APPENDIX 1 CONTENTS OF THE BSAI AND GOA FMPS

This appendix provides a synopsis of the contents of

(1) the Fishery Management Plan for the Bering Sea/Aleutian Islands Groundfish, and

(2) the Fishery Management Plan for Groundfish of the Gulf of Alaska.

Bering Sea/Aleutian Islands

The Fishery Management Plan (FMP) for the Bering Sea/Aleutian Islands (BSAI) consists of the following sections and information.

1.0 Summary Sheet---The summary sheet is administrative and is used to identify the document as the Final Environmental Impact Statement for the implementation of the groundfish fishery in the BSAI area under the MSA. The summary describes the environmental impacts of the groundfish fishery as follows (p. 1).

> Implementation of this fishery management plan within the limit of its constraints is presumed not to cause adverse impacts on the environment. Conservation measures are provided for species for which they are deemed necessary. Those measures and the conduct of the fishery as outlined will be beneficial to the ocean environment affected, to demersal and pelagic fishes and to the human environment.

The summary sheet also includes a listing of the FMP amendments through amendment 59, implemented January 25, 1999.

2.0 Executive Summary---This section lists the management objectives to be attained (see section 2.2.1 above), and a summary of the ecological, economic, and social impacts of the plan. Under ecological impacts, the executive summary states the following (p. 13).

> In the context of long-term relationships, fishery managers are just now beginning to find out, understand and quantify the complex relations among species and between biota and the environment of the ecosystem in the Bering Sea/Aleutian Islands area. Until that understanding is more fully developed, it is not possible to predict the long-term effect on the ecosystem of the current, single-species management strategies (as opposed to the integrated ecosystem method) or of subtle environmental changes....
>
> It is generally recognized by fisheries scientists that the existing theories and models pertaining to fishery resources management suffer some fundamental inadequacies; concepts and theories must be developed to answer present and future management decisions. Until such new concepts supercede the old, the latter can still serve as a useful basis for deriving management decisions, providing their limited and underlying assumptions are recognized and evaluated with the best available information. This is the philosophy and approach used throughout this plan.

3.0 Introduction to the Plan---The introduction explains that this plan replaced the preceding Preliminary Fishery Management Plan for the Trawl and herring Gillnet Fisheries of the Bering Sea and Aleutians. The introduction also describes the geographic area covered by the plan, and the goals and secondary objectives for the plan (see section 2.2.1). Finally, the introduction provides operational definitions of terms, including overfishing and the six-tier system for setting catch targets and limits.

4.0 Description of the Fishery---This section begins with a more detailed description of the geographic areas involved or potentially affected by the BSAI groundfish fishery, and then provides a brief overview of the species and stocks taken in the fishery. The remainder of the section describes the history of exploitation, with emphasis on the foreign fisheries.

5.0 History of Management---The measures used to manage the historical fishery (both domestic and foreign) are described, together with their purposes and effectiveness.

6.0 History of Research---This section provides an overview of research conducted by the U.S. and foreign scientists prior to the implementation of the plan.

7.0 Socioeconomic Characteristics of the Domestic Fishery---The socio-economics of the fishery prior to the implementation of the plan are described in this section.

8.0 Biological and Environmental Characteristics of the Fishery---This section begins with brief summaries of the target and other species, the fisheries, and limited trophic, habitat, and life history data on each species or species complex. The section then continues with dated summaries of stock units, data sources for catch per unit effort and other biological data, quality of data, ecological relationships, environmental characteristics of the affected area, biological characteristics of the Bering Sea, and ecosystem characteristics of the Bering Sea. The FMP includes in this section two figures illustrating the relations between age and numbers and biomass of pollock (FMP Fig. 21, reproduced here as Fig. 2.1), and the relations between age and biomass of pollock as consumed by fish and birds, consumed by marine mammals, removed by the fishery, and removed by natural mortality (FMP Fig. 22, reproduced here as Fig. 2.2). The section then continues with a section on status of the stocks (which is more a discussion of the allowable biological catch [ABC], maximum sustainable yield [MSY], and optimum yield [OY]) and then a description of the overall condition of the stocks. This section then ends with a description of habitat types, essential fish habitat for BSAI groundfish, fishing and non-fishing activities that may affect essential fish habitat, habitat conservation recommendations for fishing and non-fishing activities, prey species as a component of EFH, habitat areas of particular concern, and review and revision of essential fish habitat components of the FMP.

9.0 Other Considerations Which May Affect the Fishery---This section begins with a brief discussion of the potential conflict that could arise as a result of halibut bycatch in the groundfish fisheries. Next, the implications of the Marine Mammal Protection Act are described. In this section, the plan states the following (p. 275-277).

> "... this FMP is cognizant of the ecosystem and mammal population requirements. As reported in an earlier section on "Ecosystem Characteristics," a dynamic numerical marine ecosystem mode[l] is currently in use to study ecosystem interactions, including those by marine mammals. The Plan Development Team of this FMP is acutely aware and is striving for an "ecosystem approach" for managing the marine resources. It will, however, be some time (3-5 years) before an appropriate ecosystem model has become far enough developed, and empirically tested, to

> begin to be relied upon for resource management. Until that time, single species models will be applied to the fishery resources, but in a manner that will retain balance among the various fish components, be generally conservative, and be determined to be not detrimental to current marine mammal populations. The manner in which MSY, EY, and ABC were derived for each fish stock in Annex I has indirectly taken into consideration the volume of fish needed by marine mammals for their sustenance. For example natural mortality of fish stocks is taken into consideration in stock assessments and in its present application, includes the predation component by marine mammals.... Although specific ranges of optimum sustainable population have not been clearly determined for these [marine mammal] species, the impact of fisheries can be inferred from marine mammal population trends.... Of the seven species [of pinnipeds], the sea lions and fur seals might be significantly affected by groundfish harvest levels. ...[A] 50% decline in sea lion population has been noted since the late 1950s in the eastern Aleutian Islands. The factors that may have caused this decline are not certain but probably include (1) a westward shift in distribution since population abundance to the western Aleutians appears to be high; (2) commercial fisheries interaction since groundfish (primarily pollock) forms a significant portion of their diet; (3) disease such as leptospirosis; and (4) other unknown population control factors. This decline in abundance is of concern and should be watched more closely. The proposed total groundfish OY for 1980 for the Aleutians region is below past catch levels and if the abundance of fish is limiting for sea lions in this region, this FMP should leave more fish for sea lion consumption.... Although direct competition for food fish is one of many factors that affect marine mammal populations, the other factors are not readily quantifiable. Some of these mammals may be sensitive to disturbances created by fishing activities and may leave the area under such harassments.

With reference to the Endangered Species Act, the FMP simply states (p. 277) that

> The Federal action proposed in this fishery management plan is not likely to jeopardize the continued existence of endangered or threatened species, or result in the destruction or modification of habitat critical to those species.

The remainder of this section briefly describes the potential effects of activities related and unrelated to fishing activities, including the potential for habitat alteration, offshore petroleum production, coastal development and filling, marine mining, ocean discharge and dumping, derelict fragments of fishing gear and general litter, and benthic habitat damage by bottom gear. The section ends with a bio-economic factors with an example of cohort analysis for pollock, and a description of the crab-bait trawl fishery.

<u>10.0 Optimum Yield (OY) and Total Allowable Catch (TAC)</u>---This section describes MSY and OY for the groundfish complex, TACs, requirements of the Stock Assessment and Fishery Evaluation reports, the use of reserves set aside to ensure catches are consistent with quotas, and apportionments to the fishery.

<u>11.0 Catch and Capacity Descriptors</u>---This is a dated section on catch and processing capacity as the plan was being developed.

<u>12.0 Allocations between Foreign and Domestic Fishermen</u>---This section describes past allocation of quotas between foreign and domestic sectors of the fishery.

<u>13.0 Management Regime</u>---The majority of information on management of the BSAI groundfish

fisheries is included in this section. Objectives are listed first (see section 2.2.1 above), followed by a description of management areas within the BSAI region. BSAI species are then listed in five categories: prohibited, target, other, forage fish, and nonspecified. The fishing year is defined and criteria for establishing seasons are listed. Management measures for the domestic fishery are described next, including prohibited species, time/area closures and catch limits for prohibited species. These measures also include fishing area restrictions, and a section on marine mammal conservation measures, which states the following (p. 308-309).

> Regulations implementing the FMP may include special groundfish management measures intended to afford species of marine mammals additional protection other than that provided by other legislation. These regulations may be especially necessary when marine mammal species are reduced in abundance. For example, Steller sea lions are so reduced in abundance that they have been listed as threatened within the meaning of the Endangered Species Act. Even absent such a listing, regulations may be necessary to prevent interactions between commercial fishing operations and marine mammal populations when information indicates that such interactions may adversely affect marine mammals, resulting in reduced abundance and /or reduced use of areas important to marine mammals. These areas include breeding and nursery grounds, haul out sites, and foraging areas that are important to adult and juvenile marine mammals during sensitive life stages.
>
> Regulations intended to protect marine mammals might include those that would limit fishing effort, both temporarily [sic], spatially, around areas important to marine mammals. Examples of temporal measures are seasonal apportionments of TAC specifications. Examples of spatial measures could be closures around areas important to marine mammals. The purpose of limiting fishing effort would be to prevent harvesting excessive amounts of the available TAC or seasonal apportionments thereof at any one time or in any one area.

Areas closed to trawling are listed next, followed by gear restrictions. Reporting requirements and the observer program are described, followed by a description of effort-limiting programs including fixed-gear sablefish fisheries, the moratorium on the fisheries through 1999, the license limitation program initiated in 2000, and the Community Development Quota (CDQ) program. The need and mechanisms for inseason adjustments of the fisheries are explained, followed by a description of catch allocation by gear types for the different fisheries. The inshore/offshore allocation of pollock is described next, but the FMP notes that this information has been superceded by the American Fisheries Act of 1998. Experimental fishing permits are described, followed by a dated description of the management measures for the foreign fisheries. This section ends with a list of operational needs and costs, management measures to address identified habitat problems, measures to allow gear testing, and the improved retention/improved utilization program.

<u>14.0 Relationship of Recommended Management Measures to FCMA National Standards and Other Applicable Law</u>---This section is a dated description of the relation of the FMP to other federal and state laws.

<u>15.0 Research Needs</u>---This section lists and describes areas in need of research (p. 351).

> Research will be required to: (1) find means of improving the accuracy of commercial catch statistics; (2) refine estimates of abundance and biological characteristics of stocks through research resource surveys; (3) improve the capability for predicting changes in resources

abundance, composition, and availability; (4) develop means of reducing the incidental catch of non-target species; (5) identify subpopulations; and (6) examine the direct effects of man's activities on fish habitats and ecosystems.

With respect to the sixth point, this section also states the following (p. 352).

> Research needs related to maintaining the productive capacity of fish habitat can be broadly classified as those which (a) examine the direct affects of man's activities (such as fishing, oil exploration, or coastal development), and (b) apply fisheries oceanography in an ecosystem context (such as migration and transport patterns, predator/prey relationships, life histories). Both categories of research serve to increase the understanding of natural systems and the ability to detect and measure change caused by natural or man-made forces.

16.0 Statement of Council Intentions to Review the Plan after Approval by the Secretary of Commerce---This section is a statement that following implementation of the plan, the Council will maintain a continuing review of the fisheries managed under this plan through four methods.[1]

17.0 References---This section is self explanatory.

18.0 Appendices and Annexes---Appendix I is a Sample Community Profile. Appendix II is an example of a Pollock Cohort Analysis. Appendix III is a description of Closed Areas. Appendix IV describes Programs Addressing Habitat of Bering Sea/Aleutian Islands Groundfish Stocks. Annex I describes the Content of Stock Assessment and Fishery Evaluation Reports. Annex II describes the Derivation of Total Allowable Level of Foreign Fishing (TALFF). Annex III provides three tables of Catch Statistics of the Bering Sea/Aleutian Groundfish Fishery. Annex IV provides Information on Marine Mammal Population.[2] Annex IV then provides brief overviews of the Steller (northern) sea lion, northern fur seal,

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[1] The four methods listed are the following.

1. Maintain close liaison with the management agencies involved, usually the Alaska Department of Fish and Game and the National Marine Fisheries Service, to monitor the development of the fisheries and the activity in the fisheries.
2. Promote research to increase their knowledge of the fishery and the resource, either through Council funding or by recommending research projects to other agencies.
3. Conduct public hearings at appropriate times and in appropriate locations, usually at the close of a fishing season and in those areas where a fishery is concentrated, to hear testimony on the effectiveness of the management plans and requests for changes.
4. Consideration of all information gained from the above activities and development if necessary, of amendments to the management plan. The Council will also hold public hearings on proposed amendments prior to forwarding them to the Secretary for possible adoption.

[2] Annex IV states the following. "Information on distribution and migration, abundance and trends, feeding habits, and any problems induced by fisheries on seven marine mammal populations in the Bering Sea/Aleutian Region was provided by the Marine Mammal Division of the Northwest and Alaska Fisheries Center and included in this annex, the information [is] summarized mainly from the annual report of the Department of Commerce on the Administrati[on] of the Marine Mammal Protection

and bearded, ringed, harbor, larga, and ribbon seals. Annex V lists literature cited. Annex VI lists species categories for the BSAI groundfish fishery. Finally, Annex VII describes Information on Important Habitat for Non-FMP Species Pacific Halibut and Pacific Herring.

Gulf of Alaska

The Fishery Management Plan (FMP) for the Gulf of Alaska (GOA) consists of the following sections and information.

1.0 Introduction---The introduction gives general background on the FMP. With respect to environmental affects, the introduction states (p. 1) that the FMP "forms the major component of an Environmental Impact Statement which assesses the effect that implementation of this plan is expected to have on the environment of the region which encompasses the Gulf of Alaska."

2.0 Goals and Objectives---The goals and objectives of the plan are listed (as listed in 2.2.1 above), together with a section on operational definition of terms. The tier system for setting catch limits is described under the definition of overfishing.

3.0 Areas and Stocks Involved---The geographic area of the GOA groundfish fishery is described, together with listings of target stocks, prohibited stocks, forage fish, and other species.

4.0 Management Measures---This section is divided into three areas: framework measures, conventional measures, and other measures. Framework measures include the procedures for setting the TAC, the optimum yield range, the Stock Assessment and Fishery Evaluation Reports, setting of reserves (to prevent fisheries from exceeding quotas), prohibited species catch limits and incentives to reduce halibut bycatch, in-season adjustment of time and area, and time/area closures. Conventional measures describe permit requirements, general restrictions (catch, processing, gear), recordkeeping and reporting requirements, gear allocations, experimental fishing permits, inshore/offshore allocation of pollock and Pacific cod, fishing seasons, observers, habitat protection, and vessel safety considerations. Other measures pertain to access limitation for fixed sablefish fisheries, the (past) moratorium on vessels entering the fisheries, and the new groundfish license limitation program, size limits, gear testing, marine mammal conservation measures, and the improved retention/improved utilization program. The statement on marine mammal conservation measures (p. 50) is the same as provided in section 13.0 of the BSAI FMP.

5.0 Information on the Fishery and Resources---This section begins with a description of the biological and environmental characteristics of the resource species, including habitat requirements by life history stage, status of stocks, and a brief description of the habitat types in the GOA. The next part of this section describes the fisheries (domestic and foreign [which no longer exists]), the socioeconomic characteristics of the resources and fisheries, interactions between and among user groups, relationship of the management plan to other existing laws and policies, enforcement requirements, financing requirements, references, essential fish habitat for GOA groundfish, and information on important habitat for non-FMP species including Pacific halibut and GOA crab species.

Act of 1972 for the period of April 1, 1977 through March 31, 1978 (DOC, 1978) and the Final Environmental Impact Statement on Consideration of a Waiver of the Moratorium and Return of Management of Certain Marine Mammals to the State of Alaska, Volumes I and II (DOC and DOI, 1977.)"

APPENDIX 2 TARGET SPECIES AND FISHERIES

This appendix presents descriptions of major target species summarizing important life history traits, trophic interactions, habitat, stock assessment. and status. Additional information is available in the 2000 Stock Assessment and Fishery Evaluation reports, available from the North Pacific Fishery Management Council (605 West 4th, Suite 306, Anchorage, Alaska 99501-2252)

Pollock

Stock Description and Life History

Pollock (*Theragra chalcogramma*) is the most abundant species within the eastern Bering Sea (EBS) and the second most abundant groundfish stock in the Gulf of Alaska (GOA). It is widely distributed throughout the North Pacific in temperate and subarctic waters (Wolotira et al. 1993). Pollock is a semidemersal schooling fish, which becomes increasingly demersal with age. Approximately 50 percent of female pollock reach maturity at age four, at a length of approximately 40 cm. Pollock spawning is pelagic and takes place in the early spring on the outer continental shelf. In the EBS, the largest concentrations occur in the southeastern area north of Unimak Pass. In the GOA, the largest spawning concentrations occur 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 piscivorus 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.

Although stock structure of Bering Sea pollock is not well defined (Wespestad 1993), three stocks of pollock are recognized in the BSAI for management purposes: EBS, Aleutian Islands and Aleutian Basin (Wespestad et al. 1997b). Pollock in the GOA are thought to be a single stock (Alton and Megrey 1986) originating from springtime spawning in Shelikof Strait (Brodeur and Wilson 1996).

The Fishery

Pollock supports the largest fishery in Alaskan waters. In the Bering Sea/Aleutian Islands region (BSAI), pollock comprise 75-80 percent of the catch. In the GOA , pollock constitute 25-50 percent of the catch. In the BSAI, pollock can only be targeted with pelagic trawl gear to minimize the potential interaction with other groundfish species and to reduce the magnitude of bottom disturbance. Pollock are also caught with bottom-trawl gear as bycatch from other fisheries.

In the BSAI, the season has traditionally been broken into two parts, a roe season during early winter, and a surimi (imitation crab)/filet season during the second half of the year. Currently, to minimize the potential indirect interaction with Steller sea lions (*Eumetopias jubatus*), the seasons have been managed to occur over broader areas and over seasons that are less contracted in time.

BSAI pollock are caught as bycatch in other directed fisheries but because they occur primarily in well defined aggregations, the impact of this bycatch is typically minimal. Discard rates through the early 1990s (discards/retained catch) of pollock in the directed fishery have been about 7-8 percent but in 1998 dropped to 1.5 percent (Ianelli et al. 1999). This is due to the fact that in 1998, discarding of pollock was prohibited except in the fisheries where pollock are in bycatch-only status. Pollock are caught as bycatch in the trawl Pacific cod, rock sole, and yellowfin sole fisheries.

In the GOA, major exploitable concentrations are found primarily in the central and western regulatory areas (147° - 170° W). Pollock from this region are managed as a single stock that is separate from the BSAI pollock stocks (Alton and Megrey 1986). The pattern of the fishery generally reflects the broad spatial distribution of pollock throughout the Central and Western regions of the GOA. Concentrations of pollock shift to reflect the seasonal migrations to spawning locations. The fishery generally occurs at depths between 100 and 200 m (Hollowed et al. 1997). Important pollock fishery locations include Shelikof Strait, the canyon regions of the east side of Kodiak Island, and Shumagin Canyon.

Megrey (1989) documented the historical expansion of the pollock fishery in the GOA. He identified four phases of expansion, beginning with a developmental phase between 1964-1971 when the fishery was dominated by foreign trawlers that captured pollock incidentally in mixed species catches. The second phase occurred between 1972 and 1980 when directed pollock harvests were initiated by foreign and joint venture fisheries. Floating freezer-surimi trawlers were active in the GOA during the second phase of fishery development. The third phase of development occurred between 1981- 1985. This phase was characterized by joint venture operations. During this period, the Shelikof Strait spawning concentrations were discovered. Surimi production and roe harvest were emphasized during this phase of development. Foreign vessels were eliminated from the pollock fishery in the late 1980s. This phase was marked by the passage of the in-shore/off-shore amendment which mandated that 100 percent of the pollock catch would be processed at shoreside plants. During this period the fishing community moved from a bottom trawl fishery to a mid-water fishery due to management measures established to control bycatch of prohibited species. Pacific halibut (*Hippoglossus stenolepis*) taken in the pollock fishery are added to the total for the shallow water complex halibut mortality cap. When the halibut cap is reached for the shallow water complex, trawling for species in the complex is prohibited except for vessels using pelagic trawls.

Trophic Interactions

The diet of pollock in the EBS has been studied extensively (Dwyer 1984, Lang and Livingston 1996, Livingston 1991b, Livingston and DeReynier 1996, Livingston et al. 1993). These studies have shown that juvenile pollock is the dominant fish prey in the EBS; other fish are also consumed by pollock including juveniles of Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, rock sole, yellowfin sole, Greenland turbot, Pacific halibut and Alaska plaice. On the shelf area of the EBS, the contribution of these other fish prey to the diet of pollock tends to be very low (i.e., usually less than 2 percent by weight of the diet; (Livingston 1991b, Livingston and DeReynier 1996, Livingston et al. 1993). However, in the deeper slope waters, deep-sea fish (myctophids and bathylagids) are a relatively important diet component (12 percent by weight), along with euphausiids, pollock, pandalid shrimp and squid (Lang and Livingston 1996).

The cannibalistic nature of pollock, particularly adults feeding on juveniles, is well-documented by field studies in the EBS (Bailey 1989, Dwyer et al. 1987, Livingston 1989b, 1991b, Livingston and DeReynier 1996, Livingston and Lang 1997, Livingston et al. 1993). As mentioned previously, 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 40cm are higher than those by pollock less than 40cm. Most pollock cannibalized are age-0 and age-1 fish, with most age-1 pollock being consumed northwest of the Pribilof Islands where most age-1 pollock are found. 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 have shown the possibility of cannibalism among age-0 pollock (Sogard and Olla 1993). Field samples have confirmed this interaction, but so far this interaction appears not to be very important.

Field and laboratory studies on juvenile pollock have examined behavioral and physical factors that may influence vulnerability of juveniles to cannibalism (Bailey 1989, Olla et al. 1995, Sogard and Olla 1993, 1996). Although it had previously been hypothesized that cannibalism occurred only in areas with no thermal stratification, 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, and all age-0 fish tend to inhabit surface waters at night for feeding. Most cannibalism may occur 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 as an energy-conserving mechanism. Thus, prediction of cannibalism rates may require knowledge of 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 1984, Honkalehto 1989, Knechtel and Bledsoe 1981, 1983, Laevastu and Larkins 1981, Livingston 1991a, 1994, Livingston et al. 1993). The Knechtel and Bledsoe (1983) size-structured simulations produced several conclusions regarding cannibalism. Under conditions simulating the current fishing mortality rate (F=0.3yr-1) the population tended toward equilibrium. They also found 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 concluded that food was limiting, particularly for adult pollock. Maximization of average catch occurred at an extremely high F value (F=3.0 yr-1) that is about ten times higher than the actual fishing mortality rates in the EBS. However, the interannual variation in catches under this hypothetical scenario were 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 is to obtain better estimates of juvenile pollock abundance and mortality rates, which can improve our knowledge of factors affecting recruitment of pollock into the commercial fishery at age 3. Results from Livingston (1993, 1994) highlight several points with regard to cannibalism. 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 for juvenile pollock 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 biomasses appears to be due to cannibalism. There also appears to be an environmental component to juvenile pollock survival (Wespestad et al. 1997a), wherein surface currents during the first 3 months of life may transport larvae to areas more favorable to survival (e.g., away from adult predators or in areas more favorable for feeding). Estimates of total amount of pollock consumed by important groundfish predators show that cannibalism is the largest source of removal of juvenile pollock by groundfish predation (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1993).

Other groundfish predators of pollock include Greenland turbot, arrowtooth flounder, Pacific cod, Pacific halibut, and flathead sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1986, 1993). 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 even eaten by small-mouthed flounders such as yellowfin sole and rock sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1993). 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 ranging in age 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. Studies suggest that pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair et al. 1997, 1994). Squid and other small pelagic fish are also eaten by northern fur seals in slope areas or in other seasons. The main sizes of pollock consumed by fur seals range from 3-20 cm or age-0 and age-1 fish. Older age classes of pollock may appear in the diet, during years of lower abundances of young pollock (Sinclair et al. 1997). Pollock has been noted as a prey item for other marine mammals including northern fur seals, harbor seals, fin whales, minke whales, and humpback whales, but stomach samples from these species in the EBS have been very limited, so the importance of pollock in the diets has not been well-defined (Kajimura and Fowler 1984). 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).

Essentially five species of piscivorus birds are dominant in the avifauna of the EBS: northern fulmar, red-legged kittiwake, black-legged kittiwake, common murre, and thick-billed murre (Kajimura and Fowler 1984, Schneider and Shuntov 1993). Pollock is sometimes the dominant component in the diets of northern fulmar, black-legged kittiwake, common murre and thick-billed murre, while red-legged kittiwakes tend to rely more heavily on myctophids (Hunt et al. 1981, Kajimura and Fowler 1984, Springer et al. 1986). 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 Pacific 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 such as 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 (Canino 1994, Kendall et al. 1987). Early juveniles (25-100 mm) of pollock in the GOA primarily eat juvenile and adult copepods, larvaceans, and euphausiids while late juveniles (100-150 mm) eat mostly euphausiids, chaetognaths, amphipods, and mysids (Brodeur and Wilson 1996, Grover 1990, Krieger 1985, Livingston 1985, Merati and Brodeur 1997, Walline 1983). 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 and shrimp and fish are more important to larger pollock in that area. Copepods are not a dominant prey item of pollock in the embayments of southeast Alaska but appear mostly in the summer diet. Similarly, the summer diet of pollock in the central and western GOA does not contain as much copepods (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.

Fish prey become an increasing fraction of the pollock diet with increasing pollock size in the GOA. Over 20 different species of fish have been identified in the stomach contents of pollock from this area but the dominant fish consumed is capelin (Yang 1993). A high diversity of prey fish were also found in pollock stomachs. Commercially important fish prey included: Pacific cod, pollock, arrowtooth flounder, flathead sole , Dover sole, and Greenland halibut. Forage fish such as capelin, eulachon and Pacific sand lance, were also found in pollock stomach contents.

