3.5 Target Groundfish Species

3.5.1 Target Groundfish Species

Bering Sea and Aleutian Islands Target Groundfish Species

This section presents descriptions of major target species, summarizing important life history traits, their habitat environment, prey base, past effects, stock management, stock assessment, and current status and trends of the stocks. Additional information on life history and habitat features for each major groundfish species can be found in the following three documents: 1) EA of the EFH (NPFMC 1998a), 2) EFH assessment report for the groundfish resources of the BSAI region (NPFMC 1998b), and 3) EFH assessment report for the groundfish resources of the GOA region (NPFMC 1998c).

3.5.1.1 BSAI Walleye Pollock

Life History and Distribution

Walleye pollock (*Theragra chalcogramma)* is the most abundant groundfish species within the EBS. It is widely distributed throughout the NPO 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 4 years, at a length of approximately 40 centimeters (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 southeast, north of Unimak Pass (Kendall *et al.* 1996). Pollock are comparatively short-lived (Hollowed *et al.* 1997, Wespestad and Terry 1984), with a maximum recorded age of around 22 years. Table 3.5-1 summarizes the biological and reproductive traits and habitat associations of pollock at its different life stages.

Trophic Interactions

The diet of pollock in the EBS and GOA has been studied extensively (Dwyer 1984, Lang and Livingston 1996, Livingston 1991b, Livingston and deReynier 1996, Livingston *et al.* 1993, Yang and Nelson 2000). These studies have shown that pollock feed on euphausiids and calanoid copepods and other crustaceans. As the pollock increase in size, their diet begins to include juvenile pollock and other teleosts. Other fish consumed by pollock include 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, 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). Cannibalism rates in the EBS vary depending on year, season, area, and predator size (Dwyer *et al.* 1987, Livingston 1989b, Livingston and Lang 1997). Rates are highest in autumn, next highest in summer, and lowest in spring. Cannibalism rates by pollock larger than 40 cm are higher than those by pollock smaller than 40 cm. Most pollock cannibalized are age-0 and age-1 fish, with most age-1 pollock being consumed northwest of the Pribilof Islands where 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 stomach contents is quite low. Laboratory studies have shown the possibility of cannibalism among age-0 pollock (Sogard and Olla 1993a). Field samples have confirmed this interaction, but so far this interaction appears not to be very important. Cannibalism by pollock in the Aleutian Islands region has not yet been documented (Yang 1996).

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 1993a and 1993b). Although it had previously been hypothesized that cannibalism occurred only in areas with no thermal stratification, these recent studies indicate that age-0 pollock can move below the thermocline into waters inhabited by adults. All age-0 fish tend to inhabit surface waters for feeding at night, but larger age-0 fish tend to move below the thermocline during the day. 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, even small age-0 fish move toward 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.

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.* 1993). These species are some of the more abundant groundfish in the EBS, and pollock constitute 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 and has been the focus of many studies. Studies suggest that pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair *et al.* 1994 and 1997). The main sizes of pollock consumed by fur seals range from 3 to 20 cm for age-0 and age-1 fish. Older age groups 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. The importance of pollock in these species' diets has not been well-defined due to the limited number of collected stomach samples from the EBS (Kajimura and Fowler 1984). Pollock are among 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).

Pollock can be the dominant component in the diets of northern fulmars, black-legged kittiwakes, common murres, and thick-billed murres, while red-legged kittiwakes tend to rely more heavily on myctophids (Hunt *et al.* 1981a, Kajimura and Fowler 1984, Shuntov 1993, Springer *et al.* 1986). Age-0 and age-1 pollock are consumed by these bird species, and the dominance of a particular pollock age-group in the diet varies by year and season.

Aydin *et al.* (2002) have conducted a mass-balance food-web model comparing the western and eastern Bering Sea (EBS) ecosystems. These researchers have found that on a per-unit-area measure, the western Bering Sea is more productive than the EBS. Pollock is a keystone species in both ecosystems, although the pathways of energy flow differ (Figure 3.5-1).

BSAI Pollock Management

Although stock structure of Bering Sea pollock is not well defined (Wespestad 1993), the U.S. portion of Bering Sea pollock is considered to form three stocks for management purposes: the EBS stock found on the EBS shelf from Unimak Pass to the U.S.-Russia Convention line; the Aleutian Islands region stock found on the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the central Bering Sea-Bogoslof Island pollock stock, which is a mixture of pollock that migrate from the U.S. and Russian shelves to the Aleutian Basin. In the Russian EEZ, the pollock population forms two stocks, one centered in the Gulf of Olyutorski (western Bering Sea stock) and the other, northern stock located along the Navarian shelf from 171°E to the U.S.-Russian Convention line. Researchers are currently investigating Bering Sea pollock stock structure using genetic analyses (Ianelli *et al.* 2001b).

Under current management, the general impacts of fishing mortality within BSAI FMP Amendment 56/GOA FMP Amendment 56 (Amendment 56/56) ABC and overfishing level (OFL) definitions discussed in Appendix B, apply to pollock in the BSAI. Pollock in the EBS fall within Tier 1a of the ABC/OFL definitions, and the Aleutian Islands and central Bering Sea-Bogoslof Island regions fall within Tier 5. In the Aleutian Islands region, no directed pollock fishing is allowed under current management, a strategy that eliminates the risk of overfishing the stock (Ianelli *et al.* 2001b).

In the EBS, based on Tier 1a, reliable estimates of biomass ($B_{40\%}$) and fishing mortality ($F_{40\%}$) are required to determine OFL and ABC values, respectively. Under the definitions and current stock conditions, the OFL value equals 3,530,000 mt for 2003 and the ABC for EBS pollock equals of 2,330,000 mt. The TAC will be set below this ABC value (Ianelli *et al.* 2002b).

The central Bering Sea-Bogoslof region stock is managed under Tier 5, and requires that the maximum permissible ABC is 75 percent of the product of the natural mortality rate (0.30) and biomass. Therefore, the ABC value for 2003 is 34,000 mt. The OFL is the product of the natural mortality rate and biomass, equating to 45,300 mt in 2003. However, following Alaska Fisheries Science Center (AFSC) recommendations, the 2003 ABC value is reduced to 4,074 mt (Ianelli *et al.* 2002b).

The Aleutian Island region stock is also managed under Tier 5. The 2002 Aleutian Islands bottom trawl survey yielded an estimated biomass of 175,280 mt, leading to an ABC of 39,438 mt. The OFL based on the 2002 biomass estimates is 52,585 mt (Ianelli *et al.* 2002b). See Table 3.5-2 for status and catch specifications (mt) of walleye pollock in the BSAI in recent years

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 from June through August and provide a consistent time series of adult population abundance from 1982 to 2002. Echo-integrated-trawl (EIT) surveys are run every three years (typically) and provide an abundance index on more pelagic (typically younger) stock segments. Both surveys separate their catches into their relative age compositions prior to analyses. Fishery data include estimates of the total catch by area/time strata and 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 NPFMC's BSAI Stock Assessment and Fishery Evaluation (SAFE) report. Also included are separate analyses on pollock stocks in the Aleutian Islands and central Bering Sea-Bogoslof Island areas. In the Aleutian Islands, information comes from observer data and triennial bottom trawl surveys. 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. These analyses are constrained by data limitations and are presented relative to the status of the EBS stock. This analysis focuses specifically on the EBS stock with the view that extensions to these other areas are equally applicable. The stock assessment is reviewed by both the BSAI Groundfish Plan Team and NPFMC's Scientific and Statistical Committee (SSC) before being presented to NPFMC.

The trend in more recent modeling efforts (Honkalehto 1989, Livingston 1993, 1994a and 1994b) 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 years. Effects of variable temperatures on pollock abundance and distribution have also been taken into account by modeling efforts in recent years (Ianelli *et al.* 2002b).

Past/Present Effects Analysis

The geographic scope for the BSAI pollock past/present effects analysis is the same as the BSAI FMP management area (Figure 1.2-2). The temporal scope for this effects analysis begins in 1958 with the start of intensive foreign fishing of pollock in the Bering Sea and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-3 provides a summary of the pollock past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on pollock:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).
- Change in reproductive success due to removal of predators, cannibalism, spatial/temporal concentration of fishery catch/bycatch, roe stripping, fishery selectivity of juveniles, and climate changes and regime shifts (indirect effect).
- Change in prey availability due to fishery catch/bycatch of prey species, marine pollution and oil spills, introduction of exotic species, and climate changes and regime shifts (indirect effect).
- Change in important habitat due to fishery gear impacts, marine pollutants and oil spills, introduction of exotic species, and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and oil spills was not brought forward for analysis. The NOAA National Status and Trends (NS&T) program has produced a summary of Alaska marine environmental quality through its research and sampling projects, including the Mussel Watch Project and the Benthic Surveillance Project. This report is available on the NOAA website at: <http://ccmaserver.nos.noaa.gov/NSandT/BrochurePDFs/Alaska.pdf>. This report was produced in 1999 and will be updated periodically. The document reports that the source of major and trace elements in sediments are likely from local mineralogy rather than human contaminants. The presence of chemicals such as *para*-dichlorodephenyltrichloroethane (DDTs) and metabolites found in fish liver and mussel tissue has shown a decreasing trend over time (1986-1995), probably due to the ban on those chemicals. No obvious trend in contaminant concentrations could be determined from the mussel tissue program over the duration of the monitoring program (Cantillo *et al.* 1999). Furthermore, international, federal and state laws and enforcement agencies are in place to monitor marine pollution.

