The Threatened Status of Steller Sea Lions, *Eumetopias jubatus*, under the Endangered Species Act: Effects on Alaska Groundfish Fisheries Management

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Introduction

During the 1970's, the U.S. Congress passed legislation which significantly altered fishery resource management in the Gulf of Alaska, Bering Sea, and Aleutian Islands regions. In 1976, the Magnuson Fishery Conservation and Management Act (MFCMA) instituted a fishery management system under NOAA's National Marine Fisheries Service (NMFS) and established the North Pacific Fisheries Management Council (NPFMC). Earlier, the Marine Mammal Protection Act (MMPA) of 1972 addressed the diminished status of many marine mammal populations and introduced mechanisms to limit their mortality in commercial fisheries operating inside the U.S. 3–200 n.mi. Exclusive Economic Zone (EEZ). And in 1973, the Endangered Species Act (ESA) established rules to protect species considered to be threatened with or in danger of extinction.

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ABSTRACT—In April 1990, the Steller sea lion, Eumetopias jubatus, *was listed as threatened under the U.S. Endangered Species Act by emergency action. Competitive interactions with the billion-dollar Alaska commercial groundfish fisheries have been suggested as one of the possible contributing factors to the Steller sea lion population decline. Since the listing, fisheries managers have attempted to address the potential impacts of the groundfish fisheries on Steller sea lion recovery. In this paper, we review pertinent Federal legislation, biological information on the Steller sea lion decline, changes in the Alaska trawl fishery for walleye pollock,* Theragra chalcogramma, *since the late 1970's, and possible interactions between fisheries and sea lions. Using three cases, we illustrate how the listing of Steller sea lions has affected Alaska groundfish fisheries through: 1) actions taken at the time of listing designed to limit the potential for direct human-related sea lion mortality, 2) actions addressing spatial and temporal separation of fisheries from sea lions, and 3) introduction of risk-adverse stock assessment methodologies and Steller sea lion conservation considerations directly in the annual quota-setting process. This discussion shows some of the ways that North Pacific groundfish resource managers have begun to explicitly consider the conservation of marine mammal and other nontarget species.*

Even as the MFCMA shaped the character of U.S. fisheries, the MMPA and particularly the ESA influenced fisheries management where interactions with marine mammals occur. This broadened attention to potential relationships between commercial fisheries and marine mammals was evident in the Alaska groundfish fisheries after the NMFS listed the Steller sea lion, *Eumetopias jubatus*, as a threatened species under the ESA (5 April 1990; 55 FR 12645). The Steller sea lion listing has been an important factor in the recent evolution in North Pacific groundfish fisheries management and has heightened awareness of the impact fisheries may have on marine ecosystems in general and on nontarget, nonfish species in particular.

Prior to 1990, the only marine mammal species inhabiting Alaska waters listed under the ESA were large cetaceans. These animals were among the first to be listed in 1973 after nearly two centuries of commercial whaling significantly reduced their populations. The majority of these harvests occurred outside of Alaska waters. In contrast, the Steller sea lion listing addressed a more recent phenomenon, and it was prompted by studies in the 1970's and 1980's that revealed major declines in abundance in the core of the species' range (Fig. 1) (Braham et al., 1980; Merrick et al., 1987; Loughlin et al., 1992) and a deterioration in individual condition (Calkins and Goodwin[1]). For the first time under the ESA, a coastal piscivorous marine mammal was listed which had both a history of high incidental takes by fisheries and an overlap in diet and distribution with those fisheries (Calkins and Pitcher, 1982; Loughlin and Nelson, 1986; Perez and Loughlin, 1991; Calkins and Goodwin[1]).

The listing of Steller sea lions as a threatened species created new challenges for fisheries managers needing to balance the conservation and recovery requirements of the ESA for Steller sea lions with the needs of the Alaska groundfish fishery, one of the largest fisheries in the world. This paper examines how the threatened status of the Steller sea lion has affected groundfish fisheries management off Alaska using three examples of management actions from the time of listing to the present.

[1] Calkins, D., and E. Goodwin. 1988. Investigation of the declining sea lion population in the Gulf of Alaska. Rep. Alaska Dep. Fish Game, 333 Raspberry Road, Anchorage, AK 99518-1599, 76 p.

These actions are placed in context by first reviewing 1) the legal and management framework under which Alaska groundfish fisheries are managed, 2) the recent history of the largest fishery off Alaska, the trawl fishery for walleye pollock, *Theragra chalcogramma*, 3) possible causes of the decline in the Steller sea lion population in Alaska, and 4) the nature of the interactions between Steller sea lions and commercial groundfish fisheries.

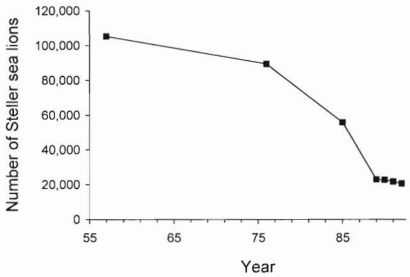

Figure 1. — Number of adult and juvenile Steller sea lions counted on trend rookeries and haul outs from the Kenai Peninsula (long. 150°W) to Kiska Island (long. 177°E), Alaska, during 7 surveys conducted from 1957 to 1992.

Legal and Management Framework

Magnuson Fisheries Conservation and Management Act

The primary objective of the MFCMA is to conserve and manage U.S. fishery resources for sustained human use. To achieve this goal, regional fishery management councils (e.g., the NPFMC) were established to manage fisheries inside the U.S. EEZ. Councils manage fisheries through development of fishery management plans (FMP's) which outline how optimum yields will be achieved while preventing overfishing.[2] Management councils are composed of representatives of Federal and state agencies as well as the private sector. The NPFMC receives advice from a Scientific and Statistical Committee (SSC) on the acceptable biological catch (ABC) and overfishing level for each target species, and an Advisory Panel (AP) of industry representatives on the total allowable catch (TAC) based on economic and social concerns. The ABC's are initially determined by stock assessment scientists and reviewed by separate Bering Sea and Aleutian Islands (BSAI) region and Gulf of Alaska (GOA) Plan Teams. The ABC's have generally been developed using single-species stock assessment philosophies (e.g., Pope, 1972; Deriso et al., 1985; Methot, 1990; Clark, 1991) which maximize yield while preventing overfishing of each species, but do not explicitly account for trophic interactions with other taxa.

[2] Groundfish fisheries off Alaska are managed by two FMP's covering 1) the Gulf of Alaska (GOA; the southern coast to long. 170°W), and 2) the Bering Sea/Aleutian Islands (BSAI).

Marine Mammal Protection Act

The purpose of the MMPA is to provide protection for marine mammals so

Steller sea lions, *Eumetopias jubatus*.

that their populations are maintained as significant, functioning elements of a healthy marine ecosystem. The MMPA placed a moratorium on the take (i.e., harassment, hunt, capture, or kill) and importation of marine mammals, but contained provisions for limited takes in the course of commercial fishing operations. Although the ultimate goal was to reduce takes to negligible levels, two mechanisms were established for allowing some incidental take: general permits and small take exemptions (added to the MMPA in 1981). The former mechanism allowed large numbers of a species to be taken if it was at or above its optimum sustainable population (OSP), while the latter allowed more limited taking without the need to establish the status of the affected population.

Prior to 1988, many of the Alaskan trawl fishery participants were covered under the MMPA by general permits. However, the Kokechik decision[3] placed most Alaska fisheries in jeopardy since the court refused to allow the NMFS to issue general permits for any taking if some marine mammals taken were not at or above its OSP. Consequently, the 1988 amendments to the MMPA contained provisions for a 5-year interim exemption period to allow takes in commercial fisheries while a new management regime was designed. This new management regime, contained in the 1994 amendments to the MMPA, requires the NMFS, as part of an assessment of each marine mammal population in U.S. waters, to identify strategic stocks, or those which have a level of human-caused mortality that is likely to cause the stock size to be reduced or kept below its optimum sustainable population. The NMFS must establish teams of experts in marine mammal conservation and biology and fishing practices that will develop plans to reduce the levels of incidental take of strategic stocks in fisheries. The 1994 amendments retain the zero mortality rate goal for marine mammals in fisheries and specify that all fisheries must attain that goal within seven years.

[3] Kokechik Fishermen's Association vs. the Secretary of Commerce. Alaska Native fishing groups and environmental organizations filed actions after an MMPA general permit to take Dall's porpoise in fishing operations inside the U.S. EEZ had been issued to the Japan Salmon Fisheries Cooperative Association. The plaintiffs challenged the permit on grounds that the MMPA did not allow issuance of a permit for one species when other species that were below OSP (in this case, northern fur seals) would also be taken in the same operations. The U.S. District Court for the District of Columbia ruled in favor of the plantiff (June 15, 1987).

Endangered Species Act

The goals of the ESA are to prevent the extinction of species, to encourage recovery of listed species to the point that they no longer need protection, and to preserve their ecosystems. Conservation and recovery of listed species are accomplished through the prohibition of certain acts that are known or thought to harm the species and by requiring Federal agencies to review their proposed activities throughout the species' range.

Once it is determined that a species should be listed under the ESA, the agency responsible for management of the species (e.g., NMFS in the case of Steller sea lions) appoints a team of scientists and managers familiar with the biology, history, and management of the species. This recovery team is charged with drafting a species recovery plan, which can include recommendations for research into possible causes of the decline and measures to promote recovery. The Steller sea lion recovery team was formed by the NMFS in March 1990, 1 month prior to the emergency listing of the species as threatened. The draft Steller sea lion recovery plan was completed and made available for public review on 15 March 1991 (56 FR 11204), and the final NMFS recovery plan was published in December 1992 (NMFS,1992). While the team recommended that the NMFS and others (e.g., Alaska Department of Fish and Game) begin a series of long-term monitoring and research studies aimed at determining the cause of the sea lion population decline, no specific measures to restrict fisheries were proposed.

