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POSTBREEDING DISPERSAL AND DRIFT-NET MORTALITY OF ENDANGERED JAPANESE MURRELETS

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ABSTRACT.—The incidental catch of seabirds in high-seas drift nets was recorded in 1990–1991 by scientific observers on commercial squid and large-mesh fishery vessels operating in the North Pacific Transitional Zone. Twenty-six *Synthliboramphus* murrelet deaths were recorded in the months of August through December. All but one were from the Korean squid fishery in a small area bounded by 38°–44°N and 142°–157°E. Five specimens of the dead birds were collected and later identified as Japanese Murrelets (*S. wumizusume*). As fishing effort was widely distributed over a large area east of Japan, these data suggest that postbreeding Japanese Murrelets migrate north to winter in a relatively small area southeast of Hokkaido, where persistent eddies form at the confluence of the Oyashio and Kuroshio currents. Fronts between cold Oyashio water and Kuroshio warm-core eddies promote the aggregation of zooplankton and pelagic fishes, which in turn may attract murrelets during the nonbreeding season. The estimated total mortality of Japanese Murrelets in high-seas drift-net fisheries represents a significant proportion of the total world population of this rare and endangered species. *Received 12 October 1992, accepted 4 April 1993.*

THE JAPANESE (CRESTED) MURRELET (*Synthliboramphus wumizusume*) is the rarest member of the Alcidae, and its populations are seriously threatened (Collar and Andrew 1988, Gaston 1992, Ono 1993, Springer et al. 1993). Along with the endangered Short-tailed Albatross (*Diomedea albatrus*), Japanese Murrelets have been declared a National Monument in Japan (Hasegawa 1984). Little is known of their population status, but numbers appear to be declining (Brazil 1991, Ono 1993). Hasegawa (1984) estimated 1,650 birds from colony counts and observations at sea. Higuchi (1979) and Ono (1993) reported confirmed records of breeding on eight islands or island groups, and at least 19 breeding locations are presently known or suspected (Fig. 1). The largest colonies were found at Biro Island (2,000 in 1992), Kozu Island (600 in 1991), Mimiana Island (150–200 birds in 1979), and Koya Island (408 birds in 1974, 282 in 1976, 30 in 1991) [see below]). It is unlikely that all breeding colonies have been located; however, it is also unlikely that a large colony remains to be discovered (Ono 1993). A recent compilation of available data (Ono 1993) suggests that fewer than 4,000 Japanese Murrelets exist today.

Disturbance, habitat destruction and introduced predators are serious problems at many colony sites (Brazil 1991, Springer et al. 1993). In 1987, the remains of 145 individual murrelets were found on Koya Island, where the birds apparently were killed by introduced rats (Takeishi 1987, Ono 1993). The estimated total mortality was 414 birds, and few breeding murrelets are presently found in what was once a very large colony. The frequency of carcasses on other islands (Higuchi 1979) suggests that predation of adults is a widespread problem. In the Izu islands, increasing human trash has promoted growth in populations of the Jungle Crow (*Corvus macrorhynchos*), a common predator of murrelet eggs (M. Ueta pers. comm.). Human visitation and the ensuing destruction of eggs and nest sites also appears to be an increasing problem at several colonies (Higuchi 1979, Brazil 1991, Ono 1993).

Away from their colonies, Japanese Murrelets are potentially threatened by oil pollution and gill nets (Kazama 1971, DeGange and Day 1991, DeGange et al. 1993). The adverse effect of these mortality factors may be underestimated, however, because of the difficulty in distinguishing Japanese Murrelets from their closely related congener, the Ancient Murrelet (*S. antiquus*). Outside of the breeding season, when Japanese Murrelets possess distinctive plumes at the back of the crown, they differ from Ancient Murrelets only in having less white on the sides of the neck and a slightly longer bill (Gaston 1992).