Change in important habitat and prey availability due to the introduction of exotic species by way of ballast water and climate changes and regime shifts has not been brought forward since the impacts on pollock in the Bering Sea as a result of these events have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation on the occurrences of unusual species in the BSAI.

The past/present events determined to be applicable to the pollock past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1958-1976)
  - Russian pollock fishery (1976-present)
  - State of Alaska groundfish fisheries
  - State of Alaska herring fisheries
  - Subsistence and personal use fisheries
  - Commercial whaling
  - Seal harvests
  - Cannibalism
  - Climate changes and regime shifts
  - Marine pollution and oil spills

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1991)
  - JV groundfish fisheries (1980-1991)
  - Domestic groundfish fisheries (1988-1991)

- Past/Present Management Actions
  - Bilateral agreements
  - IWC management
  - MMPA of 1972
  - Convention of the Conservation and Management of the Pollock Resources
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions

- Steller sea lion protection measures
- Preliminary groundfish FMPs (pre-MSA)
- FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1958-1976)

The earliest documented exploratory pollock fishery ran from 1933-1937 with a Japanese fleet fishing off Bristol Bay. Foreign groundfish fishing in the EBS did not resume until 1954 after the signing of the peace treaty between the U.S. and Japan in 1952. Following the overfishing of yellowfin sole in 1958, the Japanese pollock fishery developed, making up approximately 80 percent of the total Japanese catch by 1970 (Forrester *et al.* 1974).

The Russian fishery that would later develop into the Russian pollock fishery started in the EBS in 1967 along the outer continental shelf from Unimak Pass to northwest of the Pribilof Islands. This fishery focused on pollock by 1971 and has remained predominantly the same to the present. Russia has also trawled for pollock along the Aleutian Islands in recent years, although the effort has been relatively low (Chitwood 1969, Forrester *et al.* 1974, Office of Enforcement and Surveillance 1965, 1967-1970, and Law Enforcement Division 1974, 1975, and 1977).

A fleet from the Republic of Korea targeting pollock around the eastern Aleutian Islands, west of the Pribilof Islands, and the EBS began exploratory fishing in 1968, reaching its peak in 1976. A small Taiwanese fishery focusing on pollock and flounder and consisting of one or two independent stern trawlers began in 1974 along the continental shelf edge west and southwest of the Pribilof Islands (Office of Enforcement and Surveillance 1967-1970, Law Enforcement and Surveillance Division 1971, 1973, 1974, 1975, and 1977).

By 1972, foreign catch of pollock in the EBS had peaked at over 1.8 million mt. In 1973, a bilateral agreement between the U.S. and Japan and the then U.S.S.R. (Soviet Union) included annual catch quotas, which reduced the catch of pollock to 1.2 million by 1976. However, each country was still responsible for monitoring its catch quotas, the only internationally acceptable arrangement at the time. With the passing of the MSA and the increase of U.S. and JV groundfish fisheries, foreign groundfish catch in the Bering Sea had dropped below 1 million mt by 1985 (NPFMC 2002a).

Although large removals of pollock occurred during the foreign fisheries, there does not appear to be a lingering effect on the BSAI pollock populations.

External Russian Pollock Fishery (1967-present)

Harvests by Russian fishing vessels and Russia-licensed vessels from third countries of pollock originating from the EBS pollock stock are considered insufficient in magnitude to push the fishing effort close to the overfishing level threshold. Evidence that this may be occurring stems from the research showing that the pollock of the EBS range westward beyond the U.S. EEZ into waters under the jurisdiction of the Russian Federation and mix with Russian pollock stocks before returning to U.S. waters (Wespestad *et al.* 1996). Moreover, a Russian and a Russia-licensed fishery occurs on the U.S.-Russian Convention Line of 1867 targeting pollock stocks that straddle the boundary line (Pautzke 1997).

Internal Foreign, JV and Domestic Groundfish Fisheries (1976-present)

The U.S. began fishing for pollock in 1980 in the EBS in conjunction with foreign fisheries called JV groundfish fisheries. The U.S. fisheries worked with over 28 different countries, including Japan, South Korea, Poland, the Soviet Union, Portugal, and Iceland. The catch history of pollock in the EBS and Aleutian Islands from 1979-2002 is detailed in Ianelli *et al.* 2002b.

BSAI FMP Amendments 1, 2, 4, 6, and 11 were proposed partially in response to concerns that the domestic annual harvest (DAH) was being dominated by the foreign and JV groundfish fisheries. Since 1977, the pollock fishery in the BSAI evolved from an entirely foreign-harvested fishery to a predominantly domestic-harvested fishery. Yet the volume of fish delivered to foreign groundfish processors continued to largely exceed the amount delivered to domestic groundfish shore-based processors. In 1986, nearly 95 percent of the total 886,000 mt DAH was taken in JV groundfish operations.

Instead of relegating JV groundfish operations to specific areas and prohibiting roe-stripping, BSAI FMP Amendment 11 adopted a split-season proposal to reduce the amount of pollock harvested by the JV groundfish fisheries during the spawning season. This action was designed to prevent the further development of a pollock roe fishery, as well as allow for the expansion of the domestic groundfish processing fishery. Although there have been large removals of pollock by the JV and past domestic fisheries, there does not appear to be a lingering effect on the BSAI pollock populations.

By 1991, foreign groundfish fishing had been phased out of the EEZ and in that year the entire BSAI groundfish harvest (2,126,000 mt) was taken by 391 U.S. vessels. NPFMC has since prohibited the practice of roe-stripping of pollock. With the advent of the U.S. EEZ, DAH levels have ranged between 0.9 million to 1.5 million mt annually, with an average harvest of 1.2 million mt annually (Ianelli *et al.* 2001b).

Change in Reproductive Success

External Foreign Groundfish Fisheries (1958-1976)

Bycatch in the foreign groundfish fisheries has not been well documented; however, it is assumed that bycatch of pollock consisted mainly of juveniles. Few observers were allowed on Soviet vessels under the bilateral agreements, and the Soviets were well-known for under-reporting their catches of target species and, presumably, bycatch as well.

The fisheries could potentially have had a positive effect on the pollock recruitment by reducing the adult pollock biomass. Since mature pollock are known to cannibalize on juvenile pollock, a reduction of mature pollock biomass could actually increase juvenile recruitment.

Internal Foreign Groundfish Fisheries (1976-1991)

Foreign groundfish vessels began fishing the "Donut Hole," the international fishing zone of the Bering Sea, in the mid-1980s. Foreign groundfish vessels from Japan, South Korea, Poland, and China moved into the Donut Hole to fish pollock because they were displaced from U.S. waters by the growth of U.S. domestic groundfish fisheries. Pollock catch increased rapidly, peaking in 1989 at 1.45 million mt, and then declined more rapidly. A moratorium on fishing since 1993 has been observed by all countries including the U.S. and

Russia. The Convention on the Conservation and Management of the Pollock Resources in the central Bering Sea, which outlines the fishing moratorium and establishes an approach for future fishing operations if the stock is to become sustainable, was signed on June 16, 1994, by representatives of the People's Republic of China, and the Republic of Korea, and the Russian Federation (Colson 1994 as referenced by Pautzke 1997). The past foreign fisheries are considered to have overfished the Donut Hole and Bogoslof region pollock populations. Furthermore, these fisheries have changed the spatial/temporal distribution of those pollock populations through the spatial/temporal concentration of the fisheries.

In 1992, NPFMC passed BSAI FMP Amendment 17, establishing the Bogoslof District which was intended to protect the Aleutian Basin pollock stock associated with the Donut Hole. This amendment allowed for a separate TAC for pollock in this subarea, thereby providing regulatory protection of Aleutian Basin pollock during spawning to help rebuild the stock.

The fisheries could potentially have had a positive effect on the pollock recruitment by reducing the adult pollock biomass. Since mature pollock are known to cannibalize on juvenile pollock, a reduction of mature pollock biomass could actually increase juvenile recruitment.

External Russian Pollock Fishery (1967-present)

Scientists and managers are presently concerned that strong to moderate year-classes may reside in the Russian EEZ adjacent to the U.S. EEZ as juveniles. It has been acknowledged that potential large catches and discards of juvenile pollock may be occurring in the Russian EEZ and may effect the EBS stocks that migrate to that area, possibly requiring the reduction of U.S. TACs (Wespestad *et al.* 1996).

