Endangered Species Act

Section 7 Consultation - Biological Opinion

Agency:	National Marine Fisheries Service
Activities Considered:	Authorization of an Atka mackerel fishery under the BSAI groundfish Fishery Management Plan between 1999 and 2002; Authorization of a walleye pollock fishery under the Bering Sea-Aleutian Island groundfish Fishery Management Plan between 1999 and 2002, and Authorization of a walleye pollock fishery under the Gulf of Alaska groundfish Fishery Management Plan between 1999 and 2002.
Consultation By:	NMFS - Alaska Region

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1.0 PURPOSE AND CONSULTATION HISTORY

Section 7(a)(2) of the Endangered Species Act, 16 U.S.C. § 1531 et seq., requires that each Federal agency shall insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species. When the action of a Federal agency may adversely affect a protected species, that agency is required to consult with either the National Marine Fisheries Service or the U.S. Fish and Wildlife Service, depending upon the protected species that may be affected. For the actions described in this document, the “action” agency is the Sustainable Fisheries Division of the National Marine Fisheries Service. The consulting agency is the Office of Protected Resources, also of the National Marine Fisheries Service. Section 7(b) of the Act requires that the consultation be summarized in a biological opinion detailing how the action may affect protected species.

This opinion fulfills the section 7 requirements for consultation on three separate agency actions that have been proposed: (1) authorization of an Atka mackerel fishery under the Bering Sea and Aleutian Islands (BSAI) groundfish fishery management plan between 1999 and 2002; (2) authorization of a walleye pollock fishery under the BSAI groundfish fishery management plan between 1999 and 2002; and (3) authorization of a walleye pollock fishery under the Gulf of Alaska (GOA) groundfish fishery management plan between 1999 and 2002. Section 7 regulations allow a formal consultation to encompass a number of similar actions within a given geographic area or a segment of a comprehensive plan (50 CFR 402.14). Consistent with this regulatory provision and for purposes of efficiency, these three actions are being summarized in a single biological opinion. The opinion analyzes the effects of these actions on the endangered western population of Steller sea lions and its critical habitat.

The Steller sea lion was listed as threatened in 1990. On April 18, 1991, the National Marine Fisheries Service (NMFS) issued two biological opinions on the groundfish fisheries off Alaska pursuant to section 7 of the Endangered Species Act, as amended. The first biological opinion was prepared on the effects of the Fishery Management Plan (FMP) for the BSAI Management Area, and the second opinion was prepared on the effects of the FMP for the GOA groundfish fisheries. Both opinions concluded that the fisheries were not likely to jeopardize the continued existence and recovery of the Steller sea lion.

Between 1991 and 1996, NMFS evaluated the effects of various changes to both the BSAI and GOA groundfish fisheries (Table 1), and collected additional data on the fisheries. During this period, the western population of sea lions continued to decline. In 1993, critical habitat was designated for the species and, in 1995, NMFS issued a proposed rule to list the western population as endangered.

In 1995, NMFS reinitiated formal consultation on the effects on the Steller sea lion of the BSAI and the GOA groundfish fisheries as managed under the FMPs, and the proposed 1996 total allowable catch (TAC) specifications. Consultation was reinitiated because of 1) new information on the fisheries and their management, and 2) continued decline of the sea lion. On January 26, 1996, NMFS issued two new biological opinions, both of which concluded that the respective FMPs, the fisheries, and the 1996 TAC specifications were not likely to jeopardize the continued existence of Steller sea lions or to result in the destruction or adverse modification of their critical habitat.

On January 17, 1997, NMFS issued a Decision Memorandum on the 1997 BSAI and GOA TAC specifications and the need for section 7 consultation. NMFS determined that the groundfish fisheries were not likely to affect Steller sea lions in a way or to an extent not already considered in previous section 7 consultations on this fishery and reinitiation of formal consultation was not required.

On September 10, 1997, NMFS issued an environmental assessment/regulatory impact review (EA/RIR) on a proposed action to remove blue and black rockfish species from the GOA FMP (amendment 46) and allow the State of Alaska to assume management of these species. NMFS also determined that this action 1) was not likely to adversely affect those threatened and endangered species under its jurisdiction, and 2) was also not likely to result in the adverse modification of any designated critical habitats of these species.

On February 26, 1998, NMFS determined that the 1996 biological opinion on the effects of the BSAI groundfish fishery on Steller sea lions remained valid for the 1998 BSAI groundfish fishery.

On March 2, 1998, NMFS issued a biological opinion that concluded that the 1998 GOA groundfish fishery was not likely to jeopardize the continued existence and recovery of Steller sea lions or to adversely modify critical habitat. NMFS noted that the biological opinion only addressed the 1998 fishery, not the continued implementation of the GOA FMP beyond 1998. The Alaska Region would need to reinitiate section 7 consultation for the fishery in 1999 and beyond.

In June 1998, the North Pacific Fishery Management Council (NPFMC) adopted a precautionary approach in approving a regulatory amendment to reduce the probability of localized depletion of Atka mackerel in critical habitat for Steller sea lions. The amendment would allocate the Atka mackerel TAC on a seasonal basis and shift the spatial allocation of the TAC over the next four years until 40% is taken within critical habitat and 60% is taken outside of critical habitat.

In June 1998, the NPFMC also approved an FMP amendment to alter the allocation of BSAI pollock to inshore and offshore sectors of the fishery from 35%:65% (respectively) to 39%:61% (respectively).
On October 21, 1998, the President signed into law the American Fisheries Act (AFA), which changed the allocation scheme for pollock in the BSAI beginning in 1999.

2.0 DESCRIPTION OF THE PROPOSED ACTIONS

The purpose of this section is to describe the three proposed actions that are the subject of this consultation and opinion and thereby provide the background information needed to analyze their potential effects on protected species and, in particular, the western population of Steller sea lions. The actions being considered in this Biological Opinion are:

- *Authorization of an Atka mackerel fishery under the BSAI groundfish FMP between 1999 and 2002.* Consultation on this fishery was initiated because of new information indicating fishery-induced localized depletion of Atka mackerel stocks that could have a detrimental effect on the foraging of Steller sea lions or other protected species.

- *Authorization of a walleye pollock fishery under the BSAI groundfish FMP between 1999 and 2002*. Consultation on this fishery was initiated because of a new scheme for allocation of pollock

TAC to inshore/offshore sectors of the fishery. The implementation of the pollock fishery under this allocation scheme may also have a detrimental effect on foraging of Steller sea lions or other protected species.

- *Authorization of a walleye pollock fishery under the GOA groundfish FMP between 1999 and 2002*. Consultation on this fishery was initiated because the last completed consultation expires at the end of 1998, and this fishery may compete with Steller sea lions or other protected species.

These three actions are separate actions that would be taken by NMFS and are each separately subject to consultation pursuant to section 7 of the ESA. They have been grouped into this single Biological Opinion for efficiency and in compliance with the regulatory language of section 7 which allows NMFS to group a number of similar, individual actions within a given geographic area or segment of a comprehensive plan (50 CFR 402.14(b)). In addition to the three consultations summarized in this opinion, a separate consultation will be conducted on the 1999 TAC specifications. For the purpose of these three consultations, the Biological Opinion assumes that the TAC-setting process will proceed as usual, and will be based on estimated stock biomass, the overall cap on groundfish removals in both the BSAI and GOA regions, harvest rates in accordance with recent years, and other considerations normally taken into account. Reinitiation of formal consultation is required if the actions contemplated in this biological opinion are significantly altered when final rules are promulgated for each action, or if the agency action is subsequently modified in a manner that causes an effect to a listed species or critical habitat that was not considered in this biological opinion.

2.1 BSAI Atka mackerel fishery

2.1.1 Distribution and life history of Atka mackerel

The Atka mackerel (*Pleurogrammus monopterygius*) is a member of the family Hexigrammidae, order Scorpaeniformes. Atka mackerel are distributed from Kamchatka peninsula through the Aleutian Islands and GOA to southeast Alaska. The center of abundance appears to be in the Aleutian Islands from Seguam Pass to Buldir Island. Results from the 1991 and 1994 stock assessment surveys indicate areas of concentration at Seguam Pass, Tanaga pass, Petrel Spur, Amchitka and Kiska Islands, Tahoma and Buldir Reefs, and Stalemate Bank; all areas consistent with the historical distribution of the fishery (Figure 1).

The spatial dynamics of Atka mackerel are poorly understood. Morphological and meristic studies (Levada 1979, Lee 1985) suggested the possibility of separate stocks in the BSAI and the GOA, but genetic studies (Lowe *et al* 1998) indicate the stocks in these regions are well mixed. The larger size of Atka mackerel in the GOA, the greater sensitivity to fishing in that region, and the time-lagged correspondence of recruitment in the two regions all support the hypothesis that the GOA stock may be dependent on recruitment from the BSAI stock (Lowe and Fritz 1997).

Atka mackerel are pelagic during much of the year but migrate from the edge of the shelf to shallow coastal waters to spawn. In the Aleutian Islands, the spawning period peaks in August (McDermott and Lowe 1997). During spawning, Atka mackerel aggregate near the bottom in dense schools. Females lay their eggs in crevices or among stones, and males guard the eggs until they hatch in 40-45 days (Musienko 1970). The larvae are planktonic and little is known of their life history until they reach the age of two to three years and begin to appear in the fishery. They appear to grow rapidly until reaching maturity at about 4 years (50%) to 6 years (100%), and can reach a maximum size of about 50-55 cm. The natural mortality rate used in the stock assessment is 0.3, and the maximum age observed is 15 years, with most of the population ≤10 years.

2.1.2 Trends in Atka mackerel biomass

Estimated biomass for BSAI Atka mackerel rose to a peak in 1981 at 1,027,000 mt, dropped to 750,000 mt in 1986, then reached a second peak at just under 1,300,000 mt in 1991, and thereafter dropped steadily to about 605,000 mt in 1998 (Figure 2). Recruitment at age 2 (Figure 3) has been variable with strong year classes from 1975, 1977, 1984-86, and 1988 (all ≥0.777 billion fish). The 1992 year class (0.676 billion fish) is the largest for the 1990s. Lowe and Fritz (1997) suggest that recruitment is likely environmentally driven, as they have been unable to detect a relation between stock size and recruitment.

2.1.3 Overview of the Atka mackerel fishery

2.1.3.1 Distribution of fishing effort

The Atka mackerel fishery occurs in relatively predictable or constant areas throughout the central and western Aleutian Islands. The geographic distribution of the fishery in 1993-97 in the Aleutian Islands is illustrated in Figure 4. Lowe and Fritz (1997) provide the following description.

> ". . . the fishery is highly localized and usually occurs in the same few locations each year. . . . In the early 1970s, most Atka mackerel catches were made in the western Aleutian Islands (west of 180°W longitude). In the late 1970s and through the 1990s, fishing effort moved eastward, with the majority of landings occurring near Seguam and Amlia Islands. In 1984 and 1985 the majority of landings came from a single ½ ° latitude by 1° longitude block bounded by 52°30'N, 53°N, 172°W, and 173°W in Seguam Pass (73% in 1984, 52% in 1985). Other areas fished since the mid 1980s include north of the eastern Aleutian Islands (in areas 518 and 519 in the eastern Bering Sea), Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the sea mounts and reefs near Buldir Island . . . ."

Since 1979, the Atka mackerel fishery has occurred largely within areas designated in 1993 as Steller sea lion critical habitat (Figure 5). The amount of Atka mackerel taken from critical habitat ranged between approximately 3,000 and 30,000 mt through the early 1990s, but then increased about three-fold in 1995 and 1996 due to a steady increase in the TAC during the 1990s.

Prior to the early 1990s, the Atka mackerel fishery occurred primarily in the spring and summer months. Since the early 1990s, the fishery has started earlier (January) and has been condensed into a shorter season, so that most or all of the TAC has been taken by late March or April (Figure 6). In 1995 and 1996, the fishery was also open briefly in July and/or August to allow complete removal of the TAC.

2.1.3.2 Atka mackerel fishery methods

The Atka mackerel fishery is prosecuted almost entirely by large catcher processors. From 1992 to 1996, the numbers of vessels participating in the fishery annually were 34, 23, 15, 17, and 17, for an annual total of 106, 122, 126, 144, and 191 vessel-weeks (Kinoshita *et al*. 1997). Twelve vessels participated in the fishery in 1997, including 1 vessel 200 feet in length, 8 vessels between 200 and 250 feet in length, and 3 vessels greater than 250 feet in length.

Annual fishing effort generally occurs first in the eastern management district (management area 541), then moves westward to area 542, and then area 543 as area-specific TACs are taken. The catch is taken by trawling along the bottom, almost exclusively at depths of 200 m or less. Atka mackerel are difficult to detect with sonar because they do not have swim bladders. Furthermore, areas inhabited by Atka mackerel are generally rocky and include some areas too rough to fish even with bottom trawls equipped with roller gear used by the fishery. Therefore, fishing vessels tend to rely on certain "traditional" locations for trawling. Given the time of year and latitude, much of the trawling occurs at night. Tidal cycles, heights, and currents are thought to influence the success of catch, but the relations between tides and catch have not been described. The catch is either frozen whole or headed and gutted.

2.1.3.3 Atka mackerel catch history

In the 1970s, participants in the BSAI fishery for Atka mackerel included vessels from Russia, Japan, and the Republic of Korea (Lowe and Fritz 1997). U.S.-foreign joint ventures began in 1980 and dominated the fishery until 1988. Since 1990, the fishery has been entirely domestic.

From 1978 to 1983, total annual catch varied from just under 12,000 mt to just over 24,000 mt (Figure 7). From 1984 to 1987, total annual catch was higher, ranging from 30,000 mt to 38,000 mt. Catch was reduced again until 1992, but then increased incrementally until it reached 104,000 mt in 1996. In 1997, catch was about 66,000 mt, and the 1998 TAC was set at about 64,000 mt. Estimated harvest rates (catch/estimated biomass; Figure 7) were 6% or less until 1993, but increased thereafter to a peak of 15% in 1996.

2.1.3.4 Age-size-sex structure of the Atka mackerel stock and catch

The distribution and life history of Atka mackerel prior to recruitment into the fishery are largely unknown. These fish begin to appear in survey trawls at about age 2 to 3 years, and are fully recruited by about age 5. Age of Atka mackerel is determined by counting annuli on otoliths. The age composition of the catch is approximated by determining the length frequency of the catch and comparing that frequency to length-at-age relations based on samples from the catch or from surveys. The results indicate that Atka mackerel grow faster in the eastern portions of their Alaskan range than in the west (Lowe *et al*. 1998). Their length distribution varies annually due to variance in the size of recruiting year-classes, and spatially due to variability in the distribution of those year-classes. These variances are apparent in Figure 8, which illustrates length-frequency data collected on fishing vessels in 1996 and 1997 in the Aleutian Islands, western GOA, and southern Bering Sea. In 1996, two distinct size modes were present in most areas fished. In 543 (western Aleutian Islands) and the western portions of 542 (Petrel Bank and Amchitka), the larger mode was centered at approximately 40 cm while the smaller mode was at 31-35 cm. In eastern 542 (Delarofs) and in 541 (Seguam), the smaller size mode was similar in size to that observed in the west, but the larger mode was 1-2 cm longer. East of Seguam, Atka mackerel smaller than 40 cm were rare in fishery samples, and modal lengths increased to between 45-47 cm. In 1997, a single size mode of Atka mackerel was present in the areas fished, and the modal length increased from 35-37 cm in 543 and the western portions of 542 to 39-40 cm in east 542 and 541.

With respect to the sex ratio of the catch, Lowe and Fritz (1997) report:

> "In certain areas and months, female Atka mackerel greatly outnumbered males in fishery catches (Fritz and Lowe 1998). While reasons for this are not known, this may be related to their reproductive and spawning behavior. In Russian waters, male Atka mackerel have been observed guarding nests of fertilized demersal eggs (Zolotov 1993). Therefore, catches composed predominately of females may be the result of a sexually segregated population, possibly during nest-guarding periods after spawning. In the Aleutian Islands, females are more likely to outnumber males in fishery catches in late summer and fall than during winter, but there is considerable variability in the sex ratios geographically within the same season. More research on seasonal and tidal distribution patterns and rates of seasonal, geographic and ontogenetic maturity are necessary before these observations can be fully explained."

2.1.3.5 Bycatch in the Atka mackerel fishery

Prohibited species bycatch rates by the Atka mackerel target fishery in 1994, 1996, and 1997 are summarized in Table 2 for areas inside and outside of Steller sea lion critical habitat. The years 1994, 1996, and 1997 were chosen because 1996 and 1997 represent the two most recent complete years of data, and 1994 is the most recent year during which significant Atka mackerel fishing effort occurred outside of critical habitat in area 542. Halibut and salmon bycatch rates by the fishery were low both inside and outside of critical habitat in the Aleutian Islands (all areas), and trends were not apparent by management area or with respect to critical habitat. King crab bycatch rates by the fishery have generally been higher in areas 542 and 543 than in area 541, but there is no consistent trend with respect to critical habitat. For instance, in 1994 in management area

542, the king crab bycatch rate outside of critical habitat (on Petrel Bank) exceeded 0.1 crab/mt of Atka mackerel, while that inside critical habitat was 0. However, in 1996 and 1997, king crab bycatch rates were higher inside critical habitat than outside. In 1996 in area 543, almost 0.2 crab/mt were caught inside critical habitat (west of both Buldir and Kiska Islands), while the "outside" rate was 0 (Tahoma reef). In 1997 in area 542, 0.16 crab/mt were caught inside critical habitat (at the Delarof Islands and west of Kiska Island), while none were caught outside (though only 588 mt of Atka mackerel was observed outside of critical habitat at Petrel Bank compared with over 12,000 mt inside). In area 543 in 1997, the highest rate of crab bycatch, almost 0.5 crab/mt, was observed inside critical habitat, primarily west of Kiska Island. The rate outside of critical habitat in area 543 in 1997 was only 0.02 crab/mt (on Tahoma reef).

Bycatch rates of other groundfish species by the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat are summarized for 1994, 1996, and 1997 in Table 3. The predominant bycatch groundfish species by weight were Pacific cod, walleye pollock, and various rockfish, including Pacific ocean perch and northern rockfish. These bycatch rates do not indicate a consistent pattern with respect to critical habitat. Cod bycatch rates have been as high as 15% (in 1994, BSAI-wide), but were generally less than 10%. Bycatch rates of pollock were low (each time/area cell less than 1%). Bycatch rates of Pacific ocean perch have generally been less than 2%, but have been as high as 15% in some time/area cells (in 1997, outside critical habitat in area 543). Examination of the other rockfish bycatch by species in 1997 suggests that most is northern rockfish; rates were as high as 4% in area 543 in 1997, and the aggregate BSAI rate for the Atka mackerel fishery was 2.5%.

The data in Tables 2 and 3 represent summaries of haul-by-haul observer data. As such, they represent "natural" bycatch of prohibited and other groundfish species in the Atka mackerel fishery. The practice of "topping off" with other groundfish species, which can appear as high bycatch in weekly aggregated data (e.g., the blend), does not influence these results. The target fishery was determined on a haul-by-haul basis according to the dominant species in the observer's species composition sample.

2.1.4 Fishery management and the setting the Atka mackerel harvest parameters

Atka mackerel was first included as a reported fishery species in the BSAI in 1978. The BSAI Groundfish FMP became effective in 1982, and has since provided the regulatory framework for the fishery. In 1993, the Aleutian Islands were divided into three management areas for the purpose of apportioning Atka mackerel TACs (Amendment 28 to the FMP). The geographical apportionment of the TAC was intended as a conservation measure for the fish stock, but may have provided indirect benefit to other consumers of Atka mackerel (e.g., Steller sea lions) by geographically distributing the catch.

The FMP regulates the Atka mackerel fishery through a number of mechanisms, in addition to geographical allocation of TAC (see TAC-setting below). Vessels fishing for Atka mackerel must have a groundfish moratorium permit and they must meet record-keeping and reporting requirements. Due to their length (all > 125 feet), all vessels in this fishery must have fishery observers on board. In any given year, trawl fishing can not begin before 20 January, and the length of the season is subject to adjustment (closure) based on removal of catch in each management area. Fishing areas are restricted; vessels cannot fish within year-round 10-nautical mile no-trawl zones around major rookeries west of 150°W long., nor can they fish within seasonal (20 January to 15 April) 20-nautical mile no-trawl zones around six rookeries in the BSAI region (at Sea Lion Rock and Ugamak, Akun, Akutan, Seguam, and Agligadak Islands). The fishery is also potentially constrained by bycatch limits of prohibited species (halibut, salmon, herring, and crab) and overfishing restrictions on other groundfish (particularly various rockfish species).

The process of setting harvest parameters such as the TAC involves a number of steps, including stock assessment based on surveys and modeling exercises, review by several committees of the NPFMC, and deliberations by the NPFMC on TAC amounts to be recommended to the Secretary of Commerce.

2.1.4.1 Stock assessment of Atka mackerel

Early attempts to evaluate the conditions of Atka mackerel stocks in the Aleutian Islands were severely restricted by limited biological data and lack of measures of relative and absolute stock abundance. In the northeast Pacific, Atka mackerel distribution appeared to be centered in the western Aleutian Islands and Kodiak Island (Wespestad and Ronholt, 1977). Soviet hydroacoustic surveys conducted in 1974 and 1975 in the Aleutian Islands provided the only available biomass estimates (each approximately 100,000 mt). Based on these estimates, the Soviets estimated that MSY would equal one-third of the standing stock, or 33,000 mt. Because neither the Soviet data nor the analytical procedures used to estimate biomass and sustainable yield were made available, those estimates were considered provisional.

In the BSAI FMP, the optimum yield (OY) of this species was set at 24,800 mt, 75 percent of the unverified Soviet estimate of MSY. The 1978 allowable catch was set equivalent to the 24,800 mt OY and remained in place until 1984. Stock assessments from 1978 to 1981 contained only biological information (mean length, weight, and age) and catch and CPUE data from observers on Soviet vessels, and did not include formal analyses of abundance trends or yield estimations.

U.S.-derived biomass estimates for the Aleutian Islands Atka mackerel were not provided in the stock assessments until 1982. The first estimate was originally 158,000 mt and was based on demersal trawl surveys conducted cooperatively by the U.S. and Japan in 1980. In 1983, this estimate was increased to 182,800 mt to include eastern Bering Sea (EBS) biomass and, in subsequent years, the 1980 Atka mackerel survey biomass was finalized at 197,529 mt. The 1983 and 1984 stock assessments included an analysis of MSY based on the newly available survey biomass (Ronholt 1982,1984). Estimates of MSY ranged from 22,666 to 28,300 mt with a midpoint of 25,500 mt.

The biomass-based Stock Reduction Analysis (SRA) model was used in the 1985, 1986, and 1987 stock assessments to evaluate BSAI Atka mackerel (Kimura and Ronholt 1985; Ronholt and Kimura 1986, 1987). These analyses used the 1983 survey biomass estimate of 300,000 mt to estimate MSY. The 1988 stock assessment included the newly available 1986 survey biomass estimate of 544,754 mt, and used age-structured models for the first time (virtual population analysis (VPA) and least-squares catch-at-age analysis; Kimura and Ronholt 1988). The catch-at-age data were dominated by the strong 1977 year class, which indicated that biomass would be expected to increase through the early 1980s and then decrease. Contrary to this expectation, the survey biomass estimates increased over time. The difference was reconciled by weighting the fits to the catch-at-age analysis by the coefficient of variation (CV) of the survey biomass estimates. Using the estimated CVs from the survey data, the catch-at-age analysis indicated a much lower (relative to the 1986 survey) biomass ranging from 52,000 to 106,000 mt with an average estimate of 78,000 mt. From 1989-1991, the most current survey biomass estimate was from the 1986 survey, and correspondingly, a biomass time series was estimated using the age-structured model only through 1986. In each of these three years, the age-structured model was not updated in the stock assessment.

The 1992 stock assessment utilized the stock synthesis age-structured model which is still currently being used to assess BSAI Atka mackerel (Lowe, 1991). The 1992 stock assessment included the newly available biomass estimate (over 600,000 mt) from the 1991 survey. The large biomass indicated by the 1991 survey was consistent with strong recruitment from the 1988 year class. The stock synthesis model projected a 1992 biomass (for ages 3-7) of 868,500 mt, orders of magnitude higher than previous estimates of biomass. As an alternative to estimating F_{MSY} (the fishing rate which would result in maximum sustainable yield) which was unknown, the stock assessment estimated the $F_{0.1}$ level. This rate was extremely high (attributed to maximum biomass being reached before full recruitment into the fishery) and considered inappropriate for Atka mackerel yield analyses. As an alternative, the stock assessment recommended a yield of 260,000 mt which was derived by applying a harvest rate equal to the natural mortality rate (0.3) to the current biomass. While the Scientific and Statistical Committee of the NPFMC accepted the new analysis and higher biomass estimate, they were reluctant to increase the allowed biological catch (ABC) by several orders of magnitude in one year and recommended a 6-year phase in of the higher exploitation rate. According to this scheme, the 1992 ABC was estimated as (0.30/6) x 870,000 = 43,000 mt, and the NPFMC set the 1992 ABC and TAC at this level.

The 1993 stock assessment included a projection of 1993 biomass of 1,171,000 mt from the stock synthesis analysis (Lowe, 1992). This projection was higher than the 1992 projection due to the inclusion of updated 1991 survey data and fish older than age 7 that appeared in fishery catches. Consistent with the 6-year phase-in plan, the stock assessment recommended an ABC of 117,100 mt. The 1993 stock assessment noted that the recommended yield was based on an Aleutian-wide analysis, and raised the issue of disproportionate harvesting of Atka mackerel biomass. It was noted that the bulk of the fishery occurs in the eastern Aleutians (around Seguam Island), whereas the major portion of survey biomass has been consistently found in the western Aleutians. In the absence of a means to apportion ABCs, and the possibility of localized depletion of Atka mackerel and the resulting impact on predator populations, the Scientific and Statistical Committee set the ABC at 32,100 mt, the amount that was determined could be safely taken from the eastern Aleutians (Scientific and Statistical Committee minutes, December 1992). The Scientific and Statistical Committee strongly recommended that the NPFMC develop a plan amendment to allow TACs to be apportioned geographically in the Aleutian Islands. In order to protect Atka mackerel stocks from over-harvesting, the NPFMC set the 1993 TAC for BSAI Atka mackerel at 32,100 mt, well below the ABC of 117,100 mt. Amendment 28 to the BSAI FMP divided the Aleutian Islands into three districts. After it became effective in mid-1993, an additional 32,000 mt of Atka mackerel TAC was released to the Central (27,000 mt) and Western (5,000 mt) districts, for a total 1993 Atka mackerel TAC of 64,000 mt.

The 1994 stock assessment (stock synthesis analysis) projected a 1994 biomass of 816,000 mt (Lowe, 1993). The analysis showed that Atka mackerel biomass peaked in 1990. Based on a 15% harvest rate (according to the phase-in of the 30% harvest rate), the stock assessment recommended an ABC of 122,400 mt. Based on industry needs, the NPFMC set the Atka mackerel TAC at 68,000 mt, well below the ABC of 122,400 mt.

The projected 1995 biomass from the stock synthesis analysis was 832,000 mt (Lowe and Fritz, 1994). Although Atka mackerel biomass was still thought to be declining, the 1995 biomass was similar to the 1994 estimate based on upward revisions of past strong year classes. However, because of the lack of updated survey information (the 1994 survey biomass estimate was not available for the 1995 stock assessment) and fishery data (too few otoliths were collected from the 1993 fishery to update catch-at-age data), the stock assessment authors recommended maintaining the 15% harvest rate resulting in an ABC of 124,800 mt. Again, based on industry needs, the NPFMC set the Atka mackerel 1995 TAC at 80,000 mt.

The 1996 stock assessment included the 1994 survey biomass estimate of 623,800 mt, similar in magnitude to the 1991 survey biomass estimate (Lowe and Fritz, 1995). Maturity-at-age data was also available for the first time and allowed better estimation of spawning biomass and the $F_{40\%}$ reference fishing mortality rate. The projected 1996 biomass was 577,800 mt. The 1996 stock assessment noted that the phase-in fishing mortality rates were now at levels above or approaching the commonly applied reference fishing mortality rates and recommended application of the $F_{40\%}$ fishing mortality rate for BSAI Atka mackerel. The 1996 recommended yield was 116,000 mt. The NPFMC set the 1996 BSAI Atka mackerel ABC and TAC at 116,000 mt and 106,157 mt, respectively.

The projected 1997 biomass from the stock synthesis analysis was 450,200 mt (Lowe and Fritz, 1996). The 1997 stock assessment incorporated revised reference fishing mortality rates. These rates were considerably lower than those reported in the 1996 stock assessment. Previously, the spawning biomass estimate was calculated at the beginning of the year. Since Atka mackerel are summer-fall spawners, a January 1 date was not a good proxy for the month of peak spawning. Consequently, a change to a more appropriate mid-August assumption to represent peak spawning in the spawning biomass calculation resulted in significantly lower reference fishing mortality rates. The resulting ABC based on a revised estimation of the $F_{40\%}$ rate was 66,700 mt. The NPFMC set the 1997 ABC and TAC at 66,700 mt.

The most recent (1998) stock assessment included the 1997 Atka mackerel survey biomass estimate of 348,000 mt, down about 50% relative to the 1991 and 1994 survey estimates. For 1998, the stock assessment recommended a fishing mortality rate lower than the maximum allowed under the ABC and overfishing level (OFL) definitions, and the NPFMC set the 1998 ABC and TAC at 64,300 mt.

2.1.4.2 Stock assessment model for Atka mackerel

The stock synthesis model (Methot 1990) used to assess the status of Aleutian Islands Atka mackerel is a catch-at-age analysis designed to incorporate diverse auxiliary information. The model uses a maximum likelihood approach (Fournier and Archibald 1982) and simultaneously analyzes catch biomass, age composition and effort from multiple fisheries, and abundance and age composition from multiple surveys (Methot 1990). In stock synthesis, fits to the catch biomass and the catch age composition are determined in separate steps to account for variability in the age determination process.

A simulated population is created to generate expected population parameters, and deviations between these expected parameters and parameters estimated from the real population (from the fishery and surveys) are quantified with a specified error model and cast in terms of log-likelihood. Lognormal error is assumed for estimates of survey abundance, and multinomial error structure is assumed for analysis of the survey and fishery age compositions. The overall log-likelihood (L) is the weighted sum of the calculated log-likelihoods for each type of data or component. The sum of the weights given to each component should equal 1 in a perfectly specified model. The weights are referred to as emphasis factors, and they are subjectively adjusted to distinguish those components which may be subject to greater error (i.e. those components in which less confidence is placed). The set of parameters values that maximizes the correspondence between the simulated and real populations is found by an iterative searching algorithm using a numerically estimated derivative of L with respect to each of the parameters. The result is referred to as the maximum likelihood solution.

Fishery data used in the model consist of total catch biomass and the age composition of the catch from 1977-1996. The age composition is estimated using length frequencies of the catch, and age-length relations based on formulas described by Kimura (1989). Fishery-independent data include relative indices of abundance and the associated standard errors, and corresponding age compositions from the 1980, 1983, 1986, and 1991 Aleutian surveys, and absolute abundance and the associated standard errors, and corresponding age compositions from the 1986, 1991, and 1994 surveys. The current assessment also incorporates the most recent 1997 mean biomass estimate from the bottom trawl survey.

(The corresponding age composition is not available). These data sets are incorporated into the model to calibrate the estimated abundance to the appropriate level. The relative indices of abundance exclude biomass from the 1-100 m depth strata of the Southwest region due to lack of sampling in this strata in some years. The current assessments also uses updated weight-at-age vectors, which are estimated separately for the fishery and survey data sets. The current survey and fishery vectors were updated to include 1986, 1991, and 1994 survey data, and 1990 and 1996 fishery data, respectively.

Basic assumptions of the stock synthesis model include the following. First, catch-at-age is well approximated by the Baranov catch equation. Second, catch biomass is measured with much greater precision than other types of data. Thus, in stock synthesis, the level of fishing mortality is calculated so that the estimated catch biomass matches the observed catch biomass. Then, the pattern of selectivity-at-age is determined which will maximize the log-likelihood of the observed catch proportion at age. The log-likelihood of each observation is calculated from a multinomial error structure. And third, fishing mortality is separable into a year-dependent factor and an age-dependent factor.

Additional assumptions specific to the Atka mackerel application include the following. First, natural mortality is equal to 0.3 and is constant for all ages and years. Second, survey data which exclude the 1-100 m depth strata in the Southwest region represent an index of relative abundance, and estimates of abundance from the 1986, 1991, 1994, and 1997 surveys are absolute. Third, catchability associated with estimates of absolute biomass is 1.0, and the catchability of the indices of abundance is less than 1.0 and estimated by the model. Fourth, survey selectivities are well estimated from the survey age compositions. And fifth, fishery selectivity-at-age vectors are well estimated for two different time periods, 1972-1983 and 1984-1997.

The likelihood components of the model are: catch biomass, catch age composition, catch length composition, survey biomass (indices), survey age composition (indices), survey biomass (absolute), survey age composition (absolute), stock-recruitment-individual, and stock-recruitment-mean. Each of these components is given equal weight in calculating L. The stock recruitment-individual component relates to the residual mean square error of the individual recruitment about the stock recruitment curve. The stock recruitment-mean component relates to the deviation between the stock recruitment curve parameters and the mean and variance of the individual recruitment estimates.

Finally, the model allows for some constraints on parameter values. The parameters, taken altogether, constitute a parameter space that the model searches for the most likely solution. Some parameter values are known to fall within certain limits, and such limits must be incorporated into the model either by setting bounds on those parameter values , or by allowing the parameters to assume only certain predetermined values. For instance, since estimation of natural mortality is confounded with estimation of selectivity, natural mortality is set to a constant and conservative value of 0.3.

2.1.4.3 Setting the Atka mackerel TAC

Following stock assessment, the results are reviewed by the BSAI plan team, which prepares a stock assessment and fishery evaluation (SAFE) report. The report includes preliminary recommendations on pertinent harvest specifications for the stock, including the OFL, and the ABC. The Scientific and Statistical Committee reviews the OFL and ABC recommendations, the Advisory Panel reviews the ABCs and makes TAC recommendations, and both of these committees submit their recommendations to the NPFMC. The NPFMC then makes its recommendations to the Secretary of Commerce for final ruling. The OFL and ABC are set using a 6-tier system that determines these values on the basis of the amount of information available for each stock. The TAC is set either at or below the ABC, and incorporates stock-specific information plus additional considerations which may be unrelated to the status of the stock.

For Atka mackerel, OFL and ABC are determined according to the guidelines in tier 3a, which is based on reliable point estimates of biomass (B), the spawner biomass-per-recruit level that would correspond to 40% of the unfished level ($B_{40\%}$), the fishing mortality rates that would result in spawner biomass-per-recruit levels equal to 30% or 40% of the unfished level ($F_{30\%}$ and $F_{40\%}$), and a $B/B_{40\%}$ ratio > 1.0. In past years, the TAC has been set lower than the ABC level for a variety of reasons, including limits on the combined TAC for all groundfish fisheries in the Bering Sea, requirements of the fishing industry, uncertainty about stock assessment results, and unexplained interannual variability in biomass estimates. Such considerations may be considered in setting the TAC or the ABC level. For example, for the 1998 fishery, the SAFE report recommended an ABC level lower than that based on an $F_{40\%}$ rate.

Lowe and Fritz (1997) provided the following reasons for the change: (1) stock size has been steeply declining since 1991 according to the age-structured analysis, (2) the 1997 Aleutian trawl survey biomass estimate was about 50% lower than the 1991 and 1994 survey estimates, (3) under an $F_{40\%}$ harvest strategy, female spawning biomass is projected to decline to almost 30% below $B_{40\%}$ within 5 years. While it is acknowledged that $B_{40\%}$ represents the long-term average about which the stock may safely fluctuate, we know little about threshold biomass for Atka mackerel, (4) while the spawner-recruit relationship for Atka mackerel is uncertain, some of its life history and behavioral characteristics (low female fecundity and male nest-guarding) suggest that the relationship may be more direct, particularly at medium population levels, than for other groundfish (e.g., gadid), (5) Estimated local Atka mackerel fishery harvest rates have been much greater (on the order of 3-5 times) than the Aleutian-wide harvest rates estimated from the model. While this pattern of fishing apparently does not affect local fishing success from one year to the next, we are uncertain about the long-term effects on the population and particularly the spawning stock.

Based on the above rationale, the SAFE report recommended a harvest rate no greater than that estimated for 1997 (12%) in the face of a declining Atka mackerel stock; this translated to an ABC recommendation of 64,300 mt. The NPFMC set the 1998 ABC and TAC at 64,300 mt.

2.1.4.4 Allowance for other marine predators

Management mechanisms provide an opportunity to mitigate harvest impact on other marine consumers. The maintenance of a 2 million mt optimum yield cap for all BSAI groundfish fisheries combined is viewed as a conservation measure designed to maintain the integrity of the entire ecosystem. In addition, the harvest of groundfish such as Atka mackerel can be and is limited or controlled by various spatial and temporal allocations, closed areas, gear restrictions, bycatch limits, etc., to mitigate potential adverse impacts.

The mechanisms for setting Atka mackerel harvest specifications (OFL, ABC, and TAC), however, do not include explicit mandatory allowance for the needs of other marine predators. The 6-Tier system for setting harvest specifications is intended to be conservative in terms of the fished stock and its persistence, but the role of that fished stock (Atka mackerel) in the ecosystem and its importance to other marine predators (e.g., Steller sea lions) or competitors is not an explicit consideration. Once the stock assessment is complete, such concerns may be introduced in the process of setting harvest specifications.

2.1.5 Action area for the Atka mackerel fishery

At a minimum, the action area pertaining to the Atka mackerel fishery extends from the eastern border of management area 541 (Figure 4), which runs through the Islands of the Four Mountains, to the western border of area 543, just west of Stalemate Bank, or midway between Attu Island (U.S.) and Medney Island (Russia). The north and south borders of these management areas are 55°N lat. and the boundary of the exclusive economic zone south of the Aleutian Islands, respectively. Twenty Steller sea lion rookeries and 28 major haulouts are located in this region (50 CFR, Tables 1 and 2 for part 226.12). Virtually all of the fishery occurs within these limits. Seventy percent or more of the fishery in 1995 through 1997 occurred within Steller sea lion critical habitat (i.e., within 20 nautical miles of these rookeries and haulouts or within the Seguam Pass foraging area designated as critical habitat; Figure 9).

The impacts of the fishery may extend beyond management areas 541, 542, and 543. First, sea lions may forage over relatively wide ranges (Merrick and Loughlin 1997), and sea lions from rookeries or haulouts adjacent to the management areas may, therefore, be affected if prey is reduced within their foraging range. Second, the Atka mackerel stock also may range beyond the areas fished. Lowe and Fritz (1997) suggest that Atka mackerel in the more western regions may constitute, at least to some degree, a source population for Atka mackerel found further east. If that is the case, then fishing may affect stock abundance in areas outside the three management areas.

2.1.6 Fishery-induced localized depletion of Atka mackerel

Fritz (*in prep*) suggests that localized depletions occur as a result of the Atka mackerel fishery. Initially, Fritz evaluated in-season changes in CPUE of the Atka mackerel fishery at three BSAI locations (Seguam Bank, Petrel Bank, and Kiska Island) and one location in the GOA in 1992-95. The abstract of this work states:

> "Leslie regression analyses of Atka mackerel (*Pleurogrammus monopterygius*) fishery catch per unit effort (CPUE) data collected in the Aleutian Islands and GOA in 1992-95 revealed significant reductions during the course of 8 local fisheries lasting between 3 days and 17 weeks. Estimates of harvest rate (catch divided by the initial population size estimate, B_0) ranged between 55% and 91%. Length-frequency distributions and the time-series of catches and effort suggest that the exploited populations were not closed (e.g., immigration was evident) yet the rates of removal (or emigration) apparently far exceeded rates of immigration. Estimates of B_0 from the second year (with periods of fishing separated by at least 15 weeks) were nearly identical to those from the first year. This suggests that in the Aleutian Islands, the fishery utilizes areas preferred by adult Atka mackerel and that these areas are replenished over time. Temporary reductions in the sizes of local Atka mackerel populations could affect other Atka mackerel predators, such as the Steller sea lion (*Eumetopias jubatus*).

The data analyzed were collected by fishery observers and include detailed information on catch composition, haul duration, and haul location. Leslie's method of CPUE analysis uses the resulting time series of catch and effort data to estimate catchability (q) and the biomass of the initial population (B_0) from the following linear equation (Ricker 1975):

$$\frac{C_t}{f_t} = qB_0 - qK_t$$

where C_t and f_t are catch taken (metric tons [mt] of Atka mackerel) and effort expended (hours trawled), respectively, during period t, and K_t is the cumulative catch to the start of period t plus half that taken during the period. Catchability is defined as the proportion of B_0 that is captured with one unit of effort (one hour trawled).

The application of the Leslie model and an example of within-season changes in CPUE during the course of a fishery at a single location (Kiska, from May-July 1994) are illustrated in Figure 10. The time series of Atka mackerel catches by the fleet is shown in Figure 10A (a total of 22,500 mt caught from late March - week 11, to late July - week 29). Haul-by-haul CPUE is shown in Figure 10B, while fleet CPUE pooled by week is shown in Figure 10C. For the Leslie regression line shown in Figure 10C (regression coefficient is significantly different from 0 at $p<0.001$), weekly CPUE is regressed against cumulative catch (K_t as described above). Extending this line to the x-axis (where CPUE=0) yields an estimate of the initial biomass of the fished population given the assumptions of the model. In this case, it was estimated that 32,200 mt of Atka mackerel was present prior to the fishery which caught 22,500 mt, yielding an estimate of the harvest rate of 70%. This is similar to the percentage decline in CPUE estimated from the regression: CPUE during the first week of the fishery was 37.7 mt/hour, and in the last week was 14.7 mt/hour, a decline of 61%.

Subsequent Leslie depletion analyses were completed for 37 time-area fisheries in 1986-97. The areas analyzed included east and west of Buldir Island, west of Kiska Island, two areas south of Amchitka Island, north of the Delarof Islands, the east side of Tanaga Pass, and south of Seguam Island (Figure 4). With an alpha value of 0.05, a total of 17 of the 37 time-area fisheries yielded statistically significant relationships between cumulative catch and CPUE; CPUE increased significantly in one case and declined significantly in 16 cases. In general, the greater the total catch in an area, the more likely a significant decline in CPUE.

The use of the Leslie model (as described by Ricker [1975] and Gunderson [1993]) to estimate stock abundance has been primarily restricted to intensive fishing experiments of relatively sedentary species, such as invertebrates (Ralston 1986; Joll and Penn 1990; Iribarne *et al*. 1991; Miller and Mohn 1993) or tropical reef fish (Polovina 1986), using standardized gear in well-defined areas. With a time-series of catch and effort data from such experiments, Leslie's model permits estimation of the species' initial abundance and its catchability (proportion of the stock caught with one unit of effort) within the context of certain assumptions, which include that: 1) the population being fished is closed, or alternatively that immigration and growth are equal to emigration from the area plus natural mortality, 2) catchability over the course of the experiment remains constant, and 3) changes in catch per unit effort are directly related to changes in fish density.

These assumptions appear to be reasonable for the Atka mackerel fish stock in the central and western Aleutian Islands. The fish are found in well-defined habitat and the fishery operates at relatively constant locations. The duration of the fishery is relatively short so that natural mortality and migration into and out of the fish stocks are likely limited. Catchability could change over the course of the fishery, but if such changes occur, say as a result of dispersion or altered schooling behavior, those changes could also have detrimental affects on foraging sea lions. Finally, the use of CPUE as direct measure of fish density or abundance may be considered problematic, but CPUE is commonly used as a reliable index of density or abundance.

While all of the assumptions of the Leslie model may not be met perfectly in these fisheries, the model is sufficiently reliable to indicate a consistent and meaningful pattern of depletion due to fishing. The Scientific and Statistical Committee reviewed the results of the 37 time-area fisheries and suggested a number of considerations for improving the analysis of CPUE. Nevertheless, the committee also concluded:

> ". . . the main conclusion that CPUE declines substantially in some areas at some times seems fairly certain. These declines are indicative of local depletion, although alternative hypotheses include emigration from the area, natural mortality, and changes in catchability due to changes in fish or fisher behavior. The declines are in line with expectations related to level of catch: the higher the catch and the longer the season, the more likely there is to be a substantial decline. Finally the magnitudes of the estimated decline can be quite substantial at up to 94% (although it averaged 56% in 1996 and 37% in 1997). Therefore, the Atka mackerel fishery may have a large effect on fish abundance in some areas at some times."

2.1.7 Potential direct and indirect effects of the Atka mackerel fishery on Steller sea lions

The evidence for fishery-induced localized depletion of Atka mackerel stocks raised two concerns. The first was a direct response to the evidence for localized depletion, which supported the contention that availability of prey for Steller sea lions may be reduced by the fishery. Possible reductions in prey availability had been raised as concerns in the 1991 and 1996 biological opinions on the groundfish fisheries in the BSAI and GOA regions. Reductions in prey availability could lead to decreased condition of sea lions, with subsequent decreases in reproduction or survival.

The second concern was the total amount of Atka mackerel removed by the fishery from Steller sea lion critical habitat. Critical habitat was designated in 1993, and the single most important feature of the marine areas included was their prey base. Atka mackerel are known to be an important prey for Steller sea lions in the region of the fishery (Merrick *et al*. 1997). The issue was whether large scale removals of a known important prey from critical habitat constituted adverse modification of that habitat. These potential effects of the fishery are considered further in the section on effects of the action.

2.1.8 Conservation measures associated with the Atka mackerel fishery

Conservation measures are actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions serve to minimize or compensate for project effects on the species under consideration.

The evidence for fishery-induced localized depletion of Atka mackerel stocks was reviewed and considered by the NPFMC in April and June, 1998. In June, the NPFMC moved to recommend to the Secretary of Commerce a regulatory amendment to impose an A/B season apportionment (50:50) of Atka mackerel TAC in each of the three management areas, and to incrementally shift the fishery catch in areas 542 and 543 until a target split of 40% inside and 60% outside was reached in 2002.

Percentage of annual Atka mackerel TAC taken inside of Steller sea lion critical habitat.

	Management Area	
Year	543	542
Current	85	95
1999	65	80
2000	57	67
2001	48	54
2002	40	40

Additional components of the NPFMC motion included a year-round 20-nautical-mile no-trawl zone around Seguam rookery in area 541, mandatory use of vessel monitoring systems for all vessels in the fishery, exemption of the Atka mackerel jig fishery from the motion, exemption of the Community Development Quota (CDQ) fisheries from the A/B season split, A/B seasons corresponding to A/B season dates for the pollock fishery, annual review of the amendment, and a recommendation for cooperative research by NMFS and other parties (including industry) to determine the effects of these management measures.

2.2 BSAI and GOA pollock fisheries

Walleye pollock (*Theragra chalcogramma*) is a member of the cod family, Gadidae, order Gadiformes. Hereafter, the species will be referred to simply as pollock.

2.2.1 Distribution and life history of pollock

Pollock is the most abundant species within the EBS and the second most abundant groundfish stock in the GOA. It is widely distributed throughout the North Pacific in temperate and subarctic waters (Wolotira *et al*. 1993). Pollock is a semi-demersal schooling fish, which becomes increasingly demersal with age. Approximately fifty percent of female pollock reach maturity at age four, at a length of approximately 40 cm. Springer (1992) described the spawning season: "Spawning usually begins in February over the southeastern continental slope and progresses onto the shelf north of Unimak Pass, where most eggs are released in March-April. Spawning continues, and generally declines, along the outer shelf to the northwest, with eggs being released in the vicinity of the Pribilof Islands in April-May and south and west of St. Matthew Island in May-June." In the EBS, the largest concentrations occur in the region north of Unimak Pass. In the GOA, the largest spawning concentrations are in Shelikof Strait and the Shumagin Islands (Kendall *et al*. 1996). Juvenile pollock are pelagic and feed primarily on copepods and euphausiids. As they age, pollock become increasingly piscivorous and can be highly cannibalistic, with smaller pollock being a major food item (Livingston 1991b). Pollock are comparatively short-lived, with a fairly high natural mortality rate estimated at 0.3 (Hollowed *et al*. 1997, Wespestad and Terry 1984) and maximum recorded age of around 22 years.

Stock structure of Bering Sea pollock is not well defined (Wespestad 1993), but three stocks are recognized in the BSAI for management purposes: EBS, Aleutian Islands and Aleutian Basin (Wespestad *et al*. 1997). Springer (1992) suggests that smaller pollock (<40 cm) from the EBS remain on the shelf in the summer and move to the slope in the winter. He also suggests that pollock less than 25 cm may drift to the northwest and that over 90% of this size class may be found on the shelf west and northwest of St. Matthew Island, compared with 3% in the EBS south of the Pribilof Islands. Pollock in the GOA are thought to comprise a single stock (Alton and Megrey 1986).

The diet of pollock in the EBS has been studied extensively (Dwyer 1984, Lang and Livingston 1996, Livingston 1991b, 1993, Livingston and DeReynier 1996). Pollock consume juveniles of Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, rock sole, yellowfin sole, Greenland turbot, Pacific halibut and Alaska plaice. However, pollock are cannibalistic and the dominant fish prey appears to be juvenile pollock. On the shelf area of the EBS, the contribution of the other fish prey to the diet of pollock tends to be very low (i.e., usually less than 2% by weight of the diet; Livingston 1991b, 1993, Livingston and DeReynier1996). However, in the deeper slope waters, deep-sea fish (myctophids and bathylagids) are a relatively important diet component (12% by weight), along with euphausiids, pollock, pandalid shrimp, and squid (Lang and Livingston 1996). Cannibalism by pollock in the Aleutian Islands region has not yet been documented (Yang 1996).

Cannibalism rates in the EBS vary depending on year, season, area, and predator size (Dwyer *et al*. 1987, Livingston 1989b, Livingston and Lang 1997). Cannibalism rates are highest in autumn, next highest in summer, and lowest in spring. Cannibalism rates by pollock larger than 40 cm are higher than those by pollock less than 40 cm. Most pollock cannibalized are age-0 and age-1 fish, with most age-1 pollock being consumed northwest of the Pribilof Islands where they occur in greatest abundance. Pollock larger than 50 cm tend to consume most of the age-1 fish. Smaller pollock consume mostly age-0 fish. Although age-2 and age-3 pollock are sometimes cannibalized, the frequency of occurrence of these age groups in the stomach contents is quite low. Laboratory studies (Sogard and Olla 1993) have shown and field studies have confirmed cannibalism among age-0 pollock, but so far this interaction appears not to be very important.

Field and laboratory studies have examined behavioral and physical factors that may influence
et al. 1995, Sogard and Olla 1993,

stratification, but these recent studies show that age-0 pollock do move below the thermocline into waters inhabited by adults. Larger age-0 fish tend to move below the thermocline during the day,

during the day. If food availability is high, all sizes tend to stay above the thermocline, but when food resources are low then even small age-0 fish do move towards the colder waters, perhaps as

the thermal gradient and food availability to juveniles in an area.

Various studies have modeled pollock cannibalism in either a static or dynamic fashion (Dwyer

Livingston 1991a , 1994; Livingston *et al*
structured simulations and suggested that with the current annual fishing mortality rate (F=0.3) the population tended toward equilibrium. They also suggested that cannibalism is a stabilizing influence, with the population showing less variation compared to simulations in which cannibalism was not included. Zooplankton populations were also simulated in the model, and Knechtel and Bledsoe (1983) concluded that food was limiting, particularly for adult pollock. Maximization of average catch occurred at F=3.0, which is about ten times higher than the actual fishing mortality rates in the EBS. However, the interannual variation in catches under this hypothetical scenario was extremely large.

The trend in more recent modeling efforts (Honkalehto 1989, Livingston, 1993, 1994) has been to examine cannibalism using more standard stock assessment procedures such as virtual population analysis or integrated catch-age models such as Methot's (1990) synthesis model. The purpose has been to obtain better estimates of juvenile pollock abundance and mortality rates and improve knowledge of factors affecting recruitment of pollock into the commercial fishery at age 3. Results (Livingston 1993, 1994) suggest that in the current state of the EBS, cannibalism appears to be the most important source of predation mortality for age-0 and age-1 pollock. Predation mortality rates are not constant, as assumed in most population assessment models, but vary across time mainly due to changes in predator abundance, but perhaps also due to predators feeding more heavily on more abundant year classes. The decline in pollock recruitment observed at high pollock spawning biomass may be due to cannibalism. The environment also appears to be important (Wespestad *et al*. 1997), as surface currents during the first three months of life may transport larvae to areas more favorable to survival (e.g., away from adult predators or to areas more favorable for feeding).

Other groundfish predators of pollock include Greenland turbot, arrowtooth flounder, Pacific cod, Pacific halibut, and flathead sole (Livingston *et al*. 1986, Livingston 1991a, Livingston *et al*. 1993, Livingston and DeReynier1996). These species are some of the more abundant groundfish in the EBS, and pollock constitutes a large proportion of the diet for many of them. Other less abundant species that consume pollock include Alaska skate, sablefish, Pacific sandfish, and various sculpins (Livingston 1989a, Livingston and DeReynier 1996). Small amounts of juvenile pollock are consumed by small-mouthed flounders such as yellowfin sole and rock sole (Livingston 1991a, Livingston *et al*. 1993, 1996). Age-0 and age-1 pollock are the targets of most of these groundfish predators, with the exception of Pacific cod, Pacific halibut, and Alaska skate, which may consume pollock from age 0 to greater than age 6, depending on predator size.

Pollock is a significant prey item of marine mammals and birds in the EBS. Pollock is a prey item for the Steller sea lion (NMFS 1995, Merrick *et al*. 1997; see status of the Steller sea lion below), as well as the northern fur seal, harbor seal, spotted seals, ribbon seals, fin whales, minke whales, and humpback whales. Pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair *et al*. 1994, Sinclair *et al*. 1997). The main sizes of pollock consumed range from 3 to 20 cm or age-0 and age-1 fish, but older age classes of pollock may appear in the northern fur seal diet when young pollock are less abundant (Sinclair *et al*. 1997). Pollock are one of the most common prey in the diet of spotted seals and ribbon seals, which feed on pollock in the winter and spring in the areas of drifting ice (Lowry *et al*. 1997).

Five species of piscivorus birds dominate the avifauna of the EBS: northern fulmar, red-legged kittiwake, black-legged kittiwake, common murre, and thick-billed murre (Kajimura 1984, Schneider and Shuntov 1993). Pollock is particularly important in the diets of northern fulmars, black-legged kittiwakes, common murres, and thick-billed murres, while red-legged kittiwakes tend to rely more heavily on myctophids (Hunt *et al*. 1981, Kajimura 1984, Springer 1992). Age-0 and age-1 pollock are consumed by these bird species, and the dominance of a particular pollock age-class in the diet varies by year and season. Fluctuations in chick production by kittiwakes have been linked to the availability of fatty fishes such as myctophids, capelin and sand lance (Hunt *et al*. 1995). Changes in the availability of prey, including pollock, to surface-feeding seabirds may be due to changes in sea surface temperatures and the locations of oceanographic features (e.g., fronts) which could influence the horizontal or vertical distribution of prey (Decker *et al*. 1995, Springer 1992).

The diet of pollock, particularly adults, in the GOA has not been studied as thoroughly as in the EBS. Larvae, 5-20 mm in length, consume larval and juvenile copepods and copepod eggs (Kendall *et al*. 1987, Canino 1994). Small juvenile pollock (25 to 100 mm) in the GOA primarily eat juvenile and adult copepods, larvaceans, and euphausiids while older juveniles (100 to 150 mm) eat mostly euphausiids, chaetognaths, amphipods, and mysids (Walline 1983, Kreiger 1985, Livingston 1985, Grover 1990, Brodeur and Wilson 1996, Merati and Brodeur 1997). Juvenile and adult pollock in southeast Alaska rely heavily on euphausiids, mysids, shrimp and fish as prey (Clausen 1983); euphausiids and mysids are important to smaller pollock, while shrimp and fish are more important to larger pollock. Copepods appear in the summer diet, but are not a dominant prey item of pollock in the embayments of southeast Alaska. Similarly, copepods are a relatively minor component of the summer diet of pollock in the central and western GOA (Yang 1993). Euphausiids are the dominant prey, constituting a relatively constant proportion of the diet by weight across pollock sizes groups. Shrimp and fish are the next two important prey items.

In the GOA, fish prey become an increasing fraction of the pollock diet as pollock size increases. The dominant prey is capelin (*Mallotus villosus*), but over 20 different species of fish have been identified in the stomach contents of pollock from this area (Yang 1993). Commercially important fish prey included: Pacific cod (*Gadus macrocephalus*), pollock, arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides elassodon*), dover sole (*Microstomus pacificus*), and greenland halibut (*Reinhardtius hippoglossoides*). In addition to capelin, other forage fish included eulachon (*Thaleichthys pacificus*) and Pacific sand lance (*Ammodytes hexapterus*).

Dominant populations of groundfish in the GOA that prey on pollock include arrowtooth flounder, sablefish, Pacific cod, and Pacific halibut (Jewett 1978, Albers 1985, Best and St. Pierre 1986, Yang 1993). Pollock is one of the top five prey items (by weight) for Pacific cod, arrowtooth flounder, and Pacific halibut. These species also prey on Pacific herring and capelin. Other predators of pollock include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993). As in the EBS, Pacific halibut and Pacific cod tend to consume larger pollock, and arrowtooth flounder consumes pollock that are mostly less than age 3. Unlike the EBS, however, the main source of predation mortality on pollock at present appears to be from the arrowtooth flounder (Livingston 1994). Predation mortality by arrowtooth flounder, Pacific halibut, and Steller sea lions has been included in the stock assessment for pollock in the GOA (Hollowed *et al*. 1997).

The diets of marine mammals and birds in the GOA are not as well studied as in the EBS (Pitcher 1980a, 1980b, 1981, Calkins 1987, DeGange and Sanger 1987, Lowry *et al*. 1989, Hatch and Sanger 1992, Brodeur and Wilson 1996, Merrick and Calkins 1996). Brodeur and Wilson (1996) summarized both bird and mammal predation on juvenile pollock. The main piscivorus birds that consume pollock in the GOA are common murres, thick-billed murres, tufted puffins, and horned puffins. The diets of murres have been shown to contain around 5% to 15% age-0 pollock by weight, depending on season. The tufted puffin diet is more diverse and tends to contain more pollock than that of the horned puffin (Hatch and Sanger 1992). Both horned puffins and tufted puffins consume age-0 pollock; The percent of pollock in the diet of tufted puffin varies by region with very low percents (<5%) in the north-central Gulf and Kodiak areas, intermediate amounts (5% to 20%) in the Semidi and Shumagin Islands, and large amounts (25% to 75%) in the

Sandman Reefs and eastern Aleutian Islands. The proportion of juvenile pollock in the diet of tufted puffin at the Semidi Islands varies by year and appears to be related to pollock yearclass abundance.

Walleye pollock is a major prey of Steller sea lions and harbor seals in the GOA (Pitcher 1980a, 1980b, 1981, Merrick and Calkins 1996, Merrick *et al*. 1997; see status of Steller sea lions below). Relative to Steller sea lions, harbor seals may have a more diverse diet with less frequent predation on pollock.

2.2.2 Trends in biomass of BSAI and GOA pollock

Estimated biomass of pollock in the EBS has been highly variable (Figure 11), ranging from less than 2 million metric tons (mmt) in the mid 1960s to almost 8 mmt in 1971, then declining to about 4 mmt in 1978. By 1984, estimated biomass had increased to 14 mmt, due to strong year-classes in 1978 and periodically in the 1980s, then declined to 8 mmt in 1990, increased again to over 12 mmt in 1993, and subsequently declined to about 7 mmt in 1997.

In the GOA, estimated biomass of pollock was less than 0.8 mmt in the late 1960s (Figure 12), increased to almost 3 mmt in 1980-1981, declined sharply to about 1.5 mmt in 1985, and has continued to decline to about 1 mmt in 1994-1997.

Over the last 15 years, NOAA's Fisheries Oceanography Coordinated Investigations (FOCI) targeted much of their research on understanding processes influencing recruitment of pollock in the GOA (Kendall *et al*. 1996). Bailey *et al*. (1996) reviewed 10 years of data for evidence of density dependent mortality at early life stages. They found such evidence only at the late larval to early juvenile stages of development. They hypothesized that pollock recruitment levels can be established at any early life stage (egg, larval or juvenile) depending on sufficient supply from prior stages. They labeled this hypothesis the supply dependent multiple life stage control model. In a parallel study, Megrey *et al*. (1996) reviewed data from FOCI studies and identified several events that are important to survival of pollock during the early life history period. These events are climatic in nature (Hollowed and Wooster 1995, Stabeno *et al*. 1995) and include preconditioning of the environment prior to spawning (Hermann *et al*. 1996), the ability of the physical environment to retain the planktonic life stages of pollock on the continental shelf (Schumacher *et al*. 1993, Bograd *et al*. 1994), and the abundance and distribution of prey and predators on the shelf (Bailey and Macklin 1994, Canino 1994, Theilacker *et al*. 1996). Thus, the best available data suggest that pollock year class strength is controlled by sequences of biotic and abiotic events and that population density is only one of several factors influencing pollock production.

2.2.3 Overview of the pollock fisheries

From the mid-1970s to 1990, the pollock fishery, along with all other groundfish fisheries in Alaska, was transformed by the passage of the Magnuson Fishery Conservation and Management Act (MFCMA). One of the principal objectives of the MFCMA was 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. Most of the fishery effort for pollock was located in the EBS and Aleutian Islands region (i.e., BSAI). Catches of BSAI pollock increased quickly from about 100,000 mt in 1964 to over 1.8 mmt in 1972 (Figure 13). Beginning in 1973, declines in BSAI pollock abundance led to reductions in catch quotas to about 1.0 mmt in 1977. Little fishing effort was devoted to pollock in the GOA until the mid-1970s, when about 100,000 mt was caught per year (Figure 14).

After passage of the MFCMA in 1976, increasing amounts of pollock TAC were allocated to joint-venture operations between domestic catcher vessels and foreign processing ships to encourage development of the domestic fishing industry. Joint-ventures for pollock first became important 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 mt; Figure 13). Due to declines in the size of the spawning population in Shelikof Strait, NMFS reduced the GOA pollock TAC in 1986 to about 80,000 mt. 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 (Figs. 12, 14). 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. Beginning in 1992, pollock catch quotas have been allocated separately to the onshore (i.e., shoreside or inshore) and offshore (i.e., catcher processors or factory trawlers) as a result of the passage of the Inshore/Offshore amendments to the BSAI and GOA FMPs (numbers 18 and 23, respectively). These amendments mandated that 100% of the pollock catch from the GOA be processed at shoreside plants; in the BSAI, the onshore/offshore split of the pollock TAC was 35%:65% from 1992-98.

The temporal and spatial distribution of the pollock catch changed as fishery participation changed. Between 1963 and 1997 in both the BSAI region and GOA, the pollock fishery worked increasingly in fall and winter and fished more in areas which were designated as critical habitat for Steller sea lions 1993 (see reviews of Fritz *et al*. [1995] and Fritz and Ferrero [1998]).

2.2.3.1 Temporal distribution of effort

In the BSAI region prior to 1987 (when the spawning assemblage near Bogoslof Island was first exploited), the pollock fishery was conducted primarily in spring and summer (April-September) when about 70-80% of the landings were taken (Figure 15A). Since 1987, however, the proportion caught during fall and winter (September-March) increased to between 35-65% 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 ensured sufficient pollock TAC for the B season, but also increased the first quarter's proportion of the annual pollock catch. In 1993, the A season allocation was increased to 45%, and has remained at that level since. The starting date for the B season was also moved to August 15 in 1993 and then to September 1 beginning in 1996.

The temporal distribution of pollock catches in the GOA has been different than in the BSAI region. From 1964 to 1997, a greater percentage of the pollock were harvested in the fall and winter in the GOA than in the BSAI (Figure 15B), but total removals were less. However, when landings from the GOA exceeded 150,000 mt from 1981-85 during the Shelikof roe fishery, the proportion caught in fall and winter exceeded 50%, and ranged as high as 90%. Even after catches declined in 1986-89 in response to declining pollock biomass, the proportion caught in fall and winter remained above 70%. 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 pollock fishing opportunities for vessels based in the GOA. As pollock biomass and TACs declined in the mid 1990s, the number of seasonal releases was reduced to 3 (1 January, 1 June, and 1 September), with 25% of the annual TAC assigned to the first 2 and 50% to the last. For the 1998 GOA pollock fishery, the seasonal allocations to the 2nd and 3rd trimesters were changed to 35% and 40%, respectively, to reduce the pollock catches during the fall in response to an increase in TAC.

2.2.3..2 Spatial Distribution

Increases in the proportions of the annual regional pollock TAC caught in Steller sea lion critical habitat in the BSAI and GOA occurred simultaneously with the exploitation of spawning concentrations of pollock near Bogoslof Island in 1987 and in Shelikof Strait in 1982 (Figure 16). In the BSAI, the percentage caught within critical habitat increased from between 5-20% in the late 1960s to 15-30% from 1971-86. Actual removals mirrored the total catch during this period (1964-1986; Figure 13) and peaked at over 500,000 mt in 1971 and 1972, before decreasing to between 200,000 and 300,000 mt from 1977-86. From 1987-95, however, both the catch tonnage and percentage of annual removals of pollock from critical habitat increased more than 3-fold to over 800,000 mt and 60%, respectively. This shift resulted from increasing pollock fishery effort in fall and winter (when pollock are more concentrated within critical habitat) and an evolution in fleet composition from a mobile processing fleet (e.g., foreign factory trawlers) to one increasingly dominated by shore-based processors and their catcher vessels which fish in coastal fishing areas located within critical habitat. Furthermore, the Bogoslof area (area 518; see Figure 17) was closed in 1992 to protect the Aleutian Basin pollock stock. As a result, A-season effort in the eastern Bering Sea became concentrated on the spawning aggregation on the shelf north of Unimak Island.

The recent increase in BSAI critical habitat catches has occurred principally during the A season (January-March), as evidenced by high amounts (between 250,000 mt and 550,000 mt) and percentages (between 50-90%) removed from critical habitat between 1992 to 1997 (Figure 18). Recent effort in the B season has shown some movement out of critical habitat during the summer (Figure 19). Since 1992, catches of pollock from critical habitat during the B season have declined from about 350,000-400,000 mt to 250,000 mt, while the percentages have declined from about 50% to 40% of total B-season removals. Recent 3-year averages by season are:

- A-season 73%
- B-season 44%

Observed trawl locations in the BSAI pollock fishery for 1995-1997 are shown by season in Figures 20 and 21. Fritz (1993) details trawl locations of the BSAI pollock fishery by season from 1977 to 1992. In combination, these figures show the increasing use of critical habitat by the BSAI pollock fishery during the last 20 years.

In the GOA, pollock catches from critical habitat increased (as the TAC increased) from trace amounts prior to 1979 to over 200,000 mt in 1985, primarily from Shelikof Strait (Figure 16). Pollock landings from GOA critical habitat dropped (as the annual TAC declined) to about 50,000 mt in 1986, and have ranged between 35,000 and 90,000 mt through 1997. 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%. Recent (1995-1997) percentages of pollock catch taken from critical habitat are shown by season in Figure 22. As in the BSAI, percentage removals from critical habitat during the roe-harvesting season (January) have generally been the highest. Recent 3-year averages by season are:

- January 90%
- June/July 73%
- September/October 58%

Observed trawl locations in the GOA pollock fishery for 1995 to 1997 are shown by season in Figures 23-25. Fritz (1993) details trawl locations of the GOA pollock fishery by season from 1977 to 1992. These figures in combination show the increasing use of critical habitat by the GOA pollock fishery during the last 20 years.

Recent pollock fishery distribution patterns suggest that interactions with sea lions in critical habitats are ongoing despite the partitioning that was achieved in the vicinity of rookeries with the establishment of trawl exclusion zones. In the BSAI, where the pollock quota is allocated to broad EBS and Aleutian Islands management areas, the creation of 10- and 20-nautical mile trawl exclusion zones did not constrain landings from sea lion critical habitat. Pollock removals from critical habitat began increasing prior to 1991-1993, and may have increased further if protective measures had not been enacted. It must be noted, however, that the areas within the existing trawl exclusion zones were not heavily utilized by either the BSAI or GOA pollock fisheries prior to their creation; from 1984-1991, the annual percentage of pollock caught within these areas ranged only from 1-7% in the BSAI and from 0-3% in the GOA. In the GOA, the combination of spatial pollock allocations and trawl exclusion zones may have stabilized pollock removals and effort at 1986-1991 levels, but did not reduce them.