Japanese Murrelets breed only in warm-water areas of southern Japan (Fig. 1) and tend to remain close to their colonies in the breeding season (Brazil 1991, Ono 1993). In general, the postbreeding dispersal of Japanese Murrelets is poorly known. Postbreeding birds from the Izu Islands may move northward because Japanese Murrelets are regularly observed off northern Honshu, and rarely off Hokkaido (Kuroda 1955, Brazil 1991). Vagrants have been reported as far north as Sakhalin and the Kuril Islands (Brazil 1991). Ancient Murrelets are abundant and widespread throughout boreal and subarctic waters of the North Pacific (Gaston 1992, Springer et al. 1993). A few hundred Ancient Murrelets may breed around Hokkaido (Brazil 1991, Gaston 1992), and perhaps a thousand breed along the coasts of mainland China and Korea (Gaston 1992). Ancient Murrelets are common winter visitors to coastal and offshore waters of Japan, particularly in the Sea of Japan (Brazil 1991).

Concern about the incidental catch of marine organisms in high-seas drift nets led to an international effort to monitor five major fisheries in the North Pacific: Japanese squid and large-mesh drift-net fisheries; Korean squid drift-net fishery; and Taiwanese squid and large-mesh drift-net fisheries (Canadian Department of Fisheries and Oceans 1991, International North Pacific Fisheries Commission [INPFC] 1992a).

We report here on the bycatch of *Synthliboramphus* murrelets in these five drift-net fisheries, and document the first confirmed bycatch of Japanese Murrelets in drift nets. We assess the potential impact of this bycatch on populations, and consider the geographic distribution of bycatch records as it relates to postbreeding dispersal behavior and regional oceanography.

METHODS AND STUDY AREAS

Scientific observers were placed aboard high-seas fishing vessels from Japan, the Republic of Korea, and Taiwan (the Republic of China). Observers recorded the incidental catch of marine birds in drift nets and retrieved voucher specimens for assessing the impact of these fisheries on marine bird populations (Anonymous 1991a, b, 1992a, b, Fitzgerald et al. 1992, INPFC 1991, 1992a, b, c).

Five specimens of unidentified murrelets were salvaged in 1990 and 1991 and sent to the Burke Museum, University of Washington, Seattle. Subsequently, they were identified as Japanese Murrelets. The specimens were prepared for the museum collection, stomach contents were preserved, and condition of the gonads, bursa, and body fat were recorded.

We extrapolated the total number of murrelets killed from numbers observed in nets using a simple ratio estimate (Cochran 1963). In extrapolating total bycatch, we used only fishing effort and observations in an area bounded by 36°–45°N and 141°–147°E (Fig. 1). This limit is based on the approximate range of murrelet bycatch near Japan (Fig. 1). We excluded much of the large eastern drift-net fishing area (Fig. 1) to avoid overestimating the bycatch of murrelets. We assumed that the five murrelets caught between 152°–157°E were Ancient Murrelets (see Results). Five different drift-net fisheries were monitored during 1990 and 1991, mostly in an area (Fig. 1) bounded by 31°–46°N and 151°W–141°E.

1. *Japanese squid fishery.*—The Japanese high-seas squid drift-net fishery generally operates between 170°E–145°W and 35°–46°N with designated time and area closures north of 40°N and excluding the U.S. 200-mile (320-km) fishery conservation zones. The fishing season lasts from June through December. Canadian, Japanese, and U.S. scientific observers monitored 114,095 km of Japanese squid drift nets in 1990 and 103,198 km in 1991.

2. *Japanese large-mesh fishery.*—Most Japanese large-mesh drift-net fishing occurs between 175°E–145°W and 24°–41°N, and between 141°–175°E and 24°–43°N. As in the squid fishery, there are designated time and area closures. This fishery operates throughout the year but peaks in the winter. Japanese and U.S. observers monitored 25,668 km of Japanese large-mesh drift-nets set in the North Pacific from September 1990 through May 1991.

3. *Taiwanese squid fishery.*—The major Taiwanese squid fishing grounds are between 155°E–165°W and 38°–44°N. Some fishing, however, occurs south to 33°N, north to 45°N, west to 143°E and east to 146°W. West of 170°E, fishing is prohibited north of 39°N. Time and area restrictions, and closed areas are similar to those for the Japanese fleet. Squid fishing extends from May through December. Taiwanese and U.S. observers monitored 8,521 km of squid drift nets in 1990 and 8,036 km in 1991.