Internal Foreign, JV and Domestic Groundfish Fisheries (1976-present)

Fishery Selectivity

BSAI pollock are caught as bycatch in other directed fisheries (e.g., mostly trawl Pacific cod, rock sole and yellowfin sole fisheries). However, because they occur primarily in well-defined aggregations, the impact of this bycatch is typically minimal. The directed pollock fishery has a very low bycatch rate with discards of 10 percent or less since 1992. Most of the discards in the pollock fishery are juvenile pollock, or pollock too large to fit filleting machines. In the pelagic trawl fishery, the catch is almost exclusively pollock, but in the past bottom trawl pollock fishery the bycatch of other species has been higher. Bycatch in the directed fisheries has decreased in recent years due to regulatory amendments and self-imposed actions taken by the fishing industry (Ianelli *et al.* 2002b).

The EBS pollock fishery primarily harvests mature pollock. The 50 percent selectivity corresponds to the age of 50 percent maturity, age-4 years. Fishery selectivity increases to a maximum around age 7 to 8 and then declines. The reduced selectivity for older ages is due to pollock becoming increasingly demersal with age. Younger pollock form large schools and are semi-demersal, thereby being easier to locate by fishing vessels. Immature fish (ages-2 and -3) are usually caught in low numbers. Generally the catch of immature pollock increases when strong year-classes occur and the abundance of juveniles increases sharply. This occurred with the 1989 year-class, the second largest year-class on record. Juvenile bycatch increased sharply in 1991 and 1992 when this year-class was age-2 and -3 (Ianelli *et al.* 2001b).

BSAI FMP Amendment 13 established the Observer Program in the BSAI partially in an effort to reduce bycatch on non-target species. BSAI FMP Amendments 9, 11a, and others established reporting requirements to better track the catch and bycatch of target and non-target species in the BSAI.

BSAI FMP Amendment 49, passed in 1998, requires fishermen to land all pollock harvested, including juveniles and other unmarketable fractions. Because there is little value in small fish, it is hoped that fishermen will avoid areas where juveniles are caught in large concentrations, thus avoiding the economic costs of landing an unmarketable part of the resource. The overall intent of the program is to reduce bycatch and discarding of juveniles, and thus help the stocks remain robust. This measure has dramatically reduced overall discards of groundfish.

In both the BSAI and GOA, cumulative impacts of fishing mortality on age composition are influenced by the selectivity of the fishery. The current age composition of the stocks reflects 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 depends on the biomass of spawners, as modified by abiotic and biotic conditions. Thus, the average age of unfished populations is likely to have varied interannually due to oceanic and climate conditions. The NOAA Fisheries' Fisheries Oceanography Coordinated Investigations (FOCI) (discussed below in GOA) and Coastal Ocean Program's southeast Bering Sea Carrying Capacity (SEBSCC) regional study focus research on improving understanding of mechanisms underlying annual production of pollock stocks in the GOA and EBS. NOAA's long-term goal is to improve the 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 NOAA Fisheries' ongoing studies of species interactions, fish distributions, and abundance trends. This Programmatic SEIS does not seek to evaluate the range of mean ages that could have occurred in the absence of fishing.

The fishery effects on age-at-maturity and fecundity of pollock stocks are a potential concern; investigations regarding this issue began with a new study in 2002 (Ianelli *et al.* 2002b).

Roe Fishery

BSAI Amendment 14 was passed in 1991 to address the pollock roe fishery and the following issues:

1. Roe stripping is a wasteful use of the pollock resource;
2. Roe stripping causes unintended allocation of pollock TAC among seasons and industry sectors;
3. Roe stripping may adversely affect the ecosystem;
4. Roe stripping may adversely affect the future productivity of the stock; and,
5. Roe stripping increases the difficulty of accurately monitoring the pollock TAC for inseason management.

In 1993, regulations were further tightened to close loopholes that could have potential undermined the intent of the roe stripping regulations (58 FR 57752).

The fisheries could potentially have a positive effect on the pollock recruitment by reducing the adult pollock biomass. Since mature pollock are known to cannibalize on juvenile pollock, a reduction of mature pollock biomass could actually increase juvenile recruitment.

Spatial/Temporal Concentration of Catch

The directed fishery for the BSAI pollock is conducted by catcher processors and catcher vessels using pelagic trawl gear, although bottom trawl gear was used prior to 1996. The season has traditionally been broken into two parts; a roe season during early winter, and a surimi (imitation crab) and filet season during the second half of the year. The pollock "A season" fishery, which historically focused on roe-bearing females, is concentrated mainly north and west of Unimak Island (Ianelli *et al.* 1998) and along the 100 m contour between Unimak and the Pribilof Islands. Following the closures of the Donut Hole and Bogoslof District in 1993, the fishing effort was further shifted eastward toward the southeast fishing grounds (Area 51). The 1999-2002 fishing seasons have seen a more equal take of males and females, with only slightly more females taken in this fishery in recent years. The pollock "B season" takes place west of 170°W (northwest fishing grounds, Area 52). Catches in this area have declined since 1990, although there has been a slight increase in recent years (2000-2001). Furthermore, there has been a decline in catch within the Steller sea lion conservation areas, except for the 2002 fishing season (Ianelli *et al.* 2002b).

The past JV and past domestic fisheries have overfished the Donut Hole and Bogoslof region pollock populations. Furthermore, these fisheries are found to have changed the spatial/temporal distribution of those populations through the spatial/temporal concentration of the fisheries.

Management of the pollock fishery has changed recently as NOAA Fisheries and NPFMC have taken measures to reduce the possibility of competitive interactions with Steller sea lions. In 1999, this led to further closures of critical habitat to pollock fisheries in the Aleutian Islands region, the EBS, and the GOA. A total of 210,350 km^2 (54 percent) of critical habitat was closed to the pollock fishery. Following 1998, catches of pollock and the proportion of seasonal TAC caught in the Steller Sea Lion Conservation Area and Steller sea lion critical habitat have been reduced. In the Aleutian Island region, directed fishery removals of pollock have been prohibited. Management has also attempted to disperse the fisheries temporally and spatially by means of seasonal TAC releases to further reduce fishery related impacts on the sea lion population of the EBS shelf (Ianelli *et al.* 2001b).

External Commercial Whaling and Seal Harvests

Whaling is identified as having a past beneficial effect on the recruitment of BSAI pollock stocks. Pollock has been noted as a prey item for fin whales, minke whales, and humpback whales (see Sections 3.8.12, 3.8.14, and 3.8.15). By removing the large predators, pollock recruitment is favored. In the EBS, past seal harvests are identified 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, see Section 3.8.5 and 3.8.8). The whale and seal harvests are no longer of concern with the banning of commercial whaling by the IWC and protection of marine mammals through the MMPA passed in 1972 (see Section 3.8). The continued harvest of marine mammals by subsistence users is unlikely to have a significant impact on the BSAI pollock population.

External Cannibalism

Adult pollock are known to cannibalize on juvenile pollock, especially on age-0 and age-1 pollock, the age classes in which cannibalism appears to be the most important source of predation mortality. 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 because predators feed 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 and Dawson 1992), wherein surface currents during the first three months of life may transport larvae to areas more favorable to survival (e.g., away from adult predators or 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).

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of pollock. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of the species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an in-depth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions, because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries.

Change in Prey Availability

External Foreign Groundfish Fisheries (1958 - 1976) and Internal Foreign, JV, and Domestic Groundfish Fisheries (1976 - present)

The fisheries bycatch of forage species consumed by pollock is unlikely to have a population-level effect. BSAI FMP Amendment 13 established the Observer Program in the BSAI partially in an effort to reduce bycatch on non-target species. BSAI FMP Amendments 9, 11a, and others established reporting requirements to better track the catch and bycatch of target and non-target species in the BSAI, and Amendment 36 was established to protect forage species from being marketed, thereby protecting the availability of pollock prey species.

External State of Alaska Groundfish Fisheries and Herring Fisheries

Bycatch of forage species in the BSAI State of Alaska groundfish fisheries is minimal and is unlikely to have population-level effects on the BSAI pollock stocks. Since pollock prey on a number of different species in addition to herring, it is unlikely that State of Alaska herring fisheries would have a significantly adverse impact on pollock prey availability.

External Subsistence and Personal Use Fisheries

Subsistence and personal use fishermen are known to fish a number of different species, including Pacific herring, Pacific cod, Pacific halibut, and many other target species. However, due to the small extent and localization of these users, it is unlikely that these fisheries would have a significantly adverse impact on pollock prey availability.

External Climate Change and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the prey availability of pollock. In general, a shift toward warmer waters favors recruitment and survival of pollock. In 1998/1999, the Pacific Decadal Oscillation shifted to negative, with cooler-than-average northeastern Pacific surface temperatures and warmer-than-average central Pacific surface temperatures. The Ocean Surface Current Simulations (OSCURS) model has also shown stronger on-shelf drift in the EBS from April-June in 1998, 1999, and 2002 (Ianelli *et al.* 2002b); indicating favorable conditions for pollock.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect they have on the important prey species of pollock.