Section 4 of the ESA requires, "to the maximum extent prudent and determinable," the designation of critical habitat for a threatened or endangered species within 1 year of its listing. Critical habitat is broadly defined as "the specific areas . . . essential to the conservation of the species and which may require special management consideration or protection." As discussed below with respect to Section 7 of the ESA, the areas designated as critical habitat can have important management implications: Federal agencies proposing actions within critical habitat must ensure that their actions are not likely to destroy those features which make it "critical" nor adversely modify its usefulness to the listed species. Designation of critical habitat by itself, however, does not restrict any activity in the area.

On 1 April 1993 (58 FR 17181), the NMFS published a proposal designating Steller sea lion critical habitat which included terrestrial reproductive and resting areas as well as aquatic foraging habitats; the final designation of critical habitat was published in August 1993. Specific areas designated as critical habitat were:

1) All rookeries and major haul outs (where greater than 200 sea lions had been counted, but where few pups are present and little breeding takes place), including a) a zone 914 m (3,000 feet) landward and seaward from each site east of long. 144°W (including those in Alaska, Washington, Oregon, and California); and b) a zone 914 m landward and 36.5 km (20 n.mi.) seaward of each site (36 rookeries and 79 haul outs) west of long. 144°W where the population had declined more precipitously and where the former center of abundance of the species was located; and

2) Three aquatic foraging regions within the core of the species' range (Fig. 2). As will be discussed later, specific management measures to separate trawl fisheries from sea lions were taken by the NMFS prior to critical habitat designation.

Once a species is listed under the ESA, specific conservation or recovery measures can be taken by the management agency at any time. However, the most powerful tool provided by the ESA is probably that contained in Section 7, which states that Federal agencies must ensure that their proposed actions are not likely to jeopardize the continued

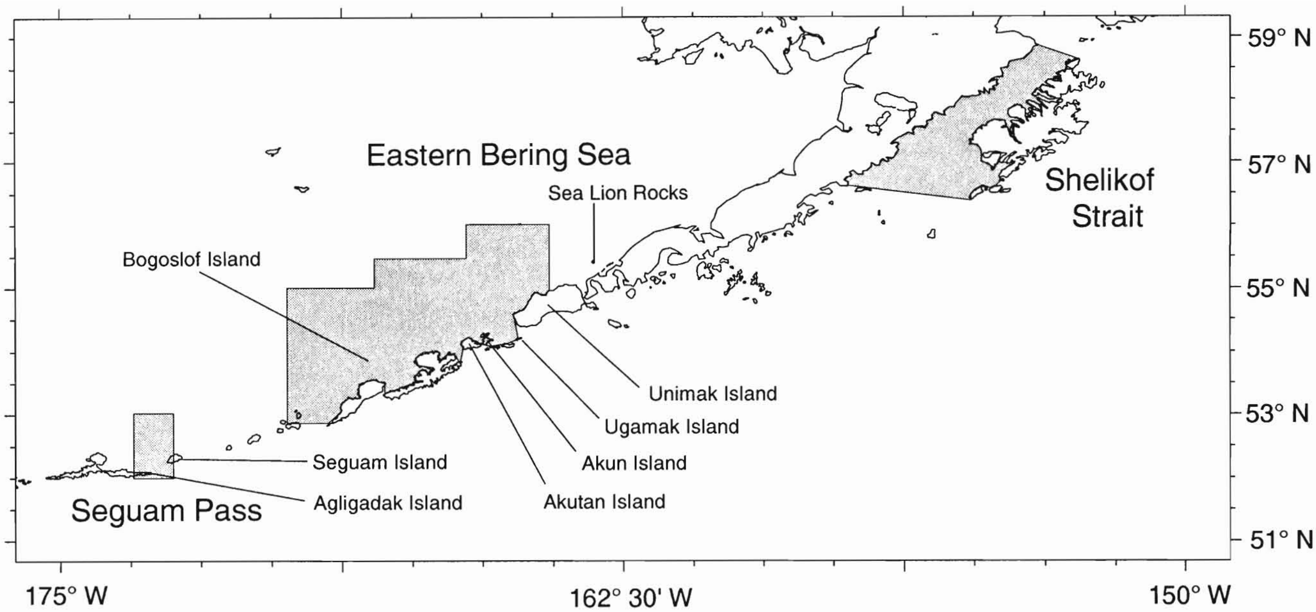

Figure 2. — Aquatic foraging areas designated as critical habitat for the Steller sea lion in the Gulf of Alaska (Shelikof Strait), eastern Bering Sea (including the area surrounding Bogoslof Island) and Aleutian Islands (Seguam Pass). Other locations mentioned in text are noted.

existence of a listed species (a "no jeopardy" decision) or adversely modify its designated critical habitat. A common method employed by Federal agencies to ensure a "no jeopardy" decision is to consult with the agency responsible for management of the listed species. Section 7 consultations involve complete descriptions of the proposed activity and any likely impacts on the listed species or its designated critical habitat. If a "jeopardy" finding is made, then the proposed action must be abandoned by the agency, mitigation measures must be taken to ensure that "jeopardy" will not occur, or a specific exemption can be provided by the Federal government. In instances where knowledge of the relationships between the listed species and the proposed activity is poor or incomplete, the ESA requires that conservation and recovery be given the highest reasonable priority.

Recent History of Pollock Fisheries off Alaska

During the same period (mid-1970's to 1990) that the population of Steller sea lions in Alaska was declining, the groundfish fisheries underwent a transformation induced primarily by the passage of the MFCMA (Megrey and Wespestad, 1990). This transformation can best be shown through examination of the trawl fishery for walleye pollock, the largest of the groundfish fisheries in the region. Between 1977 and 1992, pollock catches accounted for 40–80% of the annual groundfish landings from the GOA and 75–85% of those from the BSAI (NPFMC, 1993a, b).

One of the principal objectives of the MFCMA is to promote full domestic use of the offshore fisheries of the United States. Prior to passage of the MFCMA, most pollock harvested off Alaska were caught and processed solely by distant-water fleets of foreign nations, including Japan, the former U.S.S.R., Republic of Korea, and Poland (Fig. 3, 4). After passage of the MFCMA, increasing amounts of pollock TAC were allocated to joint ventures between domestic catcher vessels and foreign processing ships to encourage development of the domestic fishing industry. Joint ventures became most important in the pollock fishery first in the GOA after discovery of the pollock spawning assemblage in Shelikof Strait in 1980. This discovery led to a tripling of pollock landings, principally roe-bearing females caught in the winter and early spring, from the GOA between 1980 and 1985 (to about 300,000 t; Fig. 4). Concern about declines in the size of the spawning population in Shelikof Strait led the NMFS to drastically cut the GOA pollock TAC in 1986 to about 80,000 t. Seeking other sources of roe, the joint-venture fishery moved to another large spawning assemblage of pollock near Bogoslof Island in the eastern Aleutian Basin of the BSAI region. In the GOA, both catching and processing components of the pollock fishery were entirely domestic by 1988, while in the BSAI region a small amount of pollock was allocated to joint ventures as late as 1990.

Along with a change in the participants of the pollock fishery came changes in the temporal and spatial distribution of the catch. Between 1977 and 1992 in both the BSAI region and GOA, the pollock fishery worked increasingly in fall and winter, took the quota in less time, and tended to fish more in areas which would become designated as critical habitat for Steller sea lions. This resulted in a temporal compression of the fishery in the fall and winter, and a spatial compression in sea lion habitats.

In the BSAI region prior to 1987 (when the spawning assemblage near Bogoslof Island was first exploited), the pollock fishery was conducted primarily in July–September when about 50% of the landings were taken (Fig. 5). From 1987 to 1992, pollock catches during January–March or September–December increased as the fishery targeted the higher-priced roe-bearing fish available in winter. Beginning in 1990, the BSAI annual pollock TAC was divided into an "A," or roe season from January to mid-April which initially received 40% of the TAC and a "B" season beginning in June and lasting until the TAC was reached (BSAI FMP Amendment 14). This measure, while ensuring sufficient pollock TAC for the "B" season, also increased the first quarter's proportion of the annual pollock catch compared with 1977–86.

A similar change in the temporal distribution of effort occurred 5 years earlier in the GOA when the Shelikof roe fishery began in earnest in 1982 (Fig. 6). From 1983 to 1989, catches during either the first or last 3 months of the year ranged between 70% and 90% of the annual catch. In 1990, the GOA pollock TAC was allocated quarterly (GOA FMP Amendment 19) to help prevent its early preemption by large catcher/processor vessels. These vessels, which usually worked in the BSAI region where the pollock TAC is larger, caught a large percentage of the available pollock TAC in the GOA in a short amount of time, and precluded vessels based in the GOA from pollock fishing opportunities.

The lengths of pollock fishing seasons have decreased since the late 1980's due primarily to increases in the fishery's capability to capture fish (Fig. 7). One reason for this change in capacity is increases in the sizes of trawls used by the fleet. During the early 1980's (foreign and early joint-venture fisheries), midwater or pelagic trawls used in the pollock fishery generally had mouth openings in the range of 30–50 m wide and 15–30 m high (up to 1,500 m^2 trawl mouth areas) and caught 20–80 t in a single tow. As improvements in net design, construction, and materials were made in the mid-late 1980's (Laevastu and Favorite, 1988), larger trawls up to 100 m wide, 80 m high (up to 8,000 m^2 trawl mouth areas) and 350 m long were built which could catch as much as 400 t in a single haul.