2.2.3.1.3 Depth distribution

Data on the fishing depth of pelagic trawl hauls targeting pollock in the BSAI and GOA were obtained from the fishery observer database for the years 1995-97. Figure 17 shows the areas over which pollock fishery depth distributions were obtained. Data from three on-shelf areas in the eastern Bering Sea were grouped separately: Unimak, shelf east of the Pribilof Islands, and the northern shelf (northwest of the Pribilof Islands). Data from two off-shelf and slope areas in the eastern Bering Sea (Pribilof Canyon and Unalaska) and two off-shelf and slope areas in the Aleutian Islands (Atka Island and Kanaga Island) were considered separately. Data from eight areas in the GOA (Chiniak Gully, Shelikof Strait and Gully, Alitak Bay, Marmot Bay, Portlock Bank, Nagai Strait, and Unga Strait) were grouped separately. The frequency of fishing depth in 10-25 m bins was obtained, and the percentage calculated. For many areas, distance off bottom was also obtained, frequencies binned into 10 m (for on-shelf areas) or 100 m (for off-shelf and slope areas) bins, and percentages calculated. Results are shown in Figures 26 through 29. Fishing depth is most commonly measured as the depth of the headrope.

Most pelagic pollock tows on-shelf in the eastern Bering Sea had fishing depths of less than 100 m. For the area north of Unimak Island (Figure 17), the most commonly fished depths in the A-seasons of 1995-97 were in the 60-80 m bin, the second most common bin was 80-100 m, and the third was 40-60 m; the three bins accounted for over 80% of the pelagic A-season pollock tows in this area. Pelagic pollock tows were slightly deeper and bimodally distributed in the B-season north of Unimak Island, with a steep mode centered at 80-100 m (total of about 40% of the tows), and a less steep mode centered at 200-220 m. East of the Pribilof Islands, the most common fishing depths were in the 60-70 m range, and over 90% were less than 100 m (A and B-seasons combined). On the northern shelf, the modal fishing depth range was 100-110 m, and about 90% were less than 130 m (Figure 26).

Pelagic pollock tows on the slope and over deep waters in the eastern Bering Sea (Figure 27) and in the Aleutian Islands (Figure 28) tended to be deeper, particularly in the A-season, than the on-shelf tows. During the A-season, almost all tows were deeper than 400 m at Pribilof Canyon and Unalaska, (Figure 27) and deeper than 250 m north of Atka and Kanaga Islands (Figure 28). During the B-season at the two eastern Bering Sea regions, fishing depths shoaled considerably, with modal ranges between 150-175 m at Pribilof Canyon and 125-150 m at Unalaska.

In the GOA, fishing depths varied considerably depending on the local bathymetry, though at most areas, modal depth bins were less than 130 m (Figure 29). Shallow areas included Alitak Bay and Shelikof Gully, where modal depth ranges were 40-50 m and 80-90 m (but skewed to deeper tows), respectively. Fishing depths in Nagai Strait also tended to be shallow, with over 50% of them < 100 m. Within Shelikof Strait, fishing depths were bimodally distributed, with a shallow mode centered at 90-100 m, and a deeper mode centered at 180-190 m. Other areas investigated included Chiniak (modes at 120-130 m and 140-150 m, but skewed to shallow depths), Portlock Bank (mode at 120-130 m) and Unga Strait (mode at 130-140 m).

2.2.3.2 Pollock fishery methods

The BSAI pollock fishery is composed of four sectors: 1) onshore fish processing plants (principally in Dutch Harbor, AK); 2) catcher-processors (principally based in Seattle, WA) that can catch and process fish, and receive fish from catcher vessels; 3) catcher vessels that can only catch fish and deliver it to onshore plants, catcher-processors, or motherships; and 4) motherships that cannot catch fish, but receive and process fish caught and delivered by catcher vessels. In 1996, there were 166 vessels or plants which participated in the BSAI pollock fishery: 8 onshore plants, 37 catcher-processors, 118 catcher vessels, and 3 motherships. Since 1992, when the first inshore/offshore allocation mechanism was put in place (Amendments 18/23 to the FMPs of BSAI and GOA groundfish), 7.5% of the pollock TAC has been allocated to a Community Development Quota for local Bering Sea communities to harvest or sell to other concerns. Of the remaining 92.5% of the BSAI pollock TAC, 35% has been given to the onshore sector, while 65% has been given to the offshore sector. The onshore sector consists of onshore processing plants and the catcher vessels that deliver to them. The offshore sector (in this context) consists of catcher-processors, motherships, and the catcher vessels that deliver to each of them. Some of the catcher vessels (22) participated in both the inshore and offshore sectors in 1996. Most pollock are caught with pelagic trawls fished off-bottom to reduce the bycatch of undesired (e.g., other demersal fish) or prohibited species (e.g., crab and halibut).

Of the 128 catcher vessels that participated in any trawl groundfish fishery in the BSAI in 1996, most (91, or 71%) were between 60-124 feet in length, only 6 (5%) were < 60 feet in length, and the remainder (31, or 24%) were between 125-230 feet in length. Of the 58 catcher-processors that participated in any trawl groundfish fishery in the BSAI in 1996, most (34, or 59%) were between 125-230 feet, only 7 (12%) were between 60-124 feet, and the remainder (21, or 36%) were > 230 feet in length.

Currently, pollock fishing in the BSAI occurs in two seasons: a roe fishery (roe is a valuable by-product of the fishery, surimi and fillets are also products) that fishes on spawning aggregations in winter (January 20 through early March) when 45% of the eastern Bering Sea and all of the Aleutian Island pollock TAC is currently taken; and a surimi-fillet fishery that fishes in summer (currently beginning September 1). The current EBS roe fishery concentrates primarily on the spawning aggregation(s) between Unimak Island and the Pribilof Islands. In the Aleutian Islands, the fishery used to occur in area 541 (Amukta Pass and west of the Bogoslof area) as recently as 1992, but has moved west to Kanaga Island and to the Near Islands in the last several years (1994-98). The summer fishery is more widely dispersed from Unimak Pass along the middle and outer continental shelf northwest to the U.S.-Russia convention line. Currently, the only spatial allocation of pollock TAC in the BSAI is between the Aleutian Islands and eastern Bering Sea areas. Observed pollock fishery trawl locations in 1995-1997 are shown by season in Figures 20 and 21.

The GOA pollock fishery has been allocated 100% (except for bycatch) to the onshore processing sector since the first inshore/offshore allocation amendment was enacted in 1992. Onshore plants that process pollock caught in the GOA are located principally in Kodiak, Sand Point, and Dutch Harbor, AK. In 1996, there were 96 catcher vessels that delivered GOA pollock to onshore plants; 38% of these had Alaska registry, while the remainder were registered outside of AK. Of the 162 trawl catcher vessels that participated in any groundfish fishery in the GOA, 63 (39%) were < 60 feet in length, 82 (51%) were between 60-124 feet in length, and 17 (10%) were between 125-230 feet in length. Most pollock are caught with pelagic trawls fished off-bottom to reduce the bycatch of undesired (e.g., other demersal fish) or prohibited species (e.g., crab and halibut).

In 1998 GOA pollock fishery was split into three seasons: a roe fishery that fishes on spawning aggregations in winter (beginning January 20) when 25% of the GOA pollock TAC is taken; and two summer fisheries, one beginning on July 1 (with 35%), and another beginning September 1 (with 40%). Seasonal allocations in 1996 and 1997 were 25%:25%:50% for pollock fisheries beginning on the same dates, while from 1992-95, the pollock TAC was allocated evenly (each at 25%) to fisheries beginning on 20 January, 1 June, 1 July, and 1 October. As the GOA pollock TAC declined, the number of seasons was reduced from 4 to 3. Observed pollock fishery trawl locations in 1995-1997 by season are shown in Figures 23-25.

2.2.3.3 Pollock catch history

The current age and size distributions of the EBS and Aleutian Island pollock stocks are discussed in Wespestad *et al*. (1997). Estimated EBS pollock biomass from 1964 to 1997 is shown in Figure 11, along with the catch history and calculated area-wide harvest rate (catch/biomass). As noted above, pollock biomass increased to almost 8 mmt in 1971, as catches increased from negligible amounts to over 1.8 mmt. As biomass declined through 1978, catches also declined to about 1 mmt. As biomass increased after 1978 and then fluctuated into the 1990s, catches fluctuated between 1.0 mmt and 1.5 mmt. Calculated harvest rates (catch/biomass) fluctuated widely in the beginning of the fishery, from about 10-15% in the mid-1960s to between 20-35% in the mid-1970s. Since 1979, estimated area-wide harvest rates of EBS pollock have fluctuated between 7 and 15%.

The current age and size distributions of GOA pollock are discussed in Hollowed *et al*. (1997). The estimated GOA pollock population biomass from 1969 to 1997 is shown in Figure 12, along with the catch history and calculated area-wide harvest rate (catch/biomass). As pollock biomass increased to almost 3 mmt in 1981, catches increased from negligible amounts to about 140,000 mt. From 1981-85, biomass declined but catches increased to over 300,000 mt, resulting in the only period since 1969 when harvest rates exceeded 10%. From the peak in 1981, population biomass declined to less than 1 mmt in 1995 and 1996, while catches since 1986 have generally been less than 100,000 mt each year. In the last 12 years, (1986 to 1997), estimated harvest rates of GOA pollock have ranged between 4 and 10%.

2.2.3.3.1 Area-specific harvest rates for the EBS

Area-specific harvest rates can be estimated for the EBS shelf in summer. Summer bottom trawl surveys have been conducted annually on the EBS shelf, but these surveys only sample the demersal fraction of the pollock population and do not provide estimates of the pelagic portion. Hydroacoustic surveys provide estimates of pelagic pollock abundance, and have been conducted on the EBS shelf in the summers of 1979, 1982, 1985, 1988, 1991, 1994, 1996, and 1997. Combining the results of the annual bottom trawl surveys and triennial hydroacoustic surveys yields estimates of the distribution and abundance of the entire pollock population on the EBS shelf in summer.

A spatial analysis of B-season pollock harvest rates was conducted by estimating pollock abundances and catches in three areas and four years. The three areas chosen were (Figure 17): (1) the Catcher Vessel Operational Area (CVOA; nearly equivalent to Steller sea lion critical habitat with regard to pollock catch distribution; Figs. 18 and 19); (2) east of 170°W long. outside of the CVOA; and (3) west of 170°W long. The years 1991, 1994, 1996, and 1997 were chosen because combined bottom trawl-hydroacoustic surveys of the pollock population were conducted in the summers of each of these years. The following method was used to calculate areal harvest rates (Figure 30).

! The distribution of survey estimates of age 3+ pollock biomass (30+ cm in length) in each area and year was used to apportion the stock assessment model (Wespestad *et al*. 1997) estimate of total eastern Bering Sea age 3+ biomass by area and year. This yielded estimates of age 3+ pollock biomass by area for each of the 4 years.

! Observer estimates of B-season pollock catch distribution by sector (offshore, mothership, and inshore), area, and year were used to apportion the blend estimates of B-season pollock catch by sector and year to each area. This yielded estimates of B-season pollock catch (almost entirely composed of pollock age 3 years and older) by area for each of the 4 years.

! Harvest rates were calculated using the ratio of catch to biomass by area.

Harvest rates of age 3+ pollock were higher in the CVOA than in either of the other two areas analyzed in the EBS (Figure 30). For each of the four years, harvest rates in the CVOA ranged from a low of 15% in 1994 to 49% in 1997, while in the other two areas, only one of the eight annual harvest rate estimates was greater than 10% and four were 5% or less. Furthermore, data suggest that harvest rates within the CVOA increased in 1996 and 1997 (when they were 29% and 49%, respectively) relative to 1991 and 1994 (when they were 26% and 15%, respectively). Total EBS survey/model age 3+ pollock biomass declined 38% from 1994 to 1997, but this decline was not evenly dispersed among each of the three areas. The decline was steepest in the CVOA, where pollock biomass declined 81% from 1994 to 1997, while in the other areas east and west of 170°, the decline was only 30% and 26%, respectively.

2.2.3.3.2 Area-specific harvest rates for Shelikof Strait

Similarly, area specific harvest rates can be estimated for Shelikof Strait (GOA) in winter. A hydroacoustic survey of the spawning pollock aggregation in Shelikof Strait (GOA) has been conducted on an almost annual basis for more than a decade. This survey, however, does not span the entire range of pollock in the GOA. Therefore, the results are useful as a measure of spawning stock size in Shelikof Strait through time, but does not reveal changes in the spawning distribution of pollock in the GOA.

Shelikof Strait spawning pollock biomass estimates, as measured by the echo-integration midwater trawl survey, declined approximately 85%, from 2.3 mmt to 0.3 mmt, between 1983 and 1993 (Figure 31). This decline was due, in part, to a natural progression of five sequential strong year classes passing through the population. In addition, pollock catches were concentrated in Shelikof strait during the mid-1980s (1983-1986), as the fleet targeted roe-bearing fish in winter: between 65-75% of the annual catch occurred in the first quarter of the year, and almost 100% of the first quarter catch was taken in Shelikof Strait. Beginning in the 1990s, quarterly and spatial pollock allocations dispersed the catch away from such concentrated temporal and spatial fisheries. Harvest rates on Shelikof Strait pollock ranged between 7-18% from 1983-1986, and declined to between 1-7% in 1993-1997. Since 1993, spawning stock estimates in the area have increased to between 0.5 and 0.6 mmt.

Data are not available to estimate harvest rates for areas other than Shelikof Strait because complete surveys were not conducted of the GOA pollock population in winter. However, much of the first quarter pollock fishery in area 630 occurs outside of Shelikof Strait on the east side of Kodiak Island (still in Steller sea lion critical habitat), where the population has been surveyed only in summer. Data are not available to estimate the size of the pollock aggregations fished in winter on the east side of Kodiak Island.

2.2.3.4 Age-size structure of pollock stocks and catches

The estimated age composition of EBS pollock from the stock assessment model for the years 1972 to 1997 is shown in Figure 32. Ages 4+ represent the portion of the population that is more than 50% recruited to the fishery, with average (1977 to 1994) fishery selectivity of ages 2 and 3 of only 5% and 27%, respectively (Wespestad *et al*. 1997). The age composition has been dominated by strong year classes, particularly those spawned in 1978, 1982, 1984, and 1989 (yielding large numbers of 3-year-olds in 1981, 1985, 1987, and 1992, respectively; Figure 33). The abundance of these year classes is evident in echo integration trawl and bottom trawl surveys in addition to the extensive fishery age-composition data that have been collected.

The estimated 1972-1997 age composition of GOA pollock from the most recent stock assessment model (Hollowed *et al*. 1997) is shown in Figure 34. The age composition has been dominated by several strong year classes which were spawned in 1972, 1975-79, 1984, 1988, and 1994 (Figure 35). The estimated mean age of the recruited portion of the population in 1997 was 4 years. Ages 3+ represent the portion of the population that is recruited to the fishery, however, pollock in the GOA are not fully recruited to the fishery (selectivity of 1) until age 5 years; selectivity of ages 2, 3, and 4 has averaged approximately 0.1, 0.3, and 0.6, respectively, in the 1990s (Hollowed *et al*. 1997).

2.2.3.5 Bycatch in the pollock fisheries

In the BSAI, most discard of pollock occurs in the trawl fisheries targeting species other than pollock (72% of all discards in 1996). Pollock are caught as bycatch in the trawl Pacific cod, rock sole, and yellowfin sole fisheries. Recent discard rates (discards/retained catch) of pollock in the pollock fishery have been about 7% (Wespestad *et al*. 1997). In 1996, 21,300 mt of pollock were discarded in the directed fishery compared to 55,200 mt discarded in all other fisheries (Wespestad *et al*. 1997). Starting in 1998, discarding of pollock is prohibited except in the fisheries where pollock are in bycatch only status.

Bycatch species of the BSAI pollock fishery include juvenile pollock, other groundfish, and other species, most of which are caught at rates (mt bycatch species/mt pollock) well below 1% (Table 4).

In the GOA, most discard of pollock occurs in the trawl fisheries targeting species other than pollock (69% of all discards in 1996). Discard rates (discards/retained catch) of pollock in the pollock fishery were 3.4% in 1996. Pollock are also caught as bycatch in the trawl fisheries for various flatfish and Pacific cod, and to a lesser extent, rockfish. In 1996, 1,600 mt of pollock were discarded in the directed fishery compared to 3,600 mt discarded in all other fisheries. Starting in 1998, discarding of pollock is prohibited except in the fisheries where pollock are in bycatch only status.

Bycatch species of the GOA pollock fishery include juvenile pollock, other groundfish, and other species. Bycatch of groundfish other than pollock has generally been less than 5%

(mt bycatch species/mt pollock), while bycatch rates of other species has been well below 1% (Table 4).

2.2.4 Fishery management and the setting of harvest parameters for the pollock fisheries

The BSAI pollock fishery is managed under the BSAI Groundfish FMP. Regulations include moratorium permits and limited entry, record-keeping and reporting requirements, gear restrictions, observer monitoring, quotas (TACs), seasonal and geographic restrictions on the TAC, allocation of 7.5% of the TAC to CDQ groups, in-season adjustments to prevent catch above the TAC, closed areas (e.g., no-trawl zones around Steller sea lion rookeries), and allocations to different fishery sectors. Separate pollock TACs are assigned to the EBS and Aleutian Islands (AI) regions based on separate stock assessments. The EBS fishery is split into two seasonal allocations: 1) 45% of the TAC to the roe, or A, season beginning January 20 and currently lasting 5-6 weeks, and 2) 55% of the TAC to the surimi/filet, or B, season currently beginning on September 1 and lasting approximately 6 weeks. In the Aleutian Islands region, the TAC is not allocated by season, and all of the recent TAC has been taken during the A season.

The pollock fishery in the GOA is managed under the GOA Groundfish FMP. Regulations include moratorium permits and limited entry, record-keeping and reporting requirements, gear restrictions, observer monitoring, quotas (TACs), seasonal and geographic restrictions on the TAC, in-season adjustments to prevent catch above the TAC, closed areas (e.g., no-trawl zones around Steller sea lion rookeries), and allocations to different fishery sectors. Since 1993, 100% of the GOA pollock TAC has been allocated to the inshore sector. TACs in the central and western management areas are divided into three fishing periods beginning January 1 (January 20 for trawl gear), June 1, and September 1, with TAC apportioned among these seasons in the ratio 25%:35%:40%. In 1998, trawl gear was prohibited east of 140 W long. and discard of pollock was also prohibited (i.e., 100% retention was required).

In the GOA, major exploitable concentrations are found primarily in the Central and Western regulatory areas (147°-170° W Long.). Pollock from this region are managed as a single stock, separate from those in the BSAI (Alton and Megrey 1986). Currently (and since 1992), all pollock caught in the GOA must be processed onshore.

Beginning in 1990, the GOA pollock quota was apportioned seasonally, with equal apportionments to each of four quarters. The purpose of this apportionment was to ensure that fishing operations based in the GOA were not pre-empted from pollock fishing opportunities throughout the year by the larger fleet based in Dutch Harbor that normally fishes in the BSAI. As a result of decreasing TACs, the number of seasonal releases of GOA pollock was reduced from 4 to 3 in 1996. Beginning in 1991, the NPFMC apportioned the TAC spatially to enhance sea lion recovery and conservation. Consequently, the western/central GOA pollock TAC is currently allocated to each of three management areas and three seasons.

2.2.4.1 Stock assessment of BSAI pollock

Pollock in the EBS are assessed with an age-structured model incorporating catch and age composition data from the fishery and two types of surveys. Data are collected by NMFS observers aboard commercial fishing vessels and at shoreside processing plants, and by NMFS scientists conducting annual trawl surveys and triennial echo integration (hydroacoustic) trawl surveys. In the Aleutian Islands, the data are from observers on vessels and from triennial bottom trawl surveys. These different data sets are analyzed simultaneously to obtain an overall view of each stock's condition.

Bottom trawl surveys are conducted annually during June through August and provide a consistent time series of adult population abundance from 1982-1997. The bottom trawl data may not provide an accurate view of pollock distribution because a significant portion of the pollock biomass may be pelagic and not available to bottom trawls, and much of the Aleutian Islands shelf can not be trawled due to rough bottom. Echo-integrated trawl surveys are conducted every three years (typically) and provide an abundance index on more pelagic (typically younger) segments of the stock. Both surveys dispose their catches into their relative age compositions prior to analyses. Fishery data include estimates of the total catch by area/time strata and also the average body weight-at-age and relative age composition of the catch within each stratum. The results of the statistical model applied to these data are updated annually and presented in the BSAI pollock chapter of the NPFMC BSAI SAFE report. Separate analyses on pollock stocks in the Aleutian Islands and Bogoslof areas are also included. These analyses are constrained by data limitations and are presented relative to the status of the EBS stock. The stock assessment is reviewed by the NPFMC Plan Team and the Scientific and Statistical Committee, and then presented to the NPFMC.

2.2.4.2 Stock assessment of GOA pollock

The GOA pollock stock is assessed using the stock synthesis model (Methot 1990, Hollowed *et al*. 1997). This model is a maximum-likelihood approach to age-structured modeling that allows for incorporation of ancillary data from fisheries and fisheries-independent sources. Likelihood components are estimated for each component of the model (multinomial for age composition data and lognormal for survey biomass estimates) and emphasis can be subjectively adjusted for each likelihood component , with emphasis determined by the reliability and importance of the data pertinent to each component.

Model assumptions include (Hollowed *et al*. 1997): 1) natural mortality of 0.3 for all ages and years, 2) fishery mortality can be separated into age- and year-dependent factors, 3) catch at age is well described by the Baranov equation, 4) age selectivity by the fishery differs between time periods, 5) catchability for the hydroacoustic survey can be estimated and catchability of the bottom trawl survey is 1, 6) the model is robust to combining of age groups that represent less than 1% of the population, survey abundance is proportional to total abundance, 7) standard errors for the 1992 hydroacoustic surveys are indicative of errors in subsequent years, 8) domestic discards have the same age distribution as retained fish, and 9) catchability for egg production estimates equals catchability for hydroacoustic surveys in the Shelikof Strait. The model incorporates ageing imprecision and domestic discards, and length frequency data are converted to ages using the von Bertalanffy growth function with parameters estimated from age-length data collected during the 1991 and 1992 hydroacoustic surveys. Maturity-at-age is incorporated from Hollowed *et al*. (1991) and weight-at-age from Hollowed *et al*. (1995).

Sources of data for the model include observer and port sampling data, annual hydroacoustic surveys in the Shelikof Straits area, and triennial bottom trawl surveys. The data consist of estimates of total catch biomass, bottom trawl biomass estimates, hydroacoustic survey estimates of the spawning biomass in Shelikof Strait, egg production estimates of spawning biomass in Shelikof Strait, fisheries catch at age and survey size and age compositions. Fishery catch statistics (including discards) are estimated by the NMFS Alaska Regional Office. These estimates are based on the best blend of observer-reported catch and weekly production reports. Age composition data are obtained from several sources including catch-at-age aggregated over all seasons, nations, vessel classes and INPFC statistical areas for the years, and numbers at age from the spring hydroacoustic survey and the bottom trawl surveys. An additional estimate of the age composition of the population in 1973 was available from a bottom trawl survey of the GOA. Length frequency data collected from the hydroacoustic surveys are also included in the model, as is historical information on pollock size composition obtained from the Japanese Pacific ocean perch fishery from the period 1964-1975 (Hollowed *et al*. 1991). Cumulative impacts on the age composition due to fishing mortality accrue because of the selectivity of the fishery; the current age composition reflects a 36-year catch history. Selectivity varies over time due to changes in fishery regulation, gear, and year class strength. The recent fishery tends to select mature fish ages 5 to 9 years old (Hollowed *et al*. 1997). Despite the long catch history, the age structure of the population is primarily determined by incoming recruitment. As a strong year class progresses through the population, the mean age of the population increases. When several strong year classes occur in sequence, the mean age of the population decreases. Again, the stock assessment is reviewed by the NPFMC Plan Team and the Scientific and Statistical Committee, and then presented to the NPFMC.

2.2.4.3 Setting the pollock TACs

Eastern Bering sea pollock fall into tier 3 of the ABC/OFL definitions in 1997, which require reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{30\%}$ rate which is 0.65 for pollock and equates to a yield of 2.3 million mt (Wespestad *et al*. 1997). The maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate which is 0.36 for pollock and translates to a yield of 1.49 million mt. The current ABC recommendation for pollock from the stock assessment is 1.1 million mt, well below the maximum rate prescribed under tier 3a. This lower level has been adjusted downwards to provide a risk-averse harvest rate which more accurately reflects the degree of uncertainty in stock biomass and projected recruitment.

In 1997, GOA pollock also fell into tier 3 of the ABC/OFL definitions. Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawner stock biomass to 30% of its unfished level (the $F_{30\%}$ rate). In 1997, the full recruitment fishing mortality $F_{30\%}$ rate was 0.517 for pollock and equated to a yield of 170,500 mt for the Central and Western GOA (Hollowed *et al*. 1997). The projected 1998 spawner stock biomass fell below $B_{40\%}$, therefore the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate 0.341 (Hollowed *et al*. 1997). This F_{ABC} translated to a yield projection of 120,800 mt in 1998 for the western and central regions. The 1998 NPFMC ABC level was 120,800 mt for the western and central regions, which was equivalent to the recommended stock assessment ABC, and equivalent to the TAC. Current harvest rates were set to ensure a healthy spawning stock and successful recruitment over long time periods and recruitment variations.

2.2.4.4 Allowance for other marine predators

The stock synthesis model used for stock assessment can accommodate predation mortality of pollock by arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), and the Steller sea lion (Hollowed *et al*. 1997). These predators are effectively treated as fisheries with their own abundance (converted to biomass), selectivity, and catchability estimates. Consumption rates for sea lions were estimated using historical counts of sea lions in selected regions of the GOA (NMML, unpubl. data), the 1975-1978 and 1985 data from the GOA (Pitcher 1981, Calkins and Goodwin 1988), and estimates of daily ration (Perez 1990, Perez *et al*. 1990). Incorporation of predation mortality led to annual variation in natural mortality that was higher than generally assumed. The combination of variability in natural mortality and underestimation of natural mortality could mislead researchers attempting to understand recruitment processes (Hollowed *et al*. 1997). While the results of the model with natural predators are only preliminary, inclusion of such information may be a useful approach to addressing ecosystem concerns (Hollowed *et al*. 1997).

2.2.5 Action areas for the pollock fisheries

2.2.5.1 BSAI pollock fishery

The action area for the BSAI pollock fishery can be estimated using a) the observed distribution of the fishery (Fritz 1993, Fritz *et al*. 1998) from the 1970s to the present, b) the estimated distribution of pollock stocks in the Bering Sea, and c) the distribution of Steller sea lions that forage in areas where pollock stocks are fished or where pollock biomass is affected by fishing in other locations. The observed distribution of the fishery effectively encompasses the entire Bering Sea from about 62°N lat. to shelf break south of the Aleutian Islands, from the eastern areas of Bristol Bay to the Aleutian Basin and Donut Hole, and along the Aleutian Islands at least as far west as the Semichi Islands. Areas of concentrated effort include the EBS shelf, along the shelf break from the Aleutian Islands to the U.S./Russian boundary, north of Umnak Island in the waters around of Bogoslof Island. The distribution of pollock in the BSAI region varies seasonally with spawning aggregations in the EBS and vicinity of Bogoslof Island, and then dispersion northward and westward to cover the Bering Sea and Aleutian Basin.

Twenty-eight Steller sea lion rookeries and 49 major haulouts occur in this region (50 CFR, Tables 1 and 2 for part 226.12). Thus, Steller sea lions that may be affected by the pollock fishery haulout at terrestrial sites from St. Matthew (haulout) and the Pribilof Islands (haulout and rookery sites) in the north, and all along the Aleutian Chain from Amak Island and Sea Lion Rock in the southeastern Bering Sea westward to the Commander Islands. Hill and DeMaster (*in prep*) suggest a 1996 western population of 39,500, of which about 56%, or just over 22,000, occurred in the BSAI region. The extent to which sea lions from Russian territories (along the eastern shore of the Kamchatka peninsula) are affected by the pollock fishery is uncertain. With the exception of no-trawl zones, the distribution of the fishery and the distribution of foraging sea lions overlap extensively.

2.2.5.2 GOA pollock fishery

The action area for the GOA pollock fishery extends to the shelf break from the area south of Prince William Sound to west of Umnak Island in the Aleutian Islands. The fishery is divided into eastern, central, and western regions (Figure 17). The boundary between the eastern and central regions is at 147°W long., and essentially overlays the easternmost rookery and haulouts of the western population. The management areas of primary concern are, therefore, the central and western regions. The central and western regions are divided into three management areas, all of which extend from the 3-mile state boundary to the EEZ limit. Area 630 is delimited on the east by 147°W long. and on the west by 154°W long. Area 620 extends from 630 further west to 159°W long. and area 610 extends from 620 to 170°W long. Within these three management areas, fishing is concentrated south of Unimak Pass and Island (Davidson Bank), southeast and southwest of the Shumagin Islands, along the 200-fathom isobath running from the shelf break northeastward to Shelikof Strait, Shelikof Strait, and the canyon regions east of Kodiak Island.

Twelve Steller sea lion rookeries and 33 haulouts occur in the GOA region (50 CFR, Tables 1 and 2 for part 226.12). Counts in 1996 indicated that about 44% of the western population occurred in the GOA (Hill and DeMaster *in prep*), which would suggest a GOA population of just under 17,500.

2.2.6 Inshore/Offshore allocation of the pollock TACs and the American Fisheries Act

In the BSAI region, the allocation of pollock to inshore/offshore sectors of the fishing industry is a complex issue involving considerations of optimal utilization versus waste, economics and issues related to domestic versus foreign ownership, social considerations such as stability and economic well-being of local fishing communities, and ecosystem considerations such as the distribution of fishing effort in time and space and the effects of the fishery on protected species such as the Steller sea lion. These same considerations apply in the GOA, but allocation in the GOA has been primarily to prevent larger catcher-processors from preempting fishing by smaller catcher vessels, such as occurred in 1989. Strictly speaking, the question of who removes pollock from the ecosystem should not have a direct effect on Steller sea lions or other protected species. However, protected species are affected because the various sectors of the fishing industry behave or operate differently.

The industry includes three main sectors: catcher-processors, motherships, and catcher vessels. Catcher-processors have the ability to catch and process pollock, motherships are essentially floating processors that take catch from catcher vessels, and catcher vessels catch and deliver their allocation of pollock either to motherships or to shoreside processors. Catcher-processors and motherships are large vessels with large catching and/or processing capacity, while catcher vessels are smaller and have limited holding capacity. The distinction between motherships and catcher-processors assumes that motherships do not actually trawl for fish, which is not always the case. Similarly, catcher-processors may take catch from catcher vessels, thereby acting as motherships. Processing at sea (the offshore sector) allows greater flexibility in terms of areas fished, whereas processing of small vessel catch at shoreside processors (the inshore sector) provides greater economic benefits for local communities with catcher vessels and/or processing facilities. Again, these general distinctions become blurred as these fishing sectors modify their behavior (e.g., catcher vessels delivering to motherships or catcher-processors).

With respect to ecosystem effects or effects on protected species, the key differences in the operations of inshore versus offshore sectors are a) the rate at which pollock are removed and the time of year that they are removed, and b) the location where they are removed. Large catcher processors are able to remove pollock at a much greater rate. These vessels can tow larger nets with capacities of several hundred mt. Larger catcher vessels may also be able to two large nets, but smaller vessels may be limited to nets with capacities of 100 mt or less. Thus, the offshore sector can remove pollock and fill a quota (TAC) rapidly compared to the inshore sector. Given limits on the amount of pollock that can be removed (TACs), rapid removal condenses the fishery to a shorter period of time and therefore limits the length of the season. Rapid removal of pollock from an area is more likely to result in temporary localized depletion of that resource for other consumers, such as sea lions and other marine mammals. Similarly, the rapid removal of the TAC precludes a more even distribution of fishing effort throughout a season and may, therefore, be more disruptive to the ecosystem.

The second key difference between inshore and offshore sectors is the geographic distribution of fishing effort. Smaller vessels with limited storage capacities are restricted to areas closer to shore, whereas processing vessels with greater storage capacities and on-board processing plants can fish at greater distances from shore. Because of these spatial limits, the impact of the inshore sector may be concentrated geographically and in areas essential to protected species such as the Steller sea lion.

Inshore/offshore allocations of pollock were first established in 1992 under FMP amendments 18 (BSAI) and 23 (GOA). In the BSAI region, 35% of the pollock TAC (after subtraction of reserves) was allocated to the inshore sector and 65% to the offshore sector. A catcher vessel operation area (CVOA) was established with the same boundaries as currently in place except that the western boundary was 0°30' west of its current location. The CVOA was in effect from September 1 to the end of the year, and motherships (and catcher-processors acting as motherships) were allowed to receive catches inside the CVOA only if they did not participate in directed fishing for pollock. In 1995, the allocation (35%:65%) was unchanged, the CVOA was reduced to its current configuration, and catcher-processors were allowed to fish for pollock in the CVOA if the pollock allocation for the inshore sector had been taken prior to the end of the fishing season. BSAI amendment 51 would establish the following for 1999 to 2001: a) after subtraction of reserves, 39% of the BSAI pollock TAC would be allocated to the inshore sector and 61% to the offshore sector; b) a portion of the inshore allocation equal to 2.5% of the BSAI pollock TAC, after subtraction of reserves, would be set aside for catcher vessels under 125 ft length overall and would become available on or about August 25 of each year; and c) all vessels harvesting pollock for processing by the offshore component would be prohibited from fishing inside the CVOA after September 1 of each year, unless the inshore component of the pollock fishery is closed to directed fishing (i.e., the inshore portion of the TAC has been taken).

In the GOA, amendment 23 (1992) allocated 100% of the pollock TAC to the inshore sector and 90% of the Pacific cod TAC to the inshore sector; 10% of the cod TAC was left for the offshore sector. Amendment 40 (1995) maintained this allocation scheme, and amendment 51 would do the same.

On October 21, 1998, the President signed into law the American Fisheries Act (AFA), which changed the allocation scheme for pollock in the BSAI beginning in 1999. Under the AFA, 10% of the pollock TAC is allocated to the CDQ program and the remaining 90 percent of the TAC, after subtraction of an allowance for incidental catch in other fisheries, is allocated 50% to vessels delivering to the inshore sector, 40% to catcher processors and catcher vessels delivering to catcher processors, and 10% to catcher vessels delivering to motherships. These new allocation percentages mandated by the AFA represent a shift of 15% of the TAC from the offshore to the inshore sectors.

The AFA also contains a number of additional measures that affect the BSAI pollock and Atka mackerel fisheries:

- The AFA increases the US ownership requirement to 75% for vessels with US fisheries endorsements and prohibits new fisheries endorsements for vessels greater than 165 ft, LOA, greater than 750 gross registered tons, or with engines capable of producing greater than 3,000 shaft horsepower.

- Under the provisions of a $90 million buyout, nine factory trawlers will be lose their US fisheries endorsements on January 1, 1999 and eight of these vessels will be scrapped.

- Vessels and processors eligible to participate in the offshore, mothership, and inshore sectors are identified in the AFA creating a closed class of vessels eligible to participate in the BSAI pollock fishery.

- Vessels catching pollock for the offshore, mothership and inshore sectors are authorized to form harvesters cooperatives under which the various participants may agree to divide up the TAC among themselves.

- The AFA establishes various limits on the ability of BSAI pollock vessels and processors to participate in other fisheries. These limits are designed to prevent pollock vessels and processors from using the flexibility of a cooperative to increase their level of participation in other fisheries.

2.2.7 Potential direct and indirect effects of the pollock fisheries on Steller sea lions

The potential effects of the pollock fisheries on Steller sea lions can be described as either operational or biological. Operational effects include gear interactions, incidental kill of sea lions, or entanglement in fishery-related debris. Biological interactions include competition for prey, changes in community composition secondary to fishery removals, changes in size structure of prey species, or changes in the temporal and spatial distribution of prey. Exploitative competition for prey may occur because both the fishery and Steller sea lions consume pollock. Interactive competition could occur if sea lions abandon primary foraging areas due, for example, to disturbance.

While pollock fisheries were responsible for considerable incidental kills of Steller sea lions in the 1980s (Loughlin and Nelson 1986, Perez and Loughlin 1991), the number of animals lethally taken by fishing gear has declined to a small number (Hill and DeMaster *in prep*) that has negligible population impact. Entanglement of sea lions in marine debris is not observed at high rates (Loughlin *et al*. 1986), and is also not considered to be a significant factor influencing sea lion population dynamics. Therefore, biological interactions are the principal concerns with respect to the interaction of the pollock fisheries with Steller sea lions. The extent to which such interactions occur depends not only on the behavior and characteristics of the fisheries, but also on the behavior and needs of the Steller sea lion. These interactions will be discussed further in the section on effects of the action.

2.2.8 Conservation measures associated with the pollock fisheries

Deliberations on the inshore/offshore allocation schemes for the BSAI and GOA pollock fisheries (1999 to 2001) did not include specific conservation measures. However, the fishery is managed by NMFS and the NPFMC in a manner intended to protect and conserve the integrity of these ecosystems. Fishery management tools are described above in the sections on fishery management, and annual management efforts are detailed below in the section on Federal fishery management actions (in the section on the environmental baseline).

3.0 STATUS OF PROTECTED SPECIES

The following threatened and endangered species and designated critical habitat may be affected by the proposed actions:

Steller sea lion (western population)	*Eumetopias jubatus*	Endangered
Northern right whale	*Balaena glacialis*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Chinook salmon (Snake River spring/summer)	*Oncorhynchus tshawytscha*	Threatened
Chinook salmon (Snake River fall)		Threatened
Sockeye salmon (Snake River)	*Oncorhynchus nerka*	Endangered

In the action areas, critical habitat has been designated only for the western population of Steller sea lions (50 CFR 227.12).

The endangered short-tailed albatross (*Diomedea albatrus*), threatened spectacled eider (*Somateria fisheri*), and threatened Steller's eider (*Polysticta stelleri*) occur in the action areas for the three proposed actions; these species are under the jurisdiction of the U.S. Fish and Wildlife Service and will be addressed in a separate consultation with that agency. The listed cetaceans occur within the action areas, but they are not likely to be adversely affected by the proposed actions because of their distribution patterns and life history characteristics; they will not be considered further in this opinion. The listed salmon species are managed by the Northwest Region, NMFS, and are addressed in a separate consultation from that office.

3.1 Steller sea lion

3.1.1 Species description

The Steller sea lion (*Eumetopias jubatus*) is the only extant species of the genus *Eumetopias*, and is a member of the subfamily Otariinae, family Otariidae, superfamily Otarioidea, order Pinnipedia. The closest extant relatives of the Steller sea lion appear to be the other sea lion genera, including *Zalophus*, *Otaria*, *Neophoca*, and *Phocartos*, and the fur seals of the genera *Callorhinus* and *Arctocephalus*. Loughlin *et al*. (1987) provide a brief but informative summary of the fossil record for *Eumetopias*. Repenning (1976) suggests that a femur dated 3 to 4 million years old may have been from an ancient member of the *Eumetopias* genus, thereby indicating that the genus is at least that old. Presumably, *Eumetopias jubatus* evolved entirely in the North Pacific (Repenning 1976).

3.1.2 Distribution

The Steller sea lion is distributed around the North Pacific rim from the Channel Islands off Southern California to northern Hokkaido, Japan. In the Bering Sea, the northernmost major rookery is on Walrus Island (Pribilof Islands) and their northernmost major haulout is on Hall Island (off the northwestern tip of St. Matthew Island). Their distribution also extends northward from the western end of the Aleutian chain to sites along the eastern shore of the Kamchatka Peninsula. The center of distribution has been considered to be in the GOA and the Aleutian Islands (National Marine Fisheries Service [NMFS] 1992). Within this distribution, land sites used by Steller sea lions are referred to as rookeries and haulout sites. Rookeries are used by adult males and females for pupping, nursing, and mating during the reproductive season (late May to early July). Haulouts are used by all size and sex classes but are generally not sites of reproductive activity as occurs on rookeries. The continued use of particular sites may be due to site fidelity, or the tendency of sea lions to return repeatedly to the same site, often the site of their birth. Presumably, these sites were chosen and continue to be used because they provide protection from predators, some measure of protection from severe climate or sea surface conditions, and (perhaps most importantly) are in close proximity to prey resources.

The movement patterns of Steller sea lions are not yet well understood. Their movement patterns from a land base (rookery or haulout) might be categorized into at least three types. First, sea lions move on and offshore for feeding excursions. Limited data are available to describe these movements (e.g., Gentry 1970, Sandgren 1970, Merrick and Loughlin 1997), but such descriptions are essential for understanding foraging patterns, nursing strategies, and energetics. Second, at the end of the reproductive season, some females may move with their pups to other haulout sites and males may “migrate” to distant foraging locations [Spaulding 1964, Mate 1973, Porter 1997]). Limited data are available indicating that animals do shift from rookeries to haulouts, but the timing and nature of these movements need further description (i.e., what distances are involved, are movements relatively predictable for individuals, do movements vary with foraging conditions, etc.). Description of these types of movements are essential for understanding seasonal distribution changes, foraging ecology, and apparent trends as a function of season. Third, sea lions may make semi-permanent or permanent one-way movements from one site to another (Chumbley *et al*. 1997, their Table 8; Burkanov *et al*. unpubl. report [cited in Loughlin 1997]). Calkins and Pitcher (1982) reported movements in Alaska of up to1500 km. They also describe wide dispersion of young animals after weaning, with the majority of those animals returning to the site of birth as they reach reproductive age.

The distribution of Steller sea lions at sea is also not well understood. Their at-sea distribution is, however, a critical element to any understanding of potential effects of fisheries on Steller sea lions, and will be considered in greater detail below in the section on foraging patterns.

3.1.3 Reproduction

Steller sea lions have a polygynous reproductive system where a single male may mate with multiple females. As mating occurs on land (or in the surf or intertidal zones), males are able to defend territories and thereby exert at least partial control over access to adult females and mating privileges. The pupping and mating season is relatively short and synchronous, probably due to the strong seasonality of the sea lions’ environment and the need to balance aggregation for reproductive purposes with dispersion to take advantage of distant food resources (Bartholomew 1970). In May, adult males compete for rookery territories. In late May and early July, adult females arrive at the rookeries, where pregnant females give birth to a single pup. The sex ratio of pups at birth is assumed to be approximately 1:1 (e.g., York 1994) or biased toward slightly greater production of males (e.g., Pike and Maxwell 1958, Lowry *et al*. 1982, NMFS 1992).

Mating occurs about one to two weeks later (Gentry 1970). The gestation period is probably about 50 to 51 weeks, but implantation of the blastocyst is delayed until late September or early October (Pitcher and Calkins 1981). Due to delayed implantation, the metabolic demands of a developing fetus are not imposed until well after fertilization.

For females with a pup, the nursing period continues for months to several years. Thorsteinson and Lensink (1962) suggested that nursing of yearlings was common at Marmot Island in 1959. Pitcher and Calkins (1981) suggested that it is more common for pups to be weaned before the end of their first year, but they also observed nursing juveniles (aged 1 to 3). Porter (1997) distinguished metabolic weaning (i.e., the end of nutritional dependence of the pup or juvenile on the mother) from behavioral weaning (i.e., the point at which the pup or juvenile no longer maintains a behavioral attachment to the mother). He also suggested that metabolic weaning is more likely a gradual process occurring over time and more likely to occur in March-April, preceding the next reproductive season. The transition to nutritional independence may, therefore, occur over a period of months as the pup begins to develop essential foraging skills, and depends less and less on the adult female. The length of the nursing period may also vary as a function of the condition of the adult female. The nature and timing of weaning is important because it determines the resources available to the pup during the more demanding winter season and, conversely, the demands placed on the mother during the same period. The maintenance of the mother-offspring bond may also limit their distribution or the area used for foraging.

Relatively little is known about the life history of sea lions during the juvenile years between weaning and maturity. Pitcher and Calkins (1981) reported that females sampled in the late 1970s reached reproductive maturity between ages 2 and 8, and the average age of first pregnancy was 4.9 ±1.2 years. These results suggest a mean age of first birth of about 6 years. The available literature indicates an overall reproductive (birth) rate on the order of 55% to 70% or greater (Pike and Maxwell 1958, Gentry 1970, Pitcher and Calkins 1981, Pitcher *et al*. in review). York (1994) derived the age-specific fecundity rates in Table 5 based on data from Calkins and Pitcher (1982). Those rates illustrate a number of important points and assumptions. First, the probability of pupping is rare (about 10%) for animals 4 years of age or younger. Second, maturation of 100% of a cohort of females occurs over a prolonged period which may be as long as 4 years. Third, the reported constancy of fecundity extending from age 6 to 30 indicates that either senescence has no effect on fecundity, or our information on fecundity rates is not sufficiently detailed to allow confident estimation of age-specific rates for animals older than age 6. Given the small size of the sample taken, the latter is a more likely explanation for such constancy.

Merrick *et al*. (1995) compared pup sizes at different sites where Steller sea lion populations were either decreasing or increasing, to determine if pup size or growth may be compromised in decreasing populations. Their results were not consistent with that hypothesis; rather, they found that pups about two to four weeks of age were larger at sites in the Aleutian Islands and GOA than they were in southeast Alaska or Oregon. These observed differences indicate that at least this phase of reproduction may not be affected; that is, if females are able to complete their pregnancy and give birth, then the size of those pups does not appear to be compromised. Possible alternative explanations for the observed size differences are that pups were measured at different ages (i.e., pups in the GOA and Aleutian Islands may have been born earlier and therefore were older when weighed), or that over time, harsher environmental conditions have selected for larger size in pups born in the Aleutian Islands of the GOA.

The reproductive success of an adult female is determined by a number of factors. The reproductive cycle includes mating, gestation, parturition, and nursing or post-natal care. The adult female's ability to complete this cycle successfully is largely dependent on the resources available to her. While much of the effort to explain the Steller sea lion decline has focused on juvenile survival rates, considerable evidence suggests that the decline may also be due, in part, to decreased reproductive success.

- Younger females collected in the 1970s were larger than females of the same age collected in the 1980s (Calkins *et al*. 1998). As maturity is likely related to size, females in the 1980s would also be more likely to mature and begin to contribute to population productivity at a later age.

- Pitcher *et al*. (in review) provide data from the 1970s and 1980s that suggests a much higher pregnancy rate after the mating season (97%; both periods), which declined to 67% for females collected in the 1970s and 55% for females collected in the 1980s. These changes in pregnancy rate suggest a large fetal mortality rate that could be a common feature of the Steller sea lion reproductive strategy (i.e., may occur even when conditions are favorable and population growth is occurring), but is more likely an indication of stress (possibly nutritional) experienced by individual females.

- The observed late pregnancy rates (67% in the 1970s and 55% in the 1980s) were not significantly different statistically. However, the direction of the difference is consistent with the hypothesis that reproductive effort in the 1980s was compromised.

- Pitcher *et al*. (in review) did observe a statistical difference in the late season pregnancy rates of lactating females in the 1970s (63%) versus lactating females in the 1980s (30%). This difference indicates that in contrast to lactating females in the 1970s, lactating females in the 1980s were less able to support a fetus and complete a consecutive pregnancy.

Males appear to reach sexual maturity at about the same time as females (i.e., 3 and 7 years of age; Perlov 1971 reported in Loughlin *et al*. 1987), but generally do not reach physical maturity and participate in breeding until about 8 to 10 years of age (Pitcher and Calkins 1981). A sample of 185 harem bulls from the Marmot, Atkins, Ugamak, Jude, and Chowiet Islands in 1959 included animals 6 to 17 years of age, with 90% from 9 to 13 years old (Thorsteinson and Lensink 1962).

3.1.4 Survival

Much of the recent effort to understand the decline of Steller sea lions has been focused on juvenile survival, or has assumed that the most likely proximate explanation is a decrease in juvenile survival rates. This contention is supported by direct observations and a modeling study, and is consistent with the notion that juvenile animals are less adept at avoiding predators and obtaining sufficient resources (prey) for growth and survival.

The direct observations consist of extremely low resighting rates at Marmot Island of 800 pups tagged and branded at that site in 1987 and 1988 (Chumbley *et al*. 1997) and observations of relatively few juveniles at Ugamak (Merrick *et al*. 1988). The low resighting rates do not themselves confirm that the problem was a corresponding drop in juvenile survival, but only that many of the marked animals were lost to the Marmot Island population. Migration to other sites where they were not observed is a possibility, but unlikely. If the "loss" of these animals is viewed in the context of the overall sea lion decline in the central GOA (from 1976 to 1994 the number of non-pups counted at Marmot Island declined by 88.9% and by 76.9% at the 14 other trend sites in the Gulf; Chumbley *et al*. 1997), then a significant increase in juvenile mortality is a much more plausible conclusion.

Modeling by York (1994) provides evidence that the observed decline in sea lion abundance in the GOA may have been due to an increase in juvenile mortality. York used the estimated rate of decline between the 1970s and the 1980s, and the observed shift in the mean age of adult females ($\geq$3 years of age) to explore the effects of changes in adult reproduction, adult survival, and juvenile survival. While she pointed out that the observed decline did not rule out all other possible explanations, she concluded that the observed decline is most consistent with a decrease in juvenile survival on the order of 10 to 20% annually.

However, juvenile survival may not be the only factor influencing the decline of the western population of Steller sea lions. Evidence indicating a decline in reproductive success was presented above. In addition, changes in adult survival may also have contributed to the decline. At present, survival rates for adult animals can not be determined with sufficient resolution to determine if those rates have changed over time or are somehow compromised to the extent that population growth and recovery are compromised.

3.1.5 Age distribution

Two life tables have been published with age-specific rates (Table 5). The first was from Calkins and Pitcher (1982) and was based on sea lions killed in the late 1970s. York (1994) created a second life table using a Weibull model and the data from Calkins and Pitcher (1982) and Calkins and Goodwin (1988). York's analysis of these two data sets suggests a shift from the 1970s to the 1980s in the mean age of females older than 3 years of age. The shift was about 1.55 years, and provided the basis for her determination that increased juvenile mortality may have been an important proximate factor in the decline of Steller sea lions. That is, such a shift in mean age would occur as the adult population aged without expected replacement by recruiting young females.

The most apparent limitations of these data and the resulting life tables are 1) the collected sea lions were not from the same locations and the relations between populations at different sites have not been described (e.g., were they experiencing similar trends and were their age structures comparable), 2) the data and estimated vital rates are also time-specific, and do not necessarily apply to the current population, 3) the assumption of a stable age distribution (or distributions) may be faulty even if trends at these different sites were consistent, and 4) the data set is relatively small and does not provide a basis for estimating age-specific survival rates for very young ages (0-2 years of age) or for possibly senescent older animals (say >12 years of age). Until senescence is assessed, longevity for Steller sea lions will be difficult to describe. The data reported in Pitcher and Calkins (1981) indicate that female sea lions may live to 30 years of age. A Weibull function fit to these data (York 1994) indicates, however, that fewer than 5% of females live to age 20.

The present age distribution may or may not be consistent with these life tables. Nevertheless, these tables provide the best available information on vital parameters, and the present age structure of sea lions may be similar if the immediate causes of the decline (e.g., low juvenile survival or low reproductive rates) have remained relatively constant.

3.1.6 Foraging patterns

The foraging patterns of the Steller sea lion are clearly central to any discussion of the potential for interaction between this species and groundfish (or other) fisheries in the BSAI or GOA. A partial list of foraging studies is provided in Table 6, together with notes on the sample sizes, locations, years, and primary findings of those studies.

3.1.7.1 Methods for researching sea lion foraging behavior

Our current understanding of Steller sea lion foraging patterns are based on the following methods.

Observations: Foraging patterns can be discerned, in part, simply by observation studies. Observations can be useful for identifying areas that may be important foraging sites (e.g., Kajimura and Loughlin 1988, Fiscus and Baines 1966). The designation of foraging areas as part of critical habitat was based, in part, on observations that sea lions use those areas for foraging. Similarly, under certain circumstances observations can be used for identifying prey items, particularly those that may be commercially important (e.g., Jameson and Kenyon 1977). In general, however, the power of observational studies is limited to situations where sea lions bring their prey to the surface and the prey can be identified, or where the sea lions can be observed diving repeatedly and the assumption that they are foraging is reasonable.

Stomach and intestinal contents: Stomach contents are generally considered to be the most reliable indication of foraging patterns. Biases may exist from variable rates of digestion of soft tissues or variable retention of hard tissues (e.g., squid beaks), and Pitcher (1981) indicated that results from intestinal tracts may not correspond to results from stomachs. Results may also be biased by the evaluation method (e.g., use of frequency of occurrence may indicate how many animals ingested a prey type, but may not provide a good indicator of the importance of that prey; see Spalding 1964). Analyses of stomach contents have provided a large portion of our information on sea lion foraging (e.g., Calkins and Pitcher 1982, Calkins and Goodwin 1988), but under most conditions, killing for collection of stomach contents is not considered appropriate and stomach and intestinal contents are now available only from dead animals or live animals that are under sedation and can be lavaged or given an enema.

Scat analysis: Scats, or feces, are being used to study Steller sea lion prey selection, and have provided important information on the frequency of occurrence of both Atka mackerel and pollock in their diet (e.g., Merrick *et al*. 1997). Materials from scats, such as otoliths, can be used with additional information (e.g., size at age) to infer additional information about the prey consumed (Pitcher 1981, Frost and Lowry 1986). Scats are known to be a biased index of prey selection because some prey may not have hard parts that resist digestion and can be identified in a scat, and the scat generally contains prey items consumed relatively recently (depending on the rate of passage through the digestive tract). Nevertheless, scat collections provide a non-lethal means of comparing diet and diet changes over time and space, and estimating relative frequency of occurrence of prey items in the sea lion diet.

Telemetry: At least three types of telemetry are (or have been) used to study sea lion foraging. Very high frequency (VHF) telemetry can be used to determine presence or absence of an animal and, to a limited extent, animal location and whether it is on land or in the water. The use of VHF telemetry to determine the presence or absence of an animal can be used to infer the occurrence and length of foraging trips (e.g., Merrick and Loughlin 1997).

Satellite-linked telemetry is being used to determine animal location and, when coupled with time-depth recorders, diving patterns (e.g., Merrick *et al*. 1994). Satellite-linked telemetry provides an opportunity to collect information on animal location without having to recapture the animal to collect stored data. At present, satellite-linked telemetry is the primary means of assessing the distribution of foraging animals and thereby determining those regions that are critical for Steller sea lions.

Stomach telemetry is being developed and offers an opportunity to determine when an animal has consumed prey, rather than requiring the investigator to infer feeding from diving behavior. Stomach telemetry, in combination with satellite-linked telemetry, may provide greater understanding of foraging behavior and discrimination of at-sea activities that may or may not be related to foraging.

Captive studies: Studies of animals in captivity may be useful for understanding prey selection, diving and foraging physiology, and energetics. Various studies have examined assimilation efficiency, changes in weight as a function of prey type (Fadely *et al*. 1994, Rosen and Trites *in prep*), metabolic rates, and the heat increment of feeding (Rosen and Trites 1998). Energetic and nutritional studies on captive animals will likely form a basis from which dietary requirements of wild animals can be determined and understood. The issue of competition between groundfish fisheries and the Steller sea lion may be decided on the basis of demographic, ecological, or other information, but our understanding of such competition will ultimately depend on our ability to explain their energetic and nutritional needs and physiology.

Fatty acid analysis: Fish species, like pollock and Atka mackerel, vary in fatty acid composition and therefore carry their own "fatty acid signature." Removal of small tissue (blubber) plugs from Steller sea lions and analysis for fatty acid composition can be used to identify prey types. This method of prey analysis is relatively new (e.g., Iverson 1993), but has been used successfully to identify prey types of harbor seals in different regions of Prince William Sound (Iverson *et al*. *in press*). The NMFS laboratory at Auke Bay is developing the capability to conduct such analyses, and this approach to prey determination will likely prove to be useful in the near future.

Isotope analysis: Isotope ratios for various elements differ in prey types in a manner that allows estimation of general prey category and trophic level. These analyses can be conducted using small amounts of tissue (e.g., vibrissae or whiskers) and may provide evidence of long term changes in prey type, trophic level, or feeding strategy.

3.1.7.2 Foraging distributions

At present, our understanding of Steller sea lion foraging distribution is based on observations of foraging behavior (or presumed foraging behavior) in areas such as the southeastern Bering Sea (Fiscus and Baines 1966, Kajimura and Loughlin 1988), records of incidental take in fisheries (Perez and Loughlin 1991), and satellite telemetry studies (e.g. Merrick *et al*. 1994, Merrick and Loughlin 1997). Observations and incidental take of sea lions (Loughlin and Nelson 1986, Perez and Loughlin 1991) in the vicinity of Seguam Pass, the southeastern Bering Sea, and Shelikof Strait provided a basis for establishment of those areas as critical habitat (FR 58:45269-45285).

The results of telemetry studies suggest that foraging distributions vary by individual, size or age, season, site, and reproductive status (i.e., is the female still supporting a pup; Merrick and Loughlin 1997). The foraging patterns of adult females differed during summer months when females were with pups versus winter periods when considerable individual variation was observed, but may be attributable to the lactation condition of the females. Trip duration for females (n = 14) in summer was approximately 18 to 25 hours. For five of those females that could be tracked, trip length averaged 17 km and they dove approximately 4.7 hours per day. For five females tracked in winter months, mean trip duration was 204 hours, mean trip length was 133 km, and they dove 5.3 hours per day. The patterns exhibited by females in winter varied considerably, from which the investigators inferred that two of them may still have been supporting a pup. Those two females continued to make relatively shorter trips (mean of 53 km over 18 hours) and dove 8.1 hours per day, whereas the other three ranged further, dove 3.5 hours per day, and spent up to 24 days at sea. Five winter young-of-the-year exhibited foraging patterns intermediate between summer and winter females in trip distance (mean of 30 km), but shorter in duration (mean of 15 hours), and with less effort devoted to diving (mean of 1.9 hours per day). Estimated home ranges (mean ± 1 SE) were 319 ± 61.9 km^2 for adult females in summer, 47,579 ± 26,704 km^2 for adult females in winter, and 9,196 ± 6799 km^2 for winter young-of-the-year.

The sea lions used in Merrick and Loughlin's (1997) study were from the GOA (Sugarloaf Island, Latax Rocks, Marmot Island, Long Island, Chirikof Island, Atkins Island, and Pinnacle Rock), and the BSAI region (Ugamak Island and Akun Island). This information is, therefore, directly pertinent to the action areas for both the GOA and BSAI fisheries, although it is perhaps most relevant to the GOA action area.

3.1.7.3 Foraging depths

The sea lions in the Merrick and Loughlin (1997) study tended to make relatively shallow dives, with few dives recorded at greater than 250 m (Figure 36). Maximum depth recorded for the five summer adult females were in the range from 100 to 250 m, and maximum depth for the five winter adult females was greater than 250 m. The maximum depth measured for winter young-of-the-year was 72 m. These results suggest that sea lions are generally shallow divers, but are capable of deeper dives (i.e., greater than 250 m).

The instruments used to record diving depths do not determine the purpose of a dive, and many of the recorded dives (Figure 36) may not be indicative of foraging effort. Dives between 4 and 10 m depth may be for foraging, or they may simply be grooming, porpoising, or transiting between locations. For example, animals transiting to and from foraging locations during rough sea surface conditions may transit in a series of long, shallow dives to avoid such conditions. The relatively large number of dives recorded between 4 and 10 m may therefore bias the assessment of "foraging" depths for these sea lions.

The results from this study also may not be indicative of diving depths and patterns for other sea lions at other times of year or in other locations. The winter young-of-the-year were instrumented in the period from November to March, when they were probably about five to nine months old and may have still been nursing. At this age, they are just beginning to develop foraging skills, which may take years to learn. The diving depths and patterns exhibited by these young-of-the-year are likely poor indicators of the foraging patterns of older juveniles (one- to three-year-olds). For example, Swain and Calkins (1997) report dives of a 2-year-old male sea lion to 252 m, and regular dives of this animal and a yearling female to 150 m to 250 m (Figure 37). Clearly, if young-of-the-year are limited to relatively shallow depths, and older animals are capable of diving to much greater depths, then those younger animals are just beginning to develop the diving and foraging skills necessary to survive. The rate at which they develop those skills and, for example, begin to dive to greater depths or take prey at greater depths, is unknown, but probably occurs rapidly after weaning to take advantage of otherwise unavailable prey resources.

3.1.7.4 Prey, energetics and nutrition, and diversity

At the least, an understanding of Steller sea lion foraging requires a listing of their prey species, a qualitative or (preferably) quantitative measure of the relative importance of different prey types, descriptions of prey characteristics and predator-prey dynamics, and an assessment of diet diversity. A (partial) listing of Steller sea lion prey species or prey types would include (not in order of priority): Atka mackerel, capelin, crabs, dogfish sharks, eulachon, flatfish, greenling, hake, halibut, herring, lamprey, lingcod, molluscs, octopus, Pacific cod, pollock, ratfish, rockfishes, salmon, sand lance, sculpins, shrimps, smelt, squid, and yellowfin sole.

Qualitative or quantitative indices of prey importance might be developed on the basis of prey "selection" or "preference." However, we rarely have information on the distribution or availability of different prey types, and therefore don't have a basis for inferring "selection" or "preference" (Lowry *et al*. 1982, Frost and Lowry 1986). In most studies of Steller sea lion prey, rank frequency of occurrence is used as a qualitative (or semi-quantitative) index of relative importance. For example, the data from Merrick *et al*. (1997) and NMFS (1995) indicate that throughout the range of the western population of Steller sea lions, either pollock or Atka mackerel are the dominant prey on the basis of frequency of occurrence. Therefore, pollock and Atka mackerel can reasonably be assumed to be essential prey of Steller sea lions. Quantitative estimation of the importance of different prey types is considerably more difficult. The value of a prey type should be quantified on the basis of the observed net gain in calories and nutrients resulting from predation on that prey type versus other prey types. Such a determination would require information on biomass consumed, caloric and nutrient content of that biomass, energy and nutrients gained, and energy and nutrients expended (i.e., the costs of predation). Caloric and nutrient content of different prey types are relatively easy to determine using proximate analysis, although Stansby (1976) cautioned that individuals of the same prey type may vary considerably as a function of season, site, reproductive condition, and other factors. Assimilation efficiency has also been studied (Fadely *et al*. 1994, Rosen and Trites *in prep*) and appears to be relatively straightforward. Biomass consumed and costs of predation are more difficult to quantify, particularly with respect to any particular prey type. Many of the studies on Steller sea lion foraging patterns (Table 6) provide information on frequency of occurrence, but such information cannot be readily converted into biomass consumed unless additional data are provided. Biomass estimates are more readily determined from volumetric measurements of stomach contents, but can also be estimated from length-weight relationships combined with measured lengths of prey or estimated length at age (with age based on otoliths; e.g., Frost and Lowry 1986). Costs of predation may also vary considerably by prey type, depending on the distribution, life history characteristics, and behavior of the prey.

Important prey characteristics include their tissue or body composition, individual size (mass), availability, depth in the water column, their degree of association with the bottom, their reproductive behaviors, their degree of aggregation (e.g., solitary versus schooling), and their temporal and spatial distribution patterns. To date, the limited information available indicates that sea lions generally forage at depths less than 250 m. Many of their prey are, at one life stage or another, associated with the bottom. Predation on prey associated with the bottom is a common pinniped strategy, perhaps because the bottom limits the spatial dimensionality of the predator-prey arena and thereby limits the prey's alternatives for escape. Male Atka mackerel may be susceptible to predation because they fertilize and then guard eggs laid by the female on the bottom. Schooling behavior of pollock and Atka mackerel probably enhances their value as prey as such schooling may increase sea lion consumption relative to costs associated with searching and capture.

The spatial and temporal distributions of prey types is a critical determinant of their availability to sea lions. The consistent pattern of the Atka mackerel fishery over time indicates that aggregations of Atka mackerel are distributed in patches that are relatively predictable. Aggregations of pollock are less predictable in time and space than aggregations of Atka mackerel, but also demonstrate considerable predictability, particularly for winter and spring spawning aggregations. To varying degrees, then, both of these prey species appear to be distributed in more (Atka mackerel) or less (pollock) predictable prey patches, and the availability and characteristics of those patches may be essential to the foraging success of sea lions. Important patch characteristics may include their size, location, persistence, and density (number of patches per area).

The quality of the sea lion diet appears to be determined not only by the individual components (species) of the diet, but also by the mix or diversity of prey in the diet. Merrick *et al*. (1997) found a correlation between a measure of diet diversity in different geographic regions of the western population and population trends in those regions. Their conclusions were that reliance on a single prey type may not be conducive to population growth; a diversity of prey may be necessary for recovery of the western population. Unfortunately, diet diversity is a function not only of prey selection, but of the diversity of prey available. To the extent that pollock or Atka mackerel currently dominate the prey field, sea lions survive on those prey.

3.1.7.5 Foraging - integration and synthesis

While much remains to be learned about Steller sea lions, the available information is sufficient to begin a description of their foraging patterns. The emerging picture appears to be that:

- Steller sea lions are land-based predators but their attachment to land and foraging patterns/distribution may vary seasonally and as a function of age, sex, and reproductive status;

- Steller sea lions tend to be relatively shallow divers but also exploit deeper waters;

- Steller sea lions consume a variety of demersal, semi-demersal, and pelagic prey;
- a diet of a diversity of prey appears to be advantageous to Steller sea lions
- at present, pollock and Atka mackerel appear to be their most common or dominant prey;
- the life history and spatial/temporal distribution of pollock and Atka mackerel are therefore likely important determinants of sea lion foraging success;
- foraging patterns and prey requirements probably vary by season, due to changes in reproductive status, prey availability, and environmental conditions;
- foraging sites relatively close to rookeries may be particularly important during the reproductive season when lactating females are limited by the nutritional requirements of their pups; and
- the transition by young animals from dependence on their mothers to independent feeding may occur over a period of months or even years.

The question of whether competition exists between the Steller sea lion and pollock or Atka mackerel fisheries is a question of sea lion foraging success. For a foraging sea lion, the net gain in energy and nutrients is determined, in part, by the availability of prey or prey patches it encounters within its foraging distribution. Competition occurs if the fisheries reduce the availability of prey to the extent that sea lion condition, growth, reproduction, or survival are diminished, and population recovery is impeded. The question of whether competition occurs will be addressed in the "environmental baseline" and "effects of the action" sections below.

3.1.8 Natural predators

The Recovery Plan for the Steller Sea Lion (NMFS 1992) states: "Steller sea lions are probably eaten by killer whales and sharks, but the possible impact of these predators is unknown. The occurrence of shark predation on other North Pacific pinnipeds has been documented, but not well quantified (Ainley *et al*., 1981)." The likelihood of shark attack is probably greater for Steller sea lions off the Washington, Oregon, and California coasts than in waters further north. A killer whale attack has been documented off the Oregon coast (Mate 1973), but killer whales are probably much more frequent predators in the waters of British Columbia and Alaska (Barrett-Lennard *et al*., unpubl. rep.). Barrett-Lennard *et al*. surveyed 126 respondents to estimate the rate of observation of sea lion/killer whale interactions. Of 492 interactions witnessed, 32 (6.5%) reportedly involved sea lion mortality. The lethal interaction rate appeared to be greatest in the Aleutian Islands region, but those results were based on the "vague recollection" of one observer of 3 kills over a 24-year period. Perhaps the most noteworthy anecdotal observation of apparent killer whale predation on sea lions occurred in 1992, when flipper tags from 14 sea lions that were both tagged and branded were found in the stomach of a killer whale dead on the beach in Prince William Sound (NMFS 1995). Barrett-Lennard *et al*. (unpubl. rep.) model sea lion mortality due to killer whales, and suggest that while such predation may account for a significant portion of natural mortality at the current low size of the sea lion population, it was not likely to have been the cause of the decline. The most recent status report on Steller sea lions (NMFS 1995) concurs and points out that relative abundance of killer whales is likely greater off southeast Alaska, where sea lion populations have been slowly increasing.

3.1.9 Natural competitors

Competition may take several forms. For exploitative competition to occur, the potential competitors must utilize the same resource, the availability of that resource must be limited relative to the needs of the potential competitors, and use of the available resource by one of the potential competitors must impede use by the other (Krebs 1985). Interference competition can occur even when resources are not limited if the use of the resource by one potential competitor harms another. With respect to other (nonhuman) species, Steller sea lions are most likely to compete with for food, although they may also compete for habitat (e.g., potential competition with northern fur seals for rookery or haulout space).

Steller sea lions forage on a variety of marine prey that are also consumed by other marine mammals (e.g., northern fur seals, harbor seals, humpback whales), marine birds (e.g., murres and kittiwakes), and marine fishes (e.g., pollock, arrowtooth flounder). To some extent, these potential competitors may partition the prey resource so that little direct competition occurs. For example, harbor seals and northern fur seals may consume smaller pollock than Steller sea lions (Fritz *et al*. 1995). Competition may still occur if the consumption of smaller pollock limits the eventual biomass of larger pollock for sea lions, but the connection would be difficult to demonstrate. Such competition may occur only seasonally if, for example, fur seals migrate out of the area of competition in the winter and spring months. Similarly, competition may occur only locally if prey availability or prey selection varies geographically for either potential competitor. Finally, competition between sea lions and other predators may be restricted to certain age classes, as diet may change with age or size. .