Change in Important Habitat

External Foreign and JV Groundfish Fisheries (1958 - 1991)

Bottom trawl gear is the focus of most of the concerns regarding spawning habitat disruption in the NPO. Beginning in about 1960, the Bering Sea experienced rapid and intensive development of commercial bottom trawl fisheries. Between 1973 and 1997, a total of 412,040 records of observed bottom trawls were obtained from the NOAA Fisheries Observer Database (NORPAC). Note that the number of recorded observed bottom trawls is only a small portion of the total number of bottom trawls during that time period. Because gear information is not available, bottom trawls by the JV groundfish (1980–1990; 101,376 trawls) and foreign groundfish (1973–1989; 127,959 trawls) fleets were selected based on the presence of benthic organisms (e.g., crab, snails, and seastars) in the catch (see Section 3.6 for more information).

Due to intensive bottom trawling by the foreign groundfish and JV groundfish fisheries, a bottom trawling ban was initiated in pollock spawning habitats by the 1977 BSAI Preliminary FMP. Several of the foreign groundfish fisheries also imposed restrictions on themselves to reduce potential adverse effects on pollock spawning habitats.

External Climate Change and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the habitat suitability of pollock. In general, a shift toward warmer waters favors recruitment and survival of pollock. In 1998/1999, the Pacific Decadal Oscillation shifted to negative, with cooler-than-average northeastern Pacific surface temperature and warmer-than-average central Pacific surface temperatures. The OSCURS model has also shown stronger on-shelf drift in the EBS from April-June in 1998, 1999, and 2002 (Ianelli *et al.* 2002b); indicating favorable conditions for pollock.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of pollock.

Internal Domestic Groundfish Fisheries (1976 - present)

Bottom trawls by the domestic groundfish trawl fleet from 1986 to 1997 resulted in 182,705 records of observed bottom trawls obtained from the NORPAC. Note that the actual total number of unrecorded bottom trawls is much larger.

To minimize the potential interaction with other groundfish species and to reduce the magnitude of bottom disturbance, the domestic pollock fishery converted to mainly pelagic gear by 1996. Several industry-imposed restrictions also reduced bottom disturbance through modification of fishing gear. The BSAI FMP Amendment 57 went into effect in the 1999 and 2000 seasons, prohibiting the pollock fishery from using non-pelagic gear. Pelagic trawl gear, when used in mid-water, has no known direct effects on the substrate. Pelagic trawl gear can also be fished on the bottom, and sometimes is; however, the pelagic trawls used off Alaska are generally designed to fish downward from the depth of the doors, which are not designed for contact with the seafloor, although the footropes can come in contact with, and affect the bottom (see Section 3.6).

The 1991–1995 period saw broad implementation of closures to further protect Steller sea lions. For example, NOAA Fisheries closed areas year-round to trawling within 10 nm of 37 Steller sea lion rookeries, and to within 20 nm during the pollock A season (January 20 to April 15) around five rookeries in the BSAI. There were comparable closures in the GOA. These trawl closures indirectly protect pollock habitat, as well as protecting Steller sea lion habitat (Ianelli *et al.* 2001b).

BSAI FMP Amendments 55 and 65 were proposed in order to identify EFH, minimize practicable adverse effects on habitat from the fishery, and encourage conservation of Habitats of Particular Concern (HAPC) for all target species.

BSAI Pollock Comparative Baseline

The EBS bottom trawl surveys show an increasing trend in pollock abundance during the 1980s, due to strong 1978, 1982, and 1984 year-class recruitment. The population remained at a high and stable level from 1991 to 1995. As these strong year-classes were replaced by weaker year-classes, a sharp decrease in population resulted (1996), followed by an increase to the present. Most recently, there appears to be a higher-than-average year-class for 1995 and 1996; prior to that, the 1992 year-class was very high. The abundance of these year-classes is evident from the 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 age-5 years and older (Ianelli *et al.* 2001b). The estimated 2002 age composition of EBS pollock from the stock assessment model is shown in Figure 3.5-2.

The statistical catch-age model exhibits a high level of exploitable biomass (age-3+) from 1982 to 1988, with a peak occurring in 1985, followed by a decline until 1991. Since then, exploitable biomass has varied around 10 million mt (Ianelli *et al.* 2002b).

The EBS pollock stock is neither overfished, nor approaching an overfished condition. The stock assessment model indicates that the 2003 age-3+ biomass is 11,100,000 mt, higher than the previous year's assessment. The 2002 bottom trawl and EIT surveys both show an increase in pollock biomass from the 2001 estimates, with 16 and 18 percent increases, respectively (Ianelli *et al.* 2002b).

Since the Aleutian Island and central Bering Sea-Bogoslof Island regions are managed under Tier 5, it is not possible to determine whether those stocks are overfished or approaching an overfished condition. However, the 2002 bottom trawl survey estimates indicate a 65 percent increase in biomass compared to the 2000 survey in the Aleutian Island region. Note that the increase in the 2002 survey biomass may be also be attributed to survey techniques and timing. The 2002 hydroacoustic survey of the Bogoslof Island region reported a biomass estimate of 227,000 mt (Ianelli *et al.* 2002b).

BSAI Pollock Cumulative Effects Analysis Status

The BSAI pollock will be brought forward for cumulative effects analysis.

3.5.1.2 BSAI Pacific Cod

Life History and Distribution

Pacific cod (*Gadus macrocephalus*) 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 GOA and Aleutian Islands. GOA, EBS, and Aleutian Island 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 GOA (Shimada and Kimura 1994). Spawning takes place in the sublittoral–bathyal zone near the bottom, the area of the continental shelf and slope about 40 to 290 m deep. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983). Table 3.5-4 summarizes the biological and reproductive traits and habitat associations of Pacific cod at its different life stages.

Pacific cod reach a maximum recorded age of 19 years. In the BSAI, 50 percent of Pacific cod is estimated to reach maturity by the time they reach 67 cm in length, or an age of about 5 years (Thompson and Dorn 1999). The same length in the GOA stock corresponds to an age of about 7 years (Thompson *et al.* 1999).

Trophic Interactions

Pacific cod is an opportunistic feeder that feeds both in the water column and in benthic areas (Yang and Nelson 2000). In the BSAI and GOA, in terms of percent occurrence in stomach contents, 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 fish, and amphipods. 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 (Livingston 1991b). In studies conducted on GOA Pacific cod, polychaetes and cephalopods were the most frequently found invertebrates in stomach contents. However, pandalid shrimp were more important in terms of percentage of total stomach contents weight. GOA Pacific cod also consumed large amounts of tanner crabs (Yang and Nelson 2000). Predators of Pacific cod include Pacific halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffins (Westrheim 1996).

Pacific Cod Management

Pacific cod in the BSAI is currently managed under Tier 3a of NPFMC's ABC and OFL definitions (Appendix B). Management under Tier 3a requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). Under Tier 3a, the maximum permissible ABC depends on the relationship of projected female spawning biomass to $B_{40\%}$. The 2002 assessment projected a 2003 female spawning biomass of 423,000 mt, essentially unchanged from the 2001 assessment's projection for 2002 corresponding to a maximum permissible 2003 ABC of 278,000 mt. NPFMC adopted a 2003 ABC of 223,000 mt, identical to the 2002 ABC and about 20 percent below the maximum permissible value. The 2003 OFL for the BSAI stock is 324,000 mt, up 10 percent from the 2002 OFL (Thompson and Dorn 2002) (Table 3.5-2).

Beginning with the 1993 BSAI SAFE report (Thompson and Methot 1993), a length-structured synthesis model (Methot 1990) has formed the primary analytical tool used to assess Pacific cod. 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 the Aleutian Islands region fish.

Annual trawl surveys in the EBS and triennial (recently, biennial) trawl surveys in the Aleutian Islands are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and Dorn 2002, Thompson *et al.* 2002). Other available data include catch size compositions and biomass by gear, for the years 1978 through the early part of 2002. Within each year, catches are 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 January-May (early) trawl fishery, June-December (late) trawl fishery, the longline fishery, and the pot fishery. In order to account for differences in selectivity between mostly foreign, mostly domestic, and very recent fisheries, the fisheries data were split into pre-1989, 1989-1999, and post-1999 eras in the EBS. 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 Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37 (see Appendix B). Several previous assessments included statistical analyses of the uncertainty surrounding the true values of the survey catchability and natural mortality rate. These analyses of uncertainty led to a risk-averse adjustment factor of 0.87 which is multiplied by the maximum permissible F_{ABC} to obtain the recommended F_{ABC}. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates.

BSAI Pacific Cod Past/Present Effects Analysis

The geographic scope for the BSAI Pacific cod past/present effects analysis is the same as the BSAI FMP management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1864 when the BSAI domestic fishery begins and ends in 2002, the most recent year for which a stock assessment is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-5 provides a summary of the BSAI Pacific cod past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI Pacific cod:

- Mortality due to catch/bycatch and marine pollutants and oil spills (direct effect).

- Change in reproductive success due to fishery selectivity of juveniles, spatial/temporal concentration of catch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery catch/bycatch of prey species, introduction of exotic species, marine pollution and oil spills, and climate changes and regime shifts (indirect effect).

