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Incidental Catch of Marine Mammals by Foreign and Joint Venture Trawl Vessels in the U.S. EEZ of the North Pacific, 1973–88

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U.S. Department of Commerce

NOAA Technical Report NMFS

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U.S. DEPARTMENT OF COMMERCE
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National Marine Fisheries Service
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ABSTRACT

During 1973–88, 3,661 marine mammals of 17 species were reported as incidental catch by U.S. fishery observers aboard foreign and joint venture trawl vessels in the U.S. Exclusive Economic Zone in the North Pacific Ocean and the Bering Sea. Northern sea lions (*Eumetopias jubatus*) accounted for 90% of the reported incidental mortality in the Gulf of Alaska and eastern Bering Sea. Nearly half of these sea lions were taken in trawl nets in the Shelikof Strait, Alaska, joint venture fishery during 1982–84. However, high incidental mortality rates (>25 sea lions per 10,000 metric tons of groundfish catch) also occurred in the foreign fisheries near Kodiak Island and in the Aleutian Islands area in earlier years. Estimated annual mortality of incidentally caught northern sea lions in Alaska declined from 1,000 to 2,000 animals per year during the early 1970s and 1982 to fewer than 100 animals in 1988. In the Bering Sea most sea lions incidentally caught were males, while in the Gulf of Alaska females were more frequently caught. Females may also have been dominant in the incidental catch of sea lions in the Aleutian Islands area, but age and sex composition data are limited. Incidental mortality of adult female sea lions by foreign trawl fisheries in these areas could have partially contributed to the reported declines in northern sea lion populations in Alaska during the 1970s, but it cannot alone account for the present decline in population size.

Introduction

Foreign trawl fishing was first introduced as a method of harvesting Pacific Ocean perch (POP: *Sebastes alutus*), walleye pollock (*Theragra chalcogramma*), and yellowfin sole (*Limanda aspera*) by the Japanese in the northeast Pacific Ocean as an exploratory fishery in 1929 and 1933–37 (Natural Resources Consultants 1984). A Japanese mothership with 9–12 catcher vessels fished the Bering Sea during 1940; the fishery terminated during the war, then started again in 1954 with the return of two Japanese motherships and nine catcher boats (Natural Resources Consultants 1984). Soviet exploratory fishing operations in the Bering Sea began in the early 1930s, but commercial operations did not begin until 1959 (Natural Resources Consultants 1984). During the late 1950s and early 1960s Soviet and Japanese trawlers concentrated on POP and yellowfin sole until catches of both began to decline in the late 1960s. Since then walleye pollock has dominated foreign trawl catches, accounting for 60–75% of the total harvest (Natural Resources Consultants 1984).

Northern sea lions (*Eumetopias jubatus*) and other marine mammals have been caught incidentally in foreign trawl fisheries in the Bering Sea and Gulf of Alaska since the onset of these fisheries. Data on the incidental catch of marine mammals and other species were recorded for several years by U.S. observers on a few foreign ships beginning in 1973. However, passage of the Magnuson Fishery Conservation and Management Act of 1976 (FCMA) required foreign vessels to accept observers, and, as amended in 1983, established the U.S. Exclusive Economic Zone (EEZ). A standardized reporting system for the collection of data on the incidental take of marine mammals in the U.S. EEZ was developed in mid-1977, resulting in the routine collection of data by all observers since 1978.

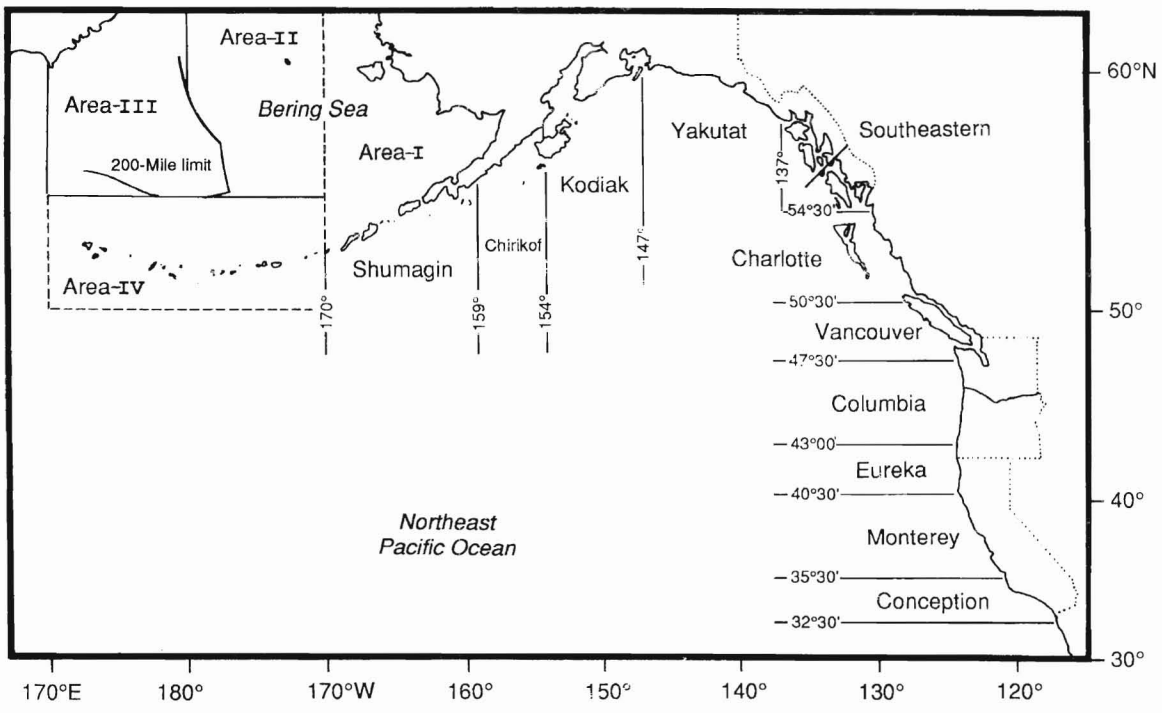

Figure 1
U.S. statistical fishing areas in the Bering Sea and northeast Pacific Ocean used to summarize catch and effort data.

Northern sea lions are the predominant marine mammal species incidentally caught in commercial groundfish fisheries in the North Pacific (Loughlin et al. 1983; Loughlin and Nelson 1986). Many sea lions incidentally caught during fishing operations are alive when brought aboard vessels (up to 34% in 1979); however, mortality of sea lions caught in joint venture (JV) fisheries composed of U.S. trawlers delivering fish to foreign processors was nearly 100% (Loughlin and Nelson 1986).

The trend in the number of adult and juvenile northern sea lions counted on land in most of western Alaska has been declining over the past 30 years at an annual rate of about 4.5%, from about 140,000 animals in 1956–60 to about 25,000 in 1989 (Merrick et al. 1987; Loughlin et al. 1990). In some areas the decline has been even more dramatic. For instance, in the eastern Aleutian Islands the count has declined by 93% (from about 41,220 in 1960 to less than 3,000 in 1989) and in the western Gulf of Alaska levels have dropped by 82% (from about 24,000 in 1956 to about 4,400 in 1989). Numbers of pups counted at western Alaskan rookeries have also declined (Merrick et al. 1987; Loughlin et al. 1990). The reasons for the decline are unknown but may be related to disease, environmental perturbations, decreased food supplies, or direct interactions with foreign and domestic commercial trawl fisheries or other types of fishing activities (Loughlin and Merrick 1989). The possible role that incidental catch had in contributing to the sea lion decline is the subject of this paper.

We present a reanalysis, by area and vessel class, of the incidental catch data for the years 1978–81, and our analysis of the combined incidental catch data for the years 1973–88. We also discuss changes in mean length and age of incidentally caught sea lions, and the relationship of these changes and the estimated level of incidental catch to recent declines in sea lion population abundance.

Methods

This paper discusses the incidental take of marine mammals in the foreign and JV groundfish fisheries occurring on independent stern trawlers and mothership-based trawl fleets. Data from longline or snail-pot fisheries were not included because the reported marine mammal incidental take is either extremely low (longline) or zero (snail-pot). Also, we do not address the issue of incidental take of marine mammals in U.S. domestic fisheries because of the paucity of incidental catch data for those fisheries through 1989.

We report marine mammal incidental take data by year, fishery (country and vessel class), and U.S. statistical reporting areas (Fig. 1). Data from JV fisheries are presented only for the total fishery, not by the country-specific ventures with the domestic

U.S. catcher boats. Data are summarized for three geographical regions: Bering Sea and Aleutian Islands; Gulf of Alaska; and Washington, Oregon, and California.

Observer Data

During the period 1973–77, U.S. observers aboard foreign vessels infrequently reported the occurrence of marine mammals in fishing trawl nets. During that period, incidental take data were recorded in an inconsistent manner. The current U.S. observer data reporting system which was developed in 1977, assigned the duty of recording standardized data on incidental take of marine mammals to all observers (Loughlin et al. 1983). However, the collection and recording of fishery-related data remained the observer's primary responsibility; marine mammal incidental catch data were secondary in nature and recording was not to interfere with the collection of fishery catch data. Data forms for recording marine mammal incidental take were not available to all observers until late 1977. Therefore, only data since 1978 have been uniformly recorded using a standardized system.

U.S. observers recorded either data on 1) hauls actually observed or sampled, or 2) all hauls, including those not observed or sampled, using information supplied by the crew. It should be noted, however, that in many cases the observer did see (and measure) the incidentally caught marine mammal from an unsampled haul (the crew reported the animal to the observer). Therefore, this paper includes incidental catch data in which the total observed fish catch (metric tons, t) includes both sampled and unsampled hauls. We were not able to exclude marine mammal data from unsampled hauls for every cruise. However, in all cases we included the fish catch for each haul with reported incidental take of marine mammals in the total catch monitored by observers. We have not included 1) reported occurrences of isolated marine mammal parts (decomposed skulls or bones, usually from large whales), 2) mammals caught in trawls on vessels without observers but cited on data forms when observers were informed by radio conversation of such occurrences, 3) mammals caught by vessels where observers were merely passengers awaiting transfer to another vessel, or 4) mammals reported caught in waters outside the U.S. EEZ on vessels with U.S. observers aboard.

Many observers did not have previous experience with marine mammal biology, and observer training on biological data collection from marine mammals was limited during most years, especially prior to 1982; collection of such data was a low priority. When observers did obtain biological data and specimens from the incidentally caught marine mammals, they did not always collect length measurements. The type of measurement, standard or curvilinear length (American Society of Mammalogists 1967), was often not recorded. Canine teeth (used for ageing by counting dentine lines of sectioned teeth) were seldom collected; most of the tooth specimens were obtained by observers in the Shelikof Strait JV fishery during 1982–84. Therefore, sample sizes for aged and sized animals differ. Although observers occasionally recorded information on the sex of incidentally caught northern sea lions, these data were unreliable. In many instances tooth specimens (which provide a better guide to the animal's sex) disagreed with the observer's recorded data. Therefore, analyses in this report using information on sex or age have been based only on data from teeth collections. Ageing of teeth was done by National Marine Mammal Laboratory (NMML) personnel; the age estimates by 3 or 4 persons were averaged. Data from canine tooth specimens were only available for 1977–87; teeth collected during 1988 have not been processed.

Data on location and fishing times, including times of net retrieval (from the bottom) and trawl duration, were available for most catches observed by U.S. observers aboard foreign independent trawlers (not mothership-based fleets) from 1980 to 1988, except during 1984. With few exceptions, location and fishing times of hauls in the JV fisheries were unavailable prior to 1985. Locations for foreign mothership catches in all years, and JV catches during 1978–84, were based on the noon position of the processor vessel.

Times of start and end of net retrieval were recorded by observers in GMT and were later converted to local time. Incidental take was summarized for daytime and nighttime periods. Sunrise and sunset times were not recorded by observers. They were estimated for this paper using the standard calculation formulae in the astronomical ephemeris and nautical almanac (without correction for refraction, changes in right ascension, or declination of the sun during the day).

In order to describe an average diel pattern of incidental take throughout the year, local clock times were converted to relative proportions of the day with respect to dawn or dusk. These proportions (percentages) were grouped into 24 equal divisions (hours) to represent a standardized fishing day for all years, months, and areas. This procedure was necessary because the length of the day varies by latitude and season. For each haul, the total number of daylight or night hours in the 24-hour period on that date was calculated. The percentage of the day or

night at which the haul occurred was calculated as the ratio of the time of net retrieval relative to the respective length (hours) of day or night.

Estimated Catch

Estimates of the total incidental take of marine mammals were calculated on the basis of the number of observed marine mammals incidentally caught per observed tonnage of groundfish. Groundfish catch (tonnage) is the only statistic for the magnitude of the fishery that is available for all trawl fisheries and years; effort data on total number of hauls are not available. Groundfish catches by all trawl gear, i.e. stern (one boat fishing separately with one net) and pair (two boats fishing together at the same speed with one net between them), were included in making estimates. We included marine mammals caught but not seen by the observer to avoid underestimating the total incidental take in the fishery when total daily tonnage was used as an indicator of the observed fish catch.

Data for the total fish catch by the foreign fisheries prior to 1978 were obtained from Murai et al. (1981) and Berger et al. (1986); data for groundfish catch by vessel class, gear type, and INPFC statistical area came from Sueto Murai (Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115, unpubl. data). Data on location and total daily fish catch for cruises with observers during 1973–77 were obtained from original master data files of the Foreign Fisheries Observer Program and the groundfish fisheries database of the Alaska Fisheries Science Center (Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115). Data for location, fishing time, and total fish catch monitored by observers during 1978–88 were obtained from marine mammal incidental take records and fish catch forms provided by observers. Data sources on observer coverage, number of fishing days, and the total fishery catch by country, statistical reporting area, vessel type, month, and year during 1978–88 are listed in Appendix 1.

The total observed tonnage of groundfish in this paper will differ somewhat from values given in the Foreign Fisheries Observer Program reports (*see* Appendix 1) which usually include only hauls sampled for catch composition. Also, observers reported only a summary of the total daily catch (all hauls combined) and not the catch in each haul for all foreign vessels during 1973–77, foreign mothership vessels during 1978–86, and JV vessels during 1978–84.

Rates of incidental take for the years 1978–88 were calculated by the following subgroups: species, statistical area, fishery, country, vessel type, and year. Average rates of incidental take were calculated by region and country for the period 1973–77. The rates were calculated as ratio estimates ($\hat{Y}_R$) from the sum of the dead marine mammals reported in the catch divided by the sum of the observed tonnage of fish catch for each subgroup. Standard errors and variance of the ratio estimate were calculated by the simple random sampling ratio estimate method discussed by Cochran (1977). The fraction of hauls (or fishing days) observed in the total fishery is unknown; instead, the percentage of total tonnage sampled was used as an estimate of the fraction of total effort observed. The normal approximation was assumed to be appropriate because the sample size (number of hauls sampled) was nearly always large (>50). The resulting values are reported as multiples of 10,000 t of fish catch. The formulae used to calculate catch rates and ratio estimates are listed in Appendix 2.

Total estimated incidental take of marine mammals for each subgroup was calculated by multiplying the observed rates of incidental take (per 10^4 t of fish catch) by the total tonnage caught by the entire fishery in that subgroup. The resulting estimated totals (ratio estimates) were summed over all subgroups to provide regional totals for all fisheries combined in each year. The variance of the total for all combined strata (subgroups) was calculated as the sum of the product of the variance of each stratum times the square of the respective total fishery catch (tonnage) in each stratum.

If the percentage of groundfish catch observed in any subgroup was less than 5% of the total fishery catch (as stated previously, tonnage was used as an estimate of total effort because the total number of trawls in the fishery is unknown), then the calculated rate of incidental take was not used. This method was used to avoid high estimates based only on one observed mammal; 5% was arbitrarily chosen on the basis of an examination of the shape of the curve of calculations with only one observed animal. Instead, one of four rates, in the following order, was used as a replacement when the percentage (tonnage basis) of the fish catch monitored by observers was equal to or greater than 5% for the replacement group: 1) the average rate for all fisheries, trawlers combined, of the same country in the same year and statistical area; 2) the average rate for all fisheries, trawlers and countries combined, in the same year and statistical area; 3) the average rate for all fisheries, trawlers combined, of the same country and statistical area for the five-year period the year under analysis belongs to (i.e., 1978 to 1982); or 4) the average rate for all foreign fisheries combined of the statistical area for the five-year period the year under analysis belongs to. This procedure was not needed for analy-

Table 1

Summary by region of incidentally taken marine mammals reported by U.S. observers on foreign and joint venture (JV) trawl vessels in the Exclusive Economic Zone (EEZ) in the North Pacific Ocean and eastern Bering Sea, 1973–88.[a] For each fishery, total observer coverage (percent) and the total groundfish catch (percent of total catch by both fisheries combined) in the EEZ during all years are listed. Decomp. = decomposed animals.

	Bering Sea and Aleutian Islands			Gulf of Alaska			Washington, Oregon, and California		
Species	Dead	Alive	Decomp.	Dead	Alive	Decomp.	Dead	Alive	Decomp.
Northern sea lion, *Eumetopias jubatus*	1,053	264	102	1,603	150	10	6	1	—
California sea lion, *Zalophus californianus*	—	—	—	—	—	—	1	—	—
Northern fur seal, *Callorhinus ursinus*	41	—	13	6	—	1	1	—	—
Northern elephant seal, *Mirounga angustirostris*	—	—	1	3	—	—	—	—	—
Harbor seal, *Phoca vitulina*	28	—	9	3	—	—	5	—	—
Spotted seal, *Phoca largha*	3	—	2	—	—	—	—	—	—
Ringed seal, *Phoca hispida*	2	—	—	—	—	—	—	—	—
Ribbon seal, *Phoca fasciata*	17	—	1	—	—	—	—	—	—
Bearded seal, *Erignathus barbatus*	4	—	1	—	—	—	—	—	—
Walrus, *Odobenus rosmarus*	76	1	68	—	—	—	—	—	—
Unidentified pinnipeds	42	2	38	2	—	—	—	—	—
Sea otter, *Enhydra lutris*	—	—	3	—	—	—	—	—	—
Minke whale, *Balaenoptera acutorostrata*	—	—	2	—	—	—	—	—	—
Risso's dolphin, *Grampus griseus*	—	—	1	—	—	—	—	—	—
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	—	—	—	—	—	—	3	—	—
Killer whale, *Orcinus orca*	1	1	2	1	—	—	—	—	—
Harbor porpoise, *Phocoena phocoena*	3	—	1	—	—	—	—	—	—
Dall's porpoise, *Phocoenoides dalli*	11	—	2	1	1	—	8	1	—
Unidentified cetaceans	7	—	18	2	—	—	9	1	—
Unidentified marine mammals	2	—	8	11	—	—	—	—	1
Total	1,290	268	272	1,632	151	11	33	3	1

	Bering Sea and Aleutian Islands			Gulf of Alaska			Washington, Oregon, and California		
	Foreign	JV	Total	Foreign	JV	Total	Foreign	JV	Total
Observer coverage (percent)[b]	32.1	56.8	37.9	13.1	69.6	30.0	17.2	74.6	34.6
Groundfish catch (percent)[c]	83.3	78.1	82.0	9.2	12.0	9.9	7.5	9.9	8.1

[a] Data reporting by Foreign Vessel Observer Program observers was consistent only for the years 1978–88.

[b] Percent of total fish catch in trawl nets of each fishery monitored by Foreign Vessel Observer Program observers during 1973–88 (years combined).

[c] Percent of total groundfish catch caught by each trawl fishery during all years (1973–88).

ses of data from 1983 to 1988 because the percentage of catch monitored by U.S. observers exceeded 5% for all statistical areas, vessel classes, and years.

Observed incidental catch rates for motherships of foreign fisheries were not used in obtaining regional totals of estimated incidental take by year. An alternative method was necessary because the total daily groundfish catch for motherships includes groundfish catch from unobserved hauls which will bias ratio estimates of incidental take downward. Thus, the observed rates for motherships were presumably low owing to the different method used to report the observer monitored fish catch (observers recorded total daily catch for motherships and individual haul catch for stern trawlers). Instead, the average rate of incidental take by independent foreign trawlers (all countries combined) in the same year and statistical area was used to estimate incidental take by mothership fleet trawlers.

The observed incidental take rates on JV vessels were always used to obtain regional totals of estimated incidental take of marine mammals by JV fisheries. Because the percentage of groundfish catch monitored by observers was always reported as ≥5%, no replacement rate method (an alternative method discussed previously which was necessary for stern trawlers to avoid high estimates based on one observed animal) was used for JV fisheries. In addition, although observers recorded total daily catch for JV fisheries prior to 1985, the approach used for foreign motherships to estimate regional totals of estimated incidental take was not used for JV fisheries.

For fishery subgroups with no observer coverage (the percentage of the total foreign vessel days on fishing grounds sampled by observers), the average rate of incidental take of marine mammals (i.e., only the marine mammal species for which rates were calculated) for all trawlers, countries, and years (1978–88) combined in the same statistical area was used to estimate the regional totals of incidental take. This average rate was also used for the unmonitored portion (tonnage for hauls and vessels not sampled by observers for incidental catch) of the fish catch in subgroups where no marine mammals were reported in the catch. A similar approach was used for JV fisheries using data only from JV fisheries.

Total mortality of northern sea lions in the trawl fisheries for years prior to 1978 was estimated using the average observed rate (and 95% confidence limits) of incidental catch of dead sea lions by foreign trawlers (mothership fleets excluded) during 1973–77. We did not estimate total mortality of other marine mammal species in the trawl fisheries for years prior to 1978.

Results

Observed Incidental Take

Seventeen marine mammal species were caught incidental to fishing operations by foreign and JV

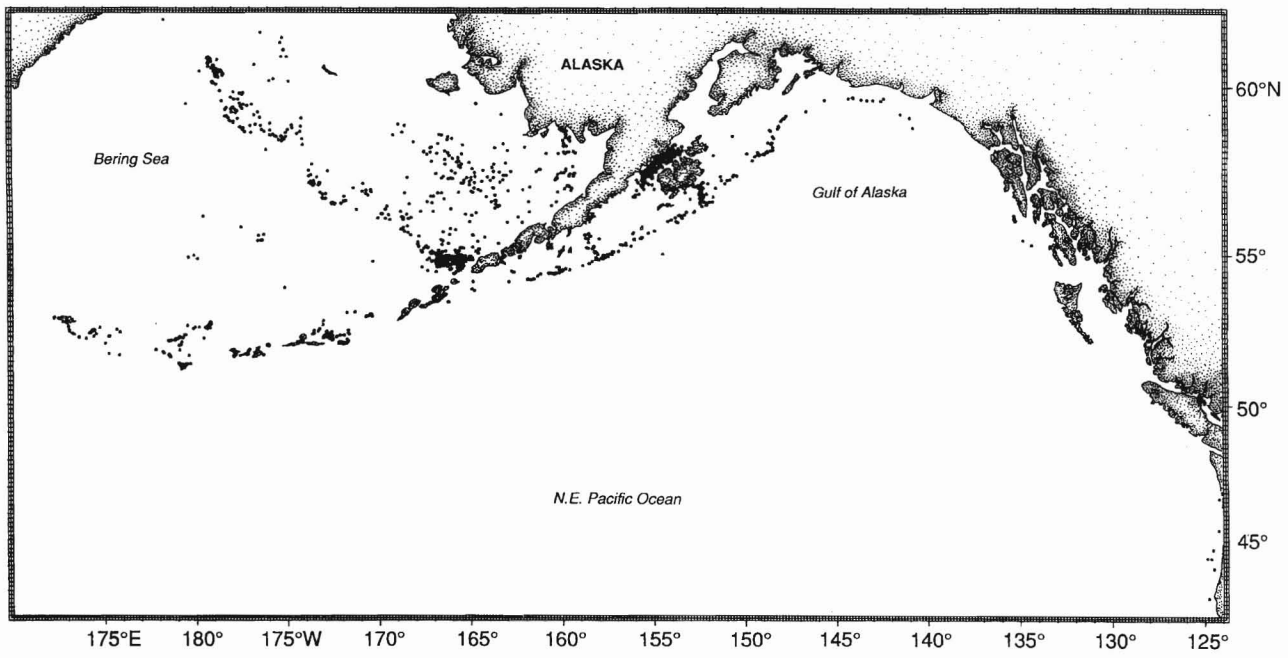

Figure 2

Locations in the Bering Sea and northeast Pacific Ocean where northern sea lions were incidentally caught during fishing operations, 1973–88. Decomposed animals were not included.

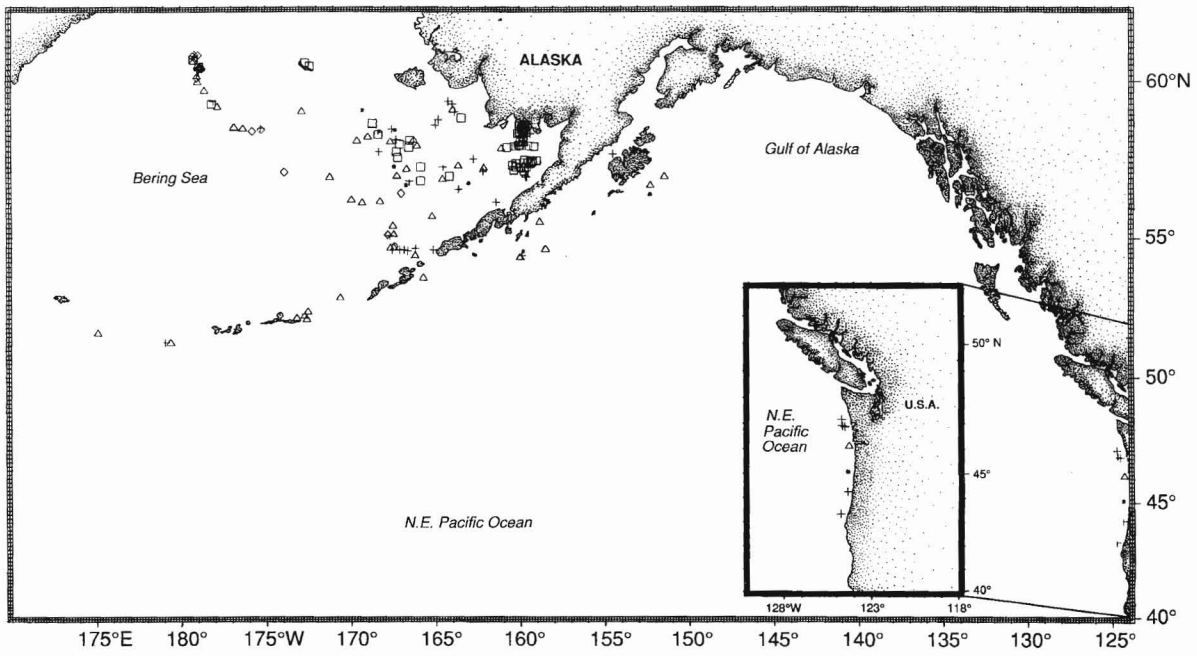

Figure 3

Locations in the Bering Sea and northeast Pacific Ocean where pinnipeds, except northern sea lions, were incidentally caught during fishing operations, 1973–88. Locations off the coast of Washington, Oregon, and northern California are shown in the inset. Decomposed animals were not included. Key to symbols: △ = northern fur seal; + = harbor seal or spotted seal; ◇ = ribbon seal; □ = walrus; and ∗ = other pinniped species.