3.1.10 Disease

Hoover (1988) lists evidence of exposure of sea lions to leptospirosis (Fay *et al*. 1978), chlamydiosis (Goodwin and Calkins 1985), and San Miguel sea lion virus (Goodwin and Calkins 1985, Barlough *et al*. 1987). Barlough *et al*. (1987) also present evidence of eight types of calicivirus (including seven types of San Miguel sea lion virus and Tillamook [bovine] virus). And recent tests, indicate exposure to brucellosis (pers. comm., K. Pitcher, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518).

Hoover (1988) also lists parasites known to infect sea lions, including cestodes of the genera *Diplogonoporus*, *Diphyllobothrium*, *Anophryocephalus*, *Adenocephalus*, and *Pyramicocephalus*; trematodes of the genera *Pricetrema*, *Zalophotrema*, and *Phocitrema*; acanthocephalans of the genera *Bulbosoma* and *Corynosoma*; and nematodes of the genera *Anisakis*, *Contracaecum*, *Parafilaroides*, *Uncinaria*, and *Phocanema* (Hill 1968, Dailey and Brownell 1972, Daily 1975, Fay *et al*. 1978, Geraci 1979, Dieterich 1981). In addition, Thorsteinson and Lensink (1962) reported two types of parasites: Body louse (*Antarctophthirus michrochir*) severely infesting pups and nose mites *(Orthohalarachne diminuta*) invariably found on adults. And Scheffer (1946) reported ascarid worms (*Porocaecum decipiens*) nearly always found in adult stomachs.

While a range of different diseases or maladies have been documented for Steller sea lions, the available evidence is not sufficient to demonstrate that disease has played or is playing any significant part in the decline of the western population. Disease may have contributed to the *in utero* mortality rate observed in animals collected in 1975-1978 and 1985-1986 (Pitcher *et al*. in review) but, again, that hypothesis is not substantiated by any data. The long-term continuous nature of the decline, and the lack of morbid or moribund specimens argue that disease has not been a primary factor.

3.1.11 Population dynamics

The breeding range of the Steller sea lion covers virtually all of the North Pacific Rim from about 34° N to 60°N lat. Within this range, sea lions are found in hundreds of rookeries and haulouts. These rookery and haulout sites are frequently grouped into rookery/haulout clusters on the basis of politics, geography, demographic patterns, genetics, foraging patterns, or other reasons related to scientific study or management. Political divisions are drawn to separate animals that are found off Japan or the Republic of Korea, in Russian territories, in Alaska, British Columbia, or along the western coast of Washington, Oregon, and California. These divisions are largely for the purpose of management or jurisdiction, but may be related to sea lion population dynamics because of differing management strategies or objectives.

Geographic distinctions are frequently made on the basis of variable habitat or ecosystem characteristics in differing parts of the range. For example, rookeries and haulouts in the Aleutian Islands are often separated from those in the GOA, and these two areas are again separated from southeastern Alaska and British Columbia. These distinctions may have demographic significance because of the important variability in ecosystem features such as prey resources. Sea lion rookeries and haulouts are also grouped on the basis of observed demographic trends (York *et al*. 1996).

Many, if not most, descriptions of the decline of Steller sea lions begin with the statement that the decline was first witnessed in the eastern Aleutian Islands in the mid 1970s and then spread westward to the central Aleutian Island and eastward to the western GOA in the late 1970s and early 1980s. Similarly, counts are frequently presented for the area from Kenai to Kiska Island (ref), which is considered to enclose the center of abundance for the species. Genetic studies (Bickham *et al*. 1996, Loughlin 1997) provided the basis for distinguishing western and eastern management stocks of the sea lion, and additional work may allow further differentiation of stocks. The relation between diet diversity and population trend was studied using rookery groups identified by geographic location and rates of change. The rookery groups were those identified by York *et al*. (1996). These examples indicate that, depending on the purpose at hand, the total sea lion population may be split meaningfully into subpopulations in any number of ways.

However, if the purpose is to study or understand the natural (i.e., without human influence) population structure of the Steller sea lion, then the biogeography of the species must be defined more narrowly. Genetic studies may provide the best description of the result of biogeographic patterns, as they are likely the least influenced by human interaction. Demographic trends and foraging patterns may be influenced by human activities and, clearly, the artificial boundaries determined for political purposes should not have an influence on the natural biogeography of sea lions.

Those natural factors that determine their biogeography include climate and oceanography, avoidance of predators, distribution of prey, the reproductive strategy of the species, and movement patterns between sites. The marine habitat of the Steller sea lion tends to reduce variation in important environmental or climatic features, allowing the sea lion to disperse widely around the rim of the North Pacific Ocean. The decline of Steller sea lions off California may indicate a contraction in their range, depending on the explanation for that decline. Avoidance of terrestrial predators must clearly be an important factor, as rookeries and haulouts are virtually all located at sites inaccessible to such predators. Distribution of prey is likely a critical determinant of sea lion biogeography, and probably determines the extent of their dispersion during the non-reproductive season. The reproductive strategy of the species, on the other hand, requires aggregation at rookery sites, and therefore likely places important limits on the species' movement patterns and dispersion. Finally, movement patterns between sites determine, in part, the extent to which such groups of sea lions at different rookeries and haulout sites are demographically independent. Steller sea lions are generally not described as migrators. Adult males, for example, are described as dispersing widely during the non-reproductive seasons, and juveniles are described as dispersing widely after weaning and not returning to the reproductive site until they are approaching reproductive age (Calkins and Pitcher 1982).

An understanding of the natural biogeography of the Steller sea lion is essential to describe their population dynamics and identify the effects of potential human-related influences on their dynamics. Without a better understanding of movement patterns of sea lions, the geographic extent of potential fisheries effects can not be estimated with confidence. For example, we can not, at this time, describe the geographic extent of fishing for Atka mackerel at Seguam pass because we can not confidently determine whether the sea lions foraging at that site are from just Seguam and Agligadak Island rookeries, or perhaps also from Yunaska and Kasatochi Island rookeries or sites more distant. Similarly, the pollock fisheries in Shelikof Strait may have influenced the dynamics of sea lion populations at Chirikof and Chowiet Islands, or may have even farther reaching effects if, for example, sea lions from the Shumagin Islands forage in Shelikof Strait. In addition, descriptions of population size, variability, and stability may vary depending on the definition of population units.

3.1.12 Population status and trends

Assessments of the status and trends of Steller sea lion populations are based largely on (a) counts of nonpups (juveniles and adults) on rookeries and haulouts, and (b) counts of pups on rookeries in late June and early July. Both kinds of counts are indices of abundance, as they do not necessarily include every site where animals haul out, and they do not include animals that are in the water at the time of the counts. Population size can be estimated by standardizing the indices (e.g., with respect to date, sites counted, and counting method), by making certain assumptions regarding the ratio of animals present versus absent from a given site at the time of the count, and by correcting for the portion of sites counted. Population estimates from the 1950s and 1960s (e.g., Kenyon and Rice 1961; see also Trites and Larkin 1992, 1996) are used with caution because counting methods and dates were not standardized, and the results contain inconsistencies that indicate the possibility of measurement error at some sites in some years. Efforts to standardize methods began in the 1970s (Braham *et al*. 1980); as a result, counts conducted since the late 1970s are the most reliable estimates of the total population or subpopulations.

For the western U.S. population (i.e., west of 144°W long.), counts of adults and juveniles have fallen from 109,880 animals in the late 1970s to 22,167 animals in 1996, a decline of 80% (Figure 38; Hill and DeMaster *in prep,* and based on NMFS 1995, Strick *et al*. 1997, Strick *et al*. *in press*). Although the number of animals lost appears to have been far greater from the late 1970s to the early 1990s, the rate of decline has remained high. The 1996 count was 27% lower than the count in 1990. Final results from counts conducted in 1998 are not yet available, but preliminary results for trend sites between the Kenai Peninsula to Kiska Island indicate a decline of about 9% in nonpups since 1996, and 19% in pups since 1994.

From the late 1970s to 1996, abundance estimates for the GOA dropped from 65,296 to 9,782 (85%), and for the BSAI region dropped from 44,584 to 12,385 (72%). Counts in Russian territories (to the west of the action area for the BSAI pollock and Atka mackerel fisheries) have also declined and are currently estimated to be about one-third of historic levels (NMFS 1992). Counts in southeast Alaska (to the east of the action area for the GOA pollock fishery) are increasing slowly.

Some demographic patterns are lost when estimates are pooled for large areas. The index counts are often described by geographic region (Figure 39; Table 7; T. Loughlin, pers. comm.). Counts at all trend sites by region indicate a slow decline in the central and western GOA between 1976 and 1985, followed by a severe drop in both regions from 1985 to 1989, and continued decline in the central Gulf continuing to at least 1997. Counts in the eastern, central, and western Aleutians all declined sharply from the late 1970s to the early 1990s, and since have been variable but declining in the western region, declined moderately in the central region, and relatively stable in the eastern region, at least through 1996. The decline of sea lions in the GOA and BSAI regions has effectively shifted the center of abundance for the species to the east. In the 1970s, for example, Ugamak Island in the eastern Aleutian Islands was the largest rookery in the world. As abundance declined at Ugamak Island, rookeries at Marmot and Sugarloaf Islands in the Central GOA became numerically dominant. But as abundance at these sites declined, the rookery at Forrester Island (southeast Alaska) became dominant.

Although the decline of Steller sea lions has occurred over extensive areas, site-by-site evaluation of the counts may be essential to understand the decline, and to anticipate the nature of threats to the species as local populations dwindle to extremely low numbers. However, changes observed at specific sites must be interpreted with caution because animals are known to move between sites on temporary, seasonal, and permanent bases. Therefore, the extent to which the collection of animals at a given site represent an independent or meaningful population unit is not yet clear.

3.1.13 Population variability and stability

Populations change as a function of births, deaths, immigration, and emigration. During the nonreproductive season, some sea lions may move between the western and eastern populations (Calkins and Pitcher 1981), but net migration out of the western population is not considered a factor in the decline. The amount of growth observed in the eastern population is equivalent to only a small fraction of the losses in the western population. Thus, the decline must be due primarily to changes in birth and death rates. As mentioned above, computer modeling (York 1994) and mark-recapture experiments (Chumbley *et al*. 1997) indicate that the most likely problem leading to the decline is decreased juvenile survival, but lower reproductive success is almost certainly a contributing factor. Finally, adult survival has not been characterized and even small changes in the survival rate of adult females may be contributing significantly to past or current population trends.

These changes in vital rates would likely lead to changes in the age structure which, in turn, may tend to destabilize populations. With declining reproductive effort or juvenile survival, populations tend to become top heavy with more mature animals (e.g., the increase in mean age of adult females described by York [1994]), followed by a drop in population production as mature animals die without replacement through recruitment of young females. The extent to which the age structure is destabilized and the effect on population growth rate depends, in part, on the length of time that reproduction and/or juvenile survival remain suppressed. Increased mortality of young adult females may have the strongest effect on population growth and potential for recovery, as these females have survived to reproductive age but still have their productive years ahead of them (i.e., they are at the age of greatest reproductive potential).

Vital rates and age structures may change as a function of factors either extrinsic or intrinsic to the population. This biological opinion addresses the question of potential effects of the three fishery actions (i.e., extrinsic factors) on the Steller sea lion. However, the potential effects will be determined, in part, by the sensitivity of the western population to extrinsic influence, its resilience, and its recovery rate. Steller sea lions fit the description of a “K-selected” species of large-bodied long-lived individuals with delayed reproduction, low fecundity, and considerable postnatal maternal investment in the offspring. These characteristics should make sea lion populations relatively tolerant of large changes in their environment. Thus, the observed decline of the western population over the past two to three decades is not consistent with the description of the species as K-selected, and suggests that the combined effect of those factors causing the decline has been severe. The ability of the population to recover (i.e., its resilience) and the rate at which it recovers will be determined by the same K-selected characteristics (longevity, delayed reproduction, and low fecundity), as well as its metapopulation structure. Its maximum recovery rate will likely be limited to 8% to 10% annually (based on its life history characteristics and observed growth rates of other Otariids), which means that recovery could require 20 to 30 years. The metapopulation structure of the western population may enhance or deter recovery. Dispersal of populations provides some measure of protection for the entire species against relatively localized threats of decline or extinction. And rookeries that go extinct may be more likely recolonized by seals migrating between sites. On the other hand, the division of the whole population into smaller demographic units may exacerbate factors that accelerate small populations toward extinction (e.g., unbalanced sex ratios, allee effects, inbreeding depression). Such acceleration has been referred to as an “extinction vortex” (Gilpin and Soulé 1986).

Finally, any description of population stability for the Steller sea lion should be written with caution. Over the past three decades (or perhaps longer), we have witnessed a severe decline of the species throughout most of its range. Our inability to anticipate those declines before they occurred, and our limited ability to explain them now, and our limited ability to predict the future suggests that we are not yet capable of describing the stability of Steller sea lion populations.

3.1.14 Population projections

Population viability analyses have been conducted by Merrick and York (1994) and York *et al*. (1996). While such analyses require some assumptions, they provide a context for management and an indication of the severity and urgency of the sea lion dilemma, given the set of assumptions made in the analyses.

The results of these analyses indicate that the next 20 years may be crucial for the Steller sea lion, if the rates of decline observed in 1985 to 1989 or 1994 continue. Within this time frame, it is possible that the number of adult females in the Kenai-to-Kiska region could drop to less than 5000. Extinction rates for rookeries or clusters of rookeries could increase sharply in 40 to 50 years, and extinction for the entire Kenai-to-Kiska region could occur in the next 100-120 years.

3.1.15 Listing Status

On 26 November 1990, the Steller sea lion was listed as threatened under the Endangered Species Act of 1972 (55 FR 49204). The listing followed a decline in the U.S. population of about 64% over the three decades prior to the listing. In 1997, the species was split into two separate stocks on the basis of demographic and genetic dissimilarities (Bickham *et al*. 1996, Loughlin 1997), the status of the western stock was changed to endangered, and the status of the eastern stock was left unchanged (62 FR 30772).

3.1.16 Critical habitat description

The term “critical habitat” is defined in the Endangered Species Act (16 U.S.C. 153#) to mean: (i) the specific areas within the geographic area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management consideration or protection; and (ii) the specific areas outside of the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential to the conservation of the species.

The definition continues to "Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species."

By this definition, critical habitat includes those areas that are essential to the "conservation" of a threatened or endangered species. The ESA defines the term "conservation" as: ". . . to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary." That is, the status of the species would be such that it would be considered "recovered." Therefore, the area designated as critical habitat should contain the physical and biological resources necessary to support and sustain a population of a threatened or endangered species that is sufficiently large and persistent to be considered recovered.

3.1.16.1 Establishment of Critical Habitat

The areas designated as critical habitat for the Steller sea lion were determined on the basis of the available information on life history patterns of the species, with particular attention paid to land sites where animals haul out to rest, pup, nurse their pups, mate, and molt, and to marine sites considered to be essential foraging areas. The foraging areas were determined on the basis of sightings of sea lions at sea, incidental catch data (Loughlin and Nelson 1986, Perez and Loughlin 1991), and foraging studies using satellite-linked tracking systems. Critical habitat areas were determined with input from NMFS scientists and managers, the Steller Sea Lion Recovery Team, independent marine mammal scientists invited to participate in the discussion, and the public. The proposed rule for establishment of critical habitat for the Steller sea lion was published on 1 April 1993 (58 FR 17181), and the final rule was published on 27 August 1993 (58 FR 45269). The following areas have been designated as critical habitat in the action area of one or more of the proposed fisheries (Figure 9).

(a) Alaska rookeries, haulouts, and associated areas. In Alaska, all major Steller sea lion rookeries identified in Table 1 [their Table 1] and major haulouts identified in Table 2 [their Table 2] and associated terrestrial, air, and aquatic zones. Critical habitat includes a terrestrial zone that extends 3,000 feet (0.9 km) landward from the baseline or base point of each major rookery and major haulout in Alaska. Critical habitat includes an air zone that extends 3000 feet (0.9 km) above the terrestrial zone of each major rookery and major haulout in Alaska, measured vertically from sea level. Critical habitat includes an aquatic zone that extends 3,000 feet (0.9 km) seaward in State and Federally managed waters from the baseline or basepoint of each major haulout in Alaska that is east of 144° W long. Critical habitat includes an aquatic zone that extends 20 nm (37 km) seaward in State and Federally managed waters from the baseline or basepoint of each major rookery and major haulout in Alaska that is west of 144° W long.

Three special aquatic foraging areas in Alaska. Three special aquatic foraging areas in Alaska, including the Shelikof Strait area, the Bogoslof area, and the Seguam Pass area.

(1) Critical habitat includes the Shelikof Strait area in the Gulf of Alaska which . . . consists of the area between the Alaska Peninsula and Tugidak, Sitkinak, Aiaktilik, Kodiak, Raspberry, Afognak and Shuyak Islands (connected by the shortest lines): bounded on the west by a line connecting Cape Kumlik (56°38″/157°26´W) and the southwestern tip of Tugidak Island (56°24′/154°41′W) and bounded in the east by a line connecting Cape Douglas (58°51´N/153°15´W)and the northernmost tip of Shuyak Island (58°37´N/152°22´W).

(2) Critical habitat includes the Bogoslof area in the Bering Sea shelf which . . . consists of the area between 170°00´W and 164°00´W, south of straight lines connecting 55°00´N/170 00´W and 55°00´N/168°00´W; 55°30´N/168°00´W and 55°30´N/166°00´W; 56°00´N/166°00´W and 56°00´N/164°00´W and north of the Aleutian Islands and straight lines between the islands connecting the following coordinates in the order listed:

52°49.2´N/169°40.4´W; 52°49.8´N/169°06.3´W; 53°23.8´N/167°50.1´W; 53°18.7´N/167°51.4´W; 53°59.0´N/166°17.2´W; 54°02.9´N/163°03.0´W; 54°07.7´N/165°40.6´W; 54°08.9´N/165°38.8´W; 54°11.9´N/165°23.3´W; 54°23.9´N/164°44.0´W

(3) Critical habitat includes the Seguam Pass area which . . . consists of the area between 52°00´N and 53°00´N and between 173°30´W and 172°30´W.

3.1.16.2 Physical and biological features of Steller sea lion critical habitat

For the Steller sea lion, the physical and biological features of its habitat that are essential to the species' conservation are those that support reproduction, foraging, rest, and refuge. Land or terrestrial habitat is relatively easy to identify on the basis of use patterns and because land use patterns are more easily observed. The areas used are likely chosen because they offer refuge from terrestrial predators (e.g., are inaccessible to bears), include suitable substrate for reproductive activities (pupping, nursing, mating), provide some measure of protection from the elements (e.g., wind and waves), and are in close proximity to prey resources.

Prey resources are the most important feature of marine critical habitat. Marine areas may be used for a variety of other reasons (e.g., social interaction, rafting or resting), but foraging is the most important sea lion activity that occurs when the animals are at sea. Two kinds of marine habitat were designated as critical. First, areas around rookeries and haulouts were chosen based on evidence that many foraging trips by lactating adult females in summer may be relatively short (20 km or less; Merrick and Loughlin 1997). Also, mean distances for young-of-the-year in winter may be relatively short (about 30 km; Merrick and Loughlin 1997). These young animals are just learning to feed on their own, and the availability of prey in the vicinity of rookeries and haulouts must be crucial to their transition to independent feeding after weaning. Similarly, areas around rookeries are likely to be important for juveniles. While the foraging patterns of juveniles have not been studied in the BSAI region, it is possible that they depend considerably on resources close to haulouts. Evidence indicates that decreased juvenile survival may be an important proximate cause of the sea lion decline (York 1994, Chumbley *et al*. 1997), and that the growth rate of individual young seals was depressed in the 1980s. These findings are consistent with the hypothesis that young animals are nutritionally stressed. Furthermore, young animals are almost certainly less efficient foragers and probably have relatively greater food requirements which, again, suggests that they may be more easily limited or affected by reduced prey resources or greater energetic requirements associated with foraging at distant locations. Therefore, the areas around rookeries and haulouts must contain essential prey resources for at least lactating adult females, young-of-the-year, and juveniles, and those areas were deemed essential to protect.

Second, three areas were chosen based on 1) at-sea observations indicating that sea lions commonly used these areas for foraging, 2) records of animals killed incidentally in fisheries in the 1980s, 3) knowledge of sea lion prey and their life histories and distributions, and 4) foraging studies. In 1980, Shelikof Strait was identified as a site of extensive spawning aggregations of pollock in winter months. Records of incidental take of sea lions in the pollock fishery in this region provide evidence that Shelikof Strait is an important foraging site (Loughlin and Nelson 1986, Perez and Loughlin 1991). The southeastern Bering Sea north of the Aleutian Islands from Unimak Island past Bogoslof Island to the Islands of Four Mountains is also considered a site that has historically supported a large aggregation of spawning pollock, and is also an area where sighting information and incidental take records support the notion that this is an important foraging area for sea lions (Fiscus and Baines 1966, Kajimura and Loughlin 1988). Finally, large aggregations of Atka mackerel are found in the area around Seguam Pass. These aggregations have supported a fishery since the 1970s, and are in close proximity to a major sea lion rookery on Seguam Island and a smaller rookery on Agligadak Island. Atka mackerel are an important prey of sea lions in the central and western Aleutian Islands. Records of incidental take in fisheries also indicate that the Seguam area is an important for sea lion foraging (Perez and Loughlin 1991).

While many of the important physical and biological elements of Steller sea lion critical habitat can be identified, most of those features (particularly biological features) cannot be described in a complete and quantitative manner. For example, prey species within critical habitat can not be described in detail or with a demonstrated measure of confidence, and the lack of such information is an important impediment to the analysis of fishery effects. Walleye pollock, Atka mackerel, Pacific cod, rockfish, herring, capelin, sand lance, other forage fish, squid, and octopus are important prey items found in Steller sea lion critical habitat but for most (if not all) of these species, we are not able to reliably describe their abundance, biomass, age structure, or temporal and geographic distribution within critical habitat with sufficient clarity and certainty to understand how they interact with Steller sea lions or other consumers, including fisheries. Atka mackerel may be one of the more easily characterized sea lion prey items, but we can not describe their onshore and offshore movements, their distribution inside and outside of critical habitat or in the vicinity of rookeries and haulouts, the relation between eastern and western stocks (or whether separate stocks exist), the causes for their (apparent) two- to three-fold changes in abundance over the last two decades, and so on. Pollock appear to be considerably more dynamic in their spatial and temporal patterns, and their presence within Steller sea lion critical habitat is even more difficult to describe in a detailed or quantitative fashion.

3.1.16.3 Critical habitat and environmental carrying capacity

Prey resources are not only the primary feature of Steller sea lion critical habitat, but they also appear to determine the carrying capacity of the environment for Steller sea lions. Therefore, the concepts of critical habitat and environmental carrying capacity are closely linked: critical habitat reflects the geographical extent of the environment needed to recover and conserve the species. The term “environmental carrying capacity” is generally defined as the number of individuals that can be supported by the resources available. The term has two main uses: first as a descriptive measure of the environment under any given set of circumstances, and the second as a reference point for the environment under “natural” conditions (i.e., unaltered by human activities). Thus, the definition can have markedly different implications depending on whether it is used as a reference point for the natural carrying capacity of the environment, or the carrying capacity of the environment as it may have been altered by human-related activities.

The changes observed in the 1970s and 1980s in Steller sea lion growth, reproduction, and survival are all consistent with limited availability of prey. At this time, the best scientific and commercial data available are not sufficient to distinguish the relative influences of natural (i.e., oceanographic) factors versus human-related activities (i.e., fisheries) on the availability of prey for sea lions. The notion that the observed changes in sea lion vital parameters are consistent with a change in “carrying capacity” does not necessarily mean that the changes are entirely natural. If carrying capacity is defined as a measure of the environment under any set of conditions, then that capacity could also have been reduced by fisheries. That is, natural and human-related changes to the carrying capacity are not mutually exclusive; both types of factors may have been operating at the same time. Natural and human-related factors that may have affected Steller sea lions or their environment in the past are described in the next section.

4.0 ENVIRONMENTAL BASELINE

4.1 Status of the species within the action areas

We begin the environmental baseline with 1) a brief summary of the status of the western population in each of the action areas, 2) some indication of the percent or amount of the species' range or critical habitat that occurs in each action area, and 3) a statement of the potential effects of each action on the population.

Total abundance for the western population of Steller sea lions in 1996 has been estimated as 39,500 animals (Hill and DeMaster *in prep*; based on 1996 counts [NMFS unpubl. data] and correction factors derived by Loughlin *et al*. [1992]). The 1996 counts used to derive this estimate included 11,710 animals (nonpups) in the BSAI region and 9,782 animals (nonpups) in the GOA. These counts suggest that, in 1996, about 54% of the western population was in the BSAI region and 46% in the GOA. These respective percents can serve as rough estimates of the portion of the western population potentially affected by the BSAI and GOA pollock fisheries. The Atka mackerel fishery may not affect all sea lions in the BSAI region. If, for example, the potential affects of the fishery occurred from Yunaska Island westward, then about one-third of the western population could be involved. These estimates should be viewed with caution as the potential effects of the fishery may extend beyond the distribution of fishing effort, because of mobility of both fish stocks and sea lions. Critical habitat for the western population (west of 144°W long.) has been designated around 40 rookeries and 82 haulouts (approximate, overlapping circles with a radius of 20 nm; Figure 9) and special foraging areas at Seguam Pass, in the southeastern Bering Sea, and in Shelikof Strait.

4.1.1 Action area of the BSAI Atka mackerel fishery

From Yunaska Island westward to Attu Island, critical habitat areas are drawn around 20 rookeries and 28 haulouts), and the special foraging area at Seguam Pass. Since 1979, counts of nonpups at trend sites in this area (rookeries and haulouts that have been regularly counted) have declined from over 50,000 to less than 8,000 in 1996, a decline of about 85%. The cause of the decline is unknown, but lack of available prey is the primary hypothesis, based on evidence of nutritional stress from the Gulf of Alaska (Calkins and Goodwin 1988).

Scat analyses (Merrick *et al*. 1997, NMFS unpubl. data) indicate that Atka mackerel are the most frequently consumed prey item for sea lions in this region. The primary concern with respect to Atka mackerel fishery effects is competition for prey, which may result from localized depletion of prey resources due to fishing effort concentrated in time and space, or from adverse modification of critical habitat by significant removal of prey, the main biological feature of critical habitat for the Steller sea lion. Competition for prey could result in decreased condition, growth, reproduction, and survival of sea lions in the action area.

4.1.2 Action area of the BSAI pollock fishery

From Sea Lion Rock (Amak Island) westward to Attu Island, critical habitat areas are drawn around 28 rookeries and 49 haulouts (Figure 9), and the special foraging areas at Seguam Pass and in the southeastern Bering Sea. Since 1977-79, counts of nonpups at trend sites have declined from about 70,000 to about 12,500 in 1996, a decline of about 82%. The cause of the decline is unknown, but lack of available prey is the primary hypothesis.

Scat analyses (Merrick *et al*. 1997, NMFS unpubl. data) indicate that Atka mackerel and pollock are major prey items in this region, with Atka mackerel dominant in the west and pollock dominant in the east. Analyses of potential localized depletion have not been conducted for the pollock fishery, as the prey stocks are more dynamic and fishing vessels can use fish-locator devices to follow or search for prey (i.e., sampling is clearly not random). The primary concerns with respect to pollock fishery effects are adverse modification of critical habitat and competition for prey, which could result in decreased condition, growth, reproduction, or survival of sea lions in the action area.

4.1.3 Action area of the GOA pollock fishery

From 144°W long. to Bird Island in the western GOA, critical habitat areas are drawn around 12 rookeries and 33 haulouts, and the special foraging area in Shelikof Strait. Since 1976, counts of nonpups at trend sites have declined from about 40,000 to less than 10,000 in 1996, a decline of about 76%. The cause of the decline is unknown, but lack of available prey is the primary hypothesis.

Stomach content analyses (Merrick and Calkins 1996) indicate pollock are a major prey item for sea lions in the GOA. Again, the primary concern with respect to pollock fishery effects are adverse modification of critical habitat and competition for prey, which could result in decreased condition, growth, reproduction, or survival of sea lions in the action area.

4.2 Known or suspected factors contributing to the current status of the western population of Steller sea lions or their critical habitat

The remainder of the environmental baseline describes the various known and suspected factors that have contributed or may have contributed to the current status of the Steller sea lion, its habitat (including designated critical habitat), and the ecosystem within the action area.

4.2.1 Predation

As noted in the above section on status of the species, killer whales and sharks prey on Steller sea lions. Anecdotal evidence of such predation is available, but the rate of predation and the potential impact on trends of the western population can not be determined with any measure of confidence. Given the reduced abundance of sea lions at multiple sites (rookeries and haulouts), predation by killer whales and other sources of natural mortality may exacerbate the decline in local areas (e.g., Barrett-Lennard *et al*. unpubl. rep.).

4.2.2 Disease

Disease and parasitism are also potential causes of population decline, and evidence is available indicating that animals have been exposed to diseases and carry parasites. However, none of the evidence available at this time provides any indication that disease or parasitism caused the decline or are impeding recovery. Disease and parasitism are common in all pinniped populations and have been responsible for major die-offs (e.g., Osterhaus *et al*. 1997), but such events are usually relatively short-lived and provide more evidence of morbidity or mortality. The ramifications of disease and parasitism remain unconcern, both as primary and secondary problems, but do not appear to be significant impediments to recovery at this time or on the basis of the information currently available.

4.2.3 Toxic substances

Several studies indicate that organochlorine pollutant residues in the tissues of California sea lions and harbor seals have been associated with reproductive failure (NMFS 1992). These pollutants have also been reported in association with impaired immune systems (Becker *et al*. 1997). A number of studies (Varanasi *et al*. 1992, Lee *et al*. 1996, Krahn 1997, Krone 1997, Becker *et al*. 1997) have also indicated relatively high concentrations of organochlorine compounds in Steller sea lions in Alaska, although these levels have not yet been associated with any changes in health or vital rates. Steller sea lions were undoubtedly exposed to oil after the Exxon Valdez oil spill, but no significant adverse effects of the oil were confirmed (Calkins *et al*. 1994; see the next section). At the present time, the available information does not support the hypothesis that contaminants are a significant contributor to the decline of sea lions, or an impediment to their recovery.

4.2.4 Oil and gas or mineral development

Previous NMFS biological opinions for both the BSAI and the GOA analyzed this factor under the heading of "human development" (NMFS 1991xx, 1996xx). In each case it was noted that human development activities that result in aquatic habitat destruction or the release of contaminants and pathogens (e.g., mineral exploration and extraction, effluent discharges into the marine environment) could directly diminish the health and reproductive success of Steller sea lions or cause them to abandon feeding, breeding, or resting sites. Development and discharge proposals typically undergo ESA section 7 consultation during the Federal permitting process.

On October 15, 1993, NMFS completed a biological opinion on the leasing and exploration activities of the Minerals Management Service in the Cook Inlet/Shelikof Strait region (lease sale Number 149). The opinion concluded that such activities were not likely to jeopardize the continued existence of any listed or proposed species, nor were they likely to destroy or adversely modify critical habitats (NMFS 1993). The biological opinion noted that "Shelikof Strait was designated as critical habitat based on its proximity to major rookeries and important haulouts, its use by foraging sea lions, and its value as an area of high forage fish production. Any impacts attributable to oil and gas development that adversely affect the forage fish resource within Shelikof Strait may also adversely modify this critical habitat." However, NMFS also noted that "the probability of an oil spill during exploration is low, and the forage resource base within Cook Inlet/Shelikof Strait is unlikely to be impacted to the point of adversely affecting this critical habitat."

In 1995, NMFS conducted another section 7 consultation with the Minerals Management Service and concluded that the lease sale and exploration activities for the proposed oil and gas Lease Sale Number 158, Yakutat were not likely to jeopardize the continued existence of any listed or proposed species, nor were the activities likely to destroy or adversely modify critical habitats (NMFS 1995).

Oil spills are expected to result in adverse effects if they contact Steller sea lions, haulouts, or rookeries when occupied, or large proportions of major prey populations (Minerals Management Service 1996). Potential effects could include: oil exposure, including surface contact and pelage fouling, inhalation of contaminant vapor, and ingestion of oil or oil-contaminated prey. Because the insulation of nonpup sea lions is provided by a thick fat layer rather than pelage whose insulative value could be destroyed by fouling, oil contact is not expected to cause death from hypothermia; however, sensitive tissues (e.g., eyes, nasal passages, mouth, lungs) are likely to be irritated or ulcerated by exposure to oil or hydrocarbon fumes. Oiled individuals probably will experience effects that may interfere with routine activities for a few hours to a few days; movement to clean water areas is expected to relieve most symptoms. Females returning from feeding trips may transfer oil to pups, which probably are more sensitive to oil contact.

The extent to which sea lions avoid areas that have been oiled is not known; individuals observed in Prince William Sound and the Gulf of Alaska after the Exxon Valdez oil spill did not appear to avoid oiled areas (Calkins and Becker 1990). Sea lions were sighted swimming in or near oil slicks, oil was seen near numerous haulout sites, and oil fouled the rookeries at Seal Rocks and Sugarloaf Island (Calkins *et al*. 1994). All of the sea lions collected in Prince William Sound in October 1989 had high enough levels of metabolites of aromatic hydrocarbons in the bile to confirm exposure and active metabolism at the tissue level. But as noted above, no evidence indicated damage caused to sea lions from toxic effects of the oil (Calkins *et al*. 1994).

Steller sea lions are probably most vulnerable to acute oil spills during mid-May through mid-July, the period of time they are on rookeries (Calkins and Pitcher 1982). An oil spill near any rookery during this time could cause abandonment of pups and interrupt the normal breeding cycle. Loss of a majority of pups from one of the large rookeries plus failure to impregnate females from that rookery could have serious implications for the western population of sea lions. Loss of prey species may pose the most serious, long term threats to sea lions in the GOA (Calkins and Pitcher 1982).

Although Alaska is estimated to contain large petroleum resources on its outer continental shelf and in state waters, the only oil produced from Alaska's outer continental shelf to date has come from Cook Inlet south of Anchorage. In the foreseeable future, the kind of extensive oil and gas activities that characterize the outer continental shelf of the central Gulf of Mexico is not likely for the GOA. Little or no oil and gas exploration or production is occurring or likely to occur soon on the Russian outer continental shelf area of the Bering Sea. The National Research Council recently concluded, therefore, that oil and gas activities in the Bering Sea have not significantly affected the Bering Sea ecosystem (NRC 1996).

4.2.5 Disturbance by activities unrelated to fishing

Several studies investigating the potential effects of oil and gas exploration and development on the Steller sea lion have noted human disturbance as a potential factor. Calkins and Pitcher (1982) found that disturbance from aircraft and vessel traffic has extremely variable effects on hauled-out sea lions. Sea lion reaction to occasional disturbances ranges from no reaction at all to complete and immediate departure from the haulout area. The type of reaction appears to depend on a variety of factors. When sea lions are frightened off rookeries during the breeding and pupping season, pups may be trampled or even abandoned in extreme cases. Sea lions have temporarily abandoned some areas after repeated disturbance (Thorsteinson and Lensink 1962), but in other situations they have continued using areas after repeated and severe harassment. Johnson *et al*. (1989) evaluated the potential vulnerability of various Steller sea lion haulout sites and rookeries to noise and disturbance and also noted a variable effect on sea lions. Kenyon (1962) noted permanent abandonment of areas in the Pribilof Islands that were subjected to repeated disturbance. A major sea lion rookery at Cape Sarichef was abandoned after the construction of a light house at that site, but then has been used again as a haulout after the light house was no longer inhabited by humans. The consequences of such disturbance to the overall population are difficult to measure. Disturbance may have contributed to or exacerbated the decline, although it is not likely to have been a major factor. At present, concern is focused on disturbance as an impediment to the study of sea lions and other potential causes of the decline (NMFS 1998).

4.2.6 Research

Steller sea lions have been taken for scientific research (Thorsteinson and Lensink 1962, Calkins and Pitcher 1982, Calkins and Goodwin 1988, and Calkins *et al*. 1994):

- Experimental commercial harvest of 630 sea lion bulls in 1959. Life history information (age, size, reproductive condition, food habits) was collected.

- Between 1975 and 1978, 250 sea lions were collected by shooting in nearshore waters and on rookeries and hauling areas of the GOA. Stomachs were removed and examined for food content, reproductive organs were preserved for examination, blood samples were taken for disease and parasite studies, body measurements were recorded for growth studies, skulls were retained for age determination, tissue samples were preserved for elemental analysis and pelage samples were taken for molt studies.

- In 1985 and 1986, 178 sea lions were collected in the GOA and Southeastern Alaska to compare food habits, reproductive parameters, growth and condition, and diseases, with the same parameters from animals which were collected in the 1970s. The study was designed to address the problem of declining numbers of sea lions in the North Pacific and particularly in the GOA.

- Sixteen animals were collected under the Natural Resources Damage Assessment study conducted on Steller sea lions in 1989 following the Exxon Valdez oil spill.

4.2.7 Entanglement in marine debris

Observations of Steller sea lions entangled in marine debris have been made throughout the GOA and in southeast Alaska (Calkins 1985), typically incidental to other sea lion studies. Two categories of debris, closed plastic packing bands and net material, accounted for the majority of entanglements. Loughlin *et al*. (1986) surveyed numerous rookeries and haulout sites to evaluate the nature and magnitude of entanglement in debris on Steller sea lions in the Aleutian Islands. Of 30,117 animals counted (15,957 adults; 14,160 pups) only 11 adults showed evidence of entanglement with debris, specifically, net or twine, not packing bands or other materials. Entanglement rates of pups and juveniles appear to be even lower than those observed for adults (Loughlin *et al*. 1986). It is possible that pups were too young during the survey to have encountered debris in the water or that pups and juveniles were unable to swim to shore once entangled and died at sea. Trites and Larkin (1992) assumed that mortalities from entanglement in marine debris were not a major factor in the observed declines of Steller sea lions and estimated that perhaps fewer than 100 animals are killed each year.

4.2.8 Commercial harvest of Steller sea lions

In 1959, the Bureau of Commercial Fisheries awarded a contract to a commercial fishing company to develop techniques for harvesting sea lions in Alaskan waters. The two-fold purpose of the contract was to reduce the sea lion herds (because of alleged depredations on salmon and halibut fisheries) and to provide an economical source of protein for fur farms, fish hatcheries, and similar purposes (Thorsteinson and Lensink 1962). In 1959, 630 sea lion bulls were killed in an experimental harvest, but the harvest proved to be uneconomical. Another study was contracted by the Bureau of Indian Affairs of the Department of Interior to analyze the feasibility of a commercial sea lion harvest in Alaska (BIA 1964). A total of 45,178 pups of both sexes were killed in the eastern Aleutian Islands and GOA between 1963 and 1972 (Merrick *et al*. 1987). Such harvests could have depressed recruitment in the short term and may have explained declines noted at some sites in the eastern Aleutian Islands or the GOA. These harvests do not appear to explain declines in other regions.

4.2.9 Subsistence harvest of Steller sea lions

The MMPA authorizes the taking of any marine mammal by Alaska Natives for subsistence purposes or for the purpose of creating and selling authentic native articles of handicrafts and clothing, given that it is not done in a wasteful manner (MMPA, Section 101[b]). The ESA also contains provisions that allow for the continued subsistence use of listed species. Both the ESA and the MMPA contain provisions that allow regulation of the subsistence harvest of endangered, threatened, or depleted species, if necessary (NMFS 1995).

Subsistence harvest of Steller sea lions from 1960 to 1990 has been estimated at 150 animals per year (Alverson 1992), but the estimate was subjective and not based on any referenced data. This estimate is well below the levels observed in the 1990s (Hill and DeMaster *in prep*), which seems inconsistent with the fact that sea lion populations are at their lowest recorded levels. In 1986, a working group organized by NMML suggested that subsistence harvest had a potentially low impact on recent Steller sea lion population declines in Alaska (Loughlin 1987). More recent estimates (Wolfe and Mishler 1993, 1994, 1995, 1996) indicate a mean annual subsistence take of

448 animals from the Western U.S. stock (i.e., the endangered population) from 1992 to 1995. The majority (79%) of sea lions were taken by Aleut hunters in the Aleutian and Pribilof Islands. The great majority (99%) of the statewide subsistence take was from west of 144°W long. (i.e., the range of the western population).

The overall impact of the subsistence harvest on the western population will be determined by the number of animals taken, their sex and age class, and the location where they are taken. As is the case for other sources of mortality, the significance of subsistence harvesting may increase as the western population decreases in size unless the harvesting rate is reduced accordingly. The current subsistence harvest represents a large proportion of the potential biological removal that was calculated for the western stock of the Steller sea lion pursuant to the Marine Mammal Protection Act (Hill and DeMaster *in prep*). However, the subsistence harvest accounts for only a relatively small portion of the animals lost to the population each year. For example, a population of about 40,000 growing at 8% per year would be expected to increase to 43,200 after one year; a gain of 3,200 animals. If, instead, that population is observed to decline by about 5%, then it would drop to 38,000, a loss of 2,000. The difference between expected and observed is, then, 5,200 animals, of which a subsistence harvest of say, 300, would account for 6%. Thus, the number of animals currently taken must contribute to the decline of sea lions, particularly at certain locations, but is not sufficient to explain the decline throughout the range of the population.

4.2.10 Natural environmental change

Discrimination between the relative influence of natural environmental factors versus human activities is controversial in both a scientific and management context. The distinction between natural and human-related impacts gets to the heart of management responsibilities under both the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). At the time these acts were passed, our conceptual model of natural ecosystems was built largely on the notion of a balance and persistence in nature, or a stable point of ecosystem equilibrium. In the past three decades, we are discovering that the term “stable” may not be such a good descriptor of ecosystems; that is, we are learning that ecosystems vary naturally. At the same time, ecosystems may be seriously perturbed by human activities (e.g., global warming, global pollution, and ever increasing demands for natural products to satisfy growing human populations), and often we can not distinguish natural variation from changes wrought by human activities.

Studies of atmospheric and oceanic circulation and physical properties indicate that the BSAI and GOA ecosystems shift between at least two types of climatic regimes (Ebbesmeyer *et al*. 1990, Trenberth 1990, Brodeur and Ware 1992, Beamish 1993, Francis and Hare 1994, Miller *et al*. 1994, Trenberth and Hurrell 1994; Ingraham *et al*. 1998). While these regimes differ in many ways, they can be simply categorized as “warm” and “cold” depending on atmospheric and oceanic temperatures. One factor inducing the shift between regimes is changes in the position of the Aleutian Low Pressure system, which leads to changes in atmospheric temperature, storm tracks, ice cover, and wind direction (Wyllie-Echeverria and Wooster 1998). Shifts between regimes can be reflected in such indices as the Southern Oscillation Index, Pacific Decadal Oscillation, and the North Pacific Index. Historical studies suggest that over the last 500 years, the system has oscillated between the two distinct regimes every 10-30 years (Ingraham *et al*. 1998).

A well-documented shift from a cold to a warm regime in 1976-77 was associated with dramatic changes in the structure and composition of the invertebrate and fish communities as well as the distribution of individual species in the North Pacific ocean and Bering Sea (Brodeur and Ware 1992, Beamish 1993, Francis and Hare 1994, Miller *et al*. 1994, Hollowed and Wooster 1992; 1995; Wyllie-Echeverria and Wooster 1998). For instance, many groundfish stocks, particularly pollock, Atka mackerel, cod and various flatfish species increased in abundance as a result of strong yearclasses spawned in the mid to late 1970s. Many of the long-lived flatfish species (e.g., arrowtooth flounder, Pacific halibut, yellowfin sole, and rock sole) remained in high abundance since then, while other shorter lived groundfish species (pollock, Atka mackerel, and Pacific cod) have oscillated in abundance. Based on these patterns, researchers have associated "warm" years (and other related environmental conditions, such as southwest winds in April [Wyllie-Echeverria and Wooster 1998]), with the production of strong yearclasses of gadids (Hollowed and Wooster 1992; 1995; Wespestad *et al*. 1997).

Increases in many broadly distributed benthic (e.g., arrowtooth flounder, Pacific halibut) and semi-demersal (e.g., pollock and Pacific cod) piscivorous groundfish species since the late 1970s has been associated with either (or both) a decline in abundance (at least in nearshore environments; Anderson *et al*. 1997) or a change in distribution of short-lived pelagic species such as capelin. Anderson and Piatt (*in prep*) describe an almost complete disappearance of capelin from bays and the nearshore environment of the western and central GOA beginning in the late 1970s and early 1980s, and increases in cod and flatfish. During this time, the prevalence of capelin in the diets of many piscivorous birds and pinnipeds in the GOA also declined. However, Livingston *et al*. (*in prep*) estimated that capelin consumption in 1990 in the GOA by the groundfish species was at least 300,000 mt. This suggests that capelin didn't necessarily disappear from the GOA (since so much was eaten), but changed its vertical distribution (went deeper), possibly in response to the warm conditions. If this change occurred, capelin would have been more susceptible to predation by piscivorous groundfish and less available to birds and pinnipeds that begin their foraging excursions from the water's surface.

As in the GOA, the prevalence of capelin in the diets of puffins, kittiwakes and other birds on the Pribilof Islands in the BSAI also declined in the mid-1980s. Furthermore, the prevalence of juvenile pollock tended to increase during this time period (Byrd *et al*. 1992, Springer 1993). Further north in the eastern Bering Sea, capelin remains a dominant feature of the kittiwake diet on St. Lawrence Island. This suggests that capelin distribution contracted to the north in response to warming conditions in the EBS in the 1980s and 1990s. Thus, capelin in the EBS may have redistributed horizontally (or geographically) in response to warming, while in the GOA, the redistribution may have been more in the vertical dimension. Regardless, these changes in prey distribution in response to changes in environmental conditions may have reduced the availability of capelin to Steller sea lions in the SE Bering Sea and GOA. During warm regimes, Steller sea lions may then depend on the availability and abundance of other resident prey in these areas for their survival.

Sea lions may have lived through many regime shifts in the few million years that they have existed. What may be different about this most recent shift is the coincident development of extensive fisheries targeting the same prey that sea lions depend on during warm regimes.

Fisheries in the Bering Sea and GOA expanded enormously in the 1960s and 1970s. The existence of a strong environmental influence on sea lion trends does not rule out the possibility of significant fisheries-related effect. The cause of the sea lion decline need not be a single factor. To the contrary, strong environmental influences on BSAI and GOA ecosystems could increase the sensitivity of sea lions to fisheries or changes in those ecosystems resulting from fisheries.

4.2.11 Prey quality

Alverson (1992) proposed that the changes in trophic structure observed in the BSAI and GOA regions resulted in the dominance of pollock, and he further proposed that the shift to ecosystems dominated by pollock has been the overriding factor in the decline of Steller sea lions. That is, Alverson (1992) suggested a link between the changes in trophic structure of these ecosystems and the decline of sea lions based on the notion that pollock are a low quality prey for sea lions and the western population has not been able to sustain itself with this low quality prey. This suggestion has become known as the "junk food hypothesis."

The notion that pollock are of low quality is based on the fact that, on average, pollock have a lower fat content (per kilogram) than many of the other species in the sea lion's diet. To drive home this difference, pollock are frequently compared with herring, which has a higher fat content than other prey species in the sea lion diet. The difference has been used to argue the pollock are a bad prey item for sea lions. Several studies have been conducted on diet physiology of California sea lions (Fadely *et al*. 1994) or Steller sea lions (Rosen and Trites *in prep*) fed solely on pollock. The study of Rosen and Trites (*in prep*) has not been made available in written form, but has been reported at meetings of the North Pacific Fishery Management Council and in other public discussions. The results of both studies are consistent with the notion that on a per kilogram basis, sea lions would have to consume a larger ration of pollock than herring if they were to survive on a diet composed of a single species. The results of the Rosen and Trites study have also been used to suggest that because the sea lions lost weight on the diet of pollock, they could not sustain themselves on that diet. But that conclusion over-reaches the data.

First, it is reasonable to suggest that pollock might not be the preferred prey of sea lions if they had a wide selection from which to choose. But as Alverson (1991) suggested, the observed change in the trophic structure of these ecosystems indicates that they do not have a wide selection. Second, sea lions in the wild are not completely limited to a single prey type. Diet studies conducted to date indicate that sea lions feed on a number of prey. The amount of diversity has varied considerably and may be an important factor (Merrick *et al*. 1997; see the section below on "changes in community composition and diet diversity"), but clearly sea lions are not limited to the extreme of only one prey type. Third, evidence for weight loss does not lead to the conclusion that the sea lions would starve to death, starvation to the point of death is not necessarily a consequence of weight loss over a period of a few weeks. The study by Rosen and Trites should be made available for review, and then should be repeated under the most realistic conditions possible to understand more about the significance of prey types to sea lions. This is a meaningful area of investigation, but it is currently premature to form any conclusions.

The value of any particular prey type is not determined solely by its fatty content, but also by factors such as individual size, total biomass, availability, behavior, degree of aggregation, temporal and spatial distribution, and so on. That is, the value of any particular prey type depends on the net gain to a sea lion from foraging on that prey, and net gain is a function of multiple factors of which fat content is an important, but not the only, determinant.

In spite of any debate about the nutritional value of pollock, the fact remains that pollock is a major prey of sea lions. Simply put, sea lions eat, and therefore depend on, pollock. In the present context, the question to be addressed is whether fishery removal of pollock from critical habitat is to the sea lions' advantage, disadvantage, or of no particular consequence. If sea lions are food stressed, then the arguments that removal of pollock could be to their advantage would be 1) the fishery removes larger cannibalistic pollock and thereby increases the total available biomass (through increased survival of smaller pollock) to sea lions, or 2) the removal of large pollock from sea lion critical habitat will result in a shift in the composition of the prey assemblage in critical habitat and thereby increase the availability of other "better" prey types. If the removal of large cannibalistic pollock does confer an advantage to foraging sea lions, then that advantage would seem most likely from fisheries that occur in summer or autumn months to the north or northwest of the CVOA, where cannibalism appears to be most prevalent. With respect to the second possible advantage, the evidence that heavy fishing of pollock will reverse the trophic shift observed in these regions is not supported by the available data at sites where pollock have already been fished heavily. These questions are addressed in further detail below in the section on fisheries impacts.

4.2.12 Fishery impacts

This consultation considers the potential effects of the BSAI and GOA pollock fisheries and the BSAI Atka mackerel fishery. These fisheries may interact with Steller sea lions in a wide variety of ways, including operational conflicts (e.g., incidental kill, gear conflicts, sea lion removal of catch) and biological conflicts (e.g., competition for prey). Operational conflicts are assessed by observers and have been reduced to low levels (Hill and DeMaster *in prep*) that are considered to be negligible at a sea lion population level. Therefore, the discussion of fishery effects will focus on biological effects and, particularly, competition.

4.2.12.1 Assessing past competition

The issue of competition between fisheries and sea lions is central to this biological opinion and a determination of whether these fisheries jeopardize the survival and recovery of the Steller sea lion or adversely modify its critical habitat. Competition can take a number of forms and involves a range of considerations, each of which will be described below. Competition occurs when two potential competitors use the same resource, the use of the resource by one potential competitor limits the availability or use by a second competitor, and the restriction in availability or use of the resource constrains or limits the second competitor in some manner. The hypothesis that competition occurs or has occurred between the Steller sea lion and these fisheries is based on information pertaining to the life history of sea lions and their population trends, the fish stock, and the fishery.

- ! The fish species targeted in these fisheries are major prey items of Steller sea lions;
- ! The geographic distributions of these fisheries overlap the foraging distribution of Steller sea lions; and
- ! Steller sea lions appear to be limited by lack of available prey.

Two approaches have been suggested to assess the potential for competition between sea lions and fisheries. The first approach involves establishment or demonstration of a direct causal link. The second approach does not require establishment of a direct link, but rather searches for correlations between observed changes in sea lion vital rates or population trends and patterns in the fishery or fished stock. This second approach, therefore, assumes a link may occur if a correlation can be demonstrated.

The first approach was suggested by Lowry *et al*. (1982), who provide the following series of questions for assessing a direct causal link between fisheries and Steller sea lion: (a) does the subject fishery affect the diet of Steller sea lions? (b) do any changes in diet compromise the condition of individual animals? (c) are any changes in condition sufficient to reduce growth, reproduction or survival? and (d) are any changes in reproduction and/or survival sufficient to have significant population effects? Unfortunately, the data available to answer these questions is either unavailable or equivocal.

The second approach uses the observation of potential relations (correlations) to indicate that a fishery may have had a significant impact on Steller sea lions. Most examples of this approach include investigations of correlations between indices of the pollock or other fisheries in the BSAI and GOA regions and indices of Steller sea lion populations (Merrick and Loughlin 1989, Alverson 1992, Trites and Larkin 1992, Fritz and Ferrero 1994). The question is whether the removal of fish biomass by the fishery reduces the availability of prey for Steller sea lions to the extent that the condition and vital rates of sea lions are compromised and local populations of sea lions are detrimentally affected.

4.2.12.2 Competition and selection of prey by size

Size selection of prey by fisheries and by sea lions may have significant bearing on the question of whether or not competitive interactions occur. Fisheries may compete with sea lions if they remove the same size of prey from the same areas. Fisheries may also reduce the spawning biomass of prey to the extent that the reproductive capacity of the fish stock is reduced and, over time, fewer fish become available for sea lions. And for pollock fisheries, size selection could alter the rate of cannibalism of young pollock by older pollock, with several potential consequences for sea lions.

Atka mackerel begin to recruit to the fishery at age two and are considered fully recruited to the fishery by age five (Lowe and Fritz 1997). Length frequency data from the catch indicate that a wide range of sizes are taken, which may reflect the size distributions available or effort by the fishery to select for certain sizes of fish. A number of factors can influence the size of fish caught, including fishing strategy, season, location, gear type, market factors, availability of different size classes, and life history of Atka mackerel. The amount of overlap in sizes of Atka mackerel taken by the fishery versus those taken by Steller sea lions is undetermined, because studies have not been conducted on sea lion selection of Atka mackerel by size. Such studies should be conducted, but the wide size range of Atka mackerel caught by the fishery suggests considerable, if not complete, overlap in sizes taken by the fishery and sea lions.

The question of size overlap in fishery catch and sea lion prey has been more of an issue with respect to the pollock fishery, and the remainder of this section will focus on pollock only.

The pollock fisheries remove intermediate sized to larger pollock. Wespestad *et al*. (1997) suggest that pollock are fully recruited to the BSAI fishery at age four, but these authors also present estimates of fishery selectivity by age which suggest that the recruitment curve is dome-shaped, with full recruitment delayed until ages six or seven, and then tapering off for older ages. Estimates of selectivity for the GOA pollock fishery also indicate that the recruitment curve is dome-shaped and peaks at about the same ages (Hollowed *et al*. 1997). Thus, the pollock catch in both regions would appear to be selective for intermediate aged fish and may tend to shift the distribution of remaining pollock to younger, smaller sizes and to a lesser extent, older, larger sizes.

- *Selection or preference* --- We do not what prey sea lions “prefer” or “select,” we only know what they consume. The data available on sizes of pollock consumed by sea lions indicate that sea lions consume a wide range of sizes (Table 8; Pitcher 1981, Loughlin and Nelson 1986, Frost and Lowry 1986, Calkins and Goodwin 1988, Lowry *et al*. 1989, Fritz *et al*. 1995, NMFS 1995, Merrick and Calkins 1996 - note that the same data may be evaluated in several papers and should therefore be reviewed with caution). Loughlin and Nelson (1986) found that pollock consumed by sea lions taken incidentally by the fishery had consumed pollock of essentially the same size as taken by the fishery ($\bar{x}$ = 40.9 cm, range = 30.0 cm to 52.0 cm). However, these authors suggest that the sea lions had likely been taking advantage of the pollock caught in fishing nets and the results would therefore be a potentially biased indication of pollock sizes consumed by sea lions under natural conditions.

The data presented in Table 8 include the mean and range of the lengths of pollock consumed by sea lions as reported in various studies. Range is not a particularly good indicator of sizes consumed, as it is susceptible to the influence of outliers. However, in the results listed in Table 8, the maximum values are consistently large, which indicates that consumption of large pollock by sea lions is more likely common than exceptional (see also Figure 40a). Frequency distributions of pollock consumed convey considerably more information. Frequency distributions of pollock available and taken by sea lions are reported in Fritz *et al*. (1995; their Figs. 11 and 12) and Merrick and Calkins (1996; their Figs. 2 and 3). Those distributions are reproduced here in Figure 40b and c. Note that the distributions illustrated in Figure 12 of Fritz *et al*. (1995) correspond approximately to the distributions illustrated in Figure 2 of Merrick and Calkins (1996). Those frequency distributions clearly indicate that the sizes of pollock removed by fisheries overlap considerably with the sizes consumed by Steller sea lions. Furthermore, Hollowed (pers. comm., Hollowed *et al*. 1997) used the data for all sizes of sea lions in the stock synthesis model used to evaluate the GOA pollock stock, and the results suggested that based on the sizes consumed and the sizes available, sea lions may have been selecting for larger fish. Selectivity values reported in Hollowed *et al*. (1997) were:

Size selectivity by sea lions (all ages) of pollock by age

Pollock age	1	2	3	4	5	6	7	8	9
Selectivity	0.22	0.87	0.99	1.00	0.99	0.99	0.99	0.99	0.99

With respect to smaller sea lions, the data in Merrick and Calkins (1996) indicates that the size of pollock consumed by juvenile sea lions was smaller than the size consumed by adults (See Figure 40a and b, and Table 8), which is not surprising. The smaller sea lions were feeding heavily on the 1984 cohort of pollock, which was present in far greater abundance than the 1982 or 1983 cohorts (A. Hollowed, pers. comm.; see Figure 35 for recruitment at age 3 for these three cohorts). Thus, their selection of pollock as reported in Merrick and Calkins (1996) appears to have been determined largely by the availability of the 1984 cohort, and may not be a reliable indicator of preference by juvenile sea lions. Furthermore, while Merrick and Calkins (1996) reported that 93.2% of the pollock consumed by 7 juvenile sea lions were smaller than 30 cm FL [fork length], they also reported that those smaller pollock only accounted for half of the pollock mass consumed. Half of the pollock mass the juveniles consumed came from pollock larger than 30 cm. Importantly, mass consumed, and not number consumed, is the appropriate indicator of dietary significance.

- *Biomass versus number* --- That is, the dietary significance of a particular length class of pollock to Steller sea lions is not so much determined by the number consumed at each length, but rather the biomass consumed at each length. (The same concept applies to the fishery - removals are measured by biomass rather than number.) Because biomass increases (geometrically) with length, sea lions may get more biomass from larger fish, even if they consume fewer of them. Figure 41 uses the data from Fritz *et al*. (1995; their Figure 11) to illustrate the potential error from assuming that the most important fish size is indicated by the number consumed by length. Their figure was based on pollock consumed by sea lions in management area 521 (northwest of the Pribilof Islands), and those pollock had a modal length of about 29 cm. On the basis of frequency alone, the reader might assume that the pollock of most importance to the diet of those sea lions diet were, therefore, those of

> about 29 cm in length. However, because biomass increases with length, those sea lions obtained more biomass from fish 6 cm to 9 cm longer.

Thus, even when one-year-old pollock dominated the prey field available in the GOA in 1985, larger pollock were taken by juvenile sea lions (and other age classes). Those larger pollock were taken less frequently but, nevertheless, provided a significant portion of the biomass consumed. The conclusions that a) sea lions (adults or juveniles) depend solely or even largely on smaller pollock and (on that basis), b) do not compete with fisheries are, therefore, not supported by this evidence.

4.2.12.3 Competition and depth of prey

The possibility of competition between Atka mackerel and pollock fisheries and the Steller sea lion has been argued on the basis of depth of trawling, and depth of diving by sea lions. The majority of trawls for Atka mackerel occur at less than 200 m. Trawling depth for pollock varies considerably, depending on location, but ranges from less than 30 m to over 500 m (Figs. 26 through 29). Diving depths summarized in Merrick and Loughlin (1997) indicate that the sea lions in their study rarely dove to 250 m or greater, with most of the dives less than 50 m (Figure 36). The argument, then, is that if sea lions forage primarily in waters less than 50 m depth, then these fisheries, and particularly the pollock fisheries, are not likely to compete because they trawl at deeper depths.

This argument is founded, in part, on the notion that the data reported in Merrick and Loughlin (1997) are characteristic of all sea lion foraging. Diving depths reported in this study were from five adult females in summer, five adult females in winter, and five young-of-the-year in winter.

The arguments that such partitioning is not likely to avoid competition are as follows. First, the diving depths indicated are not necessarily representative of foraging effort. That is, many of the dives recorded were in the range of 4 to 10 m, and some (perhaps a large) portion of these dives were likely related to activities other than foraging. For example, animals moving between locations may transit at shallow depths to avoid rough sea surface conditions - many of the dives recorded in the 4 to 10 m range could have been due to transiting.

Second, the diving patterns exhibited by these animals occurred throughout the day, but more dives occurred in the nighttime period (2100 to 0300 hours) than morning (0300 to 0900 hours), daytime (0900 to 1500 hours), or evening (1500 to 2100 hours). The vertical distribution of pollock changes in a diel pattern with a tendency for shallow depths at nighttime and deeper depths during the day (ref). Thus, sea lions may be taking advantage of the diel movement patterns of pollock, and pollock that are the target of deeper trawls during the day time may be prey of sea lions at shallower depths at night.

Third, even if sea lions were limited to depths less than 250 m, the depths of trawling indicated in Figures 26 through 29 indicate considerable overlap of sea lion and trawling distributions.

Finally, the sample sizes in this study were small and therefore not likely to represent the range of diving depths and patterns characteristic of all sea lions. For example, the five winter young-of-the-year were probably between five and nine months of age when instrumented and may not yet have weaned. These animals were, therefore, just beginning to learn to forage and their diving patterns are not likely representative of juvenile seals (ages one to four). As mentioned earlier, Swain and Calkins (1997) have documented regular diving of juveniles to 150 m to 250 m (Figure 37). The information presented in Merrick and Loughlin (1997) is part of the best scientific and commercial data available. It is not, however, the sum total of that information, and investigations of foraging patterns of other marine mammals suggests that we are just beginning to learn about the foraging patterns of Steller sea lions. These initial small samples are not likely to characterize the whole repertoire of foraging sea lions. To assume that they do would be unreasonable at this point, and would require that we ignore previous experiences with other marine mammals.

4.2.12.4 Competition and the winter season

Changes in behavior, foraging patterns, distribution, and metabolic/physiologic requirements during the annual cycle are all pertinent to consideration of the potential impact of prey removal by commercial fisheries. Steller sea lions, at least adult females and immature animals, are not like some marine mammals that store large amounts of fat to allow periods of fasting. They need more or less continuous access to food resources throughout the year. Nevertheless, the sensitivity of sea lions to competition from fisheries may be exaggerated during certain times of the year. Reproduction likely places a considerable physiological or metabolic burden on adult females throughout their annual cycle. Following birth of a pup, the female must acquire sufficient nutrients and energy to support both herself and her pup. The added demand may persist until the next reproductive season, or longer, and is exaggerated by the rigors and requirements of winter conditions. The metabolic requirements of a female that has given birth and then become pregnant again are increased further to the extent that lactation and pregnancy overlap and the female must support her young-of-the-year, the developing fetus, and herself. And again, she must do so through the winter season when metabolic requirements are likely to be exaggerated by harsh environmental conditions.

Nursing pups are still dependent, at least to some extent, on their mother. If the mother is able to satisfy all the pup's nutritional needs through the winter, then at least from a nutritional point of view, winter may not be a time of added nutritional risk to the pup. If, on the other hand, the pup begins a gradual transition to independence before or during the winter season, then the challenge of survival may be greater for the pup through the winter.

Weaned pups are independent of their mothers, but may not have developed adequate foraging skills. They must learn those skills, and their ability to do so determines, at least in part, whether they will survive to reproductive maturity. This transition to nutritional independence is likely confounded by a number of seasonal factors. Seasonal changes may severely confound foraging conditions and requirements; winter months bring harsher environmental conditions (lower temperatures, rougher sea surface states) and may be accompanied by changing prey concentrations and distributions (Merrick and Loughlin 1997). Weaned pups' lack of experience may result in greater energetic costs associated with searching for prey. Their smaller size and undeveloped foraging skills may limit the prey available to them, while at the same time, their small size results in relatively greater metabolic and growth requirements.

Diet studies of captive sea lions indicated that they adjust their intake levels seasonally, with increases in fall and early winter months (Kastelein *et al*. 1990). These adjustments varied with age and sex of the studied animals, and the extent to which the patterns observed are reflective of foraging patterns in sea lions in the BSAI or GOA regions is not known. Nonetheless, such studies support the contention that the winter period is a time of greater metabolic demands and prey requirements.

Changes in condition, availability, and behavior of prey may also be essential to successful foraging by all sea lions in winter. Pollock in reproductive condition (i.e., bearing roe—toward the end of the winter) are presumably of greater nutritional value to sea lions (for the same reasons that the fisheries would rather take roe-bearing pollock than pollock spent after the spawning season). Also, the relative value of any prey type must also depend on the energetic costs of capturing, consuming, and digesting the prey. The winter aggregation of roe-bearing pollock may lead to a reduction in sea lion energetic costs associated with foraging on this species. Pollock aggregations appear to be relatively predictable in, for example, Shelikof Strait or the southeastern Bering Sea, which supports the idea that these are important foraging areas for sea lions.

Nonetheless, the information that suggests that winter may be a crucial season for Steller sea lions does not lessen the importance of available prey year-round. The observed increases in consumption by captive animals in the fall months indicates that preparation for winter months may also be essential. In addition, Trites (1998) reviewed northern fur seal data that indicated that fur seals undergo a period of faster growth in spring months and, if sea lions experience the same seasonal pattern of growth, then spring months may also be a particularly important period. Spring may also be important as pregnant females will be attempting to maximize their physical condition to increase the likelihood of a large, healthy pup (which may be an important determinant of the subsequent growth and survival of that pup). Similarly, those females that have been nursing a pup for the previous year and are about to give birth may wean the first pup completely, leaving that pup to survive solely on the basis of its own foraging skills. Thus, food availability is surely crucial year-round, although it may be particularly important for young animals and pregnant-lactating females in the winter.

4.2.12.5 Interactive competition versus exploitative competition

Much of the preceding discussion on the potential for competition between the Steller sea lion and the Atka mackerel and pollock fisheries has focused on exploitative competition; that is, competition that occurs when fisheries remove prey and thereby reduce prey availability to sea lions. In addition to exploitative competition, fisheries may affect sea lions through interactive competition. Examples of interactive competition include disruption of normal sea lion foraging patterns by the presence and movements of vessels and gear in the water, abandonment of prime foraging areas by sea lions because of fishing activities, and disruption of prey schools in a manner that reduces the effectiveness of sea lion foraging.

The hypothesis that these types of interactive competition occur can not be evaluated with the information currently available. The only data are from “platforms of opportunity” (R. Ferrero, pers. comm.), and are not sufficient to describe the presence/absence of sea lions and their responses to fishing vessels or activities. For example, few observations of sea lions from fishing vessels could mean that a) sea lions are present and tolerant of fishing but rarely sighted, or b) that sea lions are disturbed by fishing vessels and therefore abandon areas that are being fished. Incidental catch of sea lions in the 1970s and 1980s indicates that at least some sea lions were relatively tolerant of vessels and fishing activities. On the other hand, such interactions are relatively rare today, and it is possible there has been some selection for sea lions that avoid vessels and fishing activities.

The effects of fishing on Atka mackerel and pollock schools are not understood. Vessels fishing for Atka mackerel trawl the same locations repeatedly, as they are unable to search for schools (Atka mackerel don’t have a swim bladder and therefore are not evident on fish-finders). Analyses (Fritz *in prep*) have shown that this repeated trawling can lead to severe localized depletion. The number of schools affected and the effects on schooling dynamics are not known, but these factors will be important in understanding the overall impact of trawling for Atka mackerel on Steller sea lions.

Vessels trawling for pollock can use fish finders and are therefore able to search for prey until they have found schools or aggregations of suitable density. The strategy used is to continue to trawl that school (or set of schools) until such time as their size or density is no longer sufficient to justify further trawling, and then to resume searching until another aggregation of suitable density is located.