Dominant populations of groundfish in the GOA that prey on pollock include arrowtooth flounder, sablefish, Pacific cod, and Pacific halibut (Albers and Anderson 1985, Best and St-Pierre 1986, Jewett 1978, Yang 1993). Pollock is one of the top five prey items (by weight) for Pacific cod, arrowtooth flounder, and Pacific halibut. Other prey fish of these species include Pacific herring and capelin. Other predators of pollock include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993). As found 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). Stock assessment authors have attempted to incorporate predation mortality by arrowtooth flounder, Pacific halibut, and sea lions in the stock assessment for pollock in the GOA (Hollowed et al. 1997).

Research on the diets of marine mammals and birds in the GOA was less intensive for the Bering Sea, but recently has been greatly accelerated (Brodeur and Wilson 1996, Calkins 1987, DeGange and Sanger 1986, Hatch and Sanger 1992, Lowry et al. 1989, Merrick and Calkins 1996, Pitcher 1980a, 1980b, 1981) (Section 3.5). Brodeur and Wilson's (1996) review summarized both bird and mammal predation on juvenile pollock. The main piscivorus birds that consume pollock in the GOA are black-legged kittiwakes, common murre, thick-billed murre, tufted puffin, horned puffin, and probably marbled murrelet. The diets of common murres have been shown to contain around 5 percent to 15 percent 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 amount of pollock in the diet of tufted puffin varied by region in the years studied, with very low amounts in the north-central GOA and Kodiak Island areas, intermediate (5-20 percent) amounts in the Semidi and Shumagin Islands, and large amounts (25-75 percent) in the Sandman Reefs and eastern Aleutian Islands. The proportion of juvenile pollock in the diet of tufted puffin at the Semidi Islands varied by year and was related to pollock year-class abundance.

Pollock is a major prey of Steller sea lions and harbor seals in the GOA (Merrick and Calkins 1996, Pitcher 1980a, 1980b, 1981). Harbor seals tend to have a more diverse diet, and the occurrence of pollock in the diet is lower than in sea lions. Pollock is a major prey of both juvenile and adult Steller sea lions in the GOA. It appears that the proportion of animals consuming pollock increased from the 1970s to the 1980s, and this increase was most pronounced for juvenile Steller sea lions. Sizes of pollock consumed by Steller sea lions range from 5-56 cm and the size composition of pollock consumed appears to be related to the size composition of the pollock population. However, juvenile Steller sea lions consume smaller pollock on average than adults. Age-1 pollock was dominant in the diet of juvenile Steller sea lions in 1985, possibly a reflection of the abundant 1984 year class of pollock available to Steller sea lions in that year.

Stock Assessment

Currently, information on pollock in the EBS comes from the NMFS observers aboard commercial fishing vessels, annual trawl surveys, and triennial echo integration (hydroacoustic; EIT) trawl surveys. In the Aleutian Islands, information comes from observer data and triennial bottom trawl surveys. In the GOA, stock assessment information is based on observer and port sampling data, annual hydroacoustic surveys in the Shelikof Straits area, and triennial bottom trawl surveys. These different data sets are analyzed simultaneously to obtain an overall view of each stock's condition. 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 is untrawlable due to rough bottom.

In the EBS pollock are assessed with an age-structured model incorporating fishery data and two types of survey catch data and age compositions. Bottom trawl surveys are conducted annually during June through August and provide a consistent time series of adult population abundance from 1982-1997. EIT surveys are run 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 Council's BSAI SAFE report. Also included are separate analyses on pollock stocks in the Aleutian Islands and Bogoslof areas. These analyses are constrained by data limitations and are presented relative to the status of the EBS stock. This analysis focused specifically on the EBS stock with the view that extensions to these other areas are equally applicable. The stock assessment is reviewed by the Plan Team, and by the Scientific and Statistical Committee, before being presented to the Council.

The age composition of pollock has been dominated by strong year classes—most recently there appears to be higher than average 1992 year class, and prior to that the 1989 year class was very high. The abundance of these year classes is evident from EIT and bottom trawl surveys in addition to the extensive fishery age-composition data that have been collected. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality. The fishery has tended to exhibit variable selectivity over time, but generally targets fish aged 5 years and older.

GOA pollock are also assessed with an age-structured model incorporating fishery and survey data. The data used in this analysis consist of estimates of total catch biomass, bottom trawl biomass estimates, EIT survey estimates of the spawning biomass in Shelikof Strait, egg production estimates of spawning biomass in Shelikof Strait, and 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 International North Pacific Fisheries Commission (INPFC) statistical areas for the years, and numbers at age from the spring EIT 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 EIT survey 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). Recent assessments have explored the impact of predation mortality by arrowtooth flounder, Pacific halibut and Steller sea lions by incorporating time series of estimated predator biomass, the age composition of pollock consumed by predators, and estimated consumption rates (Hollowed et al. 1997).

In the GOA, ages 3 through 15 represent the recruited population, although reliable estimates of abundance for ages 2 and above exist. The age composition is dominated by a recent strong 1994 year class; large numbers from the strong 1988 year class are still in the population. The estimated mean age of the recruited portion of the population in 1999 was 4 years.

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. These investigations led to the development of a conceptual model of factors influencing pollock recruitment (for complete review collection of papers (Kendall et al. 1996). Bailey et al. (1996) reviewed 10 years of data for evidence of density dependent mortality at early life stages. Their study revealed evidence of density dependent mortality only at the late larval to early juvenile stages of development. Bailey et al. (1996) hypothesize that pollock recruitment levels can be established at any early life stage (egg, larval or juvenile) depending on sufficient supply from prior stages. He 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 events (Hollowed and Wooster 1995, Stabeno et al. 1995), 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 (Bograd et al. 1994, Schumacher et al. 1993), 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.

In both the BSAI and GOA, cumulative impacts of fishing mortality on the age composition are influenced by the selectivity of the fishery. The current age compositions of the stocks reflect a fished population with a long catch history. In any given year, the age composition of the stock is influenced by previous year-class strength. The reproductive potential of the stock in a given year is dependent on the biomass of spawners as modified by abiotic and biotic conditions. Thus, it is likely that the average age of unfished populations would have varied inter-annually due to the history of oceanic and climate conditions. The NMFS's FOCI and the Coastal Ocean Program's Southeast Bering Sea Carrying Capacity (SEBSCC) regional study focuses research on improving our understanding of mechanisms underlying annual production of pollock stocks in the GOA and EBS. NOAA's long-term goal is to improve our ability to assess quantitatively the long term impact of commercial removals of adult pollock on future recruitment by combining the findings of process-oriented research programs such as FOCI and SEBSCC with NMFS's on-going studies of species interactions, fish distributions, and abundance trends.

ABC as Recommended in the Most Recent Stock Assessments

EBS pollock fell into Tier 3a of the ABC/OFL definitions for 2000, which require reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%.}$ Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{35\%}$ rate which is 0.65 for pollock and equates to a yield of 1.5 million metric tons (mt) (Ianelli et al. 1999). The ABC (using $F_{ABC}= F_{40\%}$) for pollock gives a yield of 1.1 million mt. This TAC was set equal to the ABC value recognizing that the $F_{40\%}$ rate was well below estimates made for F_{MSY}. This lower level has been adjusted downwards to provide a risk-averse harvest rate which more accurately reflects the degree of uncertainty.

GOA pollock fell into Tier 3 of the ABC/OFL definitions, which require reliable estimates of biomass, $B_{40\%}$, $_{F30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawner stock biomass to 35 percent of its unfished level (the $F_{35\%}$ rate). In 1999, the full recruitment fishing mortality $F_{35\%}$ rate was 0.50 for pollock and equated to a yield of 130,758 mt for the year 2000 central and western GOA (Dorn et al. 1999). The projected 2000 spawning stock biomass fell below $B_{40\%}$, therefore the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate 0.34 (Dorn et al. 1999). This F_{ABC} translated to a yield projection of 111,306 mt in 2000 for the western and central regions. The 2000 Council ABC level was 100,000 mt for the western and central regions, which was equivalent to the recommended stock assessment ABC, and equivalent to the TAC.

Pacific Cod

Stock Description and Life History

Pacific cod is a demersal species that occurs on the continental shelf and upper slope from Santa Monica Bay, California through the GOA, Aleutian Islands, and EBS to Norton Sound (Bakkala 1984). The Bering Sea represents the center of greatest abundance, although Pacific cod are also abundant in the Gulf and Aleutian Islands (OCSEAP 1987). GOA, Bering Sea, and Aleutian Islands cod stocks are genetically indistinguishable (Grant et al. 1987), and tagging studies show that cod migrate seasonally over large areas (Shimada and Kimura 1994).

In the late winter, Pacific cod converge in large spawning masses over relatively small areas. Major aggregations occur between Unalaska and Unimak Islands, southwest of the Pribilof Islands and near the Shumagin group in the western Gulf (Shimada and Kimura 1994). Spawning takes place in the sublittoral-bathyal zone (the area of the continental shelf and slope [40-290 m]) near the bottom. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983).

Pacific cod reach a maximum recorded age of 19. Estimates of natural mortality vary widely and range from 0.29 (Thompson and Shimada 1990) to 0.83-0.99 (Ketchen 1964). For stock assessment purposes, a value of 0.37 is used in both the BSAI (Thompson et al. 1999) and the GOA (Thompson and Dorn 1999). In the BSAI, 50 percent of Pacific cod are estimated to reach maturity by the time they reach 67 cm in length, or about 5 years of age (Thompson et al. 1999).

Trophic Interactions

Pacific cod are omnivorous. Livingston (1991b) characterized the diet of Pacific cod in the BSAI and GOA as follows: In terms of percent occurrence, the most important items were polychaetes, amphipods, and crangonid shrimp; in terms of numbers of individual organisms consumed, the most important items were euphausiids, miscellaneous fishes, and amphipods; and in terms of weight of organisms consumed, the most important items were pollock, fishery offal, and yellowfin sole. Small Pacific cod were found to feed mostly on invertebrates, while large Pacific cod are mainly piscivorus. Predators of Pacific cod include halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin (Westrheim 1996).

Fishery

The Pacific cod fishery is the second largest Alaskan groundfish fishery. In 1999, Pacific cod constituted

12 percent of the groundfish catch in the BSAI and 30 percent of the groundfish catch in the GOA. The fishery for Pacific cod is conducted with bottom trawl, longline, pot, and jig gear. Of these, the fishery conducted with jig gear is by far the smallest. More than 100 vessels participate in each of the three larger fisheries. The age at 50 percent recruitment varies between regions. For trawl, longline, and pot gear, the age at 50 percent recruitment in the EBS is approximately 4, 4, and 5 years, respectively (Thompson and Dorn 1999). For all three gears, the age at 50 percent recruitment in the GOA is approximately 6 years (Thompson et al. 1999). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run essentially year-round. Bycatch of crab and halibut often causes the Pacific cod fisheries to close prior to reaching the TAC. In the EBS, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagins. Pacific cod is also taken as bycatch in a number of trawl fisheries. In the EBS, Pacific cod is taken as bycatch in the trawl fisheries for pollock, yellowfin sole, and rock sole. In the Aleutian Islands region, Pacific cod is taken as bycatch in the trawl fishery for Atka mackerel. In the GOA, Pacific cod is taken as bycatch in the trawl fisheries for shallow-water flatfish, arrowtooth flounder, and flathead sole. Since 1998, discarding of Pacific cod has been prohibited except in fisheries where Pacific cod is in “bycatch only” status.

Stock Assessment

Beginning with the 1993 BSAI SAFE report (Thompson and Methot 1993) and the 1994 GOA SAFE report (Thompson and Zenger 1994), Pacific cod have been assessed with a length-based synthesis model (Methot 1990). Although the Pacific cod stocks in the EBS and GOA are modeled separately, the model structures in recent years have been identical (Thompson and Dorn 1999, Thompson et al. 1999). No formal assessment model exists for the Aleutian Islands portion of the BSAI stock. Instead, results from the EBS assessment are inflated proportionally to account for Aleutian Islands fish.

Annual trawl surveys in the EBS and triennial trawl surveys in the Aleutian Islands and GOA are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and Dorn 1999, Thompson et al. 1999). For the most recent assessments, fishery size compositions were available, by gear, for the years 1978 through the first part of 1997. The catch history was divided into two portions, determined by the relative importance of the domestic fishery. A “pre-domestic” portion was defined as those years in which the domestic fishery took less than half the catch, and a “domestic” portion was defined as those years in which the domestic fishery took at least half the catch. Within each year (in both portions of the time series), catches were divided according to three time periods: January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). Four fishery size composition components were included in the likelihood functions used to estimate model parameters: the period 1 trawl fishery, the periods 2-3 trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size composition components, likelihood components for the size composition and biomass trend from the bottom trawl surveys were included in the model. All components were weighted equally.

Quantities estimated in the most recent stock assessments include parameters governing the selectivity schedules for each fishery and survey in each portion of the time series, parameters governing the length-at-age relationship, population numbers at age for the initial year in the time series, and recruitments in each year of the time series. Given these quantities, plus parameters governing natural mortality, survey catchability, the maturity schedule, the weight-at-length relationship, and the amount of spread surrounding the length-at-age relationship, the stock assessments reconstruct the time series of numbers at age and the population biomass trends (measured in terms of both total and spawning biomass). The model around which the most recent Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates. Based on these projections, the scientists responsible for conducting the assessments recommend a pair of ABC values for the coming year (one value for the BSAI and one for the GOA).

Pacific cod is currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 56 to each of the respective FMPs). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL).

*ABC as Recommended in the Most Recent Stock Assessmen*ts

Under Tier 3 of Amendment 56 to the BSAI and GOA Groundfish FMPs, the maximum permissible ABC depends on the relationship of projected spawning biomass to $B_{40\%}$. For the BSAI, the base model in the 1999 assessment projected a 2000 spawning biomass of 355,000 mt, about 6 percent below the $B_{40\%}$ estimate of 379,000 mt, leading to a maximum permissible ABC of 206,000 mt (Thompson and Dorn 1999). For the GOA, the base model in the 1999 assessment projected a 2000 spawning biomass of 111,000 mt, about 12 percent above the $B_{40\%}$ estimate of 98,800 mt, leading to a maximum permissible ABC of 86,000 mt (Thompson et al. 1999). To determine whether ABC should be set at the maximum permissible level, the 1999 assessments presented a decision-theoretic analysis of the statistical uncertainty surrounding the respective model’s projected $F_{40\%}$ catch level, specifically the uncertainty associated with the assumed values of the natural mortality rate (M=0.37) and survey catchability coefficient (q=1.0). These analyses resulted in a recommended 2000 ABC of 193,000 mt for the BSAI region and 76,400 mt for the GOA region.

Flathead Sole

Flathead sole is distributed from northern California northward throughout Alaska (Wolotira et al. 1993). In the northern part of its range, it overlaps with the related and very similar Bering flounder (Hart 1973). Because it is difficult to separate these two species at sea, they are currently managed as a single stock (Walters and Wilderbuer 1997). Adults are benthic and occupy separate winter spawning and summer feeding distributions. From over-wintering grounds near the continental shelf margin, adults begin a migration onto the mid and outer continental shelf in April or May. The spawning period occurs in the spring, primarily in deeper waters near the margins of the continental shelf (Walters and Wilderbuer 1997). Eggs are large and pelagic. Upon hatching, the larvae are planktonic and usually inhabit shallow areas (Waldron and Vinter 1978). Exact age and size at maturity are unknown, but recruitment to the fishery begins at age 3. The maximum age for flathead sole is approximately 20 years. An estimated natural mortality rate of 0.20 is used for stock assessment (Turnock et al. 1997a, Waldron and Vinter 1978). Flathead sole feed primarily on invertebrates such as amphipods and decapods. In the EBS, other fish species represented 5-25 percent of the diet (Livingston et al. 1993). Flathead sole are taken in bottom trawls both as a directed fishery and in pursuit of other bottom dwelling species.

The following information is available to assess the unit stock condition:

Data Component	Years of Data
Fishery catch	1977 to 1999
Foreign fishery size composition data	1977 to 1989
Domestic fishery size composition data	1990 to 1998
NMFS trawl survey biomass estimates	1982 to 1999
NMFS trawl survey size composition data	1982 to 1999
NMFS trawl survey age composition data	1982, 1985, 1992, 1995

Annual trawl survey biomass results have been the primary data component used to assess stock level since 1982, although all the above information was also input into a length-based stock assessment model (Spencer et al. 1999a). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Flathead sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected flathead sole female spawning biomass for 2000 is greater than $B_{40\%}$ (261,300 > 133,800), $F_{40\%}$ (the upper limit on ABC), is recommended as the F_{ABC} harvest reference point for 2000. The 2000 TAC is well below the ABC and the 1999 catch was only 23 percent of the 1999 TAC, as follows: BSAI 2000 ABC = 73,500 mt, BSAI TAC = 52,652 mt, and BSAI 1999 catch = 17,777 mt.

Rock Sole

Rock sole are distributed from southern California northward through Alaska (Wolotira et al. 1993). Two species of rock sole occur in the North Pacific ocean, a northern rock sole and a southern rock sole. These species have an overlapping distribution in the GOA, but the northern species primarily comprise the BSAI populations, where they are managed as a single stock (Wilderbuer and Walters 1997). Adults are benthic and, in the EBS, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Spawning takes place during the late winter-early spring, near the edge of the continental shelf at depths of 125 to 250 m. Eggs are demersal and adhesive (Forrester 1964). The estimated age at 50 percent maturity for female rock sole is 9-10 years at a length of 35 cm (Wilderbuer and Walters 1997). The best estimate for natural mortality is 0.18 for the BSAI (Wilderbuer and Walters 1992) and 0.20 for the GOA (Turnock et al. 1997a). Rock sole are important as the target of a high value bottom trawl roe fishery occurring in February and March, which accounts for the majority of the BSAI catch. Although female rock sole are highly desirable when in spawning condition, large amounts are discarded in other trawl fisheries during the rest of the year. Commercial harvest occurs primarily on the EBS continental shelf and in lesser amounts in the Aleutian Islands region.

Northern and southern rock sole are managed as a single unit in the BSAI. Rock sole are abundant on the EBS shelf and to a lesser extent in the Aleutian Islands. This species represents a "data-rich" case where the following information is available.

Data Component	Years of Data
Trawl fishery catch at age	1980 to 1998
Trawl survey population age composition	1975, 1979 to 1998
Catch weight	1975 to 1999
Trawl survey biomass estimates and standard error.	1982 to 1999
Maturity schedule	1993 to 1994
Mean weight at age	1985 to 1988

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model as the primary analytical tool (Wilderbuer and Walters 1999). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Rock sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected rock sole female spawning biomass for 2000 is greater than $B_{40\%}$ (675,500 > 284,700), $F_{40\%}$ (the upper limit on ABC), is recommended as the F_{ABC} harvest reference point for 2000. ABC and TAC information are as follows: BSAI 2000 ABC = 230,000 mt, BSAI TAC = 134,760 mt, and BSAI 1999 catch = 40,362 mt.

Greenland Turbot

Greenland turbot are distributed from Baja California northward throughout Alaska, although it is rare south of Alaska and is primarily distributed in the eastern BSAI region (Hubbs and Wilimovsky 1964). Juveniles are believed to spend the first three or four years of life on the continental shelf and then move to the continental slope as adults (Alton et al. 1988, Templeman 1973). Greenland turbot are demersal to semi-pelagic. Unlike most flatfish, the migrating eye of Greenland turbot does not move completely to one side, but stops at the top of the head, which presumably results in a greater field of vision and helps to explain this species' tendency to feed off the sea bottom (de Groot 1970). Spawning occurs in winter and may be protracted, starting as early as September and continuing until March (Bulatov 1983). The eggs are benthypelagic (suspended in the water column near the bottom)(D'yakov 1982). Juveniles are absent in the Aleutian Islands region, suggesting that populations in that area originate from elsewhere (Alton et al. 1988). Greenland turbot are a moderately long-lived species, with a maximum recorded age of 21 years (Ianelli and Wilderbuer 1995) and an estimated natural mortality rate of 0.18 (Ianelli et al. 1997). Pelagic fish are the main prey of Greenland turbot, with pollock often a major species in the diet (Livingston 1991b). Greenland turbot also feed on squid, euphausiids and shrimp.

Abundance of juvenile Greenland turbot is estimated in the EBS by the annual trawl survey and in the Aleutian Islands by the triennial trawl survey. Abundance of adults has been estimated by trawl slope surveys conducted cooperatively by the U.S. and Japan. In the Gulf, abundance is estimated by the triennial trawl survey. A lack of deepwater samples, however, creates a high degree of uncertainty for these estimates (Turnock et al. 1997a). The biomass of Greenland turbot in the BSAI increased during the 1970s and is currently estimated to be about half of the unfished level. A lack of recruitment success during recent years has led to extra caution in setting harvest levels. Greenland turbot is a relatively valuable species; however, because of low ABC and TAC amounts, it is primarily a bycatch only fishery. They are caught both in bottom trawls and on longlines.

The resource in the BSAI is managed as a single stock. The following information is available to assess the stock condition of Greenland turbot in the BSAI.

Data Component	**Years of Data**
Trawl survey size-at-age	1975, 1979 to 1982
Shelf survey size composition and biomass	1979 to 1999
Slope survey size composition and biomass	1979, 1981, 1982, 1985, 1988, 1991
Longline survey size composition and abundance index	1983 to 1993
Total fishery catch data	1960 to 1999
Trawl fishery CPUE index	1978 to 1984
Trawl fishery size compositions	1977 to 1987, 1989 to 1991, 1993 to 1998
Longline catch size composition	1977, 1979 to 1985, 1992 to 1998

The time-series of fishery and survey length compositions allows the use of a length-based stock assessment model (Ianelli et al. 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Greenland turbot are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected Greenland turbot female spawning biomass for 2000 is greater than $B_{40\%}$ (165,000 > 81,300), $F_{40\%}$ is considered the upper limit on ABC. However, the recommended F_{ABC} for 2000 is 25 percent of $F_{40\%}$ due to the lack of recruitment for the past 25 years and the anticipated declining future stock condition. ABC and TAC information are as follows: BSAI 2000 ABC = 9,300 mt, BSAI TAC = 9,300 mt, and BSAI 1999 catch = 5,776 mt.

Yellowfin Sole

Yellowfin sole is distributed from British Columbia to the Chukchi Sea (Hart 1973). In the Bering Sea, it is the most abundant flatfish species and is the target of the largest flatfish fishery in the United States. While also found in the Aleutian Islands and GOA, the stock is of much smaller size in those areas. Adults are benthic and occupy separate winter and spring/summer spawning/feeding grounds. Adults overwinter near the shelf-slope break at approximately 200 m and move into nearshore spawning areas as the shelf ice recedes (Nichol 1997). Spawning is protracted and variable, beginning as early as May and continuing through August, occurring primarily in shallow water at depths less than 30 m (Wilderbuer et al. 1992). Eggs, larvae and juveniles are pelagic and usually are found in shallow areas (Nichol 1994). The estimated age at 50 percent maturity is 10.5 years at a length of approximately 29 cm (Nichol 1994). The natural mortality rate likely falls within the range of 0.12 to 0.16, with a maximum recorded age of 33 years (Wilderbuer 1997). Yellowfin sole feed primarily on benthic invertebrates, with polychaetes, amphipods, decapods and clams dominating the diet in the EBS (Livingston 1993).

Yellowfin sole stocks were over-exploited by foreign fisheries in 1959-1962. Since that time, indices of relative abundance have shown major increases in abundance during the late 1970s. Since 1981, abundance has fluctuated widely but biomass estimates indicate that the yellowfin sole population remains at a high, stable level. Information on yellowfin sole stock conditions in the BSAI comes primarily from the annual EBS trawl survey. Estimates of yellowfin sole biomass derived from these surveys have been more variable than would be expected for a comparatively long-lived and lightly exploited species (Wilderbuer 1997). The reason for this variability is not known. However, Nichol (1997) hypothesized that much of the yellowfin sole resource is found at depths less than 30 m during the summer when bottom trawl surveys are conducted. This could cause the survey to underestimate the abundance of yellowfin sole.

In the Bering Sea, yellowfin sole are considered as one stock for management purposes. The following information is available for stock assessment.

Data Component	Years of Data
Trawl Fishery catch-at-age	1964 to 1998
Trawl survey population age composition	1975, 1979 to 1998
Catch weight	1982 to 1999
Trawl survey biomass estimates and S.E..	1954 to 1999
Maturity schedule	1992 to 1993
Mean weight at age	1979 to 1990

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model (Wilderbuer 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Yellowfin sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Appendix 1; Amendment 44). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected yellowfin sole female spawning biomass for 2000 is greater than $B_{40\%}$ (789,300 > 576,600), $F_{40\%}$ (the upper limit on ABC), was recommended as the F_{ABC} harvest reference point for 2000. ABC and TAC information are as follows: BSAI 2000 ABC = 191,000 mt, BSAI TAC = 123,262 mt, and BSAI 1999 catch = 67,392 mt.

Arrowtooth Flounder

Arrowtooth flounder is common from Oregon through the EBS (Allen and Smith 1988). The very similar Kamchatka flounder also occurs in the Bering Sea. Because it is not usually distinguished from arrowtooth flounder in commercial catches, both species are managed as a group. Arrowtooth flounder is a relatively large flatfish that occupies continental shelf waters almost exclusively until age 4, but at older ages occupies both shelf and slope waters, with concentrations at depths between 100 and 200 m (Martin and Clausen 1995). Spawning is protracted and variable and probably occurs from September through March (Zimmermann 1997). For female arrowtooth flounder collected off the Washington coast, the estimated age at 50 percent maturity was 5 years with an average length of 37 cm. Males matured at 4 years and 28 cm (Rickey 1995). Values of 50 percent maturity for the Bering Sea stock are 42.2 cm and 46.9 cm for males and females, respectively (Zimmerman 1997). The maximum reported ages are 16 years in the Bering Sea, 18 years in the Aleutian Islands and 23 years in the GOA, with a natural mortality rate used for assessment purposes of 0.2 (Turnock et al. 1997b, Wilderbuer and Sample 1997). Arrowtooth flounder are important as a large and abundant predator of other groundfish species. Adults are almost exclusively piscivorus and over half their diet can consist of pollock (Livingston 1991b). Currently, arrowtooth flounder have a low perceived commercial value because the flesh softens soon after capture due to protease enzyme activity (Greene and Babbitt 1990). Enzyme inhibitors such as beef plasma have been found to counteract this flesh-softening activity, but suitable markets have not been established to support increased harvests. Thus, they are primarily caught by bottom trawls as bycatch in other high value fisheries. Stocks are lightly exploited and appear to be increasing in both the GOA and the BSAI. Information on arrowtooth flounder stock conditions in the BSAI comes primarily from the annual EBS shelf trawl survey. Limited information is also available from past slope surveys (1981-91) and catch sampling of the commercial fishery.