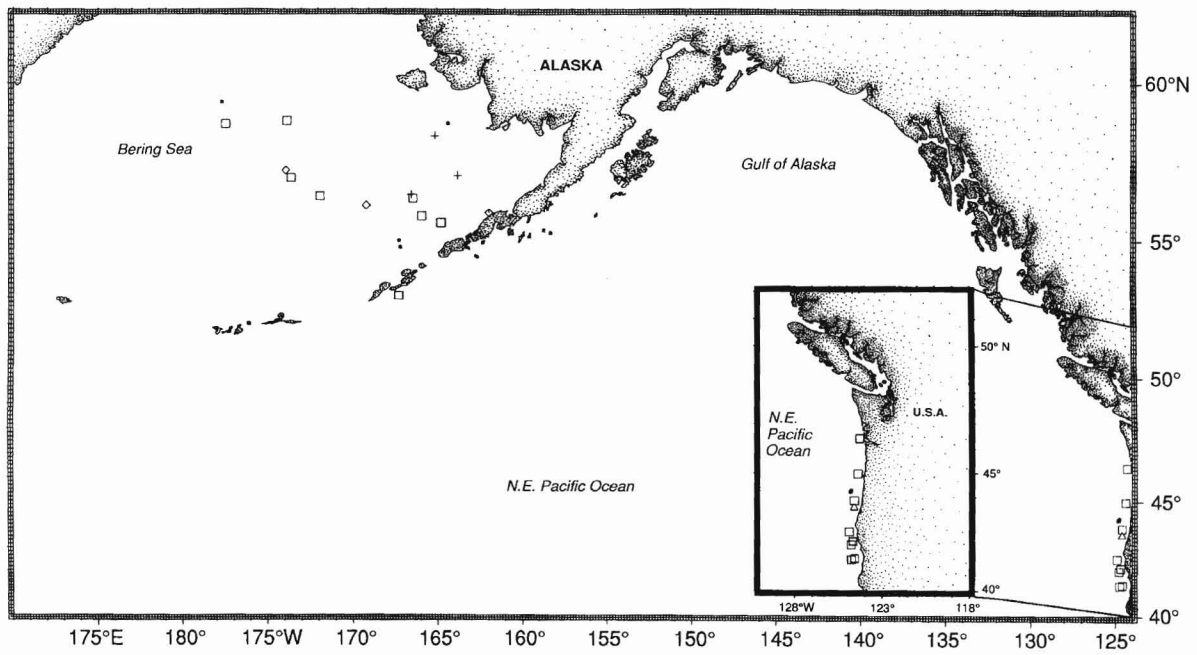

Figure 4

Locations in the Bering Sea and northeast Pacific Ocean where cetaceans were incidentally caught during fishing operations, 1973–88. Locations off the coast of Washington, Oregon, and northern California are shown in the inset. Decomposed animals were not included. Key to symbols: △ = Pacific white-sided dolphin; ◇ = killer whale; + = harbor porpoise; □ = Dall's porpoise; and ∗ = other cetacean species.

Table 2

Summary by year of incidentally taken marine mammals reported by U.S. observers on foreign and joint venture (JV) trawl vessels in the Exclusive Economic Zone (EEZ) in the North Pacific Ocean and eastern Bering Sea, 1973–88.[a] Totals include animals found dead in catch (excluding decomposed); numbers in parentheses refer to an additional number of animals caught and released alive. For each year total observer coverage (percent) and the total groundfish catch (percent of total catch by both fisheries combined) in the EEZ are listed.

Species	1973	1974	1975	1976	1977	1978	1979	1980	1981
Northern sea lion, *Eumetopias jubatus*	13(4)	73(10)	24(5)	27(11)	53(12)	72(41)	68(39)	52(7)	45(14)
California sea lion, *Zalophus californianus*	—	—	—	—	—	—	—	—	—
Northern fur seal, *Callorhinus ursinus*	—	—	1	—	—	1	2	4	1
Northern elephant seal, *Mirounga angustirostris*	—	—	—	1	—	—	—	—	—
Harbor seal, *Phoca vitulina*	—	—	—	—	1	—	1	—	1
Spotted seal, *Phoca largha*	—	—	—	—	—	—	—	—	—
Ringed seal, *Phoca hispida*	—	—	—	—	—	—	—	—	—
Ribbon seal, *Phoca fasciata*	—	—	—	—	—	1	1	—	—
Bearded seal, *Erignathus barbatus*	—	—	—	—	—	—	—	—	—
Walrus, *Odobenus rosmarus*	—	—	—	—	1	—	—	1	2
Unidentified pinnipeds	25	—	—	—	—	—	—	—(1)	—
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	—	—	—	—	—	—	—	—	—
Killer whale, *Orcinus orca*	—	—	—	—	—	—	—	—	—
Harbor porpoise, *Phocoena phocoena*	—	—	—	—	—	—	—	—	—
Dall's porpoise, *Phocoenoides dalli*	—	—	—	2	2(1)	—(1)	4	—	2
Unidentified cetaceans	—	1	—	—	—	—(1)	9	—	1
Unidentified marine mammals	—	—	—	—	—	—	—	—	1
Total	38(4)	74(10)	25(5)	30(11)	57(13)	74(43)	85(39)	57(8)	53(14)
Observer coverage (percent)[b]	7.3	7.1	5.6	6.4	34.3	34.0	37.2	16.5	23.6
Groundfish catch (percent)[c]	7.7	7.9	6.8	6.8	5.0	5.7	5.4	5.4	5.8

Species	1982	1983	1984	1985	1986	1987	1988	Total
Northern sea lion, *Eumetopias jubatus*	725(146)	425(79)	560(26)	286(14)	163(4)	44(3)	32	2,662(415)
California sea lion, *Zalophus californianus*	—	—	—	—	—	—	1	1
Northern fur seal, *Callorhinus ursinus*	4	4	17	5	4	3	2	48
Northern elephant seal, *Mirounga angustirostris*	2	—	—	—	—	—	—	3
Harbor seal, *Phoca vitulina*	1	6	4	9	6	5	2	36

Table 2 (continued)

Species	1982	1983	1984	1985	1986	1987	1988	Total
Spotted seal, *Phoca largha*	—	1	—	—	—	1	1	3
Ringed seal, *Phoca hispida*	—	—	—	—	1	—	1	2
Ribbon seal, *Phoca fasciata*	2	5	7	1	—	—	—	17
Bearded seal, *Erignathus barbatus*	—	—	—	1	2	—	1	4
Walrus, *Odobenus rosmarus*	—	3	2	20	11	20(1)	16	76(1)
Unidentified pinnipeds	1	3	3	4	3(1)	3	2	44(2)
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	—	—	—	—	—	—	3	3
Killer whale, *Orcinus orca*	—	1	1(1)	—	—	—	—	2(1)
Harbor porpoise, *Phocoena phocoena*	—	—	1	—	1	—	1	3
Dall's porpoise, *Phocoenoides dalli*	1	2	4	2	1	—	—	20(2)
Unidentified cetaceans	—	2	2	3	—	—	—	18(1)
Unidentified marine mammals	—	—	—	12	—	—	—	13
Total	736(146)	452(79)	601(27)	343(14)	192(5)	76(4)	62	2,955(422)
Observer coverage (percent)[b]	52.7	60.7	76.3	63.7	63.0	54.9	58.5	36.9
Groundfish catch (percent)[c]	5.5	5.9	7.1	7.4	6.6	5.7	5.3	100.0

[a] Data reporting by Foreign Vessel Observer Program observers was consistent only for the years 1978–88.

[b] Percent of total fish catch of all trawl fisheries monitored by Foreign Vessel Observer Program observers for incidental catch during 1973-88.

[c] Percent of total fish catch (all foreign and JV fisheries combined) during all years (1973–88) combined.

groundfish trawl vessels during the period 1973–88 in the U.S. EEZ of the North Pacific Ocean and Bering Sea (Table 1). Most of the 3,661 mammals caught died in the nets, but some (422) were released alive. Decomposed animals represented 20–50% of the incidental take of most marine mammal species caught in the nets (Table 1). Three (sea otter, *Enhydra lutris*; minke whale, *Balaenoptera acutorostrata*; and Risso's dolphin, *Grampus griseus*) species were represented only by decomposed animals.

Northern sea lions represented 87% of the total marine mammal incidental take reported by U.S. observers during 1973–88. Only 4% of the 3,189 sea lions caught were decomposed animals (Table 1). Excluding decomposed animals, 42.8% of the northern sea lions incidentally taken during this period were caught in the Bering Sea; 57.0% were caught in the Gulf of Alaska; and 0.2% were caught off Washington, Oregon and California (Table 1; Fig. 2).

Other pinniped species (excluding decomposed animals) incidentally caught during 1973–88 were 48 northern fur seals (*Callorhinus ursinus*); 1 California sea lion (*Zalophus californianus*); 36 harbor seals (*Phoca vitulina*); 17 ribbon seals (*Phoca fasciata*); 12 phocid seals of other species; 77 walruses (*Odobenus rosmarus*); and 46 unidentified pinnipeds. Most of the total catch of these species occurred in the Bering Sea (Fig. 3).

Cetaceans represented 1.5% of the total incidental take during 1973–88 (Table 1). Dall's porpoise (*Phocoenoides dalli*; 0.7%) was the most commonly caught cetacean. Most cetaceans were caught in the Bering Sea or off Washington, Oregon, and California (Table 1; Fig. 4).

Except for northern sea lions, observed incidental takes for marine mammals were low, averaging less than five animals per species per year (Table 2). The observed take of walruses per year has exceeded this average since 1985, because of increased JV fishing effort in Bristol Bay where walruses are frequently found.

Northern sea lions were observed caught in greater numbers by JV fisheries (66% of all sea lions taken, Table 3) than by foreign fisheries during 1978–88,

Table 3

Summary by country of incidentally taken marine mammals reported by U.S. observers on foreign and joint venture (JV) trawl vessels in the Exclusive Economic Zone (EEZ) in the North Pacific Ocean and eastern Bering Sea, 1973–88.[a] For each country total observer coverage (percent) and the total groundfish catch (percent of total catch by all countries combined) in the EEZ during all years are listed.

Species	Bulgaria	People's Republic of China	West Germany	Japan	Republic of Korea	Mexico
Northern sea lion, *Eumetopias jubatus*	—	—	13	512(301)	63(22)	2
California sea lion, *Zalophus californianus*	—	—	—	—	—	—
Northern fur seal, *Callorhinus ursinus*	—	—	—	26	3	—
Northern elephant seal, *Mirounga angustirostris*	—	—	—	3	—	—
Harbor seal, *Phoca vitulina*	1	—	—	14	4	—
Spotted seal, *Phoca largha*	—	—	—	1	—	—
Ringed seal, *Phoca hispida*	—	—	—	—	—	—
Ribbon seal, *Phoca fasciata*	—	—	—	17	—	—
Bearded seal, *Erignathus barbatus*	—	—	—	1	—	—
Walrus, *Odobenus rosmarus*	—	—	—	19	3	—
Unidentified pinnipeds	—	—	—	33	—	—
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	—	—	—	—	—	—
Killer whale, *Orcinus orca*	—	—	—	1(1)	—	—
Harbor porpoise, *Phocoena phocoena*	—	—	—	—	1	—
Dall's porpoise, *Phocoenoides dalli*	1	—	—	7	—	—
Unidentified cetaceans	—	—	—	8	—	—
Unidentified marine mammals	—	—	—	1	—	—
Total	2	0	13	643 (302)	74 (22)	2
Groundfish catch (t)	38,566	2,007	110,731	14,163,598	2,095,920	10,632
Percent of all-nation combined groundfish catch[c]	0.1	<0.1	0.4	51.7	7.6	<0.1
Observer coverage (percent)[d]	21.6	70.5	37.6	34.0	30.5	12.0

Species	Poland	Portugal	Taiwan	U.S.S.R.	Total foreign[b]	JV
Northern sea lion, *Eumetopias jubatus*	22	—	2(2)	97(11)	713(336)	1,949(79)
California sea lion, *Zalophus californianus*	1	—	—	—	1	—
Northern fur seal, *Callorhinus ursinus*	—	—	—	1	30	18

Table 3 (continued)

Species	Poland	Portugal	Taiwan	U.S.S.R.	Total foreign[b]	JV
Northern elephant seal, *Mirounga angustirostris*	—	—	—	—	3	—
Harbor seal, *Phoca vitulina*	1	—	—	—	20	16
Spotted seal, *Phoca largha*	—	—	—	—	1	2
Ringed seal, *Phoca hispida*	—	—	—	—	—	2
Ribbon seal, *Phoca fasciata*	—	—	—	—	17	—
Bearded seal, *Erignathus barbatus*	—	—	—	—	1	3
Walrus, *Odobenus rosmarus*	—	—	—	—	22	54(1)
Unidentified pinnipeds	—(1)	—	—	—	33(1)	11(1)
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	3	—	—	—	3	—
Killer whale, *Orcinus orca*	—	—	—	—	1(1)	1
Harbor porpoise, *Phocoena phocoena*	—	—	—	—	1	2
Dall's porpoise, *Phocoenoides dalli*	2(1)	—	—	4(1)	14(2)	6
Unidentified cetaceans	1	—	—	9(1)	18(1)	—
Unidentified marine mammals	1	—	—	—	2	11
Total	31(2)	0	2(2)	111(13)	880(341)	2,075(81)
Groundfish catch (t)	794,886	182	25,118	3,443,646	20,685,285	6,706,260
Percent of all-nation combined groundfish catch[c]	2.9	<0.1	0.1	12.6	75.5	24.5
Observer coverage (percent)[d]	34.3	75.3	4.4	3.8	28.9	60.1

[a] Totals include animals found dead in catch (no decomposed); numbers in parentheses refer to an additional number of animals caught and released alive.
[b] Includes animals for which data on country-specific fishery were not recorded.
[c] Percent of total groundfish catch (all foreign and JV fisheries combined) during all years (1973–88) combined.
[d] Percent of total fish catch of that country-specific fishery monitored by Foreign Vessel Observer Program observers during 1973–88 (years combined).

particularly during 1982–84 in Shelikof Strait in the northwestern Gulf of Alaska. Walruses were also incidentally caught more often (70%) by JV fisheries in the Bering Sea, but 66% of the other marine mammal species were caught more frequently by foreign fisheries (Table 3). Japanese vessels accounted for most (77%) of the incidentally caught marine mammals in the foreign fisheries, as well as 52% of the total fish catch during 1973–88 by all fisheries combined (Table 3). Although JV fisheries caught most of the observed take of northern sea lions, they caught only 24% of the total fish catch during 1973–88 (Table 3).

Fishery trends by year, region, and country must be considered when comparing the reported incidental takes of marine mammals in Tables 1–3. The effort of the foreign fishing fleets was reduced annually with the rise of the JV and domestic fisheries. The foreign trawl fisheries ceased fishing in the U.S. EEZ in Alaska in 1988. Joint venture fisheries in the U.S. EEZ of the North Pacific Ocean first began in 1978 with low fishing effort. The total fish catch by JV fisheries has increased each year, exceeding the catch of foreign fleets off Washington, Oregon, and California in 1982 (Fig. 5A); in the Gulf of Alaska by 1983 (Fig. 5B); and in the Bering Sea by 1986 (Fig. 5C).

Foreign and JV fisheries varied by region during 1973–88 when 82% of the total fish catch was taken in the Bering Sea, 10% in the Gulf of Alaska, and 8% off Washington, Oregon and California (Table 1). Foreign fisheries accounted for 78.8% of the total 340,170 trawl vessel fishing days from 1978 to 1988 and JV fisheries account for the difference. During this period, foreign trawl vessels operated a total of 14,859 days (5%) fishing in the U.S. EEZ off Washington, Oregon, and California (Fig. 6A); 31,342 days (12%) fishing in the U.S. EEZ in the Gulf of Alaska (Fig. 6B); and 221,836 (83%) days fishing in the U.S. EEZ in the Bering Sea (Fig. 6C). Joint venture vessels operated a total of 14,338 days (20%) fishing in the U.S. EEZ off Washington, Oregon and California (Fig. 6A); 8,464 days (12%) fishing in the U.S. EEZ in the Gulf of Alaska (Fig. 6B); and 49,331 days (68%) fishing in the U.S. EEZ in the Bering Sea (Fig. 6C).

Observer coverage on foreign vessels increased from 10–35% during 1978 to 90–100% during 1988 (Fig. 7, A through C) (observer coverage of JV fisheries during 1978 was near 100% because the fishery began late in the year with a few vessels). Coverage was similar among regions, but higher for the

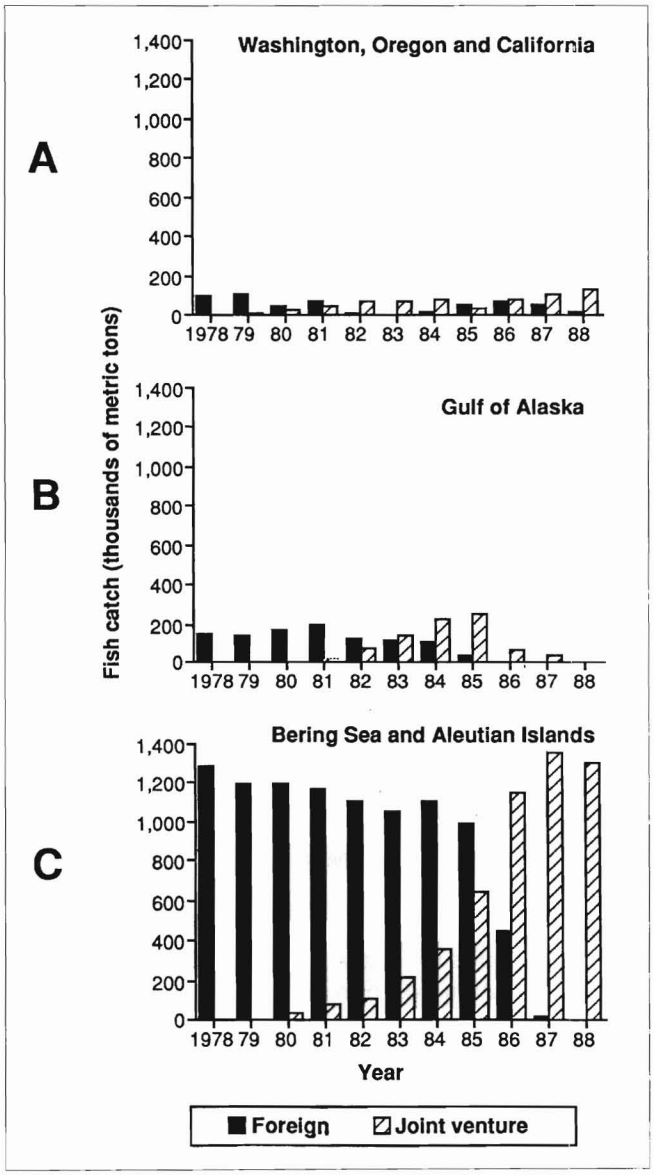

Figure 5
Total metric tons of fish caught by foreign and joint venture fishing vessels in the U.S. Exclusive Economic Zone, 1978–88: (**A**) off the coast of Washington, Oregon, and California; (**B**) in the Gulf of Alaska; and (**C**) in the Bering Sea and Aleutian Islands region.

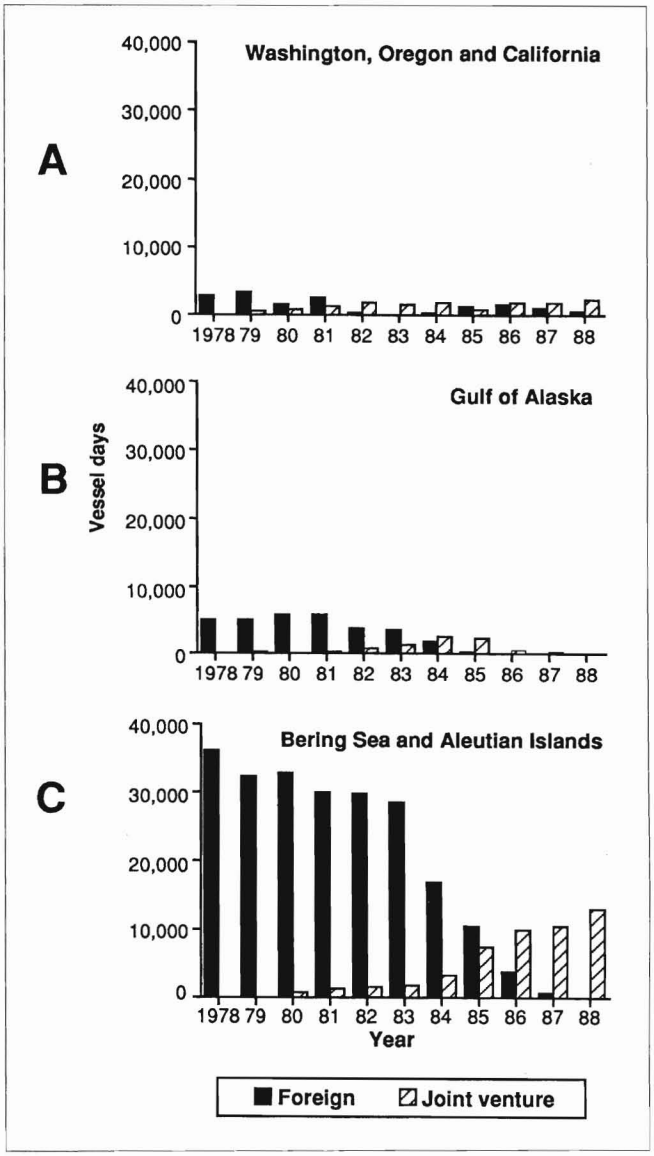

Figure 6
Total number of vessel days with fishing operations for foreign and joint venture fisheries in the U.S. Exclusive Economic Zone, 1978–88: (**A**) off the coast of Washington, Oregon, and California; (**B**) in the Gulf of Alaska; and (**C**) in the Bering Sea and Aleutian Islands region.

Table 4

Number of northern sea lions reported by U.S. fishery observers incidentally caught by subgroup (area, vessel class, nation, and year) in the U.S. Exclusive Economic Zone in the Bering Sea, 1978–88, and an estimation of the total incidental take of northern sea lions in the fishery. Catch rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take of only dead animals to observed groundfish catch (per 10,000 metric tons [t] basis). Estimated takes of only dead sea lions are the ratio estimate ($\hat{Y}_R$) ± the 95% confidence limits ($L_{95\%}$). Refer to Figure 1 for the locations of the areas in the left column. * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers; ** = the estimated lower 95% confidence level was less than zero.