For both fisheries, the strategies used likely alter schooling dynamics and important features of target schools: their number, density, size, and persistence. If sea lion foraging strategies are adapted to take advantage of prey aggregations or schools, then trawling may result not only in exploitative competition through removal of prey, but also in interactive competition through disruption of schools or aggregations and their normal dynamics. For example, the removal of a portion of a fish school by a trawl net must create at least a temporary localized depletion (i.e., a gap in the prey school). How long that gap persists and the responses of the remainder of the schooling prey to trawling are unknown. The school may aggregate again, either quickly or over time, or it may disperse. The short-term effects may be prolonged when trawling is repeated. Hypothetically, it is possible that sea lions in the immediate vicinity of the trawled school are able to take advantage of the disruption to isolate and capture prey. On the other hand, sea lion foraging patterns are more likely adapted to normal schooling behavior of prey, and trawling may disadvantage sea lions not only because it results in removal of potential prey (exploitative competition), but also because it may disrupt normal aggregation of the school.

Thus, the overall effect of interactive competition between fisheries and sea lions is unstudied and unknown, but could exaggerate the effects of exploitative competition or removal of prey.

4.2.12.6 Changes in community composition and prey diversity

Fisheries could alter the composition of the BSAI and GOA ecosystems in a number of ways, including enhancement of a prey species by removal of a predator, enhancement of one competitor by removal of another, and suppression of a predator by removal of prey. Examples of such effects may be more common for terrestrial species, but such effects are also observed in aquatic ecosystems (e.g., Paine 1966, Power and Gregoire 1978). In addition to direct removal or reduction of a species, indirect consequences may accrue depending on the role of the species removed (e.g., keystone predator) and the method of removal (e.g., bottom trawling).

Atka mackerel are a major groundfish species in the central and western Aleutian Islands. Their ecological niche in those regions has not been described in detail, but they presumably compete with other zooplanktivores for copepods and euphausiids, and serve as prey for a range of consumers including other groundfish, marine mammals (humpback whales, fur seals, sea lions), and seabirds. To date, the only significant evidence that their removal by the fishery has a significant impact on the biological community is based on evidence of fishery-induced localized depletion of prey (Fritz *in prep*), which has been a primary concern with respect to Steller sea lions, but may also affect other consumers of Atka mackerel.

The Atka mackerel fishery may also have an impact on local biological communities because the principal fishing method for this species is bottom trawling. At the main fishery sites in the Aleutians, trawling tends to occur in locations where a) the bottom is sufficiently smooth, and b) previous trawling has been successful. Repeated trawling over the same area may lead to considerable disruption or restructuring of local bottom habitat and demersal communities where the bottom is suitable for trawling. The overall effect on community structure can not be described at this time.

In the future, the effects of the BSAI pollock fishery on local communities may be related to ecological relationships rather than disruption of bottom structure, as bottom trawling may be banned for this fishery. Springer (1992) reviewed the role of pollock in the BSAI region and considered its role both in bottom-up processes as a competitor for zooplankton or secondary production and in top-down processes as a competitor and predator of forage fish (including itself), and prey for top-level predators. He argued that pollock are the key species in the trophic web of the North Pacific, with ecological roles that are likely pivotal, even if not fully describable at present. Lowry *et al*. (1982) suggested that the current position of pollock in the North Pacific food web may, itself, be the result of previous commercial harvesting of marine mammals that compete with or prey on pollock. The question of whether the pollock fishery has seriously altered the community composition in the BSAI or GOA regions is focused primarily on its potential role in the trophic shifts observed in these communities and on its potential role in returning the communities to a more diverse equilibrium by reducing pollock abundance and mitigating its significant role in the community.

A diverse biological community may facilitate Steller sea lion population growth and recovery. Merrick *et al*. (1997) suggested that diet diversity was correlated to population growth in different parts of the Steller sea lion's range. Diversity may be necessary to ensure that sea lions are getting sufficient amounts of calories and essential nutrients, or to ensure that total available prey is adequate even if the availability of certain prey is variable and sometimes inadequate. Prey diversity has also been discussed in the context of changes in the trophic structure in the BSAI and GOA (e.g., Alverson 1992, Anderson *et al*. 1997), which resulted in a biological (prey) community dominated by pollock and flatfish rather than a variety of forage fish. The general consensus seems to be that a more diverse prey assemblage is likely better for sea lions.

The relevance of fisheries to the issue of diversity is based on two questions: (1) did the expansion of fisheries over the past four decades contribute significantly changes in the trophic structure of the fish community and (2) can the changes in trophic structure be reversed (to a more diverse state) by intense fishing of pollock (e.g., Merrick 1995)? The answer to the first question appears to be "yes" based on, for example, observed declines in Pacific ocean perch or yellowfin sole. But the role of fisheries in contributing to the shift from forage fish to a pollock-dominated system is not clear. As described previously, important physical changes in the BSAI and GOA ecosystems have occurred and likely contributed to the shift in community composition. However, current information is not sufficient to distinguish between the effects of fisheries and natural physical or oceanographic changes.

The answer to the second question is equally unclear. Can a fishery, acting as a predator, alter the structure of an ecosystem by controlling a dominant competitor (pollock)? The concept of predatory control of a dominant competitor is well established in the ecological literature (e.g., Paine 1966). Springer (1992) suggested that pollock may maintain their dominance in the trophic structure both by out-competing some forage fish for zooplankton prey, and by preying on others. Skud (1982) suggested that environmental factors are important determinants of the abundance of dominant competitors, but abundance of subordinate competitors is also determined by interspecific interactions. He also suggested that if the abundance of the dominant competitor is reduced, then the subordinate competitor might increase even if climate factors are not wholly favorable. If BSAI and GOA relationships are, in fact, that simple, then greater removal of pollock may lead to a reversal of the recent changes in community composition and a greater abundance of, for example, forage fish.

The contention that increased fishing of pollock will reverse observed changes in the BSAI and GOA biological communities is, however, questionable. First, if the changes in the 1970s were due, in large part, to changes in physical conditions, then the structure of these ecosystems may be determined primarily by bottom-up processes rather than top-down processes (predator-prey-competitor relations). (As Skud (1982) suggested, both bottom-up and top-down factors may be operating.) Second, the notion that human activities can alter these ecosystems seems reasonable (given the extent of our interaction with them), but the question of whether we can predict the direction of our effect seems presumptuous, at least at present. A review of the Steller sea lion decline, the history of human activities in these ecosystems, and the changes observed in the ecosystems suggests that we are far from a working understanding of these systems, and therefore our ability to predict even the near future is limited, at best. Third, certain areas (Donut Hole, Bogoslof, and Shelikof Strait) have been intensely fished for pollock and such fishing may have contributed to significant reductions of pollock in those regions. To date, however, the trophic structure in those regions has not returned to state more consistent with that observed prior to the mid to late 1970s. At present, the primary factors responsible for determining the structure of ecosystems in the BSAI and GOA regions are unclear.

4.2.12.7 Incidental take of Steller sea lions

Steller sea lions have been caught incidentally in the foreign commercial trawl fisheries in the BSAI and GOA since those fisheries developed in the 1950s (Loughlin and Nelson 1986, Perez and Loughlin 199). Alverson (1992) suggested that from 1960 to 1990, incidental take may have accounted for over 50,000 animals, or almost 40% of his estimated total mortality due to various fishery and subsistence activities. Perez and Loughlin (1991) reviewed fisheries and observer data and reported that from 1973 to 1988, sea lions comprised 87% (over 3000) of the marine mammal incidental take reported by observers. They extrapolated the take rate to unobserved fishing activities and suggested that the incidental take during 1978 to 1988 was over 6,500 animals. Using the average observed incidental rates during 1973 to 1977, they also estimated that an additional 14,830 animals were incidentally taken in the trawl fisheries in Alaska during 1966 to 1977. Finally, they concluded that incidental take was a contributing cause of the population decline of Steller sea lions in Alaska, accounting for a decline of 16% in the BSAI and 6% in the GOA. However, because the actual decline has exceeded 80 percent since 1960, incidental take does not appear to be the only or principal factor in the decline.

Estimates for more recent years indicate a reduction in the incidental take levels. The mean estimated annual (total) mortality for the BSAI and GOA groundfish trawl and longline fisheries for 1990 to 1996 is 11.4 animals and the estimate from the Prince

William Sound salmon drift gillnet fishery is 14.5 animals; resulting in a total estimated mean mortality rate in observed fisheries of 25.9 sea lions per year from the endangered Western stock (Hill and DeMaster *in prep*).

Satellite tracking studies suggest that Steller sea lions rarely go beyond the U.S. EEZ into international waters. Given that the high-seas gillnet fisheries have ended and other net fisheries in international waters are minimal, the probability that significant numbers of Steller sea lions are taken incidentally in commercial fisheries in international waters may be low. NMFS has concluded that the number of Steller sea lions taken incidental to commercial fisheries in international waters is insignificant (Hill and DeMaster *in prep*).

4.2.12.8 Intentional take of Steller sea lions

Historically, Steller sea lions and other pinnipeds were seen as nuisances to the fishing industry and management agencies because they damaged catch and fishing gear and were thought to compete for fish (Mathisen 1959). Sea lion numbers were reduced through bounty programs, controlled hunts, and indiscriminate shooting. As noted above, they were also killed for bait in the crab fishery. Government sanctioned control measures and harvests stopped in 1972 with the introduction of the MMPA.

The total number of sea lions killed since the early part of this century is unknown. Alverson (1992) suggested that intentional take may have reached or exceeded 34,000 animals from 1960 to 1990. Fishermen were seen killing adult animals at rookeries, haulout sites, and in the water near boats. The loss of that many animals would have an appreciable effect on the population dynamics of sea lions, but the effect would not account for the total decline of the western population. The effect was likely concentrated in areas closer to fishing communities and less important in more isolated areas (e.g., central and western Aleutian Islands).

Sea lion populations appear to be growing slowly in southeast Alaska, where considerable commercial fishing occurs. Expanded observer coverage in the domestic groundfish fishery after 1989 and increased public awareness of the potential economic and conservation impacts of continued sea lion declines have probably reduced the amount of shooting.

Nevertheless, anecdotal reports of shootings continue and a small number of prosecutions have occurred or are occurring in 1998. The full extent of incidental killing is undetermined and therefore should be considered a potential factor in the decline of sea lions at some locations.

4.2.12.9 Alaska State fisheries

The Alaska Department of Fish and Game (ADF&G) manages fisheries out to three miles, oversees crab fisheries in federal waters (EEZ) under the FMP adopted by the NPFMC.

With the exception of the Alaska state sablefish fishery, ADF&G coordinates their fishery openings and in-season adjustments with federal fisheries.

Herring: Herring have been fished in Alaska since 1878. At present, the state fishery is located in the following areas: Prince William Sound, Cook Inlet, Kodiak, Alaska Peninsula, Bristol Bay, Kuskokwim, Norton Sound, Southeast, and Port Clarence. Fisheries in the Southeast and Port Clarence regions are not likely to affect the western population of Steller sea lions and are not considered further. Harvest methods are by gillnet, purse seine, and handpicking of roe from kelp. Herring are primarily caught for their roe during the sac roe harvest in the spring. Harvest levels for 1998 are expected to be about 36,000 mt, similar to the last few years. Figure 42a shows herring catches by season and by region, and also shows the effort level depicted by the number of landings. Bristol Bay is the primary producer with recent catches of about 23,000 mt annually. Effort over the last two decades has decreased in Prince William Sound and Cook Inlet, but increased in Kuskokwim, Kodiak, and Bristol Bay. Since the early 1980s, the total state catch of herring has been relatively constant, with some variability in the late 1980s and early 1990s, but then constant again through 1997 (Figure 42b).

Miscellaneous Shellfish (Invertebrates): Clam, abalone, octopus, squid, snail, scallop, geoduck clams, sea urchins, and sea cucumbers have been harvested throughout the state (Figure 43a). Of these, octopus and squid are the most likely prey of sea lions. Most of the catch of shellfish is taken from April to September, and they are taken by hand-picking, shovel, trawl, pot, and dredge gear. Harvest levels were relatively consistent through the 1980s, but have increased dramatically in amount and annual variation in the 1990s (Figure 43b). The variability has been due, in large part, to recent but sporadic catches in Bristol Bay and the Bering Sea, areas not usually fished for shellfish (Figure 43a). With the exception of the recent large catches in these areas, most of the shellfish fisheries have traditionally taken place in the Kodiak and Cook Inlet areas.

Crab: The state manages all crab fisheries in the BSAI and GOA. King (brown, red, blue), Dungeness, and Tanner crabs are taken by hand-picking, shovel, trawl, pot, and dredge gear. Crab fisheries began in the early 1960s when the stocks were abundant, then declined due to the King Crab recession in the early 1980s. State crab fisheries occur in Bristol Bay, Dutch Harbor, Alaska Peninsula, Kodiak, Cook Inlet, Adak and W. Aleutian Islands, and Prince William Sound (Figure 44a). This fishery primarily occurs during the winter season. In the past ten years, the industry has focused on Alaska snow crab (*C. opilio*), and the catch exceeded historical levels of king crab in the early 1990s (Figure 44b). The Bering Sea fishery produces the vast majority of crab that is harvested in Alaska but has also been declining since 1993. Catch per landing has been greatest in the Bering Sea, and worst in the Kodiak and Cook Inlet areas (Figure 44a). In the 1970s, the crab fleet purportedly killed sea lions for bait; the numbers killed is not known.

Shrimp: The shrimp fishery occurs primarily in the southeast and Yakutat areas, and to a lesser extent in Prince William Sound, Kodiak, Dutch Harbor, Cook Inlet, and the Alaska Peninsula. Shrimp are harvested by pot gear and often sold to floating processors. In

1995, over 45,000 mt of shrimp were harvested by 351 vessels. In the last ten years, effort has increased in the southeast due, in part, to the availability of floating processors, which allow fishing vessels to devote more of their time to fishing. Figures 45a and b show the decline in shrimp fisheries in areas other than southeast and Yakutat. Effort was highest during the late 1970s and 1980s, but has since ceased in most areas.

Groundfish: The state manages groundfish within the 3-mile limit for lingcod, Pacific Ocean perch, flathead sole, rex sole, arrowtooth flounder, sablefish, black rockfish, and pollock. Fisheries occur in the Alaska Peninsula, Kodiak, Bering Sea, Dutch Harbor, Adak and W. Aleutian Islands, Cook Inlet, Prince William Sound, and Southeast areas.

Pacific Cod: The Pacific cod fishery is undergoing a change in management from federal to state authorities. A total TAC is set for Pacific cod, and that TAC is divided into federal and state shares. In 1997 and 1998, the state assumed management responsibility of 15% of the total TAC for cod, and is expected to manage 20% in 1999. Under current regulations, the state portion of the total TAC can not exceed 25%. The state fishery is limited to pot and jig gear only. The Pacific Cod fishing season is primarily in the winter.

Salmon: The state salmon fishery includes five species: chinook, sockeye, coho, pink, and chum. These fisheries are divided into southeast, Prince William Sound, Cook Inlet, Bristol Bay, Kodiak, Chignik, Alaska Peninsula, Kuskokwim, Yukon, Norton Sound, and Kotzbue management areas (Figure 46a). The state has a long history of salmon fishing. Salmon are taken by purse seines, gill nets, trolling, and beach seining. The catch in 1974 was just over 60,000 mt, then increased four-fold by 1981, was relatively constant through the 1980s, and then increased in the early 1990s to a record catch of over 450,000 mt (Figure 46b). In 1997, 123 million salmon were caught in Alaska, amounting to about 280,000 mt. The 1998 catch was expected to be higher than 1997, but has been low due to poor returns in Bristol Bay. Bristol Bay harvest levels have historically been the highest with Kuskokwim and Chignik being the lowest (Figure 46a). In 1997, 26% of the commercial catch was from hatcheries. Economically, the salmon fishery is worth more than all other state fisheries combined.

4.2.13 Federal fishery management actions affecting the Steller sea lion or its critical habitat

In 1989, the Environmental Defense Fund and 17 other environmental organizations petitioned NMFS to list all populations of Steller sea lions in Alaska as endangered. Justification was based on evidence of a major decline in their abundance throughout most of their range, but most acutely in the core region from the Kenai Peninsula to Kiska Island (Braham *et al*. 1980, Merrick *et al*. 1987). In this region, counts of adult and juvenile Steller sea lions had declined by about 80% since the late 1950s. Since 1990, the decline, while continuing, has slowed to an average of about 5 percent per year through 1996.

Concurrent with the sea lion decline, Alaskan groundfish fisheries underwent a period of unprecedented growth. Between the late 1950s and the early 1990s, the total annual removal of groundfish from Alaskan waters increased from about 27,000 mt to about 2.1 mmt. The fishing fleets of Japan and the Soviet Union were the first to exploit the region's groundfish resources in the 1950s, targeting Pacific ocean perch and yellowfin sole. By the early 1960s, trawl fisheries for walleye pollock and Pacific cod were established. By the late 1970s, American catcher boats had formed joint ventures with foreign processing vessels, beginning the domestication of Alaska groundfish fishing. Growth of the fishery and decline of the sea lion coincided in time and space, and the two overlapped in target (or prey) species. The following chronology describes management efforts protect the Steller sea lion, and to evaluate and mitigate the potential for competition between the sea lion and fisheries in the BSAI and GOA.

1990: On April 5, 1990, NMFS issued an emergency interim rule (55 FR 12645) to list the Steller sea lion as a threatened species under the ESA and established protective regulations as emergency interim measures to begin the population recovery process. NMFS implemented the following emergency conservation measures:

Management Actions:
1. Monitoring of incidental take and monthly estimates of the level of incidental kill of Steller sea lions in observed fisheries.

2. Aggressive enforcement of protective regulations, especially as they relate to intentional, lethal takes of Steller sea lions.

3. Establishment of a Recovery Team to provide recommendations on further conservation measures.

Protective Regulations:
1. Prohibition of shooting at or within 100 yds of Steller sea lions (this did not apply to Alaska native subsistence hunting).

2. Establishment of 3 nm "no-approach" buffer zones around the principle Steller sea lion rookeries in the GOA and AI.

3. Reduction of incidental kill quota from 1,350 to no more than 675 Steller sea lions.

Fritz *et al*. (1995) summarized the rationale supporting these actions and reviewed their impact on the groundfish fishing industry. NMFS issued the final rule for the Steller sea lion listing as threatened under the ESA and for the above actions on November 26, 1990 (55 FR 49204). NMFS also appointed a Recovery Team in 1990.

1991: On January 7, 1991, NMFS issued a final rule to implement regulations for BSAI/GOA FMP amendments 14/19 that limited pollock roe-stripping and seasonally allocated the pollock TAC in the BSAI and GOA (56 FR 492). For BSAI fisheries, the pollock TAC was divided between an A (roe) season and a B season (summer-fall). In the GOA fisheries, the pollock TAC for the Central and Western (C/W) Regulatory Areas was divided into 4 equal seasons. NMFS noted in the proposed rule (55 FR 37907, September 14, 1990) that "shifting fishing effort to later in the year may reduce competition for pollock between the fishery and Steller sea lions whose populations have been declining in recent years". Also, given the recent listing of Steller sea lions as threatened under the ESA, a conservative course of action seemed prudent.

The listing of the Steller sea lion also prompted NMFS to initiate section 7 consultation on the GOA and BSAI FMPs. On April 5, 1991, NMFS issued biological opinions to evaluate the potential impacts of the pertinent fisheries on endangered and threatened species, including the Steller sea lion (NMFS, 1991). The potential adverse effects to Steller sea lions of the GOA and BSAI groundfish fisheries include: 1) reduction of food availability (quantity and/or quality) due to harvest; 2) unintentional entanglement of marine mammals in fishing gear; 3) intentional harassment (including killing and wounding) of animals by fishermen; and 4) disturbance by vessels and fishing operations. Both biological opinions concluded that the fishery was not likely to jeopardize continued existence and recovery of the Steller sea lion. The following conservation recommendations were made:

1. NMFS should expand its research effort and initiate projects specifically designed to assess the effects of fisheries on Steller sea lion, their prey, and their feeding efficiency.

2. Law enforcement efforts should be increased to ensure compliance with Steller sea lion rookery buffer zones and shooting prohibitions.

3. NMFS should continue the Steller sea lion public relations and fishery information effort to maintain awareness of the Steller sea lion decline and conservation prohibitions in place.

4. NMFS should work with the State of Alaska to obtain more accurate estimates of the subsistence take of Steller sea lions.

5. NMFS and the State of Alaska should initiate an outreach program to facilitate efficient taking, as well as to obtain biological data from harvested animals.

On June 5, 1991, NMFS issued a biological opinion that focused on the potential effects of the GOA pollock fishery, as specified in the 1991 TAC specification, on food availability to Steller sea lions. Although the opinion concluded that the GOA 1991 pollock TAC specification was not likely to jeopardize the continued existence of any endangered or threatened species under NMFS' jurisdiction, the opinion noted that changes in the temporal and spatial distribution of the pollock fishery may have contributed to the Steller sea lion decline. Specifically, the fishery operated more in fall and winter, caught the quota in less time, and fished more often in areas later designated (in 1993) as Steller sea lion critical habitat under the ESA (Fritz *et al*. 1995).

On June 19, 1991, NMFS issued an emergency interim rule (effective through September 17, 1991) to ensure that pollock fishing did not jeopardize the continued existence or recovery of the threatened Steller sea lion (56 FR 28112). The preamble to this rule referenced the April 19 and June 5, 1991 biological opinions. The rule contained measures to protect the Steller sea lion by:

1. allocating the pollock TAC for the combined W/C Regulatory Areas equally between two subareas located east and west of 154°W,

2. limiting the amount of unharvested pollock TAC that may be rolled over to subsequent quarters in a fishing year, and

3. prohibiting fishing with trawl gear in the EEZ within 10 nm of 14 Steller sea lion rookeries.

On September 19, 1991, NMFS extended the above measures through December 16, 1991 (56 FR 47425).

NMFS reinitiated Section 7 consultation on the GOA pollock fishery because the 1991 3rd quarter pollock TAC was exceeded by 26%. On September 20, 1991, NMFS concluded that because of the small size of the 4th quarter harvest (27,000 mt), a fishery-caused reduction in local abundance of pollock, and thus, availability to Steller sea lions, does not appear likely. This opinion concluded that the proposed 1991 4th quarter pollock harvest was not likely to jeopardize the continued existence or recovery of Steller sea lions.

Since 1991, NMFS has conducted numerous section 7 informal consultations on the effects of various GOA and/or BSAI groundfish fishery management actions on the Steller sea lion (Table 1). In these instances, NMFS determined that the action was not likely to affect listed species under NMFS' jurisdiction in a way that was not already considered in previous biological opinions, therefore, section 7 formal consultation was not required. The 1992 to 1995 consultations on the potential effects of the GOA groundfish TAC specifications and the 1993 to 1995 consultations on the potential effects of the BSAI groundfish TAC specifications were informal as described above.

Section 4(f) of the ESA requires NMFS to develop and implement plans for the conservation and survival of endangered and threatened species. NMFS had appointed a Steller Sea Lion Recovery Team to draft a Recovery Plan, and the draft Recovery Plan was released for public review and comment on March 15, 1991.

1992: On January 23, 1992, NMFS issued a final rule to implement amendments 20/25 to the BSAI and GOA FMPs (57 FR 2683). The amendments authorized regulations to protect marine mammal populations as follows:

1. prohibited trawling year-round within 10 nm of 37 Steller sea lion rookeries in the GOA and BSAI;

2. expanded the prohibited zone to 20 nm for 5 of these rookeries from January 1 through April 15 each year;

3. established 3 GOA pollock management districts; and

4. imposed a limit on the amount of an excess pollock seasonal harvest that may be taken in a quarter in each district.

On January 21, 1992, NMFS issued a biological opinion that evaluated the potential adverse effects of the 1992 BSAI fishery on Steller sea lions and concluded that the 1992 TAC specifications and the BSAI groundfish fishery were not likely to jeopardize their continued existence and recovery. The biological opinion also included the following discretionary conservation recommendation:

> "NMFS should amend the BSAI FMP to provide a mechanism to spatially allocate TACs in the Aleutian Islands in the future. For example, Atka mackerel are abundant in shelf waters near AI Steller sea lion rookeries and are eaten by Steller sea lions. Presently, the Atka mackerel harvest is only a minor component of the exploitable biomass and spatial and/or temporal concentration of the fishery is not expected to have any biological significance. However, if yearly TACs increase, as appears likely, spatial distribution of the harvest may be warranted to prevent local depletion of fish stocks."

On March 4, 1992, NMFS issued a biological opinion that evaluated the likely effects of the proposed BSAI FMP amendment 18 to proportionately allocate the yearly available harvest of pollock to inshore, offshore, and western Alaska community sectors of the BSAI fishing industry. This biological opinion concluded that based on the available data and management measures currently in place, that adoption of the proposed FMP amendment was not likely to jeopardize the continued existence and recovery of Steller sea lions. The biological opinion continued that:

> "However, since the southeastern Bering Sea shelf is considered to be an important foraging habitat for Steller sea lions, concerns regarding fishery removals from this area remain. Therefore, NMFS will continue to evaluate the suitability of existing management measures for the BSAI fishery to ensure adequate protection of Steller sea lions and their essential habitats. Since knowledge regarding the relationship between Steller sea lions and the commercial fishery remains very limited, it is essential that results from 1992 fisheries and Steller sea lion research efforts be factored into this analysis.

Additional management measures for the southeastern Bering Sea shelf fishery that will be evaluated during 1992 include: (1) limits on total harvest from the southeastern Bering Sea shelf; (2) modification of Steller sea lion rookery buffer zones; and (3) limits on available pollock TAC in the "A" season. Evaluation and selection of an appropriate management regime will be conducted in consultation with NPFMC and the concerned public, and be completed prior to the start of the 1993 fishery."

1993: NMFS provided notice on January 7, 1993 that the final Recovery Plan for the Steller sea lion was available (58 FR 3008).

On March 12, 1993, NMFS issued a final rule to implement an expanded no-trawl zone around the Ugamak Island Steller sea lion rookery in the eastern Aleutian Islands during the pollock roe fishery season in the BSAI (58 FR 13561). The expanded zone was expected to better encompass Steller sea lion winter habitats and juvenile foraging areas in this portion of the southeastern Bering Sea shelf during the BSAI winter pollock fishery.

On April 28, 1993, NMFS issued a biological opinion that evaluated the potential effects on Steller sea lions of delaying the start of the BSAI pollock fishery "B" season from June 1 to August 15. NMFS concluded that it would take appropriate steps to ensure that delaying the BSAI "B" season would not result in a concentration of the BSAI fishery into the winter months and the southeastern Bering Sea shelf. Therefore, the proposed action was not likely to jeopardize the continued existence and recovery of Steller sea lions. Possible management measures to mitigate any significant increase in the winter fishery could include: 1) establishing a directed pollock fishery closure date of November 1 to ensure no increase in winter harvests, or 2) seasonally expanding rookery trawl closure zones until the entire "B" season TAC has been harvested to provide additional protection to Steller sea lion foraging areas.

On July 13, 1993, NMFS issued a final rule to implement regulations (BSAI FMP amendment 28) that subdivided the Aleutian Islands subdistrict into three subareas (areas 541, 542, 543) (58 FR 37660). This rule was implemented because of concerns that the concentration of fishery removals, particularly Atka mackerel, in the eastern Aleutian Islands could cause localized depletion of groundfish stocks. While dispersal of the Atka mackerel TAC was initiated to conserve fish, it was also consistent with the objectives of the fishery management measures enacted for Steller sea lion recovery.

On August 27, 1993, pursuant to the ESA, NMFS designated critical habitat for the Steller sea lion (58 FR 45269). The primary benefit of the designation is that it provides notice to Federal agencies that a listed species is dependent on these areas (and their features) for its continued existence and that any Federal action that may affect these areas (and their features) is subject to the consultation requirements of section 7 of the ESA.

On November 1, 1993, NMFS initiated a status review of the Steller sea lion to determine whether a change in classification to endangered is warranted (58 FR 58318). NMFS solicited comments and biological information concerning the status of the Steller sea lion to be used for consideration in its comprehensive review.

1994: On November 29-30, 1994, NMFS convened the Steller Sea Lion Recovery Team specifically to consider the appropriate ESA listing status for the Steller sea lion and to evaluate the adequacy of ongoing research and management programs. The Recovery Team recommended that NMFS list the Steller sea lion as two separate population segments, split to the east and west of 144°W. The Recovery Team also recommended that the western population segment be listed as endangered and the eastern population segment be listed as threatened.

1995: On February 22, 1995, NMFS Alaska Region (AKR) and the Alaska Fisheries Science Center AFSC) forward its recommendation to NMFS Headquarters that: 1) the U.S. Steller sea lion population should be managed as two distinct population segments under the ESA, split to the east and west of 144°W, and 2) that the listing status of the western population should be changed to endangered. The AKR/AFSC recommendation was supported by a draft proposed rule and a draft status review document.

1996: On January 26, 1996, NMFS reinitiated a section 7 formal consultation on the effects of the BSAI and GOA FMPs and the 1996 TAC specifications on the Steller sea lion. Although NMFS had evaluated the effects of proposed changes to both the BSAI groundfish fishery the GOA groundfish fishery since 1991, it had been over 4 years since the last formal consultation on either fishery. During this period, the Steller sea lion population had continued to decline. Furthermore, NMFS had also collected additional data on Steller sea lions and the GOA and BSAI groundfish fisheries.

NMFS concluded that the BSAI and GOA FMPs, fisheries, and harvests under the proposed 1996 TAC specifications were not likely to jeopardize the continued existence of Steller sea lions or to result in the destruction or adverse modification of their critical habitat. NMFS noted that "the reasons for the decline of Steller sea lion populations and the possible role of the fisheries in the decline remain poorly understood.

The biological opinion included the following conservation recommendations: (1) In consultation with the Steller Sea Lion Recovery Team, the NPFMC, and other affected parties, NMFS should review the adequacy of existing buffer zones around Steller sea lion rookeries and the ecological consequences of various harvest strategies for groundfish; (2) In cooperation with the state of Alaska, NMFS should review the location, duration, and effects of state-managed herring and salmon fisheries; (3) NMFS should fund and/or undertake research to determine the local effects of fishing on sea lion prey resources.

The biological opinion also included an incidental take statement, in which NMFS specified an annual incidental take level of 15 sea lions for the GOA groundfish fishery and 30 for the BSAI groundfish fishery. NMFS also identified a (non-discretionary) reasonable and prudent measure necessary to minimize the impact of the incidental take: For both BSAI and GOA, NMFS must ensure that observers monitor the take of Steller sea lions incidental to the groundfish fisheries.

On March 12, 1996, NMFS issued a final rule to implement GOA FMP amendment 45 that combines the 3rd and 4th quarterly allowances for pollock in the 3 statistical areas of the combined W/C Regulatory Area into single seasonal allowances that will become available on September 1 of each fishing year (61 FR 9972).

1997: On January 17, 1997, NMFS issued a Decision Memorandum on the BSAI and GOA 1997 TAC Specifications with respect to Steller sea lion section 7 consultations. Based on available information on the fishery and Steller sea lions, NMFS determined that the GOA and the BSAI groundfish fisheries were not likely to affect Steller sea lions in a way or to an extent not already considered in previous section 7 consultations on these fisheries. Therefore, reinitiation of consultation under the ESA was not required.

On May 5, 1997, NMFS reclassified Steller sea lions as two distinct population segments under the ESA (62 FR 24345). The reclassification was based on biological information collected since the species was listed as threatened in 1990. The Steller sea lion population segment west of 144°W (a line near Cape Suckling, AK) was reclassified as endangered; the listing for the remainder of the U.S. Steller sea lion population remained as threatened.

1998: On February 26, 1998, NMFS noted a) the conclusion of the 1996 opinion that the BSAI groundfish fishery was not likely to jeopardize the continued existence of Steller sea lions or destroy or adversely modify their critical habitat, and b) NMFS had previously determined that reinitiation of consultation was not required for the 1997 fishery because none of the elements that would trigger reinitiation had occurred. NMFS also noted that the 1996 biological opinion remained valid for the 1998 BSAI groundfish fishery.

On March 2, 1998, NMFS issued a biological opinion that evaluated the effects of the GOA FMP and the 1998 pollock TAC specifications on the Steller sea lion. NMFS concluded that the 1998 GOA fishery was not likely to jeopardize the continued existence and recovery of Steller sea lions or to adversely modify critical habitat. NMFS noted that the biological opinion only addressed the 1998 fishery, not the continued implementation of the GOA FMP beyond 1998. The Alaska Region would need to reinitiate Section 7 consultation for the fishery in 1999 and beyond.

This opinion authorized the same incidental take level that was authorized in the 1996 opinion (15 Steller sea lions for the GOA). The authorization would be re-evaluated when additional data become available on the number of sea lions injured or killed annually by gear associated with this fishery. No reasonable and prudent measures were identified. NMFS must monitor the level of incidental take that occurs as a result of the 1998 GOA fishery and complete a report by March 15, 1999.

NMFS included the following conservation recommendations in this biological opinion: (1) Fritz and Ferrero (in press), in an analysis of options in Steller sea lion recovery and groundfish fishery management, suggest three general categories of management measures that could be employed to minimize the effects of fishing on Steller sea lion recovery: (a) gear modifications or restrictions, (b) reductions in total catch, and (c) further temporal and spatial distribution of the fisheries. NMFS should carefully analyze and consider the potential benefits of these options; (2) Initiate studies of the efficacy of buffer zones as soon as possible; (3) Continue studies to determine the foraging range of young-of-the-year Steller sea lions; (4) Continue to educate the fishing community about Steller sea lions and techniques to reduce or eliminate incidental take of the species; (5) Conduct studies of the site-by-site relation between fishing effort and trends in juvenile survival or counts at nearby rookeries.

On March 17, 1998, NMFS issued regulations for amendments 36/39 to the BSAI and GOA FMPs (63 FR 13009). This action created a forage fish species category in FMPs and implemented associated management measures. Directed fishing for forage fish would be prohibited at all times in the Federal waters of the BSAI and GOA. The intended effect of this action was to prevent the development of a commercial directed fishery for forage fish, a critical food source for many marine mammal, seabird, and fish species. The proposed rule (62 FR 65402, December 12, 1997) stated that a) forage fish are important prey for marine mammals, seabirds, and commercially important groundfish species, and b) decreases in the abundance of these predators may be related to declines in forage fish.

On June 11, 1998, NMFS issued a final rule to change the seasonal apportionment of the pollock TAC in the W/C Regulatory Areas of the GOA by moving 10% of the TAC from the 3rd fishing season (starting September 1) to the 2nd fishing season (starting June 1; 63 FR 31939). This seasonal shift of TAC was a precautionary measure intended to reduce the potential impacts of pollock fishing on Steller sea lions by reducing the percentage of the pollock TAC that is available to the fishery during the fall and winter months.

At its June 1998 meeting, the NPFMC adopted a precautionary approach by approving a regulatory amendment to reduce the probability of localized depletion of Atka mackerel in critical habitat for Steller sea lions. The NPFMC recommended both spatial and temporal redistribution of the BSAI Atka mackerel TAC as a further sea lion protective measure.

4.3 Integration and synthesis of the environmental baseline

The decline of the western population of Steller sea lions is not the result of a single factor, and to search for *the single cause* is a misleading oversimplification. Multiple factors have contributed to the decline, and multiple factors may still be preventing recovery. The identification of one such factor does not rule out the possibility that others are also acting, perhaps synergistically, to prolong the decline. Furthermore, the causes for the decline appear to include both natural and anthropogenic influences.

- Intentional take of sea lions has occurred coincident with fisheries. From the 1950s (and probably before) to the 1970s, such take was not only condoned, but in many cases encouraged or rewarded. The rate or magnitude of intentional take has been estimated (Alverson 1992), although reporting and documentation have not been sufficient to provide reliable estimates of total take. Intentional take has likely subsided considerably since the passage of the MMPA and other protective legislation, although anecdotal reports indicate that some level of intentional take may still continue.

- Incidental take in trawl fisheries included thousands or tens of thousands of animals (Loughlin and Nelson 1986, Perez and Loughlin 1991) through the 1980s, and contributed to the decline of the population in the 1970s and 1980s. Currently, however, incidental take has been reduced to negligible levels.

- Commercial harvest of adult males in 1959 likely had no significant effect on population trends. However, harvest of over 45,000 pups in 1963 to 1972 contributed to local population trends in the 1960s through the early 1980s in the GOA and the eastern Aleutian Islands. Similarly, subsistence harvests prior to the 1990s were not measured but may have contributed to population decline in localized areas where such harvests were concentrated.

- Pollutants and marine debris (entanglement) may have contributed to the decline by altering growth, reproduction, or survival of sea lions. The evidence available to date does not support the contention that these factors have played a significant role.

- Harassment has likely occurred in many areas and may have been very disruptive to sea lion colonies on rookeries or haulouts, thereby leading to redistribution or deaths of animals. Such harassment could have contributed to mortality if animals were shot, females were separated from their pups for long periods, or animals (especially pups) were trampled or crushed or otherwise injured in the stampedes that often accompany such harassment. Nevertheless, harassment is thought to be less common at present, and the data are not sufficient to demonstrate that harassment was a significant contributor to the decline. Harassment is also a less likely explanation in the remote areas of the sea lion range where declines have, nonetheless, been observed (e.g., central and western Aleutian Islands).

- Disease has the potential to cause a major decline but, to date, the available information does not support the contention that disease was a significant factor.

- Killer whales and sharks take Steller sea lions, but such predation is not thought to have caused the decline. The significance of predation may have increased with the decline of sea lions. That is, if the number of sea lions taken has remained relatively constant, then the rate of mortality due to predation would increase because the abundance of sea lions has declined so significantly. However, the number of sea lions taken by killer whales and sharks is not known, and it is also possible that the number of sea lions taken has decreased in proportion to the decline of sea lions.

- Major changes have occurred in the BSAI and GOA ecosystems. Variation in physical and biological factors, in combination, likely contributed to the observed shift in trophic structure, and the dominance of pollock and flatfish in these systems.

- At the same time, the BSAI and GOA ecosystems have experienced the development and expansion of major fisheries for essential sea lion prey. The fisheries have also contributed to changes in the trophic structure of these ecosystems, but as is the case with natural changes, the extent of fisheries-related effects on the ecosystems, at large, can not be determined. To date, neither our science nor our management regimes are structured to distinguish natural from fisheries related effects on these ecosystems. With respect to Steller sea lions, however, fisheries target important prey resources at times and in areas where sea lions forage.

In the face of all these changes and influencing factors, the western population of Steller sea lions has not been able to maintain itself. The available evidence suggests that a significant part of the problem is lack of available prey. Studies of animals collected in the GOA in 1975-1978 and 1985-1986 indicate that animals in the latter collection were smaller, took longer to reach reproductive maturity, produced fewer offspring, tended to be older, and exhibited signs of anemia --- all observations consistent with the hypothesis of nutritional stress (Calkins and Goodwin 1988, Pitcher *et al. in review*, York 1994). In addition, survival of juvenile animals appeared to have dropped in both the eastern Aleutian Islands (Ugamak Island; Merrick *et al*. 1987) and the GOA (Marmot Island; Chumbley *et al*. 1997). These results, the evidence of substantial changes in the physical and biological features of the BSAI and GOA ecosystems, and the expansion of fisheries in these regions all support the contention that lack of available prey has contributed significantly to the past decline of the western population, and may still be so contributing.

5.0 EFFECTS OF THE ACTIONS

This biological opinion assesses the effects of three separate Federal actions on the endangered western population of Steller sea lions and the critical habitat designated for them: (1) authorization of an Atka mackerel fishery under the BSAI groundfish Fishery Management Plan between 1999 and 2002; (2) authorization of a walleye pollock fishery under the Bering Sea-Aleutian Island groundfish Fishery Management Plan between 1999 and 2002, and (3) authorization of a walleye pollock fishery under the Gulf of Alaska groundfish Fishery Management Plan between 1999 and 2002. Based on this effects analysis and an analysis of cumulative effects, NMFS separately determines whether one or more of these proposed fisheries are likely to jeopardize the continued existence of the western population of the Steller sea lion, or destroy or adversely modify its designated critical habitat.

Jeopardy analyses usually focus on the effects of an action on a species' population dynamics while adverse modification analyses usually focus on the effects of an action on the physical, chemical, and biological resources that support a population. A conclusion of "jeopardy" for an action (any one of the fisheries) means that the action could reasonably be expected to reduce appreciably the likelihood of both the survival and recovery of the western population of Steller sea lions. A conclusion of "adverse modification" means that the action could reasonably be expected to appreciably diminish the value of critical habitat for both the survival and recovery of the western population. Such actions include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical (50 CFR 402.02).

This section assesses the potential effects of the three proposed fisheries based on the description of the fisheries, the status of the Steller sea lion, and the information just presented in the environmental baseline. We begin with a review of the major points from each of the above sections, and then describe a conceptual model of sea lion foraging, based on the available life history information. We use that review and model to identify key principles or criteria on which to judge the potential effects of the three actions, and finally we re-examine each of the three fisheries being considered in this Biological Opinion using those principles and criteria.

5.1 Background to the Effects Analysis

Fisheries interact with marine mammals either operationally or biologically (Lowry et al. 1982). Operational interactions between marine mammals and fishing gear (whether it is actively fishing or derelict; e.g., ghostfishing or entanglement in debris) consist of removal or destruction of catch from the gear by marine mammals, or either incidental or intentional injury or killing of marine mammals. Operational interactions may directly affect marine mammals populations, but are not likely to directly affect their habitat. Biological interactions result from disturbance of normal marine mammal foraging behavior, competition with marine mammals for prey, changes in prey size/age structure, and changes in the composition of the marine community. This Biological Opinion assess the effects of both forms of interaction between the three proposed fisheries and the endangered western population of Steller sea lions.

Assessing the operational effects of the three proposed fisheries on the endangered western population of Steller sea lions is possible because fishery observer programs have generated substantial information on operational interactions between Steller sea lions and fisheries. Prior to the mid- to late-1980s, the operational effects of fisheries on Steller sea lions were significant; in some areas, those effects appear to have been devastating. However, based on more recent data, gear associated with the walleye pollock and Atka mackerel fisheries has a negligible, direct effect on the status and trends of Steller sea lions (Hill and DeMaster *in prep*.).

The potential biological effects of the three proposed fisheries on the endangered western population of Steller sea lions are more significant than current operational effects. There is general scientific agreement that the decline of the western population of Steller sea lions results primarily from declines in the survival of juvenile Steller sea lions. There is also general scientific agreement that the cause of the decline in the survival of juvenile Steller sea lions probably has a dietary or nutritional cause. There is much less agreement on whether fishery-induced changes in the forage base of Steller sea lions have contributed to and continues to contribute to the decline of the Steller sea lion. However, based on the best scientific and commercial information available, the three proposed fisheries may adversely affect Steller sea lions by (a) competing for sea lion prey and (b) affecting the structure of the fish community in ways that reduce the availability of alternative prey (National Research Council 1996).

Any suggestion that one or more of the proposed fisheries may compete with Steller sea lions by reducing the abundance of Steller sea lion prey at local scales relevant to individual sea lions raises questions of local depletions. NMFS cannot demonstrate, conclusively, that the pollock trawl fishery locally depletes the remaining pollock resource. Nor can we prove that the pollock biomass remaining in local areas after fishing effort is limiting to Steller sea lions. The information required to conclusively determine the presence *or absence* of local depletions has not been collected. Similarly, the information required to conclusively determine whether fisheries conpete with Steller sea lions has not been collected.

For many years, investigators have analyzed the available data in a search for conclusive evidence, with no success (Alverson 1991, Ferrero and Fritz 1994, Fritz 1993, Loughlin and Merrick 1989, Merrick et al. 1987, Merrick et al. 1997, Springer 1992, Trites 1992). Workshops that specifically addressed the issue of the effects of groundfish fisheries on food in the Aleutian Island, Bering Sea, and Gulf of Alaska ecosystems have been held by the Alaska Sea Grant (1993) and National Research Council (1996) only to conclude that there is no conclusive evidence available to resolve the issue and associated questions.

No new studies have been conducted that provide conclusive evidence to help us resolve this issue in this Biological Opinion. Trites (personal communication) recently completed a study that suggests that walleye pollock have lower caloric and nutritive value to Steller sea lions than species like herring, capelin, or eulachon. There seems to be general agreement in the scientific community that the western population of Steller sea lions would fare better on a more diverse diet consisting of herring, capelin, or eulachon. However, since Steller sea lion diets seem to consist of food that is available to them in their foraging environment - and there is also general agreement that the availability of herring, capelin, eulachon, and related species has shifted or reduced - agreeing that pollock have lower caloric and nutritive value to Steller sea lions does not resolve the question that is central to this assessment: is the pollock fishery likely to reduce the availability of pollock to Steller sea lions in a way that appreciably reduces their likelihood of survival and recovery in the wild?

In the absence of definitive data or conclusive evidence, NMFS made the following three assumptions to address this question in this Biological Opinion (the information supporting these assumptions is presented after the assumptions):

1. The abundance of any species in a particular space at a particular time is finite. Therefore, an activity that can remove hundreds of pounds in a single tow and thousands of tons of fish per day must, on at least a very local scale and for short periods of time, reduce the biomass of the targeted fish remaining in the ocean. By extension, it is reasonable to assume that, as fishing effort increases or is concentrated in a particular area in a specific period of time, the extent and duration of those reductions would increase.

2. The likelihood of locally depleting a fish resource increases when that resource is patchily distributed. That is, fish species are not homogeneously distributed throughout the water column. Instead, there are specific areas that have larger numbers of fish and other areas that have limited numbers of fish (Bakun 1996). Walleye pollock and Atka mackerel are schooling fish that are patchily distributed: within a school their biomass is very high while outside of a school their densities are low. Fishing effort that targets schools of pollock or mackerel and removes a significant percentage of a school is likely to reduce the biomass remaining in the ocean for at least a short period of time in a particular space.

   This assumption is partially supported by the behavior of the fishing fleet itself. Fishing vessels use electronic equipment on their vessels to locate large aggregations of pollock. When vessels locate aggregations of pollock, they deploy their nets and continue to fish that school until the density of the aggregation declines to the point at which continued harvest becomes unprofitable.

3. If these reductions in schools of pollock or mackerel occur within the foraging areas of the endangered western population of Steller sea lions, the reduced availability of prey is likely to reduce the foraging effectiveness of sea lions. The effects of these reductions become more significant the longer they last and the reductions are likely to be most significant to adult female and juvenile Steller sea lions during the winter months when these animals have their highest energetic demands.

These assumptions seem reasonable and are consistent with assumptions made by others who have tried to resolve the issue of fishery effects on Steller sea lions (National Research Council 1996). In fact, the National Research Council (1997) concluded that “since the late 1970s, fishing for pollock has been concentrated at some places. This would imply that pollock are effectively removed from some areas at some time, and the local populations would probably take at least days or week to be rebuilt by in-migration from elsewhere. It is thus possible that food shortage for some mammals and birds - perhaps at crucial times and places for juveniles - have been exacerbated by this intense pulse fishing.”

The limited evidence of localized depletions of walleye pollock possibly associated with fishing effort is drawn from the Bogoslof Island area of the Aleutian Islands, the “donut hole” region of the Bering Sea, and Shelikof Strait in the Gulf of Alaska. Pollock were once abundant in these areas, were heavily exploited by fisheries, and now consist of reduced stocks. While these stocks may have declined, in part, for natural reasons, exploitation appears to have contributed to those declines. Shelikof Strait has been cited as the more dramatic example of possible localized depletion of walleye pollock (Fritz et al. 1995, National Research Council 1997). A fishery developed after a large spawning aggregation was discovered in the Strait in the late 1970s. Because of this fishery, pollock catches in the Gulf of Alaska increased from less than 100,000 metric tons to more than 300,000 metric tons. By 1993, the exploitable biomass of pollock in the Gulf of Alaska declined from 3 million tons in 1981 to less than 1 million (NPFMC 1993). The National Research Council (1997) concluded that "During this same interval, sea lion counts on nearby rookeries showed a dramatic decline, and animals began to show signs of reduced growth rate (Calkins and Goodwin 1988, Lowry et al. 1989)."

Section 7 consultation on the Atka mackerel fishery was reinitiated partly because of evidence that the fishery depleted local mackerel stocks in the Aleutian Islands (Fritz in prep.). Such fishery-induced depletions could have detrimental ecosystem effects persisting for weeks or months. The declines were consistent with expectations related to level of catch: the higher the catch and the longer the season, the more likely there was to be a substantial decline (Fritz *in prep*.). Finally, the magnitudes of the estimated decline can be quite substantial: they can represent reductions of up to 90% although they averaged 56% in 1996 and 37% in 1997.

Steller Sea lion foraging model

NMFS assessed the potential biological effects of the three proposed fisheries by first applying the following conceptual model of the probable foraging behavior of the western population of Steller sea lions, which is derived from the information available: Sea lions are land-based predators that venture away from rookeries and haulouts to find sufficient resources (prey) to sustain growth, reproduction, and survival. Virtually all of the foraging studies conducted to date indicate that pollock and Atka mackerel are, at least at present, essential prey. The characteristics of these prey items (i.e., their temporal and spatial distributions, their life history characteristics, their tendency to form patchy aggregations, their depth and movements in the water column, their composition and reproductive traits, etc.) are all relevant to their value as prey resources for sea lions. Steller sea lions appear to be relatively shallow divers and the available data suggests much of their foraging is limited to depths of 250 m or less.

Movement patterns identified from satellite telemetry, incidental kill records, and direct observations suggest that foraging areas that can be accessed in a day's outing are particularly important during the reproductive season, including the nursing period. These areas may be particularly important because they allow for relatively short absence of females from their pups, and because they result in reduced energetic and nutrient costs that would be higher if foraging required transiting and searching at more distant sites. The winter months are an important foraging period for Steller sea lions because their greater metabolic demands during the harsh winter period increase their energy demands and make them more sensitive to reductions in prey availability.

Steller sea lions are limited to the prey available to them in their foraging environment. Whether recent changes in the fish community of the BSAI and GOA were caused by changes in oceanographic conditions (the regime shift), from effects of fishing effort in the 1960s and 1970s, or both, sea lions must survive with the prey resources that are available: Atka mackerel and pollock. Whether sea lions forage in groups or as individuals, they target larger schooling fish that are pelagic, semi-demersal, or demersal. Pollock may not be the optimal prey because of its reduced fat content compared to other species that occur in Steller sea lion diets (Alverson 1992, Trites, personal communication). Nevertheless, the overall value of pollock as prey is not determined just by its fat content, but also by its availability to Steller sea lions: while pollock may not be optimal prey for Steller sea lions, pollock appears to be essential for sea lion survival when "better" prey are not available.

Assessment Approach
We used a synthesis of the preceding information to determine whether one or more of the three proposed fisheries were likely to appreciably reduce the likelihood of both the survival and recovery of the endangered western population of Steller sea lions (that is, the jeopardy standard) or appreciably reduce the value of critical habitat that has been designated for the endangered western population of Steller sea lions (the standard for destruction or adverse modification of designated critical habitat).

Using the three assumptions presented in the *Background to the Assessment* (section 5.1), we evaluated each of the proposed fisheries to determine if their spatial and temporal distribution was likely to distribute the fishery over space and time in ways that minimized the likelihood of locally-depleting the prey of Steller sea lions within important foraging areas. We also examined the proposed fisheries to determine if they dispersed the fishing effort temporally. Our examination focused on whether the proposed fisheries dispersed the effort in ways that (a) avoid the adverse effects of localized depletions during the winter season when Steller sea lions, particularly adult female and juvenile Steller sea lions, have increased energy demands, and (b) distributed fishing catch evenly throughout the remainder of the year to eliminate the probability of localized depletions associated with removing large amounts of catch in short periods of time. We next examined the proposed fisheries to determine if they dispersed fishing effort spatially. At a minimum, the spatial dispersion should distribute the catch so it was proportional to the distribution of available fish stocks. Finally, we examined the proposed fisheries to determine if the proposed management regime provide sufficent protection for areas around rookeries and haulouts, to eliminate potential competition between the fishery and foraging Steller sea lions.

This approach is also consistent with the conclusions of several investigators, including the National Research Council (1997), which concluded that "it is more likely that marine mammals and birds have been affected by the distribution in space and time of fishing effort on pollock, and thus that they would be helped by a broader distribution in space and time, especially in areas where they are known to feed." They also cautioned that even distributing fishing effort over space and time may not be sufficiently effective to reverse or even halt current population declines.

The National Research Council's cautionary note captures one of NMFS' major concerns about the plight of the endangered western population of Steller sea lions. Population viability analyses have been conducted by Merrick and York (1994) and York et al. (1996). The results of these analyses indicate that the next 20 years may be crucial for the Steller sea lion, if the rates of decline observed in 1985 to 1989 or 1994 continue. Within this time frame, it is possible that the number of adult females in the Kenai-to-Kiska region could drop to less than 5000. Extinction rates for rookeries or clusters of rookeries could increase sharply in 40 to 50 years, and extinction for the entire Kenai-to-Kiska region could occur in the next 100-120 years. Because of their life history, Steller sea lions probably cannot recover from their current decline by more than 8% to 10% per year (under ideal conditions). As a result, there is a high risk that the western population of Steller sea lions could become extinct within the forseeable future if their decline is not abated and their rate of increase is not improved immediately.

5.2 Effects of the proposed BSAI Atka mackerel fishery

In the Bering Sea and Aleutian Islands Region of Alaska, NMFS proposes to authorize a fishery for walleye pollock between 1999 and 2002. The Atka mackerel fishery occurs in relatively predictable or constant areas throughout the central and western Aleutian Islands. The geographic distribution of the fishery in 1993-97 in the Aleutian Islands is illustrated in Figure 4. Lowe and Fritz (1997) provide the following description. The action area for the Atka mackerel fishery extends from the eastern border of management area 541 (Fig. 4), which runs through the Islands of the Four Mountains, to the western border of area 543, just west of Stalemate Bank, or midway between Attu Island (U.S.) and Medney Island (Russia). The north and south borders of these management areas are 55°N lat. and the boundary of the exclusive economic zone south of the Aleutian Islands, respectively. Twenty Steller sea lion rookeries and 28 major haulouts are located in this region (50 CFR, Tables 1 and 2 for part 226.12). Seventy percent or more of the fishery in 1995 through 1997 occurred within Steller sea lion critical habitat (i.e., within 20 nautical miles of these rookeries and haulouts or within the Seguam Pass foraging area designated as critical habitat; Fig. 9).

The Atka mackerel fishery is prosecuted almost entirely by large catcher processors. From 1992 to 1996, the numbers of vessels participating in the fishery annually were 34, 23, 15, 17, and 17, for an annual total of 106, 122, 126, 144, and 191 vessel-weeks (Kinoshita et al. 1997). Twelve vessels participated in the fishery in 1997, including 1 vessel 200 feet in length, 8 vessels between 200 and 250 feet in length, and 3 vessels greater than 250 feet in length.

Prior to the early 1990s, the Atka mackerel fishery occurred primarily in the spring and summer months. Since the early 1990s, the fishery has started earlier (January) and has been condensed into a shorter season, so that most or all of the TAC has been taken by late March or April (Fig. 6). In 1995 and 1996, the fishery was also open briefly in July and/or August to allow complete removal of the TAC. Through 1998, the Atka mackerel fishery has been concentrated in time (January to March or April) and space (on average, 70% or more of the catch taken from Steller sea lion critical habitat, with up to 98% in some management areas and some years). Harvest rates in some areas approached 90% of the available stock. The effects of fishing on local abundance of Atka mackerel, then, may exceed system-wide harvest rates and could have detrimental ecosystem effects persisting for weeks or months. Harvest rates in some areas approached 90% of the available stock. The effects of the fishery on local abundance of Atka mackerel, may exceed system-wide harvest rates and could have detrimental ecosystem effects persisting for weeks or months.

As discussed in the *Background to the Effects Analysis* (section 5.1), section 7 consultation on the Atka mackerel fishery was reinitiated because of evidence that the fishery locally-depleted mackerel stocks in the Aleutian Islands (Fritz in prep.). The declines in the abundance of mackerel are consistent with expectations related to level of catch: the higher the catch and the longer the season, the more likely a substantial decline in mackerel abundance. Finally the magnitude of the estimated decline can be substantial: they can represent reductions of up to 94% although they averaged 56% in 1996 and 37% in 1997. The evidence for fishery-induced localized depletion of Atka mackerel stocks was reviewed and considered by the NPFMC in April and June, 1998.

Atka mackerel are known to be a major prey for Steller sea lions in an area where the fishery operates and where sea lion numbers have declined severely. As discussed throughout this document, the lack of available prey is the primary hypothesis for the continued decline of the western population of Steller sea lions. Steller sea lions seem to rely on aggregations of Atka mackerel, and fishing appears to diminish the number, size, density, or persistence of those schools to an extent not expected on the basis of the system-wide harvest rates set by fisheries managers. As a result, NMFS continues to be concerned that the proposed Atka mackerel fishery might seriously diminish the foraging success of sea lions leading to reductions in their condition, growth, reproduction, or survival. The recent determination that the Atka mackerel fishery is conducted in a way that appears to deplete Atka mackerel biomass on a local scale heightens our concern that the fishery is likely to appreciably reduce the likelihood of the survival and recovery of Steller sea lions in the wild.

In June 1998, the NPFMC recommended a regulatory amendment to the Secretary of Commerce that would impose an A/B season apportionment (50:50) of Atka mackerel TAC in each of the three management areas, and would incrementally shift the fishery catch in areas 542 and 543 until a target split of 40% inside and 60% outside was reached in 2002. Consequently, the proposed action includes the conservation measures recommended by the North Pacific Fishery Management Council to avoid potential competition between the Atka mackerel fishery and the Steller sea lion. Those measures reduce potential localized depletions by temporally dispersing the fishery into two seasons, and spatially dispersing the fishery among areas inside and outside of critical habitat. The subsequent division of the TAC among seasons and sites should reduce considerably the potential for localized depletion of prey resources at any particular point in time or space. The incremental approach to reductions of TAC in Steller sea lion critical habitat is reasonable since it allows some time for detection of unanticipated adverse effects that might result from redistribution of the fishery.

As proposed, the conservation measures will be fully implemented by 2002. If these conservation measures are fully implemented, the proposed action should not appreciably reduce the likelihood of both the survival and recovery of the Steller sea lion.

5.3 The proposed BSAI pollock fishery

In the Bering Sea and Aleutian Islands Region of Alaska, NMFS proposed to authorize a walleye pollock fishery between 1999 and 2002 and implement a new scheme for allocating the pollock TAC to the inshore and offshore sectors of the fishery. The BSAI pollock fishery effectively encompasses the entire Bering Sea from about 62°N lat. to shelf break south of the Aleutian Islands, from the eastern areas of Bristol Bay to the Aleutian Basin and Donut Hole, and along the Aleutian Islands at least as far west as the Semichi Islands. Areas of concentrated effort include the eastern Bering Sea shelf, along the shelf break from the Aleutian Islands to the U.S./Russian boundary, north of Umnak Island in the waters around Bogoslof Island. The distribution of pollock in the BSAI region varies seasonally, with spawning aggregations in the Eastern Bering Sea and vicinity of Bogoslof Island, and then dispersion northward and westward to cover the Bering Sea and Aleutian Basin.

The BSAI pollock fishery is composed of four sectors: 1) onshore fish processing plants (principally in Dutch Harbor, AK); 2) catcher-processors (principally based in Seattle, WA) that can catch and process fish, and receive fish from catcher vessels; 3) catcher vessels that can only catch fish and deliver it to onshore plants, catcher-processors, or motherships; and 4) motherships that cannot catch fish, but receive and process fish caught and delivered by catcher vessels. Catcher-processors have the ability to catch and process pollock, motherships are essentially floating processors that take catch from catcher vessels, and catcher vessels catch and deliver their allocation of pollock either to motherships or to shoreside processors. Catcher-processors and motherships are large vessels with large catching and/or processing capacity, while catcher vessels are smaller and have limited holding capacity. Catcher-processors may take catch from catcher vessels, thereby acting as motherships. Processing at sea (the offshore sector) allows greater flexibility in terms of areas fished, whereas processing of small vessel catch at shoreside processors (the inshore sector) provides greater economic benefits for local communities with catcher vessels and/or processing facilities.

In 1996, 166 vessels or plants participated in the BSAI pollock fishery: 8 onshore plants, 37 catcher-processors, 118 catcher vessels, and 3 motherships. Since 1992, when the first inshore/offshore allocation mechanism was put in place (Amendments 18/23 to the FMPs of BSAI and GOA groundfish), 7.5% of the pollock TAC has been allocated to a Community Development Quota for local Bering Sea communities to harvest or sell to other concerns. Of the remaining 92.5% of the BSAI pollock TAC, 35% has been given to the onshore sector, while 65% has been given to the offshore sector. The onshore sector consists of onshore processing plants and the catcher vessels that deliver to them. The offshore sector (in this context) consists of catcher-processors, motherships, and the catcher vessels that deliver to each of them. Some of the catcher vessels (22) participated in both the inshore and offshore sectors in 1996. Most pollock are caught with pelagic trawls fished off-bottom to reduce the bycatch of undesired (e.g., other deferral fish) or prohibited species (e.g., crab and halibut).

Currently, pollock fishing in the BSAI occurs in two seasons: a roe fishery that fishes on spawning aggregations in winter (January 20 through early March) when 45% of the eastern Bering Sea and all of the Aleutian Island pollock TAC is currently taken; and a surimi-fillet fishery that fishes in summer (currently beginning September 1). The current roe fishery in the eastern Bering Sea targets the spawning aggregation(s) between Unimak Island and the Pribilof Islands. In the Aleutian Islands, the fishery used to occur in area 541 (Amukta Pass and west of the Bogoslof area) as recently as 1992, but has moved west to Kanaga Island and to the Near Islands in the last several years (1994-98). The summer fishery is more widely dispersed from Unimak Pass along the middle and outer continental shelf northwest to the U.S.-Russia convention line. Currently, the only regulatory, spatial allocation of pollock TAC in the BSAI is between the Aleutian Islands and eastern Bering Sea areas. Observed pollock fishery trawl locations in 1995-1997 are shown by season in Figures 20 and 21. From 1992 to 1997, the winter season catch has generally been concentrated in the CVOA (47% to 93%) and associated sea lion critical habitat (53% to 89%).

In the BSAI region, the allocation of pollock to inshore/offshore sectors of the fishing industry involves considerations of optimal utilization versus waste, economics and issues related to domestic versus foreign ownership, social considerations such as stability and economic well-being of local fishing communities, and ecosystem considerations such as the distribution of fishing effort in time and space and the effects of the fishery on protected species such as the Steller sea lion. These same considerations apply in the GOA, but allocation in the GOA has been primarily to prevent larger catcher-processors from preempting fishing by smaller catcher vessels, such as occurred in 1989. Strictly speaking, the question of who removes pollock from the ecosystem should not have a direct effect on Steller sea lions or other protected species.

With respect to ecosystem effects or effects on protected species, the key differences in the operations of inshore versus offshore sectors are a) the rate at which pollock are removed and the time of year that they are removed, and b) the location of removal. Large catcher processors are able to remove pollock at a much greater rate than catcher vessels. Catcher processors can tow larger nets with capacities of several hundred mt. Catcher vessels, on the other hand, may also tow very large nets but are generally limited capacities of 100 mt or less. Thus, the offshore sector can remove pollock and harvest a TAC rapidly compared to the inshore sector. Given limits on the amount of pollock that can be removed (TACs), rapid removal condenses the fishery to a shorter period of time and therefore limits the length of the season. Rapid removal of pollock from an area is more likely to result in temporary localized depletion of that resource for other consumers, such as sea lions and other marine mammals. Similarly, the rapid removal of the TAC precludes a more even distribution of fishing effort throughout a season and may, therefore, be more disruptive to the ecosystem.

The second key difference between inshore and offshore sectors is the geographic distribution of fishing effort. Smaller vessels with limited storage capacities are restricted to areas closer to shore, whereas processing vessels with greater storage capacities and on-board processing plants can fish at greater distances from shore. Because of these spatial limits, the impact of the inshore sector may be concentrated geographically and in areas essential to protected species such as the Steller sea lion.

Inshore/offshore allocations of pollock in the BSAI were first established in 1992 under FMP amendment 18. In the BSAI region, 35% of the pollock TAC (after subtraction of reserves) was allocated to the inshore sector and 65% to the offshore sector. A catcher vessel operation area (CVOA) was established with the same boundaries as currently in place except that the western boundary was 0°30' west of its current location. The CVOA was in effect from September 1 to the end of the year, and motherships (and catcher-processors acting as motherships) were allowed to receive catches inside the CVOA only if they did not participate in directed fishing for pollock. In 1995, the inshore/offshore allocation (35:65%) was unchanged, the CVOA was reduced to its current configuration, and catcher-processors were allowed to fish for pollock in the CVOA if the pollock allocation for the inshore sector had been taken prior to the end of the fishing season. In the BSAI, Amendment 51 would make the following changes to the fishery from 1999 to 2001: a) after subtraction of reserves, 39% of the BSAI pollock TAC would be allocated to the inshore sector and 61% to the offshore sector; b) a portion of the inshore allocation equal to 2.5% of the BSAI pollock TAC, after subtraction of reserves, would be set aside for catcher vessels under 125 ft length overall and would become available on or about August 25 of each year; and c) all vessels harvesting pollock for processing by the offshore component would be prohibited from fishing inside the CVOA after September 1 of each year, unless the inshore component of the pollock fishery is closed to directed fishing (i.e., the inshore portion of the TAC has been taken).

As discussed in the *Description of the Proposed Actions*, the recently-authorized AFA made further changes to the allocation of pollock in the BSAI beginning in 1999. Under the AFA, 10% of the pollock TAC is allocated to the CDQ program and the remaining 90% of the TAC, after subtraction of an allowance for incidental catch in other fisheries, is allocated 50% to vessels delivering to the inshore sector, 40% to catcher processors and catcher vessels delivering to catcher processors, and 10% to catcher vessels delivering to motherships. These new allocation percentages mandated by the AFA represent a shift of 15% of the TAC from the offshore to the inshore sectors.

The AFA removes approximately one-third of the factory-trawlers from the offshore fleet, divides the TAC among three sectors (motherships 10%, offshore sector 40%, and onshore sector 50%), identifies specific vessels that can participate within each sector, and authorizes the sectors to establish cooperatives. Under the provisions of a $90 million buyout, nine factory trawlers will lose their U.S. fisheries endorsements on January 1, 1999, and eight of these vessels will be scrapped.

5.3.1 Effects of the proposed BSAI pollock fishery

Twenty-eight Steller sea lion rookeries and 49 major haulouts occur in this region (50 CFR, Tables 1 and 2 for part 226.12). The proposed fishery may affect Steller sea lions that haulout at terrestrial sites on St. Matthew and sea lion rookeries and haulout areas on the Pribilof Islands in the north, and all along the Aleutian Chain from Amak Island and Sea Lion Rock in the southeastern Bering Sea westward to the Commander Islands. Hill and DeMaster (in prep) suggest that the western population of Steller sea lions numbered 39,500 individuals in 1996, of which about 56%, or just over 22,000, occurred in the BSAI region. The extent to which sea lions from Russian territories (along the eastern shore of the Kamchatka peninsula) are affected by the U.S. pollock fishery is uncertain. As mentioned several times during this discussion, with the exception of no-trawl zones, the distribution of the fishery and the distribution of foraging sea lions overlap extensively.

The fishery for pollock in the BSAI has become concentrated in time. In 1990, the fishery occurred over a period of almost 10 months, but in recent years the fishery has been completed within 3 months. The concentration has occurred in the winter (roe or A) season, and in the fall (B) season. The winter months are considered to be a period of greater sensitivity of sea lions to lack of available prey and competition. This sensitivity is a function of both the life history of sea lions and their greater metabolic demands during the harsh winter period. In the winter (A) season, catch is concentrated in the CVOA, based on model estimates of overall biomass and survey estimation of stock distribution. The CVOA overlaps considerably with critical habitat that has been established for Steller sea lions in the Bering Sea. This increases the risk of the fishery adversely affecting Steller sea lions, particularly since 45% of that catch is removed in the winter season when sea lions may be particularly sensitive to decreased availability of prey.

The fishery for pollock in the BSAI is also concentrated in space and overlaps considerably with critical habitat that has been designated for Steller sea lions. Since the mid 1980s, the amount and percent of the BSAI pollock TAC caught in Steller sea lion critical habitat has doubled. The percentage of pollock caught within critical habitat (or areas designated as such in 1993) in the BSAI region increased from between 5-20% in the late 1960s to 15-30% from 1971-86 and 70% between 1992 and 1997. Actual removals mirrored the total catch during this period (1964-1986; Fig. 13) and peaked at over 500,000 mt in 1971 and 1972, before decreasing to between 200,000 and 300,000 mt from 1977-86. From 1987-95, however, both the catch tonnage and percentage of annual removals of pollock from critical habitat increased more than 3-fold to over 800,000 mt and 70%, respectively. This shift resulted from increasing pollock fishery effort in fall and winter (when pollock are more concentrated within critical habitat) and an evolution in fleet composition from a mobile processing fleet (e.g., foreign factory trawlers) to one increasingly dominated by shore-based processors and their catcher vessels which fish in coastal fishing areas located within critical habitat.

