus antiquus* were taken in gill nets set close to the Japanese coast. However, based on collections made at the time, an unknown proportion of those specimens were Japanese Murrelets *S. wumizusume* (P.J. Gould, pers. commun.).

2.5. Experimental squid fishery off British Columbia

In the late 1970s and early to mid-1980s a joint Canadian–Japanese experimental fishery for flying squid existed in the eastern North Pacific (Bernard 1981; Robinson and Jamieson 1984; Sloan 1984; Jamieson and Heritage 1987, 1988). The fishery was concentrated within the 200-mile Canadian EEZ and, to a lesser extent, in international waters off British Columbia, Washington, and Oregon. The experimental fishery was active in 1979, 1980, 1983, and 1985–1987.

The fishery was conducted in October 1979 and from either June or July through August or September in other years. A total of 1030 seabirds were killed in 1985–1987 (Table 3). Sooty Shearwater was the predominant species taken in the fishery (63% of the total) followed by Rhinoceros Auklet *Cerorhinca monocerata* (9% of the total). Catch rates on individual cruises ranged from 0.02 birds/km to 0.52 birds/km. Overall, 0.09 birds/km of net were killed over the three-year period when data were collected (Table 3).

Although sufficient quantities of flying squid were caught in the experimental fishery to support a commercial venture, a commercial fishery has not been developed because of the high rates of incidental take of marine mammals and salmon.

Table 3
Fishing effort, number of bird killed, and catch rates of seabirds in the Canadian–Japanese experimental squid gillnet fishery off British Columbia, 1985–1987

	1985	1986	1987
Effort (km)	2475	4308	4417
Black-footed Albatross	2	7	6
Northern Fulmar		4	
Sooty Shearwater	12	176	464
Short-tailed Shearwater	29	3	1
Flesh-footed Shearwater		6	
Unidentified shearwater	5		
Common Murre		1	1
Ancient Murrelet	2		
Cassin's Auklet		8	28
Rhinoceros Auklet	2	90	2
Unidentified alcid		2	2
Other unidentified birds		107	33
Total birds	52	416	562
Birds/km	0.02	0.09	0.13

3. Coastal gillnet fisheries

3.1. Baja California, Mexico

Little is known of seabird mortality in fishing gear off Baja California. Gillnetting is widespread in coastal portions of Baja, with rockfish, sharks, and totoaba *Totoaba macdonaldi* being the primary targets. Both surface and bottom-anchored gill nets are used (Turk-Boyer 1989). In the Sea of Cortez, gillnetting is concentrated between San Felipe and Santa Rosalia (D.W. Anderson, pers. commun.).

A minimum of seven species of seabirds have been recorded killed in gill nets in Baja California including Common Loons *Gavia immer*, Pacific Loons *G. pacifica*, Western Grebes *Aechmophorus occidentalis*, Brown Pelicans *Pelecanus occidentalis*, Brandt's Cormorants *Phalacrocorax penicillatus*, Double-crested Cormorants *P. auritus*, and scoters *Melanitta* spp. Catch rates and mortality estimates are unknown for this geographic area. D.W. Anderson (pers. commun.) reported one incident in which hundreds of Pacific Loons were killed in gill nets set along the Gulf of California coast. Although no quantitative data exist, losses of seabirds in gill nets off Baja California may be a local problem, especially for wintering species of diving seabirds.

3.2. Japan

Japanese fishermen have used drift gill nets in Japanese waters for about 100 years. At present, there is a considerable amount of drift gillnet fishing in Japanese waters, most of which is done by small boats using short nets. Nearly all species of surface-feeding fish available within Japanese waters are taken this way. The Japanese Fisheries Agency estimates the number of small coastal vessels to be in the thousands. The Japanese also use bottom-anchored gill nets in coastal areas. The magnitude and geographic extent of these fisheries are unknown.

The full extent to which seabirds are killed incidental to the coastal drift gillnet and bottom-anchored gillnet fisheries of Japan is unknown. Ogi et al. (in press) reported the loss of 652 seabirds in a greenling fishery in January 1989 off one port in Hokkaido, Japan, consisting of Common *Uria aalge* and Thick-billed murres and Pelagic Cormorants *Phalacrocorax pelagicus*.

3.3. California

The coastal gillnet fisheries in California for halibut *Paralichthys californicus*, starry flounder *Platichthys stellatus*, and white croaker *Genyonemous lineatus* provide a documented example of the impacts of gillnet fisheries on coastal populations of marine birds. Gillnet fishing has occurred in central California since at least the 1930s. In the late 1970s, the number of gillnet fishermen increased, fishing effort intensified, and fishermen switched to monofilament nets, all of which resulted in a higher catch of nontarget seabirds (Atkins and Heneman 1987).