	Groundfish				Northern sea lions		
Vessel nation year[a]	Total catch (t)	Observed catch[b] (t)	Percent of catch observed	Number of hauls observed[c] (n)	Number dead (alive) reported in catch[d]	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	$\hat{Y}_R \pm L_{95\%}$
				Area-I			
Small stern trawler							
Japan							
1978	21,482.6	1,246.8	5.8	908	0 (2)	0	—
1979	28,287.1	1,069.5	3.8	467	1 (5)	9.35 ± 18.34	26 ± 51 **
1980	42,177.0	1,318.3	3.1	373	0	0	—
1981	38,809.1	487.5	1.3	155	0	0	—
1982	34,003.1	8,018.7	23.6	2,087	1 (13)	1.25 ± 2.18	4 ± 8 **
1983	37,375.4	14,316.8	38.3	4,855	6 (10)	4.19 ± 2.69	16 ± 9
1984	54,283.0	35,434.5	65.3	5,386	19 (7)	5.36 ± 1.66	28 ± 9
1985	36,132.2	27,681.8	76.6	3,728	17	6.14 ± 1.52	22 ± 5
1986	22,871.9	16,544.9	72.3	1,361	3	1.81 ± 1.10	4 ± 3 *
1987	2,272.3	1,686.5	74.2	174	0	0	—
Republic of Korea							
1981	9,052.0	321.0	3.6	13	0	0	—
1982	13,567.9	4,053.0	29.9	241	1	2.47 ± 4.15	3 ± 5 **
1983	10,922.7	3,701.7	33.9	169	0	0	—
1984	12,401.2	7,101.4	57.3	291	0	0	—
1985	14,404.6	9,217.9	64.0	367	0	0	—
1986	8,738.4	6,320.2	72.3	265	0	0	—
Portugal							
1984	182.0	137.1	75.3	58	0	0	—
Taiwan							
1978	882.6	—	—	—	—	—	—
1979	160.3	—	—	—	—	—	—
1980	53.4	—	—	—	—	—	—
1981	1,730.6	—	—	—	—	—	—
1982	4,189.7	636.1	15.2	149	0 (2)	0	—
Large surimi trawler							
Japan							
1978[e]	142,044.2	27,683.2	19.5	1,124	19 (5)	6.86 ± 3.48	97 ± 49
1979[e]	159,280.5	30,836.2	19.4	1,555	5 (2)	1.62 ± 1.30	26 ± 20
1980	163,050.4	9,986.8	6.1	495	5	5.01 ± 5.12	82 ± 82 *
1981	164,053.8	19,271.1	11.8	1,012	1 (2)	0.52 ± 0.98	9 ± 15 **
1982	129,264.5	51,405.2	39.8	2,267	8 (6)	1.56 ± 0.85	20 ± 11
1983	64,329.1	35,832.4	55.7	1,517	1 (2)	0.28 ± 0.37	2 ± 3 **
1984	47,362.2	28,182.1	59.5	1,051	2 (5)	0.71 ± 0.64	3 ± 3 *
1985	81,514.7	49,536.8	60.8	1,453	13 (2)	2.62 ± 0.98	21 ± 8
1986	6,576.8	4,442.7	67.6	111	0	0	—
Republic of Korea							
1986	23,435.9	16,572.2	70.7	359	0	0	—
1987	501.7	327.1	65.2	18	0	0	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Large freezer trawler							
People's Republic of China							
1986	1,550.9	1,010.1	65.1	84	0	0	—
Japan							
1980	11,888.4	636.6	5.4	49	0	0	—
1981	12,897.7	588.8	4.6	106	0	0	—
1982	14,257.7	4,253.7	29.8	453	0	0	—
1983	20,707.6	8,851.0	42.7	860	1	1.13 ± 1.71	2 ± 3 **
1984	20,587.5	9,970.3	48.4	934	0	0	—
1985	16,623.1	8,069.4	48.5	681	2	2.48 ± 2.52	4 ± 4 *
1986	6,443.7	4,265.7	66.2	270	10	23.44 ± 9.24	15 ± 6 *
West Germany							
1980	6,658.3	867.0	13.0	51	0	0	—
1981	8,727.1	1,062.2	12.2	52	0	0	—
1982	1,183.9	555.9	47.0	22	2	35.98 ± 53.01	4 ± 6 **
1983	10,161.3	6,370.8	62.7	157	0	0	—
1984	7,402.3	4,104.5	55.4	104	1	2.44 ± 3.25	2 ± 3 **
Republic of Korea							
1978	51,576.1	5,292.6	10.3	199	1 (4)	1.89 ± 3.57	10 ± 18 **
1979	52,459.9	5,893.0	11.2	267	0 (2)	0	—
1980	85,178.2	6,816.2	8.0	281	2	2.93 ± 3.99	25 ± 33 **
1981	90,493.7	15,974.8	17.6	592	0	0	—
1982	124,811.1	46,285.4	37.1	1,538	9 (5)	1.94 ± 1.14	24 ± 14
1983	185,897.6	82,249.8	44.2	2,557	4	0.49 ± 0.36	9 ± 7 *
1984	177,121.8	110,900.4	62.6	3,199	9 (2)	0.81 ± 0.33	14 ± 5
1985	173,564.7	114,031.5	65.7	2,998	17 (2)	1.49 ± 0.45	26 ± 8
1986	54,744.3	40,266.1	73.6	1,248	1	0.25 ± 0.26	1 ± 1 *
1987	1,116.7	647.1	58.0	40	0	0	—
Poland							
1979	12,114.7	1,042.1	8.6	122	0	0	—
1980	26,168.4	2,036.0	7.8	196	0	0	—
1981	32,184.9	5,658.7	17.6	402	3	5.30 ± 9.62	17 ± 30 **
1984	46,728.7	30,858.5	66.0	1,582	4	1.30 ± 0.75	6 ± 4 *
1985	20,399.0	14,540.2	71.3	732	2	1.38 ± 1.04	3 ± 2 *
1986	3,633.3	2,341.6	64.4	148	0	0	—
Taiwan							
1978	805.2	—	—	—	—	—	—
1980	742.1	—	—	—	—	—	—
1981	1,578.7	—	—	—	—	—	—
1982	1,510.0	460.9	30.5	76	2	43.39 ± 51.94	7 ± 8 **
U.S.S.R.							
1978	94,820.9	6,210.7	6.5	700	1 (1)	1.61 ± 3.11	15 ± 29 **
1979	62,928.2	5,028.8	8.0	474	0	0	—
1980	4.0	—	—	—	—	—	—
1984	22,812.6	12,272.0	53.8	722	0	0	—
1985	10,652.3	6,263.1	58.8	405	1	1.60 ± 2.05	2 ± 2 *
Surimi mothership[f]							
Japan							
1978[g]	235,210.0	186,197.3	79.2	293	6 (2)	0.32 ± 0.14	8 ± 4 **
1979[g]	207,610.0	156,732.6	75.5	293	0	0	—
1980	176,450.0	42,612.0	24.2	70	0	0	—
1981	357,340.0	153,844.4	43.1	253	0	0	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (*n*)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
1982	366,490.0	332,381.3	90.7	554	0	0	—
1983	269,380.0	246,501.1	91.5	452	0	0	—
1984	2,880.0	2,410.0	83.7	7	0	0	—
1985	25.3	—	—	—	—	—	—
Freezer mothership							
Japan							
1980	38,515.5	35,381.3	91.9	115	0	0	—
1981	41,129.9	40,000.5	97.2	129	0	0	—
1982	40,597.7	38,032.5	93.7	130	0	0	—
1983	39,717.3	39,717.3	100.0	144	0	0	—
1984	39,829.6	39,240.7	98.5	136	0	0	—
1985	33,898.2	33,898.2	100.0	124	0	0	—
1986	33,048.3	31,142.4	94.2	109	0	0	—
Joint venture mothership (countries combined)							
1980	32,126.2	8,863.1	27.6	203	1	1.13 ± 1.94	4 ± 6 **
1981	74,122.0	28,625.3	38.6	264	1	0.35 ± 0.62	3 ± 4 **
1982	89,270.3	61,525.6	68.9	695	3	0.49 ± 0.37	4 ± 4 *
1983	192,598.8	107,811.2	56.0	779	21	1.95 ± 0.88	38 ± 17
1984	261,128.0	220,343.2	84.4	1,831	21	0.88 ± 0.25	25 ± 6 *
1985[h]	574,785.0	246,974.0	43.0	11,949	29	1.10 ± 0.33	65 ± 19
1986[h]	780,652.6	412,128.0	52.8	16,294	42	0.94 ± 0.25	78 ± 19
1987[h]	944,213.2	507,665.0	53.8	14,996	8	0.16 ± 0.08	15 ± 7
1988[h]	971,629.0	577,946.4	59.5	19,692	23	0.40 ± 0.11	39 ± 11
				Area-II			
Small stern trawler							
Japan							
1978	103,332.3	4,079.7	4.0	2,399	0 (4)	0	—
1979	69,976.6	4,221.0	6.0	1,562	0 (5)	0	—
1980	65,432.7	1,728.3	2.6	619	2	11.57 ± 15.76	76 ± 103 **
1981	69,308.4	4,745.2	6.8	1,394	8 (6)	16.86 ± 11.50	117 ± 78
1982	53,055.9	11,366.8	21.4	5,478	1 (36)	0.88 ± 1.56	5 ± 8 **
1983	52,010.9	21,638.8	41.6	10,297	10 (15)	4.62 ± 2.23	24 ± 11
1984	52,626.2	38,560.3	73.3	7,729	6	1.56 ± 0.66	8 ± 4 *
1985	35,050.1	28,947.2	82.6	3,980	2 (4)	0.69 ± 0.41	2 ± 2 *
1986	17,778.1	13,709.6	77.1	1,758	0 (1)	0	—
1987	13,609.1	8,697.7	63.9	1,312	0	0	—
Republic of Korea							
1981	2,052.1	—	—	—	—	—	—
1982	3,456.3	225.6	6.5	39	0	0	—
1983	1,356.6	—	—	—	—	—	—
1984	2,010.7	917.1	45.6	38	1	10.90 ± 16.47	2 ± 4 **
1985	936.8	814.3	86.9	18	0	0	—
1986	9.9	—	—	—	—	—	—
Taiwan							
1978	1,027.5	—	—	—	—	—	—
1979	1,123.0	—	—	—	—	—	—
1980	3,069.0	—	—	—	—	—	—
1981	774.0	—	—	—	—	—	—
1982	350.8	—	—	—	—	—	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Large surimi trawler							
Japan							
1978[e]	203,135.8	28,466.5	14.0	937	2 (1)	0.70 ± 0.92	14 ± 19 **
1979[e]	149,818.9	31,011.0	20.7	1,144	4 (2)	1.29 ± 1.15	19 ± 17 *
1980	125,926.9	11,919.6	9.5	569	0	0	—
1981	128,479.8	10,435.5	8.1	594	0	0	—
1982	164,072.0	35,633.5	21.7	1,425	1 (2)	0.28 ± 0.50	5 ± 8 **
1983	181,242.2	76,654.2	42.3	3,060	4 (3)	0.52 ± 0.49	9 ± 8 *
1984	176,734.5	103,524.4	58.6	3,683	8	0.77 ± 0.39	14 ± 6
1985	112,880.3	72,435.0	64.2	2,330	1	0.14 ± 0.17	2 ± 1
1986	29,332.8	14,638.6	49.9	279	0	0	—
Republic of Korea							
1986	2,221.5	2,027.2	91.3	35	0	0	—
Large freezer trawler							
People's Republic of China							
1986	51.2	7.3	14.3	4	0	0	—
West Germany							
1980	32.4	—	—	—	—	—	—
1981	2,400.4	157.4	6.6	11	0	0	—
1982	696.6	—	—	—	—	—	—
1984	1,003.0	805.7	80.3	34	0	0	—
Japan							
1980	1,429.0	93.6	6.6	17	0	0	—
1981	421.3	—	—	—	—	—	—
1982	207.6	—	—	—	—	—	—
1983	608.0	583.5	96.0	29	0	0	—
1984	4,605.9	1,397.7	30.4	137	0	0	—
1985	364.4	201.2	55.2	20	0	0	—
1986	1,137.7	573.0	50.4	30	0	0	—
Republic of Korea							
1978	15,691.4	621.9	4.0	66	0	0	—
1979	44,466.7	6,149.3	13.8	418	0	0	—
1980	71,986.4	5,374.0	7.5	223	0	0	—
1981	40,507.4	3,930.0	9.7	224	0	0	—
1982	34,713.9	6,442.1	18.6	216	0	0	—
1983	15,088.0	1,168.2	7.7	30	0	0	—
1984	31,915.1	17,370.5	54.4	570	0	0	—
1985	21,931.4	14,443.1	65.9	380	0	0	—
1986	2,917.0	2,440.7	83.7	52	0	0	—
Poland							
1979	6,169.0	2,212.5	35.9	203	0	0	—
1980	16,007.5	905.6	5.7	95	0	0	—
1981	17,242.6	3,462.3	20.1	310	0	0	—
1984	363.0	80.0	22.0	6	0	0	—
1985	2,440.8	2,440.8	100.0	163	1	4.10	1
Taiwan							
1978	510.8	—	—	—	—	—	—
1979	729.1	—	—	—	—	—	—
1980	1,616.0	—	—	—	—	—	—
1981	1,895.5	—	—	—	—	—	—
1982	791.6	—	—	—	—	—	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
U.S.S.R.							
1978	101,789.1	1,978.2	1.9	122	1	5.06 ± 9.97	51 ± 101 **
1979	64,402.3	6,506.5	10.1	609	5	7.68 ± 8.76	49 ± 56 **
1980	2,592.6	—	—	—	—	—	—
1984	24.1	—	—	—	—	—	—
Surimi mothership[f]							
Japan							
1978[g]	248,880.0	214,052.9	86.0	282	2	0.09 ± 0.08	2 ± 2 *
1979[g]	251,620.0	239,990.1	95.4	338	0	0	—
1980	246,870.0	73,504.2	29.8	155	0	0	—
1981	52,240.0	30,228.4	57.9	62	0	0	—
1982	32,040.0	16,511.6	51.5	41	0	0	—
1983	88,620.0	57,652.7	65.1	98	0	0	—
1984	330,260.0	268,620.2	81.3	499	0	0	—
1985	379,571.4	328,385.8	86.5	539	0	0	—
1986	212,430.8	186,338.3	87.7	264	0	0	—
Freezer mothership							
Japan							
1980	74.0	—	—	—	—	—	—
Joint venture mothership (countries combined)							
1980	169.4	141.7	83.6	4	0	0	—
1981	398.1	—	—	—	—	—	—
1982	75.1	75.1	100.0	1	0	0	—
1983	63.7	—	—	—	—	—	—
1984	44,808.5	44,226.3	98.7	155	0	0	—
1985[h]	11,062.1	4,973.3	45.0	154	0	0	—
1986[h]	298,939.1	155,621.0	52.1	3,537	0	0	—
1987[h]	339,633.6	160,640.5	47.3	3,775	5	0.31 ± 0.24	6 ± 4 *
1988[h]	263,278.0	129,751.7	49.3	2,811	0	0	—
				Area–III			
Small stern trawler							
Japan							
1978	205.5	—	—	—	—	—	—
1979	163.8	—	—	—	—	—	—
1980	197.9	—	—	—	—	—	—
1981	4.6	—	—	—	—	—	—
1982	218.3	—	—	—	—	—	—
1983	5.5	—	—	—	—	—	—
Republic of Korea							
1984	88.0	84.0	95.4	4	0	0	—
Large freezer trawler							
Japan							
1984	27.0	—	—	—	—	—	—
Republic of Korea							
1978	35.0	—	—	—	—	—	—
1982	5.2	—	—	—	—	—	—
1984	160.5	160.5	100.0	18	0	0	0
Poland							
1984	72.4	—	—	—	—	—	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Joint venture mothership (countries combined)							
1980	185.0	—	—	—	—	—	—
1987	690.9	—	—	—	—	—	—
				Area -IV			
Small stern trawler							
Japan							
1978	36,331.5	2,336.7	6.4	1,210	0 (2)	0	—
1979	56,383.7	2,279.8	4.0	1,180	3 (12)	13.16 ± 14.89	74 ± 82 **
1980	74,142.6	1,032.8	1.4	263	19 (1)	183.97 ± 135.61	1,364 ± 990
1981	58,364.2	1,265.7	2.2	331	1	7.90 ± 15.68	46 ± 90 **
1982	46,691.5	4,331.5	9.3	1,648	3 (7)	6.93 ± 7.63	32 ± 35 **
1983	38,159.6	8,591.8	22.5	1,300	18 (23)	20.95 ± 9.63	80 ± 36
1984	37,794.0	24,801.5	65.6	1,865	3 (1)	1.21 ± 0.82	5 ± 3 *
1985	30,986.2	26,291.2	84.8	496	2 (1)	0.76 ± 0.59	2 ± 2 *
1986	6,387.1	5,247.6	82.2	126	0	0	—
Republic of Korea							
1981	2,017.4	49.7	2.5	2	0	0	—
1982	1,358.4	206.6	15.2	18	0	0	—
1983	1,261.3	—	—	—	—	—	—
1984	1,402.8	356.1	25.4	14	0	0	—
1985	445.8	211.0	47.3	6	0	0	—
1986	575.8	539.0	93.6	15	0	0	—
Large surimi trawler							
Japan							
1978[e]	1,223.4	—	—	—	—	—	—
1979[e]	2,487.1	80.3	3.2	48	0	0	—
1980	6,741.8	—	—	—	—	—	—
1981	3,342.5	—	—	—	—	—	—
1982	3,037.8	—	—	—	—	—	—
1983	4,411.6	—	—	—	—	—	—
1984	4,464.7	1,959.7	43.9	67	6	30.62 ± 25.79	14 ± 11 **
1985	3,859.3	3,405.7	88.2	51	1	2.94 ± 2.01	1 ± 1 *
Republic of Korea							
1986	2,082.0	1,158.1	55.6	13	0	0	—
Large freezer trawler							
People's Republic of China							
1986	399.9	394.0	98.5	23	0	0	—
West Germany							
1980	38.8	—	—	—	—	—	—
1981	745.3	140.3	18.8	13	10	712.76 ± 895.19	53 ± 73 **
1982	14,550.7	8,120.1	55.8	283	0	0	—
1983	13,641.2	6,348.2	46.5	177	0	0	—
1984	15,489.3	13,137.1	84.8	377	0	0	—
Japan							
1980	2,051.8	44.3	2.2	15	0	0	—
1981	3,946.8	189.7	4.8	72	0	0	—
1982	2,933.7	863.7	29.4	60	0	0	—
1983	1,396.0	984.2	70.5	50	0	0	—
1984	1,004.3	860.6	85.7	57	0	0	—
1985	779.9	55.1	7.1	5	0	0	—

Table 4 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ (x10^{-4})	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Republic of Korea							
1978	1,110.6	—	—	—	—	—	—
1979	905.7	—	—	—	—	—	—
1980	20,251.0	253.4	1.2	10	0	0	—
1981	23,184.4	2,631.8	11.4	85	0	0	—
1982	14,591.6	2,820.9	19.3	194	2	7.09 ± 9.08	10 ± 13 **
1983	14,285.1	874.0	6.1	63	0	0	—
1984	10,385.7	2,357.2	22.7	77	0	0	—
1985	5,426.1	2,669.2	49.2	64	0	0	—
1986	2,661.4	1,506.2	56.6	25	0	0	—
Poland							
1980	5,917.6	371.2	6.3	64	1	26.94 ± 53.10	16 ± 31 **
1981	5,597.1	436.2	7.8	34	0	0	—
1984	5,108.3	4,057.0	79.4	212	0	0	—
1985	9,379.5	7,320.4	78.0	393	0	0	—
1986	3,222.2	2,315.1	71.8	157	0	0	—
Taiwan							
1980	27.5	—	—	—	—	—	—
U.S.S.R.							
1978	24,375.1	3,709.1	15.2	541	0 (1)	0	—
1979	23,445.2	2,734.5	11.7	256	18 (3)	65.83 ± 40.29	154 ± 93
1980	960.1	120.9	12.6	9	7	578.99 ± 1,193.22	56 ± 132**
Joint venture mothership (countries combined)							
1980	91.2	—	—	—	—	—	—
1981	4,014.9	—	—	—	—	—	—
1982	19,382.0	12,883.1	66.5	113	8 (2)	6.21 ± 3.00	12 ± 6 *
1983	18,492.3	14,741.8	79.7	95	64 (3)	43.41 ± 12.28	80 ± 23 *
1984	51,605.9	47,097.9	91.3	511	122 (4)	25.90 ± 8.14	134 ± 41 *
1985[h]	53,574.4	34,031.7	63.5	1,617	79 (1)	23.21 ± 7.14	124 ± 38
1986[h]	70,621.5	43,645.1	61.8	1,647	49	11.23 ± 2.89	79 ± 20
1987[h]	71,363.5	47,241.0	66.2	1,847	13 (2)	2.75 ± 0.89	20 ± 7
1988[h]	66,509.0	38,284.7	57.6	1,188	2	0.52 ± 0.48	3 ± 3 *

[a] Small stern trawler: trawl vessel <1,500 gross tons; large surimi trawler: trawl vessel >1,500 gross tons targeting on pollock to produce surimi, a minced meat product; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products; surimi mothership: vessel with a fleet of catcher boats targeting on pollock to produce a minced meat product; freezer mothership: vessel with a fleet of catcher boats which produces frozen whole fish or frozen products; joint venture mothership: processing vessel of the joint venture fisheries which receives catches from U.S. fishing vessels.

[b] Observed tonnage listed for motherships (all years) and joint venture vessels (1978–84) are total daily catch, and include hauls not sampled for fish composition nor monitored for presence of marine mammals.

[c] Data are fishing days with observer coverage for motherships (all years) and joint venture vessels during 1978–84.

[d] Totals include only dead animals (excludes "decomposed in catch"); numbers in parentheses are additional animals caught and released back to sea still alive.

[e] During 1977–79 Japan reported total tonnage in the fishery only by large trawler classes (not distinguished between surimi or freezer vessels). These categories have been lumped.

[f] Excludes Danish seine catches.

[g] During 1977–79 Japan reported total tonnage in the fishery only by motherships (not distinguished between surimi or freezer vessels). These categories have been lumped.

[h] Observer data were based on hauls observed for joint venture vessels during 1985–88.

Table 5

Number of northern sea lions reported by U.S. fishery observers incidentally caught by subgroup (area, vessel class, nation, and year) in the U.S. Exclusive Economic Zone in the Gulf of Alaska, 1978–88, and an estimation of the total incidental take of northern sea lions in the fishery. Catch rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take of only dead animals to observed groundfish catch (per 10,000 metric tons [t] basis). Estimated takes of only dead sea lions are the ratio estimate ($\hat{Y}_R$) ± the 95% confidence limits ($L_{95\%}$). Refer to Figure 1 for the locations of the areas in the left column. * = the estimated lower 95% confidence level was less than the number of animals reported by U. S. observers; ** = the estimated lower 95% confidence level was less than zero.

	Groundfish				Northern sea lions		
Vessel nation year[a]	Total catch (t)	Observed catch[b] (t)	Percent of catch observed	Number of hauls observed[c] (n)	Number dead (alive) reported in catch[d]	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	$\hat{Y}_R \pm L_{95\%}$
Shumagin							
Small stern trawler							
Japan							
1978	2,262.1	267.4	11.8	200	0 (7)	0	—
1979	1,990.7	74.8	3.8	41	0	0	—
1980	1,209.8	2.6	0.2	1	0	0	—
1981	5,116.8	734.0	14.3	154	0	0	—
1982	8,782.0	4,203.6	47.9	1,142	0 (2)	0	—
1983	6,175.1	3,014.9	48.8	867	1 (1)	3.32 ± 4.73	2 ± 3 **
1984	4,080.6	2,634.5	64.6	173	8	30.37 ± 24.15	12 ± 10 *
1985	6.0	0.2	3.3	1	0	0	—
Republic of Korea							
1981	3,863.1	130.2	3.4	16	0	0	—
1982	1,230.1	234.9	19.1	18	0	0	—
1983	2,602.8	1,013.2	38.9	28	1	9.87 ± 15.97	3 ± 4 **
1984	1,719.3	1,502.7	87.4	49	0	0	—
1985	552.8	379.8	68.7	13	0	0	—
Mexico							
1979	3,528.4	70.5	2.0	16	0	0	—
Large surimi trawler							
Japan							
1978[d]	4,904.0	91.0	1.9	24	0	0	—
1979[d]	2,944.8	214.5	7.3	44	0	0	—
1980	10.2	—	—	—	—	—	—
1981	9,864.7	1,969.4	20.0	85	0	0	—
1982	12,901.6	4,784.9	37.1	237	0	0	—
1983	11,527.6	4,352.9	37.8	251	0 (2)	0	—
1984	16,041.8	7,704.7	48.0	244	25	32.45 ± 20.45	52 ± 32 *
1985	16,027.2	8,553.1	53.4	260	1 (1)	1.17 ± 1.60	2 ± 3 **
Large freezer trawler							
Japan							
1980	334.9	38.7	11.6	19	0	0	—
1981	2,559.6	767.4	30.0	95	0	0	—
1982	5,171.5	1,594.2	30.8	241	0	0	—
1983	3,362.3	850.2	25.3	156	0	0	—
1984	657.5	243.3	37.0	64	0	0	—
Republic of Korea							
1978	33,402.4	2,478.0	7.4	122	1	4.04 ± 7.83	13 ± 26 **
1979	25,489.8	2,340.1	9.2	107	0	0	—
1980	31,194.2	4,966.9	15.9	134	0	0	—
1981	25,960.3	2,109.6	8.1	72	0	0	—
1982	20,897.7	4,604.1	22.0	200	0	0	—

Table 5 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Republic of Korea (continued)							
1983	23,412.8	8,374.4	35.8	241	0	0	—
1984	21,199.4	15,016.1	70.8	306	0	0	—
1985	7,396.6	5,341.9	72.2	84	0	0	—
Mexico							
1979	1,847.9	—	—	—	—	—	—
Poland							
1979	283.9	—	—	—	—	—	—
1980	5,970.8	89.2	1.5	10	0	0	—
1981	16,817.2	1,712.4	10.2	89	0	0	—
U.S.S.R.							
1978	1,955.9	0.6	0.03	3	0	0	—
1979	248.1	56.1	22.6	15	0	0	—
1980	18,404.7	1,363.8	7.4	189	1	7.33 ± 14.19	13 ± 26 **
Joint venture mothership (countries combined)							
1978	48.0	48.0	100.0	4	0	0	—
1979	37.6	37.6	100.0	3	0	0	—
1980	135.9	65.0	47.8	3	0	0	—
1981	21.2	15.6	73.6	1	0	0	—
1982	182.7	182.7	100.0	5	0	0	—
1983	4,321.8	3,018.6	69.8	83	0	0	—
1984	11,470.6	10,274.4	89.6	176	1	0.97 ± 0.81	1 ± 1 *
1985[e]	15,247.3	10,621.5	69.7	415	1	0.94 ± 1.04	1 ± 2 **
1986[e]	7,448.5	6,771.0	90.9	206	1	1.48 ± 0.89	1 ± 1 *
1987[e]	25,653.0	11,786.5	46.0	332	1	0.85 ± 1.25	2 ± 3 **
1988[e]	7.0	6.5	92.9	1	0	0	—
Chirikof							
Small stern trawler							
Japan							
1978	617.1	56.8	9.2	32	0	0	—
1979	1,233.3	4.5	0.4	1	0	0	—
1980	2,917.5	468.5	16.1	72	0	0	—
1981	3,765.1	996.2	26.5	215	0 (1)	0	—
1982	5,849.6	3,424.8	58.6	541	1 (2)	2.92 ± 3.75	2 ± 2 *
1983	5,068.5	2,966.3	58.5	644	1 (2)	3.37 ± 4.35	2 ± 2 *
1984	3,452.5	2,604.3	75.4	323	0 (1)	0	—
Republic of Korea							
1981	5,461.9	147.9	2.7	12	0	0	—
1982	3,100.8	1,619.1	52.2	113	0	0	—
1983	2,522.5	375.4	14.9	11	0	0	—
1984	642.5	538.0	83.7	13	0	0	—
Mexico							
1979	812.1	169.3	20.8	36	2	118.13 ± 141.02	10 ± 11 **
Large surimi trawler							
Japan							
1978[d]	8,968.3	1,294.2	14.4	152	5 (2)	38.63 ± 51.42	35 ± 45 **
1979[d]	3,316.6	781.2	23.6	80	0	0	—
1980	6,756.6	48.1	0.7	6	0	0	—
1981	19,832.0	1,162.0	5.9	39	1	8.61 ± 16.86	17 ± 34 **
1982	20,092.3	9,487.0	47.2	347	0 (2)	0	—
1983	18,070.8	7,742.4	42.8	309	11	14.21 ± 8.95	26 ± 16 *