The spatial concentration of pollock landings from what would be defined as critical habitat for sea lions occurred simultaneously with the exploitation of spawning concentrations of pollock near Bogoslof Island in 1987 and in Shelikof Strait in 1982. Pollock landings (and fishery effort) in BSAI critical habitat increased from about 250,000 t (or 20–30% of the annual landings) in 1981–86, to 400,000–650,000 t (or 35–55% of the annual landings) from 1987 to 1992 (Fig. 8). Most of this increase in landings and effort came from the Eastern Bering Sea critical habitat foraging area (Fig. 2). In the GOA, pollock catches from critical habitat increased from trace amounts in 1980 to over 200,000 t in 1985, primarily from the Shelikof Strait foraging area (Fig.

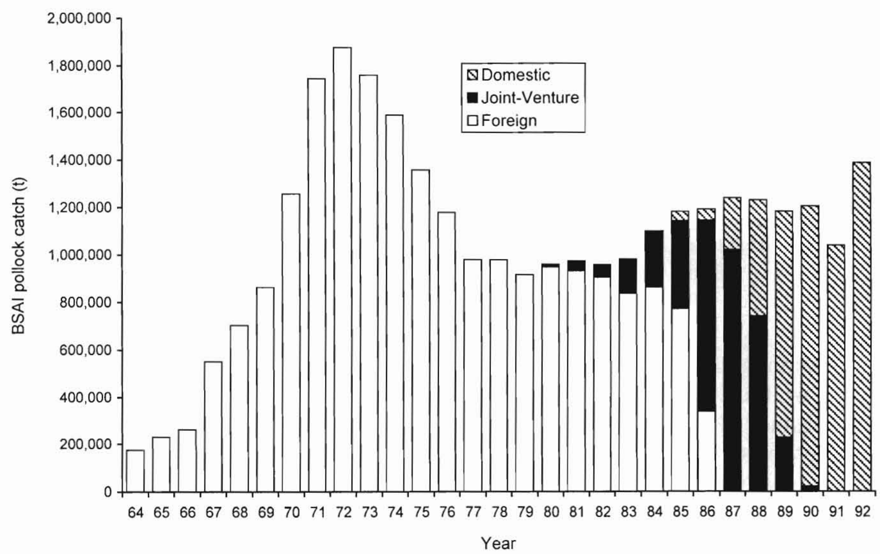

Figure 3. — Catches of walleye pollock from the Bering Sea and Aleutian Islands by foreign, joint-venture, and domestic vessels, 1964–92 (data from Wespestad, 1993).

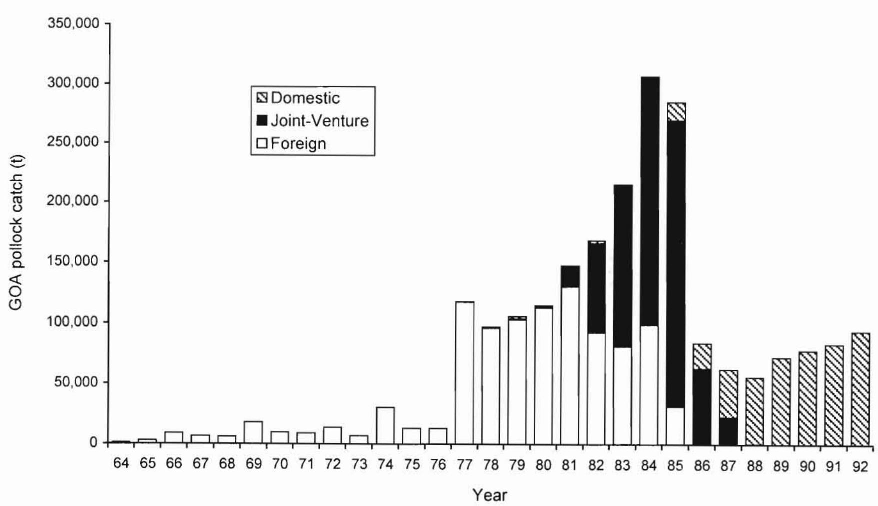

Figure 4. — Catches of walleye pollock from the Gulf of Alaska by foreign, joint-venture, and domestic vessels, 1964–92 (data from Hollowed et al., 1993).

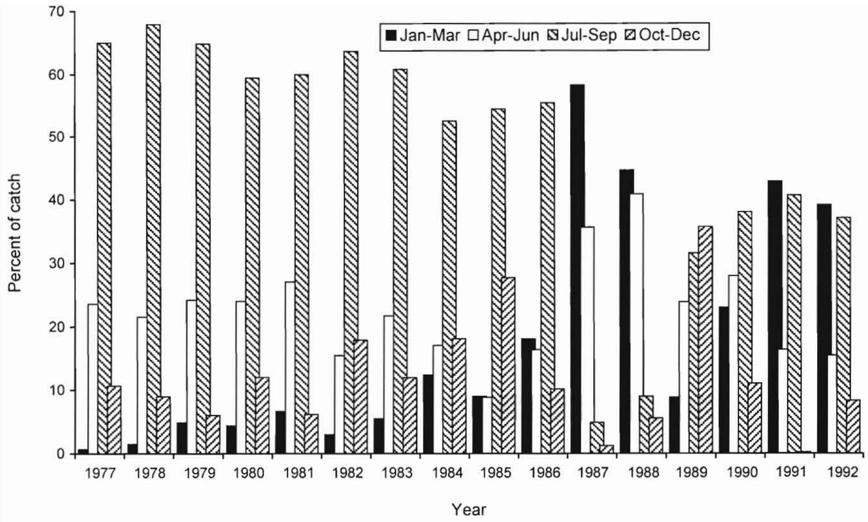

Figure 5. — Quarterly distribution of walleye pollock catches from the Bering Sea and Aleutian Islands by all vessels, 1977–92.

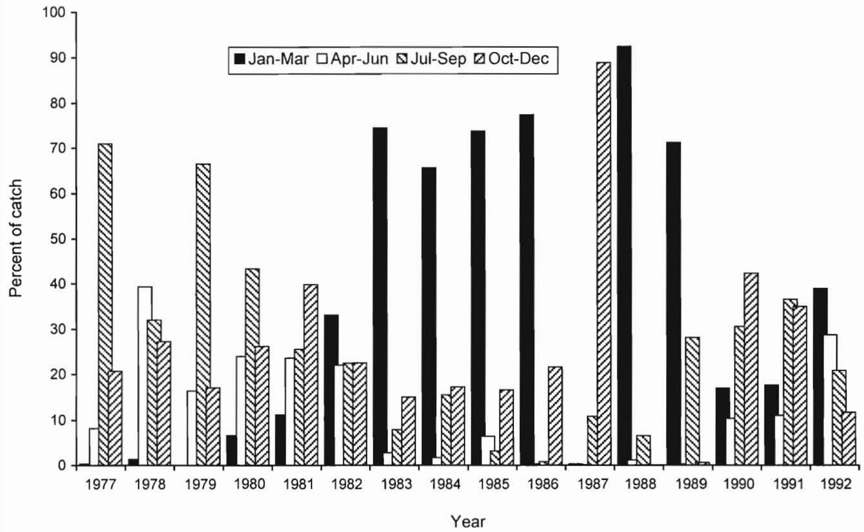

Figure 6. — Quarterly distribution of walleye pollock catches from the Gulf of Alaska by all vessels, 1977–92.

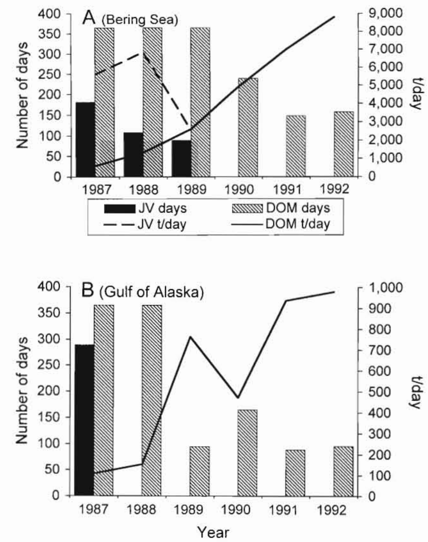

Figure 7. — Length of time (days) that directed fishing for walleye pollock was permitted in the Bering Sea (A) and the Gulf of Alaska (B) for joint venture (JV) and domestic (DOM) vessels. Average catch rate (metric tons (t) of pollock per day) for each year and area is also plotted.

2, 9). Pollock landings from GOA critical habitat dropped (as the annual TAC declined) to about 50,000 t, and have remained at that level through 1992. However, the percentage of total annual GOA pollock catches taken from critical habitat did not decline after 1985, but has remained between 50% and 90%.

Causes of the Steller Sea Lion Decline

The recent (since the 1970's) decline in the Alaskan Steller sea lion population began in the eastern Aleutian Islands and spread to the east and west in the 1980's (Braham et al., 1980; Merrick et al., 1987; Loughlin et al., 1992). Results of field and modeling studies conducted in the last decade suggest that the most likely proximate cause of the decline is a reduction, perhaps between 20% (York, 1994) and 60% per year (Pasqual and Adkison, 1994), in the survival of weaned pups and juveniles. Condition of nursing pups during the first few months of life does not appear to have been compromised (Castellini et al., 1993; Rea et al., 1993), suggesting that the population decline was not caused by reduced survival of nursing pups nor reduced condition of pregnant or lactating females. More direct evidence for a decline in survival rates of weaned pups and juveniles came from a mark-and-resighting experiment begun in 1987 and 1988, where 424 female pups on Marmot Island were tagged.[4] Female Steller sea lions have a strong fidelity to their native rookery when they reach breeding age (4–5 years), and it was expected that as many as 100 marked female pups should have been resighted, beginning in 1992; however, a maximum of only 15 marked females have been resighted.