From 1979 to 1982, fishing effort was concentrated in Monterey Bay and it was evident by 1980 that large numbers of murres and other seabirds were being killed (Stenzel et al. 1988). After 1982, a northward shift in fishing effort occurred to between Half Moon Bay and Bodega Bay.

Species of seabirds killed in gill nets from 1980 to 1987 included Common, Pacific, and Red-throated *Gavia stellata* loons, Western and Clark *Aechmorphorus clarkii* grebes, Sooty Shearwaters, Brandt's and Pelagic cormorants, Common Murres, Pigeon Guillemots *Cepphus columba*, and Marbled Murrelets *Brachyramphus marmoratus* (California Department of Fish and Game 1981, 1987; Carter and Erickson 1988). Common Murres accounted for 50–97% of the mortality between 1980 and 1986, and an estimated 70 000–75 000 Common Murres were killed from 1979 to 1987 (Takekawa et al. 1990).

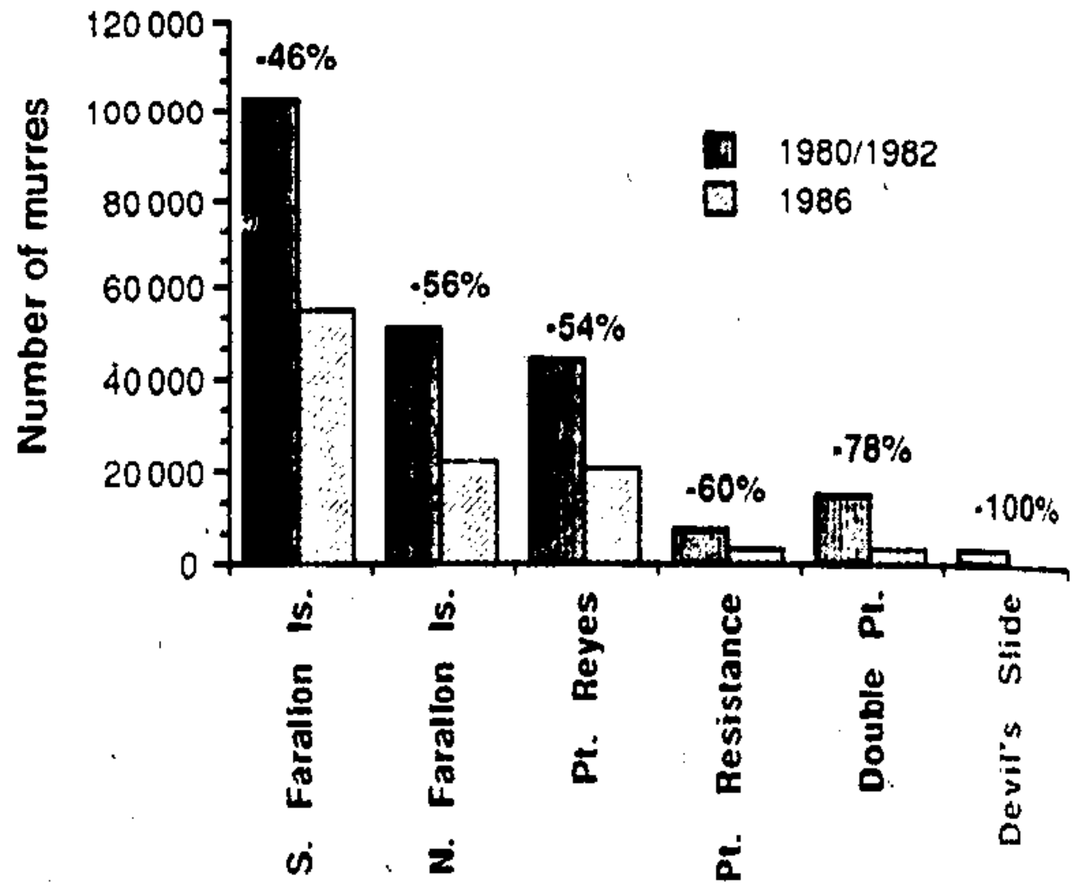
The total breeding population of Common Murres in central California declined 52.6% from 229 080 in 1980–1982 to 108 530 in 1986 (Takekawa et al. 1990). Most of this decline was a result of gillnet mortalities, although oil spills and the 1982–83 El Niño event also contributed. Individual colonies declined between 45.8 and 100.0% (Fig. 3). The Devil's Slide Rock colony disappeared entirely, with its loss attributed to high fishing effort within 1–2 km of the colony and the *Apex Houston* oil spill in February 1986 (Page et al. 1990). The breeding population of murres on South Farallon Islands, which had peaked at 102 110 birds in 1982, declined by 46.8% to only 54 370 birds by 1985. Numbers at the North Farallon Islands peaked at 51 540 in 1980 but by 1986 had declined by 55.6% to 22 900. In contrast, populations of Common Murres in northern California, outside the gillnetting area, remained largely unchanged between 1979 and 1986.