4. *Taiwanese large-mesh fishery.*—The Taiwanese large-mesh fishery operates mostly in the area between 144°E–154°W and 30°–44°N. Fishing occurs from May through December. Time and area restrictions are similar to those for the Japanese fleet. Taiwanese and U.S. observers monitored 9,748 km of large-mesh drift nets in 1990 and 11,876 km in 1991.

5. *Republic of Korea squid fishery.*—The Korean squid fishing grounds are between 141°E–150°W and 30°–46°N. The season extends from April through December. In April and May, fishing is mostly in the southeastern part of this area and moves to the northeast in early summer (June–July). In August some fishing shifts to western areas and, from September through December, all fishing occurs west of 170°E. Korean and U.S. observers monitored 33,483 km of Korean squid drift nets in 1990 and 21,126 km in 1991.

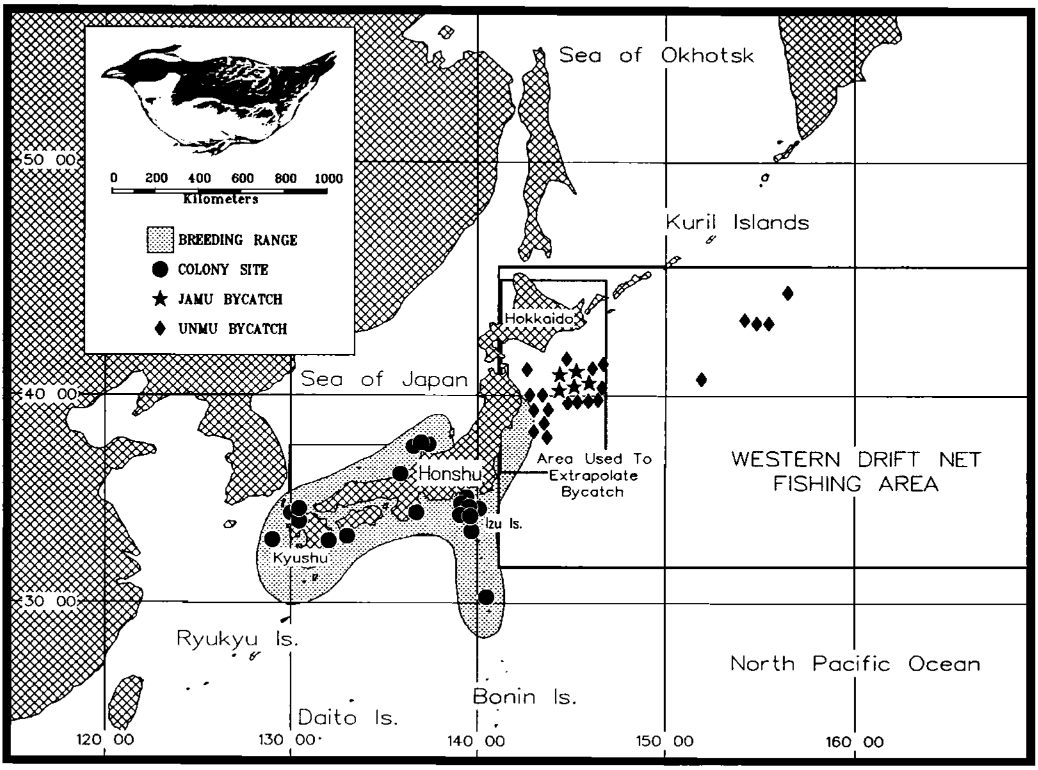

Fig. 1. Distribution of Japanese Murrelet (*Synthliboramphus wumizusume*) breeding colonies and bycatch in high-seas drift nets (JAMU = Japanese Murrelets; UNMU = unidentified murrelets). Western drift-net fishing area indicated by large boxed area, and extends eastward to 151°00′ West longitude.

Results

Incidental catch of murrelets in high-seas drift-net fisheries.—Twenty-six *Synthliboramphus* murrelets were recorded as bycatch during the high-seas drift-net scientific observer programs in 1990–1991 (Table 1). One was taken in the Taiwanese squid fishery and the remainder were taken in the Korean squid fishery. No murrelet bycatch was noted for the Japanese squid fishery, probably because these vessels do not set nets west of 160°E. Catch rates of marine birds smaller than albatrosses in large-mesh drift nets are considerably lower than rates in squid drift nets because of the differences in mesh size used (INPFC 1992b). This partly explains the absence of murrelet bycatch in the Japanese and Taiwanese large-mesh drift-net fisheries.