Information on Bering Sea arrowtooth flounder is available from the following sources:

Data Component	**Years of Data**
Fishery catch	1970 to 1999
Shelf survey biomass and Southeast	1982 to 1999
Slope survey biomass and Southeast	1981, 1982, 1985, 1988, 1991
Shelf survey size composition (by sex)	1979 to 1999
Slope survey size composition (by sex)	1981, 1982, 1985, 1988,1991
Fishery length-frequencies from observers	1978 to 1991

The time-series of fishery and survey size compositions allows the use of an size-based stock assessment model (Wilderbuer and Sample 1997). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available (Appendix 1; Amendment 44). Arrowtooth flounder are managed under Tier 3 of the ABC/OFL definition since equilibrium recruitment could be approximated by the average recruitment from the time-series estimated in the stock assessment, and $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ could be estimated. In the 1999 assessment, projected biomass in 2000 is greater than $B_{40\%}$ (496,000t >194,600 t) so the $F_{40\%}$ fishing mortality rate (the upper limit) was recommended for calculating ABC. The 2000 Council TAC was set equal to the ABC. Increased future harvest is likely constrained by Pacific halibut bycatch limitations. ABC and TAC information are as follows: BSAI 2000 ABC = 131,000 mt, BSAI TAC = 131,000 mt, and BSAI 1999 catch = 10,679.

Information on GOA arrowtooth flounder used for stock assessments is available from the following sources:

Data Component	Years of Data
Fishery catch	1960 to 1999
IPHC trawl survey biomass and S.E.	1961 to 1962
NMFS exploratory research trawl survey biomass and S.E.	1973 to 1976
NMFS triennial trawl survey biomass and S.E.	1984, 1987, 1990, 1993, 1996, 1999
Fishery size compositions	1977 to 1981, 1984 to 1993, 1995 to 1996
NMFS triennial trawl survey size compositions	1984, 1987, 1990, 1993, 1996, 1999
NMFS GOA groundfish surveys length-at-age data	1975, 1977 to 1978, 1980 to 1983
NMFS triennial trawl survey length-at-age data	1984, 1987, 1990, 1993, 1996

Current abundance estimates indicate that arrowtooth flounder have the largest biomass of the groundfish species inhabiting the GOA. The time-series of fishery and survey size compositions allows the use of a size-based stock assessment model (Turnock et al. 1997b). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which are used to calculate ABC. The stock assessment is updated annually and incorporated into the GOA SAFE report.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available. Assuming that equilibrium recruitment can be approximated by the average recruitment from the time-series estimated in the stock assessment, $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ are known and because biomass in 2000 is greater than $B_{40\%}$ (1,075,900 > 436,700), $F_{40\%}$ (the upper limit) is the recommended fishing mortality rate to calculate ABC. The 2000 Council TAC of 35,000 mt is well below the ABC of 145,360 mt recommended from the stock assessment. Increased future harvest is likely constrained by Pacific halibut bycatch limitations. ABC and TAC information are as follows: BSAI 2000 ABC = 145,360 mt, BSAI TAC = 35,000 mt, and BSAI 1999 catch = 16,062 mt.

Other Flatfish

In the Bering Sea, eight other flatfish species are managed under the FMPs. Alaska plaice, rex sole, Dover sole, starry flounder, English sole, butter sole, sand sole, and deep sea sole. Adults of all species are benthic and occupy separate winter spawning and summer feeding grounds. Adults overwinter in deeper water and move into nearshore spawning areas in the late winter and spring. Spawning takes place as early as November for Dover sole (Hagerman 1952) but occurs from February through April for most species (Hart 1973). All flatfish eggs are pelagic and sink to the bottom shortly before hatching (Alderdice and Forrester 1968, Hagerman 1952, Orcutt 1950, Zhang 1987), except for butter sole, which has demersal eggs (Levings 1968).

In the Bering Sea, Alaska plaice is the most abundant and commercially important of the other flatfish species. It is a comparatively long-lived species, and has frequently been aged as high as 25 years. For stock assessment purposes, a natural mortality rate of 0.25 is used (Wilderbuer and Walters 1997). Alaska plaice appear to feed primarily on polychaetes, marine worms and other benthic invertebrates (Livingston and DeReynier 1996, Livingston et al. 1993). For the other seven species in the BSAI “other flatfish” management category, little is known of their feeding habits, spawning, growth characteristics or seasonal movements and population age/size structure.

In general, other flatfish are taken as bycatch in bottom trawl fisheries for other groundfish. Alaska plaice are also taken in directed bottom trawl fisheries in the EBS. Because other flatfish are generally not targeted, commercial catch data is of limited use for stock assessment purposes. The principal source of information for evaluating the condition of other flatfish stocks in the BSAI is the annual EBS shelf trawl survey.

A moderate amount of information is available for Alaska plaice in the Bering Sea and is summarized below.

Data Component	**Years of Data**
Catch number at age	1971 to 1979, 1988, 1995
Total catch weight	1971 to 1999
Age-specific estimates of proportion of mature females	1971 to 1996
Trawl survey biomass estimates and S.E.	1982 to 1999
Survey age composition	1979, 1981, 1982, 1988, 1992 to 1995

The time series of fishery and survey age compositions allows the use of an age-based stock assessment model (Spencer et al. 1999b). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future stock abundance, are used to calculate ABC. For the rest of the species of the “other flatfish” management group, annual trawl survey biomass estimates are considered the best information available to determine the stock biomass. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report. ABC and TAC information are as follows: BSAI 2000 ABC = 117,000 mt, BSAI TAC = 83,813 mt, and BSAI 1999 catch = 15,184 mt.

The other flatfish species complex in the GOA is currently managed as four categories with separate

ABCs: shallow-water flatfish, deep-water flatfish, flathead sole and rex sole. The shallow-water flatfish consists of Alaska plaice, starry flounder, yellowfin sole, English sole, butter sole, northern rock sole, and southern rock sole. Deep-water flatfish are: Dover sole, Greenland turbot, and deepsea sole. The shallow water category catch in 1999 was about 60 percent rock sole (southern and northern combined), 15 percent butter sole, 11 percent starry flounder, 4 percent English sole, 4 percent yellowfin sole, <1 percent Alaska plaice and 5 percent sand sole. The deep water catch is practically all Dover sole (over 99 percent in 1999).

The classification into the shallow-water and deep-water groups was due to significant differences in halibut bycatch rates in directed fisheries targeting on shallow and deep water flatfish species. Flathead sole were assigned a separate ABC due to their overlap in depth distribution of the shallow and deep water groups. In 1993, rex sole was split out of the deep-water management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery. The information available for each species varies.

Data Component	**Years of Data**
Age composition from surveys-not all species	Various years
Triennial bottom trawl survey biomass and S.E.	1984, 1987, 1990, 1993, 1996, 1999
Total fishery catch weight by management category	Various years
Survey size composition	1984, 1987, 1990, 1993, 1996, 1999

Stock assessment models were not used for any of the species here due to the lack of available information (Turnock et al. 1999). Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993, 1996 and 1999 are considered the best information available to determine the stock biomass for all of the “other flatfish” species.

The reference fishing mortality rate and ABC for the flatfish management groups are determined by the amount of population information available. Rock sole, for which maturity information from Bering sea rock sole is deemed adequate, are in Tier 4 of the ABC and overfishing definitions, where $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{30\%}$. ABCs for all flatfish except rock sole, deep-sea sole and Greenland turbot were calculated using $F_{ABC} = 0.75\ M$ and $F_{OFL} = M$ (Tier 5), because maturity information was not available. Natural mortality was assumed to be 0.2 for all flatfish species except Dover sole where natural mortality is 0.1. Greenland turbot and Deep-sea sole are in Tier 6 because no reliable biomass estimates exist, where ABC = 0.75 OFL and the overfishing level (OFL) = the average catch from 1978 to 1995.

The TAC is well below the ABC for shallow-water group and flathead sole. The ABC, TAC, and catch are summarized below. The TAC is essentially the same as the ABC for the deep-water group and rex sole. The flatfish fishery in the GOA mainly targets rock sole, rex sole, and Dover sole. The catch of flatfish is limited by the bycatch of halibut and does not reach the TAC for any species group.

GOA Management Group	**GOA 2000 ABC**	**GOA 2000 TAC**	**GOA 1999 Catch**
Shallow-water	37,860	19,400	2,545
Deep-water	5,300	5,300	2,285

Flathead sole	26,270	9,060	891
Rex sole	9,440	9,440	3,057

Sablefish

Sablefish is found from northern Mexico to the GOA, westward to the Aleutian Islands, and in gullies and deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). Several studies have shown sablefish to be highly migratory for at least part of their life cycle (Heifetz and Fujioka 1991, Maloney and Heifetz 1997), and substantial movement between the BSAI and the GOA has been documented (Heifetz and Fujioka 1991). Thus sablefish in Alaskan waters are assessed as a single stock (Sigler et al. 1999). Adults reach maturity at 4 to 5 years and a length of 51 to 54 cm (McFarlane and Beamish 1990). Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (McFarlane and Nagata 1988). Juveniles are pelagic and appear to move into comparatively shallow near-shore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). Sablefish are long-lived, with a maximum recorded age in Alaska of 62 years (Sigler et al. 1997). For stock assessments, a natural mortality rate of about 0.1 has been estimated (Sigler et al. 1999). It appears that sablefish are opportunistic feeders. Feeding studies conducted in Oregon and California, found that fish made up 76 percent of the diet (Laidig et al. 1997). Other studies, however, have found a diet dominated by euphausiids (Tanasichuk 1997).

Alaskan sablefish are considered a single stock and assessed in a combined area (BSAI and GOA) with an age-structured model incorporating fishery and survey catch data and age and length compositions. Survey data come from annual sablefish longline surveys in the GOA, and biennial longline surveys in the BSAI. These surveys indicate that the stock size peaked in the mid-1980s because of a series of strong year classes and has declined to lower level since.

The stock assessment includes catch history, fishery description, assessment methods, abundance and exploitation trends, and projected catch and abundance. Sablefish fall into Tier 3 of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. Under the definitions and projected stock conditions in 1999, the overfishing fishing mortality rate was the adjusted $F_{35\%}$ rate which was 0.136 for sablefish and equated to a combined stock yield of 21,400 mt. Projections for 2000 showed that the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate (0.109) and translated to a combined stock yield of 17,300 mt. The 2000 ABC recommendation was set at the adjusted $F_{40\%}$ rate. The stock assessment authors also constructed an approximate probability figure on the odds of the year 2004 spawning biomass dropping below the projected year 2000 level. They determined that a constant 5-year catch scenario of 17,000 mt was appropriate for minimizing the risks of further stock declines.

Relatively strong yearclasses include the 1990 and 1995 cohorts, and the 1997 appears to be relatively strong although this assessment is based on only a single year of data. Abundance has fallen in recent years because recent recruitment is insufficient to replace strong year classes from the later 1970s which are dying off. The estimated mean age of the recruited portion of the population is 7.3 years. The dominating factor determining the age composition is the magnitude of the recruiting year classes. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and the current composition is also the result of a fished population with a several-decade catch history. How the current age composition of the population compares with the unfished population is unknown.

The directed fishery for sablefish is prosecuted by longlining. Sablefish are caught incidentally in trawl fisheries. A tiny amount of sablefish is caught by pot boats. By gear, the catches in 1998 were longlines (90 percent), trawls (10 percent) and pots (<1 percent). The directed fishery occurs on the upper continental slope and a few deepwater gullies, the areas inhabited by adult sablefish. The average discard from 1994 to 1997 was 3 percent for all longline fisheries and 27 percent for all trawl fisheries.

Larval sablefish feed on a variety of small zooplankton ranging from copepod nauplii to small amphipods. The epipelagic juveniles feed primarily on macrozooplankton and micronekton (i.e., euphausiids). The older demersal juveniles and adults appear to be opportunistic feeders, with food ranging from variety of benthic invertebrates, benthic fishes, as well as squid, mesopelagic fishes, jellyfish, and fishery discards. Gadid fish (mainly pollock) comprise a large part of the sablefish diet. Nearshore residence during their second year provides the opportunity to feed on salmon fry and smolts during the summer months. Young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the southeast troll fishery during the late summer.

Rockfish

At least 32 rockfish species of the genus *Sebastes* and *Sebastolobus* have been reported to occur in the GOA and BSAI (Eschmeyer et al. 1984), and several are of commercial importance. Pacific ocean perch has historically been the most abundant rockfish species in the region and has contributed most to the commercial rockfish catch. Other species such as northern rockfish, rougheye rockfish, shortraker rockfish, shortspine thornyheads, yelloweye rockfish, and dusky rockfish are also important to the overall rockfish catch. The TAC levels for these and all other rockfish species are determined on an annual basis by the Council. Among the main inputs needed for making this determination are the ABC and OFL recommendations from annual stock assessments conducted for each species and/or species assemblage.

Rockfish in the GOA is currently managed as four assemblages: 1) slope rockfish, 2) pelagic shelf rockfish, 3) demersal shelf rockfish, and 4) thornyheads. Separate ABCs, OFLs, and TACs are set for each assemblage except for slope rockfish which is further subdivided into four subgroups with separate ABCs, OFLs, and TACs: 1) Pacific ocean perch, 2) shortraker and rougheye rockfish, 3) northern rockfish, and 4) “other slope rockfish”.

Rockfish in the BSAI are currently managed as two assemblages; 1) Pacific ocean perch complex and 2) other rockfish. The Pacific ocean perch complex includes Pacific ocean perch, rougheye rockfish, shortraker rockfish, sharpchin rockfish, and northern rockfish. For the EBS region, the Pacific ocean perch complex is divided into two subgroups with: 1) Pacific ocean perch, and 2) shortraker, rougheye, sharpchin, and northern rockfish combined. For the Aleutian Islands region, the Pacific ocean perch complex is divided into three subgroups: 1) Pacific ocean perch, 2) shortraker and rougheye rockfish, and 3) sharpchin and northern rockfish. Separate ABC, and TAC, and OFLs are assigned to each subgroup. Other rockfish includes all *Sebastes* and *Sebastolobus* species in the BSAI region other than the Pacific ocean perch complex. Shortspine thornyheads account for more than 90 percent of the estimated biomass of the other rockfish assemblage in the BSAI.

Rockfish are assessed with either an age structured model or trawl survey based model, depending on the management group. Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch and age composition data. Most other species of rockfish are assessed based on trawl survey catch data. Survey data are from the NMFS triennial trawl surveys. The stock assessments provide the best available information. For all rockfish management groups, the assessment includes catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA and BSAI stock assessment report, which is incorporated into the NPFMC SAFE reports.

Pacific ocean perch

Pacific ocean perch is primarily a demersal species which inhabits the outer continental shelf and slope regions of the North Pacific and Bering Sea, from southern California to Japan (Allen and Smith 1988). As adults, they live on or near the sea floor, generally in areas with smooth bottoms (Krieger 1993), generally at depths ranging from 180 to 420 m. The diet of Pacific ocean perch appears to consist primarily of plankton (Brodeur and Percy 1984); euphausiids are the single most important prey item (Yang 1996).

Though more is known about the life history of Pacific ocean perch than about other rockfish species (Kendall and Lenarz 1986), much uncertainty still exists about its life history. Pacific ocean perch are viviparous, with internal fertilization and the release of live young (Hart 1973). Insemination occurs in the fall, and release of larvae occurs in April or May. Pacific ocean perch larvae are thought to be pelagic and drift with the current. Juveniles seem to inhabit rockier, higher relief areas than adults (Carlson and Straty 1981, Krieger 1993). Pacific ocean perch is a slow growing species that, in the Gulf, reaches maturity at approximately 10 years, or 36 cm in length (Heifetz et al. 1997) and has a maximum life span of 90 years (Chilton and Beamish 1982). The natural mortality rate likely is between 0.02 and 0.08 (Archibald et al. 1981, Chilton and Beamish 1982).

Pacific ocean perch is the most commercially important rockfish in Alaska’s fisheries and is taken almost exclusively with bottom trawls. The species is highly valued and supported large Japanese and Soviet trawl fisheries throughout the 1960s. Apparently, stocks were not productive enough to support the large removals that took place, and they declined throughout the 1960s and 1970s, reaching their lowest levels in the early 1980s. Since that time, stocks have stabilized in the EBS, and increased in the Aleutian Islands and GOA.

A time series of fishery and survey age compositions allows the use of an age-based stock assessment model for POP. The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model uses the ratio of female spawning biomass to that which would exist without fishing to estimate reference fishing mortality rates. The reference fishing mortality rates are used to calculate ABC, and the assessment is updated annually.

In the GOA, Pacific ocean perch fall into Tier 3 of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate for Pacific ocean perch is the $F_{35\%}$ adjusted rate which is 0.078 for Pacific ocean perch and equates to a yield of 15,385 mt. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 3 is the $F_{40\%}$ adjusted rate which is 0.065 for Pacific ocean perch and translates to a yield of 13,020 mt. The stock assessment fishing mortality rate for ABC is equivalent to the maximum allowable fishing mortality rate. The current Council TAC level is 13,020 mt, equal to the recommended stock assessment ABC.

The current age and size distributions of Pacific ocean perch in the GOA are discussed in Heifetz et al. (1999). Information is available from the 1984, 1987, 1990, 1993, and 1996 surveys. The dominating factor determining the age composition is the magnitude of the recruiting year classes which are highly variable. The first three surveys show a strong 1976 year-class, and the 1980 year-class appears strong in the 1987 survey and average in the 1990 survey. The 1986 year-class appears strong in the 1990 survey, and exceptionally strong in the 1993 and 1996 surveys. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and it is not certain how the current age composition of the population would compare to an unfished population.

In the GOA, the directed fishery for Pacific ocean perch is prosecuted by catcher-processor and catcher bottom trawlers. The percentage of Pacific ocean perch taken by pelagic trawls has increased from 2-8 percent during 1990-1995 to 14-20 percent during 1996-1998. Factory trawlers continue to take nearly all the catch in the eastern and western GOA; however, since 1996, the percentage of Pacific ocean perch in the central GOA taken by shore-based trawlers has ranged from 28 percent to 49 percent. The fishery generally occurs at depths between 150 and 300 m along the outer continental shelf, the upper continental slope and at the mouth of gullies. Important Pacific ocean perch fishery locations include: in the eastern GOA, the gully and slope southwest of Yakutat Bay and off Cape Omaney; in the central GOA, the shelf, slope and gullies off of Kodiak Island south of Portlock Bank and near Albatross Bank; and in the western GOA, the shelf and slope south of Unimak and Umnak Islands.

In the GOA, Pacific ocean perch are caught as bycatch (not necessarily discarded) in other directed fisheries aimed mostly at other species of rockfish. Heifetz and Ackley (1997) analyzed bycatch in rockfish fisheries of the GOA. Bycatch rates of Pacific ocean perch are highest in the pelagic shelf rockfish, “other slope rockfish”, and shortspine thornyhead fisheries. Information on bycatch in non-rockfish fisheries has not been analyzed. Recent discard rates (discards/total catch) of Pacific ocean perch have been about 15 percent (Heifetz et al. 1997). In 1997, about 1,360 mt of Pacific ocean perch were discarded compared to a total catch of 9,500 mt.

The diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). About 98 percent of the total stomach content weight of Pacific ocean perch in the study was made up of invertebrates and 2 percent of fish. Euphausiids (mainly *Thysanoessa inermis*) were the most important prey item. Euphausiids comprised 87 percent by weight of the total stomach contents. Calanoid copepods, amphipods, arrow worms, and shrimp were frequently eaten by POP. Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it likely that Pacific cod and arrowtooth flounder also prey on POP. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other demersal fish.

In the BSAI, Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Survey data are from the NMFS triennial trawl groundfish surveys and the fishery data comes from the observer program. The stock assessment is based on the best available information. It includes catch history, characterizations of the fishery, assessment methodology, abundance and exploitation trends, and projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions (Ito et al. 1999). The assessments for the other species in the Pacific ocean perch complex and for the "other rockfish" management category are based on substantially less information (Ito and Spencer 1999, Ito et al. 1999).

The current spawning biomass for Pacific ocean perch in the Aleutian Islands is about 2,500 mt below its long-term average under an $F_{40\%}$ (=0.072) harvest strategy. Our current estimate of spawning biomass for this stock is about 97,800 mt, whereas, the long-term equilibrium spawning biomass is about 100,300 mt. Based on the guidelines established under Tier 3, the adjusted F_{ABC} was calculated as 0.0702, which equates to an ABC estimate of approximately 12,300 mt. The total Aleutian Islands recommended ABC was then apportioned among Aleutian Islands subareas based on survey distribution, as follows: western = 5,670 mt, central = 3,510 mt, and eastern = 3,120 mt. This was done to better distribute fishing effort over a wider area, thereby reducing the chance for localized depletion. The OFL was determined using an adjusted $F_{35\%}$ rate of 0.0826 which translates to an OFL of 14,400 mt.

For the EBS stock of POP, the estimate of current spawning biomass is also below its long-term average. The current estimate of spawning biomass for this stock is about 24,900 mt and its long-term equilibrium spawning biomass is 26,200 mt. The same adjustment procedure used for the Aleutian Islands $F_{40\%}$ rate was also applied to the EBS $F_{40\%}$ estimate. This procedure produced an F_{ABC} of 0.0544 and an ABC estimate for the EBS of approximately 2,600 mt. The overfishing mortality level (FOFL) was given as an adjusted $F_{35\%}$ and was 0.0653, which translates to an OFL of about 3,100 mt.

Shortraker and Rougheye Rockfish

Shortraker and rougheye rockfish inhabit the outer continental shelf of the north Pacific from the EBS as far south as southern California (Kramer and O'Connell 1988). Adults of both species are semi-demersal and are usually found in deeper waters (from 50 to 800 m) and over rougher bottoms (Krieger and Ito 1999) than POP. Little is known about the biology and life history of these species, but they appear to be long-lived, with late maturation and slow growth. Shortraker rockfish have been estimated to reach ages in excess of 120 years and rougheye rockfish in excess of 140 years. Natural mortality rates have been estimated by Heifetz and Clausen (1991) at 0.025 for rougheye rockfish and 0.030 for shortraker rockfish. Like other members of the genus *Sebastes*, they are viviparous (bear live young) and birth occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of rougheye rockfish is dominated by shrimp. The diet of shortraker rockfish is not well known, based on a small number of samples, the diet appears to be dominated by squid. Because shortraker rockfish have large mouths and short gill rakers, it is possible that they are potential predators of other fish species (Yang 1993). Though shortraker and rougheye rockfish are highly valued, amounts available to the commercial fisheries are limited by relatively small TAC and ABC amounts that are fully needed to support bycatch needs in other groundfish fisheries. As a result, the directed fishery for these species typically is closed at the beginning of the fishing year.

The primary methods of harvest for shortraker and rougheye rockfishes are bottom trawl and longline gears. The bulk of the commercial harvest usually occurs at depths between 200 and 500 m along the upper continental slope. Both species are associated with a variety of habitats from soft to rocky habitats, although boulders and sloping terrain appear also to be desirable habitat. Age at recruitment is uncertain, but is probably on the order of 20+ years for both species. Length at 50 percent sexual maturity is about 45 cm for shortraker rockfish and about 44 cm for rougheye rockfish (McDermott 1994).

A sufficient time series of fishery and survey age compositions is not available to construct an age-based stock assessment model for shortraker and rougheye rockfish. Thus assessment is based mostly on exploitable biomass estimates provided by trawl surveys. Specifically, exploitable biomass for the GOA stocks is estimated as the unweighted average of the three most recent surveys (1993, 1996, and 1999), excluding the 1-100 m depth stratum (which contains largely unexploitable juvenile fish). Life history information allows estimates of reference fishing mortality rates which are used to calculate ABC. The stock assessment is updated annually.

In the GOA, shortraker rockfish falls into Tier 5, and rougheye rockfish falls into Tier 4 of the ABC/OFL definitions. Under these definitions, the overfishing fishing mortality rate for shortraker rockfish is the

F=M rate of 0.03. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 5 for shortraker rockfish is the F=0.75M rate which is 0.023. The maximum allowable fishing mortality rate for ABC (F_{ABC}) for rougheye rockfish defined by Tier 4 is $F_{40\%}$ which is 0.032. The stock assessment F_{ABC} for rougheye set equal to the natural mortality M of 0.025, which is lower than the maximum allowable fishing mortality rate for ABC. This results in the recommended ABC of 1,730 mt for shortraker and rougheye rockfish, and this level was adopted as the ABC and TAC by the Council. Because the shortraker and rougheye rockfish ABC and TAC are set more conservatively than the maximum prescribed under the definitions, less of a risk of the F_{ABC} rate being an overly aggressive harvest rate for shortraker and rougheye rockfish exists. This affords more protection to the stocks given the variability and uncertainty associated with the abundance.

For the Aleutian Islands shortraker and rougheye rockfish stocks, the assessment is also based on catch and survey data. The biomass estimates from U.S. domestic Aleutian Islands bottom trawl surveys (1991, 1994, 1997) are averaged to obtain the best estimate of biomass for the species in this subcomplex; earlier U.S.-Japan cooperative surveys were excluded because of differences in survey gear. The 2000 biomass estimates of rougheye and shortraker rockfish were 12,762 mt and 28,713 mt, respectively. In 1996, the Council's Science and Statistical Committee determined that reliable estimates of the natural mortality rate existed for the species in this subcomplex, and that shortraker and rougheye rockfish in the Aleutian Islands therefore qualified for management under Tier 5. The accepted estimates of M is 0.025 for rougheye rockfish and 0.030 for shortraker rockfish. The Plan Team recommends setting F_{ABC} at the maximum value allowable under Tier 5, which is 75 percent of M. This produced F_{ABC} of 0.019 for rougheye rockfish and 0.023 for shortraker rockfish. Multiplying these rates by the biomass estimates and summing across species gives a 2000 ABC of 885 mt. The Plan Team's OFL was determined from the Tier 5 formula, where setting F_{OFL}=M for each species gives a combined OFL of 1,180 mt.