Table 5 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Japan (continued)							
1984	19,370.3	10,525.0	54.3	362	16 (1)	15.20 ± 7.49	29 ± 15 *
1985	206.3	131.3	63.6	16	0	0	—
Large freezer trawler							
Japan							
1980	2,328.9	90.7	3.9	17	1	110.25 ± 218.82	26 ± 54 **
1981	6,729.5	2,083.8	31.0	145	2	9.60 ± 11.39	6 ± 8 **
1982	5,775.7	1,778.5	30.8	300	1	5.62 ± 9.39	3 ± 6 **
1983	8,393.6	2,781.7	33.1	428	1	3.60 ± 5.88	3 ± 5 **
1984	2,019.7	875.1	43.3	303	0	0	—
1985	869.1	756.3	87.0	16	0	0	—
Republic of Korea							
1978	875.8	189.9	21.7	11	0	0	—
1981	31,658.0	1,628.8	5.1	69	0	0	—
1982	23,444.4	3,747.7	16.0	179	5 (1)	13.34 ± 20.19	31 ± 47 **
1983	19,733.4	6,702.9	34.0	173	0	0	—
1984	16,145.8	11,258.2	69.7	282	0	0	—
1985	869.1	756.3	87.0	16	0	0	—
Mexico							
1979	17.5	—	—	—	—	—	—
Poland							
1979	18,673.7	204.0	1.1	20	0	0	—
1980	7,303.6	—	—	—	—	—	—
1981	24,237.5	570.6	2.4	45	4	70.10 ± 106.23	170 ± 259 **
1984	665.3	399.1	60.0	30	2	50.11 ± 65.06	3 ± 5 **
U.S.S.R.							
1978	56,323.1	2,110.3	3.8	210	10 (1)	47.39 ± 32.42	267 ± 180
1979	8,156.8	367.7	4.5	58	0	0	—
1980	19,565.9	492.9	2.5	47	0	0	—
Joint venture mothership (countries combined)							
1979	61.5	61.5	100.0	4	0	0	—
1980	876.7	—	—	—	—	—	—
1981	16,944.3	4,439.0	26.2	23	13	29.29 ± 29.24	50 ± 51 **
1982	71,126.9	32,159.7	45.2	231	651 (5)	202.43 ± 105.80	1,440 ± 742
1983	125,127.5	110,034.3	87.9	549	255 (1)	23.17 ± 5.66	290 ± 70 *
1984	178,062.8	165,400.2	92.9	875	211 (1)	12.76 ± 1.72	227 ± 30 *
1985[e]	214,376.7	113,265.7	52.8	2,993	52 (2)	4.59 ± 1.53	98 ± 32
1986[e]	42,654.7	22,886.8	53.7	596	38 (1)	16.60 ± 8.40	71 ± 35 *
1987[e]	1,626.9	1,376.6	84.6	84	0	0	—
1988[e]	1,136.0	1,034.9	91.1	57	0	0	—
				Kodiak			
Small stern trawler							
Japan							
1978	5,344.6	1,146.2	21.4	543	10 (2)	87.24 ± 57.30	47 ± 30
1979	5,399.5	975.2	18.1	401	1	10.25 ± 18.60	6 ± 9 **
1980	9,581.5	571.3	6.0	179	0 (1)	0	—
1981	7,157.7	342.4	4.8	126	0 (3)	0	—
1982	5,853.7	1,723.5	29.4	766	0 (1)	0	—
1983	5,359.6	2,027.1	37.8	1,105	2 (13)	9.87 ± 11.01	5 ± 5 *
1984	6,515.0	4,366.5	67.0	589	1 (1)	2.29 ± 2.64	1 ± 1 *
1985	8.6	1.8	20.9	3	0	0	—

Table 5 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Republic of Korea							
1981	163.3	4.7	2.9	4	0	0	—
1982	2.1	0.3	14.3	1	0	0	—
Mexico							
1979	4,143.4	804.3	19.4	86	0	0	—
Large surimi trawler							
Japan							
1978[d]	15,522.4	3,972.4	25.6	691	11 (2)	27.69 ± 22.56	43 ± 34 *
1979[d]	25,059.6	5,020.4	20.0	379	15 (4)	29.88 ± 23.86	75 ± 59
1980	16,949.6	616.0	3.6	50	0	0	—
1981	4,037.7	—	—	—	—	—	—
1982	2,119.5	673.0	31.8	21	0	0	—
1983	2,806.9	1,179.6	42.0	62	0	0	—
1984	10,488.2	6,356.6	60.6	225	4	6.29 ± 4.85	7 ± 5 *
1985	6,762.4	3,088.8	45.7	115	0	0	—
Large freezer trawler							
Japan							
1980	9,233.2	181.5	2.0	41	0	0	—
1981	4,646.3	472.7	10.2	96	1	21.16 ± 40.46	10 ± 18 **
1982	8,580.9	2,569.9	30.0	761	1 (3)	3.89 ± 6.51	3 ± 6 **
1983	5,446.1	1,266.3	23.2	504	1	7.90 ± 13.86	4 ± 8 **
1984	1,827.2	706.8	38.7	278	0	0	—
Republic of Korea							
1981	95.5	0.6	0.6	2	0	0	—
1982	938.7	740.6	78.9	34	0	0	—
Poland							
1978	1,266.0	—	—	—	—	—	—
1980	786.9	—	—	—	—	—	—
1984	2,246.8	1,321.8	58.8	95	0	0	—
U.S.S.R.							
1978	4,342.0	165.1	3.8	54	0	0	—
1979	22,577.9	3,156.2	14.0	467	5	15.84 ± 13.10	36 ± 29
1980	16,632.4	775.7	4.7	161	5 (1)	64.46 ± 65.77	107 ± 108**
Freezer mothership							
Mexico							
1979	234.3	234.3	100.0	9	0	0	—
Joint venture mothership (countries combined)							
1979	1,332.3	205.5	15.4	15	0	0	—
1980	898.1	—	—	—	—	—	—
1982	3,140.4	1,428.8	45.5	14	10	69.99 ± 51.09	22 ± 17 *
1983	13,534.9	11,302.0	83.5	245	13 (1)	11.50 ± 8.79	16 ± 11 *
1984	30,091.7	28,283.1	94.0	801	71 (3)	25.10 ± 6.02	76 ± 17 *
1985[e]	17,580.7	12,160.1	69.2	609	2	1.64 ± 1.29	3 ± 2 *
1986[e]	15,183.8	7,998.5	52.7	317	4	5.00 ± 3.44	8 ± 5 *
1987[e]	5,245.7	4,437.4	84.6	330	0	0	—
1988[e]	2,628.0	1,697.5	64.6	101	0	0	—

Table 5 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
				Yakutat			
Small stern trawler							
Japan							
1978	5,644.8	498.1	8.8	330	3 (2)	60.23 ± 66.42	34 ± 37 **
1979	4,024.6	316.9	7.9	108	1	31.56 ± 60.82	13 ± 24 **
1980	6,705.5	406.7	6.1	161	0 (1)	0	—
1981	7,201.3	93.9	1.3	57	0	0	—
1982	9.6	5.6	58.3	11	0	0	—
1983	20.2	—	—	—	—	—	—
Republic of Korea							
1981	630.7	—	—	—	—	—	—
Mexico							
1979	48.2	—	—	—	—	—	—
Large surimi trawler							
Japan							
1978[d]	2,321.6	351.2	15.1	106	0 (1)	0	—
1979[d]	4,330.6	624.7	14.4	104	0	0	—
1980	497.4	1.0	0.2	1	0	0	—
1981	188.3	—	—	—	—	—	—
Large freezer trawler							
Japan							
1980	8,495.2	238.6	2.8	58	0 (1)	0	—
1981	4,736.0	223.0	4.7	60	0	0	—
Republic of Korea							
1979	3,243.5	—	—	—	—	—	—
1980	210.2	62.6	29.8	11	1	159.74 ± 303.85	3 ± 7 **
1981	6,847.1	29.9	0.4	1	0	0	—
Poland							
1981	27.8	—	—	—	—	—	—
U.S.S.R.							
1978	7.0	—	—	—	—	—	—
1979	63.6	19.6	30.8	17	0	0	—
Joint venture mothership (countries combined)							
1979	47.8	37.0	77.4	6	0	0	—
				Southeastern			
Small stern trawler							
Japan							
1978	59.0	—	—	—	—	—	—
1979	1,224.9	139.3	11.4	96	0	0	—
1980	557.1	101.9	18.3	43	0	0	—
1981	594.4	63.8	10.7	22	0	0	—
Large surimi trawler							
Japan							
1978[d]	5,252.2	195.0	3.7	31	0	0	—
1979[d]	6,583.1	1,756.5	26.7	485	0 (3)	0	—
1980	9.9	—	—	—	—	—	—

Table 5 (continued)

Vessel nation year[a]	Groundfish: Total catch (t)	Groundfish: Observed catch[b] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[c] (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Northern sea lions: $\hat{Y}_R \pm L_{95\%}$
Large freezer trawler							
Japan							
1980	6,144.9	529.6	8.6	180	0	0	—
1981	6,049.9	41.8	0.7	14	0	0	—
Republic of Korea							
1978	3.3	—	—	—	—	—	—
1979	412.2	—	—	—	—	—	—
U.S.S.R.							
1978	8.0	—	—	—	—	—	—
Joint venture mothership (countries combined)							
1979	11.5	8.6	74.8	2	0	0	—

[a] Small stern trawler: trawl vessel <1,500 gross tons; large surimi trawler: trawl vessel >1,500 gross tons targeting on pollock to produce surimi, a minced meat product; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products; surimi mothership: vessel with a fleet of catcher boats targeting on pollock to produce a minced meat product; freezer mothership: vessel with a fleet of catcher boats which produces frozen whole fish or frozen products; joint venture mothership: processing vessel of the joint venture fisheries which receives catches from U.S. fishing vessels.

[b] Observed tonnage listed for motherships (all years) and joint venture vessels (1978–84) are total daily catch, and include hauls not sampled for fish composition nor monitored for presence of marine mammals.

[c] Data are fishing days with observer coverage for motherships (all years) and joint venture vessels during 1978–84.

[d] Totals include only dead animals (excludes "decomposed in catch"); numbers in parentheses are additional animals caught and released back to sea still alive.

[e] During 1977–79 Japan reported total tonnage in the fishery only by large trawler classes (not distinguished between surimi or freezer vessels). These categories have been lumped.

[f] Observer data were based on hauls observed for joint venture vessels during 1985–88.

relatively smaller fisheries off Washington, Oregon, and California (Fig. 7A) and in the Gulf of Alaska (Fig. 7B) than for the large fisheries in the Bering Sea (Fig. 7C). The percentage of the total fish catch sampled by U.S. observers by region was likewise similar; about 35% of the total fish catch during 1973–88 was monitored for incidental take of marine mammals and the amount of observer coverage increased each year to about 60% by 1988 (Tables 1 and 2). However, fish catch sampling by observers by year averaged less than 50% of the total fish catch prior to 1982 (Table 2) and less than 10% during 1973–76. The combined foreign and JV fisheries have been at a similar level of groundfish catch each year since 1977, and foreign fisheries were slightly higher (7–8%) during 1973–76 (Table 2). Thus, numbers of incidentally caught mammals reported by observers during 1973–81 on a regional or country-specific fishery basis were probably less than the true level of incidental take (on vessels with observers aboard) at that time because observers had less opportunity to see marine mammals in the catch.

Northern Sea Lions in Alaska

Incidental Catch Rates—Most northern sea lions caught died during fishing operations (Tables 1, 4, and 5). From 1978 to 1988, 14% of the incidental catch of northern sea lions were alive when the haul was retrieved, and these were released (Table 1). It was more common to observe live sea lions caught in trawl gear in the 1970s and early 1980s in the foreign fisheries than in recent years in the JV fisheries which had a predominance of dead sea lions in the catch (Fig. 8).

Incidental take of northern sea lions, both reported and estimated, during 1978–88 is listed by country, vessel class, and statistical fishing area in Table 4 for the Bering Sea and Table 5 for the Gulf of Alaska. Catch rates ranged from zero to 713 sea lions taken incidentally per 10,000 t of fish caught in the Bering Sea. The highest observed catch rates for the Bering Sea occurred in Area-IV during 1980–81 in the large freezer trawler (vessels >1,500 gross tons producing frozen whole fish and fillet products)

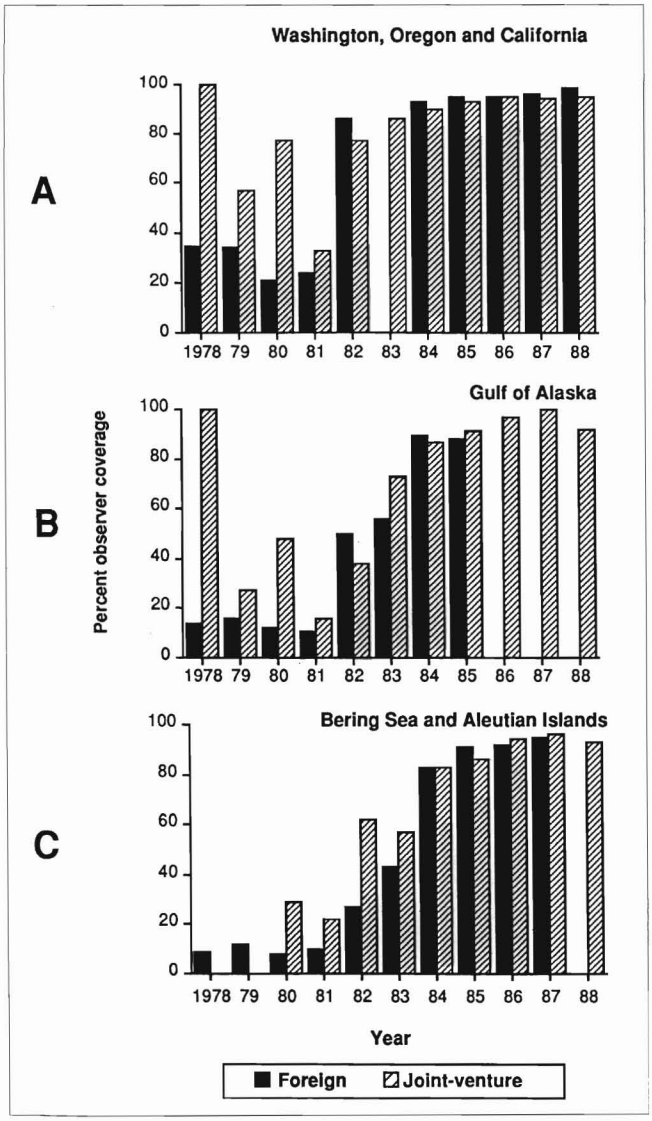

Figure 7

Percent observer coverage of the total number of fishing days by foreign and joint venture (JV) vessels in the U.S. Exclusive Economic Zone, 1978–88: (**A**) off the coast of Washington, Oregon, and California; (**B**) in the Gulf of Alaska; and (**C**) in the Bering Sea and Aleutian Islands region. Observer coverage of JV fisheries during 1978 (first year of the JV fisheries) was near 100% because total fishing effort that year was very low, occurring on a few boats all of which had observers aboard.

fisheries of the U.S.S.R. (579 sea lions per 10^4 t; 1980) and West Germany (713 sea lions per 10^4 t; 1981) (Table 4). In the Gulf of Alaska incidental catch rates of northern sea lions ranged from zero to 202 animals per 10^4 t of fish caught. The highest observed catch rate of northern sea lions in the Gulf of Alaska occurred in the Chirikof area during 1982 in the JV fisheries in Shelikof Strait (Table 5). On a regional basis, the average observed rates of incidental take of dead northern sea lions during 1978–88 were higher for statistical areas in the Gulf of Alaska region than for those in the Bering Sea (Table 6).

These average rates are values expressed on a 10,000 t basis. They do not reflect estimates of total incidental take in the fishery, which were often substantially less than the observed rate for a specific fishery, area, and time period (Tables 4 and 5). The percentage of the total groundfish take monitored for the presence of incidentally caught marine mammals ranged from 0.03% to 100% on foreign trawlers, and from 15.4% to 100% on foreign and JV processors (mothership vessels). Also, the calculated incidental catch rates in Tables 4 and 5 may, in some cases, be underestimated for foreign processors because observers had less opportunity to observe incidentally caught marine mammals in the mothership-based foreign fisheries (and incidental catch rates were calculated on the basis of total daily groundfish catch, rather than observed hauls).

Calculated standard errors of incidental catch rates (from the ratio of observed marine mammal mortality to groundfish catch) were often high, almost equal to the value of the calculated catch rate. Thus, calculated 95% confidence limits for these rates often yielded lower limit estimates of total take that were less than the actual take seen by U.S. fishery observers, and sometimes even less than zero (Tables

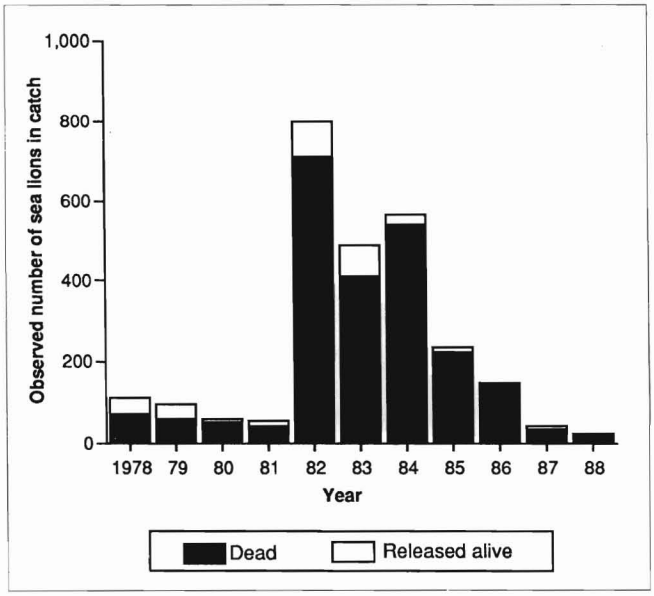

Figure 8

Total number of northern sea lions reported by U.S. fishery observers seen in the groundfish catch on foreign and joint venture vessels in the U.S. Exclusive Economic Zone in Alaska during 1978–88. Decomposed animals were not included.

Table 6

Observed incidental mortality rate of northern sea lions per 10^4 metric tons of groundfish caught by region, area, fishery, and year (1978–88) in the U.S. Exclusive Economic Zone in Alaska.[a] Catch rates are the ratio ± twice the standard error of observed incidental take to observed groundfish catch. The sample size is shown in parentheses below each rate.[b] Refer to Figure 1 for the locations of the areas in the left column. JV = joint venture fishery; NF = no fishery.

Region area fishery	1978	1979	1980	1981	1982	1983
Bering Sea and Aleutian Islands						
Foreign	2.94 ± 1.35	3.63 ± 1.41	8.27 ± 4.73	3.25 ± 2.35	1.62 ± 0.53	1.64 ± 0.41
	(8,206)	(8,305)	(3,329)	(5,402)	(16,194)	(25,121)
JV	NF	NF	1.11 ± 1.93	0.35 ± 0.63	1.48 ± 0.63	6.95 ± 2.22
			(207)	(264)	(809)	(874)
Area-I						
Foreign	5.19 ± 2.56	1.37 ± 1.04	3.23 ± 2.67	0.92 ± 1.37	1.99 ± 0.72	0.79 ± 0.34
	(2,931)	(2,885)	(1,445)	(2,332)	(6,833)	(10,115)
JV	NF	NF	1.13 ± 1.94	0.35 ± 0.62	0.49 ± 0.37	1.95 ± 0.88
			(203)	(264)	(695)	(779)
Area-II						
Foreign	0.85 ± 0.94	1.80 ± 1.33	1.00 ± 1.36	3.52 ± 2.39	0.37 ± 0.47	1.40 ± 0.62
	(3,524)	(3,936)	(1,523)	(2,533)	(7,158)	(13,416)
JV	NF	NF	0	—	0	—
			(4)	(0)	(1)	(0)
Area-III						
Foreign	—	—	—	—	—	—
	(0)	(0)	(0)	(0)	(0)	(0)
JV	NF	NF	—	NF	NF	NF
			(0)			
Area-IV						
Foreign	0	41.22 ± 23.05	148.14 ± 109.92	23.34 ± 31.80	3.06 ± 2.46	10.72 ± 4.94
	(1,751)	(1,484)	(361)	(537)	(2,203)	(1,590)
JV	NF	NF	—	—	6.21 ± 3.00	43.41 ± 12.28
			(0)	(0)	(113)	(95)
Gulf of Alaska						
Foreign	31.21 ± 12.51	14.04 ± 8.06	7.24 ± 5.57	5.23 ± 4.70	1.94 ± 1.78	4.22 ± 1.97
	(2,509)	(2,561)	(1,380)	(1,518)	(4,912)	(4,779)
JV	0	0	0	29.18 ± 29.02	195.73 ± 100.45	21.55 ± 5.49
	(4)	(30)	(3)	(24)	(250)	(877)
Shumagin						
Foreign	3.52 ± 6.84	0	1.55 ± 2.93	0	0	1.14 ± 1.27
	(349)	(223)	(353)	(511)	(1,838)	(1,543)
JV	0	0	0	0	0	0
	(4)	(3)	(3)	(1)	(5)	(83)
Chirikof						
Foreign	41.08 ± 26.65	13.10 ± 18.16	9.09 ± 18.01	10.62 ± 10.54	3.49 ± 3.52	6.32 ± 3.67
	(405)	(195)	(142)	(625)	(1,480)	(1,565)
JV	NF	0	—	29.29 ± 29.24	202.43 ± 105.80	23.17 ± 5.66
		(4)	(0)	(23)	(231)	(549)
Kodiak						
Foreign	39.74 ± 21.70	21.09 ± 13.00	23.32 ± 24.16	12.19 ± 23.83	1.75 ± 2.88	6.71 ± 6.36
	(1,288)	(1,333)	(431)	(228)	(1,583)	(1,671)
JV	NF	0	—	NF	69.99 ± 51.09	11.50 ± 8.79
		(15)	(0)		(14)	(245)
Yakutat						
Foreign	35.32 ± 38.71	10.40 ± 20.12	14.11 ± 27.72	0	0	—
	(436)	(229)	(231)	(118)	(11)	(0)
JV	NF	0	NF	NF	NF	NF
		(6)				
Southeastern						
Foreign	0	0	0	0	NF	NF
	(31)	(581)	(223)	(36)		
JV	NF	0	NF	NF	NF	NF
		(2)				

Table 6 (continued)

Region area fishery	1984	1985	1986	1987	1988
Bering Sea and Aleutian Islands					
Foreign	1.31 ± 0.24 (28,215)	1.52 ± 0.24 (18,270)	1.03 ± 0.33 (6,363)	0 (1,544)	NF
JV	4.34 ± 1.13 (2,497)	3.58 ± 1.01 (13,720)	1.41 ± 0.27 (21,478)	0.36 ± 0.10 (20,618)	0.34 ± 0.09 (23,691)
Area-I					
Foreign	1.46 ± 0.33 (13,327)	2.27 ± 0.39 (10,364)	1.53 ± 0.46 (3,846)	0 (232)	NF
JV	0.88 ± 0.25 (1,831)	1.10 ± 0.33 (11,949)	0.94 ± 0.25 (16,294)	0.16 ± 0.08 (14,996)	0.40 ± 0.11 (19,692)
Area-II					
Foreign	0.92 ± 0.32 (12,197)	0.34 ± 0.19 (6,891)	0 (2,158)	0 (1,312)	NF
JV	0 (155)	0 (154)	0 (3,537)	0.31 ± 0.24 (3,775)	0 (2,811)
Area-III					
Foreign	0 (22)	NF	NF	NF	NF
JV	NF	NF	NF	— (0)	NF
Area-IV					
Foreign	1.89 ± 0.99 (2,669)	0.75 ± 0.52 (1,015)	0 (359)	NF	NF
JV	25.90 ± 8.14 (511)	23.21 ± 7.14 (1,617)	11.23 ± 2.89 (1,647)	2.75 ± 0.89 (1,847)	0.52 ± 0.48 (1,188)
Gulf of Alaska					
Foreign	8.48 ± 2.60 (3,336)	0.55 ± 0.72 (508)	NF	NF	NF
JV	13.88 ± 1.73 (1,852)	4.04 ± 1.26 (4,017)	11.42 ± 4.94 (1,119)	0.57 ± 0.77 (746)	0 (159)
Shumagin					
Foreign	12.18 ± 5.53 (836)	0.70 ± 0.89 (358)	NF	NF	NF
JV	0.97 ± 0.81 (176)	0.94 ± 1.04 (415)	1.48 ± 0.89 (206)	0.85 ± 1.25 (332)	0 (1)
Chirikof					
Foreign	6.87 ± 2.91 (1,313)	0 (32)	NF	NF	NF
JV	12.76 ± 1.72 (875)	4.59 ± 1.53 (2,993)	16.60 ± 8.40 (596)	0 (84)	0 (57)
Kodiak					
Foreign	3.92 ± 2.61 (1,187)	0 (118)	NF	NF	NF
JV	25.10 ± 6.02 (801)	1.64 ± 1.29 (609)	5.00 ± 3.44 (317)	0 (330)	0 (101)
Yakutat					
Foreign	NF	NF	NF	NF	NF
JV	NF	NF	NF	NF	NF
Southeastern					
Foreign	NF	NF	NF	NF	NF
JV	NF	NF	NF	NF	NF

[a] Incidental take rates in the table refer only to dead sea lions caught (no decomposed animals nor animals caught and released alive). Dashes indicate that no northern sea lions were observed in the catch, but since observer coverage was rarely near 100%, the true rate was not necessarily zero. Rates for the foreign fishery were based only on reported takes and fish catch which occurred on independent stern trawlers.