Five murrelets were salvaged and later identified as Japanese Murrelets. Most were adult birds undergoing molt from summer to winter plumage (Table 2). Another five birds were classified as Japanese Murrelets at the time of collection, but not substantiated by voucher specimens. Similarly for the remaining 16 birds at the time of collection, 6 were classified as Ancient Murrelets, 9 as unidentified murrelets, and 1 as a Rhinoceros Auklet (*Cerorhinca monocerata*). Based on postcruise debriefings and examination of photographs, all these specimens were later categorized as unidentified *Synthliboramphus* murrelets by P. Gould (Table 1). No Ancient Murrelets were verified by voucher specimens as bycatch in squid or large-mesh drift-net fisheries. The specimens reported tentatively as Ancient Murrelets in 1990 (Anonymous 1991b) were misidentifications by us from photographs. That error is corrected here and elsewhere (Anonymous 1992b).

Impact assessment.—We calculate that at least 98 Japanese Murrelets were killed in 1990 (Table 3). This lower estimate is conservative because it is based only on the five voucher specimens that were positively identified. Assum-

TABLE 1. Records of murrelets from North Pacific high-seas drift-net fisheries in 1990-1991. Positions summarized by 1° latitude-longitude blocks (identified by position of southwest corner at start of net retrieval). Temperatures (lowest-highest) obtained at start of net set, end of net set, beginning of net retrieval, and end of net retrieval.

Murrelet species	*n*	Date	Latitude and longitude	Kilometers of net	Murrelets per 1,000 km of net	Surface temperature (°C)
Japanese	1	August 1990	40°N, 144°E	246.5	4.1	19.7-20.3
Japanese	1	August 1990	40°N, 145°E	373.4	2.7	18.6-21.4
Unidentified	2	August 1990	40°N, 146°E	126.0	15.8	21.9-22.8
Unidentified	2	August 1990	41°N, 146°E	629.9	3.2	19.3-22.8
Unidentified	1	August 1990	41°N, 152°E	16.0	64.1	19.5-19.7
Unidentified	1	August 1990	43°N, 154°E	223.6	4.5	15.8-17.9
Unidentified	1	August 1990	43°N, 155°E	131.5	7.6	15.2-18.7
Japanese	1	September 1990	41°N, 144°E	73.1	13.8	17.5-19.9
Unidentified	1	September 1990	43°N, 154°E	357.3	2.8	15.2-16.6
Unidentified	1	September 1990	44°N, 156°E	412.8	2.4	14.0-15.8
Unidentified	1	October 1990	39°N, 144°E	343.9	2.9	15.2-16.4
Japanese	1	October 1991	41°N, 143°E	77.5	12.9	14.5-15.0
Unidentified	2	November 1991	40°N, 142°E	36.9	54.2	13.2-13.6
Unidentified	1	November 1990	40°N, 145°E	262.5	3.8	14.9-17.4
Japanese	1	November 1990	40°N, 145°E	262.5	3.8	16.0-16.8
Unidentified	3	November 1990	40°N, 145°E	262.5	15.2	16.0-16.8
Unidentified	1	November 1990	41°N, 142°E	90.0	11.1	14.3-14.5
Unidentified	3	December 1990	38°N, 143°E	172.5	17.4	13.8-15.7
Unidentified	1	December 1990	39°N, 143°E	22.5	44.4	14.3-15.0

ing that all the unidentified birds caught were Japanese Murrelets, then as many as 417 may have been killed in 1990. This upper estimate is probably too high because it seems likely that a few of the birds were Ancient Murrelets. Similarly, between 40 and 160 Japanese Murrelets may have been killed in 1991 (Table 4). Summed-monthly-ratio estimates yielded slightly lower total bycatch estimates (Tables 3 and 4). We prefer the unweighted annual estimates, however, because the low frequency of bycatch records weakens the extrapolation for individual months in which an increased observer effort would likely have yielded bycatch records (e.g. October 1990).