Finding the ultimate cause of the Steller sea lion population decline, or the reason for a large reduction in juvenile survival, has been more difficult.

[4] NMFS Natl. Mar. Mammal Lab., Seattle, Wash. Unpubl. data.

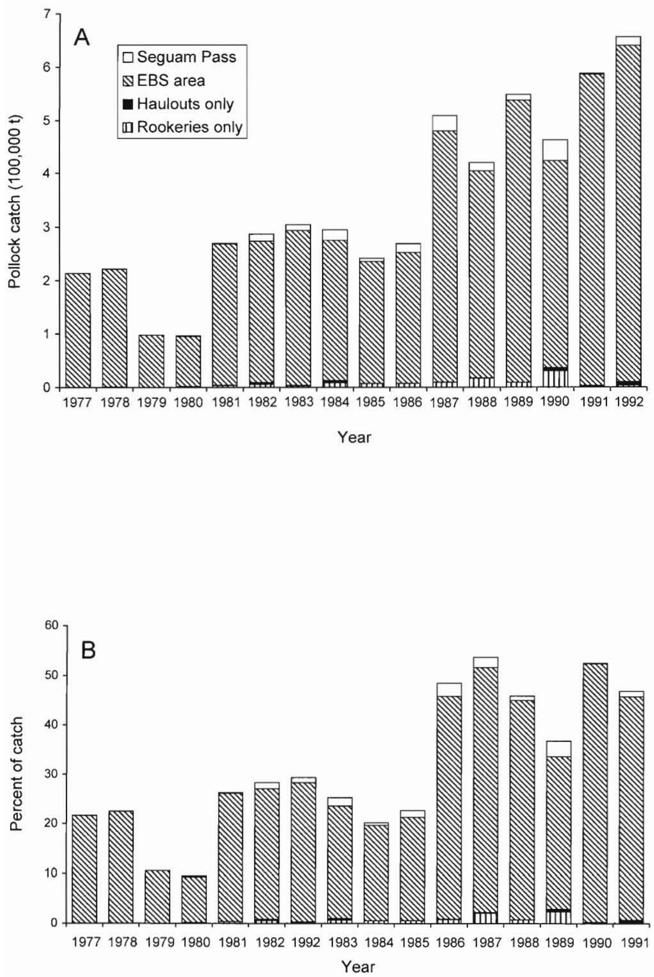

Figure 8. — Catches of walleye pollock and fishery effort in Steller sea lion critical habitat in the Bering Sea and Aleutian Islands from 1977 to 1992. A = Pollock catches from critical habitat. B = Percent of total catch of pollock in the Bering Sea and Aleutian Islands caught in critical habitat.

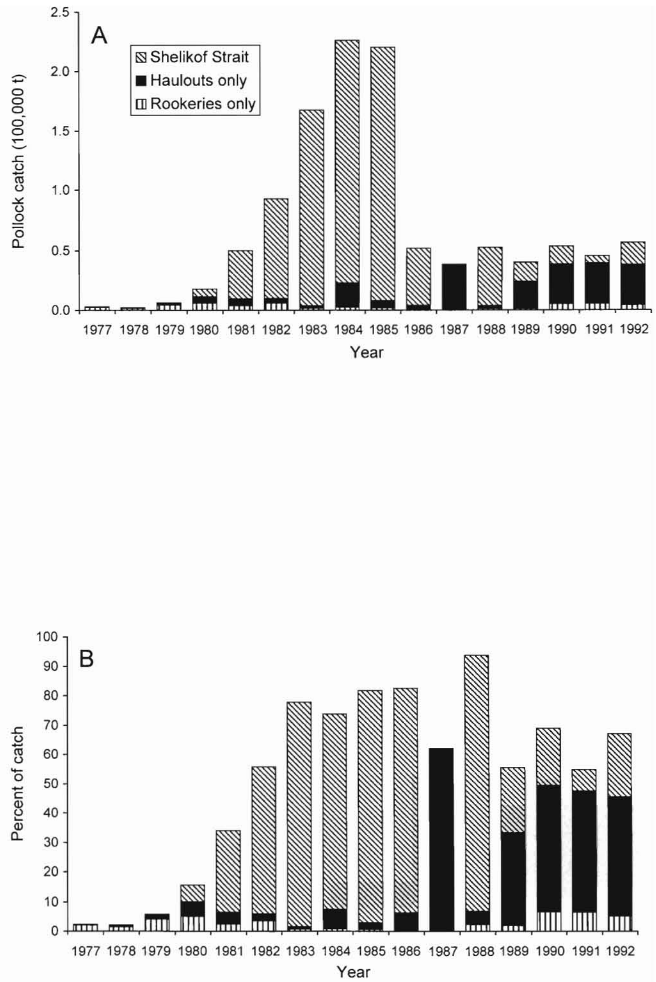

Figure 9. — Catches of walleye pollock and fishery effort in Steller sea lion critical habitat in the Gulf of Alaska from 1977 to 1992. A = Pollock catches from critical habitat. B = Percent of total catch of pollock in the Gulf of Alaska caught in critical habitat.

Loughlin[5] lists nine potential ultimate causes of the sea lion population decline, which are (modified slightly): entanglement in marine debris, increased predation, pollution, harassment, commercial pup harvests prior to 1972, subsistence harvests, disease, oceanographic changes, and all of the effects of fisheries. While four of these factors, entanglement, predation, pollution, and harassment, could affect juveniles to a greater extent than adults, there is no evidence that any of them, acting either alone or in concert with other factors, caused the large reductions in juvenile survival that have driven the population decline (NMFS, 1992). Merrick et al. (1987), Trites and Larkin (1992) and Pasqual and Adkison (1994) examined the possible residual effects of pup harvests on the population size and found that they did not produce a decline in size of the adult population of the magnitude or duration observed. Similarly, subsistence harvests, thought to be on the order of 200–700 animals per year (Haynes and Mishler, 1991; Wolfe and Mishler, 1993) could have affected local groups but are not likely to have contributed significantly to the population decline as a whole. Disease could affect juvenile survival more than adults. However, no evidence exists to demonstrate that infection rates of known diseases have increased or that new diseases among juveniles or adults sea lions have developed. Despite this lack of evidence, disease has not been entirely eliminated

[5] Loughlin, T. R. 1987. Report of the workshop on the status of northern sea lions in Alaska. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Alaska Fish. Sci. Cent., 7600 Sand Point Way N.E., Seattle, WA 98115-0070. NWAFC Processed Rep. 87-04.

from the list of possible ultimate causes of the decline, particularly if sea lions have been stressed from other causes (T. Loughlin[6]).

Many researchers (e.g., Anderson, 1991; Hollowed and Wooster, 1992; Fritz et al., 1993; Livingston, 1993; Anderson et al.[7]) have documented substantial shifts in the structure and composition of the North Pacific fish and benthic communities over the last 40 years, possibly in response to changes in ocean temperature, circulation, or upwelling patterns (Ebbesmeyer et al., 1991; Beamish, 1993; Wooster and Hollowed, In press). Some of the many documented shifts in community structure include increases in the population sizes of some semidemersal and demersal species of flatfish and gadids, decreases in some pelagic species, such as herring, *Clupea harengus*; capelin, *Mallotus villosus*; and eulachon, *Thaleichthys pacificus*, decreases in pandalid shrimps, *Pandalus* spp., and increases in salmon, *Oncorhynchus* spp. Since recently weaned sea lions do not appear to dive deeper than about 20 m and stay relatively close to shore,[4] the availability of prey near the surface or in shallow water may be critical to their survival as they learn to forage for themselves. Loughlin and Merrick (1989) suggest that reductions in juvenile sea lion survival rates may be due to declines in availability (due to lower numbers or changes in depth distribution) of their small pelagic prey (e.g., herring, capelin, juvenile pollock). Reduced food availability could lead to both starvation or increased susceptibility to disease. Knowledge of how North Pacific and Bering Sea biological communities respond to changes in oceanic conditions is limited. Virtually no information exists to address how often changes of the magnitude observed recently have occurred in the 3–4 million-year history of Steller sea lions (NMFS, 1992); only the changes have been described, not the processes which initiate and sustain them. Similarly, it has not been possible to sort the effects of removals by fisheries of certain fish species on fish community structure from that induced by "natural" change.

Fishery and Sea Lion Interactions

Interactions between fisheries and Steller sea lions can be divided into two basic types (Lowry, 1982): direct or operational, and indirect or biological interactions. Direct interactions are those in which sea lions are injured or killed as a result of capture by fishing gear (incidental take) or intentional means (e.g., shooting). Competition for similar prey resources and disturbance by fishing activities are examples of indirect interactions. While data often are available to describe rates of direct interaction (e.g., incidental take), indirect interactions are more difficult to document because they are complex (and as such, hard to measure) and may occur over large areas and at short or unpredictable time scales.

Direct Interactions with Fisheries

Direct interactions between Steller sea lions and groundfish fisheries in the GOA and BSAI region contributed to declines in sea lion numbers observed in the 1970's, but they are not thought to have been factors in the steeper decline observed in the late 1980's (NMFS, 1992). The number of Steller sea lions killed incidental to fishing operations in the North Pacific has declined significantly in the last 25 years (Fig. 10) (Loughlin et al., 1983; Perez and Loughlin, 1991). Sea lion mortality attributed to Alaska groundfish fisheries averaged over 1,600 animals per year from 1968 to 1973, but declined to only about 600 per year (except for 1982) from 1974 to 1985. In 1982, almost 1,800 sea lions were killed by groundfish fisheries, primarily in the GOA Shelikof Strait pollock fishery. Between 1984 and 1992, the period with the steepest rate of decline in the sea lion population, mortality associated with incidental take in the Alaska groundfish fishery dropped from over 400 to less than 20 animals per year. Much of the reduction in incidental take may have been due to the smaller sea lion population size, but some of it is due to changes in fishing techniques, such as reducing the amount of time the trawl was in the water and not setting the net in the presence of sea lions (Loughlin and Nelson, 1986).