[b] The sample size is the number of hauls observed for presence of marine mammals, except for joint venture vessels during 1978–84 for which the number of fishing days was used as the sample size.

4 and 5). Neither of these cases are realistic, and either zero or the actual reported take, whichever was higher, was used as the minimum estimate in such cases in summing incidental takes for specific fisheries and areas to get totals by region and year. The calculated negative lower confidence limits suggest that either the underlying distribution of the data may not be normal or the sample size is too small, or both. These confidence intervals have been reported (Tables 4 and 5) to show the status and variability of the data. In many cases bootstrapped variances will yield more realistic confidence interval values. However, this procedure was not used, nor were the data transformed, because of the small num-

Table 7

Observed incidental mortality rates of northern sea lions taken by vessel class (countries combined) and area in the foreign trawl fishery (motherships excluded) in the U.S. Exclusive Economic Zone off Alaska, 1978–87. The number of hauls observed, average groundfish catch (metric tons, t) per observed haul, and percent of the total fishery by area are also shown. Mortality rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take to observed fish catch (per 10,000 t). Refer to Figure 1 for the locations of the areas in the left column.

Area vessel[a]	Percent of total fishery[b]	Number of hauls observed (n)[c]	Average observed fish catch per haul (t)	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)
Area-I				
Small stern trawler	13.8	21,047 (35)	6.6	3.45 ± 0.86
Large surimi trawler	33.9	10,532 (28)	25.7	1.88 ± 0.50
Large freezer trawler	52.3	22,731 (38)	25.0	1.32 ± 0.26
Area-II				
Small stern trawler	23.5	36,623 (25)	3.8	2.15 ± 0.68
Large surimi trawler	54.3	14,051 (31)	27.5	0.52 ± 0.21
Large freezer trawler	22.2	3,974 (15)	20.2	0.88 ± 0.77
Area-IV				
Small stern trawler	60.2	8,474 (20)	9.2	6.32 ± 2.17
Large surimi trawler	4.3	131 (23)	49.8	10.73 ± 9.66
Large freezer trawler	35.5	3,364 (28)	19.4	5.81 ± 3.11
Shumagin				
Small stern trawler	11.8	2,719 (33)	5.2	7.01 ± 6.28
Large surimi trawler	18.2	1,094 (41)	25.1	9.47 ± 6.15
Large freezer trawler	69.9	2,198 (21)	23.7	0.38 ± 0.48
Chirikof				
Small stern trawler	9.2	2,013 (38)	6.6	2.99 ± 2.36
Large surimi trawler	21.9	1,165 (36)	25.9	10.95 ± 4.48
Large freezer trawler	68.9	2,579 (14)	14.4	7.01 ± 3.47
Kodiak				
Small stern trawler	23.4	3,803 (24)	3.1	11.70 ± 6.20
Large surimi trawler	20.4	801 (40)	21.5	13.34 ± 8.23
Large freezer trawler	56.3	3,235 (13)	4.6	13.31 ± 6.21
Yakutat				
Small stern trawler	44.0	667 (5)	2.0	3 0.28 ± 29.48
Large surimi trawler	1.2	10 (35)	24.3	0
Large freezer trawler	54.8	348 (4)	3.8	7.65 ± 15.00

[a] Small stern trawler: trawl vessel <1,500 gross tons; large surimi trawler: trawl vessel >1,500 gross tons targeting on pollock to produce surimi, a minced meat product; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products.

[b] The percent of the total fishery of the three vessel classes in each area. During 1977–79 Japan reported total tonnage in the fishery only by large trawler classes (not distinguished between surimi or freezer vessels). Estimates of the total fish catch for Japan by each large trawler class during 1977–79 were based on the relative proportion of the total fish catch by each of the two Japanese large trawler classes during 1980–88.

[c] The numbers in parentheses are the percent of observer coverage of the total fish catch by the vessel class fishery in the respective area.

ber of hauls with incidentally caught marine mammals. Even if such efforts were undertaken, they would not help in understanding the data any better.

The observed average incidental take rates ranged from 0.35 to 8.28 dead northern sea lions per 10^4 t of total fish catch each year in the Bering Sea during 1978–88 in the foreign and JV fisheries (Table 6). Except for the years 1978 and 1980 for Area-I and 1981 for Area-II, incidental take rates of dead sea lions occurring in fishing trawls were equivalent or lower than two animals per 10^4 t (Table 6). Northern sea lions were not observed caught in the U.S. EEZ in Area-III. However, fishing effort was low during 1978–88 in Area-III and the size of the U.S. EEZ in Area-III is also very small (Fig. 1). Although the rate of sea lions taken incidentally in the U.S. waters of Area-III may be zero, the catch rate for international waters of Area-III cannot be ascertained (but observers aboard foreign vessels passing through international waters have reported some sea lions incidentally caught there). The likelihood of northern sea lions being incidentally caught in trawls in the Bering Sea was greatest in Area-IV where catch rates ranged from 0.52 to 143.80 dead sea lions per 10^4 t of fish catch in the foreign and JV fisheries during 1978–88 (Table 6). Higher incidental take rates for Area-IV should be expected because Area-IV encompasses a large part of the Aleutian Islands where several northern sea lion rookeries are located (Loughlin et al. 1984).

In the Gulf of Alaska average incidental catch rates ranged up to 31 dead sea lions per 10^4 t of fish catch in trawls of the foreign fishery and up to 196 dead sea lions per 10^4 t in trawls of the JV fishery by year during 1978–88 (Table 6). These were based primarily on observed incidental catch in the Chirikof, Kodiak and Yakutat statistical fishing areas where sea lions are most numerous in the Gulf of Alaska (Loughlin et al. 1984). Dead sea lions were not observed in the Southeastern fishing area where fishing effort was low (Table 5). Except for 1984, dead sea lions occurred in fishing trawls in the Shumagin area

Table 8

Estimated incidental mortality of northern sea lions in the foreign and joint venture groundfish trawl fisheries (all countries combined) in the U.S. Exclusive Economic Zone of the Bering Sea and Aleutian Islands during 1978–88. Estimates of the number of dead northern sea lions are the ratio estimate ($\hat{Y}_{R_s}$)[a] and the lower (L_1) and upper (L_2) 95% confidence limits.[b] * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers (the latter was used as the minimum estimate); ** = the estimated lower 95% confidence level was less than zero (the number of animals reported caught by U.S. observers was used as the minimum estimate).

	Foreign fisheries					Joint venture fisheries				
			Estimated number of dead sea lions[e]					Estimated number of dead sea lions		
Year	Total groundfish catch (t)[c]	Percent fish catch observed[d]	$\hat{Y}_{R_s}$	L_1	L_2	Total groundfish catch (t)[c]	Percent fish catch observed[f]	$\hat{Y}_{R_s}$	L_1	L_2
1978	1,284,470	10.2	335	249	421			no fishery		
1979	1,194,532	13.5	465	340	590			no fishery		
1980	1,196,256	5.9	472	304	640	32,572	27.6	4	1 **	10
1981	1,170,521	9.8	422	295	549	78,535	36.4	9	4	14
1982	1,102,650	28.0	210	158	262	108,727	68.5	16	11 *	23
1983	1,050,960	41.1	198	156	240	211,155	57.9	118	90	146
1984	1,107,131	61.2	147	126	168	357,542	92.2	157	143 *	199
1985	991,368	67.3	112	97	127	639,422	47.2	187	145	229
1986	442,253	69.3	31	24	38	1,150,213	56.0	154	126	182
1987	17,500	64.9	0	0	0	1,355,901	53.0	46	34	58
1988		no fishery				1,301,416	57.3	43	32	54
Total	9,557,639	29.8	2,392	2,122	2,662	5,235,483	56.8	734	660	808

[a] The sum of estimates for the subgroups (area, vessel class, country, and year) used in Table 4.

[b] Sample size (number of hauls observed, or observed fishing days for joint venture fisheries during 1980–84) can be summed from the data by area, vessel class, country, and year in Table 4.

[c] Trawl catches only during 1978–88. Danish seine catches by Japanese mothership-based fisheries were excluded for foreign fisheries.

[d] Values in this column were based on independent stern trawler data only; no mothership-based fishery data.

[e] The estimated number of dead northern sea lions includes estimates for the Japanese mothership-based trawl fisheries using observed mortality rates from independent foreign (all countries combined) stern trawlers as an estimate.

[f] Values for the percent of fish catch observed during 1980–84 listed in this column are higher than true values (unknown) since joint venture data for those years were based on total daily fish catch rather than hauls observed.

Table 9

Estimated incidental mortality of northern sea lions in the foreign and joint venture groundfish trawl fisheries (all countries combined) in the U.S. Exclusive Economic Zone of the Gulf of Alaska during 1978–88. Estimates of the number of dead northern sea lions are the ratio estimate ($\hat{Y}_{Rs}$)[a] and the lower (L_1) and upper (L_2) 95% confidence limits[b]. * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers (the latter was used as the minimum estimate); ** = the estimated lower 95% confidence level was less than zero (the number of animals reported caught by U.S. observers was used as the minimum estimate).

	Foreign fisheries					Joint venture fisheries				
			Estimated number of dead sea lions					Estimated number of dead sea lions		
Year	Total groundfish catch (t)[c]	Percent fish catch observed	$\hat{Y}_{Rs}$	L_1	L_2	Total groundfish catch (t)[c]	Percent fish catch observed[d]	$\hat{Y}_{Rs}$	L_1	L_2
1978	149,080	8.6	247	164	330	48	100.0	0	0	0
1979	145,655	11.7	197	125	269	1,491	23.5	2	2	2
1980	171,801	6.4	240	128	352	1,911	3.4	3	2	4
1981	198,242	7.7	159	109	209	16,966	26.3	50	13 **	101
1982	124,750	33.0	68	21	115	74,450	45.4	1,462	721	2,203
1983	114,502	37.2	69	49	89	142,984	87.0	306	268 *	376
1984	107,072	61.7	115	78	152	219,625	92.9	304	283 *	339
1985	31,829	57.4	8	5	11	247,205	55.0	102	70	134
1986		no fishery				65,287	57.7	80	44	116
1987		no fishery				32,526	54.1	4	1	7
1988		no fishery				3,771	72.6	1	1	1
Total	1,042,930	21.5	1,103	926	1,280	806,263	69.6	2,314	1,569	3,059

[a] The sum of estimates for the strata (area, vessel class, country, and year) in Table 5.

[b] Sample size (number of hauls observed, or observed fishing days for joint venture fisheries during 1978–84) can be summed from the data by area, vessel class, country, and year in Table 5.

[c] Trawl catches only during 1978–88.

[d] Values for the percent of fish catch observed during 1978–84 listed in this column are higher than true values (unknown) since joint venture data for those years were based on total daily fish catch rather than hauls observed.

at rates similar to those for the adjacent Area-I of the Bering Sea.

Catch rates were generally highest (>10 dead sea lions per 10^4 t of fish catch) for large surimi trawlers (vessels >1,500 gross tons targeting on pollock to produce surimi, a minced meat product) in areas of high sea lion abundance (Area-IV, Chirikof and Kodiak; Table 7). Rates for small stern trawlers (vessels <1,500 gross tons) were higher than for large trawlers in Area-I and Area-II of the Bering Sea (Table 7). However, rates for small stern trawlers were less than those of large freezer trawlers in all other areas of Alaska except Yakutat where observer coverage for small stern trawlers was very low (5%).

The declines in incidental catch rates seen in recent years by foreign fisheries is principally a function of decreasing fishing effort. JV fisheries, which reported the highest incidental take of northern sea lions during 1978–88 and had the lower fishing effort, caught a higher average number of mammals per day or haul than foreign fisheries.

Estimated Take—A total estimate of 6,543 (lower 95% confidence limit, L_1 = 5,728; upper 95% confidence limit, L_2 = 7,358) northern sea lions were incidentally caught and died in trawls of both the foreign and JV fisheries throughout Alaska during 1978–88 based on U.S. observer data of dead animals (Tables 8 and 9). However, there has been a declining trend in total estimates of northern sea lions caught by foreign and JV groundfish fisheries in Alaska during the 1980s (Fig. 9). For example, an estimated 335 sea lions were incidentally taken by these fisheries in the Bering Sea during 1978, but only 43 were taken in 1988 (Table 8). Likewise, 247 were estimated to have died during fishing operations in 1978 in the Gulf of Alaska, but only one sea lion was estimated to have been killed during 1988 (Table 9). With the exception of the 1982 Shelikof Strait JV fishery (estimated total incidental catch of 1,440 ± 742 dead sea lions in the Chirikof area based on an average observed mortality rate of 202.4 ± 52.9 dead sea lions per 10^4 of fish catch; Table 5), JV fisheries throughout Alaska were estimated to have an average incidental mortality in the catch of less than 500 sea lions per year (Fig. 9). Foreign fisheries were estimated to have caught more than 500 sea lions each year prior to 1982 (Fig. 9).

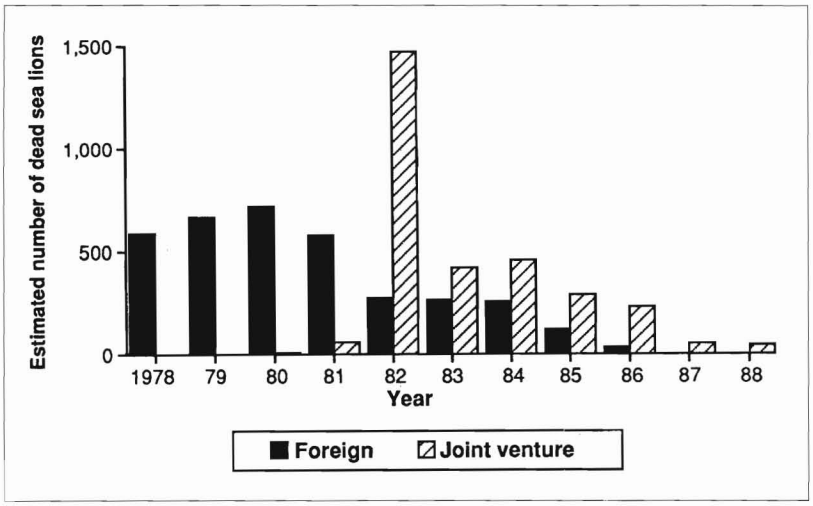

Figure 9
Estimated number of incidentally taken northern sea lions which died during trawl fishing operations of foreign and joint venture vessels in the U.S. Exclusive Economic Zone in Alaska during each year, 1978–88.

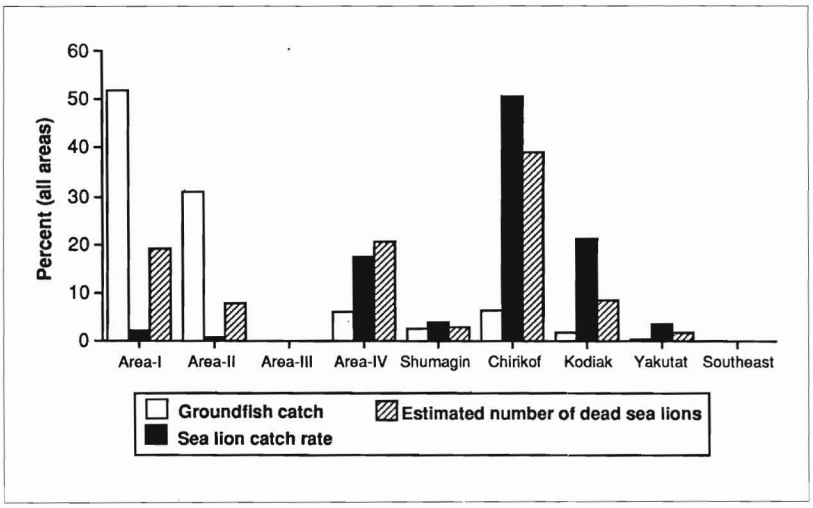

Figure 10
Percent of total for the amount of metric tons of groundfish caught in the fishery, incidental catch rate (ratio of observed number of dead (no decomposed) sea lions per 10^4 metric tons of groundfish catch), and the total estimated number of incidentally taken northern sea lions which died during trawl fishing operations of foreign (motherships excluded) and joint venture vessels in the U.S. Exclusive Economic zone in the seven statistical areas of Alaska during 1978–88.

Table 10
Number of northern sea lions incidentally caught as reported by U.S. fishery observers by region, vessel class, and nation in the U.S. Exclusive Economic Zone in the Bering Sea and Gulf of Alaska, 1973–77.[a] Catch rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take of only dead animals to observed groundfish catch (per 10,000 metric tons (t) basis).

Vessel nation year[b]	Groundfish: Observed catch[c] (t)	Groundfish: Number of observer days (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)[e]
Bering Sea and Aleutian Islands				
Small stern trawler				
Japan				
1976	9.6	1	0	0
1977	2,048.7	252	0 (1)	0
Large surimi trawler				
Japan				
1973	28,480.7	191	28 (2)[f]	9.83 ± 3.24
1974	24,497.1	201	52 (9)	21.23 ± 11.14
1975	20,236.0	182	14 (1)	6.92 ± 3.93
1976	23,612.1	204	2 (3)	0.85 ± 1.20
1977	28,105.0	297	13 (1)	4.63 ± 3.54

Table 10 (continued)

Vessel nation year[b]	Groundfish: Observed catch[c] (t)	Groundfish: Number of observer days (n)	Northern sea lions: Number dead (alive) reported in catch[d]	Northern sea lions: $\hat{R} \pm 2\, s(\hat{R})$ $(\times 10^{-4})$[e]
Large freezer trawler				
Korea				
1977	8,081.0	93	5 (2)	6.19 ± 5.45
U.S.S.R.				
1975	1,176.2	26	1	8.50 ± 16.92
1976	1,933.1	31	0	0
1977	11,223.9	269	9 (9)	8.02 ± 6.68
Surimi mothership				
Japan				
1973	110,800.0	145	4	0.36 ± 0.36
1974	112,556.0	177	14 (1)	1.24 ± 0.64
1975	68,821.0	86	3	0.44 ± 0.50
1976	62,885.3	112	9 (1)	1.43 ± 1.22
1977	337,449.2	453	6	0.18 ± 0.08
Freezer mothership				
Japan				
1973	12,730.0	27	7 (2)	5.50 ± 3.20
1974	14,876.5	49	3	2.02 ± 2.98
1975	9,470.0	23	2	2.11 ± 2.96
1976	13,173.0	41	2 (2)	1.52 ± 2.07
1977	35,439.0	111	2	0.56 ± 0.79
		Gulf of Alaska		
Small stern trawler				
Japan				
1975	347.2	46	0	0
1976	1,790.9	117	7 (5)	39.09 ± 39.63
1977	2,097.8	230	1 (1)	4.77 ± 9.51
Large surimi trawler				
Japan				
1975	1,775.9	65	0 (2)	0
Large freezer trawler				
Japan				
1975	711.0	15	2 (1)	28.13 ± 37.84
1976	1,170.0	46	0	0
1977	6,748.2	197	4 (6)	5.93 ± 5.82
U.S.S.R.				
1974	432.5	10	4	92.49 ± 118.76
1975	468.0	22	2 (1)	42.74 ± 52.02
1976	1,054.2	46	5	47.43 ± 67.88
1977	4,824.4	184	11 (1)	22.80 ± 17.95

[a] Only fisheries with observer coverage during 1973–77 are listed.

[b] Small stern trawler: trawl vessel <1,500 gross tons; large surimi trawler: trawl vessel >1,500 gross tons targeting on pollock to produce surimi, a minced meat product; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products; surimi mothership: vessel with a fleet of catcher boats targeting on pollock to produce a minced meat product; freezer mothership: vessel with a fleet of catcher boats which produces frozen whole fish or frozen products.

[c] Total daily catch; includes hauls not monitored by observers for fish composition or presence of marine mammals.

[d] Does not include decomposed sea lions. The numbers in parentheses refer to the number of additional sea lions which were caught alive and released back to sea.

[e] The observed sampling fraction of the total fishery is not known by vessel class from 1973 to 1977, but was assumed to be low at that time. This parameter was ignored in the calculation of standard errors of incidental take rates for this time period. The effect of ignoring the correction for the observed sampling fraction is to overestimate the standard error of the ratio estimate (Cochran 1977).

[f] Includes unidentified pinnipeds from the earliest observer cruises in 1973. These animals were most likely northern sea lions based on cruise reports.

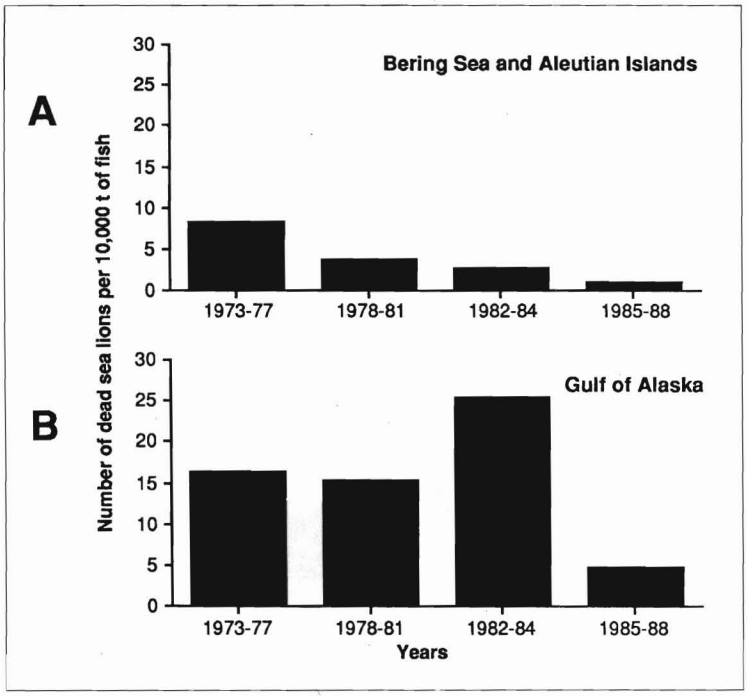

Figure 11
Incidental mortality of northern sea lions (per 10^4 metric tons of groundfish) by foreign (motherships excluded) and joint venture fisheries in the U.S. Exclusive Economic Zone during four time periods (1973–77, 1978–81, 1982–84, and 1985–88) in (**A**) the Bering Sea and Aleutian Islands region and (**B**) the Gulf of Alaska.

Within Alaska, 79% of the total estimated mortality of northern sea lions occurred in three statistical fishing areas: 19% in Area-I of the Bering Sea, 21% in Area-IV of the Bering Sea, and 39% in the Chirikof area in the Gulf of Alaska (Fig. 10). About 89% of the total groundfish catch in the fishery occurred in these three areas, but not in the same proportions as the estimated incidental catch of marine mammals. The observed rate of incidental mortality of northern sea lions was 25 times higher for Chirikof than for Area-I where the total groundfish catch was over eight times greater (Fig. 10). However, because of greater fishing effort in the Bering Sea, the total estimated take of northern sea lions in trawls in Area-I was half what it was in Chirikof during 1978–88 (Fig. 10).

The 1973–77 catch rates of northern sea lions, by year and vessel class, were generally higher than those during 1978–88 (Table 10, Fig. 11). During 1973–77 the average rates of dead sea lions per 10^4 t of fish catch in the Bering Sea and in the Gulf of Alaska were 8 and 16, respectively. These data suggest a declining trend in incidental take during 1973–77, similar to 1978–88 (Tables 4 and 5). The decline in catch rates of dead sea lions in the foreign fisheries from 1973 to 1988 is also illustrated by Figure 11. There was a 50% reduction in the incidental mortality rate in the Bering Sea from 1973–77 to 1978–81 (but observer coverage was low at that time). There was also a nearly 50% reduction in catch rates by successive, approximate four-year periods during 1973–88. Average incidental catch rates of dead northern sea lions during 1973–77 were also higher in the Gulf of Alaska than in the Bering Sea during all years from 1973 to 1988 (Fig. 11).

Incidental Take by Month and Time of Day—Northern sea lions were caught in nets in all months of the year—seasonal peaks occurring by region and type of fishery. In the Bering Sea, foreign trawlers caught 29% of their annual incidental take of northern sea lions from February to May and 55% from September to December (Fig. 12A). Joint venture vessels caught 62% of their annual incidental take in the Bering Sea during April-May (Fig. 12B). In the Gulf of Alaska, foreign trawlers caught 65% of their incidental take from September to November (Fig. 12C). Joint venture vessels caught 92% of their incidental take of northern sea lions in the Gulf of Alaska, primarily in Shelikof Strait, from February to April (Fig. 12D).

Total reported incidental take by both fisheries during late spring and summer (June to August) in both regions was lower (<25%) than in the remainder of the year combined, even though fishing effort was not low during summer months (38% of annual total). There was a significant difference (chi-square test; $P < 0.001$) between summer months and the remainder of the year in the number of observed hauls with incidental mortality of northern sea lions versus the number of hauls without sea lions. Incidental take of northern sea lions during summer months was presumably low because that is the time of year when these animals breed and remain near rookeries.