If we assume a total population of 4,000 birds, an annual bycatch of 40 to 417 birds, and an adult to immature ratio of 3:2 in both the population and the bycatch (Table 2), then the annual mortality of adults (24-250) in drift nets would equal 1.0 to 10.4% of the breeding population. Annual mortality of adults in a relatively undisturbed population of Ancient Murrelets has been estimated at about 20% (Gaston 1992). If Japanese Murrelets have similar annual mortality rates, then drift-net mortality may account for a significant proportion of total adult mortality.

Distribution of murrelet bycatch.—The five Japanese Murrelets salvaged from the Korean fishery were from an area bounded by 40°-42°N and 143°-146°E. These were taken in the months of August through November and in relatively warm waters. Sixteen of the unidentified murrelets were taken in a slightly larger area (38°-45°N and 142°-147°E) encompassing the Japa-

TABLE 2. Japanese Murrelet specimens collected during 1990-1991 high-seas drift-net observer programs. Fat levels were "moderate" for all specimens.

Recovery location	Date	Sex	Body molt	Bursa	Estimated age
40.3°N, 145.8°E	13 September 1990	M	Heavy	Fleshy	Immature
40.7°N, 144.2°E	18 August 1990	M	Heavy	None	Adult
41.1°N, 144.3°E	6 September 1990	M	Heavy	None	Adult
40.3°N, 145.3°E	6 November 1990	F	None	Fleshy	Immature
41.0°N, 143.9°E	2 October 1991	M	Heavy	None	Adult

TABLE 3. Extrapolated incidental catch of Japanese Murrelets (JAMU) and unidentified *Synthliboramphus* murrelets (UNMU) in five large-scale drift-net fisheries[a] in North Pacific east of 147°E from March through December 1990.

			Bycatch (*n*)			
	No. 50-m net panels		Observed		Estimated	
Month	Commerical	Observer	JAMU	UNMU	JAMU	UNMU
March	252	0	—	—	—	—
April	4,902	951	0	0	0	0
May	858	0	—	—	—	—
June	0	0	—	—	—	—
July	111,023	0	—	—	—	—
August	1,173,844	74,304	2	4	32	63
September[b]	405,257[c]	25,752	1	0	16	0
October[b]	793,381	1,470	0	0	0	0
November	752,412[d]	23,262	1	5	32	162
December	101,529	6,729	0	4	0	60
Total					80	285
Grand total	3,226,423	131,517	4	13	98[e]	319[e]

[a] Includes Japanese squid, Japanese large-mesh, Korean squid, Taiwanese large-mesh, and Taiwanese squid fisheries.
[b] Assumes 720 50-m panels set per day in Taiwanese squid fishery.
[c] Excludes two Korean operations (2,203 50-m panels) in areas of 46°N, 142°E and 46°N, 145°E.
[d] Excludes one Korean operation (1,200 50-m panels) in area of 46°N, 144°E.
[e] Extrapolated by ratio estimate from total bycatch throughout March to December.

nese Murrelet bycatch area, and five were taken in an area (41°–45°N and 152°–157°E) well away from the coast of Japan (Table 1 and Fig. 1). The 16 murrelets recorded west of 147°E were taken from August through December in surface waters ranging from 13.8° to 22.8°C.

The five voucher specimens of Japanese Murrelet were randomly selected (Table 1) from the total of 21 specimens recorded near Japan; moreover, the five specimens tentatively identified as Japanese Murrelets were from the same area. Therefore, it seems likely that most or all of the remaining 11 birds also were Japanese Murrelets. Based on limited knowledge of distribution patterns, the other five specimens (i.e. those recovered south of the Kuril Islands; Fig. 1) were more likely to have been Ancient Murrelets (Brazil 1991, Gaston 1992). Indeed, two of these birds were tentatively identified as Ancient Murrelets at the time of collection.

TABLE 4. Extrapolated incidental catch of Japanese Murrelets (JAMU) and unidentified *Synthliboramphus* murrelets (UNMU) in five large-scale drift-net fisheries[a] in North Pacific east of 147°E from April through December 1991.