- Change in important habitat due to impacts of fishery gear, marine pollutants and oil spills, introduction of exotic species and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species by way of ballast water and climate changes and regime shifts has not been brought forward since the impacts on Pacific cod in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the Pacific cod past effects analysis include the following:

- Past/Present External Events
  - Subsistence and personal use
  - Foreign groundfish fisheries (1964-1976)
  - State of Alaska crab bait fishery
  - IPHC longline bait fishery
  - Marine pollution and oils spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1988-1991)
  - Domestic groundfish fisheries (1864-1950; 1981 - present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the Pacific cod fishery. Amendments discussed in Section 3.2 which impact the target fisheries as a whole are not repeated here.

Mortality

External Subsistence and Personal Use

The earliest fisheries for groundfish in the EBS and Aleutian Islands were the Native subsistence fisheries. They are an important part of the life of Native people, and dependence on demersal species of fish may have been critical to their survival in periods of the year when other sources of food were scarce or lacking. Fishing often takes place in near-shore waters utilizing such species as Pacific cod, Pacific halibut, rockfish, and other species. These small-scale subsistence fisheries have continued through to the present time, although there is likely no impact on Pacific cod at a population-level (NPFMC 2002a).

External Foreign Groundfish Fisheries (1964-1976)

During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for pollock expanded and Pacific cod became an important bycatch and an occasional target species when concentrations were detected during pollock operations (NPFMC 2002a).

The Soviet groundfish fishery that would later develop into the Soviet pollock fishery targeted Pacific cod, rockfish, pollock and various flatfish species north of Dutch Harbor beginning in 1968. In 1969, the fishery became a year-round operation peaking in late winter when fishing vessels from the herring and flounder fishery joined the fleet. The emphasis of the fishery shifted mainly to pollock in 1971 (NPFMC 2002a).

Catches of Pacific cod in the EBS increased steadily in the earlier years of the fishery to reach levels of more than 50,000 mt by 1968. Annual catches remained relatively stable for several years thereafter, ranging around 50,000 mt with the largest catch of 70,000 mt taken in 1970. Catches in the Aleutian Island region were not recorded until the late 1960s, followed by a slight increase, probably due to better identification of Pacific cod in bycatch, although catch remained relatively low throughout the foreign engagement there (NPFMC 2002a).

The foreign fisheries contributed to fishing mortality in the BSAI. However, the foreign fisheries are thought to have had no observable effect on the BSAI Pacific cod populations.

External State of Alaska Crab Bait Fisheries and IPHC Longline Bait Fisheries

The State of Alaska crab bait fisheries and the IPHC longline bait fisheries contributed to fishing mortality in the BSAI through removal of Pacific cod as bycatch and removal to be used in the fisheries as bait. The influence of these removals is noted as adverse.

Internal JV and Domestic Groundfish Fisheries (1864-present)

The first commercial venture for bottomfish occurred in 1864 when a single schooner fished for Pacific cod in the Bering Sea (Cobb 1927). The cod fishery did not commence on a regular annual basis until 1882. This domestic groundfish fishery continued until 1950 when demand for cod declined and economic conditions caused the fishery to be discontinued (Alverson *et al.* 1964). Fishing areas in the EBS were from north of Unimak Island and the Alaska Peninsula to Bristol Bay (Cobb 1927). Vessels operated from home ports in Washington and California and from shore stations in the eastern Aleutian Islands. Canadian vessels also participated in the cod fishery to a limited extent.

The early domestic cod fishery reached its peak during World War I when the demand for cod was high. Numbers of schooners operating in the fishery ranged from 1-16 prior to 1915 and increased to 13-24 in the period from 1915 to 1920. Estimated catches during the peak of the fishery ranged annually from 12,000-14,000 mt (Pereyra *et al.* 1976). Numbers of vessels in the fishery declined following 1920 until the fishery was terminated in 1950. From 1930-1958, annual catch was less than 200 mt, then rose sharply to about 4,900 mt in 1963, and back down to 450 mt in 1977. The decline in catch since 1963 resulted from reduced abundance and restrictions on the fishery. In years of high production, the catch was split about evenly between Canadian and U.S. vessels up until 1972, after which the U.S. share was larger. There was no catch reported in the Aleutian area before 1960 (NPFMC 2002a). The catch history of Pacific cod in the EBS and Aleutian Islands regions is detailed in Thompson and Dorn 2002.

By 1981, a U.S. domestic groundfish trawl fishery and several JV groundfish fisheries had again begun operations in the BSAI. The foreign and JV sectors dominated catches through 1988, but by 1989 the domestic groundfish sector was dominant. The foreign and JV sectors had been displaced entirely by 1991.

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components (Thompson and Dorn 2001).

Allocation of the BSAI Pacific cod TAC among gear types began in 1993. Amendment 24 to the BSAI FMP established an explicit allocation of the Pacific cod TAC between gear types. The percentage allocations for the 1994, 1995, and 1996 fishing seasons were: trawl gear 54 percent, fixed gear 44 percent, and jig gear 2 percent. At that time, NPFMC was in the initial stages of developing its Comprehensive Rationalization Plan, which emphasized the allocation as a stabilizing mechanism and bridge to overall comprehensive rationalization (NPFMC 2002a).

Because FMP Amendment 24 Pacific cod allocations were scheduled to expire at the end of 1996, NPFMC placed discussion of this issue on the December 1995 meeting agenda, with the intent that an amendment be prepared to allow an allocation beyond 1996. At the December 1995 meeting, NPFMC identified changes which had taken place in the Pacific cod fishery since Amendment 24 went into effect on January 1, 1994. These changes were viewed as biological, economic, and regulatory in nature. Problems identified by NPFMC included compressed fishing seasons, periods of high bycatch, waste of resource, and new entrants competing for the resource due to crossovers allowed under NPFMC's Moratorium Program. NPFMC identified the need for management measures to ensure that the cod TAC was harvested in a manner which reduced discards in the target fisheries, reduced PSC mortality, reduced non-target bycatch of cod and other groundfish species, took into account the social and economic aspects of variable allocations, and addressed impacts of the fishery on habitat. In addition, the amendment would continue to promote stability in the fishery as NPFMC continues on the path towards comprehensive rationalization (NPFMC 2002a).

Beginning in 1997, Amendment 46 to the BSAI groundfish FMP allocated the TAC for BSAI Pacific cod among jig gear, trawl gear, and fixed gear (hook-and-line and pot). It reserved two percent of the TAC for jig gear, 51 percent for fixed gear, and 47 percent for trawl gear. The amendment also split the trawl apportionment between catcher vessels and catcher processors 50/50, but it did not split the fixed gear allocation between hook-and-line and pot vessels.

In October 1999, NPFMC approved BSAI FMP Amendment 64, which split the fixed gear allocation of Pacific cod between the hook-and-line catcher processors, hook-and-line catcher vessels, and pot sectors in the BSAI. NPFMC allocated 80 percent of the fixed gear share of the Pacific cod TAC to hook-and-line catcher processors, 0.3 percent to hook-and-line catcher vessels, 1.4 percent to pot and hook-and-line catcher vessels less than 60-foot length overall, and 18.3 percent to pot vessels. The amendment was approved by the Secretary of Commerce in July 2000, and implemented by final rule on August 24, 2000 (65 FR 51553) (NPFMC 2002a).

Amendment 64 became effective on September 1, 2000. At the time NPFMC approved Amendment 64, it acknowledged that a further split among the pot sector may be necessary to ensure the historical harvest distribution among pot catcher processors and pot catcher vessels in the BSAI Pacific cod fishery. Concern was expressed that the pot sector needed the stability of a direct gear allocation, as had been implemented for the hook-and-line catcher processors and catcher vessels under Amendment 64. However, because the public had not been given notice that this action might be taken under Amendment 64, NPFMC decided to delay action specific to the pot sector and include the proposal in a follow-up amendment (BSAI FMP Amendment 68) (NPFMC 2002a).

Further changes to the BSAI cod fishery occurred in April 2000 when NPFMC approved BSAI FMP Amendment 67. Amendment 67 requires that vessels fishing with hook-and-line and pot gear that are participating in the BSAI Pacific cod fishery must qualify for a Pacific cod endorsement, which would be part of the participant's license under the LLP. Eligibility for a cod endorsement is based on past participation in the BSAI fixed gear fisheries during specific combinations of the years 1995-1999. Amendment 67 effectively granted exclusive access to longtime participants in the BSAI fixed gear cod fishery, and thus reduced the number of allowable participants, including the number of eligible pot vessels. This amendment was approved by the Secretary on November 14, 2001, and the implementing regulations were in place for the 2003 fishing season (NPFMC 2002a).