In recent years a directed fishery for shortraker and rougheye rockfish has not been allowed, because TACs are small. Shortraker and rougheye rockfishes are often caught as bycatch and retained in the sablefish and halibut longline fisheries and fisheries targeting other species of rockfish. Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of shortraker and rougheye rockfish are highest in the shortspine thornyhead and Pacific ocean perch fisheries. An analysis of bycatch rates in non-rockfish fisheries has not been conducted. Discard rates (discards/total catch) of shortraker and rougheye rockfish in the GOA during 1995 to 1999 have ranged from 22 percent to 32 percent (Heifetz et al. 1999). In 1999, about 397 mt of shortraker and rougheye rockfish were discarded compared to a total catch of 1,310 mt.

Northern Rockfish

Northern rockfish inhabit the outer continental shelf from the EBS, throughout the Aleutian Islands and the GOA (Kramer and O'Connell 1988). This species is semi-demersal and is usually found in comparatively shallower waters of the outer continental slope (from 50 to 600 m). Little is known about the biology and life history of northern rockfish. However, they appear to be long lived, with late maturation and slow growth. Heifetz and Clausen (1991) estimated the natural mortality rate for northern rockfish to be 0.060. Like other members of the genus Sebastes, they bear live young, and birth occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of northern rockfish is dominated by euphausiids. Although northern rockfish are lower in value than Pacific ocean perch, they still support a valuable directed trawl fishery, especially in the GOA.

In the GOA, northern rockfish falls into Tier 4 of the ABC/OFL definitions. The exploitable biomass is estimated as the weighted mean from the three most recent surveys; this produces an estimate of 85,357 mt for northern rockfish. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 4 is the $F_{40\%}$ rate of 0.075. The stock assessment F_{ABC} for rougheye set equal to the natural mortality *M* of 0.06, which is lower than the maximum allowable fishing mortality rate for ABC. This results in the stock assessment ABC of 5,120 mt for northern rockfish. The current Council ABC and TAC levels are 4,990 mt. Because the northern rockfish ABC and TAC are more conservative than the maximum prescribed under the definitions, less risk exists of the F_{ABC} rate being an overly aggressive harvest rate for this species. This affords more protection to the stocks given the variability and uncertainty associated with the abundance.

Age-structured information exists for GOA northern rockfish, and has led to the development of an age-structured population model (Heifetz et al 1999). It is expected that this model will be used for future assessments. The current age and size distributions of Pacific ocean perch in the GOA are discussed in Heifetz et al. (1999). Information is available from the 1984, 1987, 1990, 1993, and 1996 surveys. The dominating factor determining the age composition is the magnitude of the recruiting year classes which are highly variable. Most surveys (except the 1993 survey) indicate that 1968-1971 and 1975-1977 were periods of strong year-classes. The 1993 and 1996 surveys indicate that the 1984 and 1985 year-classes may be stronger than average. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and it is not certain how the current age composition of the population would compare to an unfished population.

The directed fishery for northern rockfish is prosecuted by catcher-processor and catcher bottom trawlers. As with the Pacific ocean perch fishery, a higher percentage of the catch in the central GOA is being taken by shore-based trawlers, ranging from 32 percent to 53 percent from 1996 to 1999. The patterns of the fishery generally reflect the distribution of the species. The fishery is concentrated at discrete, relatively shallow offshore banks of the outer continental shelf at depths between 75 and 125 m. Important northern rockfish fishery locations include Portlock Bank and Albatross Bank south of Kodiak Island, Shumagin Bank south of the Shumagin Islands, and Davidson Bank south of Unimak Island.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of northern rockfish are highest in the pelagic shelf rockfish, “other slope rockfish”, and Pacific ocean perch fisheries. Information on bycatch of northern rockfish in non-rockfish fisheries has not been analyzed. Discard rates (discards/total catch) of the GOA northern rockfish from 1995 to 1999 have ranged from 13 percent to 28 percent (Heifetz et al. 1999). In 1999, about 597 mt of northern rockfish were discarded compared to a total catch of 5297 mt.

Northern rockfish are generally planktivorous (feed on plankton) with euphausiids being the predominant prey item (Yang 1993). Copepods, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities. Predators of northern rockfish are not well documented but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

In the Aleutian Islands, northern rockfish are managed together with sharpchin rockfish. Because sharpchin rockfish are found only rarely in the Aleutian Islands, northern rockfish are, for all practical purposes, the only species in this subcomplex. As with the shortraker and rougheye stocks, the biomass estimates from U.S. domestic Aleutian Islands bottom trawl surveys (1991, 1994, 1997) are averaged to obtain the best estimate of biomass for the species in this subcomplex. This procedure produced a biomass estimate of 114,501 mt. Northern rockfish in the Aleutian Islands are managed under Tier 5 of

Amendment 44. The accepted estimate of M for northern rockfish in the Aleutian Islands is 0.06. ABC was based on maximum allowable F_{ABC} under Tier 5, which is 75 percent of M, or 0.045. Multiplying this rate by the best estimate of biomass gave a 2000 ABC of 5,153 mt. The Plan Team's OFL was determined from the Tier 5 formula, where setting $F_{OFL}=M$ gives a 2000 OFL of 6870 mt.

Pelagic Shelf Rockfish

In the GOA, pelagic shelf rockfish consist of dusky rockfish, yellowtail rockfish, and widow rockfish. Black rockfish were formerly in this group, but were removed in April, 1998, from both the pelagic shelf group and the GOA groundfish FMP. Dusky rockfish is by far the most important species in the group, both in terms of abundance and commercial value. This complex is assessed with a trawl survey-based model, with survey data coming from the NMFS GOA triennial trawl surveys. The stock assessments provide the best available information for pelagic shelf rockfish, and include discussions of catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA pelagic shelf rockfish stock assessment which is incorporated into the GOA SAFE report.

Pelagic shelf rockfish fall into Tier 4 of the current ABC/OFL definitions, which requires estimates of biomass, $F_{35\%}$, and $F_{40\%}$. Biomass estimates are produced from averaging the three most recent triennial surveys (1993, 1996, and 1999), and the current exploitable biomass is 66,443 mt. Estimates of $F_{35\%}$ and $F_{40\%}$ are derived using life history parameters for dusky rockfish. According to the definitions for Tier 4, the maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate, which is 0.11 for pelagic shelf rockfish and translates to a Gulfwide yield of 7,309 mt. The actual stock assessment F_{ABC} for pelagic shelf rockfish, however, is set to a more conservative value, $F=M$, in which F_{ABC} equals the natural mortality of dusky rockfish, 0.090. Hence, the corresponding yield is 5,980 mt, which is the recommended ABC value in the stock assessment for 2000. The Council has adopted this level for both the ABC and TAC for 2000. The corresponding OFL fishing mortality rate is $F_{35\%} = 0.136$, which results in an OFL yield of 9036 mt. Because the northern rockfish ABC and TAC are more conservative than the maximum prescribed under the definitions, less risk exists of the F_{ABC} rate being an overly aggressive harvest rate for this species. This affords more protection to the stocks given the variability and uncertainty associated with the abundance.

Age and size distributions of dusky rockfish are based on results of the five triennial trawl surveys from 1984 to 1996, and are discussed in Clausen and Heifetz (1999). Age results are only available from the 1987, 1990, and 1993 surveys, and these show that substantial recruitment of dusky rockfish appears to be a relatively infrequent event. Strong year classes are only seen for 1976 to 1977, 1979 to 1980, and 1986. The size compositions from each of the five surveys indicate that recruitment of small fish to the survey occurred only in 1993, corresponding to the 1986 year class. The effects of fishing on the age and size compositions are unknown, as no age or size data are available from either the fishery, or the unfished population prior to the beginning of the fishery.

Dusky rockfish are caught almost exclusively with bottom trawls. Factory trawlers dominated the directed fishery from 1988 to 1995. Since 1996, the percentage of the catch taken by shore-based trawlers in the central GOA has ranged from 18 percent to 45 percent. Catches are concentrated at a number of relatively shallow, offshore banks of the outer continental shelf, especially the "W" grounds west of Yakutat, and Portlock Bank. Other fishing grounds include Albatross Bank, the "Snakehead" south of Kodiak Island, and Shumagin Bank. Highest catch per unit effort is generally taken at depths of 10-150 m (Reuter 1998).

Dusky rockfish often co-occur with northern rockfish, and they are caught as bycatch in the northern rockfish and "other slope rockfish" fisheries (Heifetz and Ackley 1997). To a lesser extent, they are also taken as bycatch in the Pacific ocean perch fishery. Overall discard rates (discards/total catch) of dusky rockfish in recent years have been quite low, generally 10 percent or less (Clausen and Heifetz 1999).

Trophic interactions of dusky rockfish are not well known. Food habits information is available from just one study with a relatively small sample size for dusky rockfish (Yang 1993). This study indicated that adult dusky rockfish consume primarily euphausiids, followed by larvaceans, cephalopods, and pandalid shrimp. Predators of dusky rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth founder.

Demersal Shelf Rockfish

Demersal shelf rockfish include seven species of nearshore, bottom-dwelling rockfish: canary rockfish, China rockfish, copper rockfish, quillback rockfish, rosethorn rockfish, tiger rockfish, and yelloweye rockfish. Demersal shelf rockfish are managed by the Council as a distinct assemblage only off Southeast Alaska Outside (SEO) east of 140°W, an area which is further divided into four management units along the outer coast: the South SEO (SSEO), central SEO (CSEO), North SEO (NSEO), and East Yakatat (EYKT). Yelloweye rockfish comprise 90 percent of the catch and will be the focus of this section.

Yelloweye rockfish occur on the continental shelf from northern Baja California to the EBS, commonly in depths less than 200 m (Kramer and O'Connell 1988). They are long-lived, slow growing, and late maturing. Yelloweye have been estimated to reach 118 years and their natural mortality rate is estimated at 0.20 (O'Connell and Funk 1987). They are viviparous (live bearing) with parturition (birth) occurring primarily in late spring through mid-summer (O'Connell 1987). Yelloweye inhabit areas of rugged, rocky relief and adults appear to prefer complex bottoms with the presence of "refuge spaces" (O'Connell and Carlile 1993). Demersal shelf rockfish are highly valued and a directed longline fishery is held for these species. However, yelloweye are the primary bycatch in the halibut fishery and therefore a large portion of the TAC and ABC are set aside for bycatch. In 1998, 31 percent of the total Demersal shelf rockfish landings occurred as bycatch in the halibut fishery (O'Connell et al. 1999).

Traditional abundance estimation methods (e.g., area-swept trawl surveys, mark recapture) are not considered useful for these fishes given their distribution, life history, and physiology. However, ADF&G is continuing research to develop and improve a stock assessment approach for them. As part of that research a manned submersible, R/V Delta, is used to conduct line transects (Buckland et al. 1993, Burnham et al. 1980). Density estimates are limited to adult yelloweye, because it is the principal species targeted and caught in the fishery, and therefore ABC/TAC recommendations for the entire assemblage are keyed to adult yelloweye abundance. Total yelloweye rockfish biomass is estimated for each management subdistrict as the product of density, mean weight of adult yelloweye, and areal estimates of Demersal shelf rockfish habitat (O'Connell and Carlile 1993). For estimating variability in yelloweye biomass, log-based confidence limits are used because the distribution of density tends to be positively skewed and density is assumed to be log-normal (Buckland et al. 1993). Estimation of both line length for the transects and total area of rocky habitat are difficult and result in some uncertainty in the biomass estimates. Density estimates were made in the EYKT and SSEO areas in 1999. The density in the SSEO area increased 38 percent from the previous density estimate made in 1994, although some of this change may be due to increased sample size and a change in survey techniques. In contrast, the density in the EYKT area decreased 44 percent from the previous estimate in 1997. During the 1997 survey, the area estimate of rock habitat in the EYKT management area was reduced by 60 percent compared to past assessments, resulting in a reduction in the biomass estimate for this area. The sum of the lower 90 percent confidence limits of biomass, by area, is the reference number for setting ABC because of the continued uncertainty in yelloweye biomass estimation. This resulted in a biomass estimate of 15,100 mt for 2000.

Demersal shelf rockfish falls into Tier 4 of the ABC/OFL definitions. Under these definitions, the OFL mortality rate is $F_{35\%}$=0.028 (420 mt), and the maximum allowable fishing mortality rate for ABC is the $F_{40\%}$=0.025. However, a more conservative approach has been taken for setting ABC and TAC. By applying F=M=0.02 to yelloweye rockfish biomass and adjusting for the 10 percent of other Demersal shelf rockfish species, the recommended 2000 ABC is 340 mt. Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

The age and size distributions of yelloweye rockfish are discussed in O'Connell et al. (1999) and O'Connell and Funk (1987). Estimated length and age at 50 percent maturity for yelloweye collected in CSEO in 1988 are 45 cm and 21 years for females and 50 cm and 23 years for males. Age of first recruitment into the fishery is between 13 and 18 years. The most recent age data is from the 1998 commercial catch samples. In the CSEO, the area with the longest catch history, the 1997 distribution shows a strong mode at 28 years of age, with some younger modes. The older ages have declined in frequency over time and the average age continues to decline and remains the lowest of all areas. In the SSEO ,the 1997 age data shows pronounced modes at 16 and 20 years, with the older ages contributing less. In EYKT, the 1998 age distribution is multimodal, the largest mode at 29-30 years, and smaller modes at 33 and 40 years. Unlike other areas, no sign of recruitment is seen here. The effects of fishing on the age and size compositions are unknown, as no age or size data are available from either the fishery, or the unfished population prior to the beginning of the fishery.

The directed fishery for Demersal shelf rockfish is prosecuted by longliners. Yelloweye rockfish occur in areas of rugged, rocky bottom, commonly between 100 and 200 m. The lava fields off Cape Edgecumbe in CSEO and the offshore Fairweather Ground in EYKT are the most important fishing areas. A small amount of Demersal shelf rockfish are taken as bycatch in jig and troll fisheries. Trawling is prohibited in the eastern GOA. Yelloweye rockfish is the dominant bycatch species in the halibut longline fishery. The majority of the longline vessels in the eastern GOA are unobserved so it is difficult to get an accurate accounting of discards at sea. For the past several years we have estimated unreported mortality of Demersal shelf rockfish during the halibut fishery based on International Pacific Halibut Commission (IPHC) interview data. The 1993 interview data indicates a total mortality of Demersal shelf rockfish of 13 percent of the June halibut landings (by weight) and 18 percent of the September halibut landings. Unreported mortality data has been more difficult to collect under the halibut IFQ fishery and appears to be less reliable than previous data. The allowable bycatch limit of Demersal shelf rockfish during halibut fishing is 10 percent of the halibut weight. The total bycatch of Demersal shelf rockfish during the 1999 halibut fishery in the eastern Gulf is estimated to be 184 mt, much of which is unreported. Catch statistics do not accurately reflect true mortality of Demersal shelf rockfish.

Yelloweye are a large, predatory fish that usually feeds close to the bottom. Food habit studies indicate that the diet of yelloweye rockfish is dominated by fish remains, which comprised 95 percent, by volume, of the stomachs analyzed. Herring, sandlance and Puget Sound rockfish were particularly dominant. Shrimp are also an important prey item (Rosenthal et al. 1988).

Thornyheads

Thornyheads in Alaskan waters are comprised of two species, the shortspine thornyhead and the longspine thornyhead. Only the shortspine thornyhead is of commercial importance. It is a demersal species found in deep water from 93 to 1,460 m from the Bering Sea to Baja California (Ianelli and Gaichas 1999). Little is known about thornyhead life history. Like other rockfish, they are long lived and slow growing. The maximum recorded age is probably in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 at a length of about 21 cm. Thornyheads spawn large masses of buoyant eggs during the late winter and early spring (Pearcy 1962). Juveniles are pelagic for the first year. Yang (1993, 1996) showed that shrimp were the top prey item for shortspine thornyheads in the GOA; while cottids were the most important prey item in the Aleutian Islands region. Until recently, thornyheads were not targeted by the commercial fishery. However, they are now among the most valuable rockfish species and are harvested by trawl and longline gear. Most of the domestic harvest is exported to Japan. Thornyheads are taken with some frequency in the longline fishery for sablefish, and cod and are often part of the bycatch of trawlers concentrating on pollock and other rockfish species.

In the GOA ,shortspine thornyheads are assessed with an age-structured model incorporating data from two fisheries (longline and trawl) and two types of survey data. Bottom trawl surveys have been conducted every three years in the GOA during June through August and provide a limited time-series of abundance since 1977. Longline surveys occur annually and extend into the deeper waters (300 – 800 m) of shortspine thornyhead habitat. Both surveys provide estimates of the size distributions of their respective catches. These are used in the stock assessment model in place of age compositions because extensive age-determinations on this species are currently impractical, given the difficulties in interpretation of their otoliths. Biologically, the biggest area of uncertainty for this species is in their longevity and natural mortality rate. Currently, NMFS scientists believe they are slow-growing and long-lived fish that are relatively sedentary on the ocean floor. Survey and fishery catch rates indicate that they are relatively evenly distributed within their habitat and do not tend to form dense aggregations like many other groundfish species. This distribution pattern is important in interpreting the survey results because the assumptions implied in “area-swept” methods for the bottom trawl gear are likely to be satisfied. Fishery data include estimates of the total catch and size distribution information by gear type. The estimated biomass for 2000 is 23,084 mt, and the recommended ABC is 2,360 mt. The Council has adopted this value for both the 2000 TAC and OFL harvest levels.

In the EBS and Aleutian Islands, thornyheads are managed as part of the “other rockfish” management assemblage. Shortspine thornyheads are the primary species in the “other rockfish” management assemblage. The assessment is based on the most recent catch and survey data. Traditionally, the biomass estimates (split according to management area) from all bottom trawl surveys (EBS shelf/slope and Aleutian Islands) are averaged over all years to obtain the best estimates of biomass for the species in this complex. In 1999, this procedure produced a biomass estimate of 7,030 mt in the EBS, and a biomass estimate of 13,000 mt in the Aleutian Islands. The great majority of this biomass is comprised of thornyhead rockfish. In 1996, the SSC determined that a reliable estimate of the natural mortality rate existed for the species in this subcomplex, and that "other rockfish" in the EBS and Aleutian Islands therefore qualified for management under Tier 5 (Appendix 1; Amendment 44). The accepted estimate of M for these species in both areas is 0.07. F_{ABC} was set at the maximum value allowable under Tier 5, which is 75 percent of M, or 0.053. Multiplying this rate by the best estimate of complex-wide biomass gives an ABC of 369 mt in the EBS and 685 mt in the Aleutian Islands. The Plan Team’s OFLs were determined from the Tier 5 formula, where setting F_{OFL}=M gives an OFL of 492 mt in the EBS and 913 mt in the Aleutian Islands.

Other Rockfish Species

Numerous other rockfish species of the genus *Sebastes* have been reported in the GOA and BSAI (Eschmeyer et al. 1984), and several are of commercial importance. Most are demersal or semi-demersal with different species occupying different depth strata (Kramer and O'Connell 1988). All are viviparous (Hart 1973). Life history attributes of most of these rockfish are poorly known or virtually unknown. Because they are long lived and slow growing, natural mortality rates are probably low (less than 0.10). The diet of species for which dietary information exists seems to consist primarily of planktonic invertebrates (Yang 1993, 1996). Other rockfish species are taken both in directed fisheries and as bycatch in trawl and longline fisheries.

In the GOA, although the “other slope rockfish” management group comprises 17 species, six species alone make up 95 percent of the catch and estimated abundance. These six species are sharpchin, redstripe, harlequin, yellowstripe, silvergrey, and redbanded rockfish. Sharpchin rockfish falls into Tier 4, and the remaining species fall into Tier 5 of the ABC/OFL definitions. The overfishing fishing mortality rate for the other species is the $F=M$ rate of 0.10 for redstripe rockfish, 0.04 for silvergrey rockfish, and 0.06 for all the other species (except sharpchin rockfish). The F_{ABC} for sharpchin rockfish is $F=M$=0.05, which is less that the maximum allowable rate of $F_{40\%}$ = 0.055. For the other species the maximum allowable fishing mortality rate for ABC is the $F=0.75M$ rate which is 0.075 for redstripe rockfish, 0.030 for silvergrey rockfish, and 0.045 for the remaining species. These rates result in the recommended stock assessment ABC of 4,900 mt for “other slope rockfish”. The current Council ABC and TAC levels are equivalent to this value. Because the ABC and TAC for sharpchin rockfish component of the “other slope rockfish” are more conservative than the maximum prescribed under the definitions, less risk exists of the F_{ABC} rate and TAC being an overly aggressive harvest rate for “other slope rockfish.” This affords more protection to the stocks, given the variability and uncertainty associated with the abundance.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in rockfish fisheries of the GOA. Bycatch rates of “other slope rockfish” are highest in the pelagic shelf rockfish and Pacific ocean perch fisheries. Information on bycatch of “other slope rockfish” in non-rockfish fisheries has not been analyzed. Discard rates (discards/total catch) of “other slope rockfish” from 1995 to 1999 have ranged from 52 percent to 76 percent (Heifetz et al. 1999). In 1999, about 544 mt of “other slope rockfish” were discarded compared to a total catch of 789 mt. High discard rates are seen because many species of “other slope rockfish” are small in size and of low economic value, and fishermen have little incentive to retain these fish.

Prey of “other slope rockfish” is not documented for the GOA. Predators of “other slope rockfish” are also not well documented, but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

Atka Mackerel

BSAI

Atka mackerel are distributed from the east coast of the Kamchatka Peninsula, throughout the Aleutian Islands and the EBS, and eastward through the GOA to southeast Alaska (Wolotira et al. 1993). Their current center of abundance is in the Aleutian Islands, with marginal distributions extending into the southern Bering Sea and into the western GOA (Lowe and Fritz, 1999a). Atka mackerel are one of the most abundant groundfish species in the Aleutian Islands where they are the target of a directed trawl fishery (Lowe and Fritz 1999a). Adults are semi-pelagic and spend most of the year over the continental shelf in depths generally less than 200 m. Adults migrate annually to shallow coastal waters during spawning, forming dense aggregations near the bottom (Morris 1981, Musienko 1970). In Russian waters, spawning peaks in mid-June (Zolotov 1993) and in Alaskan waters in July through October (McDermott and Lowe 1997). Females deposit adhesive eggs in nests or rocky crevices. The nests are guarded by males until hatching occurs (Zolotov 1993). The first *in situ* observations of spawning habitat in Seguam Pass were recently (August, 1999) documented (pers. comm. Robert Lauth, AFSC). Genetic studies indicate that Atka mackerel form a single stock in Alaskan waters (Lowe et al. 1998). However, growth rates can vary extensively among different areas (Kimura and Ronholt 1988, Lowe et al. 1998, Lowe and Fritz 1999a). Age and size at 50 percent maturity has been estimated at 3.6 years and 33 to 38 cm, respectively (McDermott and Lowe 1997). Atka mackerel are a relatively short-lived groundfish species. A maximum age of 15 years has been noted, however most of the population is probably less than 10 years old. Natural mortality estimates vary extensively, and estimates have ranged from 0.12 to 0.74 as determined by various methods (Lowe and Fritz 1999a). For stock assessment purposes, a value of 0.3 is used (Lowe and Fritz 1999a).

Atka mackerel are an important component in the diet of other commercial groundfish, mainly arrowtooth flounder, Pacific halibut, and Pacific cod; seabirds, mainly tufted puffins; and marine mammals, mainly northern fur seals and Steller sea lions (Byrd et al. 1992, Fritz et al. 1995, Livingston et al. 1993, Yang 1996). Atka mackerel are also components in the diets of the following marine mammals and seabirds: harbor seals, Dall’s porpoise, thick-billed murre, and horned puffins (Yang 1996). The diets of commercially important groundfish species in the Aleutian Islands during the summer of 1991 were analyzed by Yang (1996). More than 90 percent of the total stomach contents weight of Atka mackerel in the study was made up of invertebrates, with less than 10 percent made up of fish. Euphausiids were the most important prey item, followed by calanoid copepods. Euphausiids comprised 55 percent by weight of the total stomach contents, and copepods comprised 17 percent of the total stomach contents weight. Larvaceans and hyperiid amphipods had high frequencies of occurrence (81 percent and 68 percent, respectively), but comprised less than 8 percent of the total stomach contents weight. Squid was another item in the diet of Atka mackerel; it had a frequency of occurrence of 31 percent, but only comprised 8 percent of the total stomach contents weight. Atka mackerel are known to eat their own eggs. Yang (1996) found that Atka mackerel eggs comprised 3 percent of the total stomach contents weight and occurred in 9 percent of the Atka mackerel stomachs analyzed. Walleye pollock were the second most important prey fish of Atka mackerel, comprising about 2 percent of the total stomach contents weight. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were minor components of the Atka mackerel diet; each category comprised less than 1 percent of the total stomach contents.

Atka mackerel are a difficult species to survey because they do not have a swim bladder, and therefore are poor targets for hydroacoustic surveys. They prefer rough and rocky bottoms that are difficult to sample with the current survey gear, and their schooling behavior and patchy distribution result in survey estimates with large variances. Complicating the difficulty in surveying Atka mackerel is the low probability of encountering schools in the GOA where the abundance is lower and their distribution is patchier relative to the BSAI. Because of this, it has not been possible to estimate trends in population for the species in the GOA. The stock assessment in the Aleutian Islands is based on the triennial trawl survey as well as total catch and catch at age data from the commercial fishery.

BSAI Atka mackerel are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Survey data are from the NMFS Aleutian Islands triennial trawl groundfish surveys. Fishery catch statistics (including discards) are estimated by the NMFS Regional Office. These estimates are based on the best blend of observer reported catch and weekly production reports. The stock assessment includes catch history, characterizations of the fishery, key life history parameters, survey and model estimated abundance trends, historical exploitation rates, reference fishing mortality rates, projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions, and a recommended harvest rate and catch for the upcoming year. The results of the analyses, which are updated annually, are presented in the BSAI Atka mackerel stock assessment which is incorporated into the BSAI SAFE report.