Estimated biomass, catch, and harvest rates suggest that established system-wide harvest rates are exceeded in the fall (B) season in the CVOA. The CVOA overlaps considerably with critical habitat, which suggests similar concentration in critical habitat. Catch is even more concentrated in critical habitat in the winter (roe, A) season, but surveys are not regularly conducted during this period and fish stock distribution is not known; thus, harvest rates can not be calculated for the winter season. The stock is often assumed to be concentrated in the southeastern Bering Sea; unfortunately this assumption cannot be verified, although sporadic winter surveys suggest the assumption may be flawed.

The American Fisheries Act may alter, to some degree, the extent to which the BSAI pollock fishery is concentrated in time and space. The removal of about one-third of the factory trawler (catcher-processor) fleet and the shift in TAC allocation to the onshore fleet may slow the pace of the fishery. The pace at which fish are removed is a function not only of the number of vessels, but also of the behavior of those vessels, which can not be predicted at this time. Slowing of the fishery would reduce the pulsed or derby nature of the fishery, but to what extent is undetermined. Industry predictions suggest that the added temporal dispersion will amount to about two weeks in the winter season and four weeks in the summer season. With respect to spatial dispersion, the greater allocation of TAC to the onshore fleet will likely increase the potential for concentration of catch in areas closer to shore (i.e., potentially within sea lion critical habitat). The overall effect of the American Fisheries Act will depend on the manner in which it is implemented, which had yet to be determined at the time of the writing of this opinion.

As discussed earlier in this Biological Opinion, the BSAI pollock fishery targets a major prey species of the Steller sea lion. Sizes of pollock taken by the fishery and sizes taken by adult and juvenile Steller sea lions overlap, although juvenile sea lions probably target pollock that are, on average, smaller than pollock taken by adult sea lions. Steller sea lions seem to rely on aggregations of walleye pollock, and fishing appears to diminish the number, size, density, or persistence of those schools to an extent not expected on the basis of the system-wide harvest rates set by fisheries managers.

Previously, we discussed the high risk that the western population of Steller sea lions could become extinct within the forseeable future if their decline is not abated and their rate of increase is not improved. The BSAI region is critical to the survival and recovery of the endangered western population of Steller sea lions because it supports slightly more than half of the remaining individuals. As proposed, the BSAI pollock fishery continues to concentrate the fishery in both space and time. This concentration is particularly problematic in the CVOA where 50% of the pollock harvest would occur in the winter.

Because of the importance of the BSAI to the survival and recovery of the endangered western population of Steller sea lions, NMFS continues to be concerned that the BSAI pollock fishery, as proposed, might seriously diminish the foraging success of sea lions because of the concentration of the pollock harvest spatially and temporally. Based on the trend of the Steller sea lion population in the BSAI since the 1970s, the risk of continued reductions in the condition, growth, reproduction, and survival of individual members of this population heightens our concern that the fishery is likely to appreciably reduce the likelihood of the survival and recovery of Steller sea lions in the wild.

5.4 The proposed GOA pollock fishery

In the Gulf of Alaska region, NMFS proposed to authorize a walleye pollock fishery between 1999 and 2002 and implement a new scheme for allocating the pollock TAC to the inshore and offshore sectors of the fishery. The GOA pollock fishery occurs in an area that extends from the area south of Prince William Sound to west of Umnak Island in the Aleutian Islands to the shelf break. The fishery is divided into eastern, central, and western regions (Fig. 17). The boundary between the eastern and central regions is at

147°W long., and essentially overlays the easternmost rookery and haulouts of the western population. The management areas of primary concern are, therefore, the central and western regions. The central and western regions are divided into three management areas, all of which extend from the 3-mile state boundary to the EEZ limit. Area 630 is delimited on the east by 147°W long. and on the west by 154°W long. Area 620 extends from 630 further west to 159°W long. and area 610 extends from 620 to 170°W long. Within these three management areas, fishing is concentrated south of Unimak Pass and Island (Davidson Bank), southeast and southwest of the Shumagin Islands, along the 200-fathom isobath running from the shelf break northeastward to Shelikof Strait, Shelikof Strait, and the canyon regions east of Kodiak Island.

As discussed previously in the *Description of the Proposed Action* section, the entire GOA pollock fishery has been allocated (except for bycatch) to the onshore processing sector since the first inshore/offshore allocation amendment was enacted in 1992. Onshore plants that process pollock caught in the GOA are located principally in Kodiak, Sand Point, and Dutch Harbor. In 1996, there were 96 catcher vessels that delivered GOA pollock to onshore plants; 38% of these had Alaska registry, while the remainder were registered outside of AK. Of the 162 trawl catcher vessels that participated in any groundfish fishery in the GOA, 63 (39%) were < 60 feet in length, 82 (51%) were between 60-124 feet in length, and 17 (10%) were between 125-230 feet in length. Most pollock are caught with pelagic trawls fished off-bottom to reduce the bycatch of undesired (e.g., other deferral fish) or prohibited species (e.g., crab and halibut).

In 1998, the GOA pollock fishery was split into three seasons: a roe fishery that targets spawning aggregations in winter (beginning January 20) when 25% of the GOA pollock TAC is taken; and two summer fisheries, one beginning on July 1 (with 35%), and another beginning September 1 (with 40%). Seasonal allocations in 1996 and 1997 were 25:25:50% for pollock fisheries beginning on the same dates, while from 1992-95, the pollock TAC was allocated evenly (each at 25%) to fisheries beginning on 20 January, 1 June, 1 July, and 1 October. As the GOA pollock TAC declined, the number of seasons was reduced from 4 to 3. Observed pollock fishery trawl locations in 1995-1997 by season are shown in Figures 23-25.

The temporal distribution of pollock catches in the GOA has been different than in the BSAI region. From 1964 to 1997, a greater percentage of the pollock were harvested in the fall and winter in the GOA than in the BSAI (Fig. 15B), but total removals were less. However, when landings from the GOA exceeded 150,000 mt from 1981-85 during the Shelikof roe fishery, the proportion caught in fall and winter exceeded 50%, and ranged as high as 90%. Even after catches declined in 1986-89 in response to declining pollock biomass, the proportion caught in fall and winter remained above 70%. 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 pollock fishing opportunities for vessels based in the GOA. As pollock biomass and TACs declined in the mid 1990s, the number of seasonal releases was reduced to 3 (1 January, 1 June, and 1 September), with 25% of the annual TAC assigned to the first 2 and 50% to the last. For the 1998 GOA pollock fishery, the seasonal allocations to the 2nd and 3rd trimesters were changed to 35% and 40%, respectively, to reduce the pollock catches during the fall in response to an increase in TAC.

With respect to ecosystem effects or effects on protected species, the key differences in the operations of inshore versus offshore sectors are a) the rate at which pollock are removed and the time of year that they are removed, and b) the location where they are removed. As discussed in the previous section, large catcher processors are able to remove pollock at a much greater rate. Thus the offshore sector can remove pollock and harvest their TAC rapidly compared to the inshore sector. Smaller vessels with limited storage capacities are restricted to areas closer to shore, whereas processing vessels with greater storage capacities and on-board processing plants can fish at greater distances from shore. Because of these spatial limits, the impact of the inshore sector (which is the only sector operating in the GOA) may be concentrated geographically and in essential foraging areas of the Steller sea lion.

5.4.1 Effects of the proposed GOA pollock fishery

Twelve Steller sea lion rookeries and 33 haulouts occur in the GOA region (50 CFR, Tables 1 and 2 for part 226.12). Counts in 1996 indicated that about 44% of the western population occurred in the GOA (Hill and DeMaster in prep), which would suggest a GOA population of just under 17,500.

The pollock fishery in the Gulf of Alaska is not as temporally-concentrated as the BSAI pollock fishery. However, the current division of the fishing year into three seasons represents some concentration relative to the four-season system (25% of TAC in each) used in the early 1990s. The fishery has become concentrated in Steller sea lion critical habitat, beginning with increased fishing in Shelikof Strait in 1982. Since 1982, 50% to 90% of the catch has been taken from Steller sea lion critical habitat.

In the GOA, pollock catches from critical habitat increased (as the TAC increased) from trace amounts prior to 1979 to over 200,000 mt in 1985, primarily from Shelikof Strait (Fig. 16). Pollock landings from GOA critical habitat dropped (as the annual TAC declined) to about 50,000 mt in 1986, and have ranged between 35,000 and 90,000 mt through 1997. 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%. Recent (1995-1997) percentages of pollock catch taken from critical habitat are shown by season in Figure 22. As in the BSAI, percentage removals from critical habitat during the roe-harvesting season (January) have generally been the highest. Recent 3-year averages by season are:

- January 90%
- June/July 73%
- September/October 58%

Observed trawl locations in the GOA pollock fishery for 1995 to 1997 are shown by season in Figures 23-25. These figures in combination show the increasing use of critical habitat by the GOA pollock fishery during the last 20 years.

Previously, we discussed the high risk that the western population of Steller sea lions could become extinct within the forseeable future if their decline is not abated and their rate of increase is not improved. The GOA region is critical to the survival and recovery of the endangered western population of Steller sea lions because it supports slightly less than half of the remaining individuals. As proposed, the GOA pollock fishery continues to concentrate the fishery in both space and time.

Based on the information available, we cannot determine whether the proposed GOA pollock fishery concentrates harvest rates in critical habitat in a way that is likely to reduce the potential for localized depletions, particularly during the winter period that seems critical to Steller sea lions. One possible exception is the winter harvest rate (January to March) in Shelikof Strait, which declined from about 18% in 1985 to about 7% in 1993 and less than 5% in 1994 through 1997. The low harvest rate in Shelikof Strait suggests that potential competition between the fishery and Steller sea lions within the Strait has been reduced. Elsewhere in the GOA, the pollock fishery achieves between 50 and 90% of its harvest from designated critical habitat, much of which occurs in the winter which is critical for Steller sea lions. Recent distribution patterns of the pollock fishery suggest that interactions with sea lions in critical habitats continue despite the partitioning that was achieved by establishing trawl exclusion zones in the vicinity of Steller sea lion rookeries. Because of the importance of the GOA to the survival and recovery of the endangered western population of Steller sea lions, NMFS continues to be concerned that the GOA pollock fishery, as proposed, might seriously diminish the foraging success of sea lions because of the concentration of the pollock harvest spatially and temporally. Based on the trend of the Steller sea lion population in the GOA since the 1970s, the risk of continued reductions in the condition, growth, reproduction, and survival of individual members of this population heightens our concern that the fishery is likely to appreciably reduce the likelihood of the survival and recovery of Steller sea lions in the wild.

6.0 CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

As discussed in the Environmental Baseline, the Alaska Department of Fish and Game (ADF&G) manages fisheries out to three miles, oversees crab fisheries in federal waters (EEZ) under the FMP adopted by the NPFMC. These fisheries are expected to continue into the foreseeable future. With the exception of the Alaska state sablefish fishery, ADF&G coordinates their fishery openings and in-season adjustments with federal fisheries. At present, the state fishery for herring is located in the following areas: Prince William Sound, Cook Inlet, Kodiak, Alaska Peninsula, Bristol Bay, Kuskokwim, Norton Sound, Southeast, and Port Clarence. Harvest methods for herring consist of gillnet, purse seine, and handpicking of roe from kelp. Herring are primarily caught for their roe during the sac roe harvest in the spring. Harvest levels for 1998 are expected to be about 36,000 mt, similar to the last few years. Figure 42a shows herring catches by season and by region, and also shows the effort level depicted by the number of landings. Bristol Bay is the primary producer with recent catches of about 23,000 mt annually. Effort over the last two decades has decreased in Prince William Sound and Cook Inlet, but increased in Kuskokwim, Kodiak, and Bristol Bay. The potential adverse effects of the state of Alaska herring fishery on Steller sea lions is uncertain, although herring have higher caloric and nutritional value to Steller sea lions.

Clam, abalone, octopus, squid, snail, scallop, geoduck clams, sea urchins, and sea cucumbers have been harvested throughout the state (Figure 43a). Of these, octopus and squid are the most likely prey of sea lions. Most of the catch of shellfish is taken from April to September, and they are taken by hand-picking, shovel, trawl, pot, and dredge gear. Harvest levels were relatively consistent through the 1980s, but have increased dramatically in amount and annual variation in the 1990s (Figure 43b). The variability has been due, in large part, to recent but sporadic catches in Bristol Bay and the Bering Sea, areas not usually fished for shellfish (Figure 43a). With the exception of the recent large catches in these areas, most of the shellfish fisheries have traditionally taken place in the Kodiak and Cook Inlet areas.

The state manages all crab fisheries in the BSAI and GOA. King (brown, red, blue), Dungeness, and Tanner crabs are taken by hand-picking, shovel, trawl, pot, and dredge gear. State of Alaska crab fisheries occur in Bristol Bay, Dutch Harbor, Alaska Peninsula, Kodiak, Cook Inlet, Adak and W. Aleutian Islands, and Prince William Sound (Figure 44a). This fishery primarily occurs during the winter season. In the past ten years, the industry has focused on Alaska snow crab (*C. opilio*), and the catch exceeded historical levels of king crab in the early 1990s (Figure 44b). The Bering Sea fishery produces the vast majority of crab that is harvested in Alaska but has also been declining since 1993. Catch per landing has been greatest in the Bering Sea, and worst in the Kodiak and Cook Inlet areas (Figure 44a).

The State of Alaska shrimp fishery occurs primarily in the southeast and Yakutat areas, and to a lesser extent in Prince William Sound, Kodiak, Dutch Harbor, Cook Inlet, and the Alaska Peninsula. Shrimp are harvested by pot gear and often sold to floating processors. In 1995, over 45,000 mt of shrimp were harvested by 351 vessels. In the last ten years, effort has increased in the southeast due, in part, to the availability of floating processors, which allow fishing vessels to devote more of their time to fishing. Figures 45a and b show the decline in shrimp fisheries in areas other than southeast and Yakutat.

The state of Alaska manages groundfish within the 3-mile limit for lingcod, Pacific Ocean perch, flathead sole, rex sole, arrowtooth flounder, sablefish, black rockfish, and pollock. Fisheries occur in the Alaska Peninsula, Kodiak, Bering Sea, Dutch Harbor, Adak and W. Aleutian Islands, Cook Inlet, Prince William Sound, and Southeast areas.

The State of Alaska Pacific cod fishery is undergoing a change in management from federal to state authorities. A total TAC is set for Pacific cod, and that TAC is divided into federal and state shares. In 1997 and 1998, the state assumed management responsibility of 15% of the total TAC for cod, and is expected to manage 20% in 1999. Under current regulations, the state portion of the total TAC can not exceed 25%. The state fishery is limited to pot and jig gear only. The Pacific Cod fishing season is primarily in the winter.

The State of Alaska salmon fishery includes five species: chinook, sockeye, coho, pink, and chum. These fisheries are divided into southeast, Prince William Sound, Cook Inlet, Bristol Bay, Kodiak, Chignik, Alaska Peninsula, Kuskokwim, Yukon, Norton Sound, and Kotzbue management areas (Figure 46a). The state has a long history of salmon fishing. Salmon are taken by purse seines, gill nets, trolling, and beach seining. The catch in 1974 was just over 60,000 mt, then increased four-fold by 1981, was relatively constant through the 1980s, and then increased in the early 1990s to a record catch of over 450,000 mt (Figure 46b). In 1997, 123 million salmon were caught in Alaska, amounting to about 280,000 mt. The 1998 catch was expected to be higher than 1997, but has been low due to poor returns in Bristol Bay. Bristol Bay harvest levels have historically been the highest with Kuskokwim and Chignik being the lowest (Figure 46a). In 1997, 26% of the commercial catch was from hatcheries. Salmon caught in these fisheries are seasonally important in the diet of Steller sea lions

The subsistence harvest of Steller sea lions by Alaska Natives is expected to continue into the foreseeable future. The majority (79%) of sea lions were taken by Aleut hunters in the Aleutian and Pribilof Islands. The great majority (99%) of the statewide subsistence take was from west of 144°W long. (i.e., the range of the western population). The overall impact of the subsistence harvest on the western population will be determined by the number of animals taken, their sex and age class, and the location where they are taken. As is the case for other sources of mortality, the significance of subsistence harvesting may increase as the western population decreases in size unless the harvesting rate is reduced accordingly. However, the subsistence harvest accounts for only a relatively small portion of the animals lost to the population each year.

7.0 CONCLUSION

After reviewing the current status of the Steller sea lion, the environmental baseline for the action area, the effects of the proposed 1999-2002 Atka mackerel fishery, the cumulative effects, and the conservation measures that will result from recommendations of the NPFMC, it is NMFS' biological opinion that the action, as proposed, is not likely to jeopardize the continued existence of the Steller sea lion or adversely modify its critical habitat. Barring any need for reinitiation prior to implementation of the fishery in 2003, this opinion will remain in effect until the end of calendar year 2002.

After reviewing the current status of the Steller sea lion, the environmental baseline for the action area, the effects of the proposed 1999-2002 BSAI pollock fishery, and the cumulative effects, it is NMFS' biological opinion that the action, as proposed, is likely to jeopardize the continued existence of the western population of Steller sea lions and adversely modify its critical habitat.

After reviewing the current status of the Steller sea lion, the environmental baseline for the action area, the effects of the proposed 1999-2002 GOA pollock fishery, and the cumulative effects, it is NMFS' biological opinion that the action, as proposed, is likely to jeopardize the continued existence of the western population of Steller sea lions and adversely modify its critical habitat.

8.0 REASONABLE AND PRUDENT ALTERNATIVES

Regulations (50 CFR §402.02) implementing section 7 of the Act define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that: (1) can be implemented in a manner consistent with the intended purpose of the action; (2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; (3) are economically and technologically feasible; and (4) would, the Service believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

This opinion has concluded that the BSAI and GOA pollock trawl fisheries, as proposed, are likely to 1) jeopardize the continued existence of the western population of Steller sea lions, and 2) adversely modify its critical habitat. The clause "jeopardize the continued existence of" means "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (CFR §402.02). The clause "adversely modify its critical habitat" means "a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical" (CFR §402.02).

8.1 Principles for reasonable and prudent alternatives

To avoid the likelihood of jeopardizing the continued existence of the western population of Steller sea lions, or adversely modifying its critical habitat, reasonable and prudent alternatives to the proposed pollock trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska must accomplish each of the following.

8.1.1 Temporal dispersion

The first objective of temporal dispersion is to avoid removal of prey during the winter period when Steller sea lions, and particularly adult females and juveniles, may be especially vulnerable to competition or lack of available prey. The current fishing schedule prohibits fishing from 1 November through 19 January in the pollock trawl fisheries in the Bering Sea subarea. The reasonable and prudent alternatives should continue this prohibition and expand it into the Gulf of Alaska..

A second objective of temporal dispersion is to more evenly distribute the pollock trawl fisheries catch throughout the remainder of the year and thereby eliminate the probability of localized depletions associated with removing large amounts of catch in short periods of time (e.g., "derby" fishing). In the BSAI, the pollock fishery has become temporally concentrated from about 10 months in 1990 to less than 3 months in 1998 (split into two seasons). This kind of pulsed fishery represents one extreme of temporal dispersion. At the other extreme, the catch would be evenly distributed from 20 January to December 31. An even distribution of the catch throughout the remainder of the year would reduce the likelihood for adverse ecosystem effects by minimizing the potential for temporary localized depletion. On the other hand, a significant effort by fishing vessels on a nearly year-round basis may increase the potential for interactive competition (i.e., disturbance of foraging sea lions by fishing activities). The division of the 20 January to December 31 period into four seasons represents an intermediate approach that reduces the potential for temporary depletion in either existing season by about one-half, and more evenly disperses the fishery through the period from 20 January to 31 October. The four-season approach has already been used in the GOA pollock fishery.

In the BSAI, about 45% of the entire TAC is currently taken in a six- to eight-week period during the winter roe (A) season, beginning 20 January, and then no pollock are removed until the fall season (1 September to 31 October; 55% of TAC). Because sea lions must depend on spawning aggregations of pollock during winter season, dispersal of the roe-fishery is a necessary, seasonally-specific objective of temporal dispersion. Possible protective measures could include reduction of the pollock TAC in the winter season, or splitting of the winter season into two seasons (winter and spring; e.g., January 20 and March 1), or both. Splitting of the winter TAC into two seasons reduces the potential for localized depletions, while still allowing for two seasons in which roe-bearing pollock can be fished. This approach satisfies both the need to increase protection for sea lions without unnecessarily constraining the pollock trawl fisheries. Splitting the existing winter season into two seasons represents a reasonable stepping up of protection for sea lions. The possibility of localized depletion at any one time will be reduced by about half simply by splitting the 45% allocation to the current winter season into a winter and spring season.

To ensure that seasonal TACs are reasonably balanced and accomplish the desired temporal dispersal of catch, the portion of the total TAC removed in any particular season must be constrained. An even distribution of the TAC would result in a 25% split to each of four seasons. Due to various seasonal considerations (which may be important to sea lions, the fisheries, or both) some flexibility in the single season cap is desirable. An increase from 25% in a season to 30% (which amounts to a 20% increase from an even distribution) would still maintain a four-season approach. An increase from 25% to 35% would not maintain a four-season approach as 100% of the annual TAC could be taken in three seasons. Therefore, a 30% cap is essential to maintain the integrity of the four-season approach.

To maintain the integrity of the four-season approach and ensure temporal dispersion, seasonal TACs should not be open to in-season adjustment as a simple function of fishing practices. That is, by adjusting their fishing practices, the pollock trawl fisheries should not be able to move large parts of the TAC among seasons. Some small rollover from one season to the next is reasonable if undertaken to compensate for TAC not taken due to imprecision of management monitoring and premature closure of a given season.

On the basis of these concerns, catch must be dispersed temporally in accordance with the following principles. Temporal dispersion must accomplish the following.

a) Continue current prohibition on all pollock trawling fisheries in the period from 1 November through 19 January and extend to the Gulf of Alaska.

b) Distribute the pollock trawl harvest into at least four seasons (two in the period from January through May and two in the period from June through October).

c) Limit combined TAC in the winter and spring periods to a maximum of 45% of the annual TAC (the current limit on the existing winter season).

d) Allocate single-season TACs to be no more than 30% of the annual TAC.

e) Prevent concentration of pollock catch at the end of one season and the beginning of the next season which, in effect, could result in a single pulse of fishing. Mechanisms for limiting such concentration might include inter-seasonal no-fishing periods, or limits on the proportion of a seasonal TAC that can be taken in the latter part of a season. Other measures to spread or reduce effort may be necessary.

f) Limit rollover of portions of seasonal TACs to situations only where necessary to account for premature fisheries closure resulting from inaccuracies associated with monitoring of seasonal catches.

8.1.2 Spatial dispersion

The first objective of spatial dispersion of pollock trawl fisheries is to have the distribution of catch mirror the distribution of exploitable pollock biomass for each seasonal TAC. This would include TAC allocation to areas both within critical habitat and outside of critical habitat.

In some areas, further reduction of catch may be necessary to provide sufficient protection for sea lions. That is, pollock harvest rates that are assumed to be safe for the pollock stocks may still constitute serious and detrimental competition between fisheries and the endangered and declining western population of sea lions. Thus, in some cases, the first principle of distributing catch according to the distribution of the pollock stock may not provide sufficient protection by itself.

As a management principle, the use of the pollock stock distribution to spatially allocate catch is problematic in both the BSAI and GOA. Stock assessment surveys are currently designed to determine pollock biomass, not distribution with respect to Steller sea lion critical habitat. In addition, the surveys are not conducted year-round, and are therefore sufficient to determine distribution during selected seasons only.

As fish stock distribution is generally not known in, for example, the winter season of the BSAI, then a precautionary approach must be followed to ensure that removals are not excessive in Steller sea lion critical habitat. Prior to 1987, less than 30% of the annual catch was taken from Steller sea lion critical habitat in all years except 1971 (when about 31% was taken). After 1987, the annual percent of the TAC removed from critical habitat increased to between 36% and 69%, with the 1987-1997 mean of about 52%. In the winter or A season (1995 to 1997), the mean percent of catch has been about 75%. These values provide reference points or benchmarks for reductions in catch from Steller sea lion critical habitat. With rounding, those benchmarks are:

a) 75% — mean percent catch during the A season from 1992 to 1997,
b) 50% — mean percent catch annually from 1987 to 1997, largely in summer, and
c) 30% — maximum percent catch annually prior to 1987, again largely in summer.

Of these benchmarks, setting the maximum percent to be taken from critical habitat at 75% would not result in a reduction of take and therefore would not avoid jeopardy or adverse modification. Setting the maximum percent at 50% is consistent with past fishery practices and still provides a considerable reduction from the current mean percent. Setting the summer maximum at 30% would be consistent with the history of the fishery for a period of about two decades prior to 1987. This level would provide considerably more protection for Steller sea lion critical habitat, but also increases the risk of unnecessary restriction of the pollock trawl fisheries.

In the GOA, the percent of the annual pollock TAC taken from critical habitat was on the order of a few percent until 1979, when the level rose to about 35%. From 1982 to 1997, the level has been consistently above 50%, ranging to as high as 93% in 1988. Here, a cap of 50% from critical habitat is consistent with the lower limit of catches since 1982, but also represents a meaningful reduction from the mean annual percent over this period.

Using these benchmarks, then, a cap of 50% would be required to achieve a meaningful reduction in the percent TAC taken from critical habitat. A 50% cap would also minimize the immediate consequences to the fisheries compared to the consequences under the more severe caps on percent from critical habitat.

Finally, the allocation of catch according to the geographic distribution of stock biomass implies some subdivision of the entire area of the stock into meaningful geographic units. For the pollock stocks in the BSAI region, some specific geographic areas have already been identified (e.g., Aleutian Islands area, Bogoslof area, eastern Bering Sea). The investigation of area-specific harvest rates in the BSAI that indicated excessive harvesting in the CVOA during the fall (B) season was based on the CVOA, the area outside of the CVOA but east of 170°W long., and the area outside of the CVOA but west of 170°W long. In the GOA, geographic management areas 610, 620, and 630 have already been established, and the Shelikof Strait area (combined 621 and 631) has been identified as an area of particular concern (and a site for annual hydroacoustic trawl surveys). With respect to the Steller sea lion, the areas of particular concern are identified as critical habitat. Management areas for the spatial allocation of pollock trawl fishing should be based on these and/or other meaningful geographic delineations.

On the basis of these concerns, catch must be dispersed spatially in accordance with the following principles. Spatial dispersion must accomplish the following.

a) Allocate percent TAC to areas defined by critical habitat (CH) and broad management districts (see item c) based on the pollock biomass distribution.

b) Absent good scientific estimates of pollock biomass distribution, place a maximum limit on the percent of TAC allocations from CH areas for each season. A cap of 50%, for example, is consistent with past fishing practices, but still leads to meaningful reduction in the percent of TAC from CH.

c) Allow for the possibility of further reduction of percent TAC in specific critical habitat areas.

d) Prevent redistribution of TAC from areas outside of critical habitat to areas inside of critical habitat.

e) Base spatial distribution of the TAC on existing study or management areas. In addition, in the southeastern Bering Sea, the CVOA and southeastern Bering Sea foraging area should be combined to form one CVOA-CH complex). Additional or alternative areas may be suggested but should not lead to further spatial concentration of catch. Alternative areas must distribute TAC in a manner that is equivalent to or better (for sea lions) than would be accomplished by the following set of management areas.

- Eastern Bering Sea:
  - Winter - CVOA-CH, and outside CVOA-CH
  - Summer - CVOA-CH, outside of CVOA-CH east of 170°W, and west of 170°W
- Gulf of Alaska:
  - Winter - Shelikof Strait (621 and 631 combined), 610, 620, 630
  - Summer - 610, 620, and 630
- Aleutian Islands:
  - All districts - 541, 542, and 543

8.1.3 Pollock Trawl exclusion zones

Trawl exclusion zones are an example of spatial dispersion wherein pollock catch is clearly not proportionate to pollock stock distribution. Complete exclusion of pollock trawl fishing is based on the available evidence that the regions around major rookeries and haulouts are so essential to the recovery and conservation of the western population that risk of competition from pollock trawl fisheries must be excluded completely. Such exclusions are particularly important to protection of prey resources for reproductive females and for pups and juveniles learning to forage.

Exclusion of potential competition from other fisheries may follow from consultation or review of those fisheries. Reasonable and prudent alternatives based on the pollock trawl fisheries should be limited here to measures directed at those pollock trawl fisheries.

Based on the need to eliminate the possibility of competition in foraging areas immediately adjacent to rookeries and haulouts, exclusion zones must be established to accomplish the following.

a) Spatial separation of pollock trawl fishing and Steller sea lion foraging areas adjacent to terrestrial haulouts and rookeries.

b) Protection of all rookeries and haulouts used by significant numbers of animals since the beginning of the decline in the 1970s.

c) Protection zones in the eastern Bering Sea must have a minimum radius of 20 nm, and 10 nm in the GOA and Aleutian Islands.

8.2 Incremental or phased approaches to reasonable and prudent alternatives

Some of the principles identified above may be accomplished by an incremental approach if the incremental approach does not jeopardize the continued existence of the western population of Steller sea lions. The phase in of any reasonable and prudent alternative must not be drawn out, and 2 years is a general guideline with a significant portion occurring in year one. For example, a 50% cap of removals from critical habitat could be implemented in two years, with a cap of 62.5% in the first year and 50% in the second year. Similarly, the exclusion zones could be established over a two-year period: in the first year, protected rookeries and haulouts could include those with a count of at least 200 animals in summer or 75 in winter since 1990, and in the second year, rookeries and haulouts with counts of 200 in summer and 75 in winter since 1979 would be protected. In effect, seasonal protection of rookeries and haulouts constitutes an incremental approach by season.

8.3 Review of fishery practices and fish/sea lion biological data subsequent to establishment of reasonable and prudent alternatives

The effectiveness of reasonable and prudent alternatives in redistributing fishing catch in accordance with pollock distribution, dispersing the fishery temporally, and protecting rookeries and haulouts must be evaluated annually. Additionally, scientifically valid biomass surveys should be conducted seasonally in cooperation with the industry to better assess pollock distribution and abundance relative to sea lion critical habitat.

A group including Steller sea lion researchers, federal and state managers, and industry and environmental agency representatives should be formed to develop recommendations for longterm management of fisheries relative to effects on Steller sea lions.

8.4 Example measures to implement the reasonable and prudent alternatives for pollock fisheries

The principles established in section 8.1 may be accomplished in any number of ways. The following set of recommended measures were developed by NMFS staff from the Alaska Fisheries Science Center and the Alaska Regions as an example which implements the above principles of the reasonable and prudent alternatives. See Table 9 for a summary of these recommended reasonable and prudent alternatives.

8.4.1 Temporal allocation

In both the eastern Bering Sea and the Gulf of Alaska, total allowable catch (TAC) will be distributed among four seasons. In the Aleutian Islands, seasonal allocation is not considered necessary. Rollover of seasonal TACs to must be limited to the amount of TAC remaining after premature fisheries closure resulting from inaccuracies associated with monitoring of seasonal catches.

Eastern Bering Sea (EBS)

Season	Start Date	Allocation
A1	January 20	20% of EBS pollock TAC
A2	March 1	25%
B	August 15	25%
C	September 15	30%

Gulf of Alaska (GOA)
Only for Western/Central [W/C] GOA areas 610, 620, 630

Season	Start Date	Allocation
A1	January 20	15% of W/C GOA pollock TAC
A2	March 1	30%
B	June 1	25%
C	September 15	30%

8.4.2 Spatial Allocation

In the EBS, pollock TAC will be split between two areas during the A1 and A2 seasons, and among three areas during the B and C seasons.

Eastern Bering Sea

Season	Areas	Allocation
A1 & A2	1) Catcher Vessel Operation Area (CVOA) and EBS critical habitat 2) Outside of CVOA and EBS critical habitat	(See below)
B & C	1) CVOA and EBS critical habitat 2) East of 170°W outside of CVOA and EBS critical habitat 3) West of 170°W, north of 56 °N	(See below)

For A1 and A2 seasons, apportionment of pollock TAC to the combined CVOA and EBS critical habitat area will be reduced in two increments. In 1999, no more than 62.5% of each season's TAC can be taken in the combined area; in 2000, no more than 50%.

For B and C seasons, the EBS TAC will be allocated to three areas based on the distribution of exploitable pollock (age 3+) biomass as best determined by summer bottom trawl and hydroacoustic surveys. The TAC apportioned to critical habitat may require further reduction, although no reduction in presently included in this alternative.

In the GOA, pollock TAC will be split among four areas in the A1 and A2 seasons and three areas in the B and C seasons.

Gulf of Alaska

Season	Areas	Allocation
A1 & A2	1) Shelikof areas (combined areas 621 and 631) 2) Area 610 3) Area 620 (outside of 621) 4) Area 630 (outside of 631)	(See below)
B & C	1) Area 610 2) Area 620 3) Area 630	(See below)

For A1 and A2 seasons, the Shelikof Strait TAC will be determined by first calculating the ratio of the most recent estimate of biomass in the strait (from hydroacoustic surveys) divided by the most recent estimate of total biomass in the GOA (model estimate). The ratio will then be multiplied by each seasonal TAC to determine what portion of that TAC will be apportioned to the strait. The remainder will be distributed among the other areas according to the results from the most recent summer bottom trawl survey. The TAC apportioned to the strait may require further reduction, although no reduction in presently included in this alternative.

For B and C seasons, the TAC will be apportioned among the areas according to the most recent bottom trawl survey data.

No spatial apportionment of pollock TAC is proposed for the Aleutian Islands region.

8.4.3 Trawl exclusion zones

Exclusion zones will be established around haulouts in the Aleutian Islands region, EBS, and GOA. The size of the exclusion zones in each fishery area reflects the relative widths of the continental shelf. The shelf is broader in the EBS (zones with a radii of 20 nm) than in the Aleutian Islands region or most of the GOA (zones with radii of 10 nm). Existing zones, which prohibit all trawling around rookeries, will not be affected by this alternative. New zones will prohibit trawling for pollock only, and only around haulout sites used by the western population (i.e., west of 144°W long.). These sites were selected on the basis of counts conducted since 1979 during the reproductive season (summer) and non-reproductive season (winter). The following criteria were used to identify sites that require protection zones.

1) Rookeries: 10 or 20 nm (depending on location) all-trawl exclusion zones, year-round.

2) Haulouts:

a) Those with >200 sea lions in summer surveys and <75 in winter surveys have 10 or 20 nm pollock trawl exclusion zones only during B and C seasons.

b) Those with <200 sea lions in summer surveys and >75 in winter surveys have 10 or 20 nm pollock trawl exclusion zones only during A1 and A2 seasons.

c) Those with >200 sea lions in summer surveys and > 75 in winter surveys have 10 or 20 nm pollock trawl exclusion zones during all seasons.

Because this biological opinion has concluded that the proposed pollock fishery in the Bering Sea and Aleutian Islands region and the pollock fishery in the Gulf of Alaska region is likely to jeopardize or destruction or adversely modify critical habitat), the Office of Sustainable Fisheries is required to notify the Office of Protected Resources of its final decision on implementation of the reasonable and prudent alternatives.

9.0 INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the reasonable and prudent measures and terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by NMFS so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. NMFS has a continuing duty to regulate the activity covered by this incidental take statement. If NMFS (1) fails to require the applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, NMFS must report the progress of the action and its impacts on the species as specified in the incidental take statement.

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat when the reasonable and prudent alternative(s) are implemented.

The incidental take levels specified in the 1996 biological opinions for BSAI and GOA groundfish fisheries were 30 and 15 annually for the BSAI and GOA groundfish fisheries, respectively. This are minimal levels of take that have resulted from the efforts of the industry and previous actions by the North Pacific Fishery Management Council. These levels remain valid, with the addition of the following reasonable and prudent measure, terms and conditions, and conservation recommendations. NMFS must ensure that observers monitor the take of Steller sea lions incidental to the BSAI and GOA groundfish fisheries.

This reasonable and prudent measures is designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

10.0 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. Increase survey effort in the BSAI and GOA to allow consideration of stock distribution in determining spatial allocation of catch.

2. Increase studies of Steller sea lion foraging patterns.

3. Increase studies of the factors which may be contributing to the decline of Steller sea lions.

4. Assess the effects of other fisheries on Steller sea lions. Include fisheries managed by the Federal government and the State of Alaska.

5. Monitor and evaluate the effect of management measures intended to facilitate the recovery of Steller sea lions.

6. Establish 3 nm no-entrance zones around haulout sites used by the western population of Steller sea lions.

7. Continue to educate the fishing community about Steller sea lions and techniques to reduce or eliminate incidental take of the species.

To keep NMFS informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, notification of the implementation of any conservation recommendations should be provided.

11.0 REINITIATION - CLOSING STATEMENT

This concludes formal consultation on the 1999-2002 BSAI Atka mackerel fishery, the 1999-2002 BSAI pollock fishery, and the 1999-2002 GOA pollock fishery. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or designated critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or designated critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation of consultation.

12.0 LITERATURE CITED

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13.0 TABLES AND FIGURES

Table 1. Consultation history on Bering Sea / Aleutian Island Groundfish Fishery Management Plan and Gulf of Alaska Grounc
Plans as they pertain to Steller sea lions and other protected species.

Region	Year	Date	Consultation	ACTION	CONCLUSION
BSAI					
	1998	26-Feb	Informal	1998 TAC	Reinitiation not triggered
	1997	17-Jan	Informal	1997 TAC	No adverse affects not already considered,
	1996	26-Jan	Formal	1996 TAC and BSAI FMP	No jeopardy
	1995	26-Sep	Informal	Effect of I/O (38/40) on SSL	No adverse affects not already considered,
	1995	25-Aug	Informal	Amendments 38/40, other species	No adverse affects not already considered,
	1995	3-Feb	Informal	1995 TAC	No adverse affects not already considered,
	1994	2-Feb	Informal	1994 TAC	No adverse affects not already considered,
	1993	28-Apr	Formal	Delay of pollock "B" season	No jeopardy
	1993	20-Jan	Informal	1993 TAC	No adverse affects not already considered,
	1992	9-Oct	Informal	Amendments 20/25	No adverse affects not already considered,
	1992	11-Jun	Informal	IFQ fishery	No adverse affects likely, therefore further
	1992	4-Mar	Formal	Amendment 18 inshore/offshore	No jeopardy
	1992	21-Jan	Formal	1992 TAC	No jeopardy
	1991	22-Oct	Informal	Amendments 17/22 & 20/25	No adverse affects not already considered,
	1991	19-Apr	Formal	BSAI FMP	No jeopardy
	1990	30-Oct	Formal	Bering Sea snail fishery	No jeopardy
	1990	24-Oct	Formal	BSAI crab FMP	No jeopardy
	1989	5-Jul	Formal	Issue of MMPA exemptions	No jeopardy
	1979	14-Dec	Formal	BSAI FMP	No jeopardy (only whales listed under ES.
GOA					
	1998	2-Mar	Formal	1998 TAC	No jeopardy
	1997	10-Sep	Informal	Amendment 46	Action will not adversely affect listed spec
	1997	17-Jan	Informal	1997 TACs	No adverse affects not already considered,
	1996	26-Jan	Formal	1996 TAC and GOA FMP	No jeopardy
	1995	26-Sep	Informal	Effect of I/O (38/40) on SSL	No adverse affects not already considered,

Table 1 cont.

Region	Year	Date	Consultation	ACTION	CONCLUSION
GOA					
	1995	25-Aug	Informal	Amendments 38/40, other species	No adverse affects not already considered,
	1995	3-Feb	Informal	1995 TAC	No adverse affects not already considered,
	1994	31-Jan	Informal	1994 TAC	No adverse affects not already considered,
	1993	6-Jul	Informal	Amendment 31	No adverse affects not already considered,
	1993	16-Feb	Informal	Season 2nd quarter delay	No adverse affects not already considered,
	1993	27-Jan	Informal	1993 TAC	No adverse affects not already considered,
	1993	6-Jan	Informal	EFP	Action will not adversely affect listed spec
	1992	11-Jun	Informal	IFQ fishery	No adverse affects likely, therefore further
	1992	4-Mar	Informal	Season 2nd quarter delay	Action will not adversely affect listed spec
	1991	23-Dec	Informal	1992 TAC	No adverse affects not already considered,

1991	12-Nov	Informal	Amendment 23	No adverse affects not already considered
1991	22-Oct	Informal	Amendments 17/22 & 20/25	No adverse affects not already consider
1991	20-Sep	Formal	4th quarter pollock fishery	No jeopardy
1991	5-Jun	Formal	1991 pollock TAC	No jeopardy
1991	19-Apr	Formal	GOA FMP	No jeopardy

Table 2. Bycatch rates of Pacific halibut, king crab (includes blue, golden, brown, and red), and salmon (all species) in the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat in the BSAI region in 1994, 1996, and 1997. Bycatch rates are calculated per ton of Atka mackerel caught and are in the units of kg of halibut, numbers of crab, and numbers of salmon.

1994	**Management Area**						
Inside Critical Habitat	516	517	519	541	542	543	**Grand Total**
Atka mackerel mt		1	1	5,030	16,826	8,441	30,299
Halibut kg/mt		0.0064	0.0172	0.0015	0.0020	0.0010	0.0016
King crab num/mt		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Salmon num/mt		0.0000	0.0000	0.0000	0.0162	0.0000	0.0090
Outside Critical Habitat							
Atka mackerel mt		49		5,060	9,133	49	14,290
Halibut kg/mt		0.0000		0.0013	0.0098	0.0000	0.0068
King crab num/mt		0.0000		0.0000	**0.1095**	0.0000	0.0700
Salmon num/mt		0.0000		0.0000	0.0996	0.0000	0.0637
1996							
Inside Critical Habitat							
Atka mackerel mt			270	10,023	18,541	22,218	51,052
Halibut kg/mt			0.0000	0.0077	0.0006	0.0007	0.0020
King crab num/mt			0.0000	0.0000	0.0000	**0.1971**	0.0858
Salmon num/mt			0.0000	0.0000	0.0096	0.0000	0.0035
Outside Critical Habitat							
Atka mackerel mt	10	19		9,141	3,287	5,791	18,248
Halibut kg/mt	0.0000	0.0093		0.0037	0.0059	0.0000	0.0029
King crab num/mt	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
Salmon num/mt	0.0000	0.0000		0.0000	0.0751	0.0000	0.0135
1997							
Inside Critical Habitat							
Atka mackerel mt			27	6,797	12,002	17,911	36,736
Halibut kg/mt			0.0000	0.0058	0.0003	0.0012	0.0017
King crab num/mt			0.0000	0.0000	0.1599	0.4817	0.2871
Salmon num/mt			0.6307	0.0306	0.0075	0.0000	0.0086
Outside Critical Habitat							
Atka mackerel mt				4,846	588	2,895	8,330
Halibut kg/mt				0.0016	0.0010	0.0000	0.0010
King crab num/mt				0.0000	0.0000	0.0219	0.0076
Salmon num/mt				0.0000	0.0000	0.0200	0.0070

Table 3. Bycatch rates of other groundfish species (Pacific cod, walleye pollock, Pacific ocean perch (POP), and other rockfish) in the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat in the BSAI region in 1994, 1996, and 1997. Bycatch rates are calculated per ton of Atka mackerel caught. The other rockfish bycatch is separated by species and management area for 1997.

Year	Critical habitat and species	Management Area						
		516	517	519	541	542	543	Grand Total
1994	***Inside Critical Habitat***							
	Atka mackerel mt		1	1	5,030	16,826	8,441	30,299
	Cod mt/mt		0.0000	0.0000	0.1304	0.1341	0.1831	0.1472
	Pollock mt/mt		0.0000	0.0000	0.0055	0.0070	0.0056	0.0064
	POP mt/mt		0.0000	0.0000	0.0122	0.0088	0.0070	0.0089
	Rockfish mt/mt		0.0000	0.0000	0.0015	0.0101	0.0250	0.0128
	Outside Critical Habitat							
	Atka mackerel mt		49		5,060	9,133	49	14,290
	Cod mt/mt		0.0420		0.0681	0.0386	0.0000	0.0489
	Pollock mt/mt		0.0039		0.0005	0.0005	0.0000	0.0005
	POP mt/mt		0.1650		0.0213	0.0013	0.0043	0.0090
	Rockfish mt/mt		0.0000		0.0201	0.0129	0.0482	0.0155
1996	***Inside Critical Habitat***							
	Atka mackerel mt			270	10,023	18,541	22,218	51,052
	Cod mt/mt			0.0072	0.1613	0.0462	0.0886	0.0871
	Pollock mt/mt			0.1105	0.0017	0.0045	0.0065	0.0054
	POP mt/mt			0.0103	0.0027	0.0267	0.0100	0.0146
	Rockfish mt/mt			0.1720	0.0182	0.0452	0.0482	0.0419
	Outside Critical Habitat							
	Atka mackerel mt	10	19		9,141	3,287	5,791	18,248
	Cod mt/mt	0.1978	0.0310		0.1173	0.0465	0.0159	0.0723
	Pollock mt/mt	0.4914	0.0000		0.0037	0.0003	0.0065	0.0043
	POP mt/mt	0.0000	0.0035		0.0056	0.0052	0.0456	0.0182
	Rockfish mt/mt	0.0000	0.1593		0.0214	0.0400	0.0676	0.0395
1997	***Inside Critical Habitat***							
	Atka mackerel mt			27	6,797	12,002	17,911	36,736
	Cod mt/mt			0.0385	0.0405	0.0300	0.0343	0.0340
	Pollock mt/mt			0.3146	0.0004	0.0037	0.0015	0.0023
	POP mt/mt			0.0000	0.0052	0.0189	0.0171	0.0155
	Rockfish mt/mt			0.0111	0.0077	0.0220	0.0334	0.0249
	Outside Critical Habitat							
	Atka mackerel mt				4,846	588	2,895	8,330
	Cod mt/mt				0.0524	0.0047	0.0082	0.0336
	Pollock mt/mt				0.0004	0.0014	0.0006	0.0005
	POP mt/mt				0.0023	0.0025	0.1495	0.0535
	Rockfish mt/mt				0.0147	0.0261	0.0720	0.0354
	Rockfish Bycatch by Species and Management Area in 1997							
	Atka mackerel mt			27	11,643	12,590	20,806	45,066
	Northern rockfish mt/mt			0.0111	0.0097	0.0206	0.0370	0.0253
	Sharpchin rockfish mt/mt				0.0000	0.0000	0.0000	0.00000.000
	Rougheye rockfish mt/mt				0.0000	0.0001	0.0009	0.00140.000
	Shortraker rockfish mt/mt				0.0000	0.0001	0.0000	0.00020.000

	Other Rockfish mt/mt			0.0000	0.0008	0.0006	0.0003	0.0000

Table 4. Total catch and bycatch rate of non-target species by BSAI and GOA pollock fisheries in 1996. Total pollock catch of target fishery was 1.16 mmt in the BSAI and 47,200 mt in the GOA. The information in the table assumes that all pollock discards were undersized.

BSAI	Bycatch Species	Catch (mt)	Rate (mt/mt pollock)
	Juvenile pollock	21,300	0.0181
	Pacific cod	15,200	0.0131
	Flatfish	10,100	0.0087
	Other groundfish	1,500	0.0013
	Rockfish	370	0.0003
	Atka mackerel	384	0.0003
	Sablefish	7	trace
	Herring	1,242	0.0011
	Squid	1,124	0.0010
	Skates	538	0.0005
	Sculpins	311	0.0003
	Pacific halibut	321	0.0003
		Number	Rate (#/mt pollock)
	King and Tanner crab	159,200	0.1368
	Salmon	133,000	0.1143

GOA	Bycatch Species	Catch (mt)	Rate (mt/mt pollock)
	Juvenile pollock	1,600	0.0338
	Pacific cod	844	0.0179
	Flatfish	809	0.0171
	Other groundfish	86	0.0018
	Rockfish	6	0.0001
	Atka mackerel	180	0.0038
	Sablefish	<1	trace
	Herring	2	trace
	Squid	7	0.0001
	Skates	75	0.0016
	Sculpins	7	0.0001
	Sharks	59	0.0012
	Pacific halibut	59	0.0012
		Number	Rate (#/mt pollock)
	King and Tanner crab	1,600	0.0338

Salmon	13,200	0.2793

Table 5. Life history table for Steller sea lions based on Calkins and Pitcher (1982) and York (1994). (From York 1994.)

Ages			Calkins-Pitcher life table			York life table		
From	To	Fecundity	Cum. survival	Annual survival	Percent at age	Cum. survival	Annual survival	Percent at age
0	1	0.000	1.000	0.776	16.676	1.000	0.782	16.251
1	2	0.000	0.776	0.776	12.546	0.782	0.782	12.709
2	3	0.000	0.603	0.776	9.438	0.612	0.782	9.938
3	4	0.105	0.468	0.868	7.100	0.478	0.930	7.772
4	5	0.267	0.406	0.879	6.163	0.445	0.909	7.228
5	6	0.286	0.357	0.888	5.417	0.404	0.895	6.570
6	7	0.315	0.317	0.893	4.811	0.362	0.884	5.880
7	8	0.315	0.283	0.898	4.296	0.320	0.875	5.198
8	9	0.315	0.254	0.874	3.857	0.280	0.867	4.548
9	10	0.315	0.222	0.899	3.372	0.242	0.859	3.943
10	11	0.315	0.200	0.893	3.031	0.208	0.853	3.338
11	12	0.315	0.178	0.896	2.707	0.178	0.847	2.889
12	13	0.315	0.160	0.895	2.425	0.150	0.841	2.447
13	31	0.315	0.160	0.895	15.99	0.150	p(x)d	11.239

Table 6. A partial listing of studies on the prey of Steller sea lions. When prey are listed in order of frequency of occurrence reported, an asterisk (*) or dagger (†) indicate that rank of the marked prey item was tied with the similarly marked prey item listed before or after. Sample sizes (*n*) for studies of stomach contents are given only for the number of stomachs with contents; empty stomachs are not included. Note that some studies used the same data and results are therefore redundant (e.g., Merrick and Calkins [1996] present reanalysis of data reported in Pitcher [1981], Calkins and Pitcher [1982], and Calkins and Goodwin [1988]).

Study	Years	Location	Methods	Main findings
Imler and Sarber 1947	1945-1946	Sitka to Kodiak Island	Stomach contents (*n* = 15)	- Eight sea lions sampled in southeast Alaska; all but one fed principally on pollock, and exception contained a skate and an octopus. - Three sampled from Barren Islands contained pollock, starry flounder, tom cod, arrow-toothed halibut, common halibut, and octopus. - Two from Chiswell Island contained salmon. - Two from Kodiak Island contained pollock and arrow-toothed halibut.
Sleptsov 1950 (cited in Spaulding 1964)	Unknown	Kuril Islands	Unknown	- Reported sea lion feeding on octopus.
Wilke and Kenyon 1952	1949, 1951	St. Paul Island	Stomach contents (*n* = 3)	- One sea lion contained primarily sand lance but also starry flounder, one contained halibut, cod, pollock, and flounders, and one contained a large cephalopod beak.
Pike 1958	Summary, 1901-1958	Primarily BC, but also off California and Alaska	Stomach contents, (*n* = 19)	- Reports a range of fish and cephalopods for 12 time/area studies. - Disputes claim that studies provide evidence of serious commercial competition. - For his study (in British Columbia), prey (in order of frequency of occurrence) included squid, herring, rockfish, octopus, salmon*, skate*, and hake*. - For other studies in his table (except Imler and Sarber 1947), prey items listed were (in no particular order) rockfish, perch, herring, skate, shark, squid, octopus, lamprey, salmon, “cod,” “bass,” mussels, clam, crab, dogfish, flatfish, and sardines.
Mathisen *et al*. 1962	1958	Chernabura	Stomach contents (*n* = 94; 14 yearlings, 42 adult females, 18 harem bulls, 20 unattached bulls)	- Prey (in order of frequency of occurrence) included squid/octopus , common bivalves, smelts, greenlings, shrimp/crabs, rockfish, sculpins, isopods, unclassified crustaceans*, segmented worms*, and single occurrences of lamprey, salmon, sand lance, sand dollar, and coelenterate.

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Thorsteinson and Lensink 1962	1959	Marmot, Atkins, Ugamak, Jude, Chowiet	Stomach contents (*n* = 56); primarily adult males	- Prey (in order of frequency of occurrence) included squid/octopus, clam/mussel/snail, sand lance, rockfish, crab, greenling*, sculpins*, flatfish*, and single occurrences of halibut and lumpfish.
Spaulding 1964	1956-1963(?)	British Columbia	Stomach contents (*n* = 190; overlap with specimens reported in Pike [1958] above)	- Suggests sea lions prey mainly on one item per feeding period. - Some seen feeding at surface on lingcod, rockfish, salmon, or halibut (*n* = 8). - Feed primarily at night (*n* = 269 or 393 sampled). - Consumption of herring and salmon by sea lions, fur seals, and harbor seals estimated about 2% to 4% of commercial catch. - Prey (in order of frequency of occurrence) included octopus, rockfish, herring*, withing*, salmon, dogfish, squid*, hake*, flatfish†, clam†, ratfish, shrimp*, sand lance*, graycod†, lingcod†, and single occurrences of lamprey, skate, eulachon, halibut, and mackereljack.
Tikhomirov 1964	1962	Bering Sea	Stomach contents *n* = unknown)	- Large numbers of sea lions in the southeastern Bering Sea, winter/spring of 1962. - Suggests herring "staple food" of sea lions during this period. - Suggests sea lion distribution was influenced by the distribution of herring.
Fiscus and Baines 1966	1958-1963	California to Bering Sea	Stomach contents (*n* = 22)	- Steller sea lions taken off central California and Oregon fed only on bottom fish. - Steller sea lions taken in Alaskan waters fed mainly on small, schooling fishes. - Near Unimak Pass in 1962, capelin was the major food species. - A Steller sea lion taken on the Fairweather Grounds in the eastern GOA in May 1958 had eaten three salmon. - Most of the food species (capelin, sand lance, sculpins, rockfishes and flatfishes) found in the stomachs of Steller sea lions suggest that they feed near land or in relatively shallow water (<100 fm, 180 m). - Steller sea lions were seen at distances of 70-85 miles from land by Fiscus and Kenyon in 1960 (Kenyon and Rice 1961).

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Jameson and Kenyon 1977	1973-1976	Rogue River, Oregon	Observations of sea lions feeding at surface (84 observations; number of sea lions unknown)	- Prey consisted of 73 lampreys, 2 salmonids, 9 unidentified.
Gentry and Johnson 1981	1974-1975	St. George Island (Pribilof Islands)	Observations (163 verified observations, number of sea lions unknown)	- Observed sea lions taking 163 fur seal pups. Estimated such predation may result in the mortality of about 3% to 7% of fur seal pups born at St. George Island.
Jones 1981	1968-73	North and Central California	Stomach contents (n = 9)	- Noted 9 stomachs with fish, and 7 with squid and octopus. - Grouped 127 identified fishes from northern sea lions according to schooling (open-water), bottom-dwelling (rocky), and inshore-schooling species (his Table 6), and suggested results indicate that the northern sea lion feeds mainly on bottom-dwelling fishes.

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Pitcher 1981	1975-78	GOA	Stomach contents (*n* = 153)	- Stomach contents were 95.7% fishes by volume, and included 14 species of fish in 11 families. - Gadids comprised 59.7% of total contents and occurred in 82.4% of stomachs with food. - Walleye pollock comprised 58.3% of the total volume and occurred in 66.7% of stomachs with food. - Cephalopods occurred in 36.6% of stomachs with contents but made up only 4.2% of total volume. - Predation on salmon and capelin appeared to be largely limited to spring and summer. - Prey (by combination rank index) included pollock, squids, herring, capelin, cod, salmon, octopus, sculpins, flatfishes, rockfishes. - Herring and squids were extensively used by sea lions in Prince William Sound but appeared to be relatively unimportant in other areas. - Results for sea lions similar to results for harbor seals. - Mean fork length of 2030 pollock otoliths was 29.8 cm (range 5.6 to 62.9 cm, SD = 11.6 cm)

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Calkins and Pitcher 1982 (note redundancy with previous results of Pitcher 1981)	1975-1978	GOA, including northeastern GOA, Prince William Sound, Kenai Coast, Kodiak Island, and the Alaska Peninsula region	Stomach contents (*n* = 153)	- Fishes comprised 72.8%, cephalopods (octopus and Gonatid squids) 21.5%, decapod crustaceans (shrimps, tanner and spider crabs) 4.2%, gastropods (marine snails) 0.8%, and mammals 0.4% of the prey occurrences. - Fishes included minimum of 14 species of 11 families. - Gadids composed nearly half of total occurrences and nearly 60% of total volume. - Harbor seal remains were found in two stomachs (see Pitcher and Fay 1982). - Seven top-ranked prey (in order of modified Index of Relative Importance) were pollock, herring, squids, capelin, salmon, Pacific cod, and sculpins. - Pollock was dominant prey accounting for about 39% of all occurrences and 58% of the total volume. - Pollock was top-ranked prey in all areas except Kodiak, where it was ranked second below capelin. - Herring and squid were used extensively in Prince William Sound, but not in other areas. - Predation on salmon and capelin was largely limited to spring and summer. - Geographic differences in use of salmon and capelin may have been due to sampling at different sites and seasons. - Comparison with previous studies (Imler and Sarber 1947, Mathisen *et al*. 1962, Thorsteinson and Lensink 1962, and Fiscus and Baines 1966) which had more invertebrates, no herring, but included sand lance. Noted differences in sampling for this study (throughout year at wide range of locations) versus earlier studies (near rookeries during breeding season). - Four of the five top-ranked prey were off-bottom schooling species.
Lowry *et al*. 1982	1976	Pribilof Islands	Stomach contents (*n* = 4)	- Prey (in order of frequency of occurrence) included pollock, squids, and single occurrences of octopus, flatfish, lamprey, and prickleback. - Based on otoliths, lengths of pollock consumed ranged from 34 cm to 57 cm in length. - Also mentions the following prey items from a preliminary examination of 111 stomach samples collected in the central and western Bering Sea (in no particular order): pollock, cod, Gonatid squids, herring, octopus, and sculpins.

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Frost and Lowry 1986			Stomach contents (*n* = 90; not stated how many had contents)	- Most pollock eaten by sea lions (76%) were 20 cm or longer. - Younger sea lions (≤4 yr) collected in 1981 (all were males) ate significantly smaller fish ($\bar{x}$ = 22.4 cm, *n* = 37) than did older animals ($\bar{x}$ = 26.9 cm, *n* = 51). - A sea lion collected in 1976 and another collected in 1979 (both near the Pribilofs) had eaten pollock averaging 46.9 cm in length (range 18.4-61.4 cm), while those collected in 1981 to the west had eaten substantially smaller pollock averaging 25.2 cm in length (range 8.3-64.2 cm). - In 1981 sea lions collected in the central Bering Sea had eaten larger pollock than those off the Kamchatka Peninsula ($\bar{x}$ = 26.8 cm vs. 23.5 cm). - "It is unknown whether the consumption patterns described above are a result of actual size selection of prey or if they result from coincidental distribution of predators and prey size classes." - " . . . the size range of pollock eaten by both yong and old sea lions was similar."

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Calkins and Goodwin 1988	1985-1986	GOA and southeast Alaska	Stomach contents (*n* = 88;47 had only trace amounts. Five with measurable contents and nine with trace amounts from southeast; remainder were from Kodiak area and adjacent portions of Alaska Peninsula.)	<u>Southeast</u> - Fishes comprised 98% of volume, mostly Pacific cod (57% of total volume) and pollock (32%). - Most frequently occurring were pollock (57%) and flatfishes (21%). - Only other prey observed were squid and octopus. - Mean fork length of 80 pollock otoliths from 8 sea lions in southeast was 25.5 cm (range 4.8 to 55.7 cm, SD = 10.4 cm) <u>Kodiak area</u> - Most important by volume were pollock (42%), octopus (26%), and flatfish (25%). - Most frequently occurring were pollock (58%) and octopus (32%). - Other prey (in no particular order) were other fishes, squid, decapod crustaceans, and clams. - Prey rank (based on combined rank index [Pitcher 1981]) in Kodiak area were pollock, octopus, flatfishes, sand lance, Pacific cod, and salmon. - Mean fork length of 1064 otoliths from 43 sea lions in Kodiak area was 25.4 cm (range 7.9 to 54.2 cm, SD = 12.4 cm). - Pollock was the most important prey item in both 1975-1978 collection (39% by frequency of occurrence in Kodiak area) and 1985-1986 collection (58%). - Capelin was most important in Kodiak area in 1975-1978. However, they suggest difference in capelin may be due to seasonal differences when animals collected (spring-summer 1975-1978 versus spring-autumn/early winter 1985-1986). Thus, comparisons may be compromised by potential seasonal bias. - Octopus ranked second in 1985-1986 collection near Kodiak, but fifth in 1975-1978. However, they suggest difference may be due to collection site. Thus comparisons may be compromised by potential location bias. - Sand lance occurred in 26% of sea lions from GOA in 1960s (Mathisen *et al*. 1962, Thorsteinson and Lensink 1962, Fiscus and Baines 1966), were not found in 1975-1978 sample, but were fourth in 1985-1986 sample.

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Byrnes and Hood 1994	1992	Año Nuevo, California	One observation	- Observed a territorial male Steller sea lion attack, kill, and consume what appeared to be a yearling California sea lion.
Merrick and Calkins 1996 (note redundancy with Pitcher 1981, Calkins and Pitcher 1982, and Calkins and Goodwin 1988)	1975-1978, 1985-1986	GOA	Stomach contents, (n = 178 in 1975-1978 and n = 85 in 1985-1986)	- Prey consumption was based on frequency of occurrence. - Most stomachs contained prey of only one kind. - Pollock were the most common prey of juvenile (≤4 years old) and adult sea lions in virtually all seasons and areas during these two periods. - Juvenile pollock were a major part of the diet in both periods. - Juvenile sea lions ate smaller and relatively more juvenile pollock. - Small forage fish were consumed on a seasonal basis. - Temporal comparisons were possible only in the Kodiak region. - The proportion of sea lions eating pollock increased from 49% in 1975-1978 to 69% in 1985-1986 in the Kodiak area. - Small forage fish were the second most common prey in the 1970s, and flatfish were second in the 1980s. - Of the fish consumed, 73% were < 30 cm, but they accounted for only 26.8% of the biomass consumed. - Half (50.7%) of the pollock mass consumed by juvenile sea lions came from fish <30 cm, while only 21% of the pollock mass consumed by adult sea lions came from juvenile pollock. - Seasonal differences were observed in the consumption of all prey taxa, but differences were not found in 1980s. - Between 1970s and 1980s, the portion consuming pollock and cephalopods increased significantly and the portion consuming small forage fish and other demersal fish decreased. - The increase in pollock consumed was only evident in summer months (all ages combined), but was evident in all seasons for juveniles. - (Note that sampling was not consistent with respect to seasons or specific locations between the two sampling periods, which weakens the basis for comparisons.)

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Merrick *et al*. 1997	1990-93 (summer - last week June, first week July, or first week August)	Kodiak to Agattu and Alaid - 37 collections at 19 rookeries and 3 haulouts	Scat analysis and population trends. No. scats analyzed = 338. Suggests most scats from adult females. Prey pooled into seven categories, rookeries and haulouts pooled into six areas. Report on 40 and 52 scats from Bogoslof and Ugamak (1985-89 and 1990-93, respectively), and compared with stomach contents in Kodiak area for 1976-78 (20) and 1985-89 (28), and 54 scats in 1990-93.	- Scats contained at least 13 species. - Atka mackerel most common prey category (62%), gadids second (43%), salmon (20%) third, cephalopods (12%) fourth, small schooling fish (9%) fifth, then other demersal fish (7%) and flatfish (3%). - Pollock occurred in 29% of the scats and unidentified gadids (which the authors suggest were probably pollock) in 28%. - Pollock dominated in the GOA, was approximately equal in the eastern Aleutian Islands and the area they designated as central Aleutian Islands 1, and Atka mackerel dominated further west. - Salmon, small schooling fish, and flatfish were found more commonly in the eastern areas. - Diet diversity tended to be greater east to west and was correlated with rate of population change. - "The high correlation between area-specific diet diversity and population changes supports the hypothesis that diet is linked with the Steller sea lion population decline in Alaska." - If diet diversity (as measured in this study) is related to population trends, and the indices of diet are based on adult female foraging patterns, these results would indicate that juvenile survival is not the only vital rate being affected. - Emphasizes the importance of secondary prey.

Table 6. (cont.)

Study	Years	Location	Methods	Main findings
Merrick and Loughlin 1997	1990-1993	GOA to eastern Aleutian Islands	Very High Frequency radio transmitters (*n* = 10 adult females instrumented in June-July); Satellite-linked time-depth recorders (*n* = 5 adult females instrumented in June-July, *n* = 5 adult females instrumented in November-March, and *n* = 5 young-of-the-year instrumented in November-March).	- Mean trip duration for adult females instrumented (either radio transmitter or satellite-linked time-depth recorder) on the order of 18 to 25 hours, with time on shore on the order of 18 to 19 hours, so slightly more than half of the females' cycles were spent at sea. - Mean trip duration for adult females instrumented (satellite-linked time-depth recorder) in winter was 204 hours, but time on shore was approximately the same as for summer adult females. Adult females in winter spent approximately 90% of their time at sea. - Young-of-the-year animals spent a mean time of 15 hours at sea and 25 hours on land, therefore spending about 37% of their time at sea. - Summer adult females dove about 17 times per hour, winter adult females about 12 times per hour, and young-of-the-year about 12-13 times per hour. All groups dove most frequently in the late afternoon and night. - Maximum dive depths for summer adult females was between 150 m and 250 m, for winter adult females was > 250 m, and for young-of-the-year was 72 m. - Mean number of diving hours per day was 4.7 for summer adult females, 5.3 for winter adult females, and 1.9 for young-of-the-year. - Mean trip distance for summer adult females was 17.1 km, winter adult females 133 km, and young-of-the-year 31 km (but were skewed by one trip by a young-of-the-year of 320 km). - Two of the winter adult females foraged in a manner that suggested they still were nursing pups. These females relatively dove 8.1 hours per day, made short trips (mean 53 km over 18 hours), and returned to the same or nearby haulout at the end of each trip. The remaining three winter adult females was 3.5 hours per day and spent up to 24 days at sea before returning to land. - In general, winter adult females spent more time at sea, dove deeper, and had greater home ranges than summer adult females.

Table 7. Counts of Steller sea lions by region (NMFS, unpubl. data). For the GOA, the eastern sector includes rookeries from Seal Rocks in Prince William Sound to Outer Island; the central sector extends from Sugarloaf and Marmot Islands to Chowiet Island; and the western sector extends from Atkins Island to Clubbing Rocks. For the Aleutian Islands, the eastern sector includes rookeries from Sea Lion Rock (near Amak Island) to Adugak Island; the central sector extends from Yunaska Island to Kiska Island; and the western sector extends from Buldir Island to Attu Island.

Year	Gulf of Alaska			Aleutian Islands		
	Eastern	Central	Western	Eastern	Central	Western
1975				19,769		
1976	7,053	24,678	8,311	19,743		
1977				19,195		
1979					36,632	14,011
1985		19,002	6,275	7,505	23,042	
1989	7,241	8,552	3,800	3,032	7,572	
1990	5,444	7,050	3,915	3,801	7,988	2,327
1991	4,596	6,273	3,734	4,231	7,499	2,411
1992	3,738	5,721	3,720	4,839	6,399	2,869
1994	3,369	4,520	3,982	4,421	5,790	2,037
1996	2,133	3,915	3,741	4,716	5,528	2,190
1997		3,352	3,633			

Table 8. Review of scientific and commercial data on size selection of Steller sea lions on pollock. Sample size (n) is number of sea lions. The table is taken from NMFS 1995 (and is also included in Merrick and Calkins 1996), with references added to indicate where the reader may find additional details.

				Pollock size (cm)		
Ages	Area	Year(s)	*n*	Mean	Range	Reference
All ages	GOA	1976-1978	102	29.8	5.6-62.9	Pitcher 1981
	Shelikof	1983-1984	36	40.9	30.0-52.0	Loughlin and Nelson 1986
	Kodiak Island	1985	25	25.1	7.9-54.2	Calkins and Goodwin 1988
	SE Alaska	1985	8	25.5	4.8-55.7	Calkins and Goodwin 1988
	Pribilof Islands	1976-1979	2	46.9		Frost and Lowry 1986
	Pribilof Islands	1986	2	33.5	20.8-44.5	Lowry *et al*. 1989
	Central Bering Sea	1981	19	27.4	6.2-60.1	Frost and Lowry 1986
	Central Bering Sea	1985	10	21.8	10.5-51.6	Lowry *et al*. 1989
	Western Bering Sea	1981	31	23.5	8.3-64.2	Frost and Lowry 1986
	Eastern Aleutian Islands	1981-1982	4	29.9	1.7-42.7	Lowry *et al*. 1989
Juveniles	Kodiak Island	1985	7	20.8	8.0-54.2	Merrick and Calkins 1996
	Bering Sea	1981	20	22.4	9.6-56.9	Frost and Lowry 1986
	Pribilof Islands	1986	1	25.1	20.8-28.7	Lowry *et al*. 1989
Adults	Kodiak Island	1985	18	27.9	8.7-53.1	Merrick and Calkins 1996
	Bering Sea	1981	30	26.9	8.5-63.3	Frost and Lowry 1986
	Pribilof Islands	1986	1	41.9	39.2-44.5	Lowry *et al*. 1989

Table 9. Summary table of recommended reasonable and prudent alternatives for pollock fisheries in the eastern Bering Sea, GOA, and Aleutian Islands.