Nearly 60% of northern sea lions caught incidentally in fishing operations in Alaskan waters by foreign and JV fisheries were caught at night (Table 11). Data from the JV fisheries in the Bering Sea (Table 11) suggest that an equal likelihood of

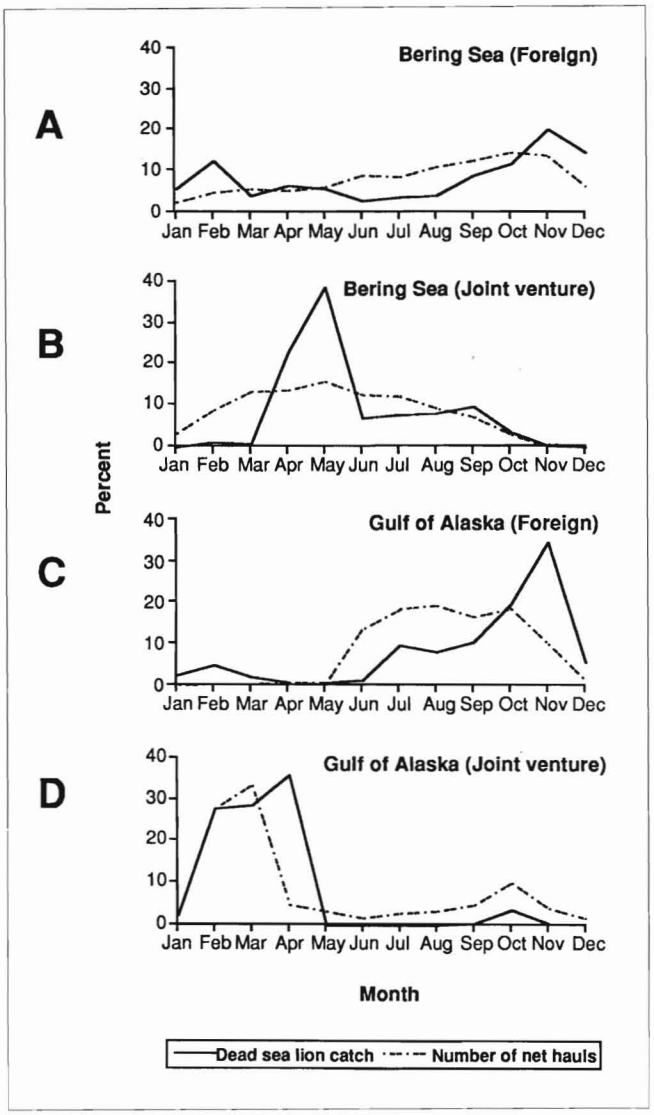

Figure 12

Percent of total by month of the number of incidentally taken northern sea lions (reported by U.S. fishery observers; no decomposed animals) which died during trawl fishing operations and the total number of net retrievals (hauls) when observers were present in the U.S. Exclusive Economic Zone during 1978–88 (years combined): (**A**) on foreign vessels (no motherships) in the Bering Sea and Aleutian Islands region; (**B**) on joint venture vessels in the Bering Sea and Aleutian Islands region; (**C**) on foreign vessels (no motherships) in the Gulf of Alaska; and (**D**) on joint venture vessels in the Gulf of Alaska.

incidental catch between day and night may have occurred since 1985, but this likelihood may be an artifact of the low rates of incidental catch of northern sea lions in recent years. Also, the fact that time of day was not available for all northern sea lions caught, especially prior to 1985, makes it difficult to compare changes in catch rates by year by diurnal period. The diel trend in number of hauls retrieved differs almost inversely with the trend in sea lion incidental catch (Fig. 13A). A greater proportion of hauls were retrieved in daylight than at night; however, fishing did occur throughout the 24-hour period (Fig. 13A).

The duration of fishing averaged from three to five hours throughout the day and night. Generally, fishing time was greater (by almost an hour per haul) for hauls retrieved three to four hours before or after sunrise in the JV fisheries, and about a half-hour longer at night in the foreign fisheries (Fig. 13B). It is not known if there is a relationship between length of fishing time and incidental catch of northern sea lions, but the rate of catch of sea lions may be higher when the fishing duration is longer. In any case, the frequency of northern sea lions caught during fishing operations was greater for hauls retrieved after sunset.

Age and Size—Male northern sea lions caught during 1977–87 in the U.S. EEZ off Alaska ranged from 1 to at least 13 years of age (n=273 aged teeth; Fig. 14A). The mean age of males caught in the Bering Sea was 5.2 years during 1977–81 and 5.9 years during 1982–87 (Table 12); this was not a statistically significant increase (P=0.131). As expected, the mean lengths (standard) of males were larger than those of females, but sample sizes were low for some ages (Fig. 15, A and B). The mean length of male northern sea lions incidentally caught in the Bering Sea during 1973–87 was 242.8 cm (standard) and 253.6 cm (curvilinear). Although there is an apparent increase in the mean standard length for all males in the 1980s, t-tests were not significant owing to low sample sizes and differences among observers in technique of length measurement.

Unlike the case for the Bering Sea, the mean age of males caught in the Gulf of Alaska significantly decreased from 6.2 years during 1977–81 to 4.7 years during 1982–87 (t-test; P=0.004). The mean length of male northern sea lions incidentally caught in the Gulf of Alaska during 1973–87 was 214.0 cm (standard) and 226.7 cm (curvilinear). The standard and curvilinear lengths significantly (t-tests; P<0.03) decreased in the 1980s as would be expected with decreasing mean age of incidentally caught animals (Table 12).

Female northern sea lions caught during 1977–87 in the U.S. EEZ off Alaska ranged from 1 to 25 years of age (n=414 aged teeth; Fig. 14B). The mean length of females taken during 1973–87 in the Bering Sea was 199.1 cm (standard) and 207.5 cm (curvilinear) (Table 12). As was the case with male sea lions, the mean age of females may have increased from 4.6 years (n=32) in 1977–81 to 5.4 years (n=51) in 1982–87, but the t-test results were not significant

Table 11

Number of northern sea lions incidentally caught by foreign fisheries during 1978–87 and joint venture fisheries during 1985–88 in the U.S. Exclusive Economic Zone off Alaska with respect to diurnal period.[a]

Fishery diurnal period	Number dead[b]	Number alive	Total taken	Percent total
		Bering Sea and Aleutian Islands		
Foreign				
Daytime	114	80	194	37.4
Nighttime	196	128	324	62.6
Total	310	208	518	100.0
Joint venture				
Daytime	75	—	75	53.6
Nighttime	62	3	65	46.4
Total	137	3	140	100.0
		Gulf of Alaska		
Foreign				
Daytime	55	31	86	37.9
Nighttime	107	34	141	62.1
Total	162	65	227	100.0
Joint venture				
Daytime	29	—	29	27.9
Nighttime	73	2	75	72.1
Total	102	2	104	100.0
		Total—Alaska		
Foreign				
Daytime	191	111	302	38.9
Nighttime	313	162	475	61.1
Total	504	273	777	100.0
Joint venture				
Daytime	82	—	82	38.7
Nighttime	125	5	130	61.3
Total	207	5	212	100.0

[a] Only animals for which the time of net retrieval was recorded were included. There was no foreign fishery in the U.S. Exclusive Economic Zone off Alaska during 1988.
[b] Decomposed animals were not included.

Table 12

Average age, standard length and curvilinear length by sex, region and fishery years for incidentally caught northern sea lions in Alaska during 1977–87. Data are $\bar{x} \pm 2$ SE. The sample size is shown in parentheses below the mean.

	Bering Sea and Aleutian Islands		Gulf of Alaska	
Measurement	Male	Female	Male	Female
1977–81				
Age (years)	5.2 ± 0.73	4.6 ± 1.00	6.2 ± 0.89	7.0 ± 1.45
	(40)	(32)	(22)	(7)
Standard length (cm)	235.7 ± 15.73	198.0 ± 15.17	236.1 ± 22.62	209.7 ± 41.77
	(15)	(8)	(7)	(3)
Curvilinear length (cm)	261.0 ± 22.95	199.0 ± 15.76	255.7 ± 18.89	243.0
	(19)	(22)	(10)	(1)
1982–87				
Age (years)	5.9 ± 0.54	5.4 ± 0.91	4.7 ± 0.41	6.6 ± 0.40
	(109)	(51)	(102)	(323)
Standard length (cm)	245.3 ± 12.14	199.5 ± 11.22	208.0 ± 11.22	198.2 ± 5.68
	(42)	(24)	(26)	(96)

Table 12 (continued)

Measurement	Bering Sea and Aleutian Islands		Gulf of Alaska	
	Male	Female	Male	Female
Curvilinear length (cm)	251.1 ± 10.81 (55)	216.5 ± 8.73 (21)	221.9 ± 8.62 (61)	206.1 ± 3.46 (214)
All years (1977–87)				
Age (years)	5.7 ± 0.44 (149)	5.1 ± 0.68 (83)	5.0 ± 0.38 (124)	6.6 ± 0.39 (330)
Standard length (cm)	242.8 ± 9.85 (57)	199.1 ± 9.12 (32)	214.0 ± 10.70 (33)	198.6 ± 5.62 (99)
Curvilinear length (cm)	253.6 ± 9.93 (74)	207.5 ± 9.41 (43)	226.7 ± 8.31 (71)	206.2 ± 3.46 (215)

(P=0.287). Average standard body length did not increase appreciably with increasing age for females (the increase in mean curvilinear length was also insignificant; t-test, n=43, P=0.061) during the 1980s, but this was most likely due to low sample size (n<50). Unlike the case for males, there was no statistically significant decrease (P=0.747) in mean age of incidentally caught female northern sea lions in the Gulf of Alaska (Table 12).

There were no statistically significant differences (with t-tests) in the mean age, standard length or curvilinear length of northern sea lions caught in the periods 1977–81 and 1982–87 by foreign fisheries in either the Bering Sea or Gulf of Alaska (Table 13). There was a significant difference (t-test; P=0.011) in mean age for sea lion males in the Gulf of Alaska between the foreign and JV fisheries (Table 13) during 1982–87, but limited sample sizes prevented statistical analysis of length differences. The difference in measurements for incidentally caught male northern sea lions between the two fisheries was probably related to the difference in primary fishing areas since the JV fisheries were more common in Area-IV, Chirikof, and Kodiak during recent years than were the foreign fisheries (Table 4).

The sizes (standard and curvilinear length) by age of female northern sea lions taken incidentally in trawl fishing operations in the Gulf of Alaska during

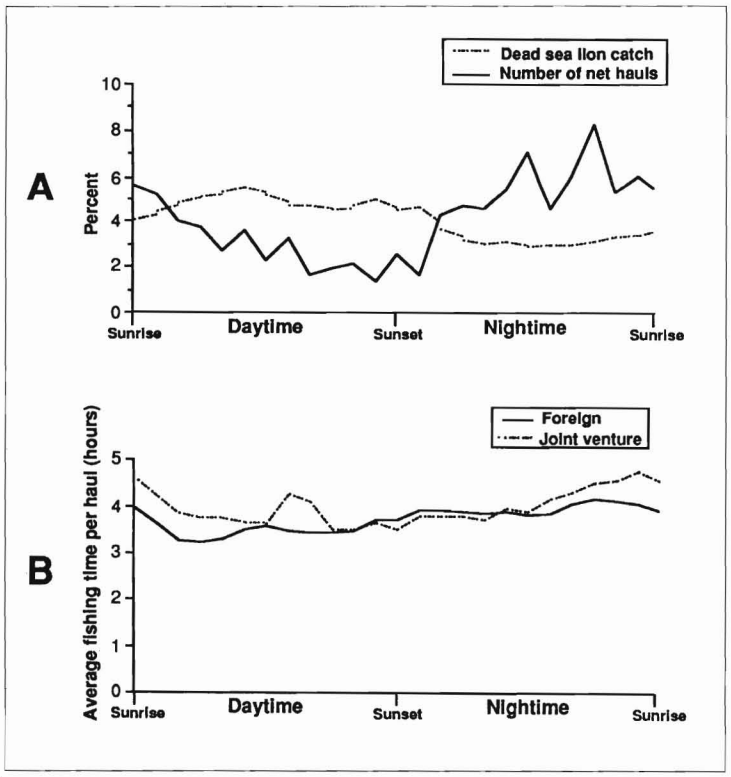

Figure 13

Percent throughout the 24-hour period during day and night hours of: (**A**) the total observed number of incidentally taken northern sea lions (reported by U.S. fishery observers; no decomposed animals) which died during trawl fishing operations (solid line) and the total number of net retrievals (hauls) when observers were present (dotted line) on foreign (no mothership) and joint venture vessels (both fisheries combined) in the U.S. Exclusive Economic Zone during 1978–88; and (**B**) the average fishing time of hauls (net in the water) by time of net retrieval for independent foreign stern trawlers during 1980–87 (solid line) and joint venture vessels during 1985–88 (dotted line).

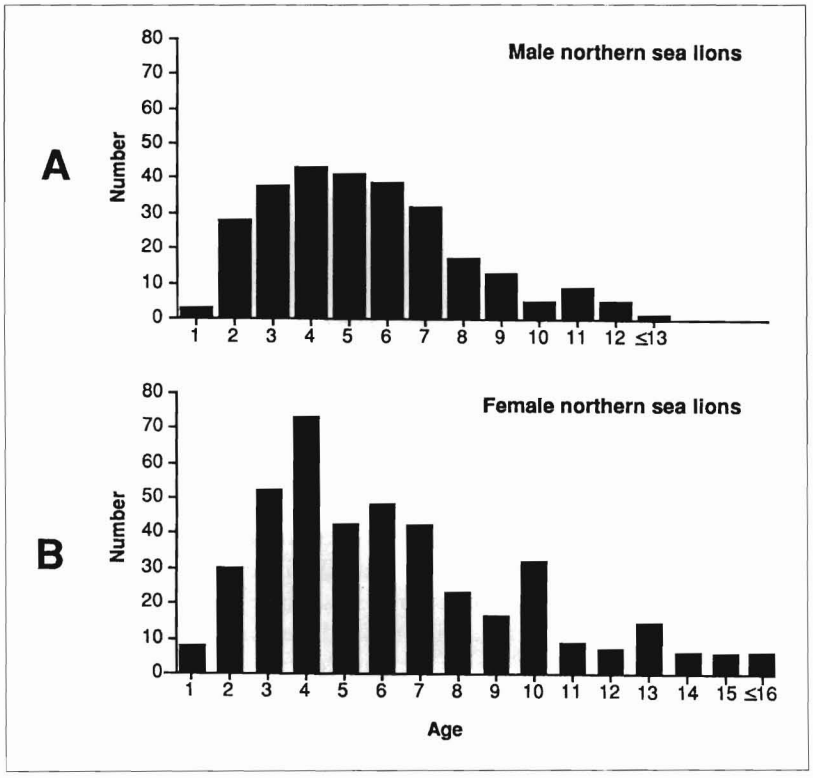

Figure 14
Number by age and sex of incidentally taken northern sea lions (observed only; no decomposed animals) which died during trawl fishing operations of foreign and joint venture vessels in the U.S. Exclusive Economic Zone in Alaska during 1978–87 (years and areas combined) based only on data from teeth specimens collected by U.S. observers: (**A**) male northern sea lions, and (**B**) female northern sea lions.

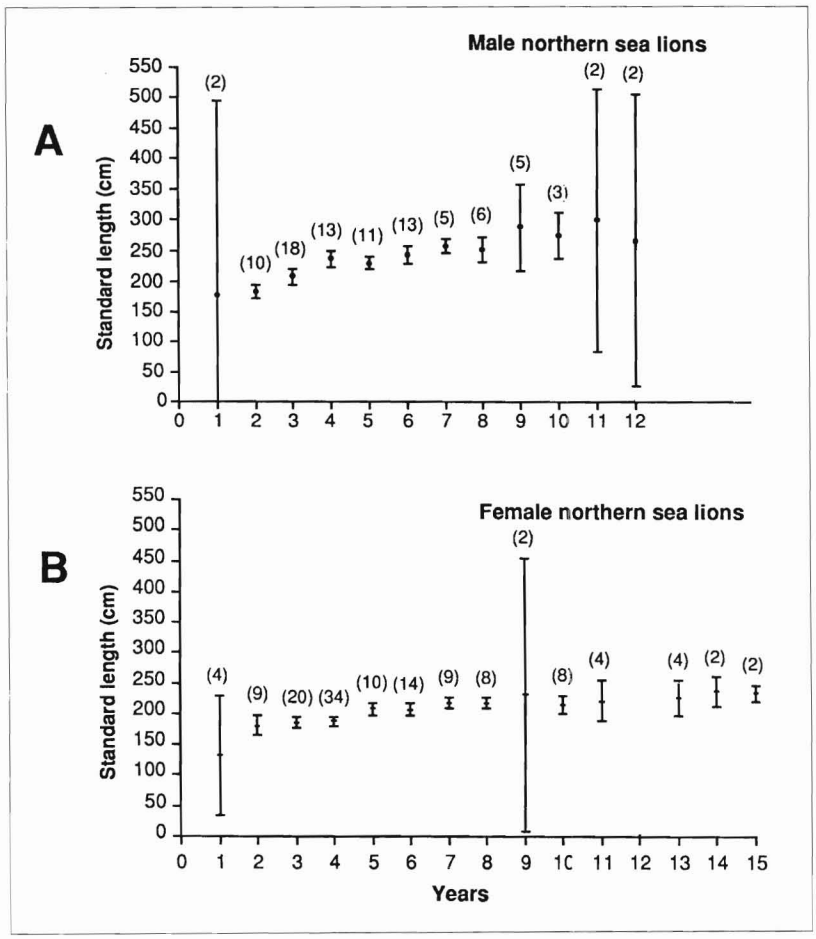

Figure 15
Standard length (cm; mean ± 95% confidence intervals) by age and sex of incidentally taken northern sea lions which died during trawl fishing operations of foreign and joint venture vessels in the U.S. Exclusive Economic Zone in Alaska during 1977–87 (years combined) based only on animals from which teeth specimens were collected by U.S. observers: (**A**) males, and (**B**) females. The sample size is shown in parentheses above each data set.

Table 13

Average age, standard length and curvilinear length by sex, region, years and fishery for northern sea lions taken incidental to fishing operations in the U.S. Exclusive Economic Zone off Alaska, 1977–87. Data are $\bar{x} \pm 2$ SE. The sample size is shown in parentheses below the mean.

Years fishery	Male			Female		
	Age (years)	Standard length (cm)	Curvilinear length (cm)	Age (years)	Standard length (cm)	Curvilinear length (cm)
Bering Sea and Aleutian Islands						
1977–81						
Foreign	5.2 ± 0.73 (40)	235.7 ± 15.73 (15)	261.0 ± 22.95 (19)	4.6 ± 1.00 (32)	198.0 ± 15.18 (8)	199.0 ± 15.76 (22)
JV	–	–	–	–	–	–
1982–87						
Foreign	5.8 ± 0.69 (62)	257.7 ± 17.16 (20)	246.2 ± 13.28 (35)	6.7 ± 2.47 (17)	203.6 ± 16.83 (8)	210.6 ± 18.31 (7)
JV	6.1 ± 0.87 (47)	234.0 ± 16.02 (22)	259.8 ± 18.37 (20)	4.7 ± 0.48 (34)	197.4 ± 14.84 (16)	219.5 ± 9.51 (14)
Gulf of Alaska						
1977–81						
Foreign	6.2 ± 0.89 (22)	236.1 ± 22.63 (7)	255.7 ± 18.89 (10)	6.8 ± 1.67 (6)	209.7 ± 41.77 (3)	243.0 (1)
JV	–	–	–	–	–	–
1982–87						
Foreign	6.3 ± 1.16 (10)	225.0 (1)	247.1 ± 32.61 (9)	15.0 (1)	235.0 (1)	–
JV	4.6 ± 0.42 (92)	207.3 ± 11.59 (25)	217.5 ± 7.98 (52)	6.5 ± 0.40 (322)	197.9 ± 5.69 (95)	206.1 ± 3.46 (214)

Table 14

Estimated mortality of five commonly encountered marine mammal species caught in trawls by foreign and joint venture fisheries in the U.S. Exclusive Economic Zone of the Bering Sea and Aleutian Islands during 1978–88. Mortality rates based on U.S. fishery observer data by area and fishery are listed in part B. * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers (the latter was used as the minimum estimate); ** = the estimated lower 95% confidence level was less than zero (the number of animals reported caught by U.S. observers was used as the minimum estimate).

Part A Estimated Mortality—ratio estimate ($\hat{Y}_{Rs}$) and the lower (L_1) and upper (L_2) 95% confidence limits[a].

Year	Walrus			Northern fur seal[b]			Ribbon seal			Harbor and spotted seals[c]			Dall's porpoise		
	$\hat{Y}_{Rs}$	L_1	L_2	$\hat{Y}_{Rs}$	L_1	L_2	$\hat{Y}_{Rs}$	L_1	L_2	$\hat{Y}_{Rs}$	L_1	L_2	$\hat{Y}_{Rs}$	L_1	L_2
1978	7	5	9	10	8	12	31	1 **	65	5	4	6	3	2	4
1979	6	5	7	18	2	34	27	1 **	60	4	3	5	23	1 **	56
1980	28	1 *	56	58	13	103	6	4	8	4	3	5	1	0	2
1981	40	2 **	96	24	1 **	52	5	3	7	4	3	5	1	0	2
1982	3	2	4	28	12	44	14	2	26	2	1	3	1	0	2
1983	13	6	20	20	11	29	21	12	30	29	17	41	6	2 *	11
1984	4	2	6	31	23	39	24	16	32	7	4	10	9	4	14
1985	27	16	38	9	4	14	5	1	9	15	9	21	2	1 **	5
1986	13	7	19	8	4 *	13	0	0	0	6	4 *	10	1	0	2
1987	32	21	43	5	3 *	9	0	0	0	7	4 *	12	1	0	2
1988	17	10	24	6	2	10	0	0	0	3	2 *	6	1	0	2
Total	190	124	256	217	157	277	133	82	184	86	71	101	49	15	83

Table 14 (continued)

Part B Observed incidental mortality rate per 10^4 t of groundfish catch—ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take to observed fish catch. Refer to Figure 1 for the locations of the areas in the left column. FF = foreign fishery (rates for independent stern trawlers only); JV = joint venture fishery (U.S.-foreign).

Area fishery	Number of hauls observed[d] (n)	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$) Walrus	Northern fur seal[b]	Ribbon seal	Harbor and spotted seals[c]	Dall's porpoise
Area-I						
FF, 1978–87	54,310	0.143 ± 0.062	0.123 ± 0.057	0.031 ± 0.029	0.143 ± 0.062	0
JV, 1980–84	3,772	0.045 ± 0.044	0.045 ± 0.044	0	0	0.067 ± 0.070
JV, 1985–88	62,931	0.195 ± 0.050	0.039 ± 0.020	0	0.061 ± 0.024	0.006 ± 0.008
Area-II						
FF, 1978–87	54,648	0.082 ± 0.074	0.165 ± 0.088	0.231 ± 0.112	0.033 ± 0.039	0.066 ± 0.056
JV, 1980–84	160	0	0	0	0	0
JV, 1985–88	10,277	0.044 ± 0.044	0.022 ± 0.032	0	0	0
Area-III						
FF, 1978–87	22	0	0	0	0	0
JV, 1980–84	0	—	—	—	—	—
JV, 1985–88	0	—	—	—	—	—
Area-IV						
FF, 1978–87	11,969	—	0.134 ± 0.166	—	0	0
JV, 1980–84	719	—	0.134 ± 0.148	—	0	0
JV, 1985–88	6,299	—	0.245 ± 0.150	—	0.123 ± 0.106	0

[a] The ratio estimates in Part A of the table are the sums of the separate ratio estimates for all strata. The strata (subgroups) for northern sea lion data (Table 4) were used for all marine mammal species.
[b] Ribbon seals were often misidentified by observers as northern fur seals, and thus some of the estimated fur seal take may include some ribbon seals.
[c] Observers were often unable to distinguish between harbor seals and spotted seals, and both species have been grouped.
[d] The sample size was the number of hauls observed, except for the joint venture fisheries during 1980–84 where the sample size was the number of fishing days with observer coverage.

Table 15

Estimated number of dead animals of three commonly encountered marine mammal species caught in trawls by foreign and joint venture fisheries in the U.S. Exclusive Economic Zone of the Gulf of Alaska during 1978–88. Mortality rates based on U.S. fishery observer data by area and fishery are listed in part B. * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers (the latter was used as the minimum estimate); ** = the estimated lower 95% confidence level was less than zero (the number of animals reported caught by U.S. observers was used as the minimum estimate).

Part A Estimated Mortality—ratio estimate ($\hat{Y}_{Rs}$) and the lower (L_1) and upper (L_2) 95% confidence limits[a].

Year	Northern fur seal $\hat{Y}_{Rs}$	L_1	L_2	Harbor seal $\hat{Y}_{Rs}$	L_1	L_2	Dall's porpoise $\hat{Y}_{Rs}$	L_1	L_2
1978	14	1 **	39	0	0 **	1	0	0	0
1979	6	1 **	16	11	1 **	32	0	0	0
1980	0	0 **	2	0	0 **	1	0	0	0
1981	2	0	4	0	0 **	1	0	0	0
1982	0	0 **	1	0	0	0	0	0	0
1983	0	0 **	1	0	0	0	0	0	0
1984	5	3 *	10	1	1 *	2	0	0	0
1985	1	1 **	3	0	0	0	0	0	0
1986	0	0	0	0	0	0	1	1 *	2
1987	0	0 **	1	0	0	0	0	0 **	1
1988	0	0	0	0	0	0	0	0	0
Total	28	6 *	55	12	2 **	33	1	1 *	2

Table 15 (continued)

Part B Observed incidental mortality rate per 10^4 t of groundfish catch—ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take to observed fish catch. Refer to Figure 1 for the locations of the areas in the left column. FF = foreign fishery (rates for independent stern trawlers only); JV = joint venture fishery (U.S.-foreign).

Area fishery	Number of hauls observed[b] (n)	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$) Northern fur seal	Harbor seal	Dall's porpoise
Shumagin				
FF, 1978–85	6,011	0.107 ± 0.184	0.107 ± 0.184	0
JV, 1978–84	275	0	0	0
JV, 1985–88	954	0.343 ± 0.432	0	0.343 ± 0.432
Chirikof				
FF, 1978–85	5,757	0.248 ± 0.441	0	0
JV, 1978–84	1,682	0	0.032 ± 0.040	0
JV, 1985–88	3,730	0	0	0
Kodiak				
FF, 1978–85	7,839	0.226 ± 0.402	0	0
JV, 1978–84	1,075	0.243 ± 0.298	0	0
JV, 1985–88	1,357	0	0	0
Yakutat				
FF, 1978–85	1,025	0	0	0
JV, 1978–84	6	0	0	0
Southeastern				
FF, 1978–85	871	0	0	0
JV, 1978–84	2	0	0	0

[a] The ratio estimates in Part A of the table are the sums of the separate ratio estimates for all strata. The strata (subgroups) for northern sea lion data (Table 5) were used for all marine mammal species.