In 1999, Atka mackerel fell into Tier 3a of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{35\%}$ rate which was estimated to be 0.42 for Atka mackerel and equated to a yield of 119,300 mt (Lowe and Fritz 1999a). The maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate which was estimated to be 0.35 for Atka mackerel in 1999, which translated to a yield of 102,700 mt (Lowe and Fritz 1999a). In 1999, the stock assessment ABC recommendation for the 2000 Atka mackerel fishery was below the maximum rate prescribed under Tier 3a, to provide a more risk-averse harvest rate and to accommodate uncertainty. The stock assessment F_{ABC} is 0.23 which translated to a yield of 70,800 mt. A recommendation lower than $F_{40\%}$ was recommended in the 1999 stock assessment because: 1) stock size as estimated by the age-structured analysis has declined by approximately 60 percent since 1991; and 2) the 1997 Aleutian trawl survey biomass estimate was about 50 percent lower than the 1991 and 1994 survey estimates.

The 1998 age and size distributions of BSAI Atka mackerel are discussed in Lowe and Fritz (1999a). The age composition is dominated by a recent strong 1992 year class (6-year- olds), and there is still evidence of the strong 1988 year class (10-year- olds) in the population. The estimated mean age of the 1998 fishery age composition is six years. The current fishery tends to select fish ages 3 to 12 years old (Lowe and Fritz 1999a). It is not known how the age composition of the population would look in an unfished population.

The directed fishery for Atka mackerel is prosecuted by catcher-processor bottom trawlers. The patterns of the fishery generally reflect the behavior of the species in that the fishery is highly localized, occurring in the same few locations each year, generally occurs at depths between 100 and 200 m (Lowe and Fritz 1999a). Important Atka mackerel fishery locations include Seguam Bank, Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the seamounts and reefs near Buldir Island.

Since 1979, the Atka mackerel fishery has occurred largely within areas designated as Steller sea lion critical habitat. While total removals from critical habitat may be small in relation to estimates of total Atka mackerel biomass in the Aleutian Islands region, fishery harvest rates in localized areas may have been high enough to affect prey availability of Steller sea lions (Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel apparently does not affect fishing success from one year to the next, since local populations in the Aleutian Islands appear to be replenished by immigration and recruitment. However, this pattern could create temporary reductions in the size and density of localized Atka mackerel populations, which could affect Steller sea lion foraging success during the time the fishery is operating and for a period of unknown duration after the fishery is closed.

To address the possibility that the fishery creates localized depletions of Atka mackerel and adversely modifies Steller sea lion critical habitat by disproportionately removing prey, the Council, in June 1998, passed a fishery management regulatory amendment which proposed a four-year timetable to temporally and spatially disperse and reduce the level of Atka mackerel fishing within Steller sea lion critical habitat in the BSAI. The temporal dispersion is accomplished by dividing the BSAI Atka mackerel TAC into two equal seasonal allowances. The first allowance is made available for directed fishing from January 1 to April 15 (A season), and the second seasonal allowance is made available from September 1 to November 1 (B season). The spatial dispersion is accomplished through maximum catch percentages of each seasonal allowance that can be caught within Steller sea lion critical habitat (CH) as specified for the central and western Aleutian Islands. No critical habitat closures are established for the eastern subarea, but the 20 nm trawl exclusion zones around the Seguam and Agligadak rookeries that have been in place only for the pollock A-season, are in effect year-round. The regulations implementing these management changes became effective January 22, 1999. The four-year timetable for spatial dispersion of the Atka mackerel fishery outside of critical habitat is:

Aleutian Island District

	Area 541		Area 542		Area 543	
Year(s)	*Inside CH*	*Outside CH*	*Inside CH*	*Outside CH*	*Inside CH*	*Outside CH*
1999			80%	20%	65%	35%
2000			67%	33%	57%	43%
2001			54%	46%	49%	51%
2002			40%	60%	40%	60%

Relative to 1998, the biggest shift in the distribution of fishing effort was observed in area 542 where effort shifted to Petral Bank in 1999.

Atka mackerel are not commonly caught as bycatch in other directed fisheries. The largest amounts of discards of Atka mackerel, which are likely undersize fish, occur in the directed Atka mackerel trawl fisheries. Recent discard rates (discards/retained catch) of Atka mackerel in the directed fishery have been below 10 percent (Lowe and Fritz 1999a). Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish (primarily Pacific ocean perch, sharpchin and northern rockfish) fisheries. It is difficult to discern the level of natural bycatch of Atka mackerel in the rockfish fisheries, as vessels may actually be targeting Atka mackerel in particular hauls, but overall they are designated as targeting rockfish on a particular trip. In 1998, 4,597 mt of Atka mackerel were discarded in the directed fishery as compared to 1,072 mt discarded in all other fisheries.

GOA

No reliable estimate exists of current Atka mackerel biomass in the GOA. Atka mackerel have not been commonly caught in each of the GOA triennial trawl surveys. It has been determined that the general GOA groundfish bottom trawl survey does not assess the Gulf portion of the Atka mackerel stock well, and the resulting biomass estimates have little value as absolute estimates of abundance or as indices of trend (Lowe and Fritz 1999b). Because of this lack of fundamental abundance information GOA Atka mackerel are not assessed with a model and the assessment does not utilize abundance estimates from the trawl survey. The stock assessment for GOA Atka mackerel consists of descriptions of catch history, length and age distributions from the fishery during 1990 to 1994, and length and age distributions from the trawl surveys (1990, 1993, and 1996). This information is presented in the GOA Atka mackerel stock assessment, which is incorporated into the GOA SAFE report.

GOA Atka mackerel fall into Tier 6 of the ABC/OFL definitions, which defines the overfishing level as the average catch from 1978 to 1995, and that ABC cannot exceed 75 percent of the OFL. The average annual catch from 1978-95 is 6,200 mt; thus ABC cannot exceed 4,700 mt. The current ABC recommendation from the stock assessment is below the maximum prescribed under Tier 6, to provide a very risk-averse harvest rate given the uncertainty about GOA Atka mackerel. The 1999 stock assessment for the 2000 fishery, recommended an ABC of 600 mt, with the intention of precluding a directed fishery, but providing for bycatch needs in other trawl fisheries. An ABC lower than the maximum prescribed under Tier 6 was recommended because: 1) When past ABCs were lower than 4,700 mt (approximately 3,000 mt in 1994), it was shown that the fishery might have created localized depletions of Atka mackerel even at those catch levels [appendix in (Lowe and Fritz 1996)]. This analysis indicated that the fishery was very efficient in removing fish from local areas and at rates which far surpassed the target harvest rate. 2) Analyses of local fishery catch per unit effort indicated that the Atka mackerel populations may have declined significantly between 1992 and 1994 (appendix in Lowe and Fritz 1996), reflecting the trend of the Aleutian Islands Atka mackerel population during that period, which has continued to decline since 1994 (Lowe and Fritz 1999b). 3) The GOA Atka mackerel population appears to be particularly vulnerable to fishing pressure because of sporadic movement of fish eastward from the Aleutian Islands.

Age and size distributions of GOA Atka mackerel are discussed in Lowe and Fritz (1999b). The most recent size and age distributions are from the 1996 and 1993 trawl surveys, respectively. Male and female size distributions had mean lengths of 45 and 47 cm, respectively. A mode of fish from 45 to 47 cm represented the 1988 year class. It appears as though little recent recruitment has occurred in the GOA population. Currently, no directed fishery for GOA Atka mackerel occurs. Atka mackerel are caught as bycatch, and the selectivity of Atka mackerel by the other fisheries is unknown. As such, Atka mackerel in the GOA are currently managed as a bycatch fishery. They are caught as bycatch in the pollock, Pacific cod, Pacific ocean perch, and northern rockfish fisheries. The low level of TAC likely precludes directed targeting of Atka mackerel on a haul by haul basis, and the catches of Atka mackerel in other directed fisheries may represent true bycatch of Atka mackerel.

The diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). Atka mackerel were not sampled as a predator species. However, it is probably a reasonable assumption that the major prey items of GOA Atka mackerel would likely be euphausiids and copepods as was found in Aleutian Islands Atka mackerel (Yang 1996). The abundance of Atka mackerel in the GOA is much lower compared to the Aleutian Islands. Atka mackerel only showed up as a minor component in the diet of arrowtooth flounder in the GOA (Yang 1993).

Squid and Other Species

Squid are found throughout the Pacific Ocean. They are not currently the target of groundfish fisheries in the GOA or BSAI, though they are taken as bycatch in trawl fisheries for pollock and rockfish. The red (magistrate) armhook squid is probably the best known species found in Alaskan waters. It is abundant over continental slopes throughout the North Pacific from Oregon to southern Japan (Nesis 1987). It is the basis of fisheries in both Russian and Japanese waters. Little is known about the reproductive biology of squid. Fertilization is internal and juveniles have no larval stage. Eggs of inshore species are often enveloped in a gelatinous matrix attached to substrate, while the eggs of offshore species are extruded as drifting masses. The red armhook squid appears to spawn in the spring and to live as long as 4 years, though most die after spawning at one year to 16 months old (Arkhipkin et al. 1996). Perez (1990) estimated that squids comprise over 80 percent of the diet of some whales. Seabirds and some salmon species are also known to feed heavily on squid at certain times of the year.

In the BSAI FMP squid are grouped in a “Squid and Other Species” group made up of squids, which are considered separately; and sculpins, skates, sharks, and octopi, which comprise the true “other species” category. Because insufficient data exists to manage each of the other species groups separately, they are considered collectively. Neither squid nor any of the species in the “other species” category are currently targeted by the groundfish fisheries in the BSAI and GOA. As such, they are only caught as bycatch by fisheries targeting groundfish. Beginning in 1999, smelts were removed from the “other species” category and have been placed, along with a wide variety of other fish and crustaceans including krill, deep-sea smelts, and lantern fishes, in the forage fish category. This action was accomplished through Amendments 36 and 39 to the BSAI and GOA groundfish FMPs. These amendments place specific catch percentage limits for forage fish on all groundfish fishery participants to prevent the development of directed forage fish fisheries. The following table presents estimated catches (mt) of other species, squid, forage fish and miscellaneous fish by groundfish fisheries in the BSAI and GOA in 1999 by target species fishery and gear using observer and NMFS blend data.

Target Groundfish Species	**Gear**	**Other Species**					**Squid**	**Forage Fish**	**Miscellaneous Fish**
		Skates	**Sharks**	**Sculpins**	**Octopus**	**Total**			
BSAI									
Atka mackerel	Trawl	96	0	285	0	382	5	-	75
Pacific cod	Trawl	831	8	954	23	1,817	2	2	132
Pacific cod	Pot	0	-	649	260	909	0	-	10
Pacific cod	Longline	9,625	105	1,139	21	10,890	0	0	113
Pacific cod	ALL	10,456	113	2,742	304	13,615	2	2	255
Flatfish	Trawl	11,750	179	9,101	11	21,041	60	20	2,589
Flatfish	Longline	5		0		5		-	42
Flatfish	ALL	11,755	179	9,101	11	21,045	60	20	2,630
Rockfish	Trawl	53	3	21	0	77	5	0	55
Rockfish	Longline	9	1	0	0	11	-	-	223
Rockfish	ALL	62	4	21	0	88	5	0	278
Pollock	Pelagic trawl	314	104	40	0	458	403	38	209
Pollock	Bottom trawl	42	2	18	1	62	4	1	10
Pollock	ALL	355	105	58	1	520	406	39	219
Rock sole	Trawl	207	0	152	12	371		0	69
Sablefish	Pot	0			0	0		-	0

Target Groundfish Species	Gear	Other Species						Forage Fish	Miscellaneous Fish
		Skates	Sharks	Sculpins	Octopus	Total	Squid		
Sablefish	Longline	105	21	0	0	126	-	-	4,730
Sablefish	ALL	105	21	0	0	126	-	-	4,730
Turbot	Trawl	11		3	0	15	4	0	12
Turbot	Pot	1	-	-	0	1	0	-	0
Turbot	Longline	273	203	2	0	479	-	-	3,840
Turbot	ALL	285	203	6	0	494	4	0	3,852
Yellowfin Sole	Trawl	566	1	935	2	1,503		2	328
ALL	Trawl	13,827	295	11,492	48	25,662	478	63	3,469
	Pot	1	-	649	260	909	0	-	10
	Longline	10,017	330	1,141	22	11,509	0	0	8,947
ALL	ALL	23,844	625	13,282	329	38,080	478	63	12,426

(continued)

Target Groundfish Species	Gear	Other Species						Forage Fish	Miscellaneous Fish
		Skates	Sharks	Sculpins	Octopus	Total	Squid		
GOA									
Pacific cod	Trawl	216	10	98	3	238	0	15	24
Pacific cod	Pot	0	1	111	115	118	-	45	13
Pacific cod	Longline	333	230	129	5	675	-	1	5
Pacific cod	ALL	549	241	338	123	1,032	0	61	42
Flatfish	Trawl	470	46	58	9	490	7	9	350
Flatfish	Longline	0	-	-	-	-	-	-	4
Flatfish	ALL	470	46	58	9	490	7	9	353
Rockfish	Trawl	46	5	26	0	17	6	101	123
Rockfish	Longline	27	58	0	-	-	-	10	6
Rockfish	ALL	73	63	26	0	17	6	111	129
Pollock	Bottom Trawl	20	63	0	0	83	2	2	107
Pollock	Pelagic trawl	2	131	3	0	118	18	23	120
Pollock	ALL	22	194	4	0	201	20	25	227
Sablefish	Trawl	0	-	0	0	-	0	0	1
Sablefish	Longline	200	126	0	0	19	1	2	9,338
Sablefish	ALL	201	126	0	0	19	1	2	9,339
ALL	Trawl	754	255	185	13	946	33	151	724
ALL	Pot	0	1	111	115	118	-	45	13
ALL	Longline	1,030	460	187	15	1,184	8	22	9,703
ALL	ALL	1,784	716	484	143	2,248	41	218	10,440

Note: Forage fish are myctophids, osmerids, bathylagids, sandfish, sand lance, gunnels, and pricklebacks. Miscellaneous fish are mostly grenadiers, but also include greenlings, poachers, lumpsuckers, ronquils, gastropods, fish waste, snipe eels, eelpouts, hagfish, pomfrets, and snailfish. "-": < 0.01 mt; "0": > 0.01 and <0.5 mt of estimated catch.

Assessment data are not available for squid from AFSC surveys because of their mainly pelagic distribution over deep water. Information on the distribution, abundance, and biology of squid stocks in the EBS and Aleutian Islands region is generally lacking. Red armhook squid predominates in commercial catches in the EBS and GOA, and *Onychoteuthis boreali japonicus* is the principal species encountered in the Aleutian Islands region.

Forty-one species of sculpins were identified in the EBS and 22 species in the Aleutian Islands region (Bakkala 1993, Bakkala et al. 1985, Ronholt et al. 1985). During these same surveys, 15 species of skates were identified but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist. Species that have been consistently identified during surveys are the Alaska skate, big skate, longnose skate, starry skate, and Aleutian skate. Biomass estimates of sculpins and skates from demersal trawl surveys serve as valuable indices of their relative abundance.

While biomass estimates have been made for sharks and octopi, the AFSC bottom trawl surveys are not designed to adequately sample the realms they inhabit. Sharks are rarely taken during demersal trawl surveys in the Bering Sea; however, spiny dogfish is the species usually caught, and the Pacific sleeper shark has been taken on occasion. Two species of octopus have been recorded, with *Octopus dofleini*, the principal species, and *Opisthoteuthis california* appearing only intermittently.

Many species in the squid and other species assemblage are important as prey for marine mammals and birds as well as commercial groundfish species. Squid and octopus are consumed primarily by marine mammals, such as Steller sea lions ((Lowry et al. 1982), northern fur seals (Perez and Bigg 1986), harbor seals (Lowry et al. 1982, Pitcher 1980b), sperm whales (Kawakami 1980), Dall's porpoise (Crawford 1981), and Pacific white-sided dolphins (Morris et al. 1983), and beaked whales (Loughlin and Perez 1985)). Sculpins have also been found in the diet of harbor seals (Lowry et al. 1982).

EBS and GOA Biomass Estimates for Squid and Other Species

Data from AFSC surveys provide the only abundance estimates for the various groups and species comprising the "other species" category. Biomass estimates for the EBS are from a standard survey area of the continental shelf. The 1979, 1981, 1982, 1985, 1988 and 1991 data include estimates from continental slope waters (200-1,000 m in 1979, 1981, 1982, and 1985; 200-800 m in 1988 and 1991), but data from other years do not. Slope estimates were usually 5 percent or less of the shelf estimates, except for grenadiers. Stations as deep as 900 m were sampled in the 1980, 1983 and 1986 Aleutian Islands bottom trawl surveys, while surveys in 1991 and 1994 obtained samples only to a depth of 500 m.

Since the survey biomass estimates for species other than squid vary substantially from year to year due to different distributions of the component species, it is probably more reliable to estimate current biomass by averaging estimates of recent surveys. The average biomass of other species from the last three EBS surveys (1997-99) is 561,600 mt; adding the estimate from the 1997 Aleutian Islands survey (48,800 mt) yields a total BSAI “other species” biomass estimate of 610,400 mt.

Biomass estimates from AFSC surveys illustrate that sculpins were the major component of this group until 1986, after which the biomass of skates exceeded that of sculpins. The abundance of skates increased between 1985 and 1990 (when a high of 583,800 mt survey biomass was observed), but has since declined to about 370,000 mt in 1999. The abundance of sculpins remained relatively stable through 1998, but declined to the lowest biomass estimate since 1975 in 1999.

Trends in the biomass of GOA "other species” (sharks, skates, sculpins, smelts, octopi, and squids) were investigated using the NMFS triennial trawl survey data from 1984 through 1999. Any discussion of biomass trends should be viewed with the following caveats in mind: 1) Survey efficiency may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Robin Harrison, personal communication). 2) Surveys in 1984, 1987, and 1999 included deeper strata than the 1990 - 1996 surveys. Therefore, the biomass estimates for deeper-dwelling components of the other species category are not comparable across all years.

The average biomass within the other species category using all six(6) survey biomass estimates is

160,000 tons. The most recent estimate of other species biomass (1999) is 213,000 tons. Skates represent 30-40 percent of the other species biomass from all surveys and are the most common group in each year except 1984, when sculpin biomass was highest within the category. Total biomass for the other species category has increased between 1984 and 1999. This is the result of apparent increases in skate, shark, and smelt biomass, some of which may be difficult to resolve from changes in survey efficiency. Sculpin biomass appears relatively stable over this period.

Individual species biomass trends were evaluated for the more common and easily identified shark and sculpin species encountered by the triennial trawl survey. In general, the increasing biomass trend for the shark species group is as result of increases in spiny dogfish and sleeper shark biomass between 1990 and 1999. Salmon shark biomass has been stable to decreasing, according to this survey, but salmon sharks are unlikely to be well sampled by a bottom trawl (as evidenced by the high uncertainty in the biomass estimates). It should be noted that both salmon shark and Pacific sleeper shark biomass estimates may be based on a very small number of individual tows in a given survey. No salmon sharks were encountered in the 1999 survey, despite reports of their increased abundance in other areas of the GOA.

Individual sculpin species display divergent biomass trends between 1984 – 1999. While the biomass of bigmouth sculpins has decreased over the period of the survey, great sculpin biomass has remained relatively stable, and yellow Irish lord biomass has increased. The biomass of yellow Irish lords appears to have increased over time despite general stability in the number of hauls where they occurred, whereas bigmouth sculpins were encountered in fewer hauls each year. Uncertainty in these estimates varies between years.

In addition to sharks and sculpins, we examined available biomass estimates for grenadiers, which are not included in the other species category. The species most commonly encountered in the triennial trawl surveys was the giant grenadier. The Pacific grenadier was present, but with much lower estimated biomass in all years. Survey coverage of deeper strata is particularly important to grenadier biomass estimates; therefore we consider the 1990–1996 survey estimates to be of little use for detecting trends in grenadier abundance

Current Stock Assessment and OFL/ABC/TAC Determinations

No reliable biomass estimates for squid exist, and no stock assessment per se. Sobolevsky (1996) cites an estimate of four million tons for the entire Bering Sea made by squid biologists at TINRO (Shuntov et al. 1993), and an estimate of 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. AFSC bottom trawl surveys almost certainly underestimate squid abundance. Squid catches and ABCs are almost certainly a very small percentage of the total squid biomass in the EBS and GOA. BSAI squid ABC and OFL are set using criteria in Tier 6 as described in Amendment 44 to the BSAI FMP given the lack of data on their population dynamics and biomass. OFL is set equal to the average annual catch from 1978 to 1995 (2,624 mt), while ABC is capped at no greater than 75 percent of OFL (1,970 mt). As currently defined, BSAI squid ABC and OFL values would remain constant in the future, unless different methodologies were employed to assess squid abundance (e.g., analysis of fishery CPUE data). This methodology change could occur under any of the alternatives considered. The BSAI squid TAC has been set equal to the stock-assessment-recommended ABC by the Council.

Reliable biomass estimates exist for two (skates and sculpins) of the groups that comprise the bulk of the biomass and fishery catches in the other species category. Survey biomass estimates for sharks, smelts, and octopi, while not reliable, represent the best data available on the abundance of these species. A single estimate of M for this diverse assemblage, while not known, is conservatively estimated at 0.2. OFL for the other species assemblage is set using the criteria in Tier 5 as described in Amendment 44, where $F_{OFL}=M$, and OFL=M x (total other species survey biomass). Using Tier 5 criteria, ABC is capped at 75 percent of OFL. However, rather than use this method, the other species ABC has been calculated as the average annual catch since 1978 to avoid potentially 5-fold increases in other species catches that could occur if it were set at 75 percent of OFL. In 1998 (for the 1999 fishery), the Council began a 10-step increase toward full $F=M$ exploitation strategy for "other species" complex by implementing the first 10 percent of the difference between that strategy and average catch since 1978. For the 2000 fishery, the Council stopped the step-wise increase and kept the ABC at a level approximately 10 percent higher than the stock assessment author's recommendation. BSAI area other species TAC has been set equal to the other species ABC by the Council. A 2000 ABC for the BSAI other species category set using this process (31,360 mt) represents an exploitation rate of about 5 percent of the best estimate of current biomass (610,400 mt). This estimate was obtained by averaging the three most recent EBS bottom trawl survey estimates of other species biomass (from 1997 to 1999: 561,600 mt), and adding the most recent Aleutian Islands bottom trawl estimate (from 1997: 48,800 mt).

The annual TAC for other species in the GOA (which includes squid) is set equal to 5 percent of the sum of all GOA groundfish TACs. Catches of other species in the GOA have ranged between 1,570 and 6,867 mt from 1990 to 1999.

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APPENDIX 3 STELLER SEA LION CASE STUDY

Annual estimates of prey availability for the entire BSAI and GOA

The current estimate of groundfish biomass in 1999 in the BSAI/GOA is approximately 21.8 million tons. The estimated annual consumption of forage by 43,000 Steller sea lions is 399,700 tons (based on the approach reported in Winship 2000). The current estimate of the ratio of biomass consumed by Steller sea lions to biomass of groundfish is approximately 1:54. The estimated equilibrium theoretical unfished stock size for 17 groundfish stocks combined was likely to be no more than 37.6 million tons (NMFS 2000), although it must be recognized that this figure represents an estimate of a hypothetical condition (i.e., the amount of groundfish biomass in the action area at this time had there been no commercial fishery ever prosecuted in this area). The estimated historical abundance of Steller sea lions (prior to their recent decline) is approximately 184,000 animals (Loughlin et al. 1984). The 1999 estimate of abundance for Steller sea lions from Winship (2000) is about 43,000 animals or roughly 23% of its historical carrying capacity, where annual consumption by sea lions in 1999 was estimated at 399,700 tons. Therefore, by analogy, 200,000 animals would be expected to eat approximately 1.71 million tons of forage annually. While crude, the estimated ratio of biomass consumed by 184,000 Steller sea lions to biomass of groundfish in an unfished environment is approximately 1:21. To interpret this estimate, it must be assumed that Steller sea lions only eat groundfish, which of course is a conservative assumption. With this assumption, it could be argued that a healthy population of Steller sea lions requires no more than 22 times as much forage as it is capable of consuming in a single year.

Another approach to estimating what the multiplier in going from prey consumed to prey available should be for a healthy marine mammal population was reported by Fowler (1999). The information reported in Fowler (1999) was extracted from Perez and McAlister (1993). Perez and McAlister reported that 32,000 Steller sea lions would consume 140,700 tons of forage. Extrapolating to the consumption of 184,000 Steller sea lions leads to a consumption estimate of 809,600 tons of forage. If it is again assumed that the unfished, equilibrium biomass of groundfish is 37.6 million tons, then the multiplier of groundfish forage available to Steller sea lions forage consumed is 46.

At present it is not possible to evaluate the relative merits of the two multipliers. Therefore, lacking alternatives, two approaches are proposed regarding the inference as to whether the current multiplier of forage available to forage consumption for a species listed under the ESA is indicative of a population that has adequate access to forage. One would be to use the average value of the two multipliers. In this case, that would be a multiplier of 34 (i.e., (22+46)/2). The other approach would be to use the more conservative estimate, as the ESA requires NMFS to err on the side of the animal when interpreting available data. The current ratio of biomass consumed by SSL to biomass available is 1:54 or a multiplier of 55. In either case, the current multiplier is greater than either of the two threshold values. This analysis, given uncertainties as discussed above, is therefore consistent with the conclusion that at the global or Action Area scale of the BSAI and GOA, Steller sea lions have adequate forage available to them to recover to optimal population levels.

Monthly estimates of prey availability for critical habitat

Average monthly estimates of biomass of pollock, Atka mackerel, and Pacific cod in critical habitat are reported in NMFS (2000). Alaska Fisheries Science Center. Biological Opinion Questions and Answers, unpublished report). In addition, monthly consumption estimates of a population of 43,000 Steller sea lions are reported in Table based on the methods reported in Winship (2000). The monthly estimates of biomass range from a low of 2.1 million tons in June to a high of 6.4 million tons in February (Table 2). Steller sea lion consumption estimates range from a low of 25,664 tons in June to a high of 35,787 tons in March. The average percent of biomass consumed was 0.88% percent or a ratio of 1:113 biomass consumed to biomass available. The lowest percentage of the twelve month period was in 0.52% in February, while the highest percentage was 1.48%. The corresponding multipliers for these percent consumption rates are 192 and 68.