Management action	Eastern Bering Sea	**Aleutian Islands**	**Gulf of Alaska**
Temporal TAC distribution	4 Seasons: A1 (Jan 20): 20% A2 (Mar 1): 25% B (Aug 15): 25% C (Sep 15): 30%	No new season allocation	4 Seasons: A1 (Jan 20): 15% A2 (Mar 1): 30% B (Jun 1): 25% C (Sep 15): 30%
Spatial TAC distribution	A1 and A2 seasons: 2-year incremental approach to a maximum of 50% of pollock TAC from EBS critical habitat foraging area and CVOA (AREA). In 1999, a maximum of 62.5% of pollock TAC from AREA; in 2000, a maximum of 50%. B and C seasons: TAC allocated to three areas on the basis of most recent surveys. Areas are: 1) AREA 2) East of 170°W outside of AREA, and 3) West of 170°W. long.	No new spatial allocation	A1 and A2 seasons: TAC distributed to Shelikof Strait (combined 621 and 631) based on ratio of Shelikof Strait biomass to stock assessment model biomass; the remainder distributed among areas 610, 620, and 630 based on the most recent bottom trawl survey. B and C seasons: TAC allocated to three areas on the basis of most recent surveys. Areas are 610, 620, and 630.
Trawl exclusion zones	20 nm around sites meeting summer, winter, or year-round criteria	10 nm around sites meeting summer, winter, or year-round criteria	10 nm around sites meeting summer, non-breeding season, or year-round criteria from 144°W long. to 164°W long., and 20 nm around sites from 164°W long. to 170°W long.

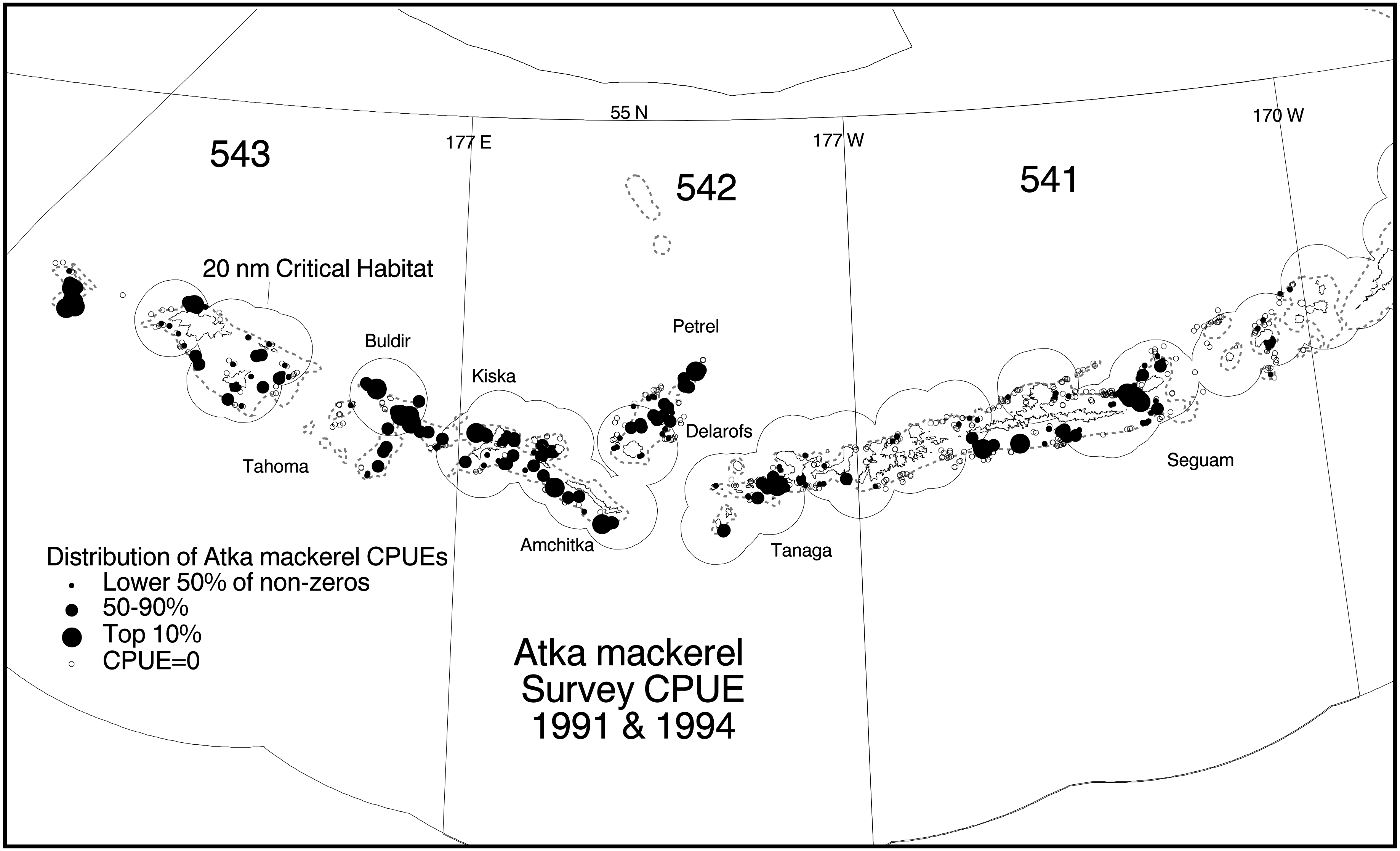


Figure 1. CPUE of Atka mackerel from the NMFS bottom trawl surveys of 1991 and 1994 in the Aleutian Islands region. Steller sea lion critical habitat zones around rookeries and haulouts, the 200 m isobath, management areas 541-543, and names of locations used by the fishery are shown.

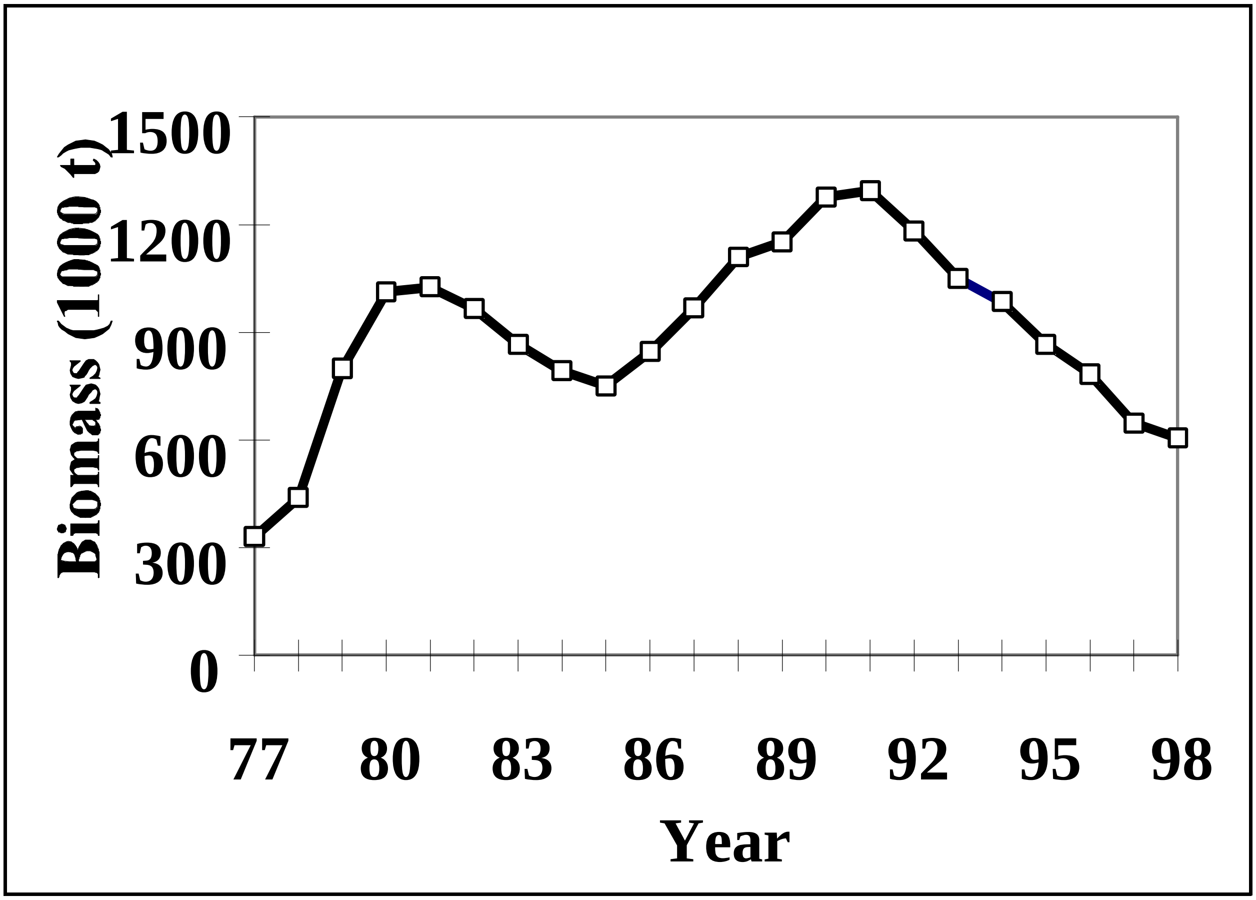


Figure 2. Estimated annual stock biomass for BSAI Atka mackerel, 1977-1998 (based on data from Lowe and Fritz 1997).

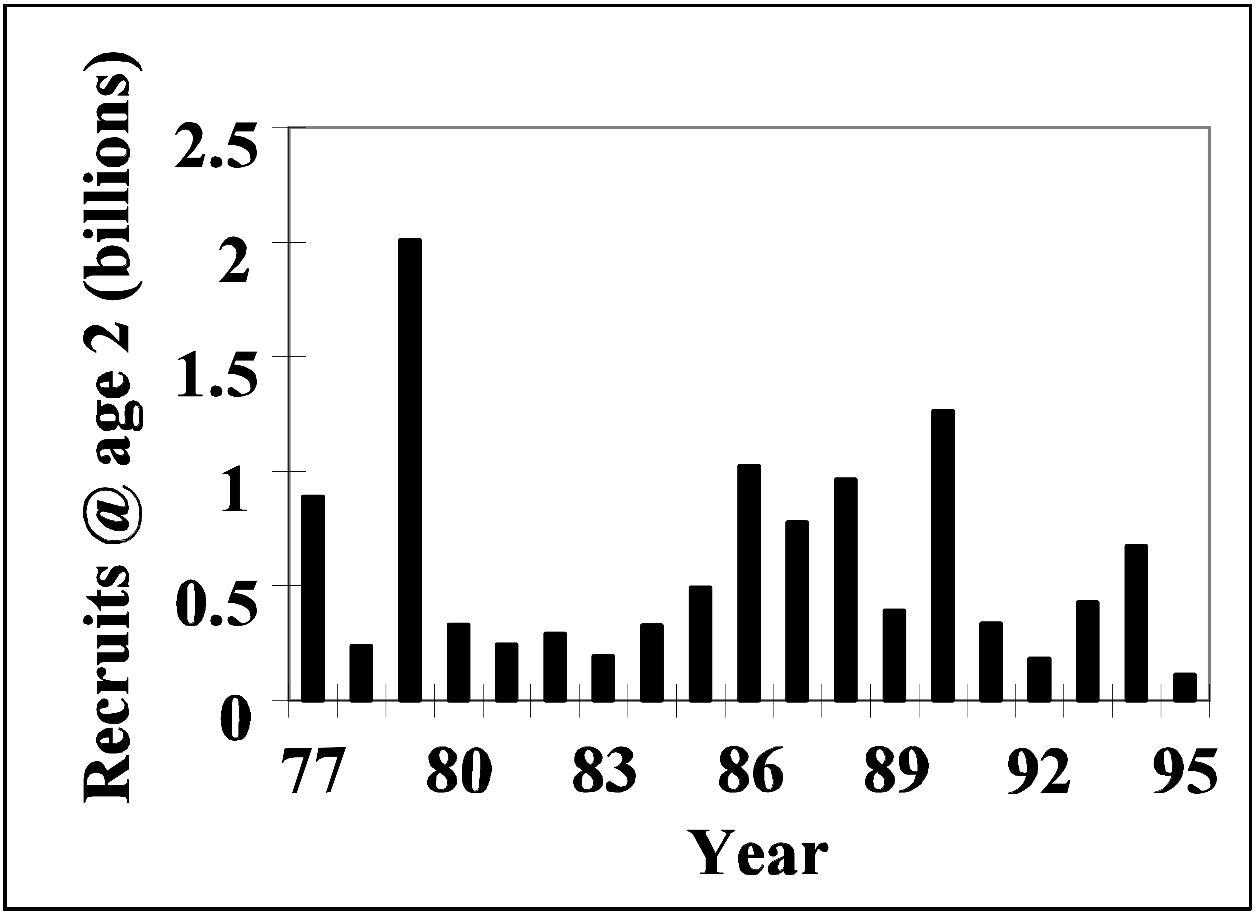
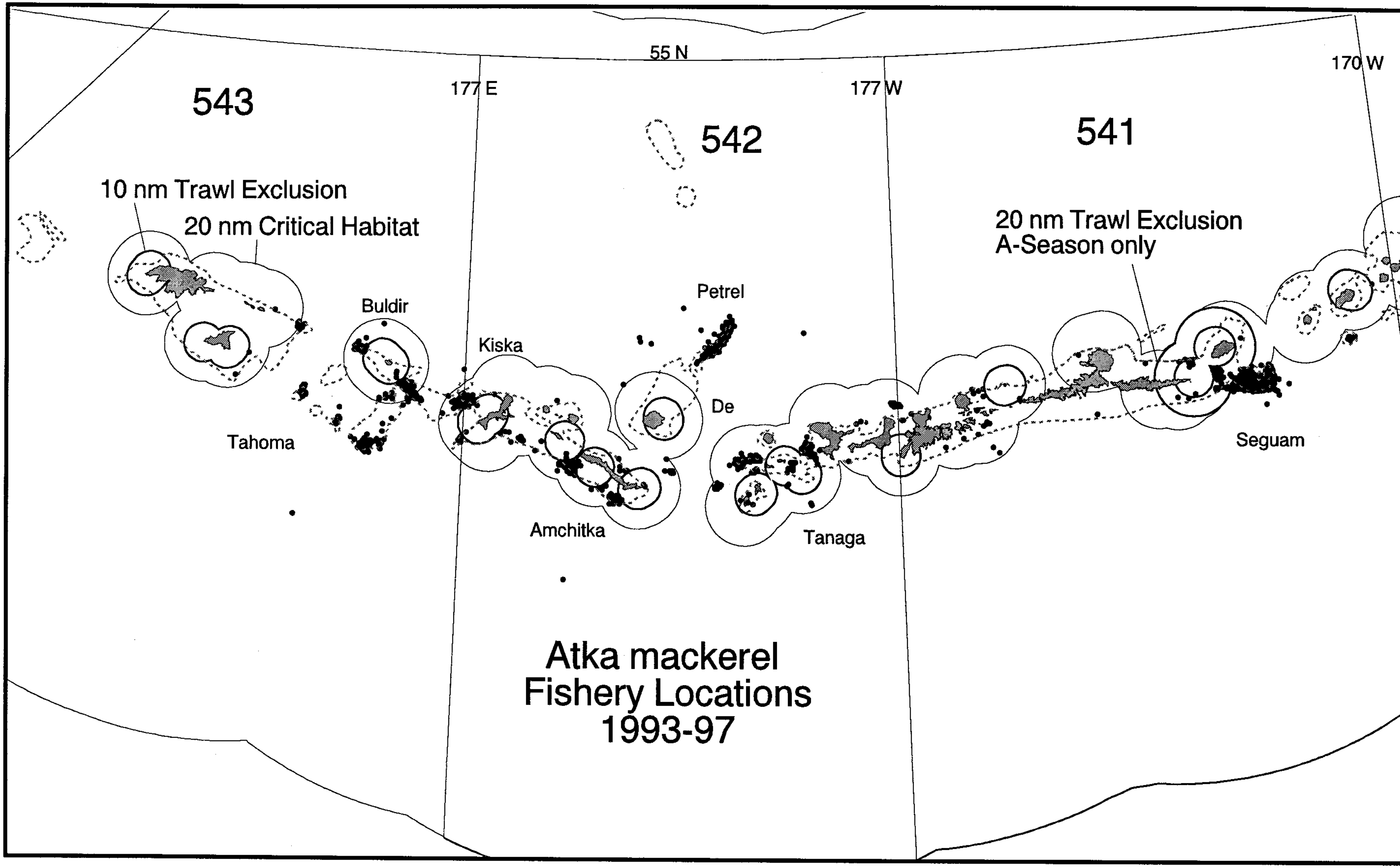


Figure 3. Estimated annual recruitment of 2-year-old Atka mackerel; e.g., the large recruitment in 1977 reflects a strong 1975 year class (from Lowe and Fritz 1997).

Figure 4. Atka mackerel fishery locations in the Aleutian Islands region in 1993-1997. Also shown are trawl exclusion zones (10- and 20-nm zones indicated around rookeries, Steller sea lion critical habitat zones around rookeries and haulouts, the 200 m isobath (dashed line around islands), management areas 541, 542, and 543, and names of locations used by the fishery (the dots indicate sites where trawling occurred).


55 N
177 E
177 W
170 W
543
542
541
10 nm Trawl Exclusion
20 nm Critical Habitat
20 nm Trawl Exclusion
A-Season only
Buldir
Kiska
Petrel
De
Tahoma
Amchitka
Tanaga
Seguam
Atka mackerel
Fishery Locations
1993-97

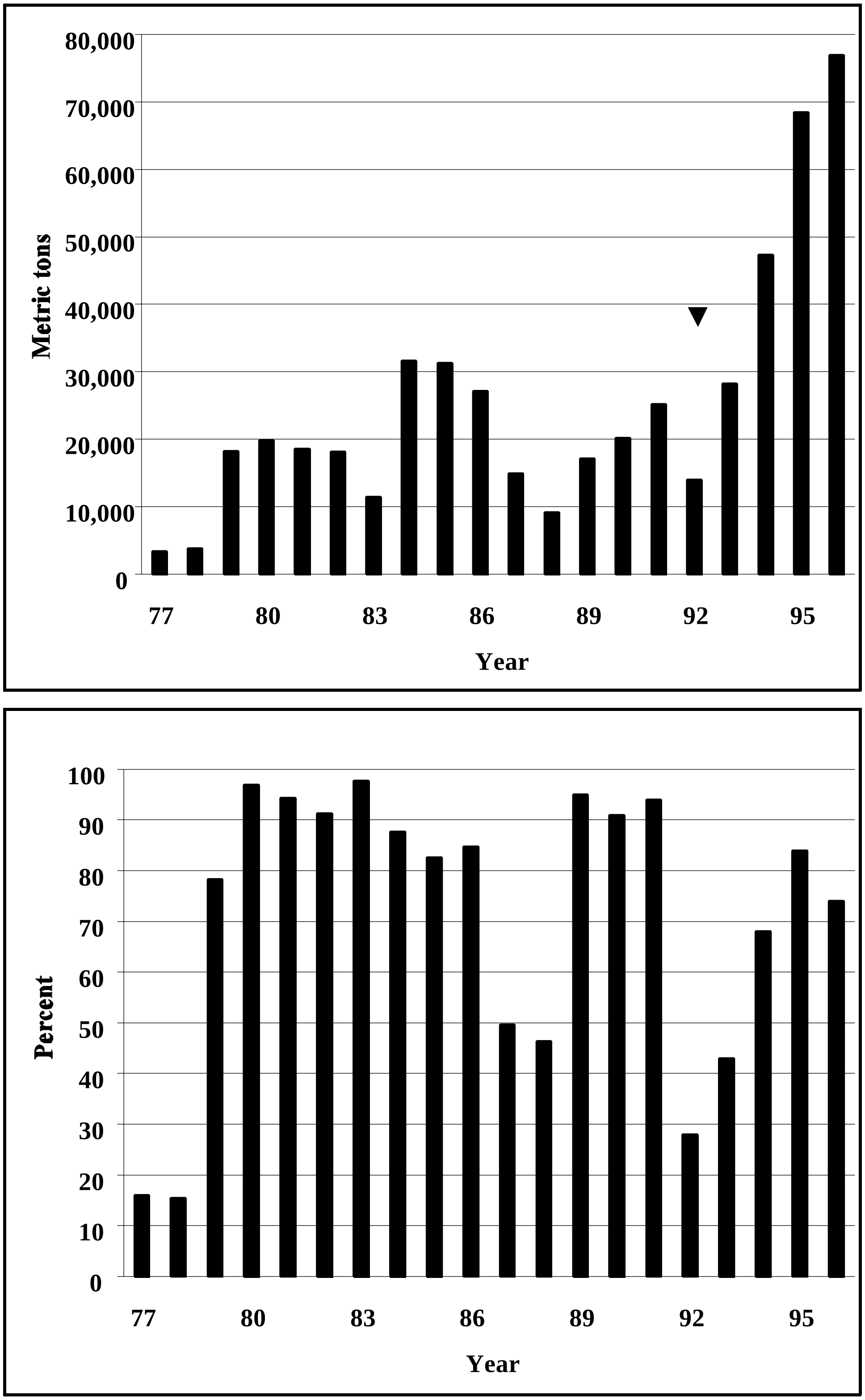


Figure 5. Annual amount (mt, top) of Atka mackerel (BSAI) caught within areas designated as Steller sea lion critical habitat, and percent (bottom) of total catch from within critical habitat, 1977-1996. No trawl zones were imposed in 1992 and 1993, and critical habitat was designated in 1993.

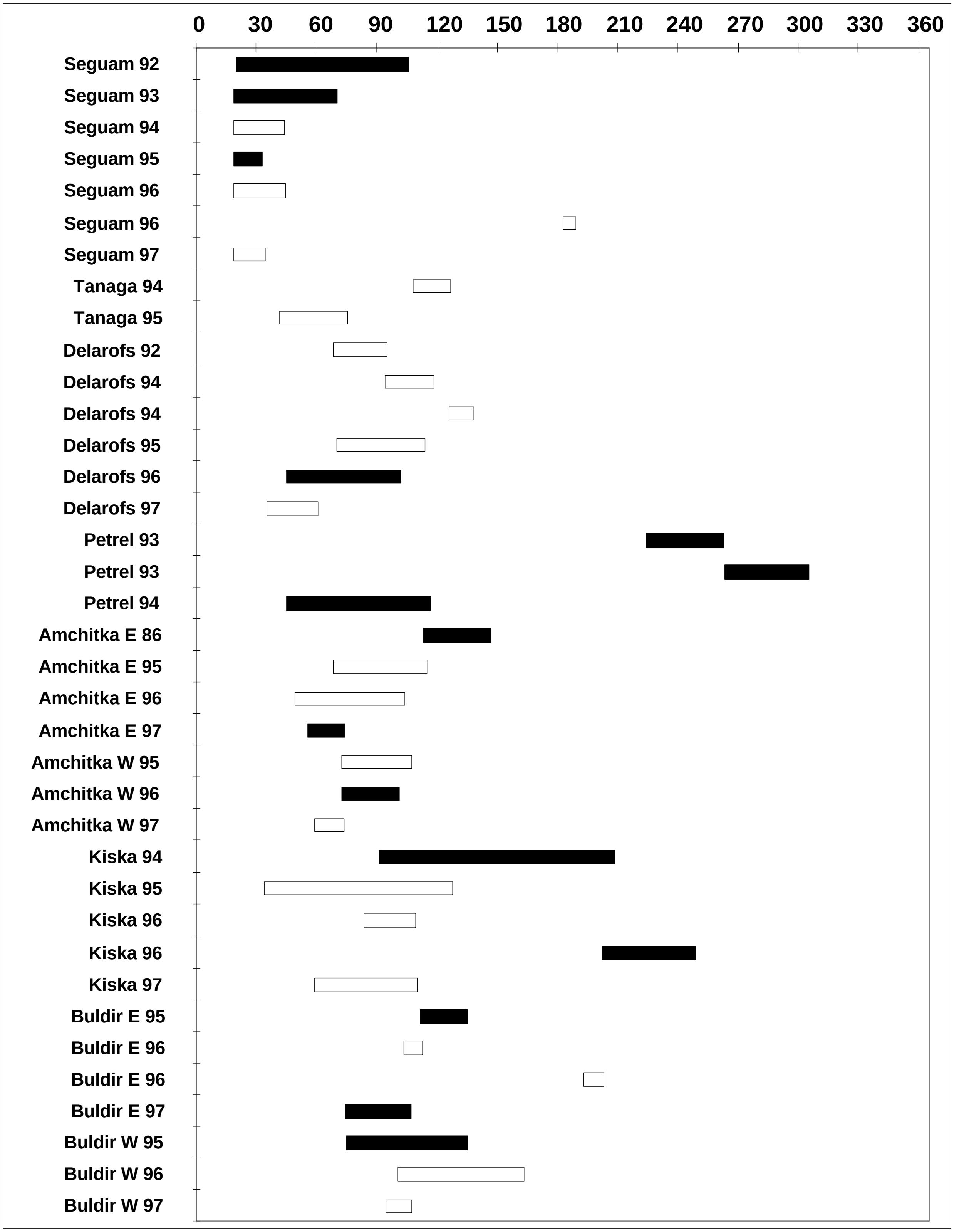


Figure 6. Time of year for studies of fishery-induced localized depletion of Atka mackerel. Solid bars indicate a statistically significant decline occurred in CPUE; open bars indicate statistical tests were not significant.

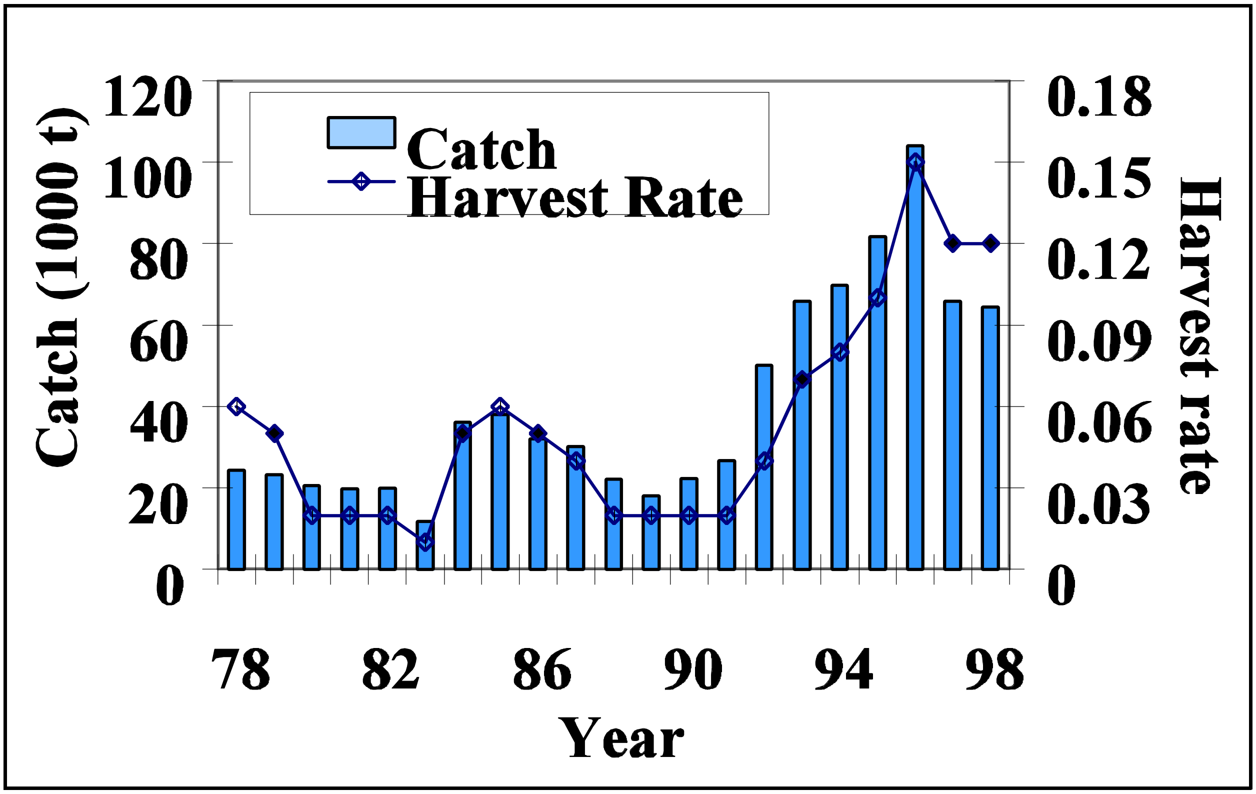


Figure 7. Estimated annual catch (1000 mt) and harvest rate (catch / estimated biomass) in the BSAI Atka mackerel fishery, 1978-1998 (from Lowe and Fritz 1997).

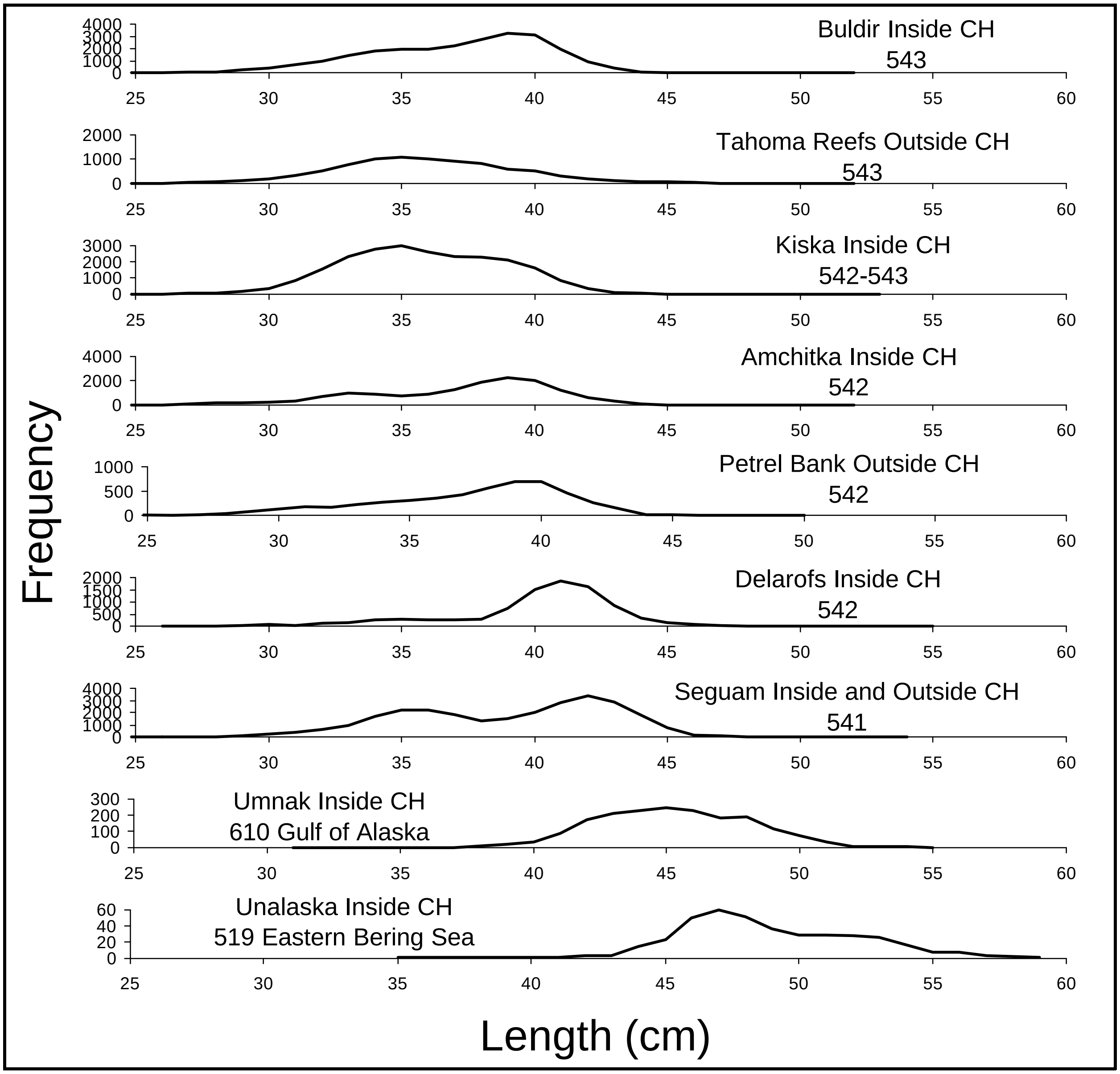


Figure 8a. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1996 from west (top) to east in the Aleutian Islands (top 7 panels), Gulf of Alaska (Umnak Island), and eastern Bering Sea management areas (Unalaska Island). CH=Steller sea lion critical habitat. Numbers 541-543, 519 and 610 are fishery management areas.

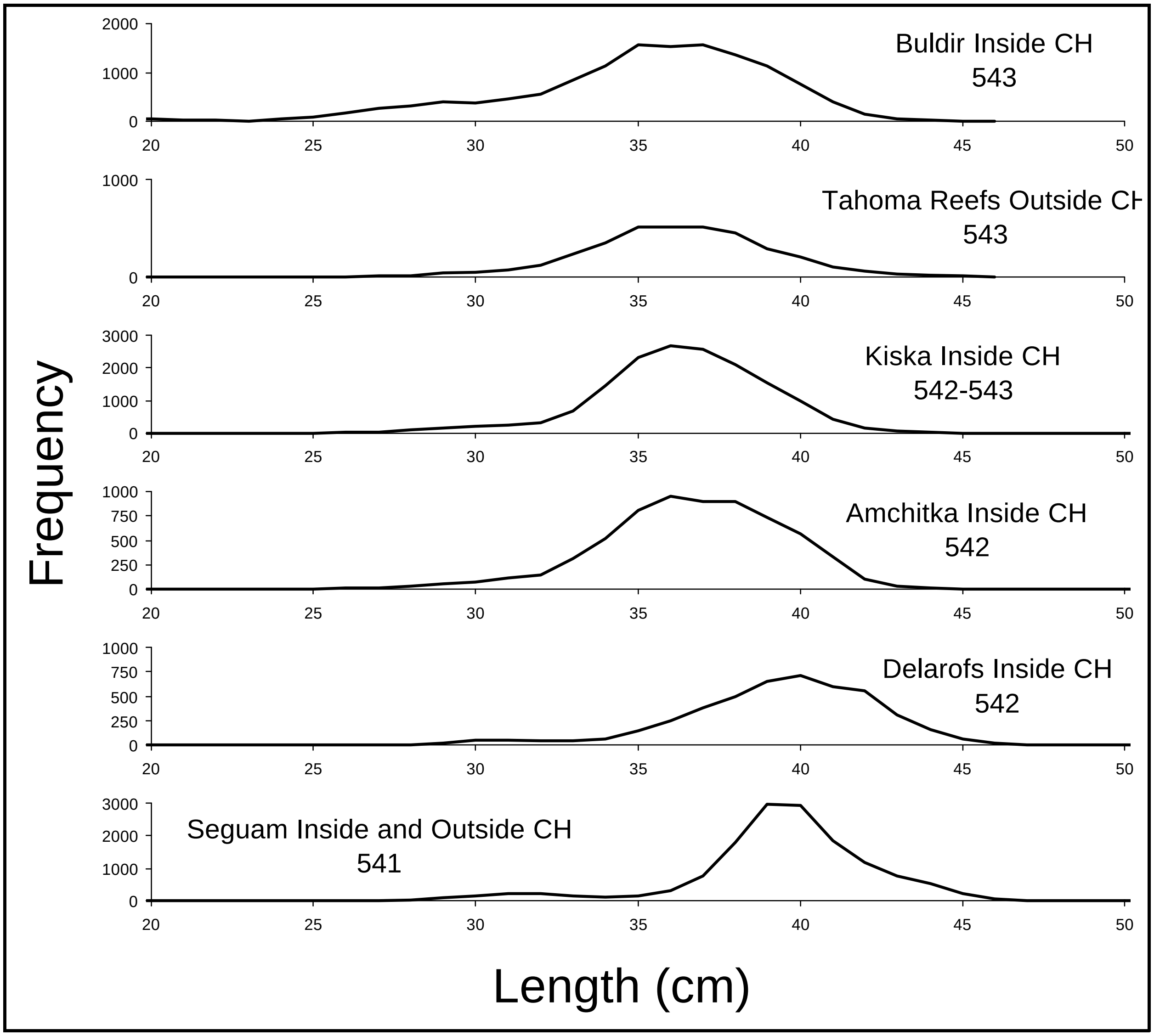
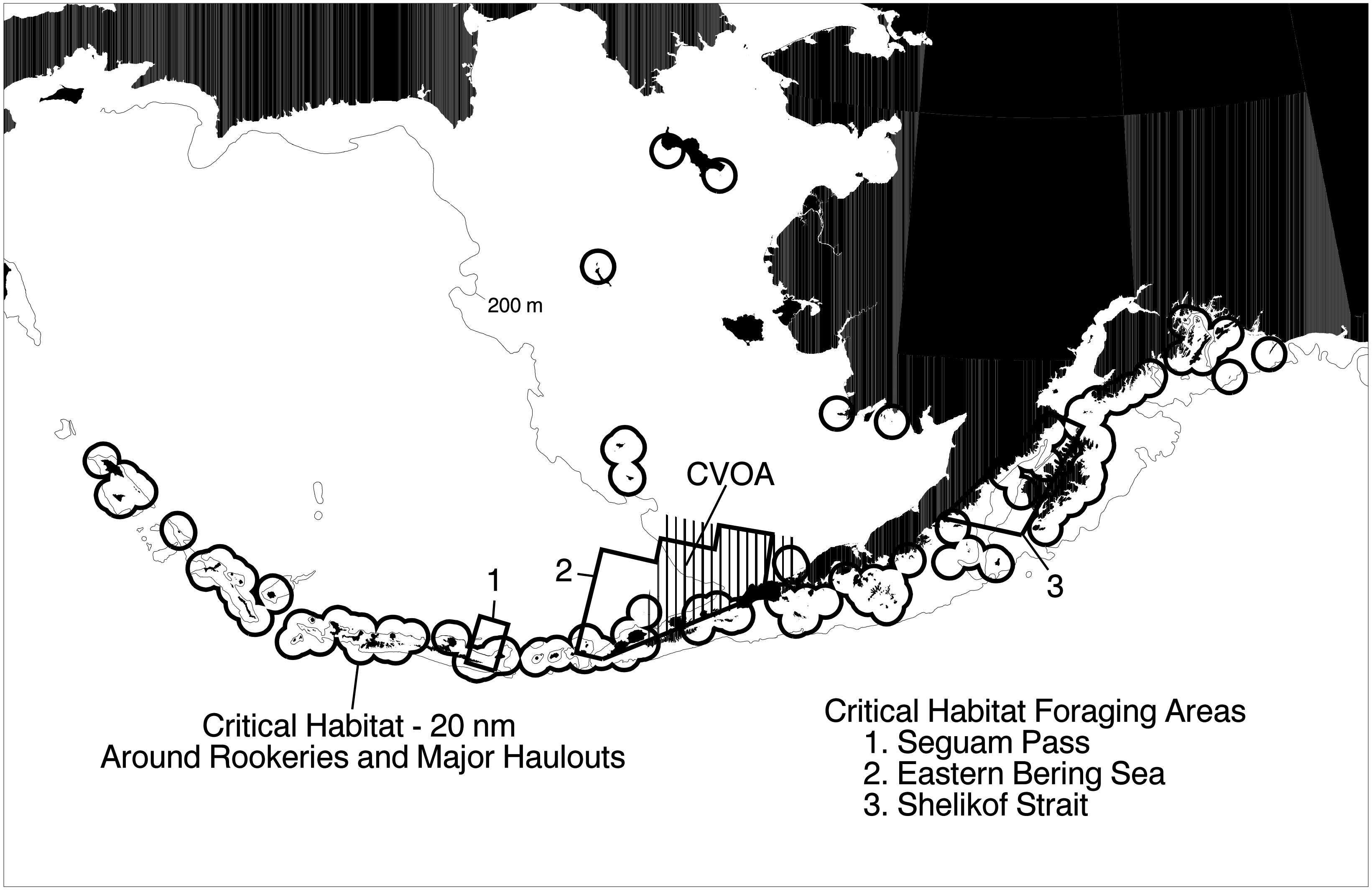


Figure 8b. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1997 from west (top) to east in the Aleutian Islands. CH=Steller sea lion critical habitat. Numbers 541-543 are fishery management areas.

Figure 9. Critical habitat of the western population of Steller sea lions.


200 m
CVOA
1
2
3
Critical Habitat - 20 nm
Around Rookeries and Major Haulouts
Critical Habitat Foraging Areas
1. Seguam Pass
2. Eastern Bering Sea
3. Shelikof Strait

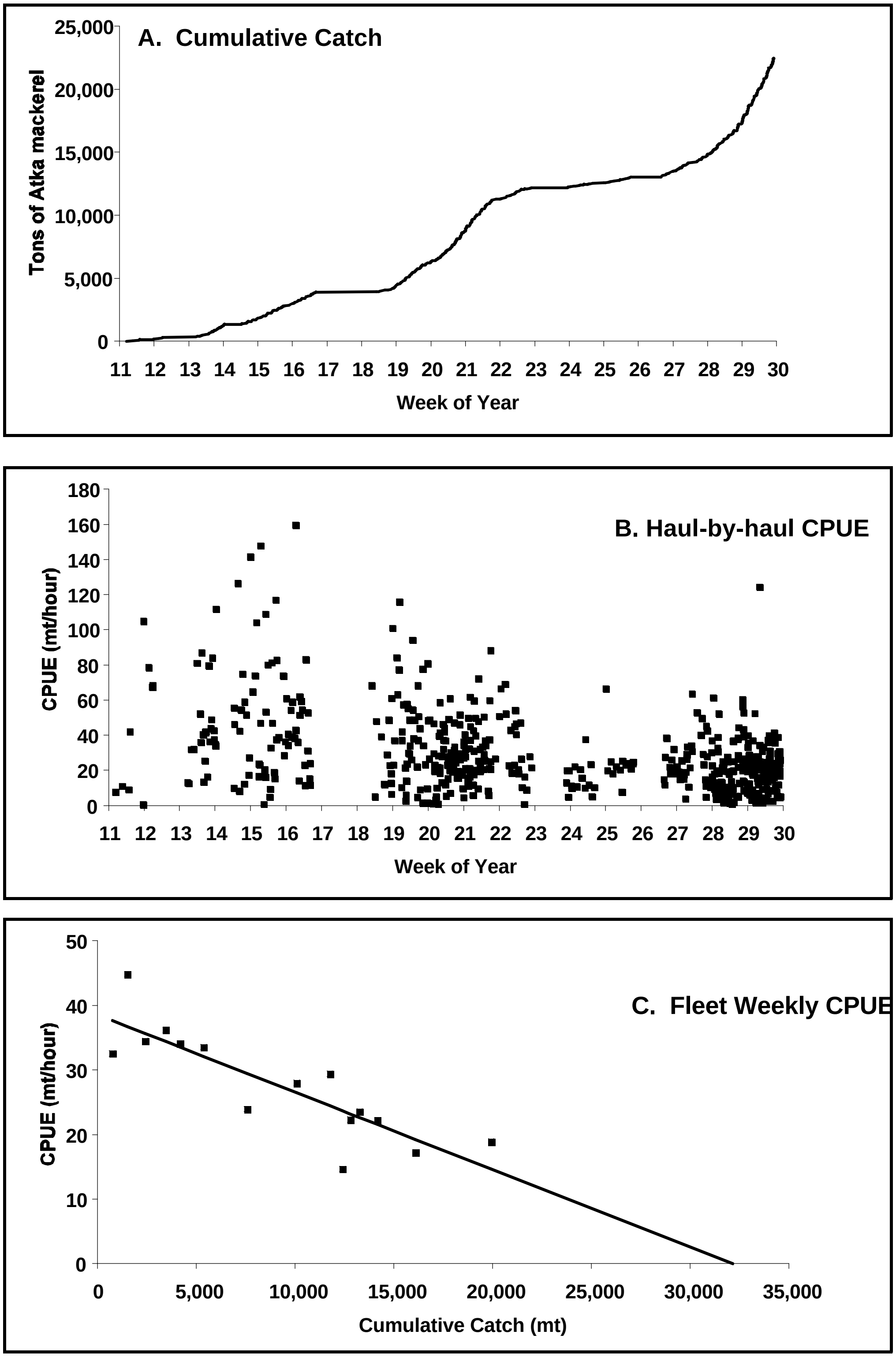


Figure 10. Atka mackerel fishery data from Kiska Island area, March-July, 1994. A. Cumulative catch. B. Haul-by-haul CPUE for all vessels (*n* = 11; # hauls = 592). C. Fleet weekly CPUE for all vessels (weeks 13-16, 18-22, and 24-29) with Leslie least squares linear regression line plotted. Estimate of initial biomass is 32,200 mt.

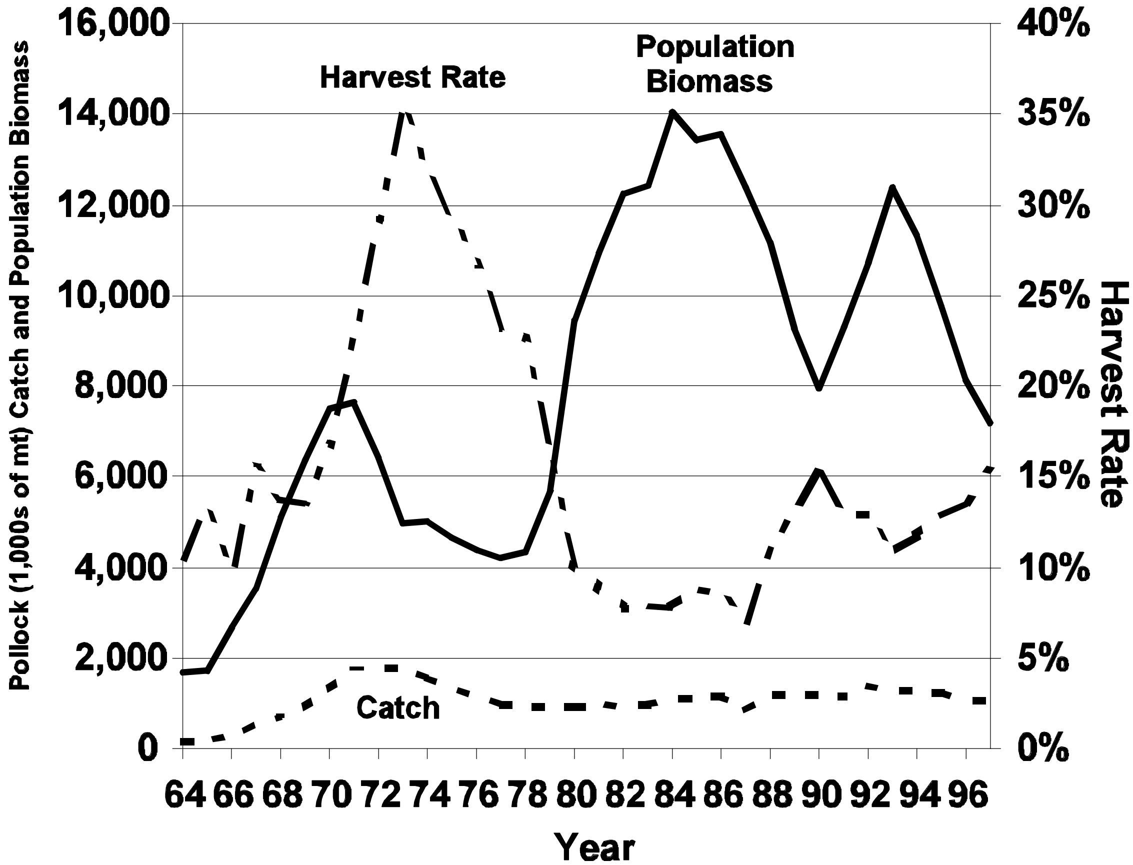


Figure 11. Population biomass, catch and harvest rate of EBS pollock from 1964 to 1997.

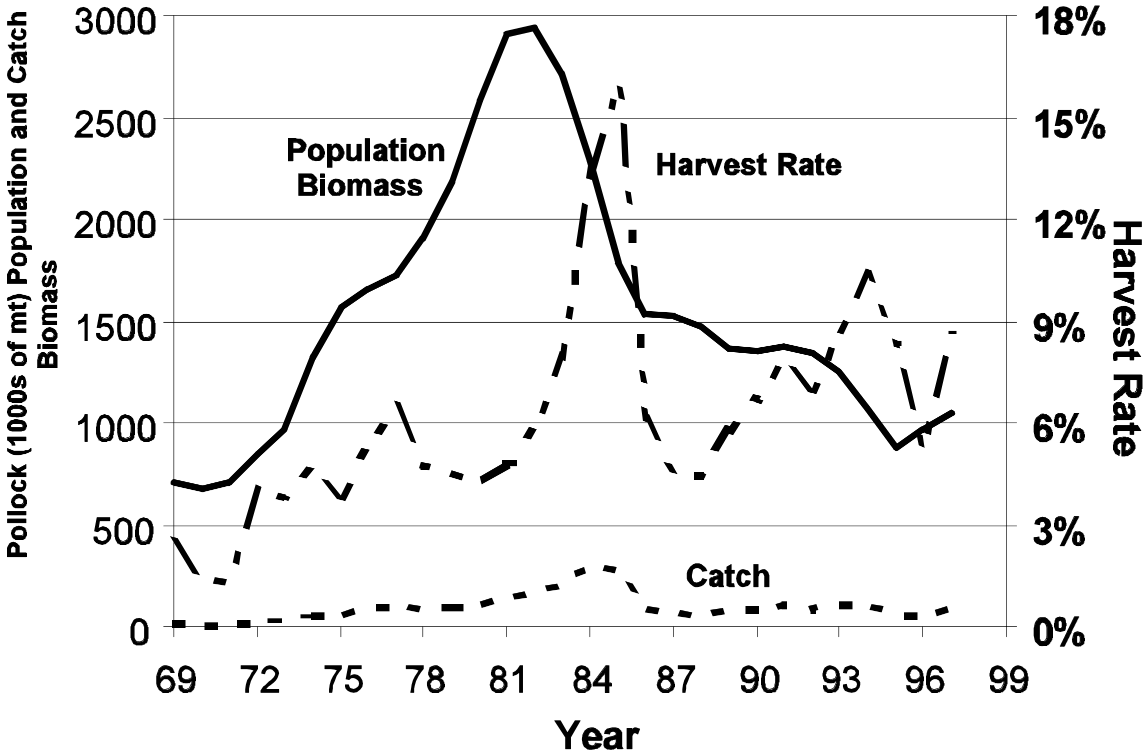


Figure 12. Population biomass, catch and harvest rate of GOA pollock from 1969 to 1997.

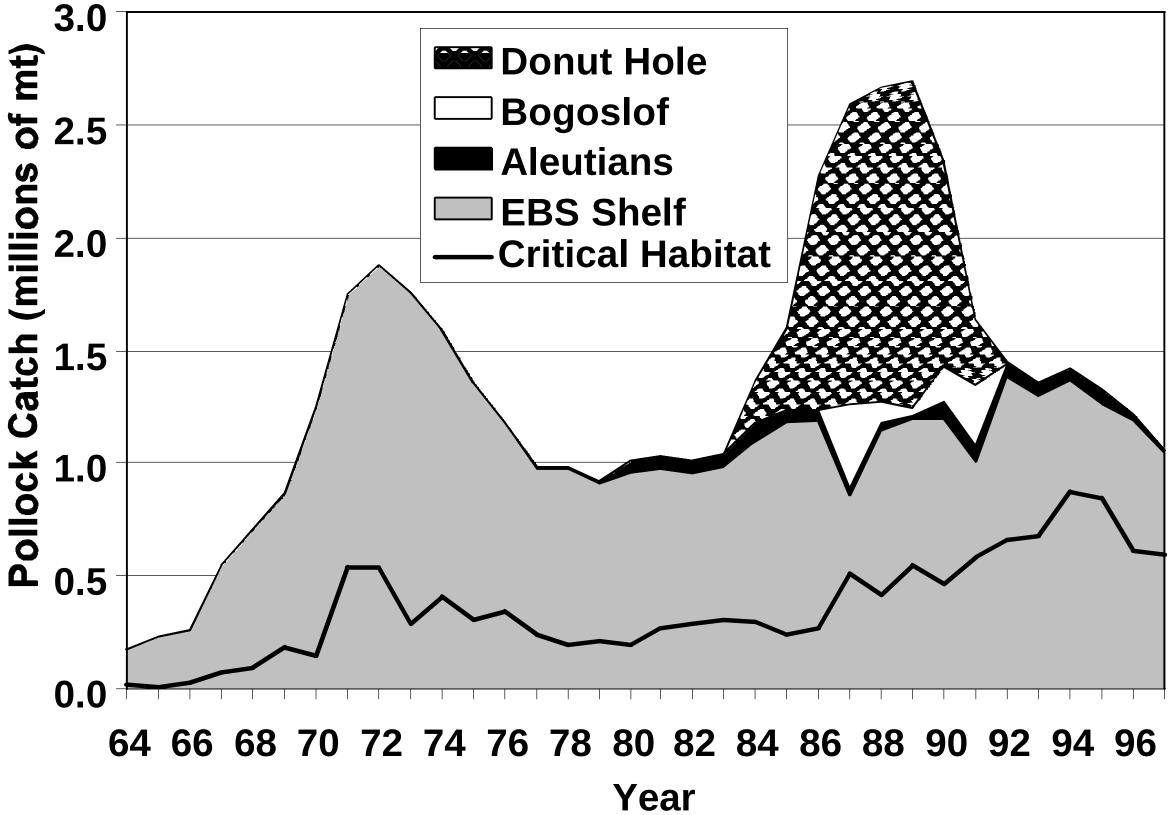


Figure 13. Catch of walleye pollock (mmt) in the eastern and central Bering Sea and Aleutian Islands from 1964 to 1997. Catch of pollock is shown in the following regions: (1) the Donut Hole, or international waters outside of the US EEZ in the central Bering Sea; (2) Bogoslof Island area in the US EEZ, a spawning area for the Donut Hole stock; (3) Aleutian Island area west of 170° W longitude and south of 55°N latitude in the US EEZ; (4) eastern Bering Sea (EBS) shelf, and (5) Steller sea lion critical habitat within the Bering Sea/Aleutian Island region. Regions 2-4 above sum to the total BSAI pollock catch within the US EEZ, while the catch within critical habitat is a portion of this total.

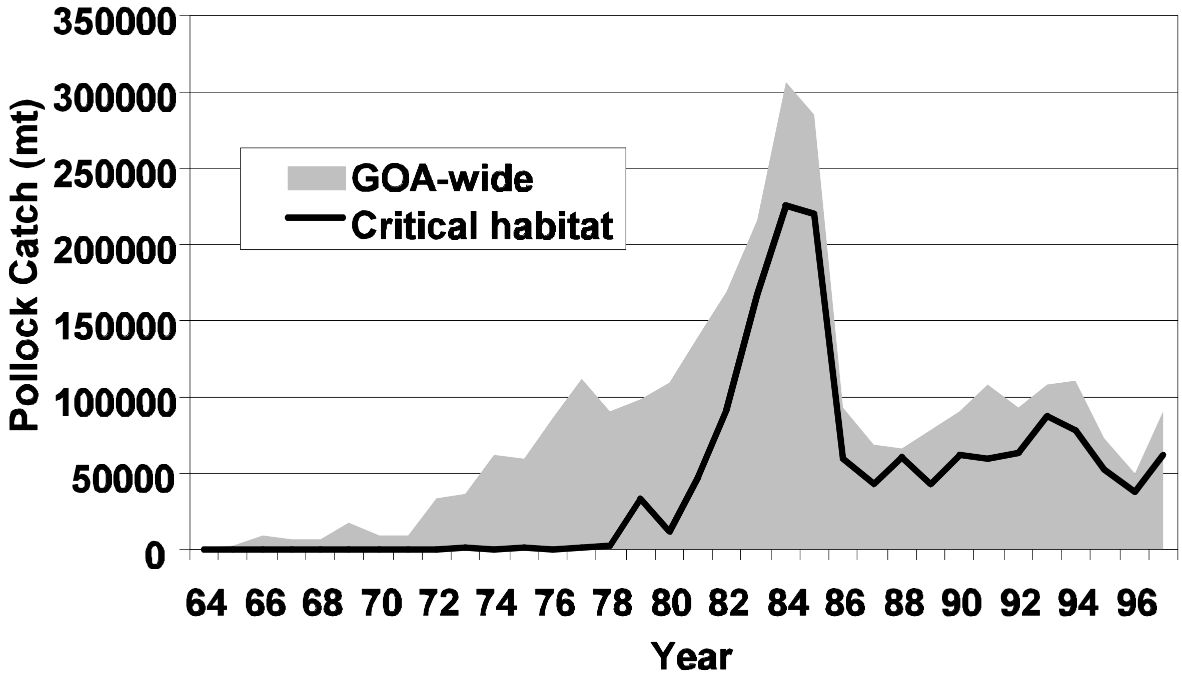


Figure 14. Catch of walleye pollock (mt) in the GOA and in GOA Steller sea lion critical habitat from 1964 to 1997.

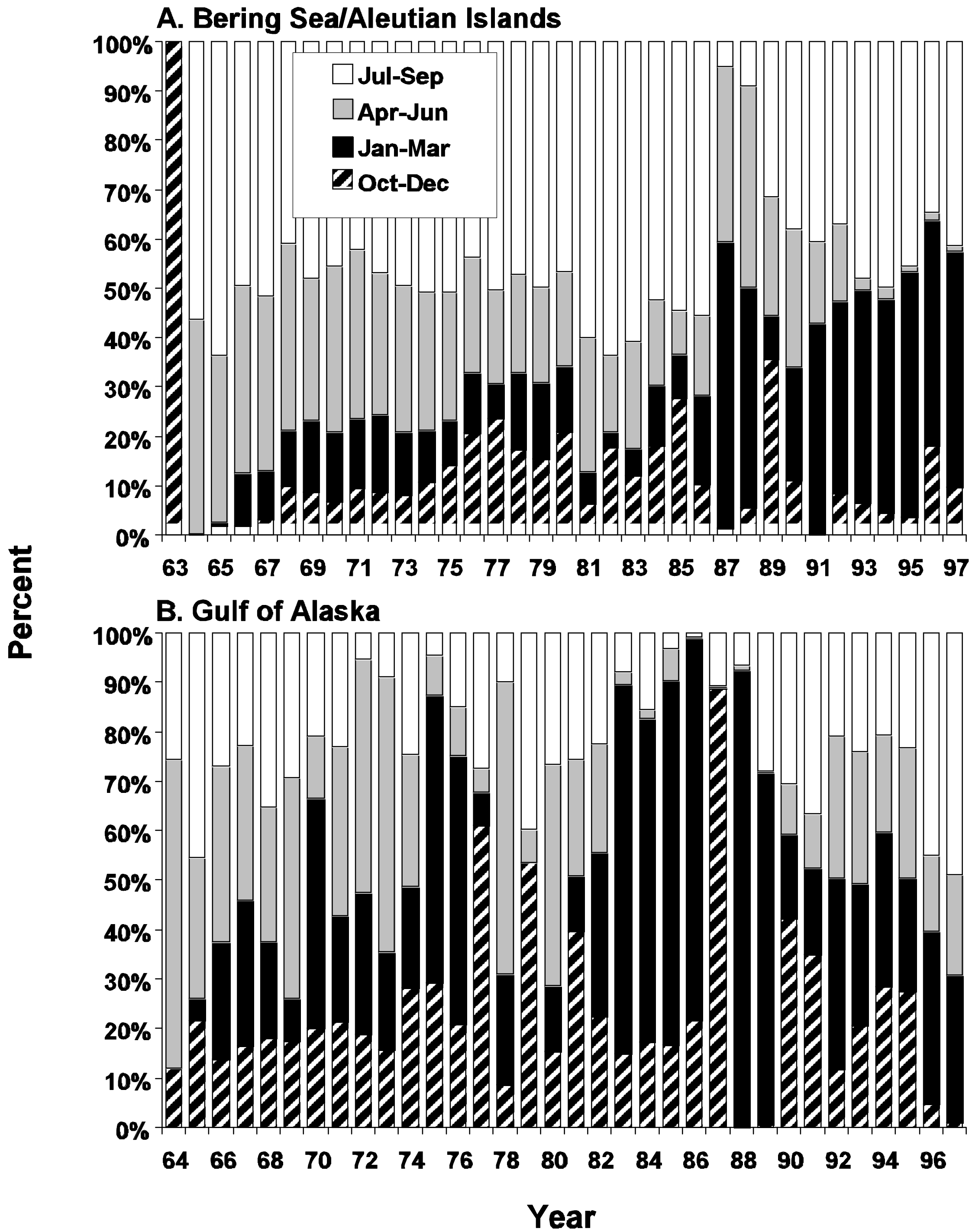


Figure 15. Quarterly distribution of pollock catch in the eastern Bering sea and Aleutian Islands (A) and the GOA (B) from 1963 to 1997.

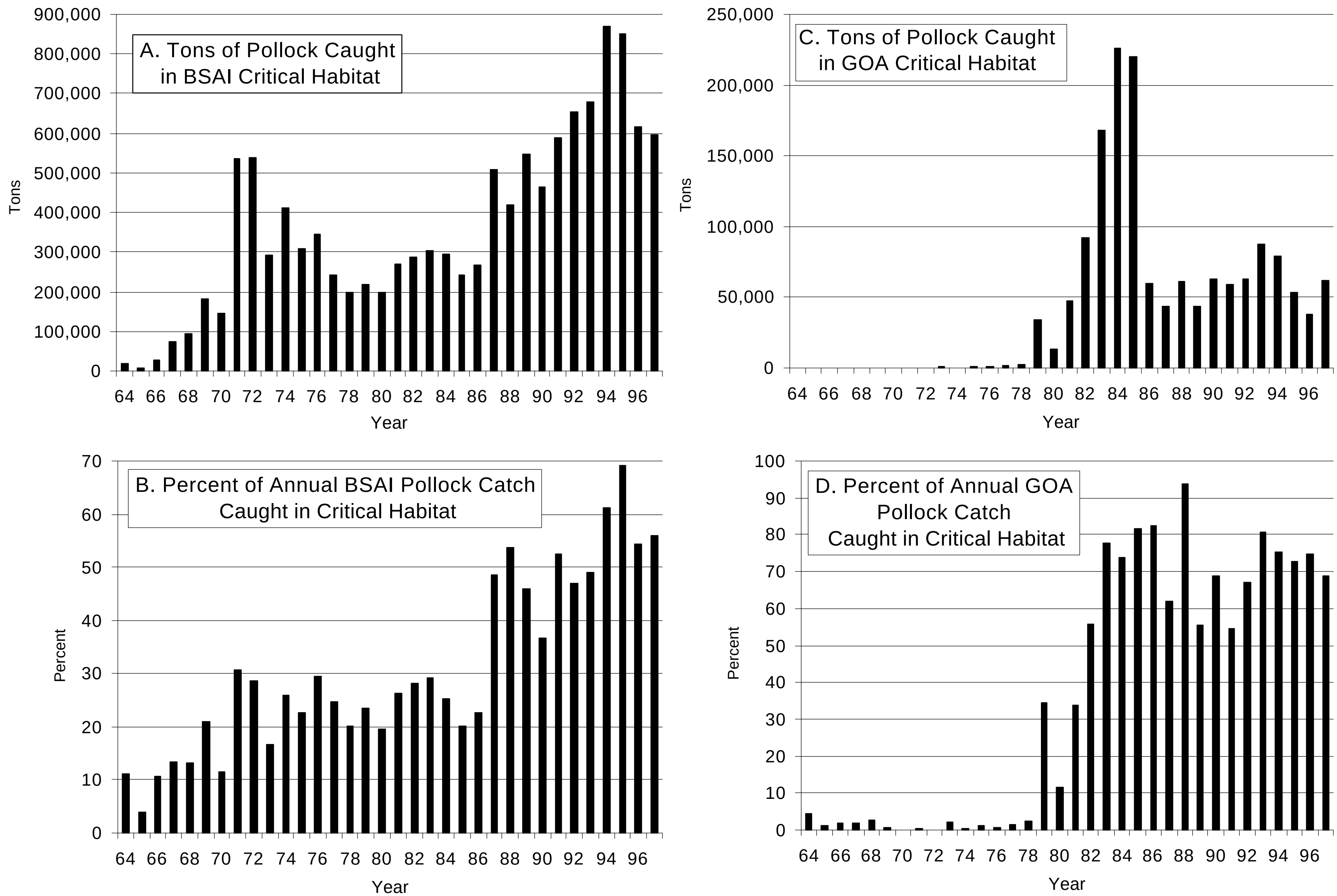
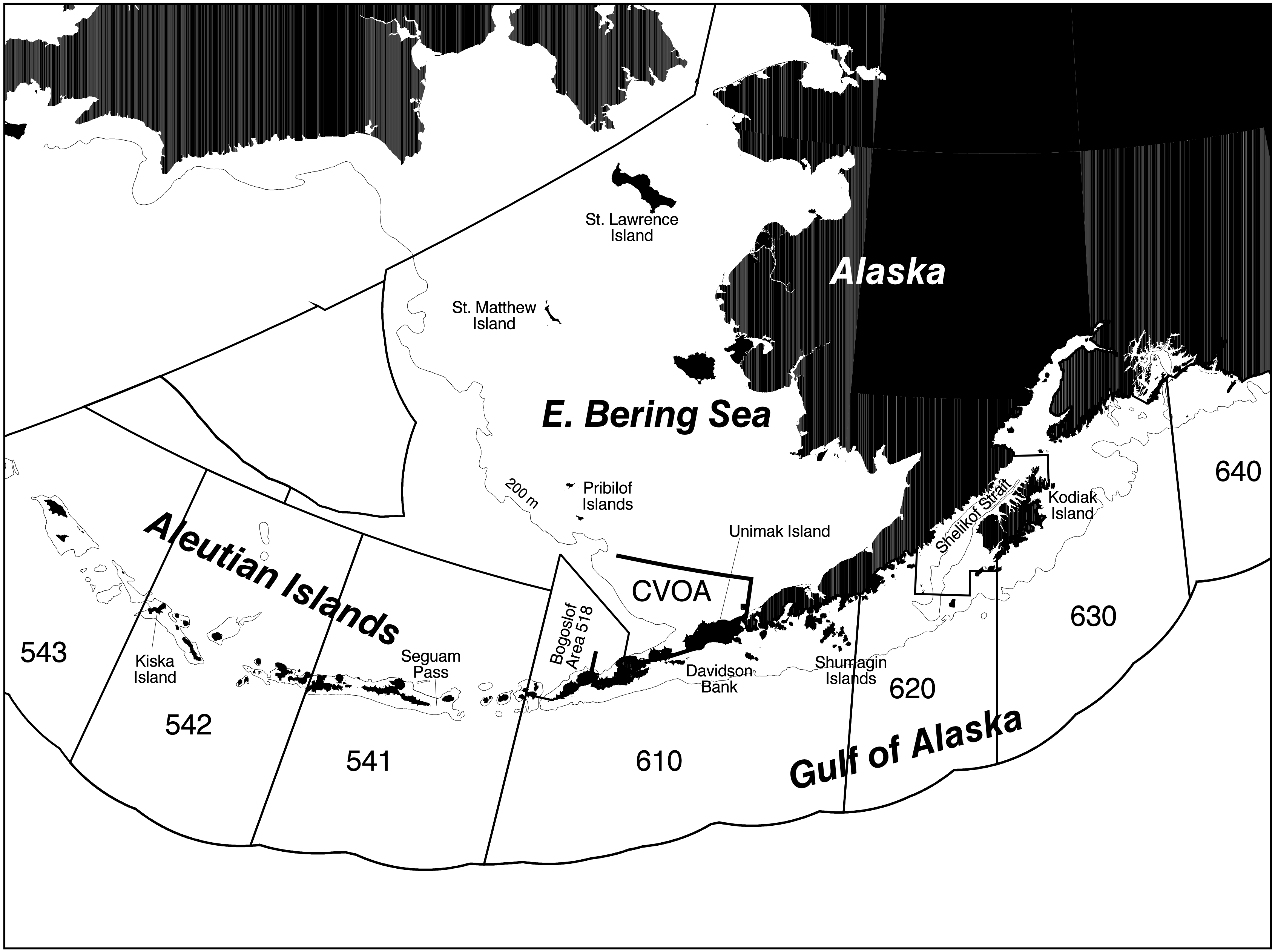


Figure 16. Catch (tons; A and C) and percent of annual regional catch of pollock (B and D) from Steller sea lion critical habitat in the BSAI (A and B) and GOA (C and D) from 1964 to 1997.