[b] The sample size was the number of hauls observed, except for the joint venture fisheries during 1978–84 where the sample size was the number of fishing days with observer coverage. There were no JV fisheries in the Yakutat or Southeastern areas during 1985–88, and there were no foreign fisheries in the Gulf of Alaska during 1986–88.

1982–84 were smaller than sizes reported by the Alaska Department of Fish and Game (ADF&G) from animals collected from haul-out sites near Kodiak during 1975–78 and smaller than animals taken from haul-out sites near Kodiak during 1985–86 (Calkins and Goodwin 1988) (Fig. 16, A through C). Analysis of covariance tests ($P<0.05$) and nonoverlapping 95% confidence intervals (primarily between ages 3 and 7) suggest that mean lengths were smaller during 1982–84 than in 1975–78, and possibly also smaller than in 1985–86.

Other Marine Mammal Species in Alaska

Incidental catch of marine mammals other than northern sea lions taken by both the foreign and JV fisheries was very low in Alaska during 1978–88. Besides northern sea lions, walruses, northern fur seals, ribbon seals, harbor seals (possibly also spotted seals, *Phoca largha*), and Dall's porpoises were most commonly encountered (Tables 1–3). During the period 1978–88, a total of 190 walruses, 217 northern fur seals, 133 ribbon seals, 86 harbor (and spotted) seals, and 49 Dall's porpoises were estimated to have died during trawl operations in the Bering Sea region (Table 14). In the Gulf of Alaska, 28 northern fur seals, 12 harbor seals, and 1 Dall's porpoise were estimated to have died during 1978–88 (Table 15). Unlike northern sea lions which have been caught in all statistical areas of Alaska, some marine mammal species have limited distributions. For example, walruses, ribbon seals, and spotted seals generally occur only in Area-I, Area-II, or Area-III of the Bering Sea. Northern fur seals, harbor seals (except Area-III), and Dall's porpoises may be encountered in all statistical areas, but these species were not observed in hauls in all areas during 1978–88 (Tables 14 and 15).

Incidental catch rates of these other marine mammal species during 1978–88 averaged less than one animal caught dead (excluding decomposed animals) per 40,000 t of groundfish caught in the Bering Sea and less than one dead mammal per 30,000 t of groundfish in the Gulf of Alaska (Tables 14 and 15).

As previously mentioned, average incidental catch rates for northern sea lions were significantly higher (Tables 4, 5, and 6). For example, at least 25 or more northern sea lions were caught for each northern fur seal taken in Area-IV, and 10 northern sea lions for each walrus taken in Area-I of the Bering Sea. However, in Area-II of the Bering Sea average incidental catch rates of ribbon seals and northern fur seals were only 4–5 times lower than catch rates for the northern sea lion. These average catch rates reflect the distribution of these mammals since northern sea lions are not very abundant in Area-II. It should also be noted that observers occasionally misidentified ribbon seals as northern fur seals. Although northern fur seals were incidentally caught in Area-II of the Bering Sea, the average catch rate for northern fur seals may be lower and the catch of ribbon seals higher than that shown in Table 14; however, the total for both species combined would be the same.

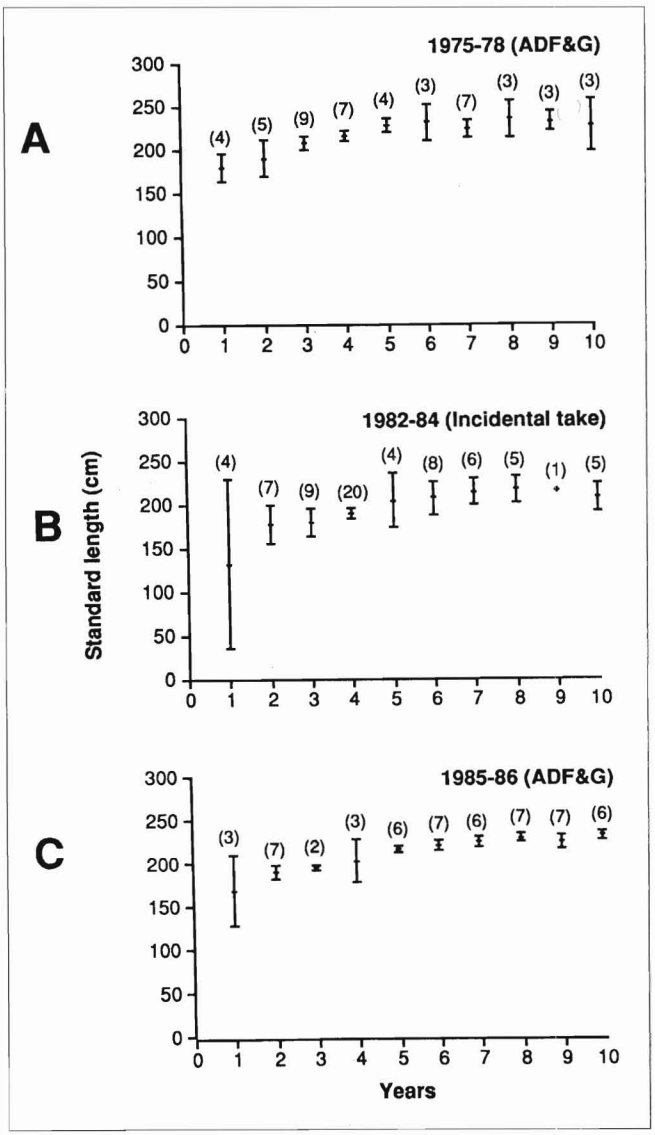

Figure 16

Standard length of female northern sea lions in the Gulf of Alaska based on measurements taken during three time periods: (**A**) during 1975–78 for data collected by ADF&G and reported by Calkins and Goodwin (1988) for animals taken on haul sites; (**B**) during 1982–84 from incidentally taken animals which died during fishing operations by trawl fisheries; and (**C**) during 1985–86 for data collected by ADF&G and reported by Calkins and Goodwin (1988) for animals taken on haul sites. The sample size is shown in parentheses above each data set.

Marine Mammal Species in Washington, Oregon, and California

Incidental take of marine mammals in trawl nets off the coast of Washington, Oregon, and California was low during all years. A total of 36 marine mammals (7 northern sea lions, 1 California sea lion, 1 northern fur seal, 5 harbor seals, 3 Pacific white-sided dolphins [*Lagenorhynchus obliquidens*], 9 Dall's porpoises, and 10 unidentified small cetaceans) were observed caught dead or alive in the catch during 1973–88 (Table 1). Nearly 80% of this incidental take occurred in the Columbia fishing area, the remainder in the Eureka fishing area (Fig. 1). Most (78%) of this incidental take occurred in the foreign fishery. The incidental catch rate has remained low for the JV fisheries, even though the total annual fish catch (Fig. 5A) and number of vessel days (Fig. 6A) since 1984 in the region is similar to or greater than that of the foreign fisheries prior to 1981.

California sea lions were not observed taken in trawl operations until 1988. Although some of the reported northern sea lions caught during 1973–88 off Washington, Oregon, and California could have been California sea lions, several were indeed northern sea lions based on identification of canine teeth collected by U.S. fishery observers.

The west coast fisheries have always had low incidental mortality rates (compared with Alaska): less than one marine mammal per 10^4 t during 1973–77 (Table 16) and one marine mammal per 10^4 t during 1978–88 (although some country-specific rates by area and year were as high as 68 mammals per 10^4 t; Table 17). Only 35% of the total fish catch during 1973–88 in the west coast fishery was monitored by U.S. fishery observers (Table 1). Using the same approach as for northern sea lions in Alaska, an estimated total of 99 marine mammals (all species combined) died during fishing operations by the foreign trawl fisheries off Washington, Oregon, and California during 1978–88 (Table 18). Similarly, for the JV fisheries there, the estimated total incidental mortality of marine mammals during 1978–88 was 7 (Table 18).

Table 16

Number of marine mammals reported by U.S. fishery observers incidentally caught by vessel class and nation in the U.S. Exclusive Economic Zone off Washington, Oregon, and California during 1973–77.[a] Catch rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take of only dead animals to observed groundfish catch (per 10,000 metric tons (t) basis).

	Groundfish		Marine mammals	
Vessel nation year[b]	Observed catch[c] (t)	Number of observer days (n)	Number dead reported in catch[d]	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)[e]
Small stern trawler				
Japan				
1976	318.2	17	0	0
Large freezer trawler				
Japan				
1975	966.0	38	0	0
1976	1,637.0	65	0	0
Poland				
1976	10,029.2	204	1	1.00 ± 1.99
1977	7,416.5	251	0	0
U.S.S.R.				
1976	1,045.6	72	0	0
1977	21,730.2	681	1	0.46 ± 0.92
Freezer mothership				
U.S.S.R.				
1977	1,191.3	34	0	0

[a] Only fisheries with observer coverage during 1973–77 are listed.
[b] Small stern trawler: trawl vessel <1,500 gross tons; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products; freezer mothership: vessel with a fleet of catcher boats which produces frozen whole fish or frozen products.
[c] Total daily catch; includes hauls not monitored by observers for fish composition or presence of marine mammals.
[d] Does not include decomposed marine mammals.
[e] The observed sampling fraction of the total fishery is not known by vessel class from 1973 to 1977, but was assumed to be low at that time. This parameter was ignored in the calculation of standard errors of incidental take rates for this time period. The effect of ignoring the correction for the observed sampling fraction is to overestimate the standard error of the ratio estimate (Cochran 1977).

Discussion

During the period 1978–81 the estimated average annual take of northern sea lions by foreign vessels was 724 animals (Loughlin et al. 1983). In the 1982–84 walleye pollock JV fishery in Shelikof Strait, Alaska, the estimated number of mortalities resulting from incidental catch ranged from 216 to 1,436 from January to April (Loughlin and Nelson 1986). The estimates reported in this study are somewhat higher because the analysis was based on subregions (statistical areas) for which estimated catch totals were summed, as opposed to the annual average method used in the earlier study. Although some data corrections have been made in the years since the previous studies were made, the results of each of the studies are essentially similar.

Northern sea lions caught by foreign vessels between 1978 and 1981 were principally females between 2 and 10 years of age, 65% of which were probably sexually mature (Loughlin et al. 1983). The average age for first ovulation and for first pregnancy for female northern sea lions in the Gulf of Alaska is 4–5 years (Pitcher and Calkins 1981). Any female age 4–5 years or older and caught incidentally was probably sexually mature; but only by examination of reproductive tracts, which was not possible, could this be verified. Northern sea lions caught in Shelikof Strait between 1982 and 1984 were predominantly female; an estimated 79% were sexually mature with an average age of 6.4 years for all females (n=228, range in age from 1 to 25 years old; Loughlin and Nelson 1986). Sexually mature males were rarely caught.

In the Shelikof Strait JV fishery, northern sea lions were usually caught during nighttime—73% caught between 2000 and 0500 hours (Loughlin and Nelson 1986). Analysis of the location of dead animals in the net suggested that they were caught during net as-

Table 17

Number of marine mammals (species combined) reported by U.S. fishery observers incidentally caught by subgroup (area, vessel class, nation, and year) in the U.S. Exclusive Economic Zone off the coast of Washington, Oregon, and California, 1978–88, and an estimation of the total incidental take of marine mammals in the fishery.[a] Catch rates are the ratio ($\hat{R}$) ± twice the standard error ($s(\hat{R})$) of observed incidental take to observed groundfish catch (per 10,000 metric tons (t) basis). Estimated takes are the ratio estimate ($\hat{Y}_R$) ± the 95% confidence limits ($L_{95\%}$). Refer to Figure 1 for the locations of the areas in the left column. * = the estimated lower 95% confidence level was less than the number of animals reported by U. S. observers; ** = the estimated lower 95% confidence level was less than zero.

	Groundfish				Marine mammals		
Vessel nation year[b]	Total catch (t)	Observed catch[c] (t)	Percent of catch observed	Number of hauls observed[d] (n)	Number reported in catch[e]	$\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	$\hat{Y}_R \pm L_{95\%}$
			Vancouver				
Joint venture mothership (countries combined)							
1980	2,736.2	1,868.4	68.3	48	0	0	—
1981	2,168.2	1,522.6	70.2	37	0	0	—
1982	31,927.2	24,232.6	75.9	459	0	0	—
1983	27,850.4	24,839.3	89.2	447	0	0	—
1984	9,056.1	7,770.9	85.8	142	0	0	—
1985[f]	7,005.4	4,711.4	67.2	319	0	0	—
1986[f]	11,687.3	9,093.2	77.8	666	0	0	—
1987[f]	7,058.9	5,697.4	80.7	380	0	0	—
1988[f]	12,642.0	8,632.7	68.3	492	0	0	—
			Columbia				
Large freezer trawler							
Bulgaria							
1981	3,665.4	1,577.3	43.0	184	1	6.34 ± 9.62	2 ± 4 **
1982	6,732.0	5,039.0	74.9	258	1	1.98 ± 2.00	1 ± 1 *
People's Republic of China							
1987	5.0	2.6	52.0	2	0	0	—
Republic of Korea							
1987	1,412.7	578.6	41.0	42	0	0	—
Poland							
1978	20,325.9	6,259.4	30.8	634	0	0	—
1979	12,271.1	2,320.0	18.9	326	0	0	—
1980	45,393.0	5,966.5	13.1	628	0	0	—
1981	43,000.7	7,098.4	16.5	862	0	0	—
1984	14,607.9	9,613.0	65.8	653	0	0	—
1985	43,660.2	29,608.8	67.8	2,583	1	0.34 ± 0.38	1 ± 1 *
1986	42,228.2	30,122.9	71.3	2,316	0	0	—
1987	48,830.4	32,815.1	67.2	2,564	3	0.91 ± 0.60	4 ± 3 *
1988	17,142.6	13,426.5	78.3	1,115	4	2.98 ± 2.20	5 ± 4 *
U.S.S.R.							
1978	51,559.1	12,671.3	24.6	1,502	0 (2)	0	—
1979	51,262.3	11,209.1	21.9	1,510	9	8.03 ± 14.20	41 ± 72 **
1984	470.7	325.5	69.2	27	0	0	—
Joint venture mothership (countries combined)							
1978	894.2	893.5	99.9	46	0	0	—
1979	8,826.8	4,771.7	54.1	182	0	0	—
1980	13,268.6	10,672.3	80.4	273	1	0.94 ± 0.83	1 ± 1 *
1981	12,697.3	4,424.2	34.8	120	0	0	—
1982	30,164.8	27,423.2	90.9	543	0	0	—
1983	39,903.3	36,546.2	91.6	633	0	0	—
1984	66,798.3	62,194.7	93.1	1,127	0	0	—
1985[f]	25,027.8	17,539.5	70.1	1,358	1	0.57 ± 0.62	1 ± 1 *
1986[f]	67,805.3	47,757.2	70.4	3,370	3	0.63 ± 0.39	4 ± 3 *

Table 17 (continued)

Vessel nation year[b]	Groundfish: Total catch (t)	Groundfish: Observed catch[c] (t)	Groundfish: Percent of catch observed	Groundfish: Number of hauls observed[d] (*n*)	Marine mammals: Number reported in catch[e]	Marine mammals: $\hat{R} \pm 2\, s(\hat{R})$ ($\times 10^{-4}$)	Marine mammals: $\hat{Y}_R \pm L_{95\%}$
1987[f]	100,092.0	74,082.5	74.0	4,837	0	0	—
1988[f]	98,256.0	68,224.6	69.4	4,249	1	0.15 ± 0.16	1 ± 1 *
			Eureka				
Large freezer trawler							
Bulgaria							
1981	3,447.5	1,249.5	36.2	99	0	0	—
1982	521.5	448.0	85.9	23	0	0	—
Poland							
1978	6,248.5	3,089.3	49.4	402	0 (1)	0	—
1979	6,134.0	2,146.3	35.0	238	0	0	—
1980	1,535.2	418.9	27.3	59	0	0	—
1981	21,193.1	3,692.2	17.4	346	2	5.42 ± 6.98	11 ± 15 **
1985	6,539.0	4,634.4	70.9	308	0	0	—
1986	28,524.6	21,710.5	76.1	1,577	0	0	—
1987	145.0	145.0	100.0	17	1	68.97	1
1988	1,195.6	806.6	67.5	49	0	0	—
U.S.S.R.							
1978	19,870.2	4,412.9	22.2	475	0	0	—
1979	38,087.1	9,098.9	23.9	1,046	3	3.30 ± 4.29	13 ± 16 **
1984	3.3	2.2	66.7	2	0	0	—
Joint venture mothership (countries combined)							
1979	226.9	46.4	20.4	7	0	0	—
1980	12,465.6	9,960.4	79.9	234	0	0	—
1981	30,275.1	10,965.3	36.2	246	0	0	—
1982	6,953.2	4,773.3	68.6	120	0	0	—
1983	2,253.4	931.1	41.3	20	0	0	—
1984	3,778.9	3,097.2	82.0	55	0	0	—
1986[f]	3,241.6	1,939.5	59.8	135	0	0	—
1988[f]	25,255.0	17,807.7	70.5	1,024	0	0	—
			Monterey				
Large freezer trawler							
Poland							
1978	676.0	11.0	1.6	3	0	0	—
1979	216.1	21.0	9.7	1	0	0	—
U.S.S.R.							
1979	71.7	4.4	6.1	1	0	0	—
Joint venture mothership (countries combined)							
1982	108.2	108.2	100.0	5	0	0	—
1983	3,238.0	2,663.8	82.3	48	0	0	—
1984	19.5	—	—	—	—	—	—
1986[f]	93.1	93.1	100.0	7	0	0	0
1988[f]	740.0	315.1	42.6	8	0	0	

[a] There were no foreign trawl fisheries off Washington, Oregon and California during 1983.
[b] Joint venture mothership: processing vessel of the joint venture fisheries which receives catches from U.S. fishing vessels; large freezer trawler: trawl vessel >1,500 gross tons which produces frozen whole fish and fillet products.
[c] Observed tonnage listed for motherships (all years) and joint venture vessels (1978–84) are total daily catch, and include hauls not sampled for fish composition nor monitored for presence of marine mammals.
[d] Data are fishing days with observer coverage for motherships (all years) and joint venture vessels during 1978–84.
[e] Totals include only dead animals (excludes "decomposed in catch"); numbers in parentheses are additional animals caught and released back to sea still alive.
[f] Observer data were based on hauls observed for joint venture vessels during 1985–88.

Table 18

Estimated incidental mortality of marine mammals (all species combined) in the foreign and joint venture groundfish trawl fisheries (all countries combined) in the U.S. Exclusive Economic Zone off Washington, Oregon, and California during 1978–88. Estimates of the number of dead marine mammals are the ratio estimate ($\hat{Y}_{Rs}$)[a] and the lower (L_1) and upper (L_2) 95% confidence limits[b]. * = the estimated lower 95% confidence level was less than the number of animals reported by U.S. observers (the latter was used as the minimum estimate); ** = the estimated lower 95% confidence level was less than zero (the number of animals reported caught by U.S. observers was used as the minimum estimate).

	Foreign fisheries					Joint venture fisheries				
			Estimated number of dead marine mammals					Estimated number of dead marine mammals		
Year	Total groundfish catch (t)[c]	Percent fish catch observed	$\hat{Y}_{Rs}$	L_1	L_2	Total groundfish catch (t)[c]	Percent fish catch observed[d]	$\hat{Y}_{Rs}$	L_1	L_2
1978	98,680	26.8	8	4	12	894	99.9	0	0	0
1979	108,042	23.0	55	12 **	128	9,054	53.2	0	0	0
1980	46,928	13.6	4	1	7	28,470	79.0	1	1 *	2
1981	71,307	19.1	17	3 *	32	45,141	37.5	0	0	0
1982	7,254	75.6	1	1 *	2	69,153	81.8	0	0	0
1983			no fishery			73,245	88.7	0	0	0
1984	15,082	65.9	1	1	1	79,653	91.7	0	0	0
1985	50,199	68.2	1	1 **	3	32,033	69.5	1	1 **	3
1986	70,753	73.3	2	1	3	82,827	71.1	4	3 *	7
1987	50,393	66.6	5	4 *	8	107,151	74.5	0	0	0
1988	18,338	77.6	5	4 *	9	136,893	69.4	1	1 **	3
Total	536,976	39.8	99	25 *	174	664,515	74.6	7	6 *	11

[a] The sum of estimates for the strata (area, vessel class, country and year) in Table 17.

[b] Sample size (number of hauls observed, or observed fishing days for joint venture fisheries during 1978–84) can be summed from the data by area, vessel class, country and year in Table 17.

[c] Trawl catches (metric tons) during 1978–88.

[d] Values for the percent of fish catch observed during 1978–84 listed in this column are higher than true values (unknown) since joint venture data for those years were based on total daily fish catch rather than hauls observed.

cent or while the net was near the surface during haulback (Loughlin and Nelson 1986).

The changes over the years in the observed and estimated totals of incidental catch of northern sea lions in Alaska may be due to a number of probable causes: 1) the northern sea lion population size has declined every year, and this has the effect of reducing the number of animals that could be caught; 2) fisheries may have shifted their fishing locations to localities away from areas of high concentration of northern sea lions (e.g., there has been less fishing in Shelikof Strait in recent years and more fishing effort in Area-I and Area-II of the Bering Sea); 3) there had been more daytime fishing in recent years compared to early years (but this may not be a significant factor because recently JV fisheries in the Bering Sea seem to catch an equal number of sea lions in either the day or night); 4) fishing techniques have improved to prevent incidental mortality and catch of marine mammals; 5) changes in fishing gear, vessel size, or catch per haul have reduced incidental catch rates (although there has been no significant relationship between vessel class and average catch size); or 6) the animals may be learning to avoid being caught in the nets.

Using limited data on groundfish catches by trawl gear, country (data for foreign countries other than Japan were only available as a combined total), statistical fishing area, and year, we calculated estimates of the northern sea lion mortality by foreign trawl fisheries in Alaska during 1966–77 using observed average rates for 1973–77 (Table 19). We assumed that sea lions were probably caught also in the side trawls which were discontinued in 1972. We used 1966 as the first year because it was the first year there were data with which to exclude catch data by other

Table 19

Estimated incidental mortality of northern sea lions in the foreign groundfish trawl fisheries (all countries combined) in Alaska during 1966–77, based on the incidental take rates during 1973–77.[a] Estimates of the number of dead northern sea lions are the ratio estimate ($\hat{Y}_R$) and the lower (L_1) and upper (L_2) 95% confidence limits.

	Bering Sea and Aleutian Islands[b]				Gulf of Alaska[c]			
		Number of dead sea lions				Number of dead sea lions		
Year	Total groundfish catch (t)[d,e]	$\hat{Y}_R$	L_1	L_2	Total groundfish catch (t)[d]	$\hat{Y}_R$	L_1	L_2
1966	326,200	260	220	300	159,000	320	180	460
1967	579,700	470	390	550	142,300	290	160	420
1968	650,800	540	460	620	127,600	240	140	340
1969	808,300	670	560	780	100,900	140	100	180
1970	1,201,300	990	840	1,140	72,900	90	70	110
1971	1,772,600	1,450	1,220	1,680	94,000	150	100	200
1972	1,900,200	1,560	1,310	1,810	151,000	290	170	410
1973	1,779,600	1,470	1,230	1,710	149,100	270	160	380
1974	1,740,100	1,410	1,170	1,650	165,900	330	190	470
1975	1,455,500	1,190	1,000	1,380	171,700	390	200	580
1976	1,413,400	1,150	960	1,340	175,400	410	210	610
1977	1,051,300	490	330	650	178,500	260	90	430
Total	14,793,849	11,650	11,040	12,260	1,894,427	3,180	2,730	3,630

[a] The estimated incidental take represents only northern sea lions which died incidental to fishing operations, and excludes those which were caught and released alive. Totals may include some animals caught outside the U.S. Exclusive Economic Zone (which was not established until 1977). Estimated incidental take was calculated for all trawl gear types during 1966–77 (i.e., stern, pair, and side trawls) using observed rates based only on stern trawl catches; but observers did report incidental take during pair trawl operations in mothership-based fisheries during 1973–86 (side trawls were not used during 1973–86). Estimates were rounded to the nearest 10.

[b] Estimates for 1966–76 were calculated with the following incidental take rates based on combined U.S. observer data from foreign trawlers in the Bering Sea during 1973–77: For Japan, $\hat{R}$ = 8.58 (L_1 = 6.11, L_2 = 11.06) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 1.26, n = 1,328 days); and for other countries (combined), $\hat{R}$ = 6.69 (L_1 = 2.76, L_2 = 10.62) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 2.00, n = 419 days). Estimates for 1977 were calculated with the rates for only 1977: For Japan, $\hat{R}$ = 4.31 (L_1 = 1.02, L_2 = 7.61) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 1.65, n = 549 days); and for other countries (combined), $\hat{R}$ = 7.26 (L_1 = 2.73, L_2 = 11.77) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 2.26, n = 362 days).

[c] Estimates for 1966–76 were calculated with the following incidental take rates based on combined U.S. observer data from foreign trawlers in the Gulf of Alaska during 1973–77: For Japan, $\hat{R}$ = 9.56 (L_1 = 3.63, L_2 = 15.49) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 3.02, n = 716 days); and for other countries (combined), $\hat{R}$ = 32.45 (L_1 = 14.18, L_2 = 50.72) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 9.28, n = 262 days). Estimates for 1977 were calculated with the rates for only 1977: For Japan, $\hat{R}$ = 5.65 (L_1 = 0.68, L_2 = 10.63) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 2.49, n = 427 days); and for other countries (combined), $\hat{R}$ = 22.80 (L_1 = 4.99, L_2 = 40.61) sea lions per 10^4 t of groundfish caught ($s(\hat{R})$ = 8.91, n = 184 days).

[d] Estimated catch totals include some catches of groundfish by longline vessels (the available data precluded exclusion of these catches which were low relative to trawl catches), but these totals exclude estimated catches of groundfish with Danish seine gear. Groundfish catch data were taken from Murai et al. (1981) for 1966–76, Berger et al. (1986) for 1977, and Sueto Murai (Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, unpubl. data) for Japanese catch data by gear type and INPFC statistical area data during 1966–77. Excludes fishing by Canada. Groundfish catch estimates were rounded to the nearest hundred.