A worst-case estimate of the percent of biomass of pollock, Atka mackerel, and Pacific cod in critical habitat, which was based on the upper 95% confidence interval for consumption and the lower 95% confidence interval for biomass available, ranges from a low of 1.27% to a high of 3.12% (i.e., multipliers of forage consumed to forage available of 79 and 32). The average percent consumption using these data was 2.01% or a ratio of 1:49 biomass consumed to biomass available (i.e., multiplier of 50).

It should be emphasized that these estimates of percent biomass consumed are likely to be positively biased (i.e., over-estimated) because the diet of Steller sea lions includes species other than the three considered in this analysis and because the foraging area of Steller sea lions in the western population is not limited to critical habitat. It should be noted that the associated estimates of precision of Steller sea lion consumption are likely negatively biased because the variance associated with the abundance estimate, age structure, and energetic needs have not been included in the analysis (as estimates for these statistics are not available). Further, in interpreting the results of these data it is necessary to assume that forage is adequately available to Steller sea lions throughout critical habitat. The information needed to test this assumption are not available. Therefore, the degree to which heterogeneity in the distribution of biomass confounds the interpretation of forage availability in critical habitat for Steller sea lions and the effects of commercial fishing on forage availability for SSL cannot be assessed at this time.

The best available data indicate that the current multiplier varies monthly between 68 and 191, where the multiplier is never less than 46. Further, using the conservative data on forage consumed to forage available, the estimated multipliers range over the 12 month period between 32 and 79. In this case, only one of the monthly multipliers is less than the threshold of a multiplier of 34, while four of the monthly multipliers are less than the more conservative threshold of 46. As noted in NMFS (2000), there is considerable uncertainty in trying to estimate monthly estimates of Steller sea lion consumption and biomass of pollock, Pacific cod, and Atka mackerel and in estimating the fraction of the total biomass of these three prey species that occur in Critical Habitat for Steller sea lions. However, given uncertainty consistent with previous analyses, the available data on monthly consumption requirements relative to the total biomass of three important prey species in critical habitat are consistent with the conclusion that forage availability (without consideration regarding species composition or spatial distribution) is adequate to support the recovery of Steller sea lions to optimal population levels.

Table 1. Summary of Steller sea lion consumption estimates by month (based on Winship 2000). The population size assumed in this analysis was 43,127 animals post-pupping.

Month	Biomass (tons)	Month	Biomass (tons)
Jan	35,093	July	32,275
Feb	33,407	Aug	32,990
Mar	35,787	Sept	33,057
Apr	34,125	Oct	34,497
May	34,127	Nov	33,775
Jun	25,664	Dec	34,872

Table 2. Summary of biomass estimates of pollock, Pacific cod, and Atka mackerel in Critical Habitat (see NMFS 2000)

Month	Biomass (tons)	% Consumed	Month	Biomass (tons)	% Consumed
Jan	**6,012,615**	0.58	July	**2,183,687**	1.48
Feb	**6,383,644**	0.52	Aug	**2,538,000**	1.30
Mar	**6,397,301**	0.56	Sept	**3,083,889**	1.07
Apr	**5,961,198**	0.57	Oct	**3,750,186**	0.92
May	**3,851,215**	0.89	Nov	**4,456,918**	0.76
Jun	**2,056,445**	1.25	Dec	**5,100,096**	0.68

The analyses that we have conducted in this biological opinion suggests that competition as the result of an overall prey removal as allowed by the FMP does not adversely modify critical habitat. Rather, this analysis raises the following issues:

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, for short periods of time (hours to days), reduce the biomass of the targeted fish remaining in the immediate area. 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. An assumption in our analyses suggested that the degree to which heterogeneity in the distribution of biomass occurs could confound the interpretation of forage availability in critical habitat for Steller sea lions. However, fish species are not

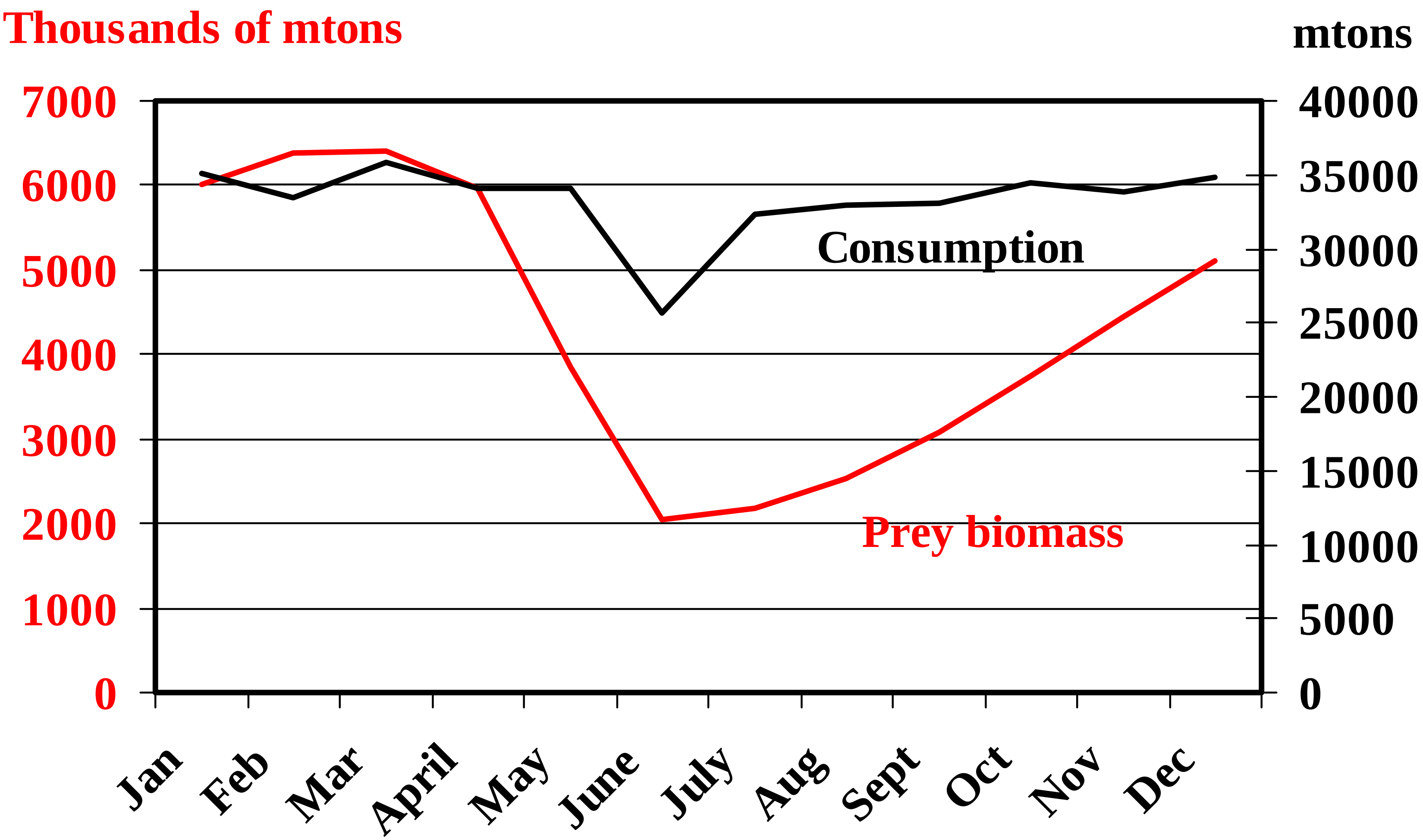
always homogeneously distributed throughout the water column. Instead, there are specific areas that have larger numbers of fish and other areas that have limited numbers of fish (Bakun 1996). Pollock and Atka mackerel are schooling fish that are patchily distributed, within a school their biomass is 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 immediate area 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, even if there is sufficient prey overall as indicated by the previous analyses. We have stated in previous opinions that 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. Based on the available biomass during the critical winter months, it is apparent that pollock availability is highest during the periods of the greatest energetic demands.

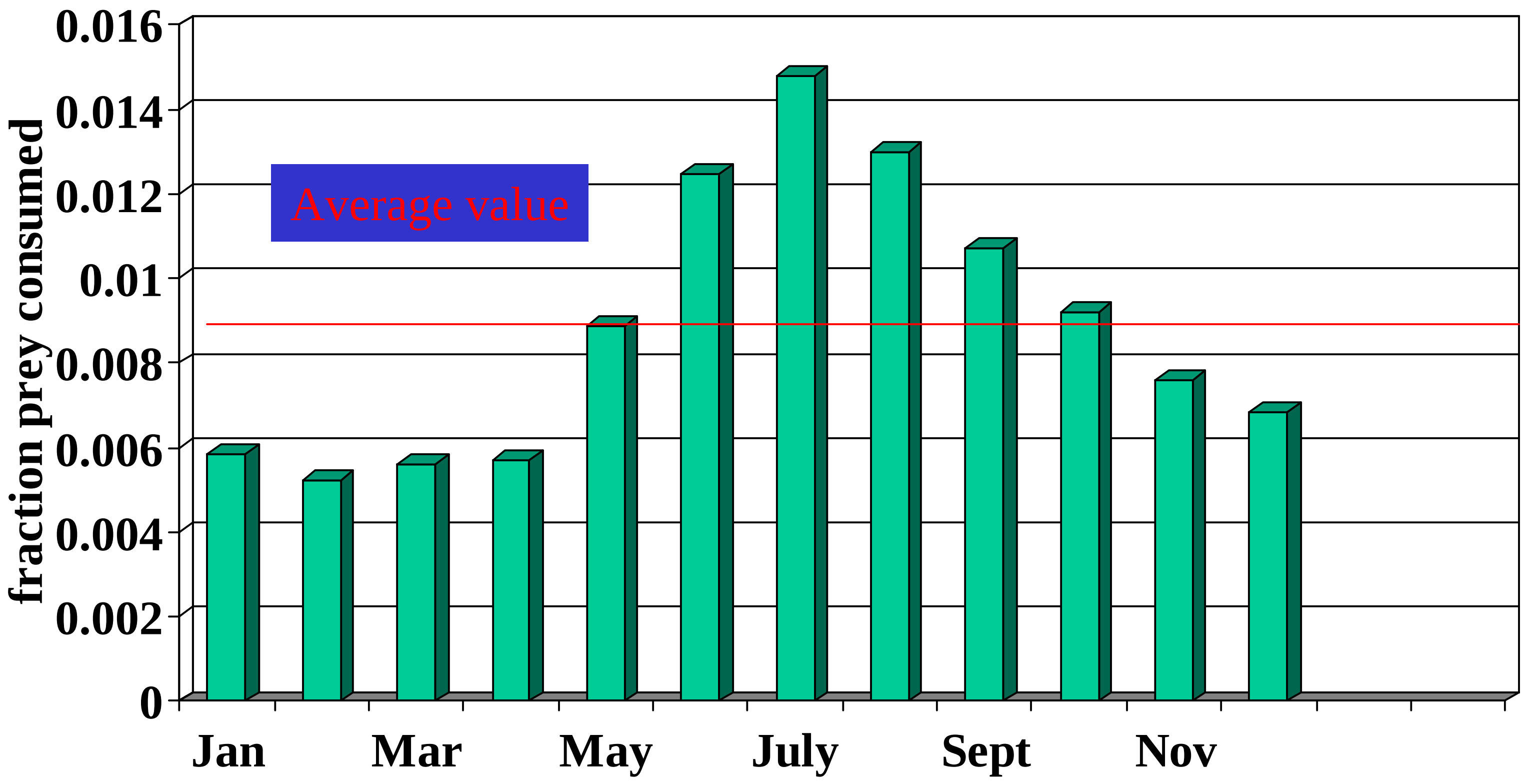
Based on the available information, it is reasonable to expect the groundfish fisheries do compete with non-human consumers in the marine ecosystem in the BSAI and GOA. However, this competition occurs as a result of the temporal and spatial behavior of the fishing fleet, and removals by this fleet on a local level, not as a result of a decrease in total prey availability due to the reduction of total fish biomass. Our current review is consistent with previous biological opinions that suggest that the harvesting ability of the fishing fleet and of individual vessels may deplete the groundfish biomass on small, spatial and temporal scales that would be expected to reduce the availability of groundfish to other, non-human consumers.

Steller Sea Lion Consumption versus Prey Availability in Critical Habitat



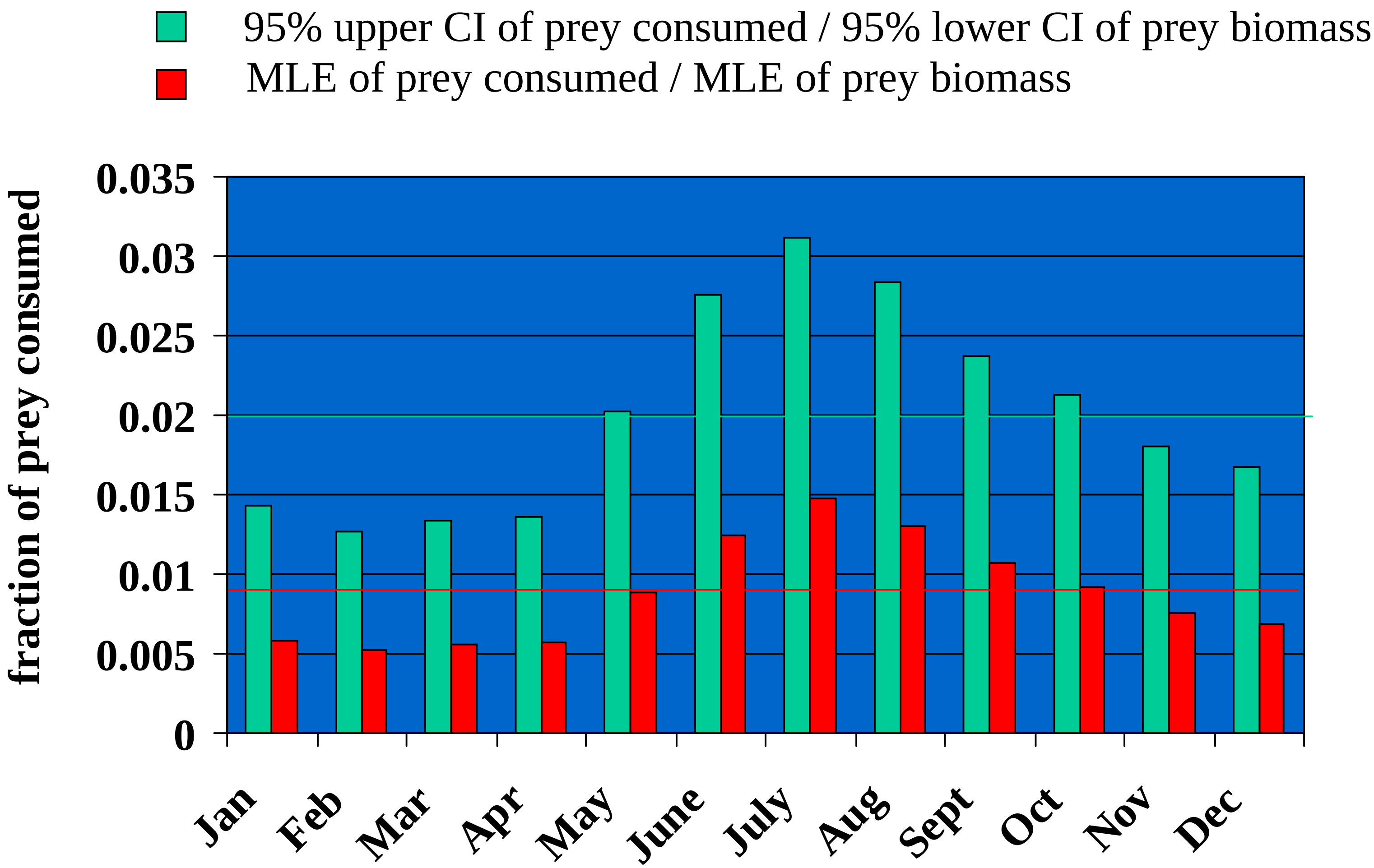
**Biomass estimates of prey are for pollock, Pacific cod and Atka mackerel*

Fraction of Prey Consumed by Steller Sea Lions in Critical Habitat



**Biomass estimates of prey are for pollock, Pacific cod and Atka mackerel*

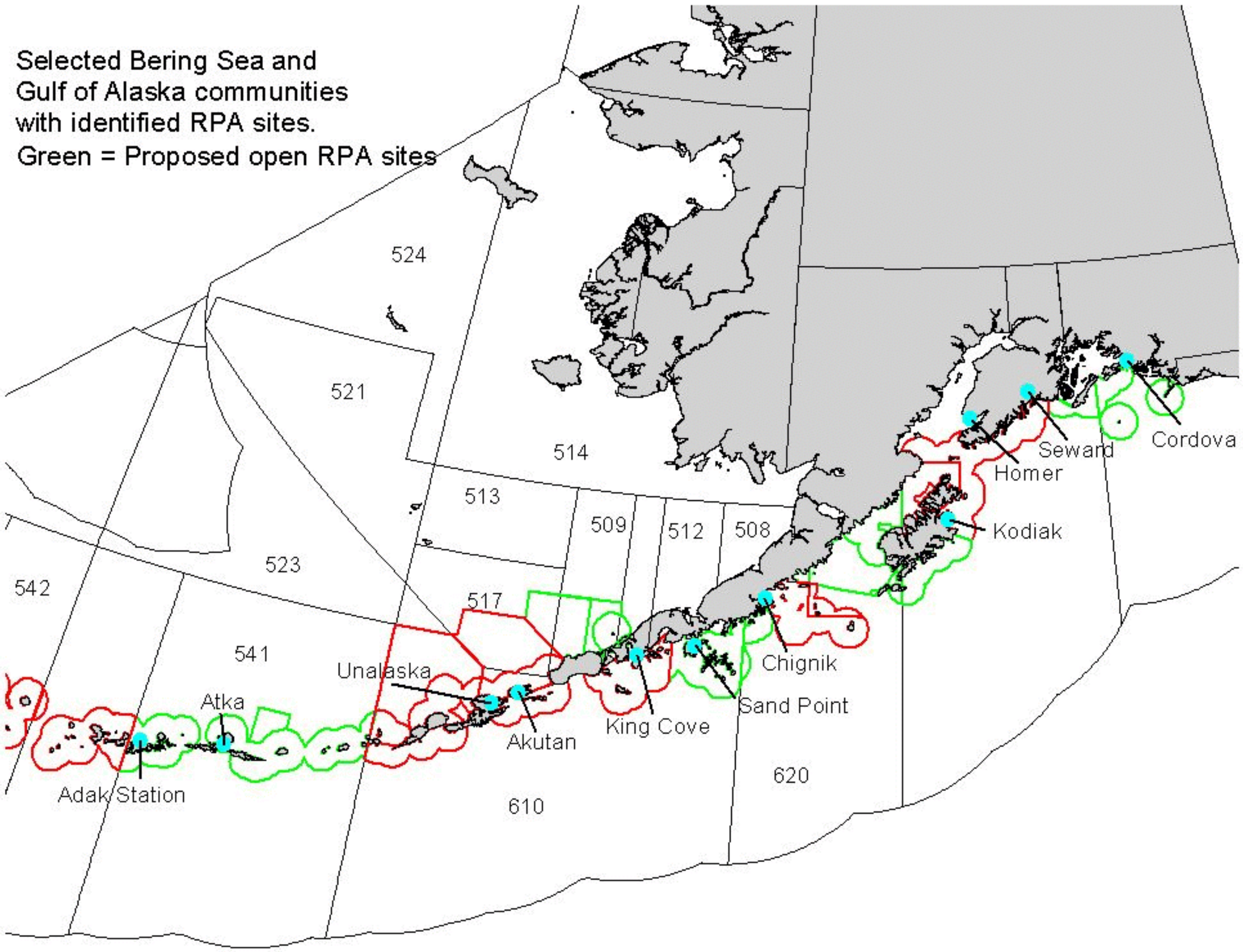
Steller Sea Lion:
Fraction of prey Consumed