Figure 17. Map of the BSAI and GOA regions, showing fishery management areas.


St. Lawrence Island
Alaska
St. Matthew Island
E. Bering Sea
640
Kodiak Island
Shelikof Strait
200 m
Pribilof Islands
Unimak Island
Aleutian Islands
CVOA
630
Bogoslof Area 518
Seguam Pass
543
Kiska Island
Davidson Bank
Shumagin Islands
620
542
Gulf of Alaska
541
610

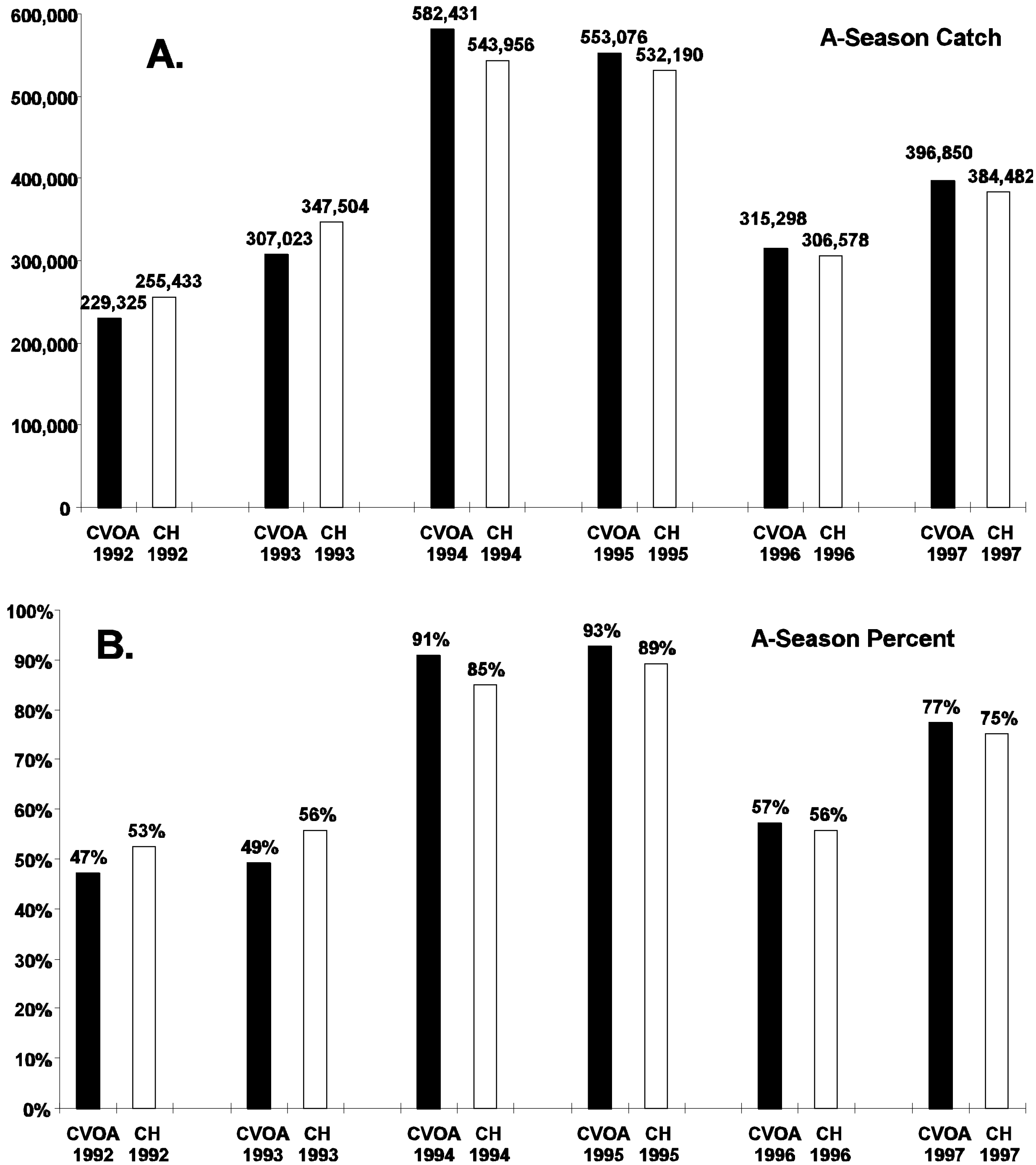


Figure 18. A-season catches (A; in mt) of pollock in the BSAI in 1992 to 1997 in the Catcher Vessel Operational Area (CVOA) and in Steller sea lion critical habitat. Percent of total A-season BSAI pollock catch is shown in B.

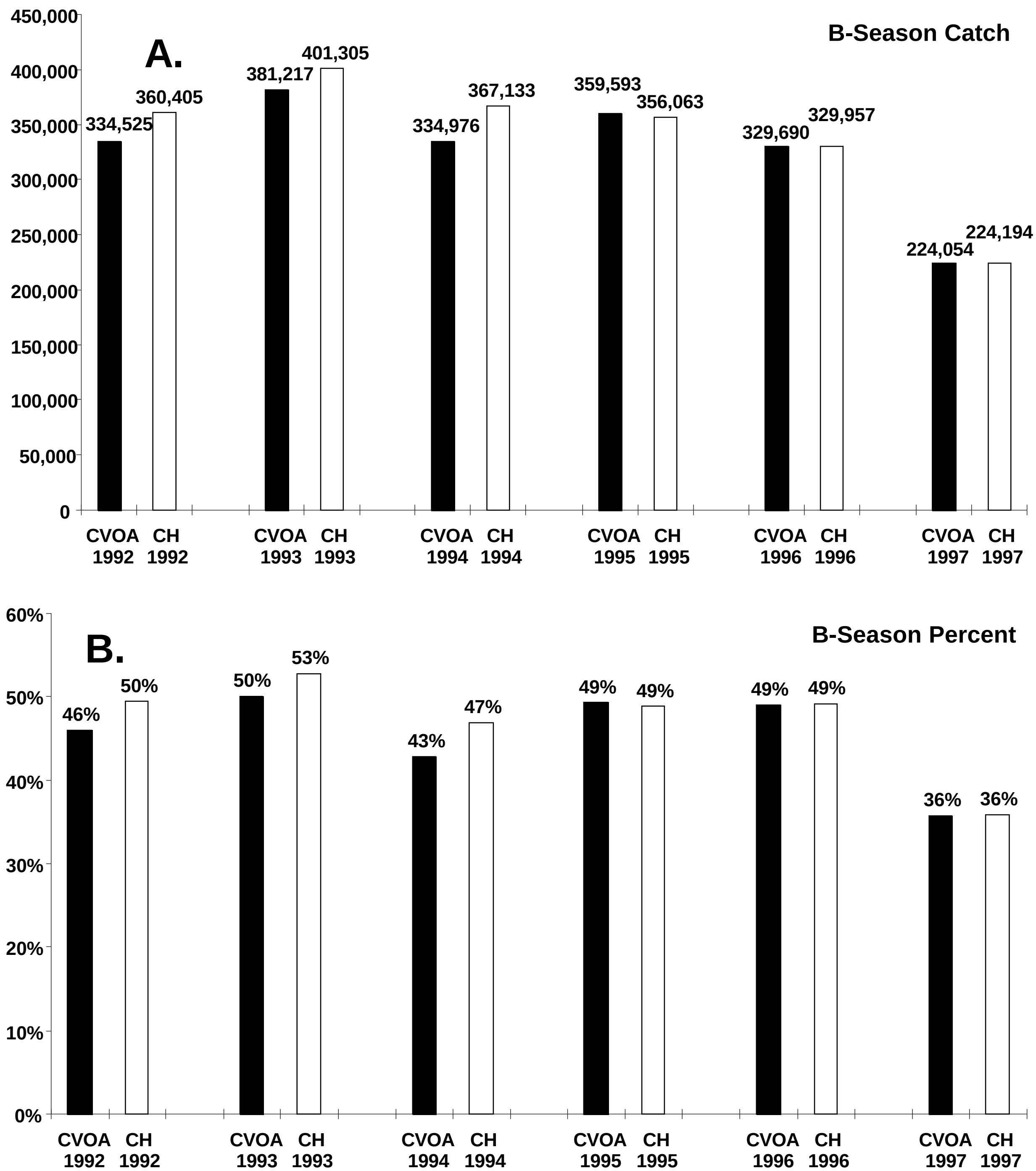


Figure 19. B-season catches (A; in mt) of pollock in the BSAI in 1992 to 1997 in the Catcher Vessel Operational Area (CVOA) and in Steller sea lion critical habitat. Percent of total B-season BSAI pollock catch is shown in B.

Figure 20. A-season observed pollock fishery trawl locations in the BSAI in 1995 (top), 1996 (middle), and 1997 (bottom). Steller sea lion critical habitat (20 nm around rookeries and haulouts and the forating areas) and the 200 m depth contour are shown.

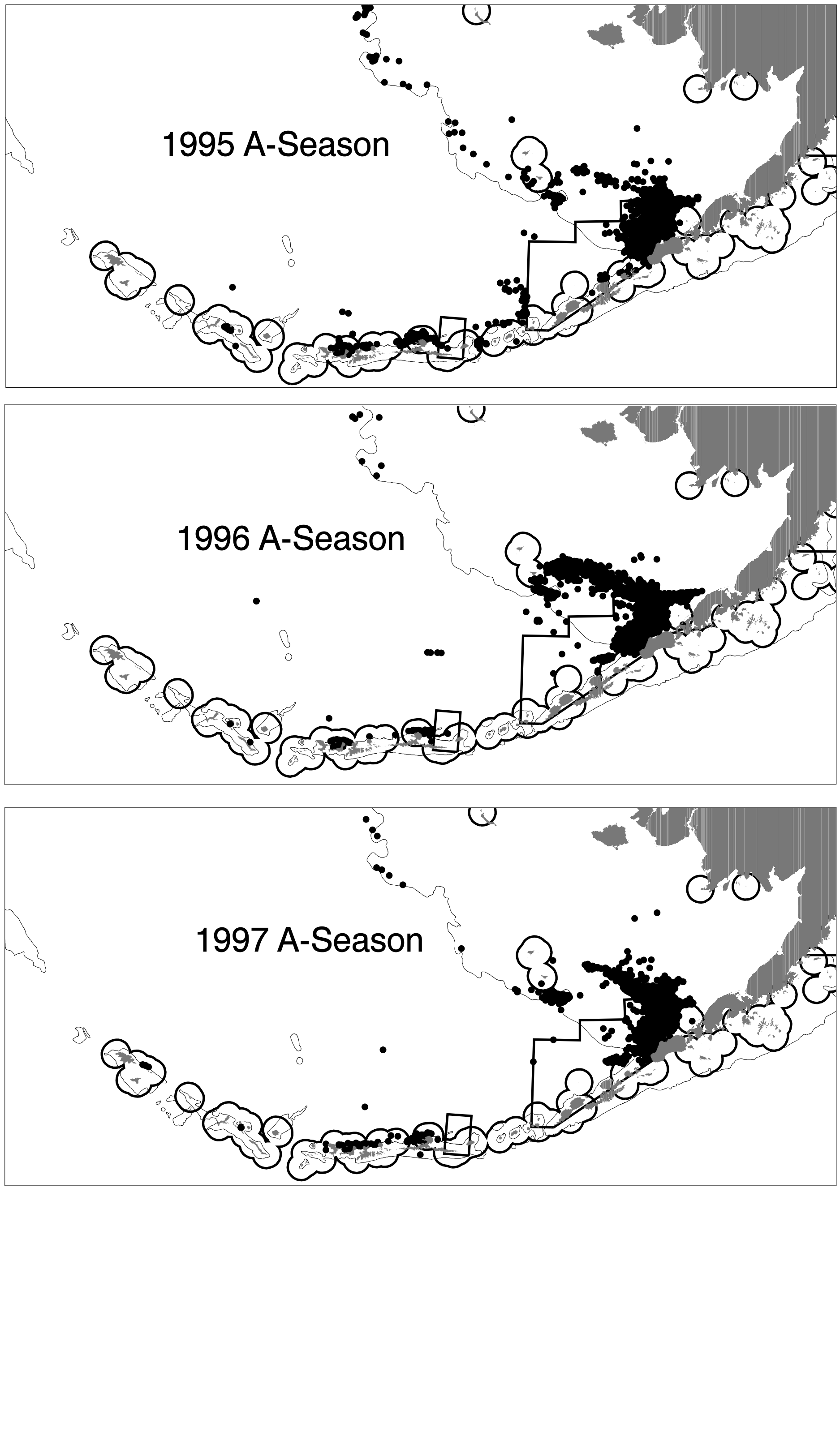
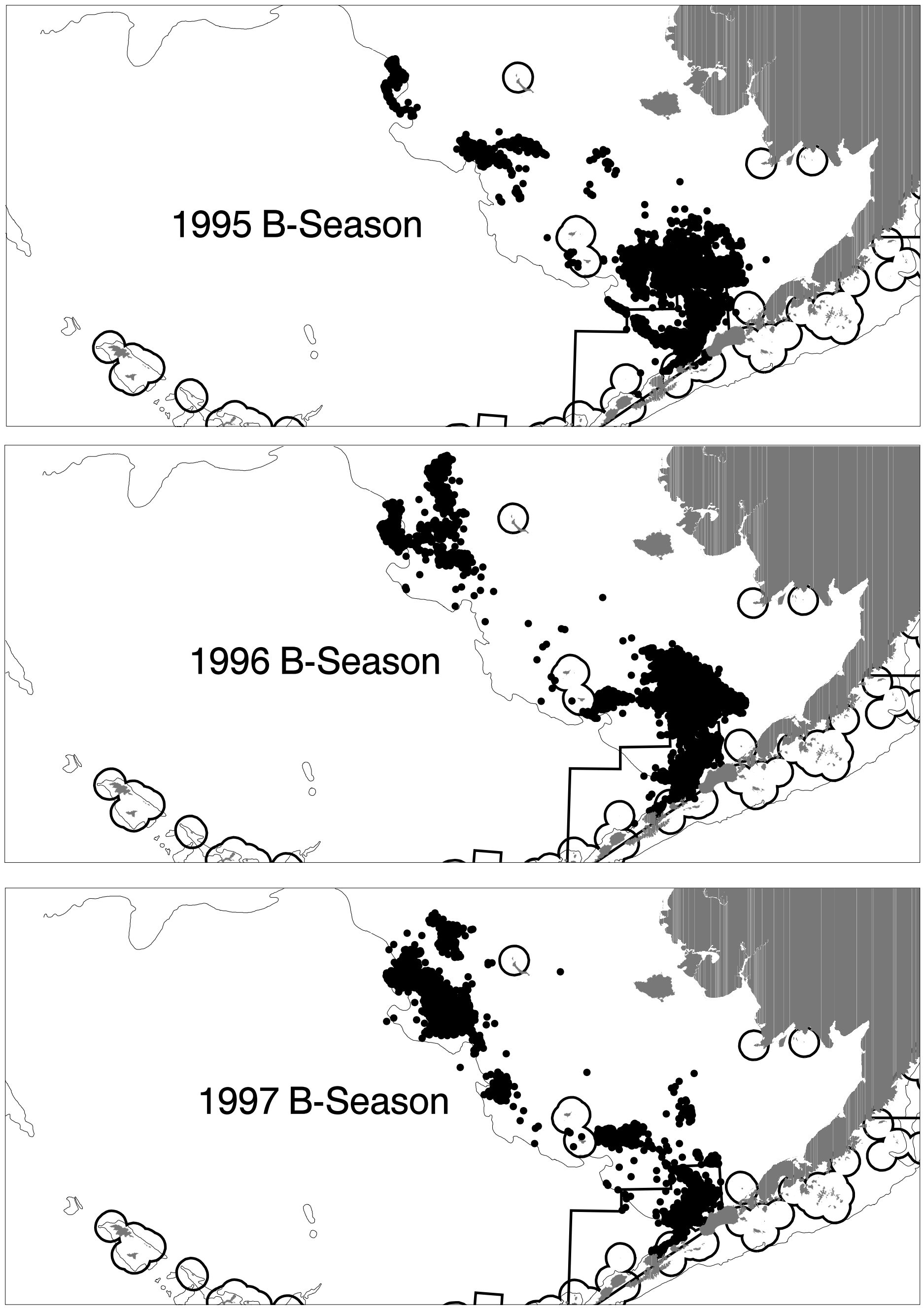

1995 A-Season
1996 A-Season
1997 A-Season

Figure 21. B-season observed pollock fishery trawl locations in the BSAI in 1995 (top), 1996 (middle), and 1997 (bottom). Steller sea lion critical habitat (20 nm around rookeries and haulouts and the forating areas) and the 200 m depth contour are shown.


1995 B-Season
1996 B-Season
1997 B-Season

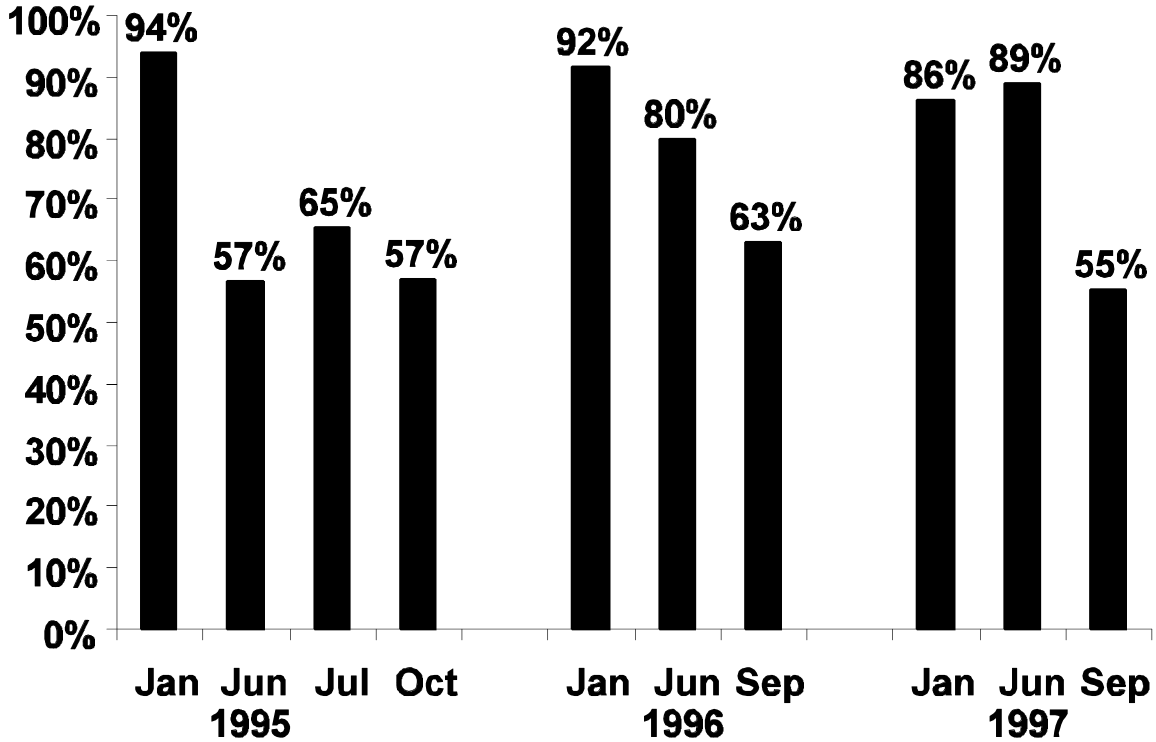


Figure 22. Percentage of observed pollock catch caught within Steller sea lion critical habitat in the GOA pollock fisheries in 1995 to 1997, by season.

Figure 23. Observed pollock fishery trawl locations in each four seasons in 1995 in the central and western GOA (areas 610-630). Steller sea lion critical habitat is also shown (20 nm around rookeries and haulouts, and the Shelikof Strait and EBS foraging areas).

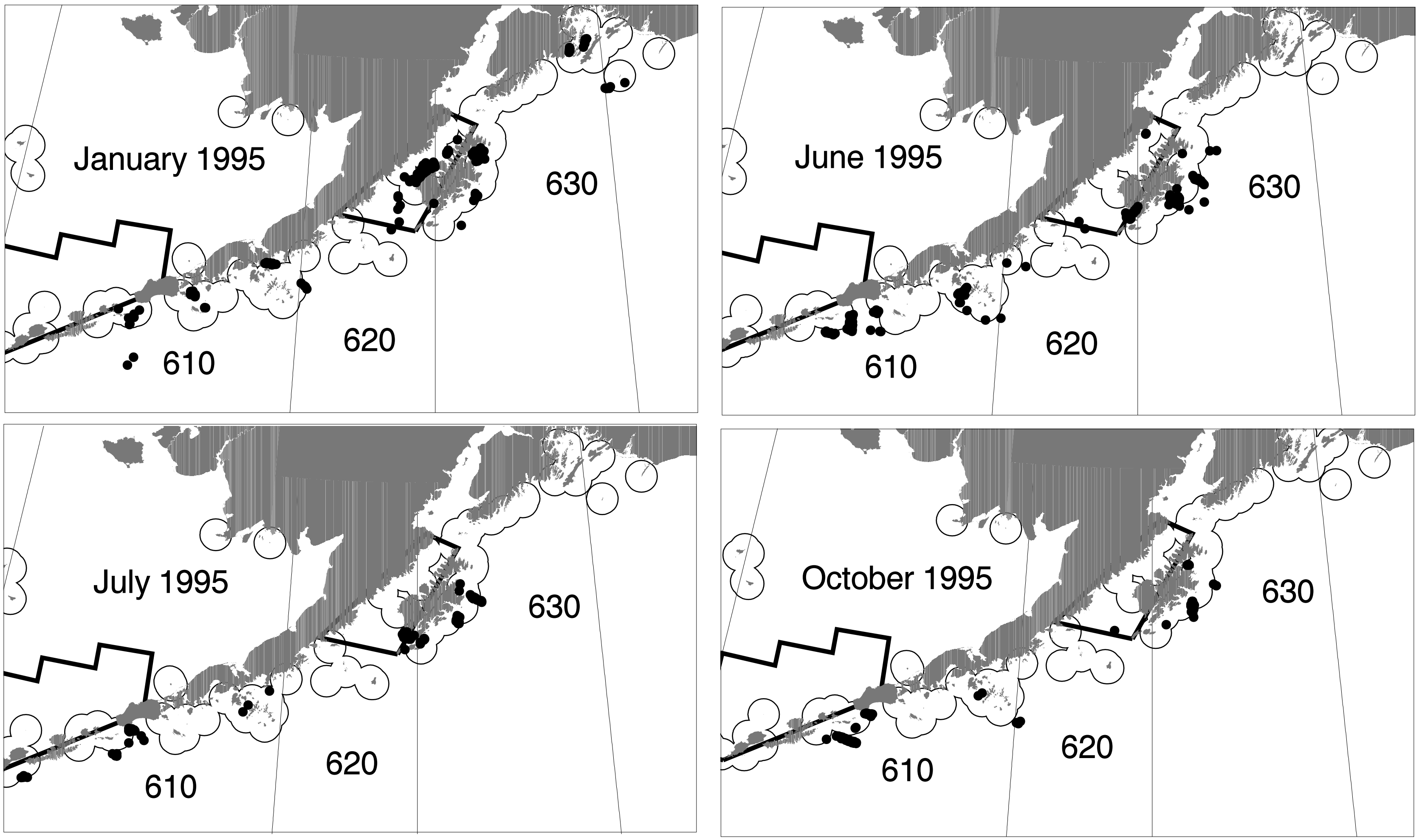

January 1995
630
620
610
June 1995
630
620
610
July 1995
630
620
610
October 1995
630
620
610

Figure 24. Observed pollock fishery trawl locations in each three seasons in 1996 in the central and western GOA (areas 610-630). Steller sea lion critical habitat is also shown (20 nm around rookeries and haulouts, and the Shelikof Strait and EBS foraging areas).

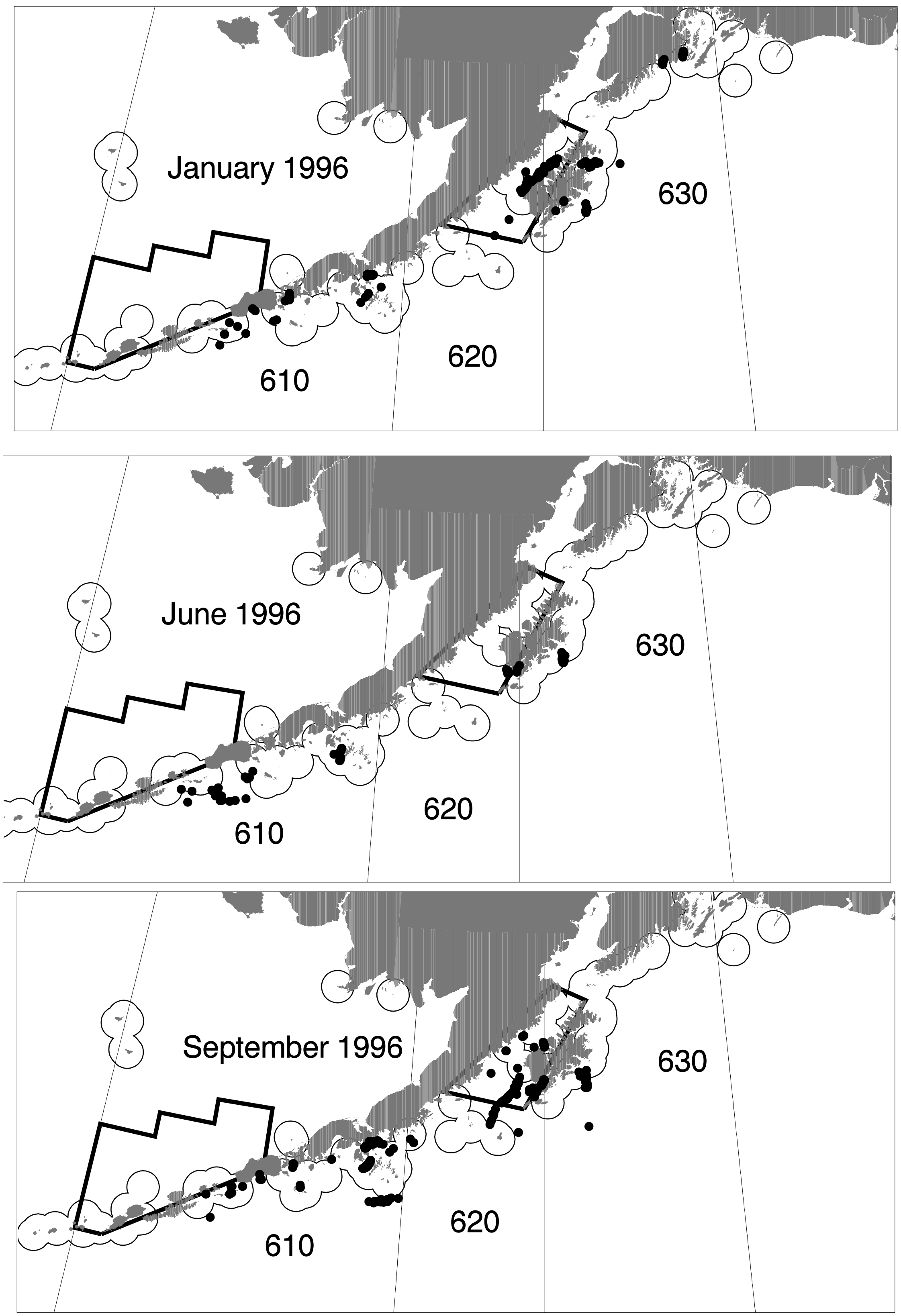
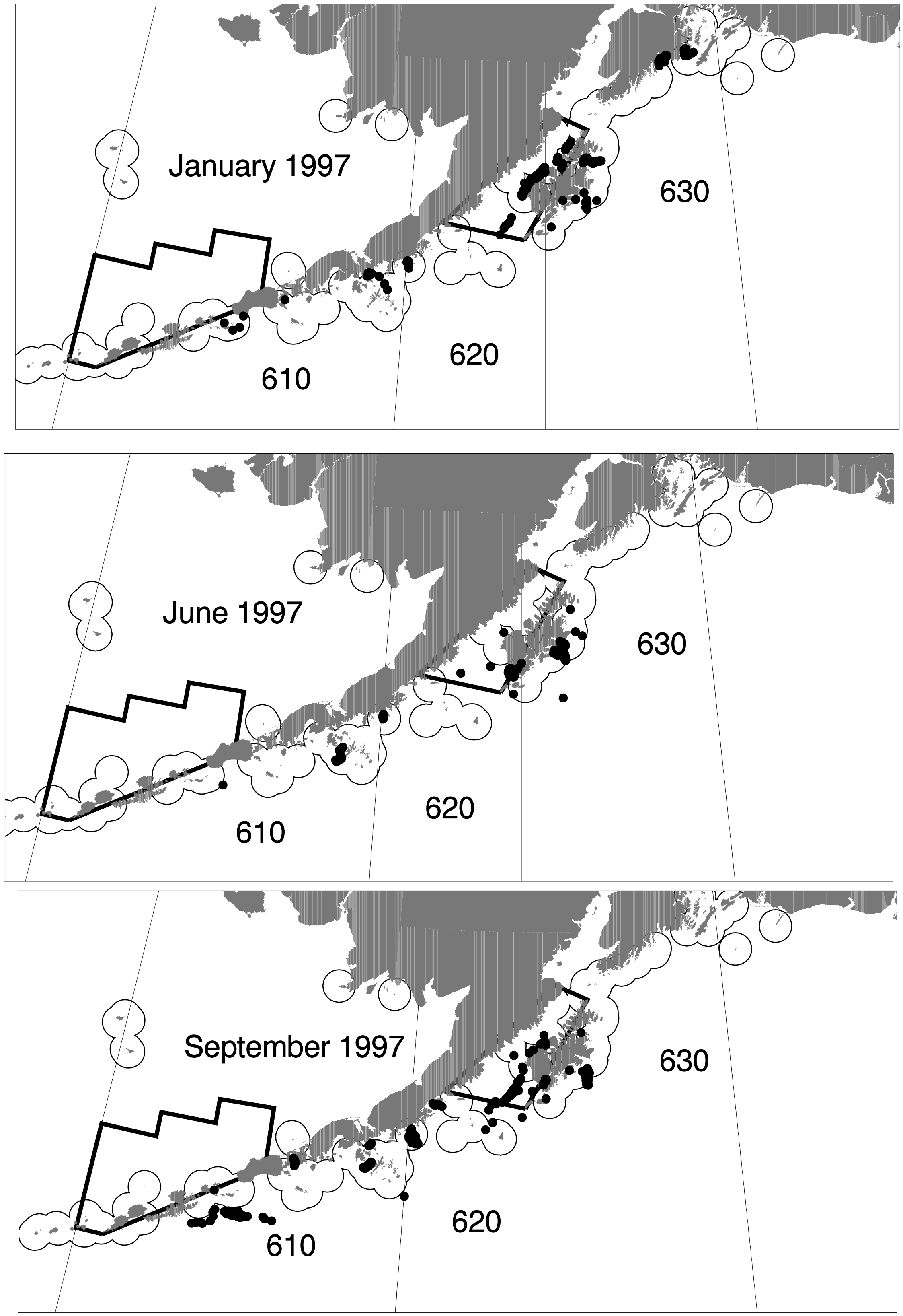

January 1996
610
620
630
June 1996
610
620
630
September 1996
610
620
630

Figure 25. Observed pollock fishery trawl locations in each three seasons in 1997 in the central and western GOA (areas 610-630). Steller sea lion critical habitat is also shown (20 nm around rookeries and haulouts, and the Shelikof Strait and EBS foraging areas).


January 1997
630
620
610
June 1997
630
620
610
September 1997
630
620
610

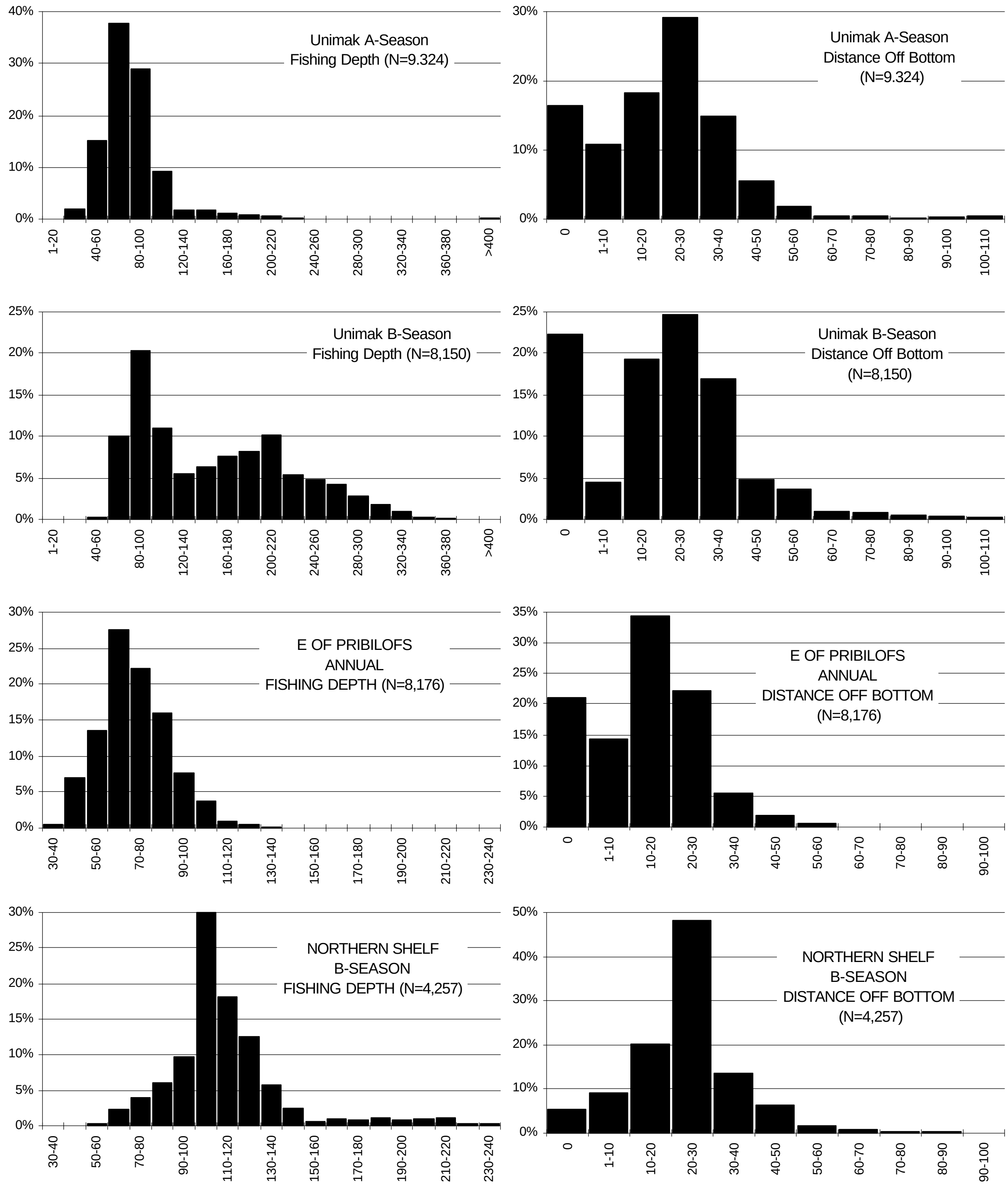


Figure 26. Fishing depth distributions and the distributions of distances off-bottom (x-axis in meters) of pelagic pollock fishery hauls in three on-shelf regions of the eastern Bering Sea in 1995-97. N is the number of hauls. See Figure 17 for locations. Data from the Unimak region is divided into A and B-seasons; the region east of the Pribilof Islands is the annual distributions; and the northern shelf region is only for the B-season.

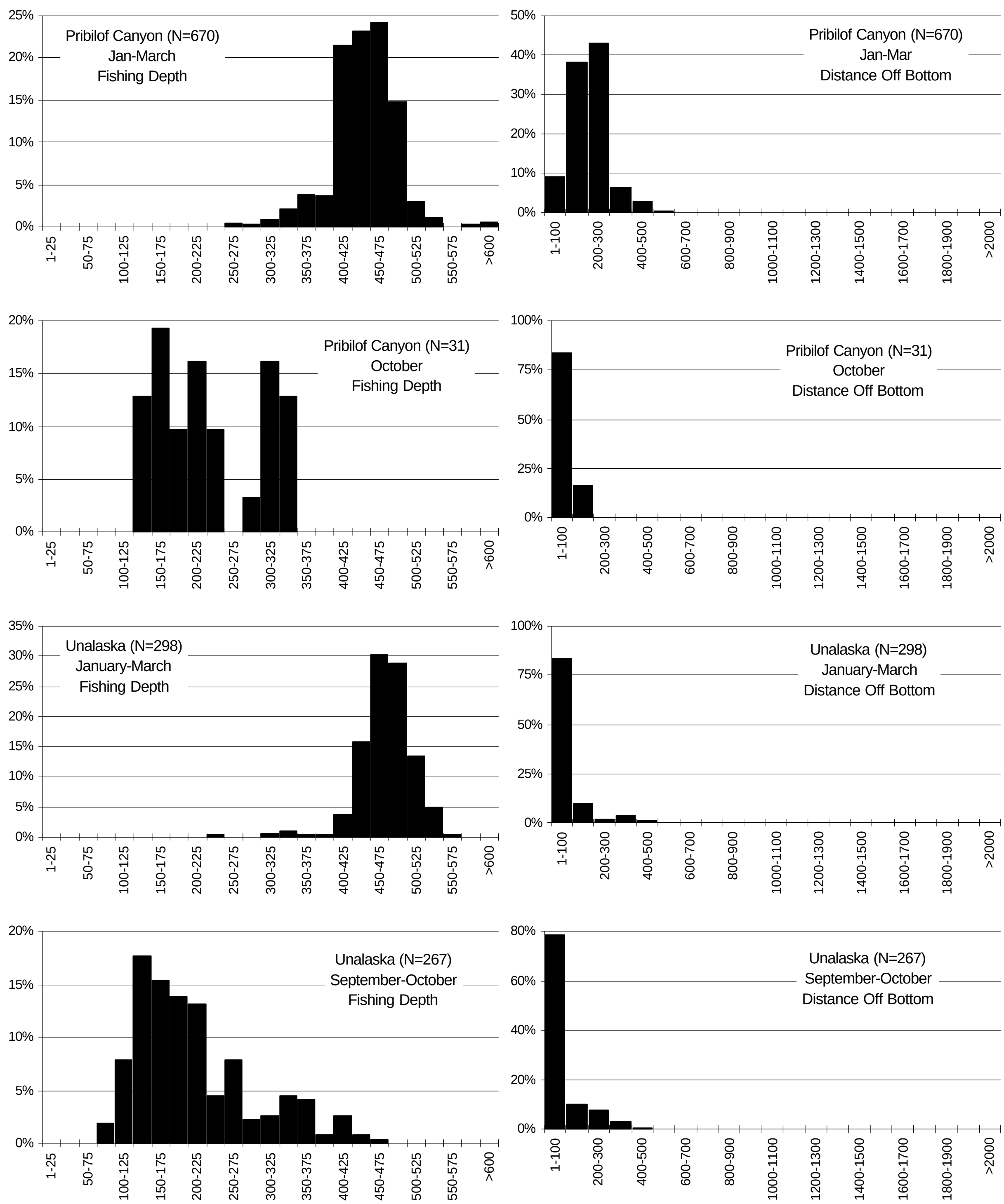


Figure 27. Fishing depth distributions and the distributions of distances off-bottom (x-axis in meters) of pelagic pollock fishery hauls in two seasons in two deepwater regions of the eastern Bering Sea in 1995-97. N is the number of hauls. See Figure 17 for locations.

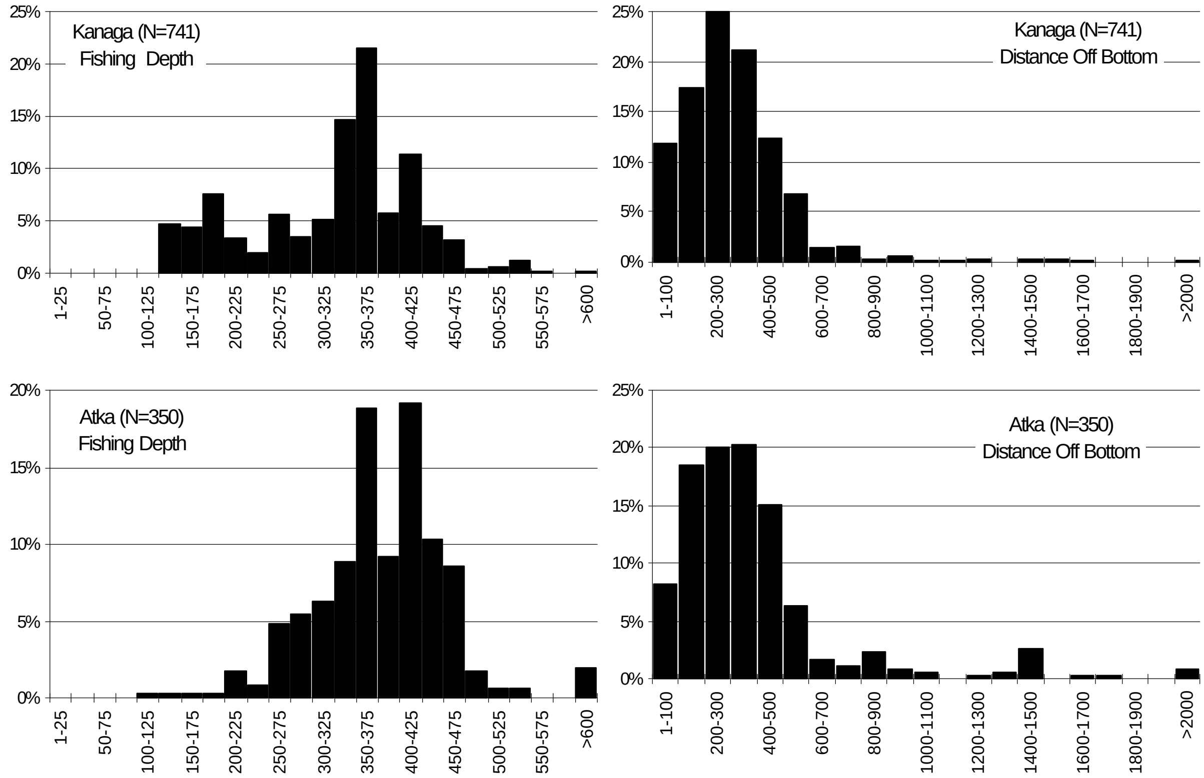


Figure 28. Fishing depth distributions and the distributions of distances off-bottom (x-axis in meters) of pelagic pollock fishery hauls in 2 regions of the Aleutian Islands in 1995-97. N is the number of hauls. See Figure 17 for locations.

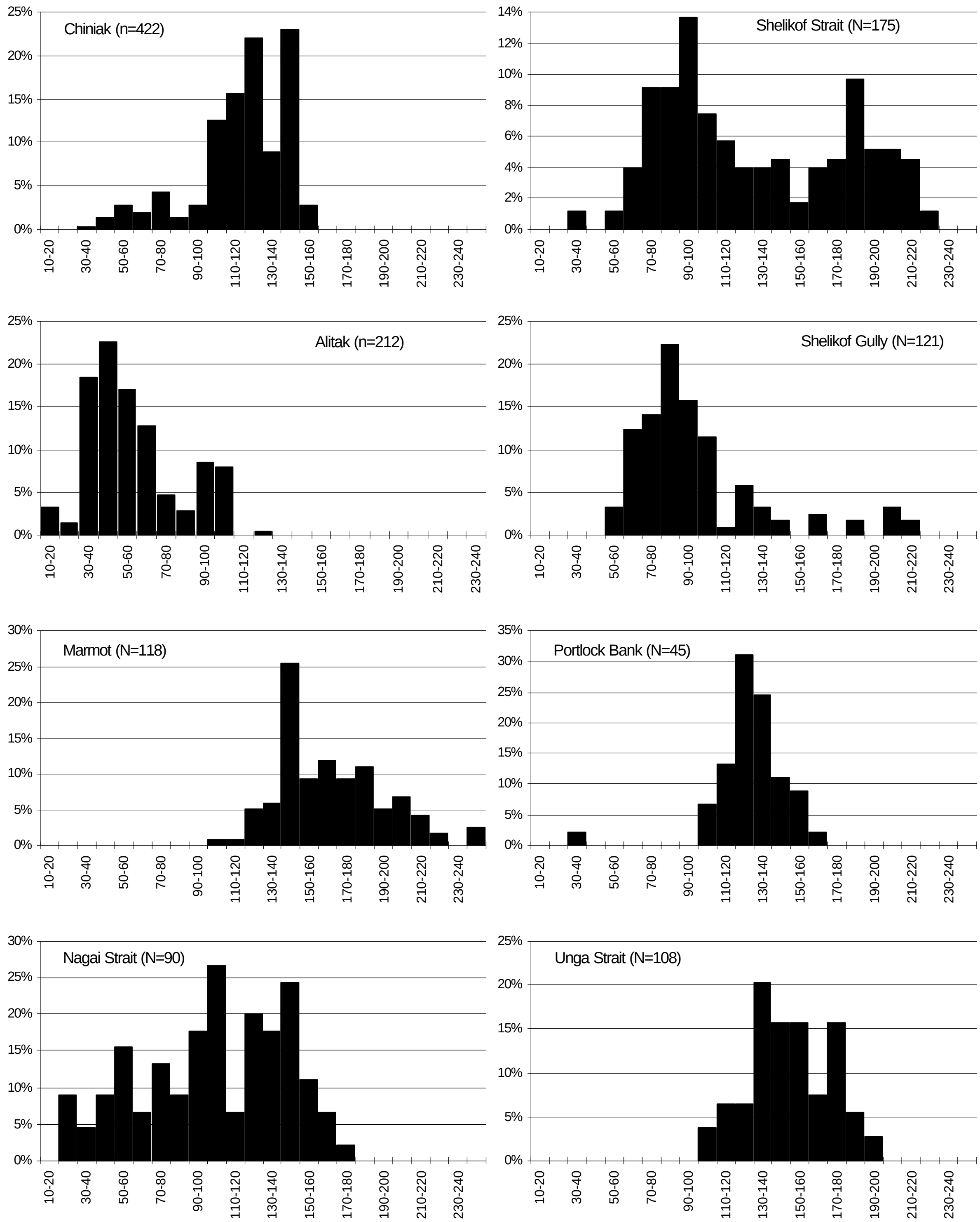


Figure 29. Fishing depth distributions (x-axis in meters) of pelagic pollock fishery hauls in 8 regions of the Gulf of Alaska in 1995-97. N is the number of hauls. See Figure 17 for locations.

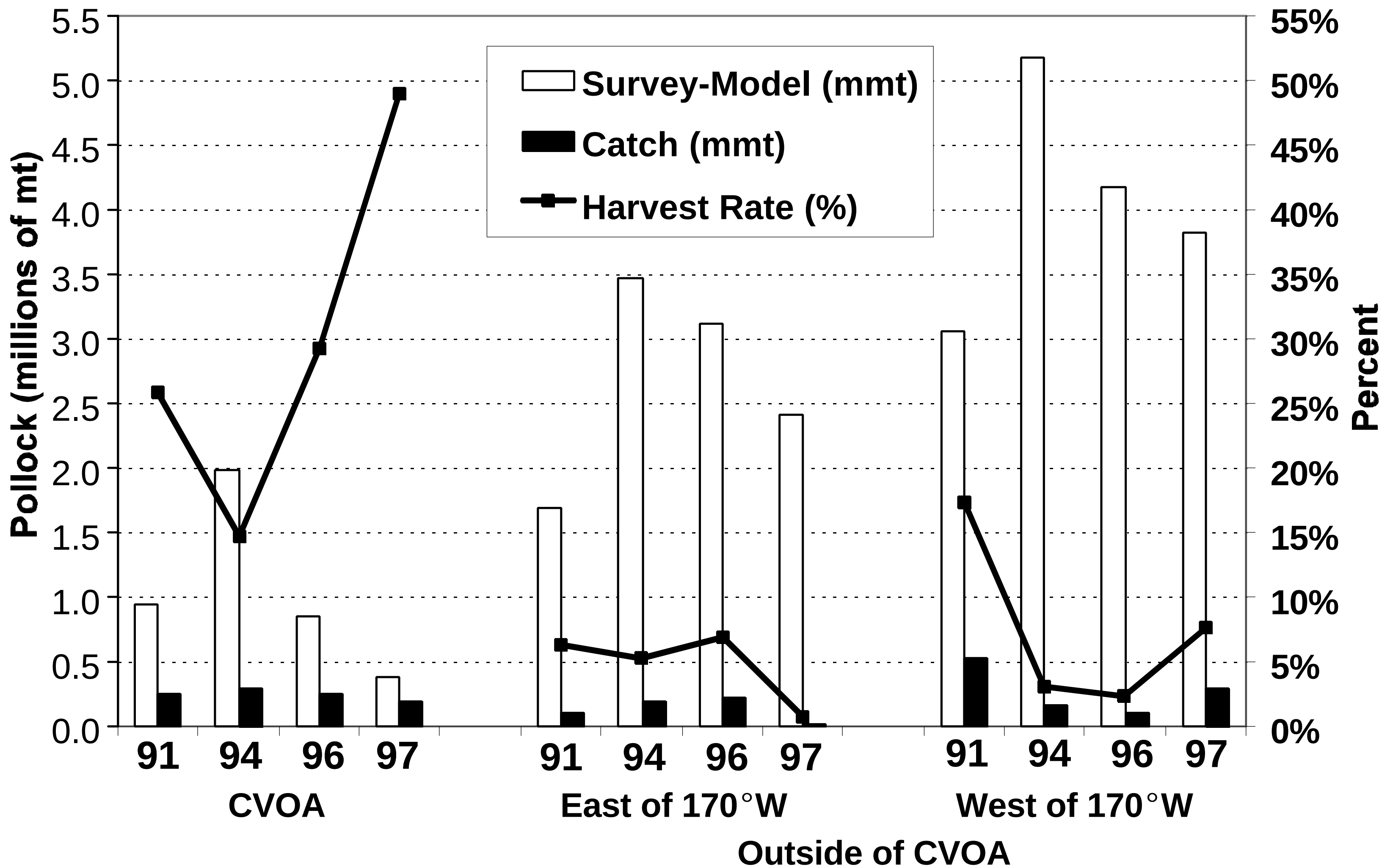


Figure 30. Distributions of age 3+ pollock biomass (mmt) from the combined bottom trawl and hydroacoustic surveys and the 1997 stock assessment, commercial catches of pollock (mmt) from observer and blend data, and pollock harvest rates (% caught) by area in the B-seasons of 1991, 1994, 1996, and 1997.

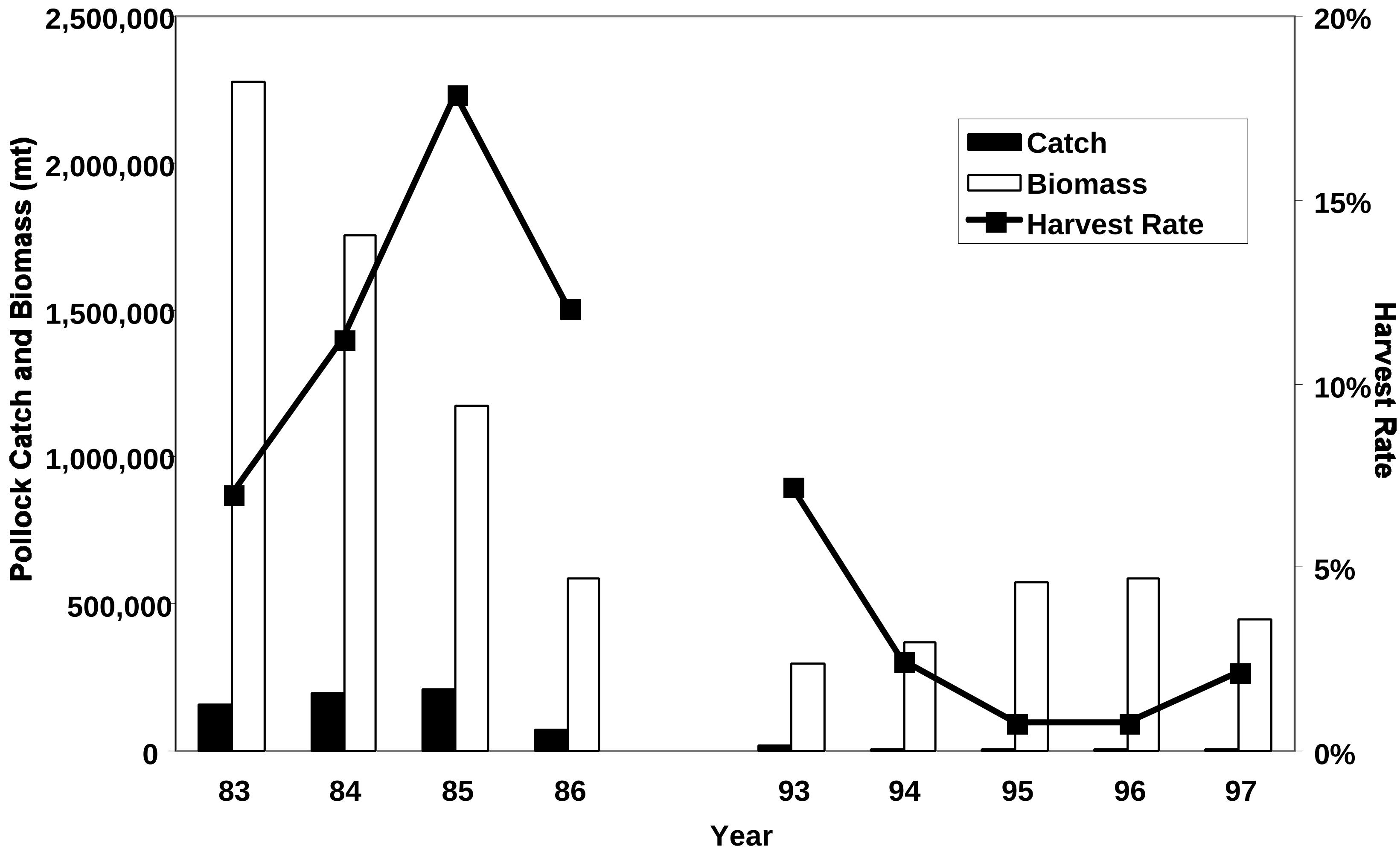


Figure 31. Estimated catch and biomass of pollock in Shelikof Strait in January-March of 1983-86 and 1993-97. Catch was estimated using observer and blend data. Biomass is from echo-integration midwater trawl surveys of the spawning aggregation in Shelikof Strait. Harvest rate=catch/biomass.

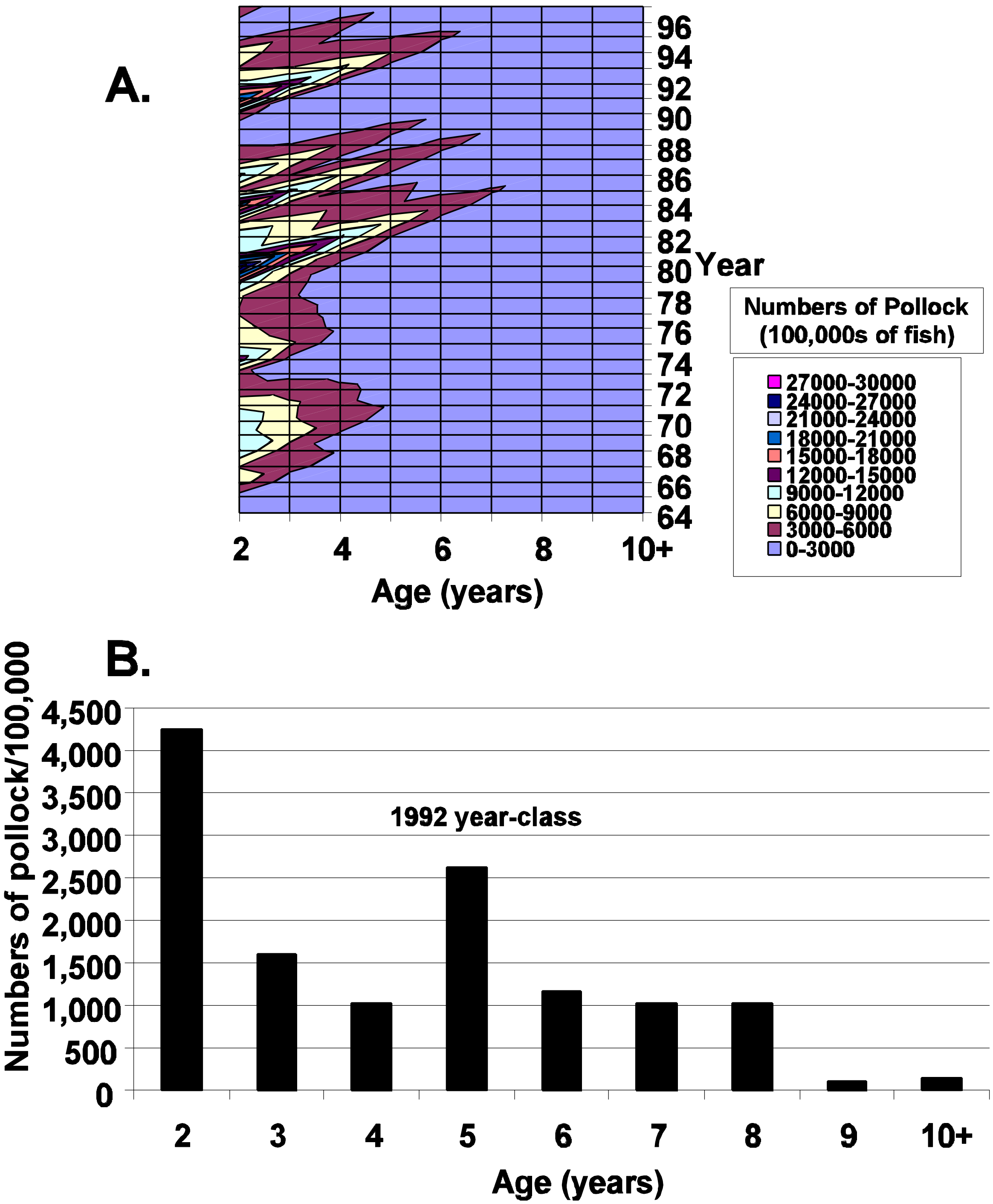


Figure 32. Age composition of the EBS pollock population (ages 2+) in 1964-97 (A) and in 1997 (B). Scale in (A) is in 100,000s of fish.

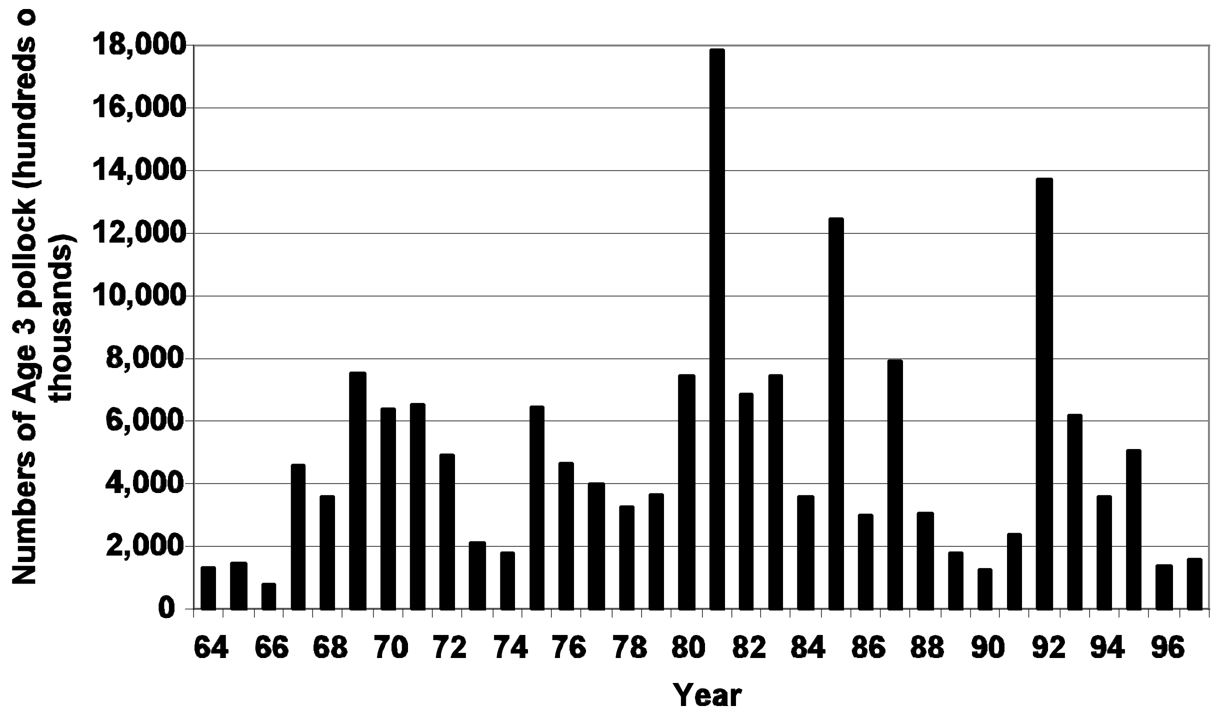


Figure 33. Numbers (hundreds of thousands) of age 3 recruits to the BSAI pollock population in 1964 to 1997 based on the 1997 BSAI pollock stock assessment (Wespestad et al. 1997).

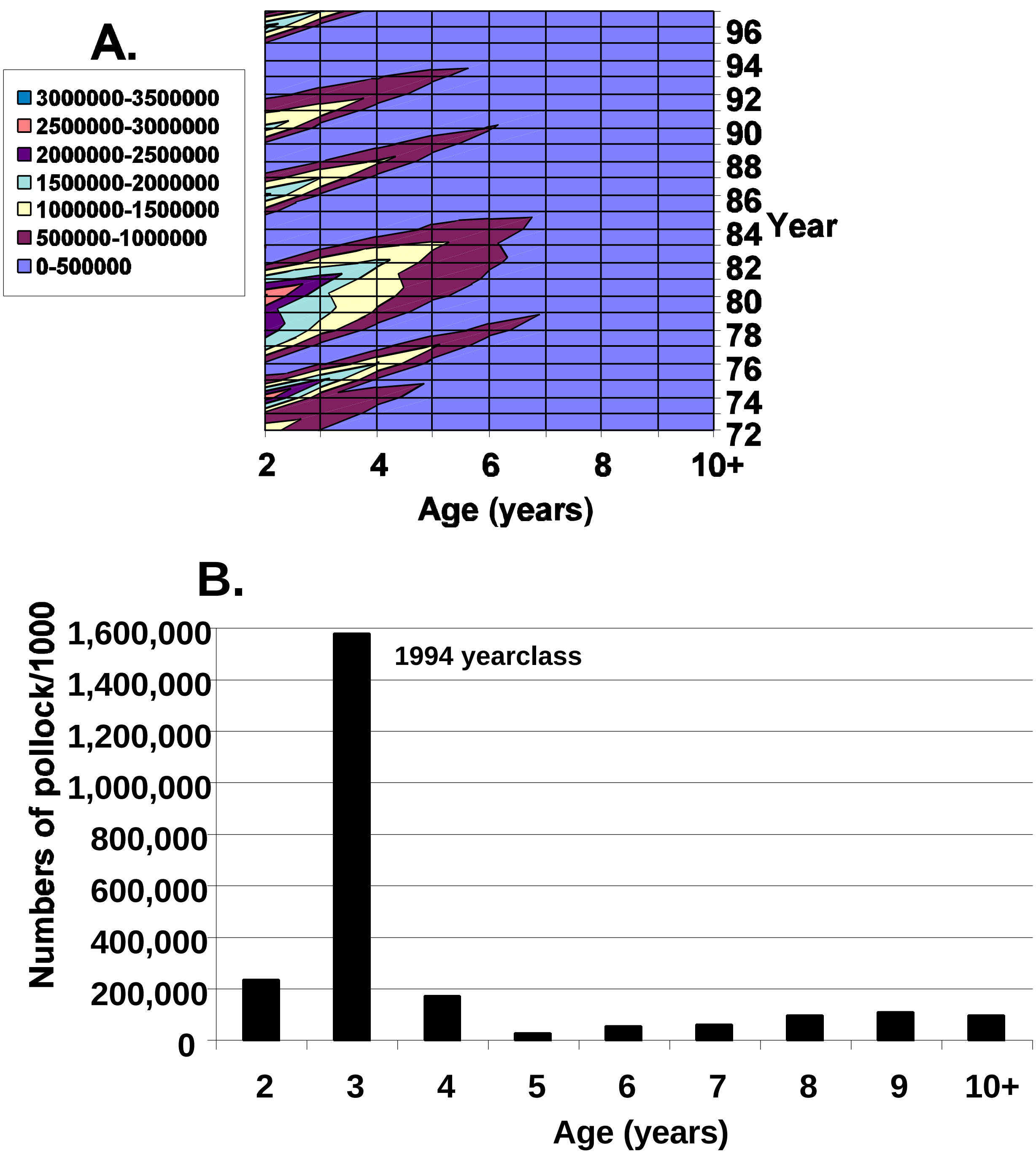


Figure 34. Age composition of the GOA pollock population (ages 2+) in 1972-97 (A) and in 1997 (B). Scale in (A) is in 1000s of fish.

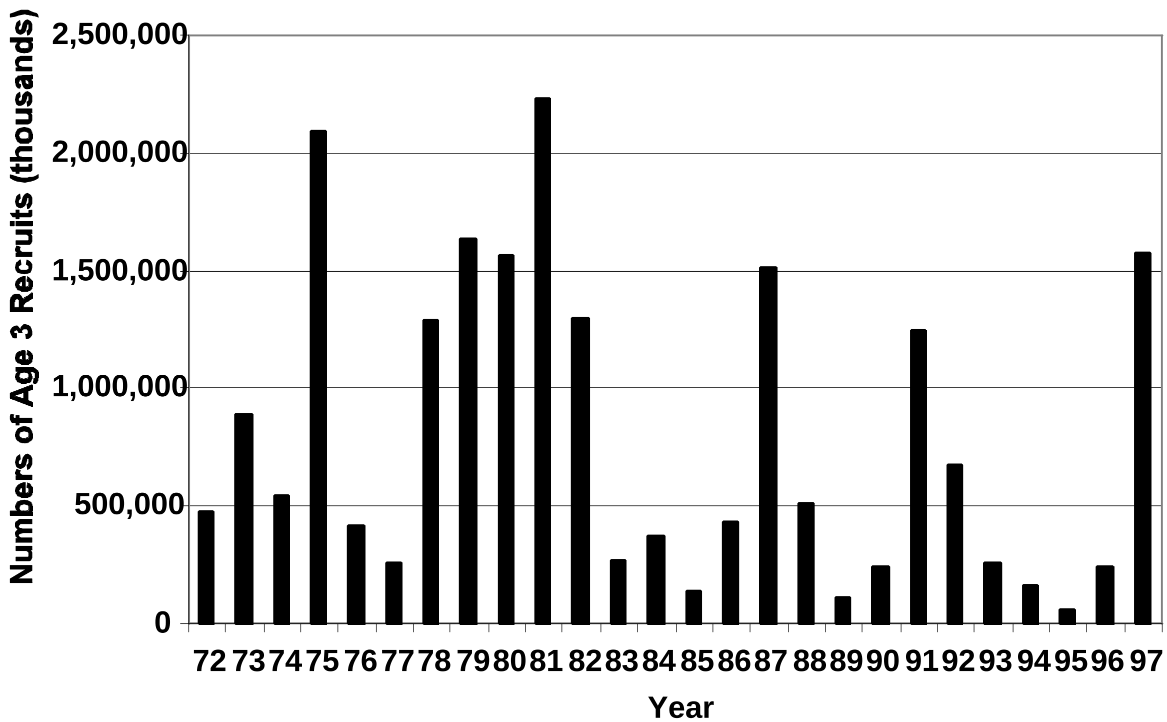


Figure 35. Numbers (thousands) of age 3 recruits to the GOA pollock population from 1972 to 1997 based on the 1997 GOA pollock stock assessment (Hollowed et al. 1997).