The number of sea lions killed by shooting and other intentional means is

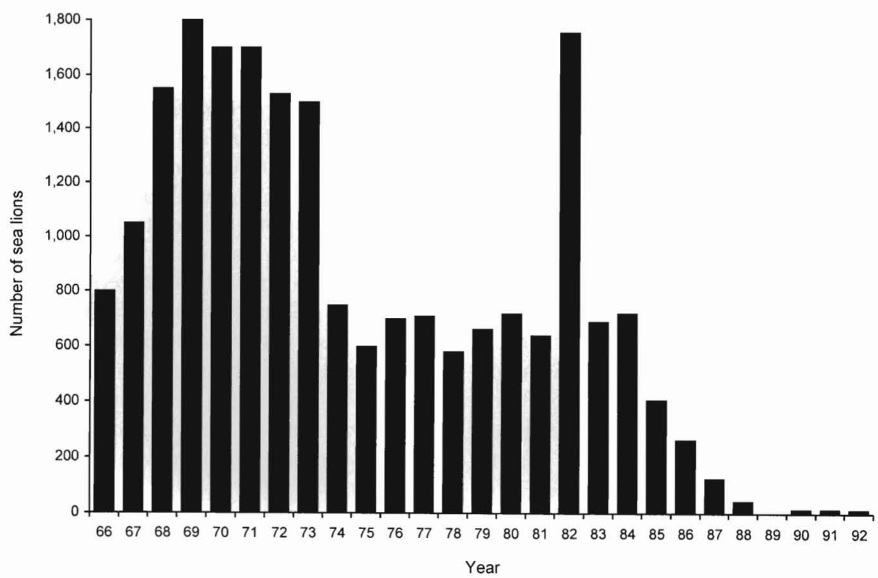

Figure 10. — Estimated number of Steller sea lions killed incidental to groundfish fisheries off Alaska (data from Perez and Loughlin, 1991).

[6] T. Loughlin, NMFS Mar. Mammal Lab., Seattle, Wash. Personal commun., 1994.

[7] Anderson, P. J., S. A. Payne, and B. A. Johnson. In prep. Long-term demersal community structure changes in Pavlof Bay, Alaska. NMFS, Alaska Fisheries Science Center, P.O. Box 1638, Kodiak, AK 99615-1638.

not known. Trites and Larkin (1992) estimated the number shot by fishermen using fishing vessel registrations records and rates of kill for each vessel type derived from interviews with fishery participants. The history of the subsistence harvest of Steller sea lions by Alaskan native communities was also recently reviewed (Haynes and Mishler, 1991; Wolfe and Mishler, 1993). These analyses and others (Alverson, 1992; Merrick[8]) suggest that intentional takes, while they contributed significantly to the decline in localized areas, were not its primary cause throughout the range.

Indirect Interactions with Fisheries

Indirect or biological effects of fishing are difficult to place in perspective with both the known direct effects of fishing and any changes in fish community structure that would have occurred naturally due to oceanographic changes. Lowry (1982) developed qualitative criteria for determining the likelihood and severity of indirect interactions between fisheries and each marine mammal species in the Bering Sea. His criteria used information on the species and size composition of each species' diet, its feeding strategy, and importance of the Bering Sea as a feeding area. Based on his assessment, three pinniped species (northern fur seals, *Callorhinus ursinus*; harbor seals, *Phoca vitulina*; and Steller sea lions), all of which have had major declines in abundance over the last 30 years (Pitcher, 1990; Loughlin et al., 1992; NMFS, 1993), had the greatest potential for adverse indirect interactions with fisheries.

Steller sea lions have a moderately diverse diet composed primarily of pelagic or semidemersal schooling fish, such as walleye pollock, Atka mackerel, *Pleurogrammus monopterygius*; capelin, Pacific herring, and salmon, most of which are commercially exploited (Calkins and Pitcher, 1982; Lowry, 1982; NMFS, 1992; Calkins and Goodwin[1]; NMML[4]). This results in some level of competition between fisheries and sea lions for certain species, particularly if the fisheries operate in areas important to sea lions. However, attempts to correlate time series of sea lion abundances on rookeries with nearby removals of pollock by fisheries have yielded ambiguous results (Loughlin and Merrick, 1989; Ferrero and Fritz, 1994).

The selectivities of the fishery and sea lions for various sizes of pollock suggests that at some level, there is direct competition every year there is a fishery (Loughlin and Nelson, 1986). The fishery, however, tends to be more size-selective than sea lions, since it generally targets and retains pollock greater than 30 cm in length (Wespestad and Dawson, 1992). Smaller fish are generally caught by the fishery roughly in proportion to their abundance (Fritz, In press). On average (based on 1979–92 data), about 4% of the total population of 2- to 3-year-old pollock (20–35 cm in length) were caught each year by fisheries in the eastern Bering Sea (EBS), and about 2% in the GOA, but very few 0- to 1-year-old pollock have been caught. Data available on feeding behavior suggest that adult Steller sea lions eat sizes of pollock nearly in proportion to their abundance (Fig. 11, 12), while juvenile sea lions (≤4 years old) may prefer pollock <30 cm in length (Calkins and Merrick[9]). Consequently, since both the fishery and sea lions capture pollock larger and smaller than 30 cm, some level of competition for pollock exists every year (Fig. 11).

Disturbance from either vessel traffic or fishing activities may also disadvantage sea lions, particularly when they are foraging. Vessel traffic alone may temporarily cause fish to compress into tighter, deeper schools (Fréon et al., 1992; Nunnallee[10]) or split schools into smaller concentrations (Laevastu and Favorite, 1988). Hydroacoustic observations of the effects of trawling on Pacific whiting, *Merluccius productus*, school structure in Puget Sound, Wash. suggest that while the school deforms and has a "hole" in it due to removal of fish and their avoidance of the gear, its structure returns relatively quickly (on the order of tens of minutes) to a pre-trawling condition (Nunnallee, 1991). Effects of repeated trawling by many vessels over several days on fish school structure are not known. However, removals of large numbers of fish alone would be expected to decrease either school density or school size for some period of time. Similarly, the effects of dispersed prey fields on Steller sea lion foraging energetics are unknown. However, data on the effects of reduced prey availability (caused by the 1982–83 El Niño) on California sea lion foraging energetics suggest that prey dispersion would likely increase energy expenditure and search time for food (Trillmich and Ono, 1991), both disadvantages to Steller sea lion fitness.

Changes in Fisheries Management

Listing Regulations: Limiting Potential for Direct Mortality

To reduce the potential for sea lion mortality from direct human interactions, the NMFS enacted the following three conservation measures simultaneously with the listing of Steller sea lions as threatened under the ESA: 1) shooting at or within 100 yards of a Steller sea lion was prohibited, 2) the number of Steller sea lions that could be killed incidental to commercial fishing was reduced from 1,350 to 675, and 3) no-entry buffer zones around all Steller sea lion rookeries (where adult males actively defend territories and most females give birth and mate) west of long. 150°W were established. These measures had only minor impacts on groundfish fisheries in the BSAI and GOA, but set the stage for other regulations (FMP Amendments) promulgated in response to ESA Section 7 consultations on the GOA pollock fishery.

The MMPA prohibited intentional lethal takes of Steller sea lions in the course of fishing operations, but did not prohibit fishermen from harassing those that were interfering with their gear or catch by shooting at or near them. The regulation accompanying the ESA list-

[8] R. Merrick, Natl. Mar. Fish. Serv. Personal commun., 1993.

[9] D. Calkins, Alaska Dep. Fish. Game, and R. Merrick, Natl. Mar. Fish. Serv. Personal commun., 1991.

[10] E. Nunnallee, Natl., Mar. Fish. Serv. Personal commun., 1994.