In 1982, State Senate Bill (SB) 1475 imposed a permanent ban on gillnet fishing in waters <10 fathoms (18.3 m) in most of Monterey Bay, and in 1984 the ban was extended to 15 fathoms (27.5 m). Temporary seasonal closures from May through October were imposed by California Department of Fish and Game during 1982–1984 in a patchwork pattern to exclude areas of highest seabird and marine mammal mortality. Despite these preventive measures murre bycatch rates remained relatively high. Colony survey data showed that the central California murre population could not sustain continued mortality, and that the continued existence of individual colonies was threatened.

In September 1987, SB 40 was passed, containing much stronger regulations, including area closures selected to eliminate murre mortality. These regulations resulted in the elimination of the nearshore halibut, shark, and white croaker fisheries north of Monterey Bay, but allowed the offshore rockfish fishery, which caused very low levels of seabird mortality, to continue.

In Monterey Bay, some gillnet fishing has continued outside of 15 fathoms. Mortality was very low in 1987 and 1988 but increased again in 1989 when a few thousand murres were killed. Continued declines may be related to earlier mortality of subadults, lowered recruitment, possibly as a result of El Niño, and continued mortality in oil spills and gill nets. The population in central California has not yet shown signs of recovery (H.R. Carter, pers. commun.).

Figure 3
Declines of Common Murres at colonies in northern California, 1980/1982 and 1986



3.4. Oregon

Gillnet fishing for salmon in Oregon is restricted to the Columbia River. In addition, a gillnet fishery for shad *Alosa sapidissima* exists in several of the major rivers in southern Oregon (K. Brown, pers. commun.). No information on the incidental take of seabirds in those fisheries is available.

3.5. Washington

Gill nets are commonly used to catch salmon in Washington. Gillnet fisheries exist in the Strait of Juan de Fuca, Puget Sound, Columbia River, and along the outer coast, particularly in Willipa Bay and Grays Harbor (M. Barker, pers. commun.). Salmon fisheries in Washington are managed by both state and tribal governments. The state regulations, which govern nontribal fishermen, limit gill nets to approximately 500 m, and these nets must remain attached to the boats. Tribal fishermen use nets of varying lengths and set nets from shore and drift them with boats. Monofilament nets are permitted for both tribal and nontribal fishermen, and much of the fishing occurs at night. The fisheries occur from mid-July to the end of November.

No data are available on the incidental take of seabirds in gill nets in Washington. Speich and Wahl (1989) report that Western Grebe, Common Murre, and Marbled Murrelet are the species most frequently taken in gill nets in Washington. A factor probably responsible for incidental mortality is the prolonged fishing season, which coincides with movement of birds southwards and into inshore protected habitats during the fall and winter. The population of Common Murres in Washington currently is at very low levels (Wilson 1991). Although the decline of Common Murres has been related to warm-water episodes along the coast, Wilson (1991) also lists oil spills and gillnet mortality as having adverse affects on the population.

3.6. British Columbia

The incidental take of seabirds in nearshore salmon gillnet fisheries in British Columbia, like its counterpart in Washington State, remains an enigma. Carter and Sealy (1984) reported on a gillnet fishery for salmon in Barkley Sound, on the west side of Vancouver Island, that killed 7.8% of the projected fall population of Marbled Murrelets in 1980. However, that fishery has not opened every year since then (H.R. Carter, pers. commun.). Other gillnet fisheries for salmon exist in the Strait of Georgia, particularly at the mouth of the Fraser River, the northern end and western side of the Strait of Juan de Fuca, and in Fitz Hugh Sound along the north-central coast of British Columbia. H.R. Carter (pers. commun.) noted mortality of at least hundreds of murres off the southwest coast of Vancouver Island on a single day in August 1979, but it was unclear if the dead murres were from Canadian or Washington gillnet boats. Uchida (1985) reported that 2508 gillnet vessels operated in British Columbia in 1981.

3.7. Alaska

Drift and set gill nets are commonly used to catch salmon and herring in Alaska. Commercial gill nets are used throughout coastal Alaska with the exception of the Beaufort Sea and the Aleutian Islands; more than 9000 limited-entry gillnet permits for salmon have been issued. Drift gill nets are limited to southeastern Alaska, Prince William Sound, Cook Inlet, the Alaska Peninsula, and Bristol Bay, whereas use of set nets is more widespread.