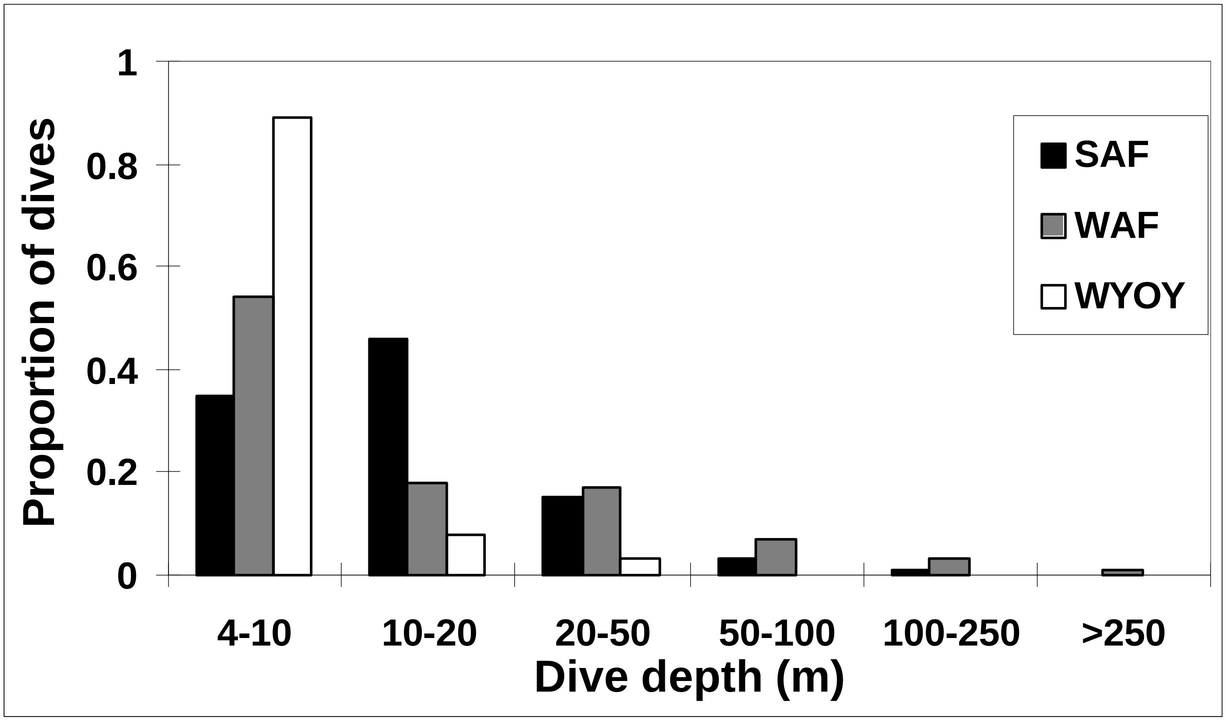


Figure 36. Proportion of dives by depth range for young-of-the-year (WYOY) and adult female Steller sea lions in summer (SAF) and winter (WAF) tracked during 1990-1993 (from Merrick and Loughlin 1997).

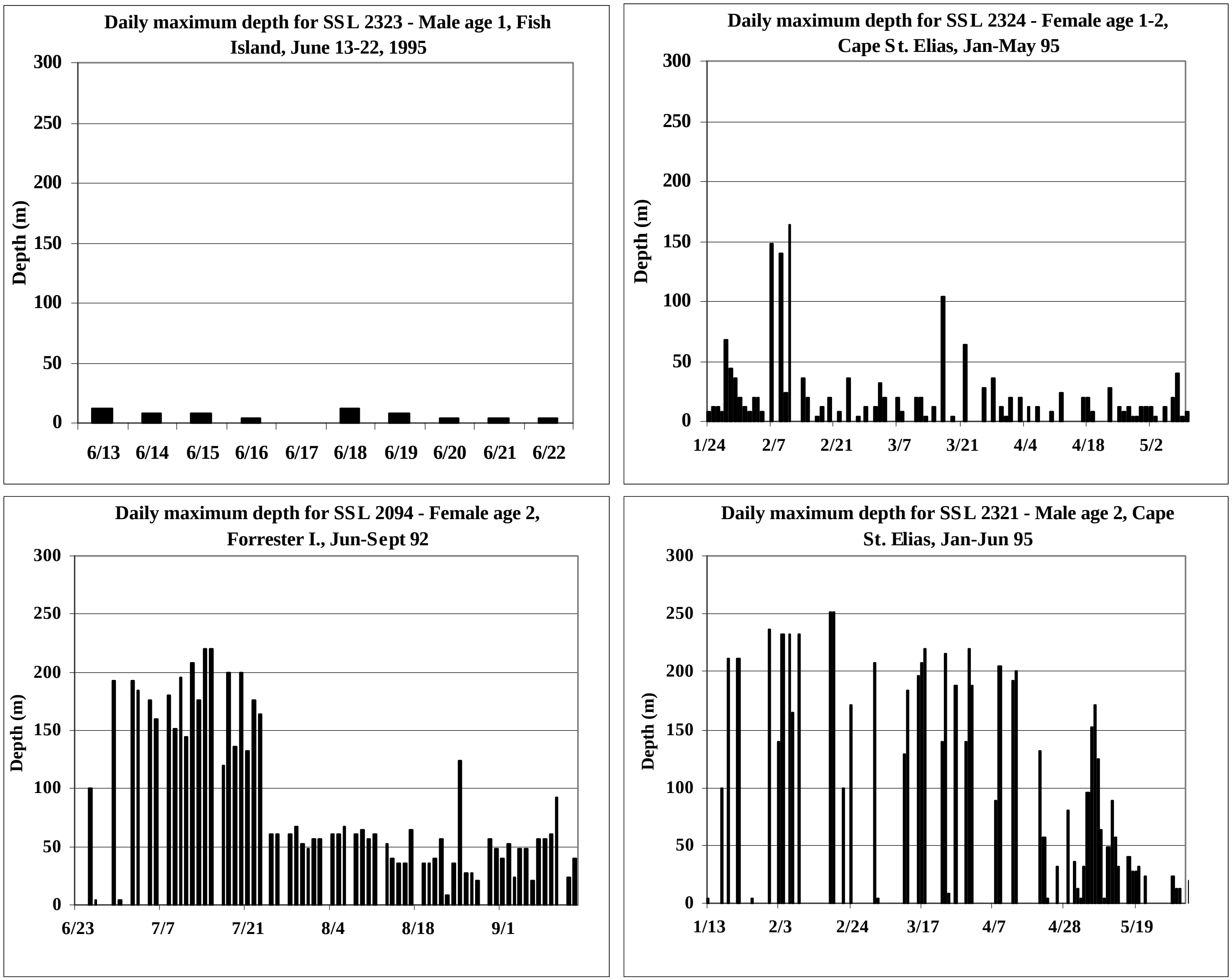


Figure 37. Maximum daily dive depths for four juvenile Steller sea lions (based on data from U. Swain, Alaska Department of Fish and Game).

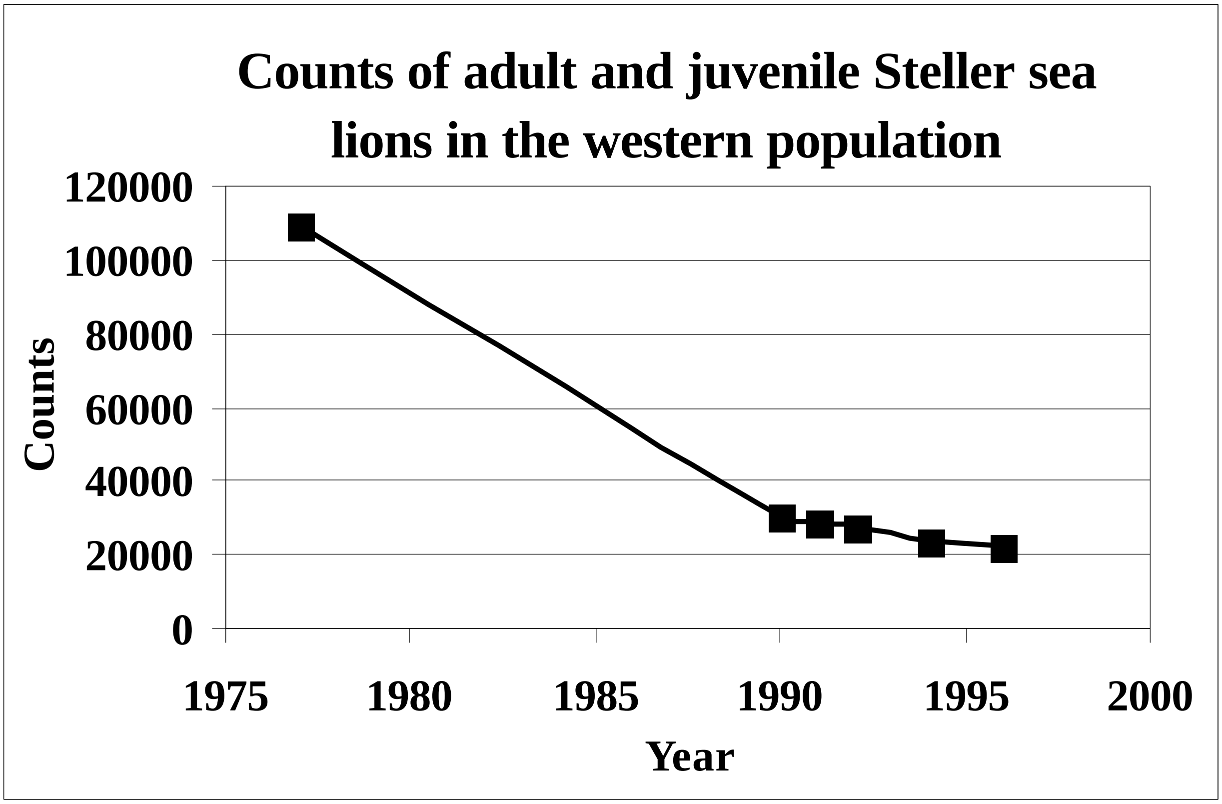


Figure 38. Counts of adult and juvenile Steller sea lions in the western population.

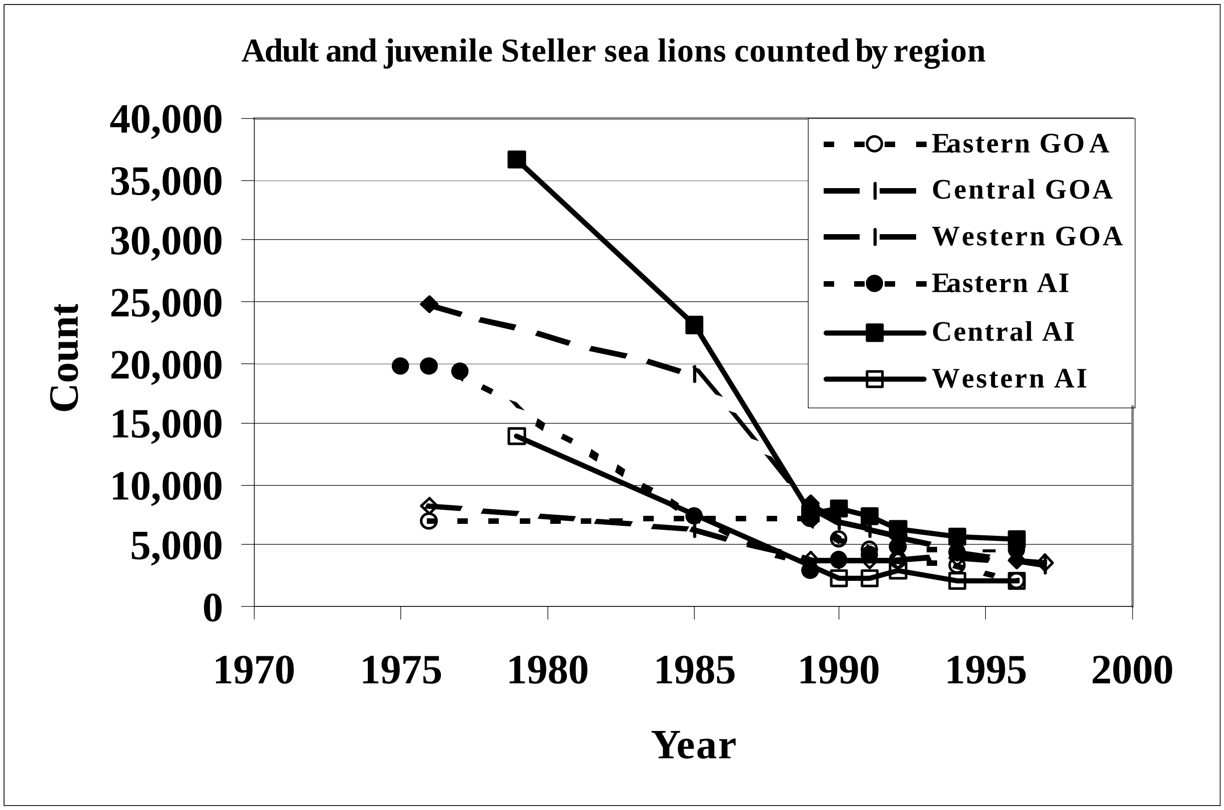


Figure 39. Counts by region of adult and juvenile Steller sea lions in the western population.

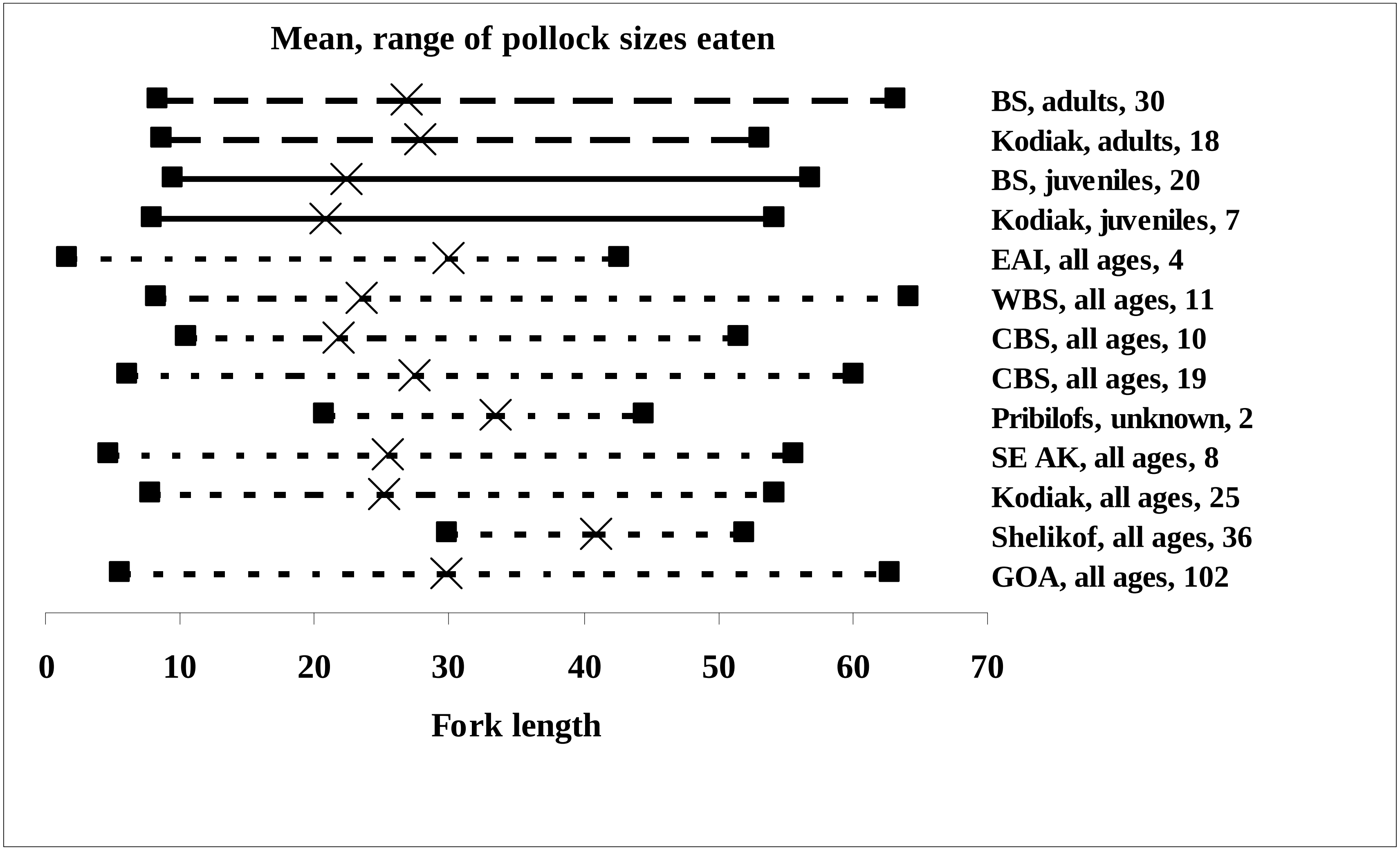


Figure 40a. Mean and range of pollock sizes consumed, based on stomach samples from Steller sea lions, as reported in Merrick and Calkins (1996; their page 164). BS = Bering Sea, EAI = eastern Aleutian Islands, WBS = western Aleutian Islands, CBS = central Bering Sea, SE AK = southeastern Alaska. Numbers indicate sample sizes (number of sea lions).

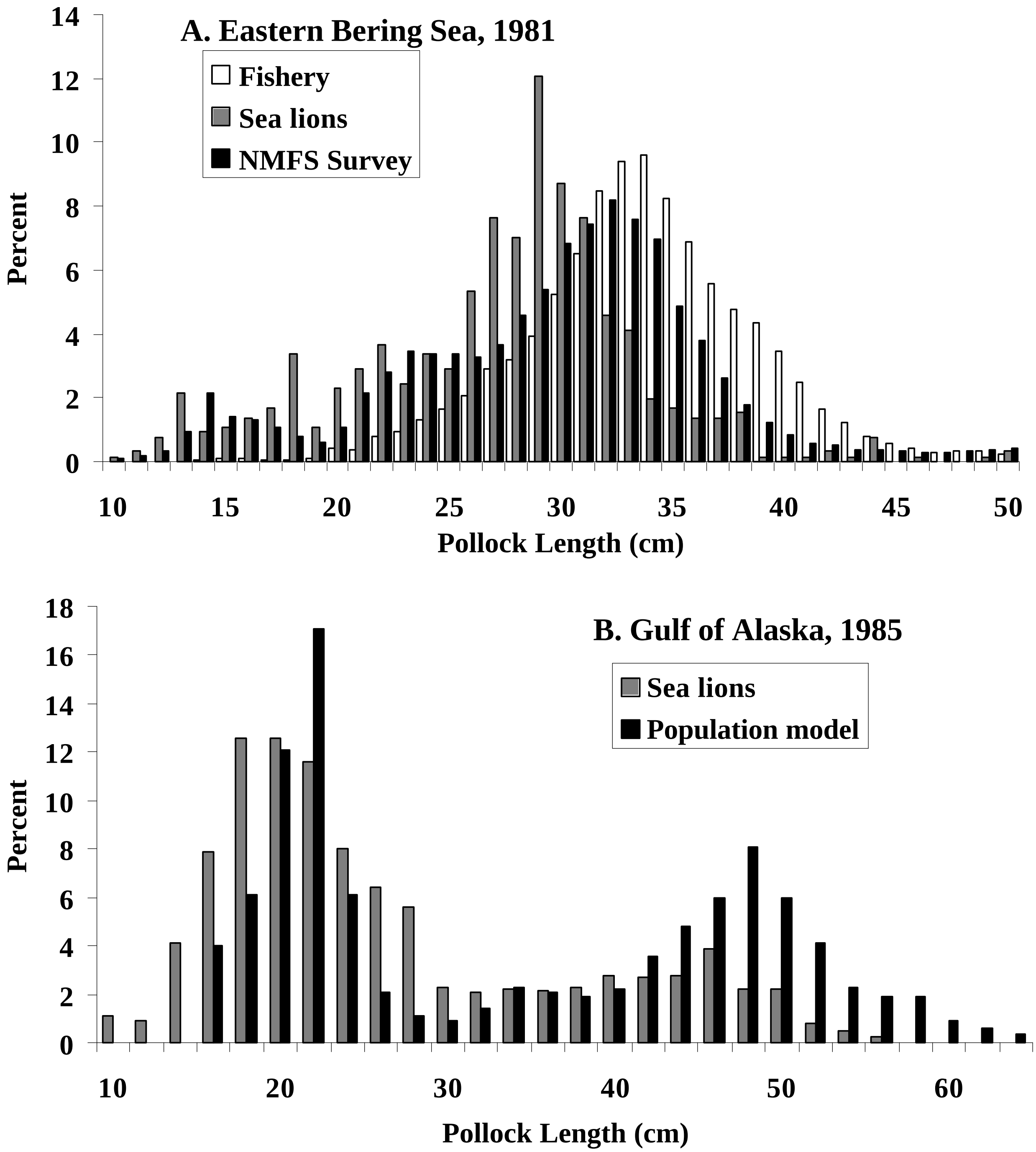
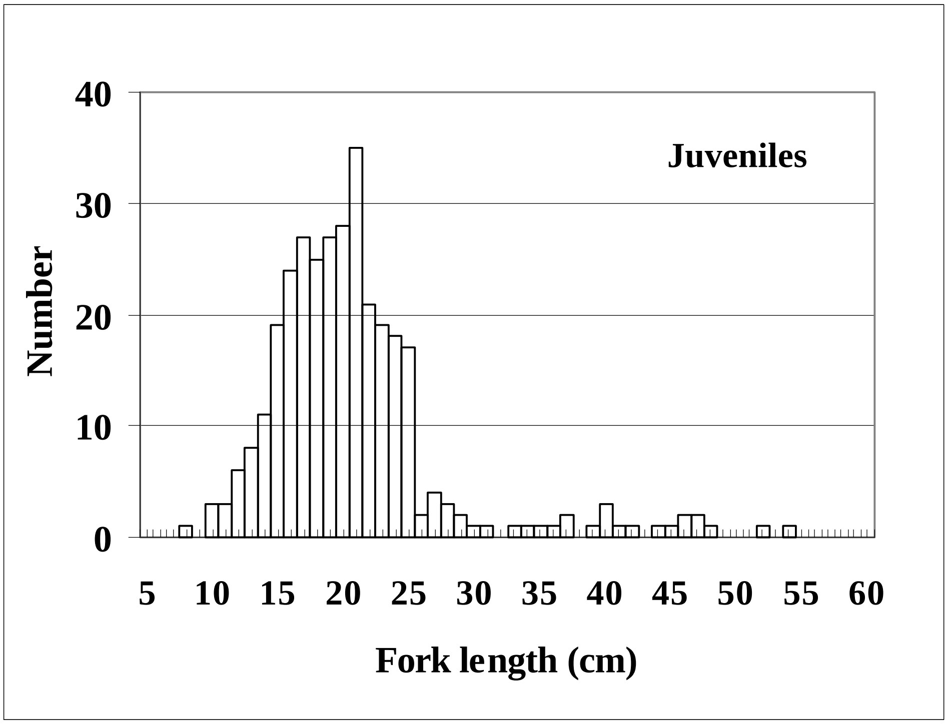


Figure 40b. (Top) Length-frequency distributions of pollock caught by the fishery, consumed by Steller sea lions, and comprising the population in the Bering Sea (from Fritz et al. 1995; their Fig. 11). (Bottom) Length-frequency distributions of pollock consumed by Steller sea lions and comprising the population in the GOA (from Fritz et al. 1995; their Fig. 12). (Note that these distributions also correspond approximately to Figure 2 in Merrick and Calkins 1996.)



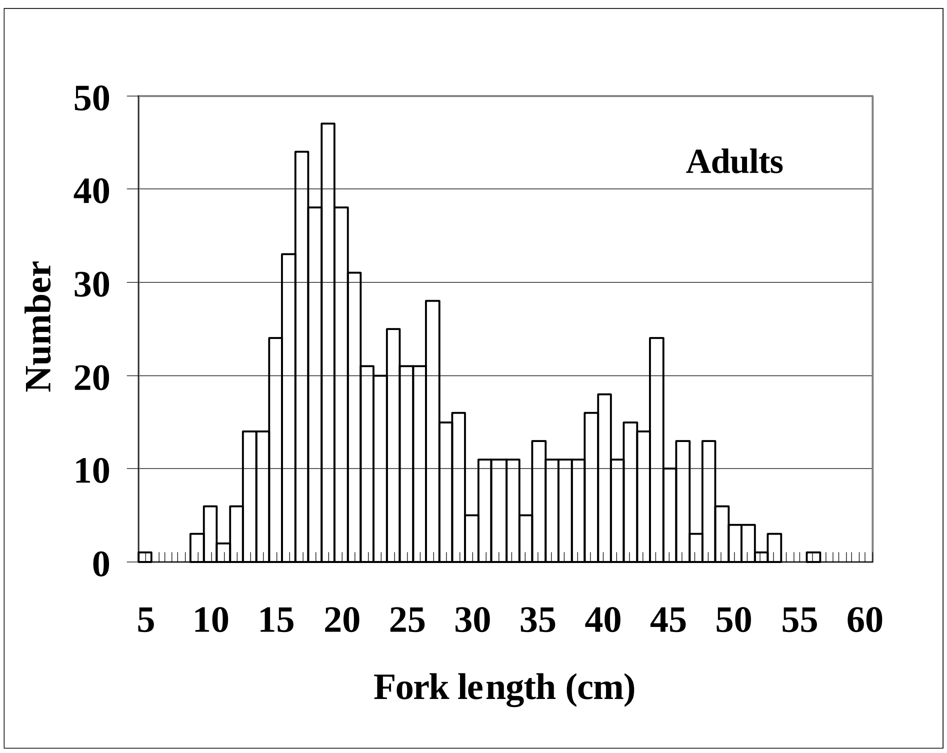


Figure 40c. Size distributions of pollock consumed by juvenile (top) and adult Steller sea lions in the Kodiak Island area in the GOA in 1985. (From Merrick and Calkins 1996; their Fig. 3.)

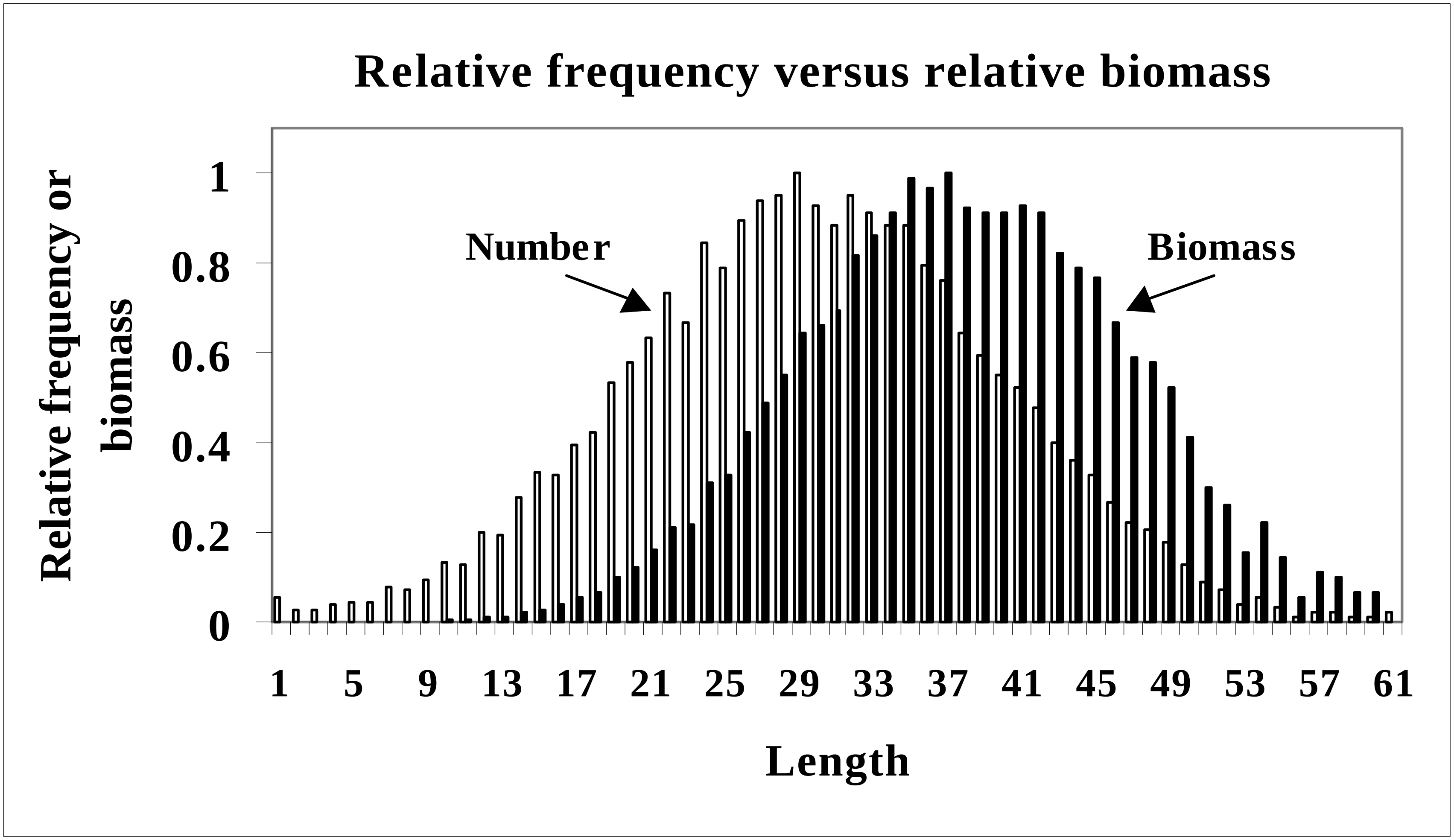


Figure 41. Comparison of hypothetical length frequency distribution of prey consumed (labeled "Number") versus relative biomass available from each length class of fish if were consumed at those frequencies (labeled "Biomass"). The length frequency distribution is based on 15,000 normally distributed deviates with mean of 29 cm and standard deviation of 10 cm. The biomass available from each length was calculated using $B = \alpha * L^{\beta}$, with α = 1.27E-05 and β = 2.885 (Hollowed et al. 1997). Because biomass increases with length, more biomass may be available from larger fish even if fewer of them are consumed. Length frequency distributions may, therefore, be biased indicators of the size of prey important to Steller sea lions or other predators.

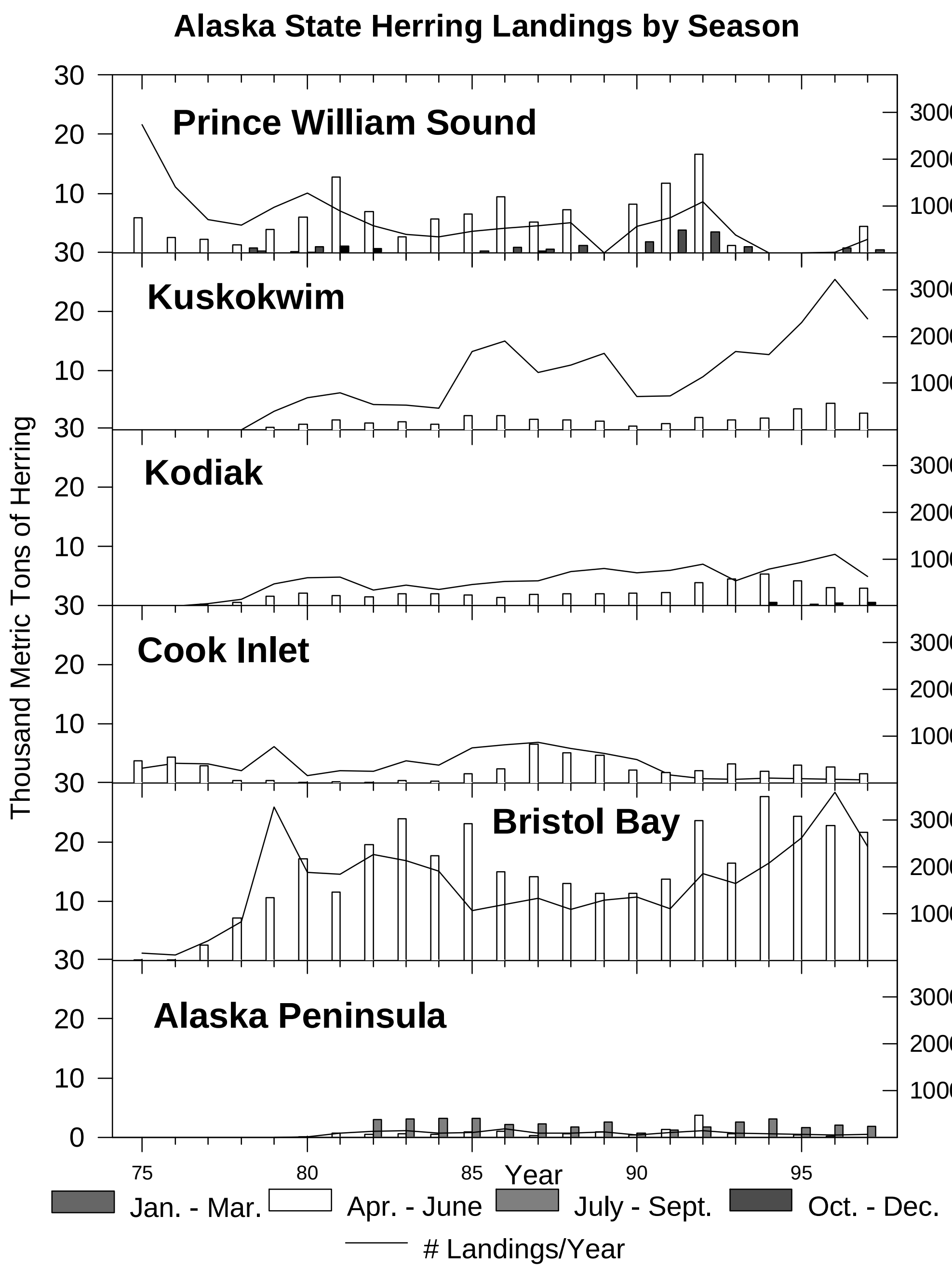


Figure 42a. Seasonal commercial catch of herring and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

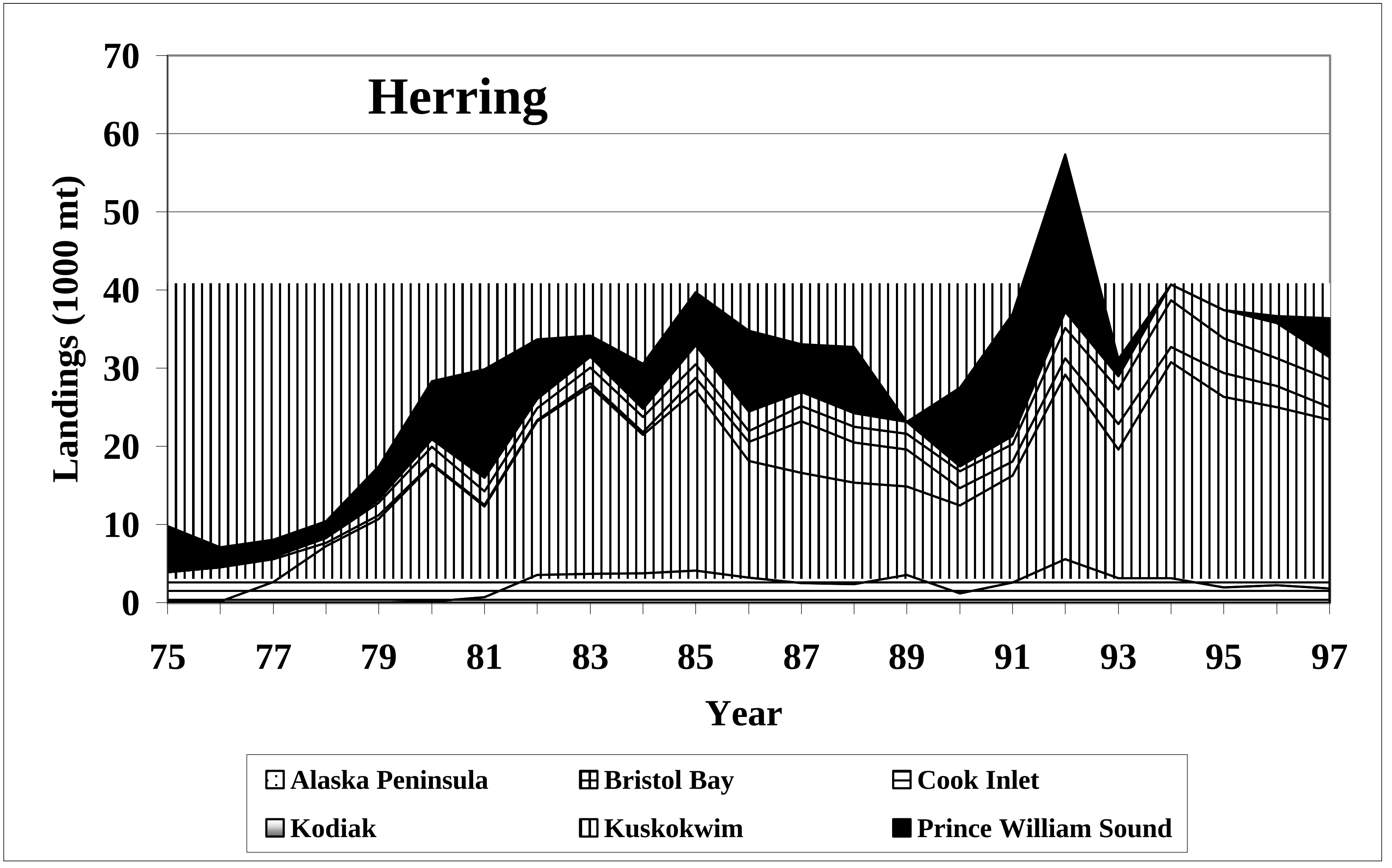


Figure 42b. Trends in Alaska State herring landings, from fish ticket data from the Alaska Department of Fish and Game.

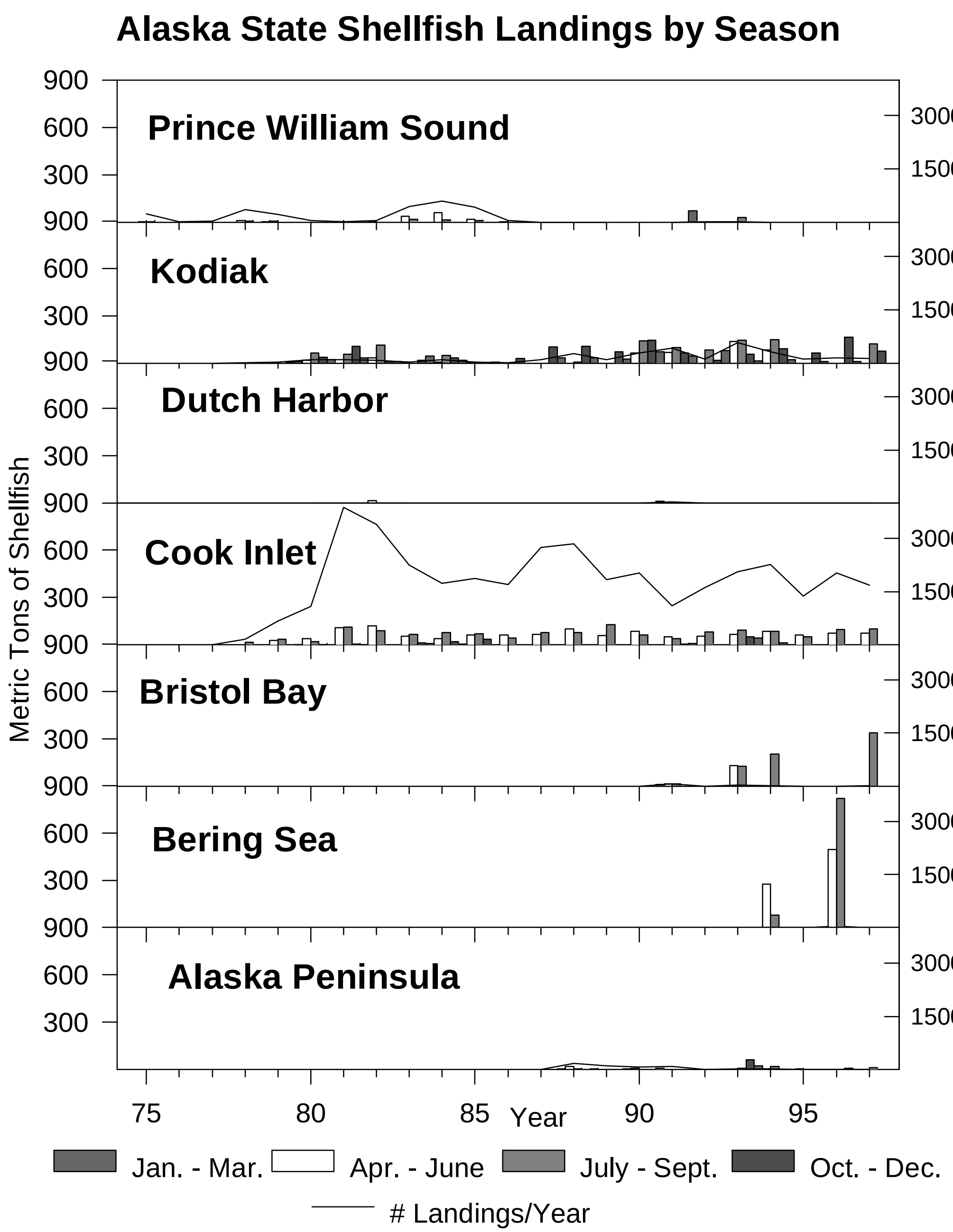


Figure 43a. Seasonal commercial catch of miscellaneous shellfish (excluding crab) and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

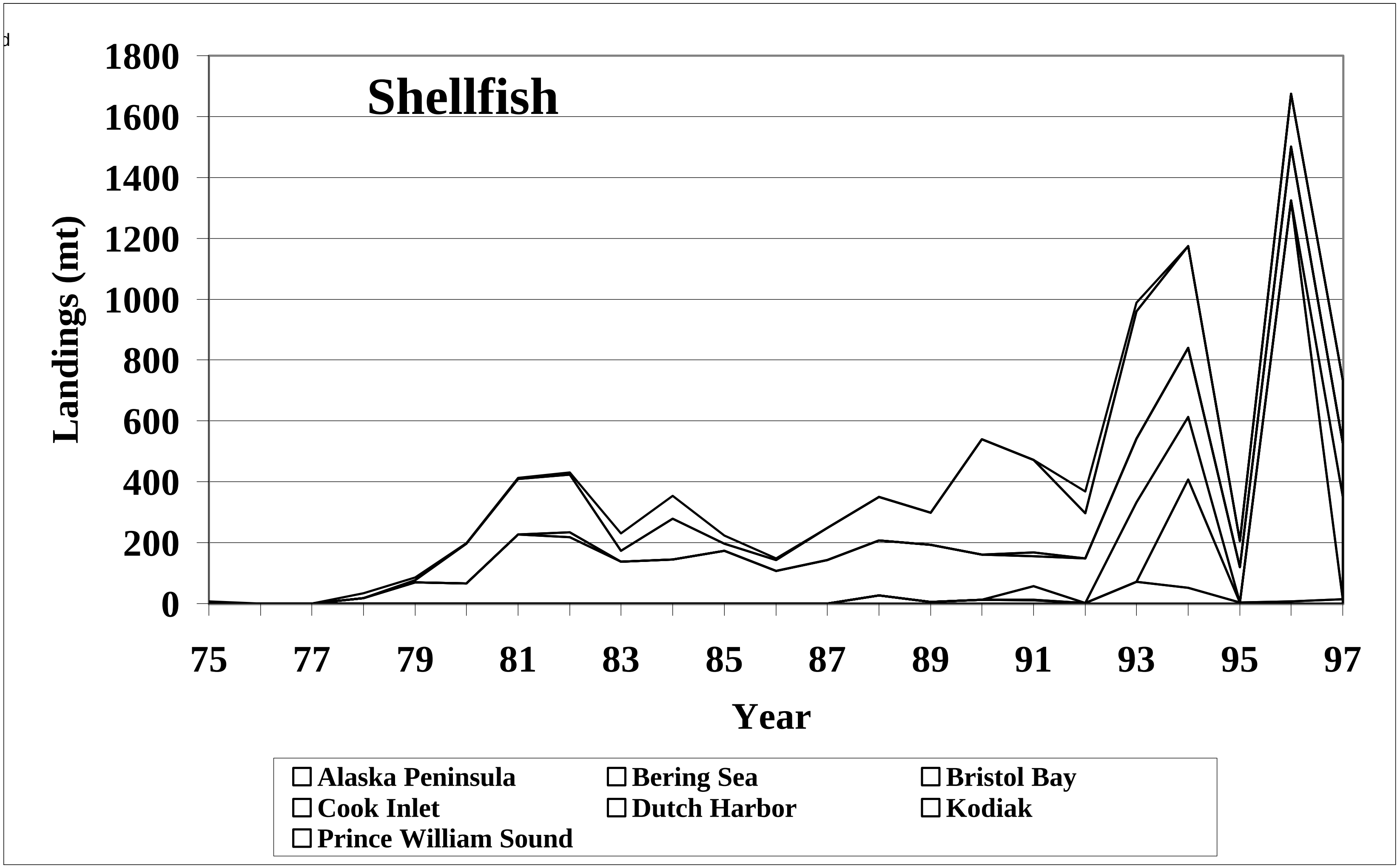


Figure 43b. Trends in Alaska State shellfish (excluding crab) landings, from fish ticket data from the Alaska Department of Fish and Game.

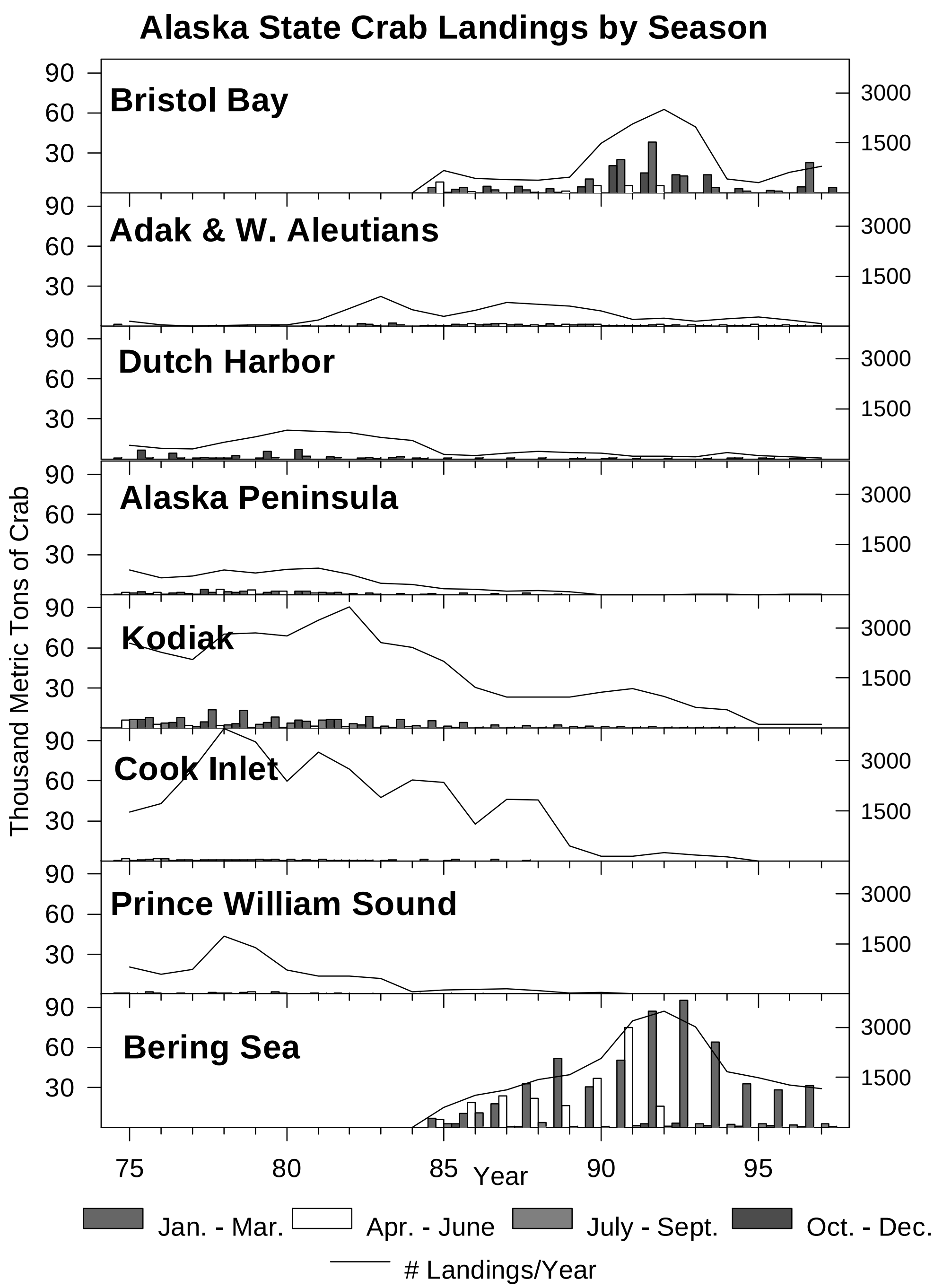


Figure 44a. Seasonal commercial catch of crab and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

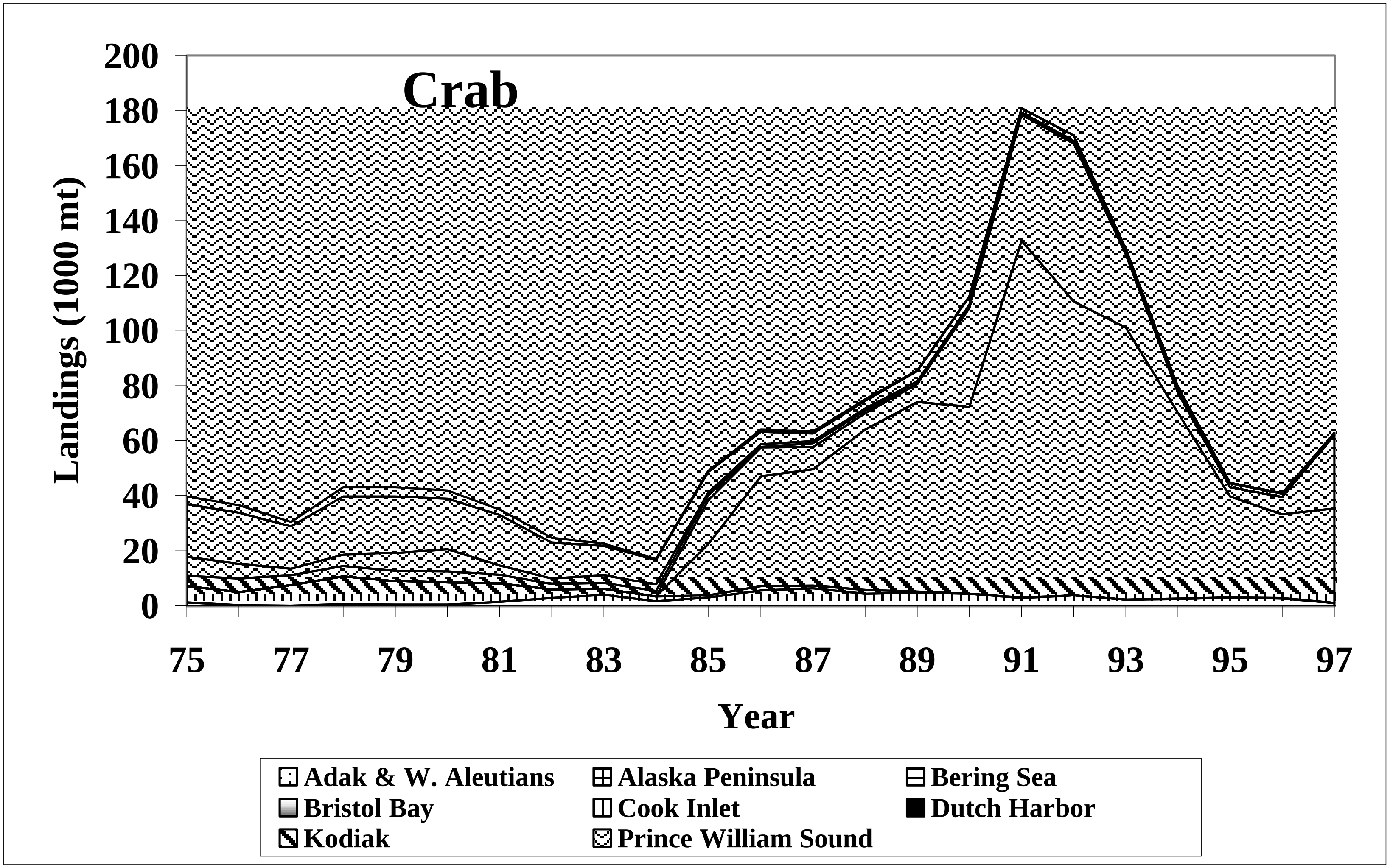


Figure 44b. Trends in Alaska State crab landings, from fish ticket data from the Alaska Department of Fish and Game.

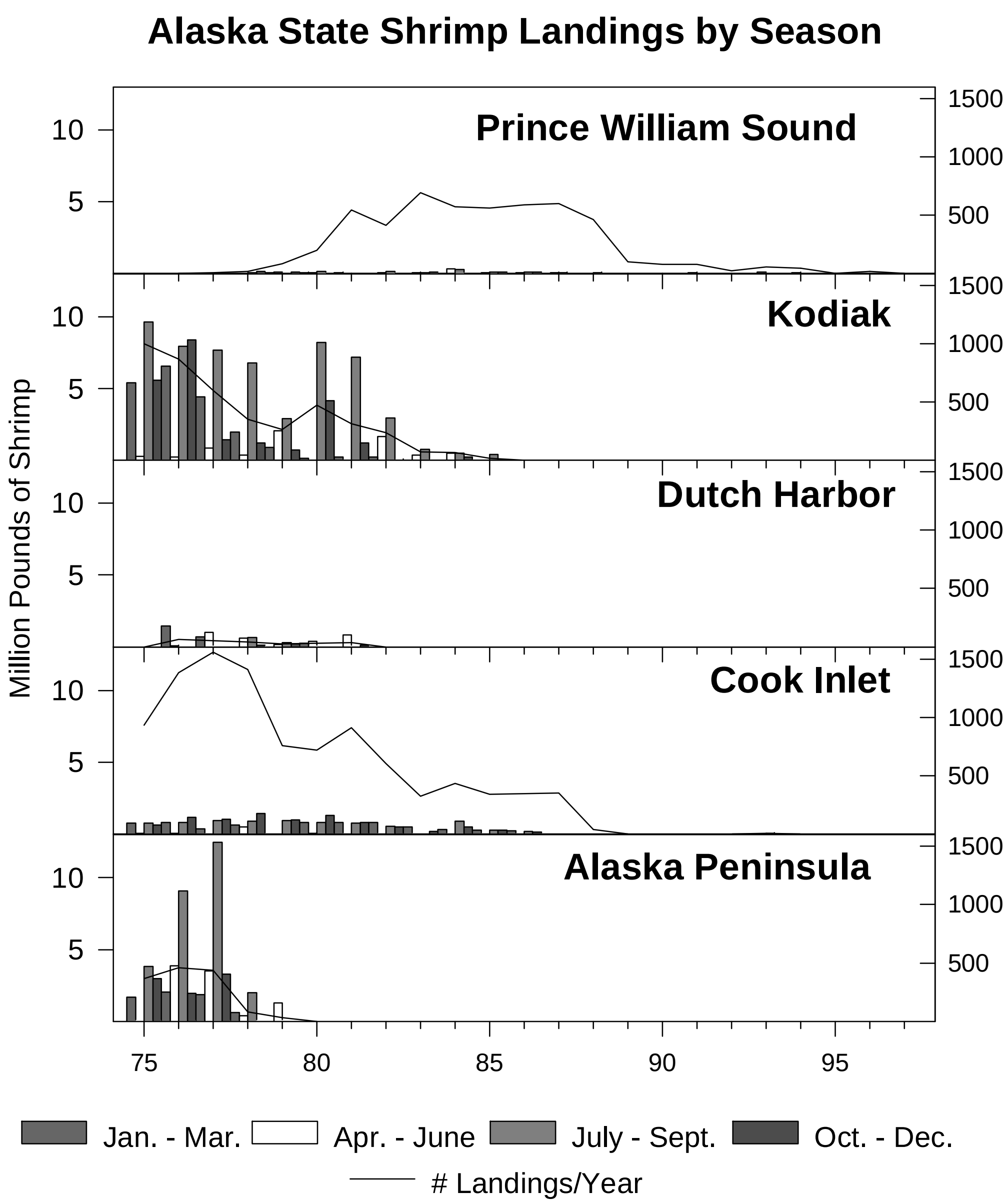


Figure 45a. Seasonal commercial catch of shrimp and annual number of landings in Alaskan waters other than in southeast Alaska or near Yakutat. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

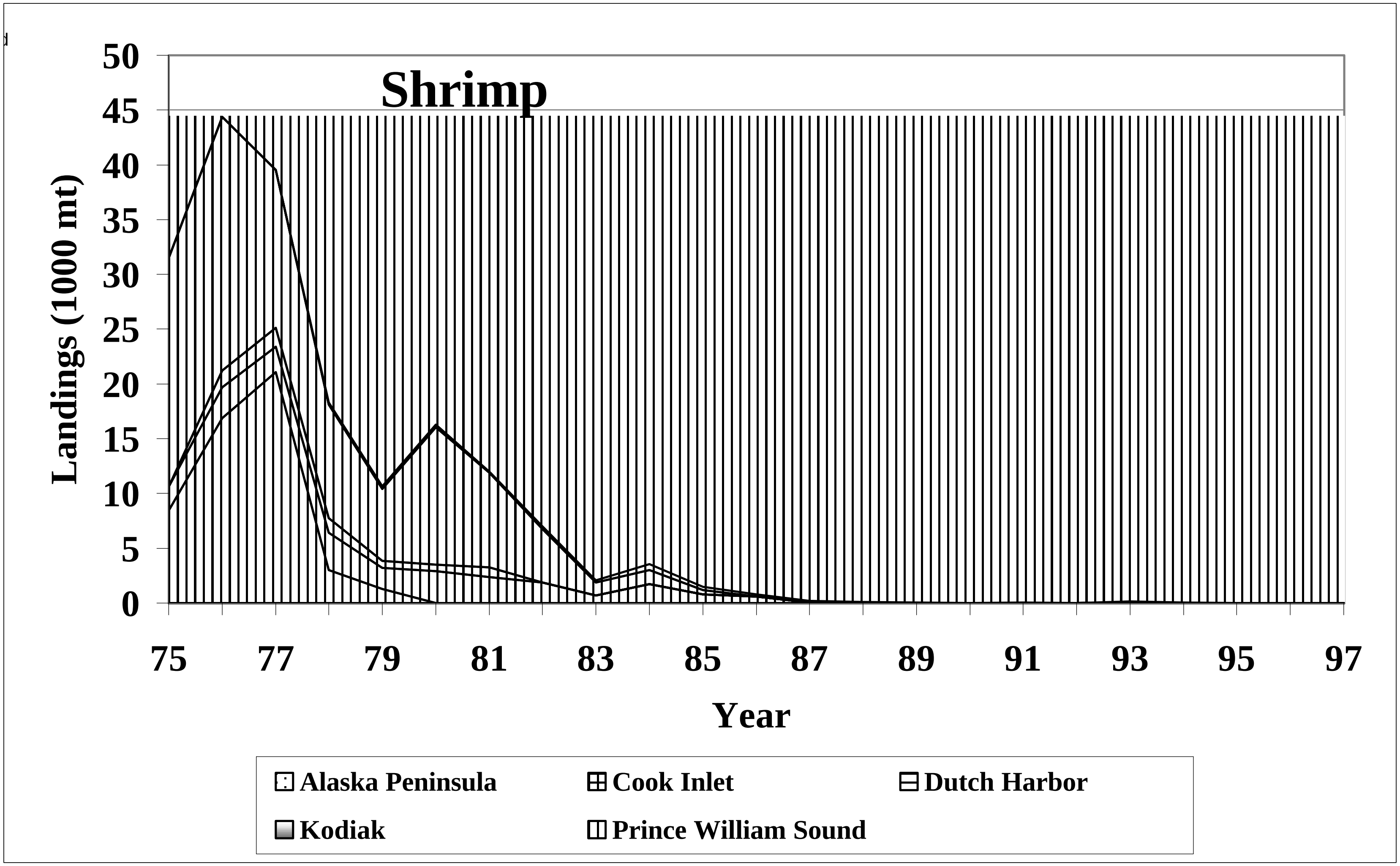


Figure 45b. Trends in shrimp landings in Alaskan waters other than in southeast Alaska and near Yakutat, from fish ticket data from the Ala Department of Fish and Game.

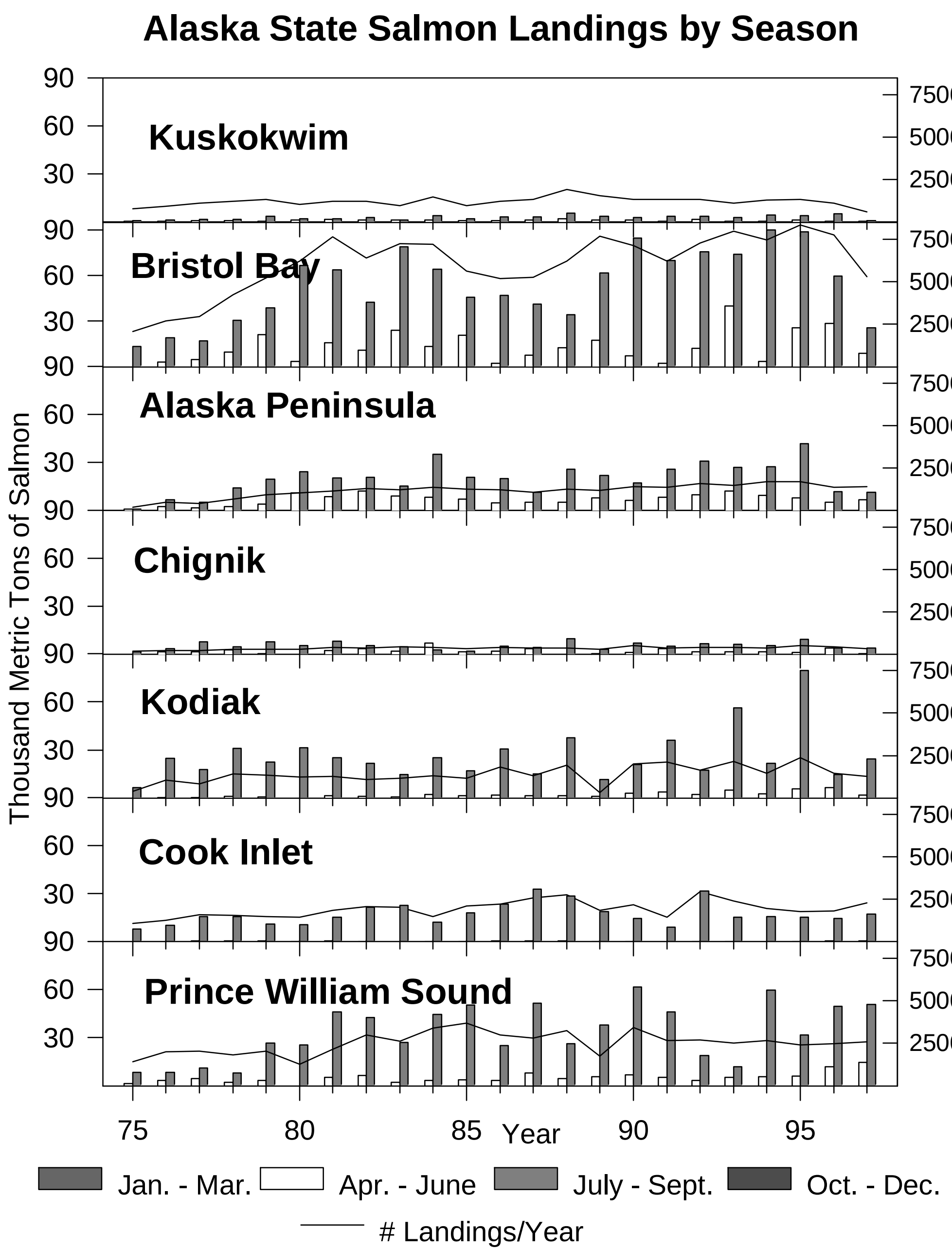


Figure 46a. Seasonal commercial catch of salmon and annual number of landings in Alaska State waters. Bars indicate harvest amounts by 3-month seasons. The line indicates the number of landings/year (right axis), based on fish ticket data from the Alaska Department of Fish and Game.

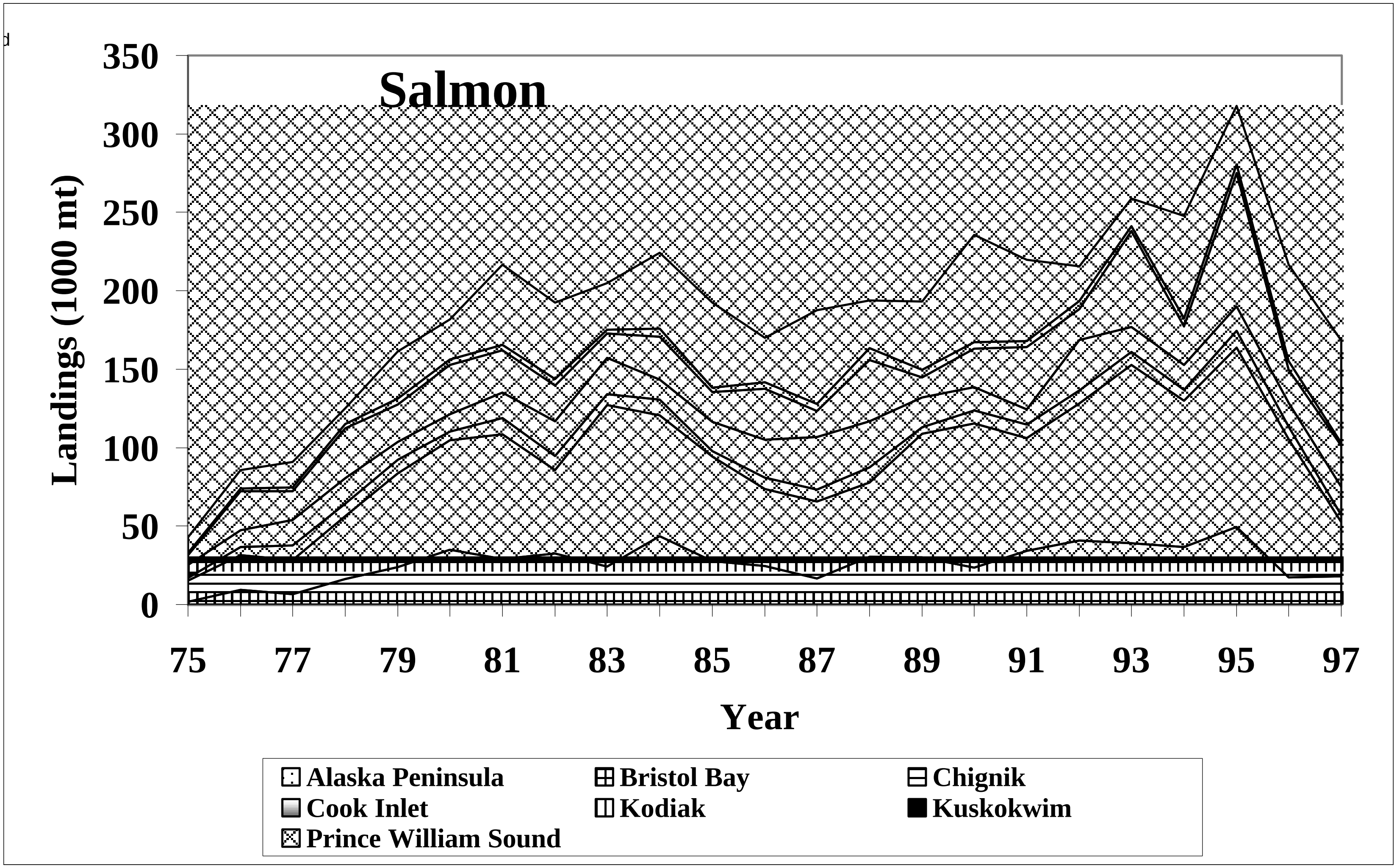


Figure 46b. Trends in Alaska State salmon landings, from fish ticket data from the Alaska Department of Fish and Game.