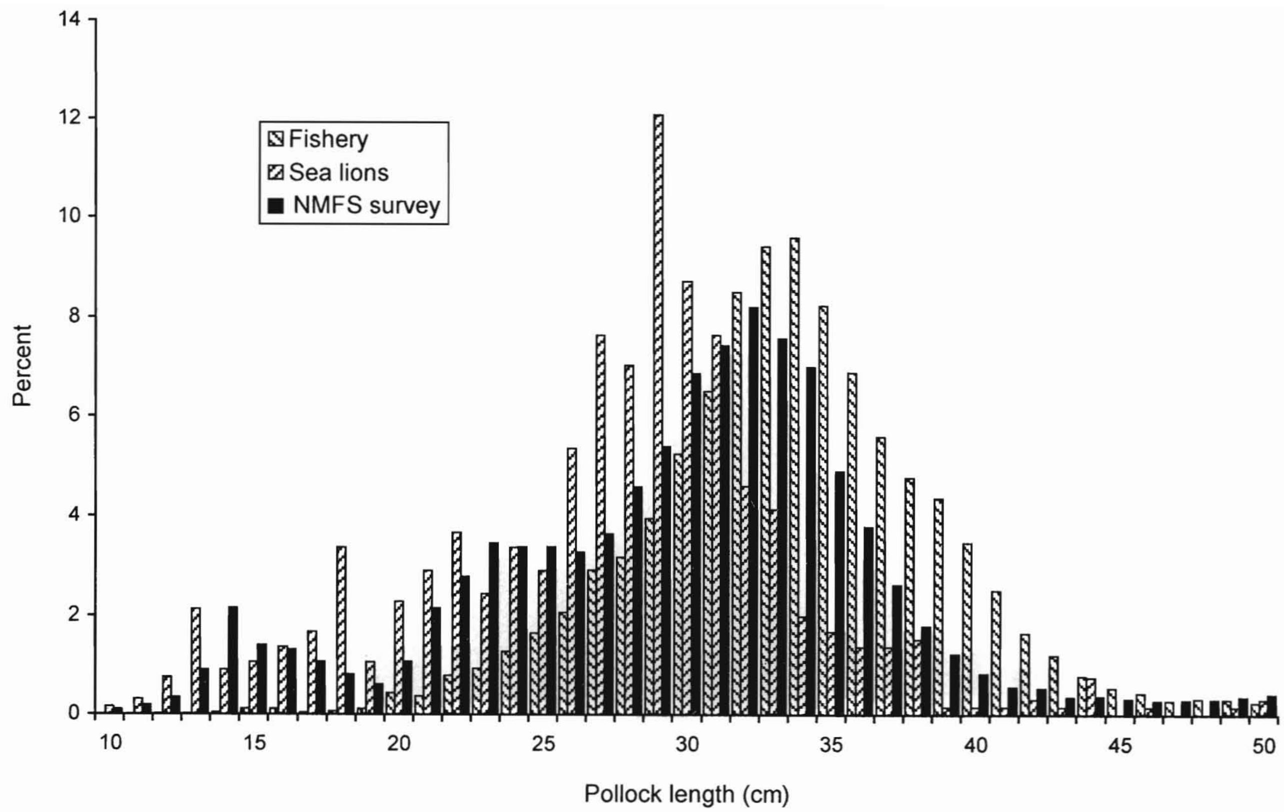

Figure 11. — Length-frequency distributions of walleye pollock caught by the fishery, consumed by Steller sea lions, and the population based on the NMFS bottom trawl survey in spring and summer of 1981 in the Bering Sea. Fishery (April–June) and survey (July–September) length-frequencies were from collections in NMFS statistical area 521, located northwest of the Pribilof Islands. Steller sea lions (n=27) were collected pelagically in area 521 in April. Pollock length data (computed from otoliths found in sea lion stomachs) were provided by D. Calkins, Alaska Department of Fish and Game, Anchorage.

ing prohibited anyone from shooting at or near Steller sea lions, except: people authorized by the endangered species permit provisions (50 CFR part 222, subpart C), government officials acting to protect the animal's or public's welfare, or Native Americans taking Steller sea lions for subsistence purposes under section 10(e) of the ESA. Because the number of Steller sea lions that had been shot and killed by fishermen prior to or after this regulation was implemented is not known, the impact on the number of intentional lethal takes of sea lions is also unknown. However, given the increased awareness of the decline in sea lion numbers as well as the effect the decline could have on the fishing industry, intentional lethal takes may have declined since the mid-1980's (Alverson, 1992; Trites and Larkin, 1992).

The 1988 amendments to the MMPA mandated a maximum mortality of 1,350 Steller sea lions caused by incidental takes in fisheries. This figure was based on the population data collected in 1985. While incidental take was not considered to be a major factor in the sea lion decline observed since 1985, the permitted level was reduced to reflect the recent (1985–89) decline in the Alaskan population of Steller sea lions. As shown in Figure 10, the reduced level of permitted incidental take (675 sea lions) would not have constrained the groundfish fishery in any of the 5 years prior to 1990, nor has it constrained the fishery since the listing.

No-entry buffer zones with a radius of 3 n.mi. seaward and 800 m landward around rookeries were established primarily to restrict opportunities for individuals to shoot at sea lions and to facilitate enforcement of the shooting prohibition. However, in discussing the reasons for the buffer zones (50 CFR Pt. 227 29792), the NMFS also cited general concerns about the indirect, nonlethal effects of disturbance and interference with sea lion behavior at these important pupping and breeding sites. Commercial groundfish fisheries used the marine portion of the no-entry zones for only a small percentage of their fish catch prior to 1990 (NMFS[11]). However, vessels of all types have used some no-entry zones for anchorage and passage, particularly those around rookeries on Akutan Island, Clubbing Rocks, and Outer Island. Since this regulation was promulgated, specific exceptions for transit through the rookery buffer

[11] Natl. Mar. Fish. Serv., Seattle, Wash. Unpubl. data.

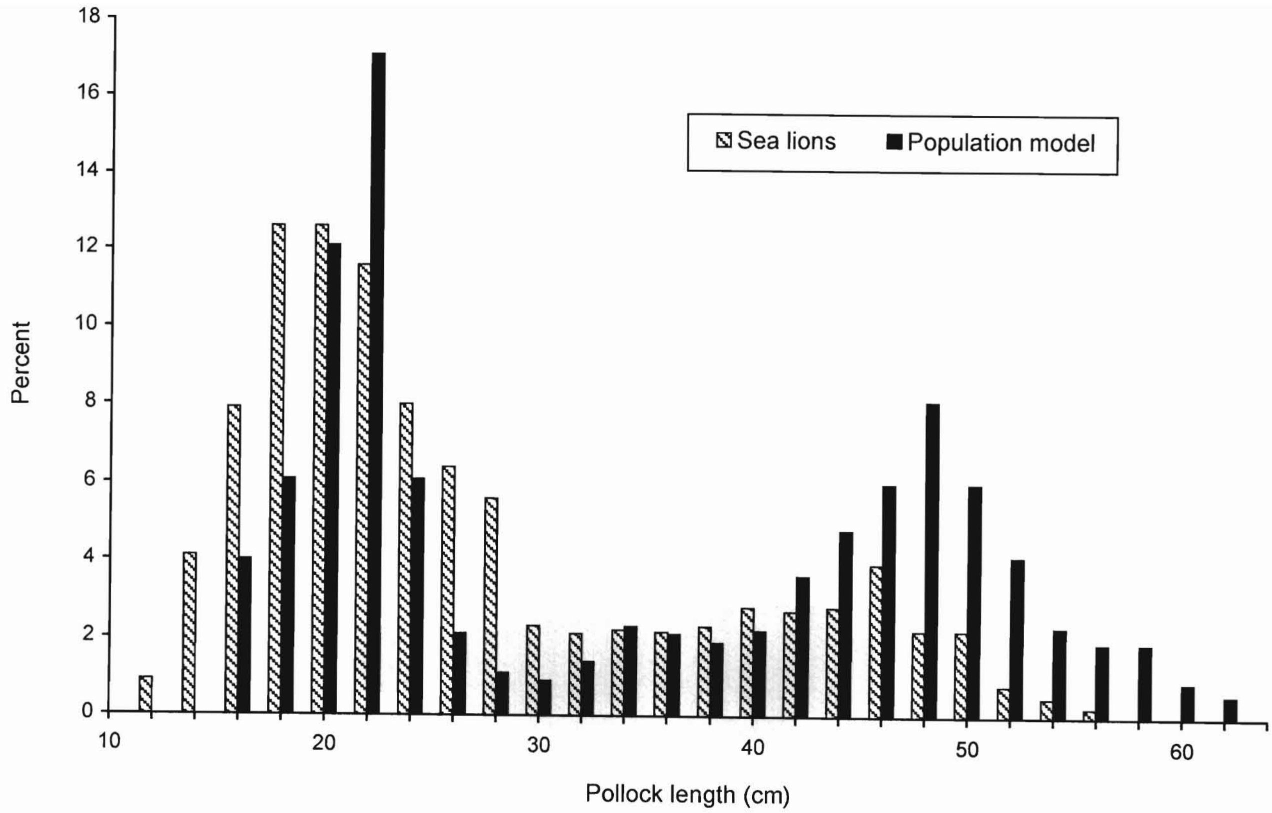

Figure 12. — Length-frequency distributions of walleye pollock consumed by Steller sea lions and the 1985 Gulf of Alaska population based on stock-synthesis model output (A. Hollowed, NMFS, Seattle, Wash., 1993, personal commun.). Steller sea lions were collected in the Kodiak Island Archipelago in summer 1985. Pollock length data (computed from otoliths found in sea lion stomachs) were provided by D. Calkins, Alaska Department of Fish and Game, Anchorage.

zones around these three islands have been granted.

ESA Section 7 Consultation on the 1991 Gulf of Alaska Walleye Pollock Fishery: Mitigation of Possible Indirect Fishery Interactions

In its ESA Section 7 consultation for the 1991 GOA walleye pollock TAC specifications, the NMFS concluded that the spatial and temporal compression of the pollock fishery that occurred during the 1980's could have created localized depletions of Steller sea lion prey, which in turn could have contributed to or exacerbated the decline of the sea lion population (5 June 1991). This conclusion was based on examination of sea lion food habits and condition data and historical fishing patterns, some of which is summarized above. These data revealed that 1) pollock is a major component of the sea lion diet; 2) sea lions collected near Kodiak Island in the 1980's were lighter, had smaller girths and thinner blubber layers than sea lions from the same area collected in the 1970's; and 3) the pollock fishery had become increasingly concentrated in time and in areas thought to be important to sea lions.

While the link between indirect effects of the GOA pollock fishery and the sea lion decline was circumstantial, the NMFS implemented emergency regulations on 13 June 1991 (56 FR 28113, June 19, 1991) to reduce the potential for competition between them to foster sea lion recovery. This was accomplished by dispersing the pollock fishery in time and space and excluding it from important sea lion habitat. The specific regulations spatially allocated the quarterly GOA pollock TAC between two areas in the GOA, limited the amount of unharvested pollock from one quarter that was available for harvest in subsequent quarters (temporal allocation), and excluded fishing with trawls within 10 n.mi. of all GOA sea lion rookeries.