An analysis of Amendment 68 (further allocation of Pacific cod among pot gear sectors) was initially reviewed by NPFMC in February 2001 and then was made available for public review with recommended revisions by NPFMC. However, because of the potential implications of Amendment 67 and the uncertainty of implications related to management measures being developed to protect the Steller sea lion, NPFMC decided to delay final action on Amendment 68 pending resolution of these issues. With both Secretarial approval of Amendment 67 and completion of the Steller Sea Lion Protection Measures Final SEIS in November 2001, NPFMC scheduled final action for Amendment 68 in June 2002. A draft EA/Regulatory Impact Review (RIR)/Initial Regulatory Flexibility Analysis (IRFA) was released for public review on May 14, 2002 (NPFMC 2002a). However, at its June 2002 meeting, NPFMC voted to take no action on BSAI FMP Amendment 68 partly due to the potential implications of the Pacific cod endorsement required under BSAI Amendment 67 and partly because BSAI Amendment 64 was scheduled to expire after the 2003 fishery anyway, meaning that continuation or modification of Pacific cod allocations among the hook-and-line and pot gear sectors in the BSAI would require a new amendment.

Past JV and pre- and post- MSA domestic fisheries contributed to the fishing mortality in the BSAI, however there are no observable lingering effects on the Pacific cod populations.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1964-1976)

Fishery Selectivity

In 1969 and 1970, the Soviet groundfish fishery targeted on arrowtooth flounder, sablefish, and pollock with bycatches of Pacific cod, rockfish, and other bottomfish. Data regarding the amount of bycatch and the age of the fish caught is not available; however, it is assumed that bycatch of juvenile Pacific cod took place. Whether fishery bycatch of juveniles has had an effect on the Pacific cod population is unknown, although it does not appear to have had a lingering adverse effect on the present Pacific cod population.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of Pacific cod. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin

(1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries.

Internal JV and Domestic Groundfish Fisheries (1864-present)

Fishery Selectivity

Pacific cod are caught as bycatch and discarded in the Pacific cod fishery and other domestic groundfish trawl fisheries, including the fisheries for pollock, yellowfin sole, and rock sole in the EBS and in the shallow water flatfish, arrowtooth flounder, and flathead sole fisheries in the Aleutian Island trawl fisheries. Since 1998 (BSAI FMP Amendment 49), discarding of Pacific cod has been prohibited except for fisheries in which Pacific cod has a bycatch only status. BSAI FMP Amendments 9, 11a, 13 and others have been designed to limit bycatch and improve reporting of target and non-target species in the BSAI.

Spatial/Temporal Concentration of Catch/Bycatch

The Pacific cod fishery has changed recently due to management measures instituted to reduce possible adverse impacts on the western population of Steller sea lions. Some of these measures attempted to distribute catch more evenly throughout the year. On average during the period 1998-2000, 81 percent of annual trawl catch, 60 percent of annual longline catch, and 82 percent of annual pot catch was taken from January to May in the Bering Sea, while 89 percent of the annual trawl catch, 69 percent of annual longline catch and 89 percent of the annual pot catch was taken from January to May in the Aleutian Islands. The attempted redistribution of Bering Sea catch appears to have been at least somewhat successful, with January to May trawl, longline, and pot catches reduced to 64 percent, 43 percent and 71 percent of their respective year-end totals in 2001. Correspondingly, fishery activity increased during the remainder of the year in the Bering Sea. The Aleutian Islands fisheries saw comparatively little change in temporal distribution, with the most significant change taking place in the pot fishery, where the January to May catch decreased from 89 percent of the year-end total in 1998-2000 to 73 percent in 2001 (Thompson and Dorn 2002).

Change in Prey Availability

External Foreign Groundfish Fisheries (1964-1976)

Foreign past fisheries in the BSAI have had an adverse impact on prey availability for large Pacific cod. Large Pacific cod are mainly piscivorus consuming pollock ranging in age from age-0 to greater than age-6 depending on predator size. However, due to the opportunistic nature of Pacific cod, it is unlikely that the fisheries would have had a population-level effect. No observable lingering negative effects are apparent in the present Pacific cod populations.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse with respect to prey availability. In general, a shift toward warmer waters appears to favor recruitment and survival of Pacific cod. As described in Section 3.10.1.5 of the Programmatic SEIS, when the Aleutian Low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian Low was strong, water temperatures were higher, and the catches were dominated by Pacific cod, pollock, and flatfishes.

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of small Pacific cod.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of Pacific cod.

Internal JV and Domestic Groundfish Fisheries (1864-present)

Past JV fisheries in the BSAI have also had a negative impact on prey availability. However, as stated above, due to the opportunistic nature of Pacific cod, it is unlikely that these past fisheries have had a population-level effect on these stocks. There is no observable lingering negative impacts on the present Pacific cod population.

Change in Important Habitat

External Foreign Groundfish Fisheries (1964-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been negatively affected by the intensity of the past foreign fisheries; however, the effects are not considered to have had a lingering influence on Pacific cod populations.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse with respect to habitat suitability. In general, a shift toward warmer waters appears to favor recruitment and survival of Pacific cod. As described in Section 3.10.1.5 of this Programmatic SEIS, when the Aleutian Low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian Low was strong, water temperatures were higher, and the catches were dominated by Pacific cod, pollock, and flatfishes.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the habitat suitability of Pacific cod.

Internal JV and Domestic Groundfish Fisheries (1864-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been adversely affected by the intensity of the past JV fisheries; however, the effects are not considered to have had a lingering influence on Pacific cod populations. BSAI FMP Amendments 55 and 65 are designed to identify EFHs, minimize practicable adverse effects on habitat, and encourage conservation. Furthermore, domestic (post-MSA) bottom trawl fisheries have been limited by regulations and FMP amendments (BSAI FMP Amendments 20, 55, 57, 65 and Steller sea lion conservation measures).

BSAI Pacific Cod Comparative Baseline

The EBS shelf trawl surveys indicate that the Pacific cod biomass increased steadily from 1978 to 1983 and remained at relatively constant levels from 1983 to 1989. Biomass estimates peaked in 1994 and decreased steadily through 1998. Biomass estimates remained steady in the 520,000 to 620,000 mt range from 1998-2000, and increased by 57 percent in 2001 to 830,479 mt, which is very likely overestimated. The 2002 estimate is 616,923 mt. The 2002 Aleutian Islands survey shows a decline from the 2000 biomass estimates at 82,853 mt (Thompson and Dorn 2002).

The stock assessment model indicates a relatively steady decline in age-3+ biomass from 1987 to the present, with the lowest estimate since 1980 occurring in 2001. The female spawning biomass estimates also show a steady decline from 1987 to 2000 with a slight increase in 2001 and 2002, although recent years' estimates are still the lowest since 1981. Regardless, model projections indicate that the BSAI stock is neither overfished, nor approaching an overfished condition (Thompson and Dorn 2002).

BSAI Pacific Cod Cumulative Effects Analysis Status

BSAI and GOA Pacific cod will be brought forward for cumulative effects analysis.

3.5.1.3 BSAI Sablefish

Life History and Distribution

Sablefish (*Anoploma fimbria*) are found from northern Mexico to the GOA, westward to the Aleutian Islands, and into the Bering Sea (Wolotira *et al.* 1993). They are often found 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). There appear to be two populations of sablefish: the Alaska population which inhabits waters near Alaska and northern British Columbia and the southern or west coast population which inhabits waters off of southern British Columbia, and Washington, Oregon, and California. Mixing of these populations occurs off southwest Vancouver Island and northwest Washington (McDevitt 1990, Saunders *et al.* 1996, Kimura *et al.* 1998). 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.* 2001a).

Spawning is pelagic at depths of 300 to 500 m near the edges of the continental slope (McFarlane and Nagata 1988). Juveniles are pelagic and appear to move into comparatively shallow nearshore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). After their second summer, juveniles begin moving offshore, eventually reaching the upper continental slope as adults. Sablefish reach maturity at 4 to 5 years (McFarlane and Beamish 1990). Sablefish are long-lived, with a maximum recorded age in Alaska of 94 years (Kimura *et al.* 1998). Table 3.5-6 summarizes the biological and reproductive traits and habitat associations of sablefish through its different life stages.

Trophic Interactions

Larval sablefish feed on a variety of small zooplankton, ranging from copepod nauplii to small amphipods. Young-of-the-year sablefish are epipelagic and feed primarily on macrozooplankton and micronekton (e.g., euphausiids) (Sigler *et al.* 2001b). Juveniles less than 60 cm feed primarily on euphausiids, shrimp, and cephlapods (Yang and Nelson 2000), while sablefish greater than 60 cm feed more on fish. Both juvenile and adult sablefish are considered opportunistic feeders. Fish most important to the sablefish diet include pollock, eulachon, capelin, Pacific herring, Pacific cod, Pacific sandlance, and some flatfish, with pollock being the most predominant (10 to 26 percent of prey weight, depending on year). Squid, euphasiids, and jellyfish were also found, squid being the most important of the invertebrates (Yang and Nelson 2000). Feeding studies conducted in Oregon and California found that fish made up 76 percent of the sablefish diet (Laidig *et al.* 1997). Off the southwest coast of Vancouver Island, euphausiids dominated (Tanasichuk 1997).