Monofilament webbing is illegal in Alaska; instead gill nets must use between six and 30 strands. These nets vary in length by region but they do not exceed 549 m (Uchida 1985).

The incidental mortality of seabirds in gill nets used in coastal Alaska is poorly documented. The following discussion provides a regional synopsis of seabird mortality in coastal salmon gill nets.

3.7.1. Southeastern Alaska

The majority of seabirds killed in gill nets in southeastern Alaska are alcids, especially Marbled Murrelets and Common Murres. P. Isleib (pers. commun.) estimates that as many as 300 murres and up to 1000 Marbled Murrelets are taken annually in this region.

3.7.2. Prince William Sound

Gillnet fisheries in Prince William Sound include a driftnet fishery on the Copper River Flats and both driftnet and setnet fisheries within the sound proper. P. Isleib (pers. commun.) estimates that a few hundred birds are killed on the Copper River Flats each summer, including murres, murrelets, loons, and scoters. Within the sound, Marbled Murrelets are taken most frequently (hundreds annually), along with lesser numbers of Kittlitz's Murrelets *Brachyramphus brevirostris*, Pigeon Guillemots, and Common Murres. Wynne et al. (1991) provide the only recent quantitative data on seabird mortality in Prince William Sound and Copper River Flats. They estimate that between 836 and 2100 marine birds were taken in the Prince William Sound–Copper River Flat fisheries in 1990, of which more than 80% were Marbled Murrelets.

3.7.3. Lower Cook Inlet and Kodiak Island

Both driftnet and setnet fishing occur in Lower Cook Inlet; only setnet fishing occurs at Kodiak Island. A few hundred birds may be taken each year in Lower Cook Inlet (P. Isleib, pers. commun.), consisting of Common Murres, Marbled Murrelets, puffins, and sea ducks. There is an incidental take of seabirds in the setnet fishery at Kodiak Island, but the take is presumed to be low.

3.7.4. Alaska Peninsula

Both setnet and driftnet fishing occur on the Alaska Peninsula. Incidental take of seabirds undoubtedly occurs, especially in the southern Unimak Island area and in the Shumagin Islands. Wynne et al. (1991) estimated that between 158 and 316 birds were killed in 1990, with Common Murres making up about 50% of the total. Other species taken included Marbled Murrelets, Sooty and Short-tailed shearwaters, and Horned and Tufted puffins.

3.7.5. Bristol Bay

Both setnet and driftnet fisheries occur in Bristol Bay. Most of the area is very turbid and densities of diving seabirds there are consequently low; hence losses of seabirds in nets are low (K. Haflinger and K. Hill, pers. commun.).

3.7.6 Yukon–Kuskokwim Delta/Norton Sound/Kotzebue Sound

Gillnet fishing for salmon in this area is restricted to setnets. There is probably little incidental take of sea ducks, loons, and grebes. Although the precipitous decline in populations of Spectacled *Somateria fischeri* and Steller's *Polysticta stelleri* eiders on the Yukon–Kuskokwim Delta has not been linked to fishery-related mortality, the fishery has been suggested as a possible source of mortality.

4. Discussion

Despite improvements in our knowledge of the numbers and kinds of marine birds being taken in various commercial gillnet fisheries in the North Pacific, it remains difficult, with the exception of the California set gillnet fishery, to demonstrate the impacts of these fisheries on breeding populations of marine birds. This is the result of the dynamic nature of most of the fisheries, too few data on incidental take, and inadequate data on the size and status of marine bird populations in fishing areas at sea and at breeding colonies.

In California, a strong link between known mortality from a shipboard monitoring program and well-documented declines of Common Murres at breeding colonies was established. With sufficient public support, legislative action was taken to reduce the incidental take problem (Atkins and Heneman 1987; Salzman 1989; Takekawa et al. 1990). On the high seas, however, cause-and-effect is more difficult to establish. Seabird species that are killed in high-seas gill nets wander widely over the oceans within preferred oceanographic and food regimes, and it usually is impossible to discern their colonies of origin. Further, gillnet fisheries also occur over huge geographic areas. Seabirds taken in gill nets may originate from many widely separated colonies in the northern hemisphere in the case of alcids, and in the southern hemisphere in the case of Short-tailed and Sooty shearwaters. This pattern of mortality tends to initially diminish the effects of the fisheries on individual colonies and consequently forces resource managers to consider only the effects on Pacific-wide populations of affected species. An exception to this were the alcids taken in the Japanese mothership fishery in 1982 and 1983, when brood patches were found on many birds taken in gill nets set close to Agattu Island, Alaska. DeGange et al. (1985) determined that the mothership fishery was adversely affecting breeding populations of seabirds in the westernmost Aleutian Islands. In

addition, declines of diving seabird populations in coastal Japan (Hasegawa 1984) may be related to extensive drift gillnet and bottom-set gillnet fisheries that occur in those waters.