The NMFS considered prohibiting fishing with any gear within 10 n.mi. of rookeries. Both walleye pollock and Atka mackerel fisheries use trawls exclusively to catch these semidemersal schooling species, while other schooling fishes, such as Pacific cod, *Gadus macrocephalus*, and rockfish, *Sebastes* spp., are commercially fished with trawls, hook and line, and pots. Trawls alone were excluded because 1) the risk of lethal incidental take of sea lions in nontrawl fisheries is low, 2) groundfish harvest with trawl gear results in greater amounts of bycatch of other important sea lion prey species, such as juvenile pollock, squid and herring, than with nontrawl gear, 3) the trawl fishery harvests the majority of the catch, and 4) the likelihood of creating localized depletions of sea lion prey, both commercially exploited and nontarget species, is greater with trawl gear than with hooks-and-lines or pots (57 FR 57726).

The NMFS intended to make the emergency regulations permanent prior to their expiration in December 1991, and, at the same time, to place 10 n.mi. trawl exclusion zones around sea lion rookeries in the BSAI. In the interim, the NMFS proposed closing statistical area 518, the area surrounding Bogoslof Island (where 30% and 60% of the BSAI pollock "A" season TAC was caught in 1990 and 1991, respectively), to directed pollock fishing in 1992. This closure was prompted by concerns about the decline in size of the Aleutian Basin pollock stock, possibly due to heavy exploitation from 1986 to 1990 in the international portion of the Bering Sea (the "donut hole"; Wespestad and Dawson, 1991). Because the size of the proposed 1992 BSAI "A" season pollock TAC was similar to that released in 1991 and area 518 was to be closed, the fleet would have to fish elsewhere to achieve its 1992 TAC. The only other large assemblage of spawning pollock available to the domestic fleet was on the continental shelf north of Unimak Island, an area used by sea lions from the eastern Aleutian Islands for foraging (letter from S. Pennoyer to N. Foster, November 13, 1991, comments on draft proposed rule for Steller sea lion critical habitat designation). Permanent regulations were promulgated implementing Amendments 20 and 25 to the BSAI and GOA FMP's, respectively, in January 1992 (57 FR 2683, January 23, 1992). These regulations increased the radius of the no-trawl exclusion zones from 10 to 20 n.mi. around five rookeries in the eastern Aleutian Islands until 15 April each year to further separate trawl fisheries, particularly the pollock trawl fisheries concentrated on the eastern Bering Sea shelf, from sea lions. These rookeries were located on Sea Lion Rocks, and Akun, Akutan, Seguam, and Agligadak Islands.[12] In Amendment 25 to the GOA FMP, the pollock TAC was further dispersed among three instead of two areas as in the emergency rules, and the rollover limitation (temporal allocation) was also made permanent.

The June 1991 emergency regulations were promulgated to increase the likelihood that the Steller sea lion population would reverse its decline. This conclusion was based on an ESA Section 7 consultation that the GOA pollock fishery could have caused localized depletions of sea lion prey and thus, contributed to the decline in sea lions. This outcome was a direct result of the listing of sea lions as threatened under the ESA. In contrast, the closure of the Bogoslof Island district, which was not considered for sea lion protective purposes, had implications for sea lion recovery because of a predicted large redistribution of pollock fishery effort to areas soon to be designated as critical habitat. While the increase in size of some trawl exclusion zones during the pollock "A" season was due to concerns about the effects that redistribution would have on the ESA-listed sea lion, NMFS implemented these regulations as FMP amendments, working through the NPFMC under the auspices of the MFCMA (Gerber, 1993).

[12] A 20 n.mi. BSAI "A" season trawl exclusion zone was placed around the rookery on Ugamak Island in 1993 to better encompass the range of winter habitats and juvenile foraging areas utilized by sea lions in the eastern Aleutian Islands.

Marine Mammal Considerations in Setting Quotas for Groundfish Fisheries: Incorporation of Marine Mammal Concerns and Risk into Fish Stock Assessments

Prior to 1991, the Plan Teams which review stock assessments for each groundfish species or species complex were composed solely of fishery biologists and Federal and state resource managers. With the listing of Steller sea lions under the ESA in 1990 and the accompanying increase in awareness of the potential for marine mammal concerns to affect groundfish fisheries, marine mammal biologists were appointed to the BSAI Plan Team in 1991, and to the GOA Plan Team in 1992. In this manner, recent information on population status, food habits, and marine mammal/fishery interactions can be discussed directly by the Plan Teams during their deliberations on groundfish stock assessments and ABC determinations.

A recent instance where concerns for the conservation of Steller sea lions were incorporated into the management of Alaskan groundfish fisheries occurred in the process of setting ABC's and TAC's for pollock in the Gulf of Alaska for the 1993 and 1994 fishing seasons. Prior to this time, the size of the GOA pollock stock was estimated, and the ABC was set each year using single-species management concepts (Pope, 1972; Deriso et al., 1985; Methot, 1990; Clark, 1991). In these stock assessment models, predation by marine mammals was considered only to the extent that it contributed to some fraction of the fish stock's natural mortality; the indirect effects of prey removal on other fish predators, including marine mammals, was not included.

Beginning in 1986, ABC's for GOA pollock were set equal to 10% of the exploitable biomass (age 3+ years old), which is refered to as "the 10% method" (Hollowed et al., 1993). The figure of 10% was based on the rate of harvest that occurred prior to the years when large pollock year classes were spawned (1975–79). This conservative approach was adopted for the 1986 fishery, and continued in subsequent years because of large reductions in the size of the Shelikof Strait spawning assemblage between 1980 and 1985 and uncertainties in the assessment of the size of the GOA-wide pollock stock. Using the 10% method to set GOA pollock ABC's resulted in lower harvesting rates (catch divided by biomass) from 1986 to 1992 (range 4–8%, median=6%) than if, for instance, the BSAI harvesting rate had been used (range 7–20%, median=13%) (Hollowed et al., 1993; Wespestad, 1993).

In 1992 (for the 1993 season), the SSC questioned the biological rationale for the GOA pollock fishing mortality rate because it was inconsistent with the current understanding of pollock population dynamics as well as rates used to set BSAI pollock ABC's. While the SSC was aware of Steller sea lion conservation concerns and the potential for a link with commercial fisheries removals, the pollock exploitation issue reflected the MFCMA mandate to manage fish stocks using the best available scientific information. In this case, setting the GOA pollock ABC at 10% or any other percentage of the exploitable biomass was not supported by data on the biology of pollock, but on the history of the pollock fishery.

Consequently, Hollowed et al. (1993) developed several alternative ways of examining the effects of various fishing mortality rates (*F*), including one which balanced yield with the risk of reducing spawner biomass below a threshold level. The models they employed estimated process error (from highly variable recruitment and an apparent shift in the probability of a strong year class recruiting to the population) as well as measurement error. Their approach resulted in a higher value of *F* than when ABC was set to 10% of the exploitable biomass, but it represented a departure from the traditional management strategy by introducing the concept of foregoing catch to reduce the risk of further reductions to spawning stock biomass. In addition, prey availability for other predators, such as marine mammals and birds, was addressed in the model since it incorporated estimates of the probability of the spawning pollock population biomass declining below a predetermined level. The risk parameter was introduced despite the highly variable relationship between the numbers of spawners and recruits into the GOA pollock population, and the absence of data suggesting that a particular spawner biomass threshold was biologically meaningful. Therefore, this approach reflected the caution of the GOA Plan Team in preserving pollock biomass in the face of a declining stock size and acknowledged that the pollock resource is important to other marine organisms including Steller sea lions and marine birds.

While the SSC considered recommending using the yield/spawner biomass model in assessing the size of the 1993 pollock stock, it chose to recommend a lower ABC using the 10% method. The SSC reasoned that a large increase in pollock removals, which would have occurred had the yield/risk approach to setting *F* been adopted, may not be adequately conservative for the pollock resource or for marine mammals. The SSC acknowledged several concerns noted by the GOA Plan Team in its review of the pollock stock assessment, including the reduced size of the pollock stock and the low levels of recent recruitment. In addition, the SSC also recognized that the population size of Steller sea lions in the GOA continued to decline. Despite the lack of hard evidence linking pollock fishery removals with the sea lion decline, the SSC expressed its desire for a cautious approach in setting the ABC for pollock to reduce the likelihood that pollock removals or fishery activity would exacerbate the sea lion decline.

During the 1993 GOA Plan Team meetings (which review the assessments for the 1994 fishery), the Hollowed/Megrey method for examining fishing mortality rates by balancing fishery yield with risk of the stock falling below a spawning biomass threshold was altered somewhat by only considering the risk component in setting *F*. The result was a more conservative ABC compared with that resulting from balancing yield and risk, and a clear recognition that while short-term fishery catches would be foregone, the risk of falling to historic lows in spawner biomass would be decreased. The level of risk that was acceptable to the GOA Plan Team, 5% chance of the stock falling below the spawning biomass threshold, was based largely on an α-level commonly used in statistical tests. The Plan Teams' recommendation was based not only on the declining trend in the pollock resource, but also on avoiding potential harm to Steller sea lions. This marked the first instance in the management of Alaska groundfish fisheries where an exploitation strategy for an important commercial fishery resource directly incorporated a safeguard for a marine mammal species from its inception in the Plan Team through subsequent approval by the SSC, AP, and NPFMC.

Incorporation of risk estimation into fish stock assessments and fishery management is not unique to the GOA pollock, but it is being used in a number of fisheries in a wide variety of ways (Smith et al., 1993). The risk approach is expected to be used in future stock assessments and ABC determinations, although other conservative approaches are currently being considered. The strategy could be modified as the status of the pollock stock changes or as more information on the relationship between Steller sea lions and pollock becomes available.