Adult coho and chinook salmon feed on young-of-the-year sablefish, the fourth most common reported species in the salmon troll logbook program from 1977 to 1984 (Wing 1985). Pacific halibut also feed on juvenile and adult sablefish, although sablefish make up less than one percent of the stomach contents (M.S. Yang, AFSC, personal communication, 14 October 1999).

Management Tier/Stock Assessment

Sablefish are managed under Tier 3b in the BSAI and GOA. The fishing mortality rate of 0.13 (Appendix B) leads to a maximum permissible ABC of 25,400 mt. In 2002, a decision analysis was conducted to determine what catch levels will likely avoid the historic low abundance of 1979; this is in contrast to past year's assessments which evaluated catch rates that would result in a stable or increasing spawning biomass. The switch in methodology came about due to an increase in sablefish abundance. The BSAI and GOA sablefish stock abundance is considered moderate and has increased from recent lows. The 2003 recommended ABC is 20,900 mt, a yield that has a 0.6 probability of reducing the 2007 spawning biomass below the historic low. This ABC is the 5-year average of catches under the $F_{40\%}$ policy. This ABC has been apportioned separately in the EBS, Aleutian Islands, and GOA at 2,900 mt, 3,110 mt, and 14,890 mt, respectively. The 2003 OFL is 4,290 mt, 4,590 mt, and 22,020 mt for the EBS, Aleutian Islands, and GOA for a total of 30,900 mt. GOA ABC and OFL are further allocated into management areas; western, central, west Yakutat, and east Yakutat/southeast outside (SEO) (eastern = west Yakutat + east Yakutat/southeast outside) (Sigler *et al.* 2002) (Tables 3.5-2 and 3.5-28).

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, 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. Sablefish are more abundant and easier to catch in the GOA. Longline survey catch rates in the EBS and Aleutian Islands from 1990-1999 average only about one-fifth of those in the GOA.

Sablefish Past/Present Effects Analysis

The geographic scope for the BSAI and GOA sablefish past/present effects analysis is the same as for the BSAI and GOA FMP management areas (Figure 1.2-2 and 1.2-3). The temporal scope for this analysis begins in 1906 when the North American sablefish fishery begins and ends in 2002, the most recent year of which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-7 provides a summary of the BSAI and GOA sablefish past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI and GOA sablefish:

- Mortality due to catch/bycatch and the EVOS (direct effect).
- Change in reproductive success due to fishery selectivity, spatial/temporal concentration of catch/bycatch, the EVOS, and climate changes and regime shifts (indirect effect).
- Change in prey availability due to fishery catch/bycatch of prey species, introduction of exotic species, the EVOS and climate changes and regime shifts (indirect effect).
- Change in important habitat due to fishery gear impacts, the EVOS, introduction of exotic species and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on sablefish in the BSAI and GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI and GOA.

The past/present event determined to be applicable to the sablefish past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (BSAI: 1958-1976, GOA: 1963-1976)
  - State of Alaska groundfish fisheries
  - IPHC halibut longline fishery
  - EVOS
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (BSAI: 1980-1991, GOA: 1976-1985)
  - JV groundfish fisheries (BSAI: 1980-1991, GOA: 1979-1991)
  - Domestic groundfish fisheries (BSAI: 1980-present, GOA: 1979-present)
  - GOA domestic U.S. National Pacific cod fisheries (1800s-1976)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the sablefish fishery. Amendments discussed in Section 3.2 which have an impact on the target fisheries as a whole are not repeated here.

Mortality

External BSAI Foreign Groundfish Fisheries (1958-1976)

Japanese longline vessels began fishing in the Bering Sea in 1958, with peak catch in 1962 at 25,989 mt. Aleutian Island sablefish catch remained relatively low during the foreign fisheries. The bilateral agreement between the U.S., Japan and the Soviet Union began to include catch quotas in the EBS and Aleutian Islands regions beginning in 1973. Evidence of decline in sablefish abundance led to fishery restrictions starting in 1978, reducing total catches to about 12,200 mt by 1985 (NPFMC 2002a).

The Soviet Union caught sablefish from 1967 to 1973 in the EBS (McDevitt 1986) and the Republic of Korea from 1974 to 1983. The Republic of Poland, Taiwan, Mexico, Bulgaria, Federal Republic of Germany, and Portugal have all reported small catches of sablefish, as well (Low *et al.* 1976).

External GOA Foreign Groundfish Fisheries (1963-1976)

Already having started a sablefish fishery in the EBS, Japanese longline vessels began fishing in the GOA in 1963, which led to a rapid increase in annual harvests of sablefish. Harvests peaked in 1972 at 36,776 mt in the GOA. Sablefish were also caught by trawl vessels in the GOA, where sablefish were bycatch in the Japanese Pacific ocean perch fishery until 1972, when some vessels started targeting sablefish (Sasaki 1973).

The sablefish population was overexploited by foreign fisheries. However there is no lingering impact. The population recovered from overfishing starting in the late 1970s due to strong year-classes during 1977-1981.

External BSAI and GOA IPHC Longline Fishery and State of Alaska Directed Sablefish Fishery

Minor state fisheries were established in Alaska in 1995 primarily to provide open-access fisheries to fishermen who could not participate in the federal sablefish IFQ fishery. These fisheries occur in the northern GOA and in the Aleutian Island region, and averaged 180 mt from 1995-1998, with catches predominantly from the Aleutian Island region (ADF&G 2000b, Sigler *et al.* 2001a). In addition, three major state fisheries targeting sablefish operate in Prince William Sound (PWS), Chatham Strait, and Clarence Strait (Sigler *et al.* 2001a).

The past State of Alaska directed fishery and the IPHC longline fishery are found to have no lingering adverse effects on the sablefish population. Although mortality rates likely were higher in some state fisheries than the federal fishery during the 1990s, the effect on the population was low because catches in the state fisheries are small compared to the federal fishery.

Internal GOA Domestic Groundfish Fisheries (late 1800s -1976)

The North American fishery consisting of both the U.S. and Canada began as a secondary activity of the halibut fishery in the late 1800s. The first fishing grounds were off the coasts of Washington and British Columbia and had spread to Oregon, California, and Alaska by the 1920s. The fishery was exclusively North American from 1906 to 1957, taking place from northern California to Kodiak Island in the GOA. Annual catches of sablefish in Alaska averaged about 1,700 mt from 1930 to 1957 and generally were limited to areas near fishing ports (Low *et al.* 1976). The catch history of sablefish in the BSAI and GOA is detailed in Sigler *et al.* 2002.

The sablefish population in Canada was overexploited by foreign fisheries. However there is no lingering impact. The population recovered from overfishing starting in the late 1970s due to strong year-classes during 1977-1981.

Internal BSAI JV and Domestic Groundfish Fisheries (1980 - present)

In the late 1980s, a substantial increase in abundance in sablefish population and the expansion of the domestic fishery increased catches, peaking in 1987 at 8,012 mt (domestic only). Annual catch declined throughout the 1990s to the present at about 1,600 mt. Some catches were not reported during the late 1980s (Kinoshita *et al.* 1995).

BSAI FMP Amendments 1, 2, 4, 6, and 11 all worked to phase-out foreign and JV fisheries and encourage the growth of the domestic fishery.

NPFMC identified concerns regarding sablefish bycatch and the unrelated 50 percent decline in the number of observed walrus hauled out on Round Island. In addition to the changes described in Section 3.5.1.1, BSAI FMP Amendment 13 also 1) allocated sablefish by gear, 2) closed areas to groundfish fishing to protect walrus, 3) deleted fishing season dates from the FMPs but retained them in regulations, and 4) clarified the authority to recommend TACs for additional or fewer target species within the target species category.

Amendment 15 established an IFQ program for sablefish fixed gear fisheries in 1995, and allocated 20 percent of the fixed gear allocation of sablefish to a CDQ reserve for the BSAI. This program was designed to promote the conservation and management of sablefish fisheries by assigning a percentage of the sablefish harvest to certain individuals who have had a history of harvest in that fishery. Over time, this program has decreased the total number of quota shareholders, reduced the amount of bycatch, increased safety, reduced gear conflicts, reduced fishing mortality due to lost gear, increased product quality, and reduced the competition for fishing grounds. Management under the IFQ program also has increased the fishery catch rate 1.8 times, decreased harvest of immature fish so that spawning biomass per recruit increased nine percent, and decreased variable costs of catching the quota from eight to five percent of landed value (Sigler and Lunsford 2001).

A regulatory amendment was passed in the BSAI (57 CFR 37906) banning the use of longline pot gear for fishing of sablefish in 1992. This prohibition was later removed except from June 1 to June 30 to prevent gear conflicts with trawlers, effective September 12, 1996.

Past JV fisheries and domestic fisheries in the BSAI may have had a lingering adverse impact on fishing mortality. Catches were under reported during the late 1980s (Kinoshita *et al.* 1995), and this may have contributed to the substantial abundance decline in the 1990s.