			Bycatch (n)			
	No. 50-m net panels		Observed		Estimated	
Month	Commercial	Observer	JAMU	UNMU	JAMU	UNMU
April	0	0	—	—	—	—
May	0	0	—	—	—	—
June	0	0	—	—	—	—
July	585,174	8,140	0	0	0	0
August	1,511,849	20,920	0	0	0	0
September	1,258,364	39,374	0	0	0	0
October	2,175,384	58,592	1	1	37	37
November	1,977,301	23,262	0	2	0	77
December	554,500	23,575	0	0	0	0
Total					37	114
Grand total	8,062,572	201,759	1	3	40[b]	120[b]

[a] Includes Japanese squid, Japanese large-mesh, Korean squid, Taiwanese large-mesh, and Taiwanese squid fisheries. Scientific observers were not placed on Japanese large-mesh vessels during this period.
[b] Extrapolated by ratio estimate from total bycatch throughout March to December.

DISCUSSION

Postbreeding dispersal.—The bycatch of Japanese Murrelets in high-seas drift nets appears to be a consequence of their northward postbreeding dispersal, which is poorly understood (Kuroda 1955, Brazil 1991). Japanese Murrelets are warmwater seabirds, and breeding is restricted to southern areas of Japan. The net-bycatch records reveal, however, that postbreeding birds move northward to overwinter in a well-defined area southeast of Hokkaido (Fig. 1). The region west of 147°E, between 38°N and 42°N, is part of the Perturbed Area (Kawai 1972). The ocean here is influenced by the interaction of three major currents. The warm Tsugaru current flows from the sea of Japan through the strait between Hokkaido and Honshu, and carries warm water south along the east coast of Honshu. The cold Oyashio current carries water from the Kuril Islands south along the east coast of Hokkaido. The warm Kuroshio current brings water from equatorial regions north along the east coast of Honshu where it meets the Oyashio and Tsugaru currents. At this confluence, currents are deflected eastward and large-scale (200+ km) anticyclonic eddies regularly detach from the Kuroshio Current (Kawai 1972). Warm-core rings form consistently in the area in which murrelets were taken in nets (Vastano and Borders 1984, Kawai and Saitoh 1986, Saitoh et al. 1986, Kawasaki et al. 1991).

Saitoh et al. (1986) suggested that zooplankton, which aggregate in the frontal zone between Kuroshio warm-core rings and cold Oyashio water (Aoki and Inagaki 1992), provide good feeding for Pacific saury (*Cololabis saira*) in September and October as they migrate southward from cold northern regions. In turn, this attracts saury predators such as skipjack tuna (*Katsuwonus pelamis*) and albacore (*Thunnus alalunga*) that typically are found in warm waters such as those within the rings. Thus, it appears that the distributions of cold- and warm-water species overlap where they forage in the productive frontal zone at the edge of the warm-core rings. The diet of Japanese Murrelets is not known, but stable nitrogen ratios of muscle tissue from three Japanese Murrelets salvaged from nets (Table 2) suggest that, like Ancient Murrelets, their diet is a mixture of euphausiids and small pelagic fishes (N^{15}/N^{14}, $\bar{x} = 13.2 \pm$ SD of 0.8 ppt; Hobson and Piatt unpubl. data, Hobson 1991). We conclude that Japanese Murrelets disperse northward in late summer to stage in persistent warm-core rings southeast of Hokkaido, where they forage on zooplankton and pelagic fishes that concentrate in the frontal zones around the rings. This conclusion is consistent with previous limited observations of postbreeding dispersal of Japanese Murrelets (Kuroda 1955, Brazil 1991), and parallels a northward postbreeding dispersal of Xantus' Murrelet (*Synthliboramphus hypoleucus*) from colonies off southern California to waters off Washington and British Columbia (Roberson 1980).

Incidental catch.—We believe that the magnitude of Japanese Murrelet bycatch reported here underestimates the actual bycatch from all the combined gill-net fisheries that operated near the coast of Japan in 1990–1991. For the fisheries we report on here, observer monitoring east of 147°E covered only 4.1% of the commercial fishing effort in 1990 and 2.5% in 1991. Although we have incorporated all monitoring efforts in our analyses, the bycatch of *Synthliboramphus* murrelets was reported only by U.S. observers. It seems unlikely that some other records of "unidentified birds" were murrelets, especially in 1990, when Korean and Taiwanese observers were first trained and participated in the program. Observers also reported that birds frequently dropped out of nets before reaching the ship and, therefore, could not be accounted for in estimates of bycatch or species composition.