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Literature Cited

Alverson, D. L. 1992. A review of commercial fisheries and the Steller sea lion (*Eumetopias jubatus*): the conflict arena. Rev. Aquat. Sci. 6(3–4):203–256.

Anderson, P. J. 1991. Age, growth, and mortality of the northern shrimp *Pandalus borealis* Kröyer in Pavlof Bay, Alaska. Fish. Bull. 89:541–553.

Beamish, R. J. 1993. Climate and exceptional fish production off the west coast of North America. Can. J. Fish.Aquat. Sci. 50:2270–2291.

Braham, H. W., R. D. Everitt, and D. J. Rugh. 1980. Northern sea lion population decline in the eastern Aleutian Islands. J. Wildl. Manage. 44(1):25–33.

Calkins, D. G., and K. W. Pitcher. 1982. Population assessment, ecology, and trophic relationships of Steller sea lions in the Gulf of Alaska. Alaska Dep. Fish Game, 333 Raspberry Road, Anchorage. Final Rep. Contr. 03-5-022-69, 129 p.

Castellini, M. A., R. W. Davis, T. R. Loughlin, and T. M. Williams. 1993. Blood chemistries and body condition of Steller sea lion pups at Marmot Island, AK. Mar. Mammal Sci. 9:202–208.

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48:734–750.

Deriso, R. B., T. J Quinn II, and P. R. Neal. 1985. Catch-age analysis using auxiliary information. Can. J. Fish. Aquat. Sci. 42:815–824.

Ebbesmeyer, C. C., D. R. Cayan, D. R. McLain, F. H. Nichols, D. H. Peterson, and K. T. Redmond. 1991. 1976 step in the Pacific climate: forty environmental changes between 1968–1975 and 1977–1984. *In* J. L. Betancourt and V. L. Tharp (Editors), Proceedings of the Seventh Annual Pacific Climate (PACLIM) Workshop, April 1990, p. 115–126. Calif. Dep. Water Resour., Interagency Ecol. Stud. Prog. Tech. Rep. 26.

Ferrero, R. C., and L. W. Fritz. 1994. Comparisons of walleye pollock, *Theragra chalcogramma*, harvest to Steller sea lion *Eumetopias jubatus*, abundance in the Bering Sea and Gulf of Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-43, 25 p.

Fréon, P., F. Gerlotto, and M. Soria. 1992. Changes in school structure according to external stimuli: description and influence on acoustic assessment. Fish. Res. 15:45–66.

Fritz, L. W. In press. Juvenile walleye pollock, *Theragra chalcogramma*, bycatch in commercial groundfish fisheries in Alaskan waters. *In* R. Brodeur, A. Hollowed, P. Livingston, and

T. Loughlin (Editors), Workshop on the importance of prerecruit walleye pollock to the Bering Sea and North Pacific ecosystems, 28–30 October 1993, Seattle, Wash. U.S. Dep. Commer., NOAA Tech. Rep. NMFS.

________, V. G. Wespestad, and J. S. Collie. 1993. Distribution and abundance trends of forage fishes in the Bering Sea and Gulf of Alaska. *In* Is it food?: addressing marine mammal and sea bird declines. Workshop summary, p. 30–43. Alaska Sea Grant Rep. 93–01. Univ. Alaska, Fairbanks.

Gerber, L. R. 1993. Endangered Species Act decision-making in the face of scientific uncertainty: a case study of the Steller sea lion. MMA Thesis, Univ. Wash., Seattle.

Haynes, T. L., and C. Mishler. 1991. The subsistence harvest and use of Steller sea lions in Alaska. Alaska Dep. Fish Game, Div. Subsistence, Tech. Pap. 198, 47 p.

Hollowed, A. B., B. A. Megrey, and E. Brown. 1993. Walleye pollock. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, p. 1–1 to 1–54. N. Pac. Fish. Manage. Counc., P.O. Box 103136, Anchorage, AK 99510.

________ and W. S. Wooster. 1992. Variability of winter ocean conditions and strong year classes of northeast Pacific groundfish. ICES Mar. Sci. Symp. 195:433–444.

Laevastu, T., and F. Favorite. 1988. Fishing and stock fluctuations. Fishing News Books Ltd., Farnham, Surrey, Engl., 239 p.

Livingston, P. 1993. Importance of predation by groundfish, marine mammals and birds on walleye pollock *Theragra chalcogramma* and Pacific herring *Clupea pallasi* in the eastern Bering Sea. Mar. Ecol. Prog. Ser. 102:205–215.

Loughlin, T. R., L. Consiglieri, R. L. DeLong, and A. T. Actor. 1983. Incidental catch of marine mammals by foreign fishing vessels, 1978–81. Mar. Fish. Rev. 45(7–8–9):44–49.

________ and R. L. Merrick. 1989. Comparison of commercial harvest of walleye pollock and northern sea lion abundance in the Bering Sea and Gulf of Alaska. *In* Proceedings of the International Symposium on the Biology and Management of Walleye Pollock, p. 679–700. Univ. Alaska Sea Grant Rep. 89–01.

________ and R. Nelson, Jr. 1986. Incidental mortality of northern sea lions in Shelikof Strait, Alaska. Mar. Mammal Sci. 2:14–33.

________, A. S. Perlov, and V. A. Vladimirov. 1992. Range-wide survey and estimation of total number of Steller sea lions in 1989. Mar. Mammal Sci. 8(3):220–239.

Lowry, L. F. 1982. Documentation and assessment of marine mammal-fishery interactions in the Bering Sea. *In* K. Sobol (Editor), Trans. 47th N. Am. Wildl. and Nat. Resour. Conf., 26–31 March 1982, Portland, Oreg., p. 300–311. Wildl. Manage. Inst., Wash., D.C.

Megrey, B. A., and V. G. Wespestad. 1990. Alaskan groundfish resources: 10 years of management under the Magnuson Fishery Conservation and Management Act. N. Am. J. Fish. Manage. 10:125–143.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1987. Decline in abundance of the northern sea lion, *Eumetopias jubatus*, in Alaska, 1956–86. Fish. Bull. 85:351–365.

Methot, R. D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm., Bull. 50:259–277.

NMFS. 1992. Recovery plan for the Steller sea lion (*Eumetopias jubatus*). Rep. prep. by Steller sea lion Recovery Team for Nat. Mar. Fish. Ser., NOAA, Silver Spring, Md.

________. 1993. Conservation plan for the northern fur seal (*Callorhinus ursinus*). U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Conserv. Plan, 78 p.

NPFMC. 1993a. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions as projected for 1994. N. Pac. Fish. Manage. Counc., P.O. Box 103136, Anchorage, AK 99510.

________. 1993b. Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994. N. Pac. Fish. Manage. Counc., P.O. Box 103136, Anchorage, AK 99510.

Nunnallee, E. P. 1991. An investigation of the avoidance reactions of Pacific whiting (*Merluccius productus*) to demersal and midwater trawl gear. Int. Counc. Explor. Sea, Pap./B:5, Sess. U., Fish Capture Committ., 17 p.

Pasqual, M., and M. Adkison. 1994. The decline of the Steller sea lion in the northeast Pacific: demography, harvest or environment? Ecol. App. 4:393–403.

Perez, M. A., and T. R. Loughlin. 1991. Incidental catch of marine mammals by foreign and joint venture trawl vessels in the U.S. EEZ of the North Pacific, 1973–88. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 104, 57 p.

Pitcher, K. W. 1990. Major decline in number of harbor seals, *Phoca vitulina richardsi*, on Tugidak Island, Gulf of Alaska.. Mar. Mammal Sci. 6:121–134.

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Res. Bull. Int. Comm. Northwest Atl. Fish. 9:65–74.

Rea, L. D., M. A. Castellini, and R. L. Merrick. 1993. Body condition and metabolic chemistry of Steller sea lion pups in the Aleutian Islands and Gulf of Alaska. Abstr. Tenth Bienniel Conf. Biol. Mar. Mamm., Galveston TX, 11–15 Nov. 1993.

Smith, S. J., J. J. Hunt, and D. Rivard. 1993. Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Trillmich, F., and K. Ono 1991. Pinnipeds and El Niño: responses to environmental stress. Ecol. Stud. 88, Springer-Verlag, NY.

Trites, A. W., and P. A. Larkin. 1992. The status of Steller sea lion populations and the development of fisheries in the Gulf of Alaska and Aleutian Islands: Report to the Pacific States Marine Fisheries Commission. Univ. Brit. Col., Fish. Cent. Rep., 133 p.

Wespestad, V. G. 1993. Walleye pollock. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions as projected for 1994, p. 1–1 to 1–26. N. Pac. Fish. Manage. Comm., P.O. Box 103136, Anchorage, AK 99510.

________ and P. Dawson. 1991. Walleye pollock. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions as projected for 1992, p. 1–1 to 1–27. N. Pac. Fish. Manage. Comm., P.O. Box 103136, Anchorage, AK 99510.

________ and ________. 1992. Walleye pollock. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions as projected for 1993, p. 1–1 to 1–32. N. Pac. Fish. Manage. Counc., P.O. Box 103136, Anchorage, AK 99510.

Wolfe, R. J., and C. Mishler. 1993. The subsistence harvest of harbor seal and sea lion by Alaska natives in 1992. Alaska Dep. Fish Game, Juneau. Tech. Pap. 229, Pt. 1, Final Rep. Year 1, Subsistence study and monitor system, prep. for NMFS.

Wooster, W. S., and A. B. Hollowed. In press. Decadal scale variations in the eastern subarctic Pacific: A. Winter ocean conditions. Can. Spec. Publ. Fish. Aquat. Sci.

York, A. E. 1994. The population dynamics of northern sea lions, 1975–1985. Mar. Mammal Sci. 10:38–51.