[e] Excludes catches of Pacific herring (classified with groundfish) because of separate pelagic foreign fisheries during some of these years.

fisheries (e.g., pelagic herring fisheries, halibut fisheries) for the Bering Sea and Gulf of Alaska. It was also about the time the trawl fisheries began to increase their effort in Alaska and was one of the peak years of abundance for the northern sea lion; sea lion abundance began to decline in the early 1970s (Merrick et al. 1987).

We estimated a total of 11,650 northern sea lions died incidentally in trawl fishing from 1966 to 1977 in the Bering Sea, and a total of 3,180 northern sea lions died incidentally with fishing effort in the Gulf of Alaska at the same time (Table 19). These estimates for 1966–77 and the estimates for 1978–88 are illustrated as a time series in Figure 17. Estimated takes of northern sea lions by year were higher before 1977 (the year the FCMA took effect) than for most years (except 1982) (Fig. 17). We have used these estimates to assess the possible impact of incidental take on the northern sea lion population in the absence of other controlling factors.

York (1990) has prepared a stable population life table for adult female northern sea lions based largely on data from Calkins and Pitcher (1982), Calkins and Goodwin (1988), and Loughlin and Nelson (1986) (*see* Table 20). York's fecundity rates are one-half the values in Calkins and Pitcher (1982). We used York's stable-age life table and estimates of the population size of adult female northern sea lions which we derived using data in Merrick et al. (1987) to calculate the effects of the estimated incidental mortality of northern sea lions on the population since 1966. These effects can only be considered hypothetical because the true population size, age and sex distribution by year and region of the sea lion population in Alaska, and the actual sex and age of each animal caught in the trawl fisheries are not known. However, declines in the northern sea lion populations of Alaska since the 1960s are real, based on actual population counts; only the level of impact due to incidental take is hypothetical.

In producing this analysis, we used the average age and sex composition of incidentally caught dead northern sea lions from Area-IV (Aleutian Islands) and the Chirikof area (based primarily on animals incidentally caught in Shelikof Strait whose teeth were aged) as an estimate (=mean estimate) for the Bering Sea and Gulf of Alaska regions, respectively (Table 21, columns 3 and 5). Minimum rates of change were calculated using the average age and sex composition for the entire Bering Sea or Gulf of Alaska in their respective analyses (Table 21, columns 2 and 4). By using the observed fishing effort and incidental catch figures by month during 1978–88 for each region, and assuming both equal effort and incidental catch for each month during 1966–77, the estimated incidental take each year was apportioned between the first and last six months of the year (all births were estimated to occur on June 15, which was also used as the end of the first six-month period). For females estimated caught and found dead in fishing trawls from June 16 to December 31 each year, their pups were also considered to have subsequently died that year because they would not have been weaned and able to survive on their own. Natural mortality rates (York 1990) were applied to the estimated population on 15 June in order to calculate the number of survivors each year if the population were stable. Incidental-take mortality was sub-

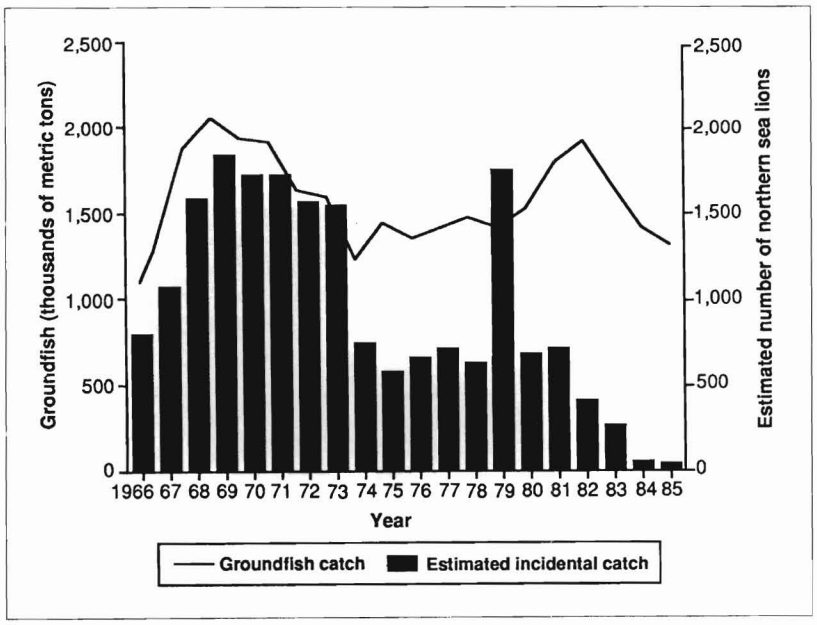

Figure 17
Total groundfish catch and estimated total number of incidentally taken northern sea lions which died during fishing operations of all foreign and joint venture trawl fisheries in Alaska during 1966–88.

Table 20

Stable population life table parameters for the female component of the northern sea lion population in Alaska, and the estimated size of the female population in 1965 for the Bering Sea and Gulf of Alaska.[a] These data were used to develop a hypothetical model of the trend in population size with the estimated level of incidental mortality of northern sea lions in trawl fisheries during 1966–88 discussed in this study.

Stable population life table for northern sea lions from York (1990)						Estimated 1965 population size of female northern sea lions[d]	
Ages[b]							
A_1	A_2	Cumulative survival	Annual survival	Fecundity[c]	Percent at age	Bering Sea and Aleutian Islands	Gulf of Alaska
0	1	1.000	0.782	0.000	16.251	13,100	14,980
1	2	0.782	0.782	0.000	12.709	10,244	11,715
2	3	0.612	0.782	0.000	9.938	8,011	9,161
3	4	0.478	0.930	0.101	7.772	6,265	7,164
4	5	0.445	0.909	0.180	7.228	5,826	6,662
5	6	0.404	0.895	0.261	6.570	5,296	6,056
6	7	0.362	0.884	0.315	5.880	4,740	5,420
7	8	0.320	0.875	0.315	5.198	4,190	4,791
8	9	0.280	0.867	0.315	4.548	3,666	4,193
9	10	0.242	0.859	0.315	3.943	3,179	3,635
10	11	0.208	0.853	0.315	3.388	2,731	3,122
11	12	0.178	0.847	0.315	2.889	2,329	2,663
12	13	0.150	0.841	0.315	2.447	1,973	2,256
13	31	$s\,0.150$[e]	$p(x)$[f]	0.315	11.239	9,058	10,358
Total		—	—	—	100.000	80,608	92,176

[a] York (1990) derived the stable population parameters and survival rates using exponential and Weibull models based on northern sea lion data collected during 1975–78 in the Gulf of Alaska (Calkins and Pitcher 1982).

[b] A_1 is the age for which the population size estimates and pup production values were calculated, and A_2 is the age of survival based on the survival rates. Animals in the population were assumed to not live past age 31 in this study, hence the survival rate for age 31 was zero.

[c] The fecundity rates are one-half the values in Calkins and Pitcher (1982).

[d] The 1965 base year population sizes were based on pup count and population trend data for the northern sea lion in Alaska (Merrick et al. 1987), assuming a constant average annual rate of decline among all rookeries in the Bering Sea and Gulf of Alaska since the 1950s proportioned to the total rate of decline. The female component of the estimated total pup level was calculated assuming a sex ratio of 0.485 for females (Calkins and Pitcher 1982). Values for ages 1–31 were calculated using the percent age values in column 6.

[e] $s = \prod_{i=13}^{age} p(i)$.

[f] $p(x) = \{IncG[1/a, ((x+1)/t)^a] - IncG[1/a, (x/t)^a]\}/\{IncG[1/a, (x/t)^a] - IncG[1/a, ((x-1)/t)^a]\}$; $IncG$ is the incomplete Gamma function, $a = 1.37$, and $t = 8.41$.

tracted from this calculated number of survivors. Density dependence was not considered.

Figure 18 shows the rate of change due only to incidental take in the trawl fisheries (other population size factors were not considered) in the Bering Sea. A minimum estimate of 6.7% for the decline during 1966–89 was calculated for the Bering Sea based on the annual trawl catches by stern trawl gear and the estimated adult female component of the lower 95% confidence level estimates of incidental take during each year. The mean estimate of the probable decline since 1966 due solely to incidental take was 16.3% in the Bering Sea, when all trawl catches (including pair and side trawls) and the upper 95% confidence limit of estimated annual incidental take was used in the calculations. A similar exercise for the Gulf of Alaska (Fig. 19) yielded a minimum decline of 3.6% since 1966 and a mean estimate of 6.4% for the decline in the northern sea lion population solely on account of incidental take.

The peak (1972) estimated upper 95% confidence limit of 2,120 dead northern sea lions in the catch throughout Alaska may be lower than the true level of incidental take during the early 1970s. It is unlikely that during 1973–77 observers reported all marine mammals incidentally caught because of limited opportunity to view and record such occurrences. Because the catch rates for the early 1970s were based

on the number of sea lions reported caught per total tonnage of groundfish caught (all hauls whether monitored or not) during the entire time the observer was aboard the vessel, the incidental take rates prior to 1978 can be considered underestimates (catch rates since 1978 were based only on the monitored portion of the groundfish catch).

An early estimate of incidental take based only on a few observations and the effort of fishing in the North Pacific Ocean and Bering Sea during the early 1970s suggested that perhaps 4,400 northern sea lions died in the Japanese trawl fisheries in 1971 (Letter dated 15 August 1973 from D. L. Alverson [then Director of the Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA] to W. F. Royce [then Associate Director for Resource Research, NMFS, NOAA, Washington, D.C.]). This early estimate may not have been far from the truth, and at the time, even that level of take was considered possibly low. For example, the greatest incidental mortality levels actually observed and reported by U.S. fishery observers during 1973–88 occurred in 1982 in Shelikof Strait when it was not uncommon for 50 or more dead sea lions to be found in a single haul. A U.S. fishery observer in 1973 reported that he was informed by the captain of the Japanese trawler *Haruna Maru* that the vessel had caught 60 northern sea lions in a single haul in March 1972 near the Pribilof Islands in the Bering Sea. Similar occurrences may have occurred at other times in the Bering Sea during the early 1970s when the northern sea lion population size was still high.

If these higher take estimates were indeed likely, then the data in Table 20 and Figures 18 and 19 suggest that incidental mortality may be a more important factor in the population decline of northern sea lions in Alaska than previously suspected. It is unlikely that it is the only factor or necessarily the principal factor, but it is certainly a contributing cause of the population decline since the 1960s. It is unfortunate that the necessary database for biological assessments of the status of the northern sea lion or data collection on observations of incidental catch did not improve until about 1980, after the bulk of the population decline occurred. It is now difficult to assess the role of each factor which may have contributed to the reduced stocks of northern sea lions in Alaska.

Table 21

Estimated age composition (based on tooth samples) of the female component (relative to the total population) of the incidental catch of northern sea lions in the foreign and joint venture trawl fisheries (1966–88) of Alaska used in a hypothetical model of the population trend of northern sea lions during since 1965.[a]

	Bering Sea and Aleutian Islands		Gulf of Alaska	
Age	Entire region	Area-IV	Entire region	Chirikof area
1	0.4	0.0	1.5	1.7
2	3.0	6.8	5.0	5.4
3	8.1	20.5	7.2	8.0
4	7.3	15.9	12.3	12.4
5	6.0	12.5	6.1	6.3
6	3.4	5.7	8.8	9.5
7	3.0	4.5	7.7	7.5
8	1.3	0.0	4.4	4.6
9	0.9	1.1	3.1	3.4
10	0.4	0.0	6.8	7.5
11	0.4	1.1	1.8	1.9
12	0.0	0.0	1.5	1.7
13-31	0.0	0.0	3.1	3.4
Total[b]	34.2	68.1	69.3	73.3

[a] Estimates based on aged canine teeth collected by U.S. fishery observers from dead northern sea lions (no decomposed animals) incidentally caught by foreign and joint venture trawl fisheries (1977–87). A zero value does not indicate there were no animals of that age group.

[b] Total percent values represent only the female component of the total northern sea lion population. The male component is the difference from 100%.

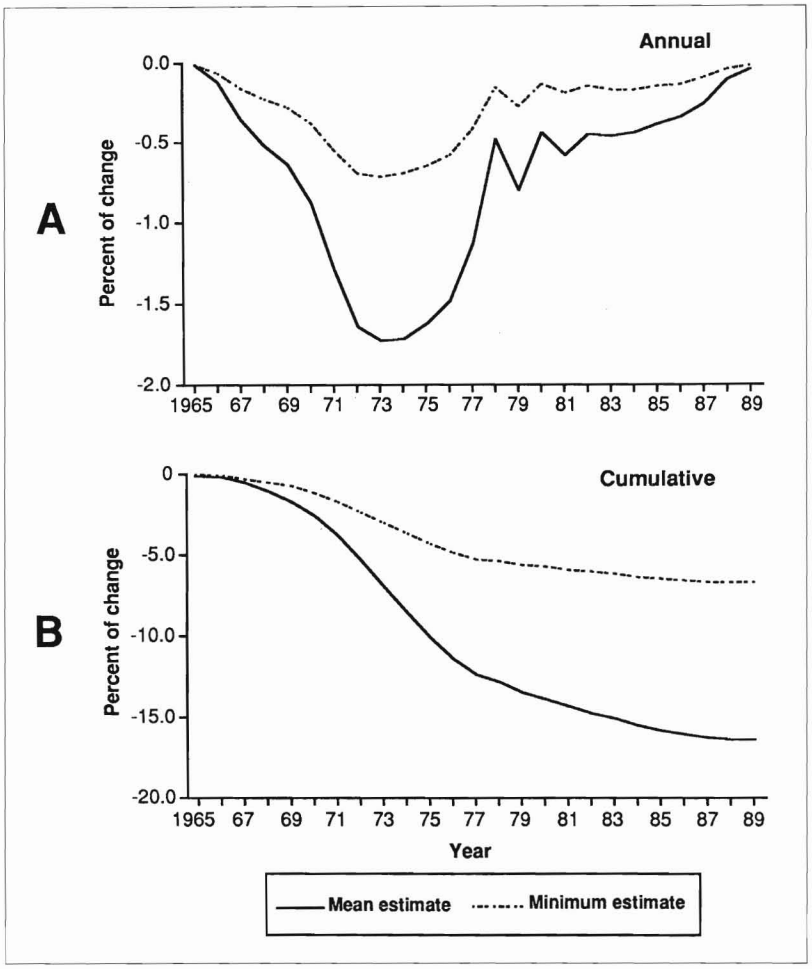

Figure 18
Yearly change in the size of the population of female northern sea lions in the Bering Sea and Aleutian Islands region during 1965–89 based on a stable life table (York 1990), an estimated baseline 1965 population of 80,608 females, the average age and sex of dead northern sea lions incidentally caught in trawl fisheries, and the total estimates of incidental mortality of northern sea lions presented in this paper: (**A**) annual rate of change (percent), and (**B**) cumulative percent of change. The mean estimate was based on the ratio estimate of incidental take and the minimum estimate was based on the lower confidence limit of the ratio estimate.

The high estimated catch of northern sea lions during the 1970s by foreign fisheries may partially account for the reported decline of their populations in the Aleutian Islands region and the western Gulf of Alaska at that time, but except for the 1982–84 Shelikof Strait fishery, incidental catch in recent years by JV fisheries is low and does not explain the present continuing decline.

Summary

U.S. fishery observers reported 17 marine mammal species caught incidentally in groundfish operations by foreign and JV trawl vessels during the period 1973–88 in the U.S. EEZ of the North Pacific Ocean and Bering Sea. Most of the 3,661 mammals caught died in the nets, but some were released alive (422) or decomposed (previously dead; 284). Northern sea lions represented 87% of the total observed marine mammal incidental take during the study period. Excluding decomposed animals, 42.8% of 3,077 northern sea lions observed incidentally taken during 1973–88 were caught in the Bering Sea; 57.0% were caught in the Gulf of Alaska; and 2.0% were caught off Washington, Oregon, and California.

Incidental take of marine mammals in trawl gear off the coast of Washington, Oregon, and California was low during all years; a total of 106 mammals (all species combined) were estimated to have died in fishing operations during 1973–88. Incidental catch of marine mammals, other than northern sea lions, by both the foreign and JV fisheries was also very low in Alaska during the same time period. The total estimated incidental take of each species (excluding sea lions) in Alaska was less than 217 for all years combined since 1978.

Northern sea lions were caught in nets during all months of the year. However, reported incidental take of sea lions in Alaska during late spring and summer (June to August) was lower (<25%) than in

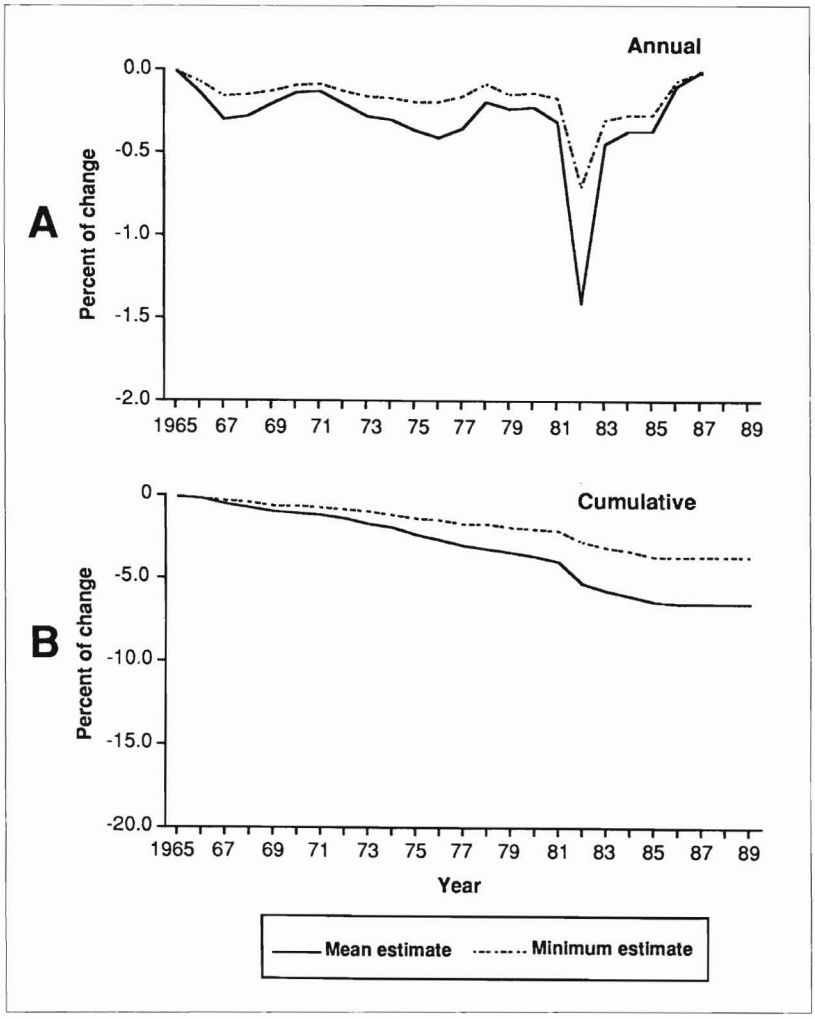

Figure 19
Yearly change in the size of the population of female northern sea lions in the Gulf of Alaska region during 1965–89 based on a stable life table (York 1990), an estimated baseline 1965 population of 92,176 females, the average age and sex of dead northern sea lions incidentally caught in trawl fisheries, and the total estimates of incidental mortality of northern sea lions presented in this paper: (**A**) annual rate of change (percent), and (**B**) cumulative percent of change. The mean estimate was based on the ratio estimate of incidental take and minimum estimate was based on the lower confidence limit of the ratio estimate.

the remainder of the year. The low catch in late spring and summer is probably due to the animals remaining near rookeries then.

Nearly 60% of northern sea lions reported caught incidentally in trawl fishing operations were caught at night (after sunset). The diel trend in number of hauls retrieved differs almost inversely with the trend in sea lion incidental catch.

Based on canine tooth samples, nearly 60% of the sea lions incidentally taken in the Gulf of Alaska were adult females (≥4 years of age), whereas less than 25% of the sea lions reported caught in the Bering Sea were adult females. However, at least 40% of the sea lions caught in Area-IV of the Bering Sea were adult females.

On the average, observed rates of incidental take of northern sea lions during 1973–88 were higher in the Gulf of Alaska region than in the Bering Sea. There was a nearly 50% reduction in catch rates by successive, approximately four-year periods during 1973–88. The observed rate of incidental mortality of northern sea lions was 25 times higher for the Chirikof area of the Gulf of Alaska than for Area-I of the Bering Sea where the total groundfish catch in the fishery was over eight times greater. However, because of the greater fishing effort in the Bering Sea, the total estimated take of northern sea lions in trawls in Area-I was half of what it was in the Chirikof area during 1978–88.

A total estimate of 6,543 (95% confidence limits, 5,728 to 7,358) northern sea lions were incidentally caught and died in trawls of both the foreign and JV fisheries throughout Alaska during 1978–88. This information is based on U.S. observer data. We estimated that an additional total of 14,830 (95% confidence limits, 14,070 to 15,590) northern sea lions

died incidentally in trawl fishing in Alaska during 1966–77, based on the average observed incidental catch rates during 1973–77.

Incidental take was a contributing cause of the population decline of northern sea lions in Alaska accounting for a decline of 16% in the Bering Sea and 6% in the Gulf of Alaska. However, because the actual population decline in Alaska based on counts of animals on land at rookeries has exceeded 80% since 1960, it is unlikely that incidental take is the only factor or necessarily the principal factor in the decline.

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We thank the hundreds of observers who spent thousands of hours aboard foreign fishing vessels for their patience and diligent effort in monitoring the incidental take of marine mammals in catches, including the collection of teeth specimens and measurement of animal lengths and the recording of these data. We thank J. Berger, R. Carlson, S. Murai, R. Nelson Jr., J. Wall, and H. Weikart for providing data on the fishery catch and observer effort necessary for the completion of this report. We thank G. Antonelis, Jr., R. DeLong, P. Gearin, H. Kajimura, and R. Merrick for their assistance in the ageing of pinniped teeth. We also thank J. Breiwick for assistance with the statistical treatment of the data. H. Braham, M. Dahlheim, R. DeLong, R. Nelson Jr., and S. Syrjala provided valuable comments during the preparation of the manuscript.

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Appendix 1

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Appendix 2

Estimates of incidental catch rates and mortality were obtained by ratio estimates of pooled data (1973–77 and summary rate comparisons) and stratified sampling by INPFC statistical area, vessel class, country, and year (subgroup = stratum, indexed by the letter h). Sampling units (indexed by the letter i) were defined as hauls for foreign trawlers (all years) and for JV vessels since 1985, and days for foreign motherships (all years) and for JV vessels during 1978–84. The phrase "marine mammals" below refers only to the marine mammal species for which catch rates were calculated in each analysis, unless specifically stated otherwise in the text. Since the catch rates (incidental take ratios) calculated with the equations below were all decimals less than one, they were multiplied by 10,000 to facilitate readability. Catch rates for pooled data analyses (1973–77 and annual averages for areas) were calculated by considering the data as a single stratum. Equations for ratio estimates were based on Cochran (1977).

Given

J = number of strata analyzed (total for year or region),

L_1 = lower 95% confidence limit,

L_2 = upper 95% confidence limit,

n_h = number of **observed** sampling units in stratum h,

N_h = total number of sampling units in the fishery in stratum h (including those not observed),

x_i = metric tons of groundfish observed in sampling unit i,

$\bar{x}_h$ = mean number of metric tons of groundfish observed in stratum h,

X_h = total metric tons of groundfish caught in the fishery in stratum h,

y_i = number of marine mammals observed in sampling unit i,

$\bar{y}_h$ = mean number of marine mammals observed in stratum h,

f_h = the sampling fraction (n_h/N_h) (since N_h is unknown for most years and areas, f was approximated by the proportion of total groundfish catch observed),

$\hat{R}$ = observed incidental take ratio (catch rate) for stratum h,

$s(\hat{R})$ = standard error of observed incidental take ratio (catch rate) for stratum h,

$\hat{Y}_R$ = ratio estimate of total incidental take for stratum h,

$\hat{Y}_{R_S}$ = stratified random sampling ratio estimator for total incidental take obtained by summing the separate ratio estimates from J strata,

$V(\hat{Y}_R)$ = variance of ratio estimate for stratum h, and

$V(\hat{Y}_{R_S})$ = variance of stratified random sampling ratio estimator from J strata.

Catch rates and ratio estimates were obtained from:

$$f_h = \frac{\sum_1^{n_h} x_i}{X_h} \tag{1}$$

$$\hat{R} = \hat{R}_h = \frac{\sum_1^{n_h} y_i}{\sum_1^{n_h} x_i} = \frac{\bar{y}_h}{\bar{x}_h} \tag{2}$$

$$s(\hat{R}) = s(\hat{R}_h) = \frac{\sqrt{1-f_h}}{\bar{x}_h \sqrt{n_h}} \bullet \sqrt{\frac{\Sigma y_i^2 - 2\hat{R}_h \Sigma y_i x_i + \hat{R}_h^2 \Sigma x_i^2}{n_{h-1}}} \tag{3}$$

$$\hat{Y}_R = \hat{Y}_{R_{h1}} = X_h \hat{R}_h \tag{4}$$

$$V(\hat{Y}_R) = V(\hat{Y}_{R_h}) = X_h^2 [s(\hat{R}_h)]^2 \tag{5}$$

$$\hat{Y}_{R_S} = \sum^{J} \hat{Y}_{R_h} \tag{6}$$

$$V(\hat{Y}_{R_S}) = \sum^{J} V(\hat{Y}_{R_h}). \tag{7}$$

Confidence intervals (CI) between L_1 and L_2 were estimated with the appropriate value of Student's t:

$$95\%\ CI = \hat{R} \pm t\,[s(\hat{R})] \tag{8}$$

$$95\%\ CI = \hat{Y}_R \pm t\,[\sqrt{V(\hat{Y}_R)}] \tag{9}$$

$$95\%\ CI = \hat{Y}_{R_S} \pm t\,[\sqrt{V(\hat{Y}_{R_S})}]. \tag{10}$$