We have only a rudimentary understanding of the location, size, and variability of seabird breeding colonies from Alaska to Baja California, and even less information from colonies in Russia, Japan, Korea, China, Taiwan, the central Pacific Islands, and, in the case of shearwaters, Australia, New Zealand, and South America. Only at widely spaced colonies are intensive monitoring programs in place.

The inception of the Japanese, Korean, and Taiwanese squid fisheries increased the complexity and scale of the problem. The size of these fisheries dictated that no high-seas fishery could be viewed in isolation, since highly mobile species (e.g., shearwaters) constituted a major portion of the overall mortality.

Based on data collected in 1990 in the various high-seas fisheries of Japan, Korea, and Taiwan, Ogi et al. (in press) estimated that approximately 500 000 seabirds were incidentally killed. Dark Shearwaters (Sooty and Short-tailed) made up about 82% of the total. It is difficult to determine how accurate these estimates are, but at least they are on the same order of magnitude as other available estimates (DeGange and Day 1991; Johnson et al., in press; Larntz and Garrot, in press). Ogi et al. (in press) estimate that the 1990 levels of mortality of Short-tailed and Sooty shearwaters would result in annual declines in breeding populations of 0.02% and 0.2%, respectively. The Short-tailed Albatross *Diomedea albatrus*, which is attracted to fishing operations, is always at risk of entanglement. Mortality of Black-footed Albatross was proportionately higher than that of Laysan Albatross, resulting in a loss of about 2.2% of the world population.

Fortunately, a number of recent actions have occurred to reduce the incidental take of seabirds and other marine organisms in high-seas drift gill nets. In 1987, the Japanese mothership salmon fleet was prevented from fishing in the U.S. EEZ. Consequently, the mothership fleet was reduced in size and limited to fishing in areas far removed from land where catch rates of seabirds are lower. The fishery was terminated following the 1991 season. The large vessel component of the land-based salmon fishery has also been reduced in size and effort in recent years (DeGange and Day 1991) and has been phased out in 1992. In 1987, the U.S. Congress passed the Driftnet Impact Monitoring, Assessment and Control Act that called for the United States to: 1) enter into negotiations with foreign governments for gathering statistically reliable information on incidental take; 2) develop recommendations for a system to determine the origin of lost, discarded, or abandoned driftnets, and for use of alternative materials in driftnets for increasing the rate of decomposition of lost or discarded driftnets; and 3) evaluate the feasibilities of and develop recommendations for implementation of a driftnet bounty system and a driftnet fishing vessel tracking system. Partly as a result of that legislation and international agreements, U.S. observers participated in a multi-nation program to obtain more reliable estimates of mortality of seabirds in the squid driftnet fisheries in 1989, 1990, and 1991 (Fitzgerald et al., in press). Finally, during the 45th session of the United Nations General Assembly in 1990, Resolution 44/225 was passed which called for a moratorium on all large-scale pelagic driftnet fishing on the high seas by 30 June 1992. As a result of concerted pressure, Japan agreed to phase out its fisheries in 1992, and Korea and Taiwan intend to follow the lead of Japan.

Although additional analyses are needed to clarify the effects of the various high-seas drift gillnet fisheries on seabirds in the North Pacific, the problem apparently has been resolved to the benefit of seabird populations. The squid fisheries in particular remain poignant testimonials to how rapidly fisheries and other perturbations to marine systems can develop, and point out the need for continued vigilance to protect important marine resources.

Perhaps attention can now be more profitably focused on coastal gillnet fisheries for which seabird mortality data are few or lacking. Among these are coastal gillnet fisheries in Washington, British Columbia, Alaska, and Japan. Although these fisheries take far fewer seabirds than their counterparts on the high seas, impacts on local breeding populations could be significant. Of particular concern is the incidental mortality of Marbled Murrelets and Common Murres in coastal gillnet fisheries along the North American coast, and perhaps also Japanese Murrelets in Japan. Such mortality may be placing additional stress on Marbled Murrelet populations already suffering from habitat loss through logging; and upon Marbled Murrelet and Common Murre populations suffering from oil spills (Carter and Sealy 1984; Carter and Erickson 1988; Marshall 1988; Page et al. 1990; Piatt et al. 1990; Takekawa et al. 1990).

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