Fishing with gill nets is common in coastal waters of Japan. Besides the large-scale drift-net fisheries reported on here and elsewhere (Anonymous 1991a, b, DeGange and Day 1991, INPFC 1991, 1992a, b, c), these fisheries include thousands of small-boat gill-netters in coastal and nearshore areas (DeGange et al. 1993). In addition to nearshore drift-net fisheries for salmon (*Oncorhynchus* spp.), marlin (*Tetrapterus audax*), and tuna (*Thunnus thynnus*), bottom-set gill nets are widely used to catch greenling (*Pleurogrammus azonus*), bastard halibut (*Pralichthys olivaceus*), sculpins (Cottidae), and sole (*Limanda herzenstenei*; Ogi and Shiomi 1991). Bottom-set gill nets are equally efficient as drift nets for catching diving species of seabirds (Piatt and Nettleship 1987, Ogi and Shiomi 1991). These coastal fisheries, which remain largely unstudied, may have a much greater effect than the large-scale drift-net fisheries on coastal species such as the Japanese Murrelet (DeGange and Day 1991, Ogi and Shiomi 1991, DeGange et al. 1993).

Because the distributions of *Synthliboramphus* murrelets overlap in Japan, and the species are difficult to distinguish, it is also possible that the bycatch of Japanese Murrelets has been overlooked previously. DeGange and Day (1991) estimated that 307 Ancient Murrelets were killed in the Japanese land-based salmon drift-net fishery in 1977 and 116 in 1987, but some of those birds could have been misidentified (A. DeGange pers. comm.). Ogi et al. (1992) estimated that, in 1990, 367 Ancient Murrelets were caught in Japanese salmon drift-net fisheries operating east of 155°E, and 61 were taken in the nearshore (small-vessel) Japanese salmon drift-net fishery. Given our experience, we speculate that some records of Ancient Murrelets were based on misidentifications of Japanese Murrelets, especially those taken west of about 150°E longitude.

We recognize the uncertainty of our total bycatch estimate based as it is on a sample of 26 identified specimens. We know the area also is used by wintering Ancient Murrelets (Brazil 1991) and, in fact, two specimens collected there in November and December were tentatively identified as Ancient Murrelets. In any case, we have confidence in the overall extrapolation because murrelets were not taken in just a few bycatch episodes, which can lead to overestimation of total bycatch in aggregated species (Piatt and Nettleship 1987). Rather, bycatch occurred on at least 18 different occasions over five months, suggesting a low but persistent rate of mortality.

Gill-net mortality may be contributing to a decline in the Japanese Murrelet population. Besides the mortality from gill nets, oil pollution that reportedly kills large numbers of Ancient Murrelets (e.g. Kazama 1971) also may be affecting Japanese Murrelets. Predation from introduced predators appears to be another serious mortality factor at colonies (Higuchi 1979, Takeishi 1987, Ono 1993). As for other seabirds, it is not known whether these unnatural mortality factors are additive to the natural mortality rate, or compensated for by density-dependent population regulation (Piatt et al. 1991). Because the total population numbers less than a few thousand, and birds breed at only a few locations, Japanese Murrelet populations are extremely vulnerable to chronic and catastrophic sources of mortality. The 38% reduction in catch rate from 1990 to 1991 may have been an artifact of sampling, or may reflect between-year variation in prey distribution and murrelet foraging effort (Piatt and Nettleship 1987). It also could reflect a steadily decreasing population of Japanese Murrelets.

On the positive side, Japan, Taiwan, and the Republic of Korea have agreed to the cessation of large-scale drift-net fisheries in international waters of the North Pacific by the end of 1992 (as outlined in United Nations Resolution 46/215). Although this action should diminish the bycatch of Japanese Murrelets, drift-net and coastal gill-net fisheries within the 200-mile (320-km) Exclusive Economic Zone of Japan likely will continue to kill Japanese Murrelets throughout their breeding and wintering range (e.g. Ogi and Shiomi 1991). Taken together, all available data point to an urgent need for research on the life history of Japanese Murrelets—including complete surveys of breeding locations, effective protection of colonies and important wintering areas, predator-control programs, and monitoring of coastal gill-net fisheries within the known range of the species.

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