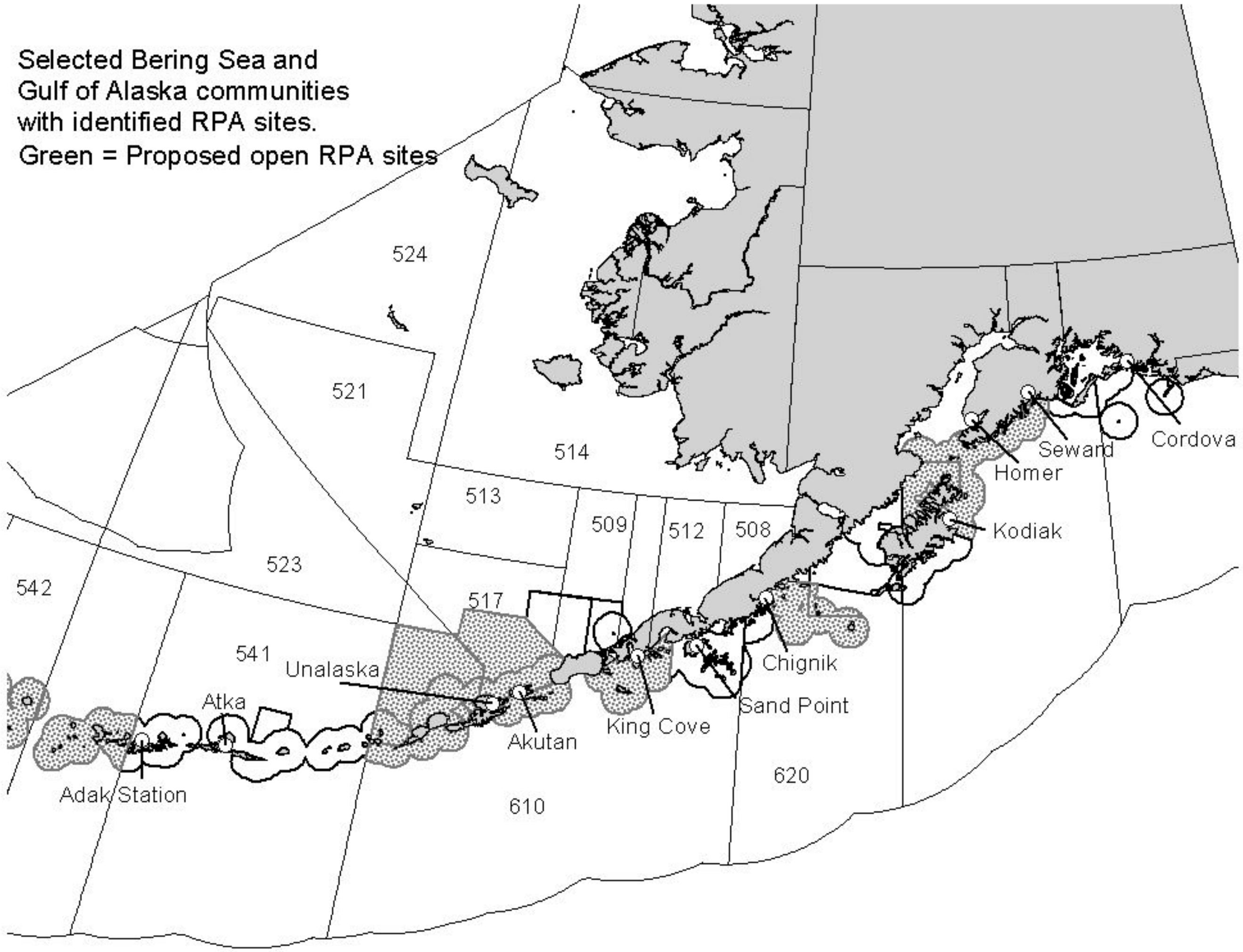


**Biomass estimates of prey are for pollock, Pacific cod and Atka mackerel*

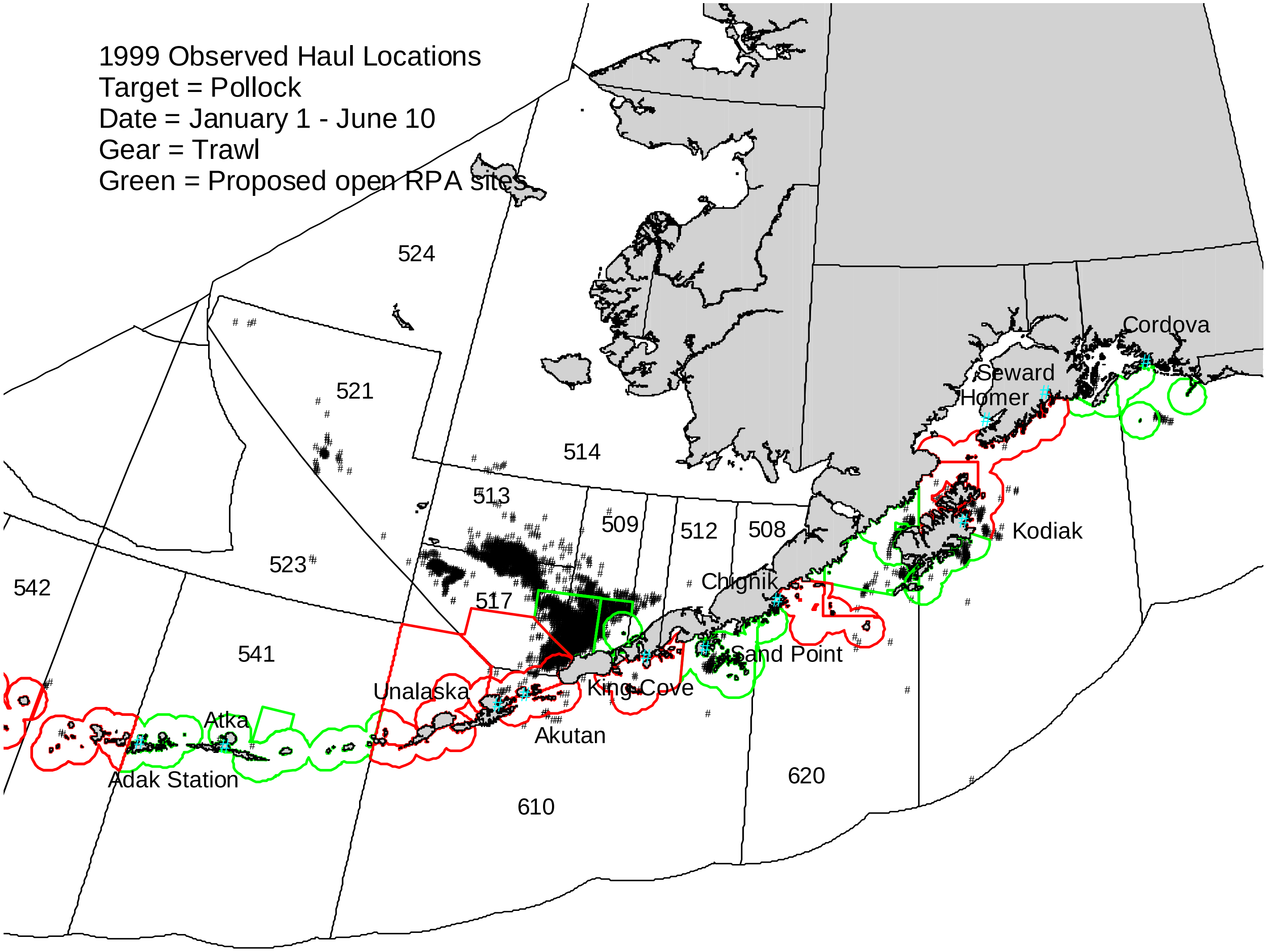
Ver 3.0

APPENDIX 4 MAPS OF FISHING EFFORT AND CLOSURE AREAS

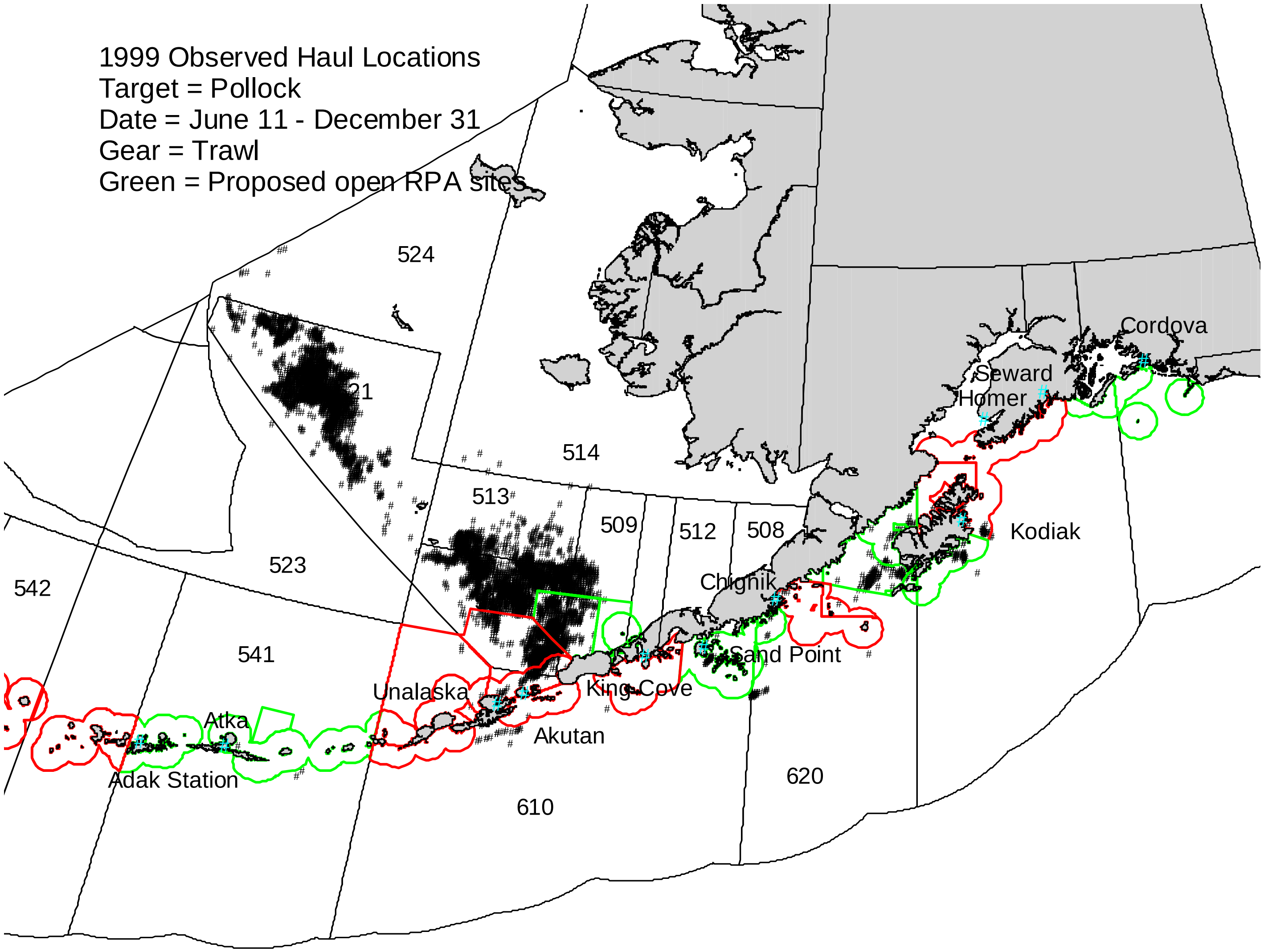




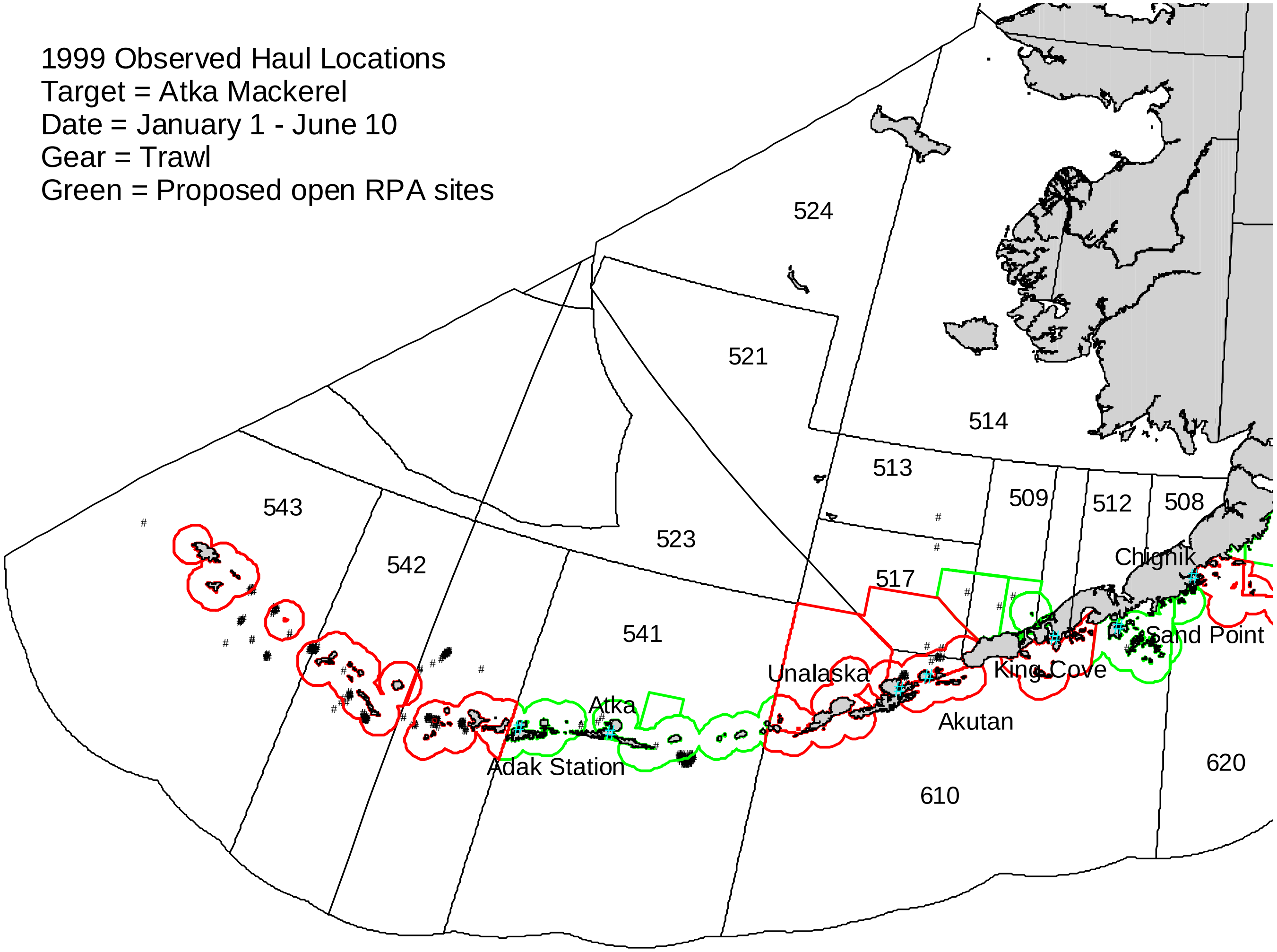
Black and white version of the previous figure.

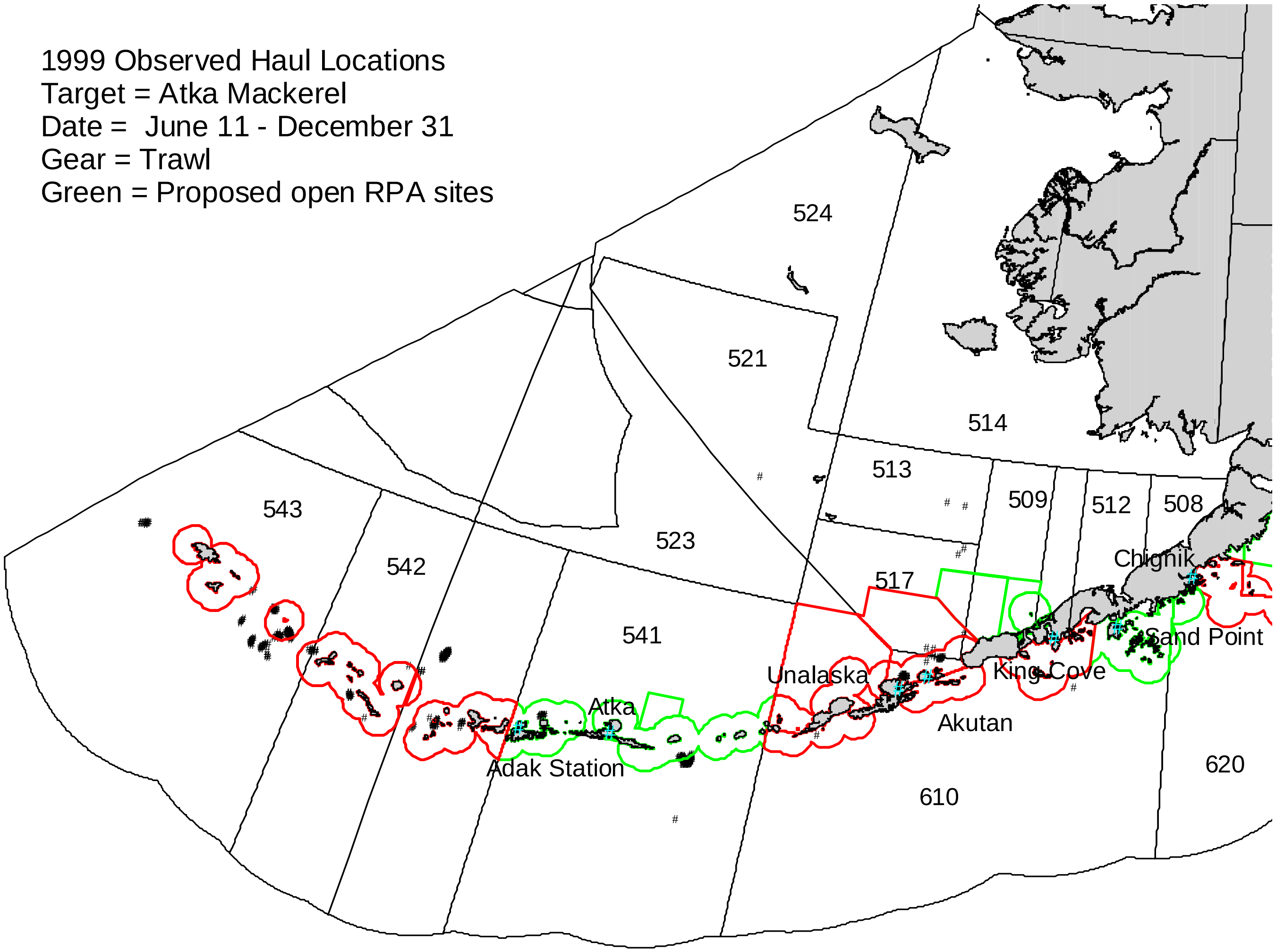


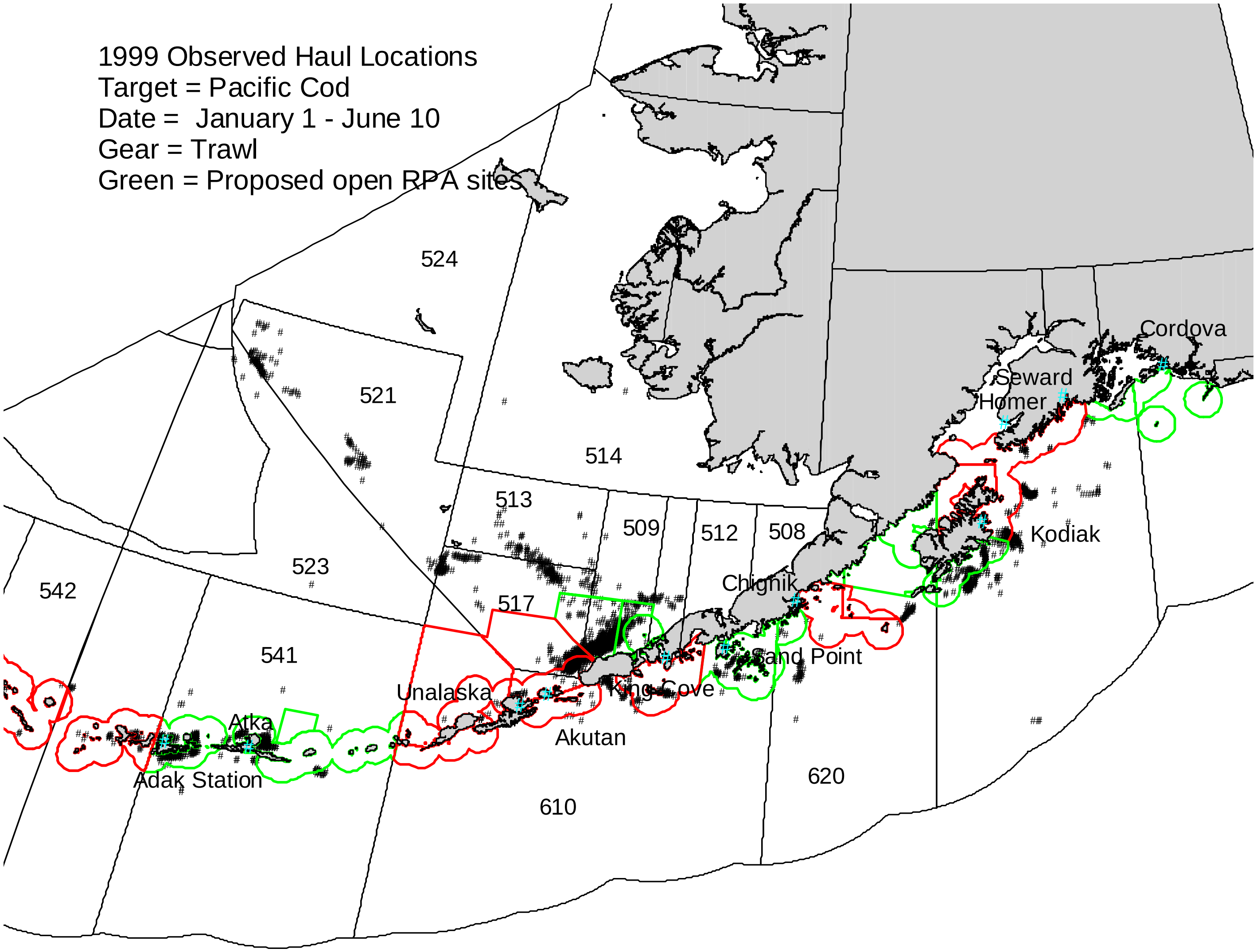
1999 Observed Haul Locations
Target = Pollock
Date = January 1 - June 10
Gear = Trawl
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
517
542
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
610
620

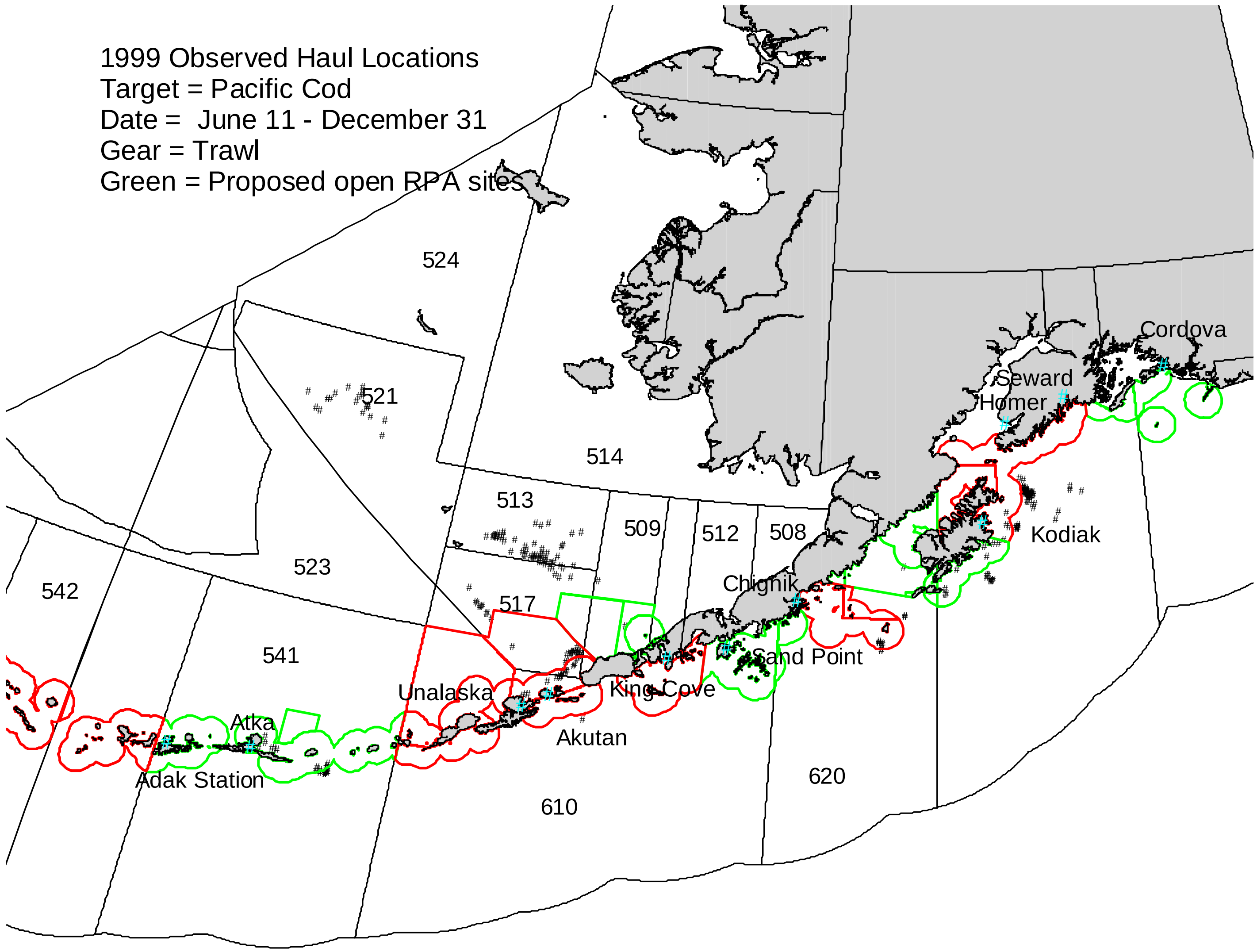

1999 Observed Haul Locations
Target = Pollock
Date = June 11 - December 31
Gear = Trawl
Green = Proposed open RPA sites
524
514
513
509
512
508
523
542
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
610
620

1999 Observed Haul Locations
Target = Atka Mackerel
Date = January 1 - June 10
Gear = Trawl
Green = Proposed open RPA sites

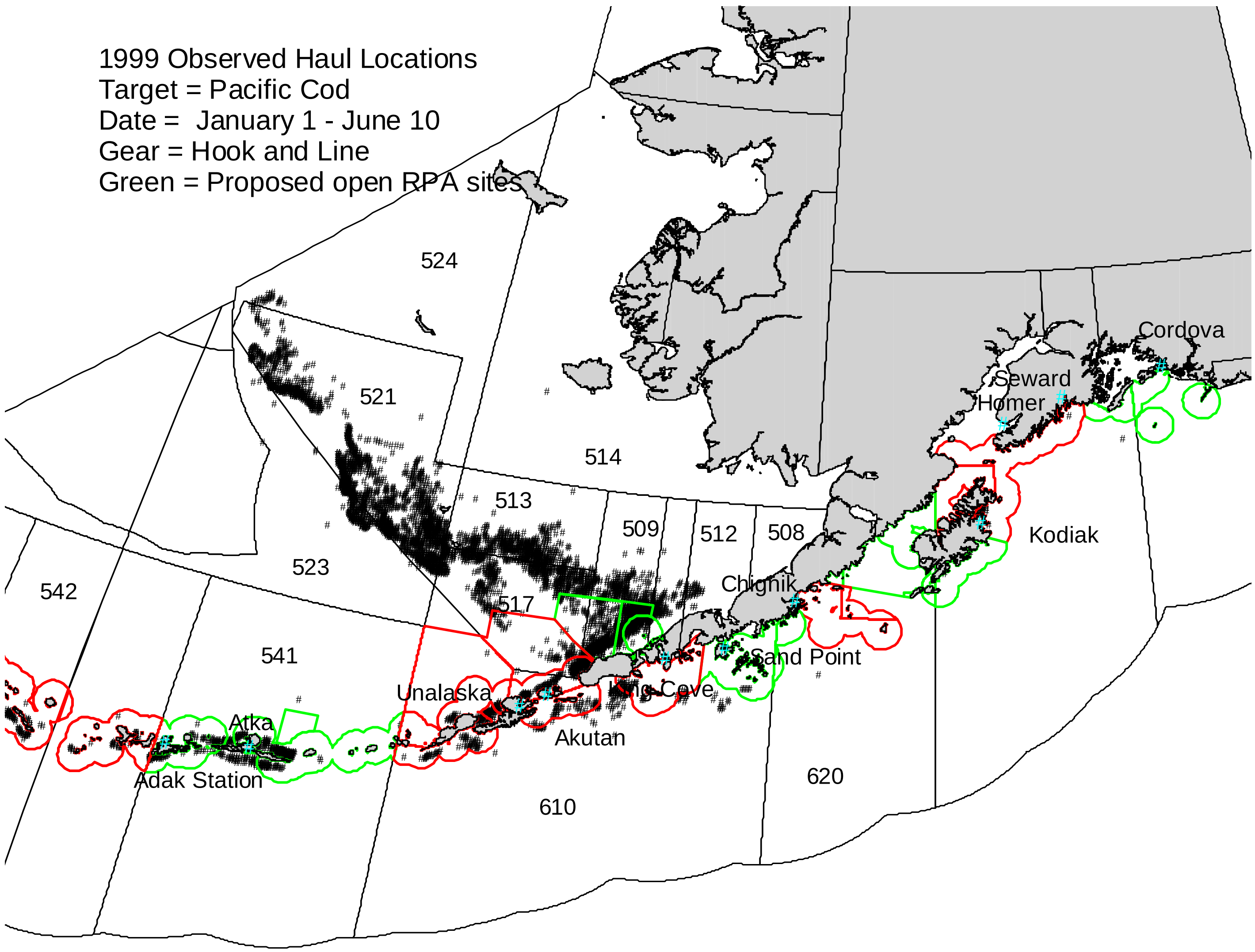



1999 Observed Haul Locations
Target = Atka Mackerel
Date = June 11 - December 31
Gear = Trawl
Green = Proposed open RPA sites
524
521
514
513
509
512
508
543
542
523
517
541
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
610
620

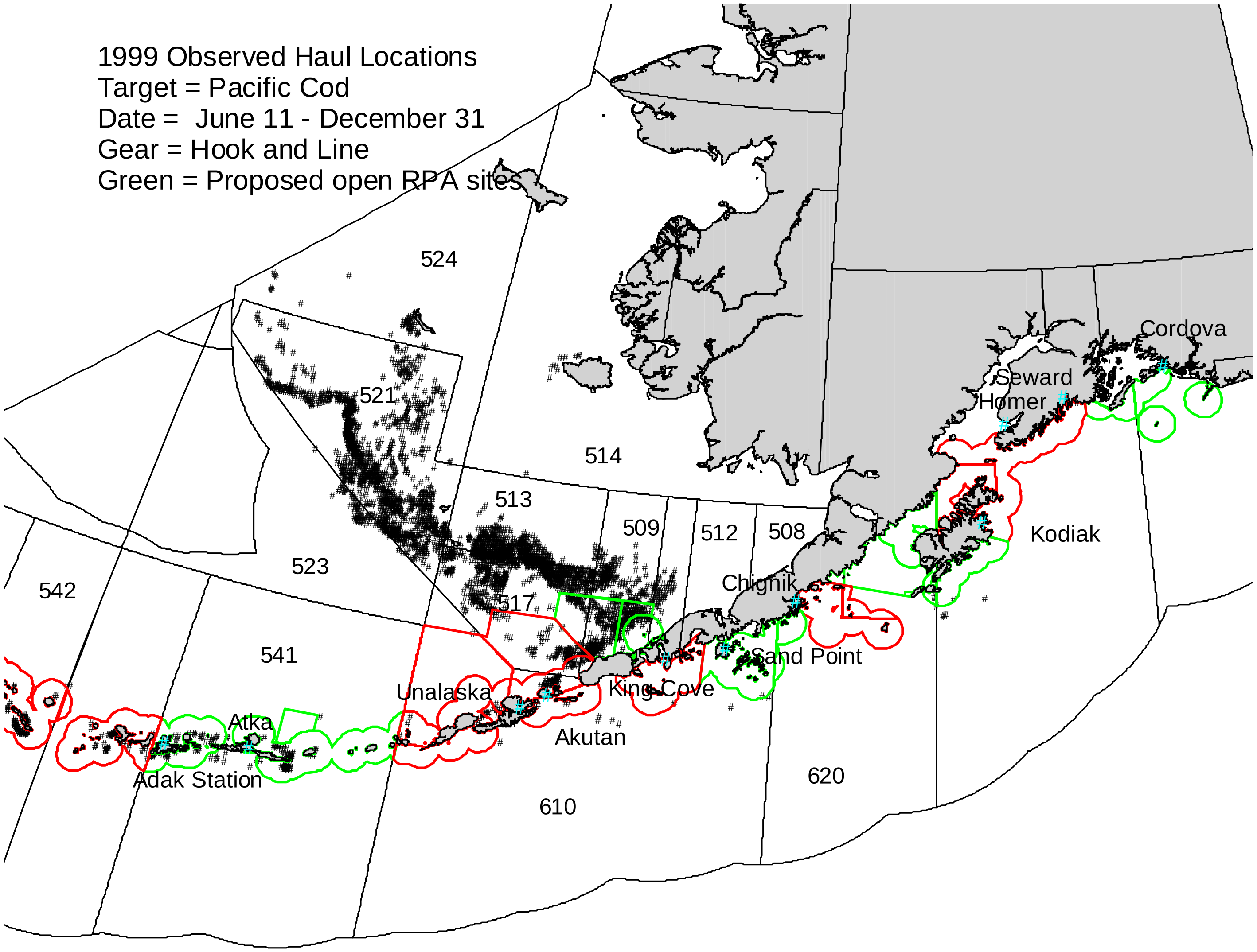

1999 Observed Haul Locations
Target = Pacific Cod
Date = January 1 - June 10
Gear = Trawl
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
542
517
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
620
610

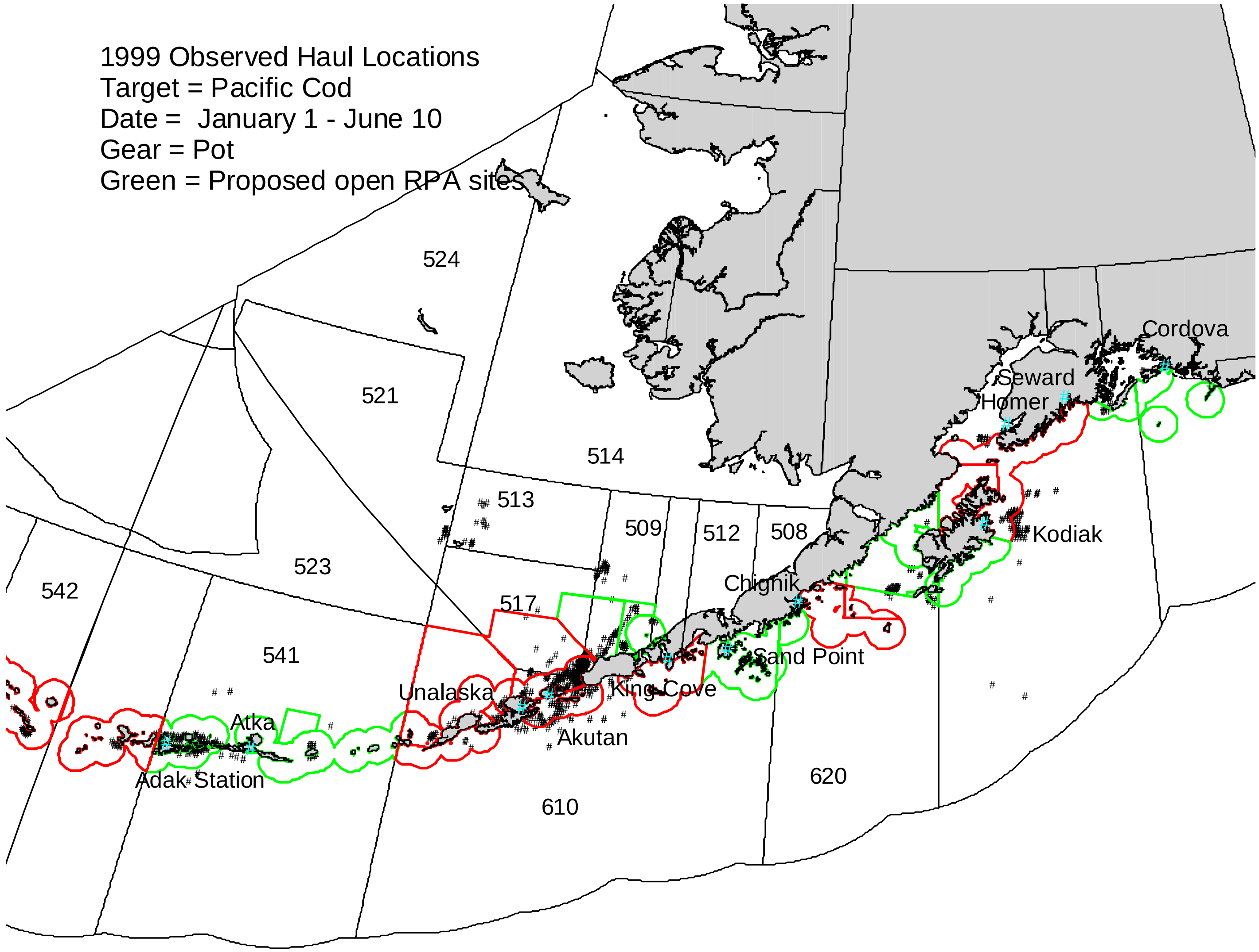


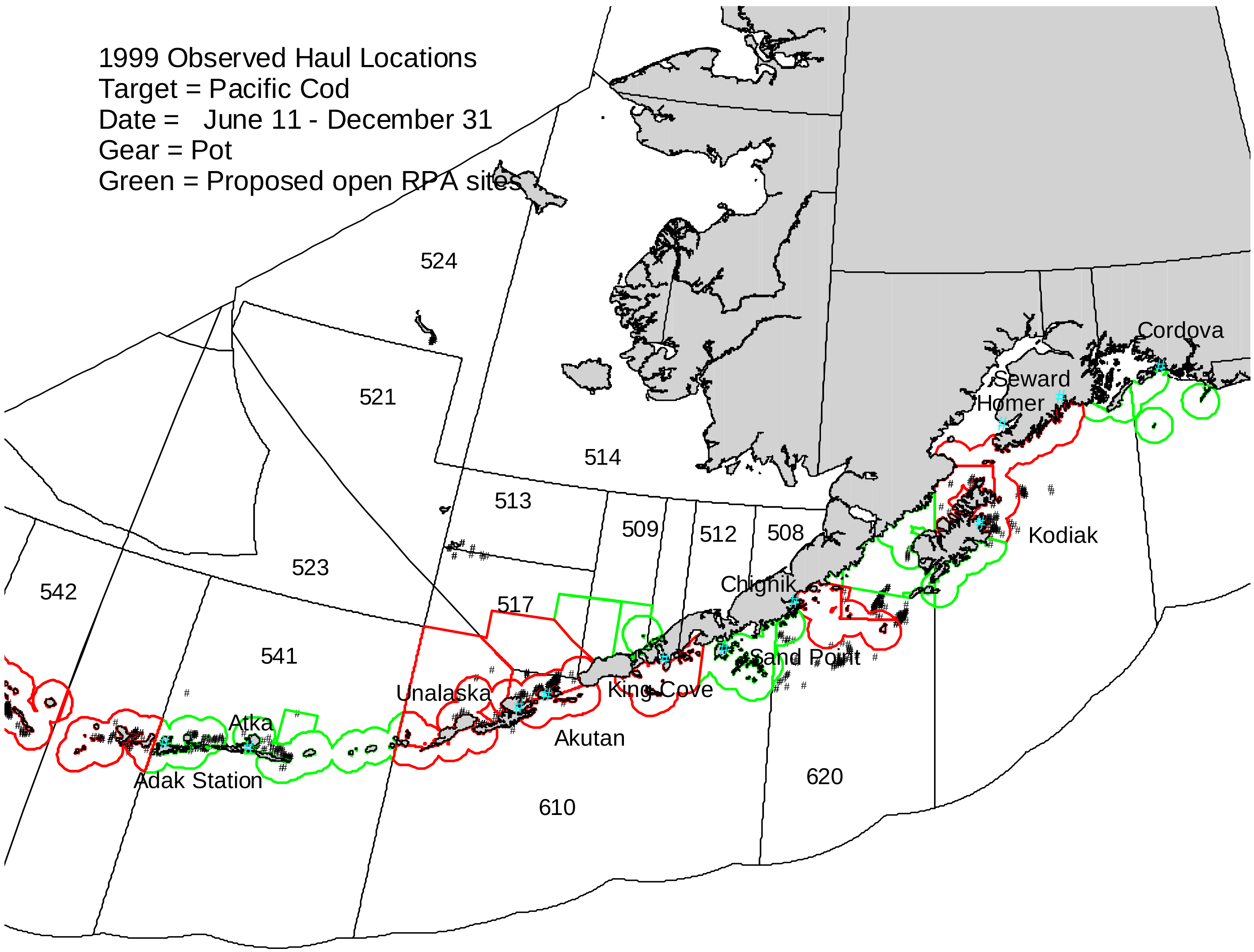
1999 Observed Haul Locations
Target = Pacific Cod
Date = June 11 - December 31
Gear = Trawl
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
517
542
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
620
610

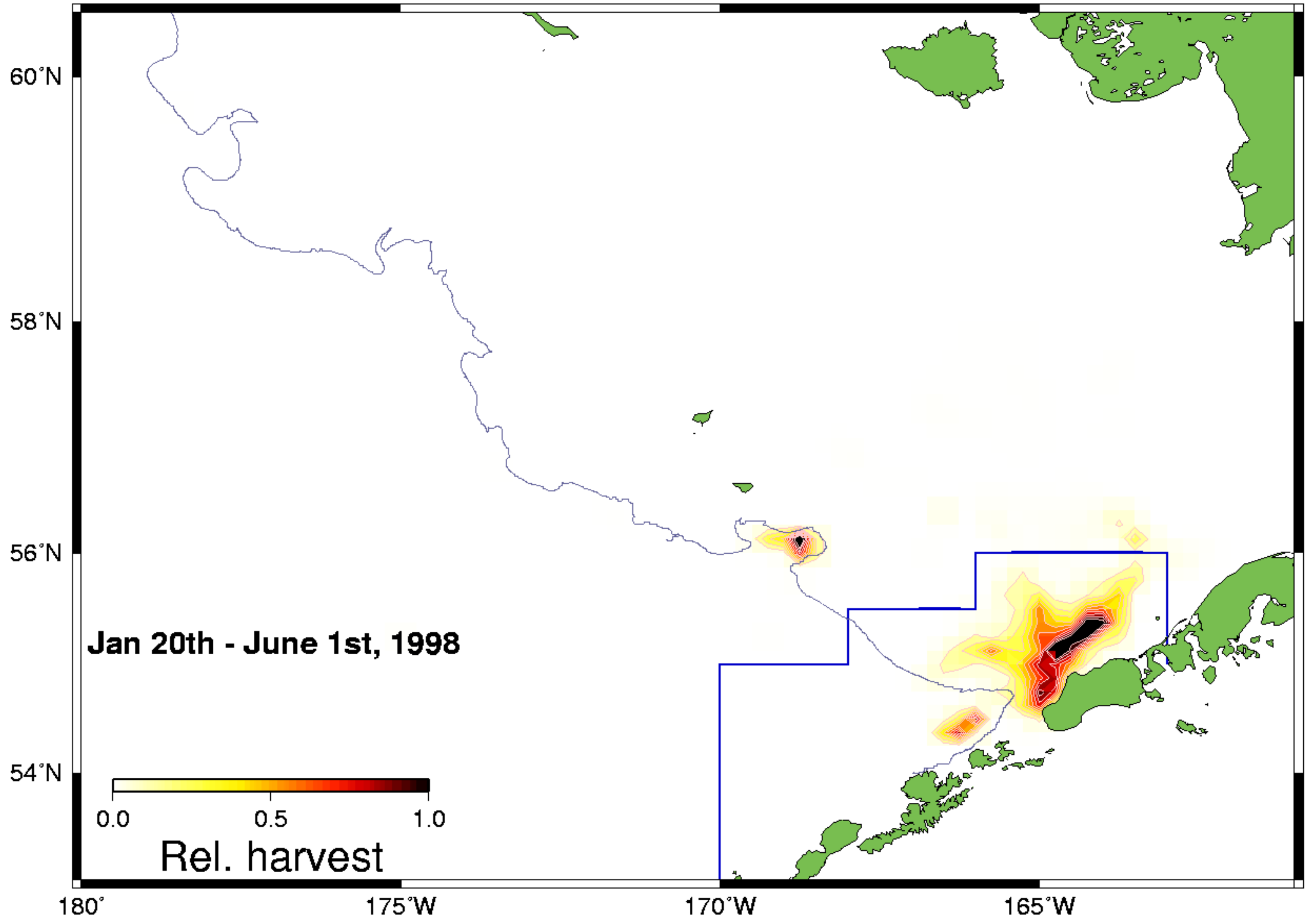


1999 Observed Haul Locations
Target = Pacific Cod
Date = January 1 - June 10
Gear = Hook and Line
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
542
517
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
620
610

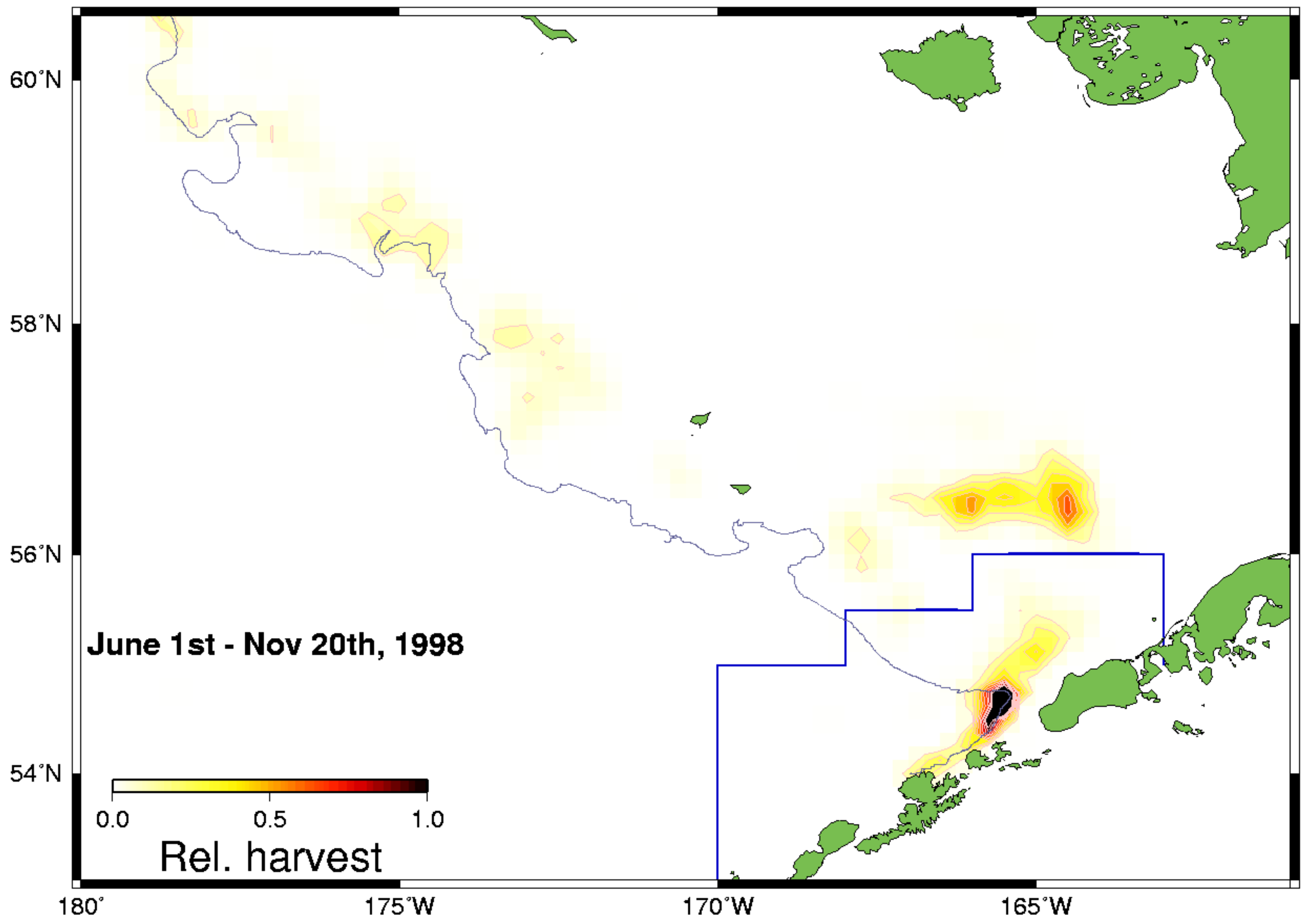

1999 Observed Haul Locations
Target = Pacific Cod
Date = June 11 - December 31
Gear = Hook and Line
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
542
517
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
620
610


1999 Observed Haul Locations
Target = Pacific Cod
Date = January 1 - June 10
Gear = Pot
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
542
541
517
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
620
610

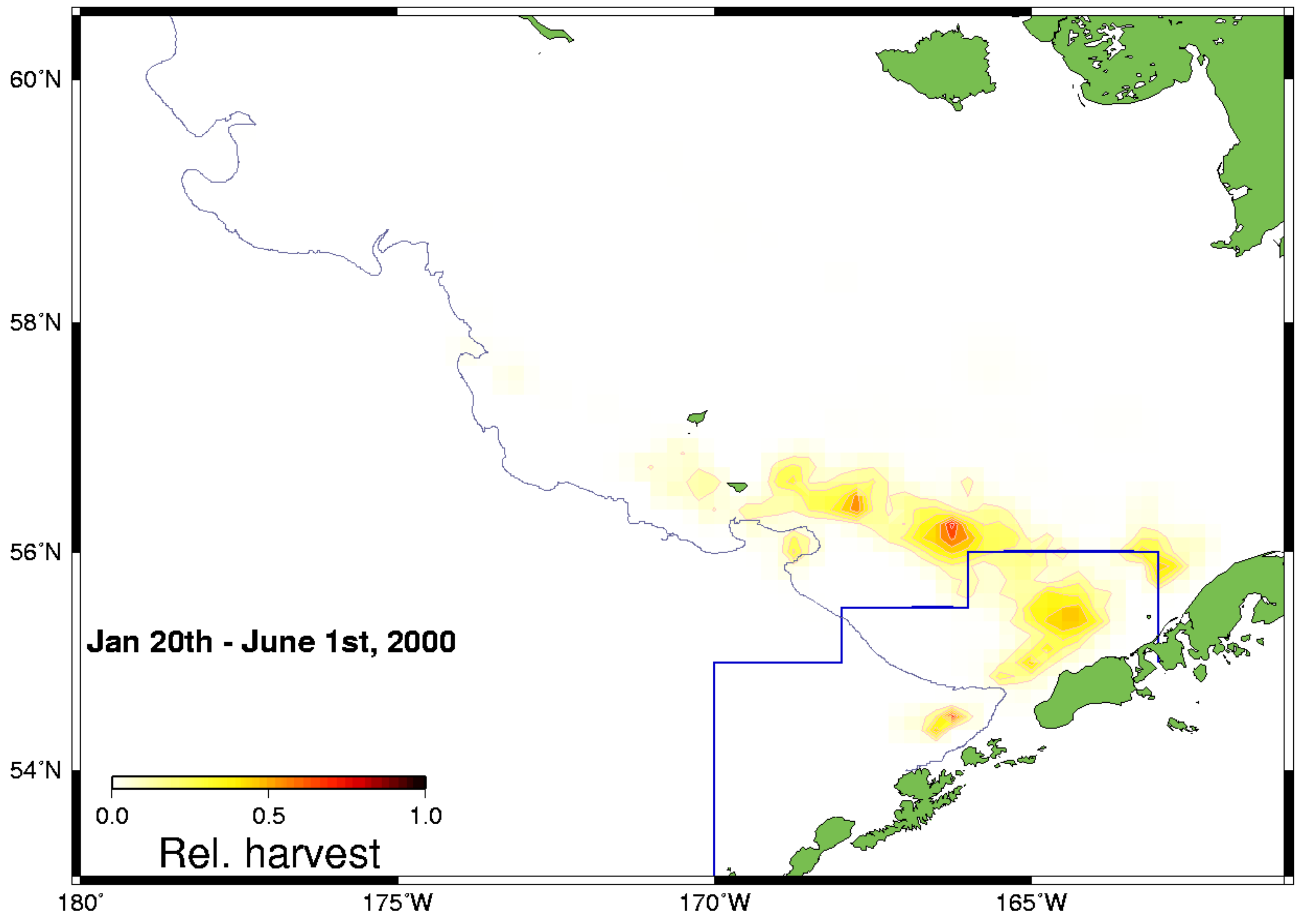

1999 Observed Haul Locations
Target = Pacific Cod
Date = June 11 - December 31
Gear = Pot
Green = Proposed open RPA sites
524
521
514
513
509
512
508
523
542
517
541
Cordova
Seward
Homer
Kodiak
Chignik
Sand Point
King Cove
Unalaska
Akutan
Atka
Adak Station
610
620



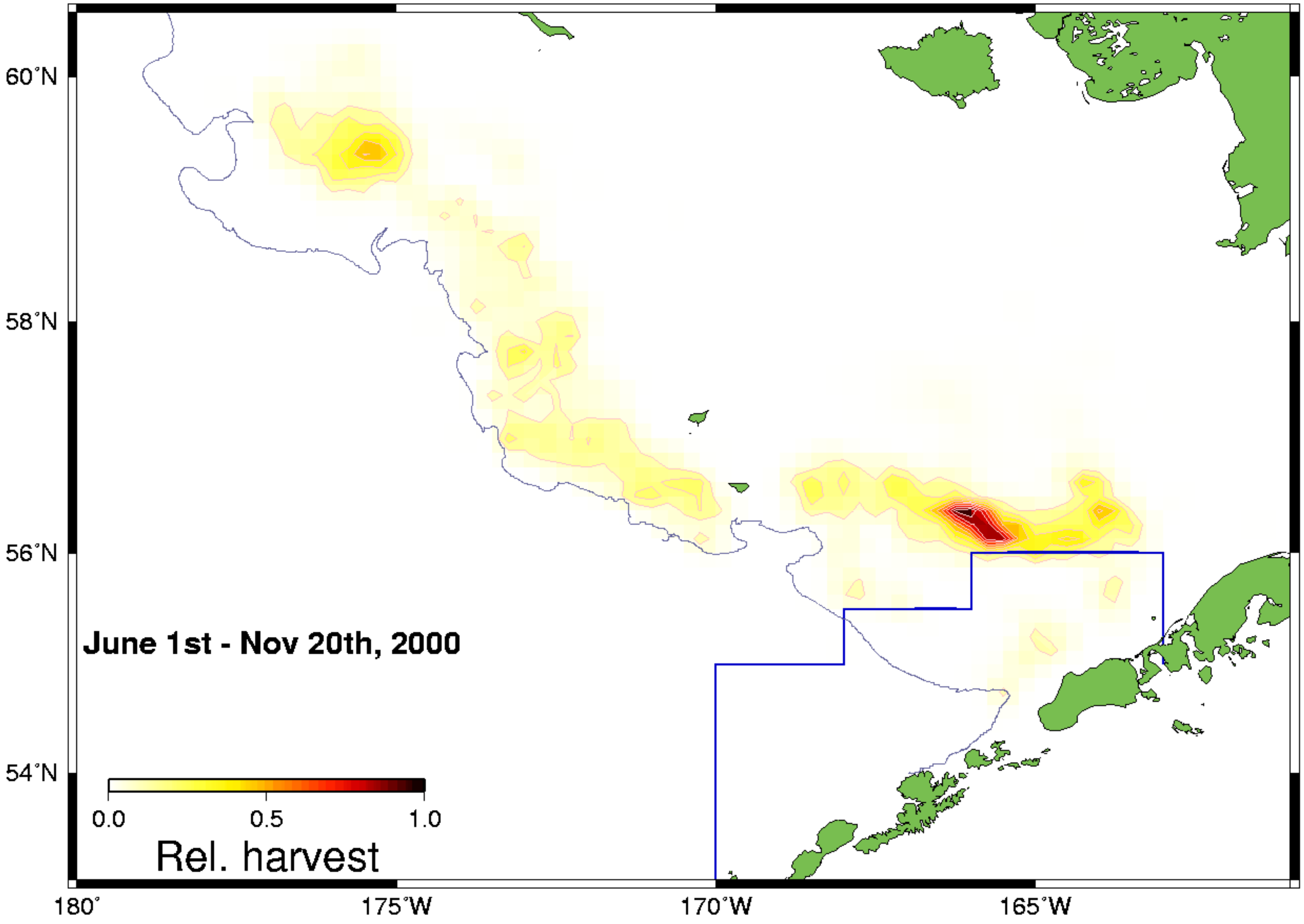
Relative harvest of pollock in the eastern Bering Sea, January 20th - June 1st, 1998.



Relative harvest of pollock in the eastern Bering Sea, June 1st - November 20th, 1998.



Relative harvest of pollock in the eastern Bering Sea, January 20th - June 1st, 2000.



Relative harvest of pollock in the eastern Bering Sea, June 1st - November 20th, 2000.