Internal GOA JV and Domestic Groundfish Fisheries (1979 - present)

JV fisheries began in the GOA in 1979, peaking in 1984 at 411 mt (NPFMC 2002b). In 1983, GOA FMP Amendment 11 lowered the sablefish quota due to reduced abundance of sablefish, and also to encourage growth of the domestic fisheries. By 1986, the sablefish resource had recovered and the quota was again increased to 15,000 mt for the domestic fishery. GOA domestic harvests peaked in 1989 at 29,900 mt and have since declined to the 2002 harvest of 13,570 mt.

In 1980, GOA FMP Amendment 8 created four species management categories (target, other species, unallocated, and non-specified) and three regulatory districts for sablefish in southeast Alaska. Its purpose was to make the GOA FMP conform to the newly adopted BSAI FMP, to enhance target species management, and to protect incidentally caught species. Information on squid, rockfish, and several other species was found insufficient to warrant OYs for the three main regulatory areas in the GOA; therefore, their management was changed to a gulfwide management strategy. Changes in sablefish management were also needed because the growing U.S. fishery tended to fish in too localized an area off southeast Alaska. The eastern regulatory area thus was divided into three smaller areas to spread the fishery out, and biodegradable panels were required to reduce ghost fishing by lost pots. Lastly, the timing of reserve releases was modified to allow for increased catches by domestic fisheries.

Amendment 14 to the GOA FMP allocated sablefish quota by gear type, effective in 1985. This FMP amendment also banned the use of pots for fishing for sablefish in the GOA, effective November 18, 1985. Amendment 20 to the GOA FMP established an IFQ management for sablefish beginning in 1995 with the same benefits as described for BSAI in the previous section. In 1997, maximum retainable bycatch percentages for groundfish were revised. The percentage is dependent on the basis species: pollock one percent, Pacific cod one percent, deep flatfish 7 percent, rex sole 7 percent, flathead sole 7 percent, shallow flatfish one percent, arrowtooth flounder 0 percent, Pacific ocean perch 7 percent, shortraker and rougheye rockfish 7 percent, other rockfish 7 percent, northern rockfish 7 percent, pelagic shelf rockfish (PSR)7 percent, demersal shelf rockfish (DSR) in the SEO 7 percent, thornyhead rockfish 7 percent, Atka mackerel one percent, other species one percent, and aggregated amount of non-groundfish species one percent.

A draft EA/RIR/IRFA document was released for public review for Amendment 66 to the GOA groundfish FMP in May of 2002. This amendment would allow for the purchase of commercial halibut and sablefish catcher vessel quota share for lease by eligible persons. This amendment is designed to help reduce unemployment and related social and economic issues in rural GOA fishing communities by allowing a few of those communities to participate in the sablefish and halibut fisheries (Hiatt *et al.* 2002).

Past JV and domestic fisheries in the GOA may have had a lingering adverse impact on the sablefish population. Catches were under reported during the late 1980s (Kinoshita *et al.* 1995), and this under reporting may have contributed to the substantial abundance declines in the 1990s.

Change in Reproductive Success

External BSAI and GOA Foreign Groundfish Fisheries (1958-1976)

Fishery Selectivity

Japanese trawlers targeting pollock, rockfishes, Greenland turbot, and Pacific cod also caught large sablefish as bycatch. From 1964-1972, the bycatch averaged nearly 12,000 mt for the Japanese trawl fisheries (Sasaki 1973). In 1968, sablefish bycatch by longline or otter trawl was allowed to be retained up to 10 percent by weight of each landing; this amount was increased to 20 percent in 1972. Bycatch of sablefish in the foreign fisheries was monitored by the foreign Observer Program, and several gear regulations were passed in an attempt to reduce bycatch (NPFMC 2002a).

In 1960, 1961, and 1967, legal gear for the taking of sablefish in directed and bait fishery was defined. Pots were allowed in 1970 and modifications required in 1976, including an untreated cotton escape which would deteriorate and allow for the escapement of bycatch if the pot were lost at sea (NPFMC 2002a).

External State of Alaska Directed Sablefish Fisheries

Spatial/Temporal Concentration of Catch/Bycatch

1999 ADF&G data show that the state sablefish fishery is somewhat concentrated; in the PWS, catch was dominated by a few statistical areas; in the Cook Inlet region, catches came from the outer coast; and in the south Alaska Peninsula fishery, catches came predominately from the areas southwest of Unimak Island. The fishery in the PWS is also concentrated temporally, lasting only a few days, whereas the Cook Inlet and south Alaska Peninsula fisheries last a few months (ADF&G 2000b).

The state fishery is found to have had an adverse effect on the spatial/temporal distribution of the sablefish stock due to the spatial/temporal concentration of the catch. However, there are no observable lingering negative effects on the sablefish population.

External Exxon Valdez Oil Spill

The effects of the EVOS on sablefish recruitment in the GOA are unknown.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of sablefish. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

The regime shift of 1976/1977 had a beneficial effect of recruitment of sablefish and other groundfish species (Sigler *et al.* 2002, Wooster and Hollowed 1995). Sablefish recruitment was high during 1977-1981, associated with the regime shift of 1976/1977. The effects of these strong year-classes lasted about two decades.

Internal JV and Domestic Fisheries (1979 - present)

Fishery Selectivity

The percent of sablefish catch discarded during 1995-2000 averaged 2.8 percent in the directed Alaska-wide sablefish longline fishery. Discards also took place in the BSAI Greenland turbot fishery (31 percent), the BSAI Pacific cod longline fishery (41.4 percent), Alaska-wide rockfish trawl fishery (17.4 percent) and Alaska-wide flatfish trawl fishery (42.1 percent) (Sigler *et al.* 2001a). BSAI FMP Amendment 13 and 15/GOA Amendment 20 helped reduce sablefish bycatch and discards by establishing the domestic Observer Program and the sablefish IFQ program, respectively.

Longline catches are typically of mature, larger sized fish, whereas trawl fisheries tend to target small to medium sized sablefish. The trawl fisheries occur within juvenile sablefish habitat, along the continental shelf. The trawl fisheries make up only 12 percent of the total catch, but may reduce sablefish recruitment by a larger amount because the fish caught are often younger, smaller fish that have not reached their full size (Sigler *et al.* 2002).

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-decades catch history. How the current age composition of the population compares with the unfished population is unknown. In the short-term, however, the impact of the current fishing mortality levels is overshadowed by the magnitude of incoming year-classes, which in turn are highly dependent on environmental conditions (Sigler *et al.* 2001a).

The IFQ program (BSAI FMP Amendment 15/GOA FMP Amendment 20) has increased fishery catch rates while decreasing the harvest of immature fish (Sigler and Lunsford 2001). Catching efficiency increased 1.8 times with the change from an open-access to an IFQ fishery. Decreased harvest of immature fish improved the chance that individual fish will reproduce at least once. Spawning potential of sablefish, expressed as spawning biomass per recruit, increased nine percent under the IFQ fishery (Sigler *et al.* 2001a).

Spatial/Temporal Concentration of Catch/Bycatch

In 1980, GOA FMP Amendment 8 allowed for changes in sablefish management that were needed because the growing U.S. fishery tended to fish in too localized an area off southeast Alaska. This amendment divided the eastern regulatory area into two smaller areas to spread the fishery out. Biodegradable panels were also required to reduce ghost fishing by lost pots.

Change in Prey Availability

<u>External BSAI and GOA Foreign Groundfish Fisheries (1958-1976)</u>

The past foreign fisheries are unlikely to have had an impact on sablefish prey availability since sablefish are opportunistic feeders as described under the trophic interactions of this section. 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. Fish comprise a large part of the adult sablefish diet. Nearshore residence during their second year provides the opportunity to feed on salmon fry and smolts during the summer months.

<u>External State of Alaska Directed Sablefish Fisheries</u>

As with the foreign fisheries, the State of Alaska directed sablefish fishery is unlikely to have an impact on the prey availability of sablefish due to the opportunistic nature of the species.

<u>External Climate Changes and Regime Shifts</u>

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

As described under trophic interactions, larval sablefish feed mostly on copepods, young-of-the-year sablefish feed mostly on euphausiids and juvenile and adult sablefish are opportunistic feeders. Larvae and young-of-the-year sablefish are more susceptible than juvenile and adult sablefish to large shifts in ecosystem productivity due to their dependence on a few species. However, time-series data are not available to link fluctuations in copepod and euphausiid abundance with larvae and young-of-the-year sablefish abundance (Sigler *et al.* 2002).

External Exxon Valdez Oil Spill

The effects of the EVOS on the abundance of sablefish prey species and on the sablefish population are unknown.

Internal JV and Domestic Fisheries (1979 - present)

Again, as with the foreign fisheries and State of Alaska directed sablefish fisheries, it is unlikely that the past JV and domestic fisheries have had an impact on the prey availability of sablefish due to the opportunistic nature of the species.

Change in Important Habitat

External BSAI and GOA Foreign Groundfish Fisheries (1958-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been adversely affected by the intensity of the past foreign fisheries in the BSAI and GOA. The effects of fishery gear on important sablefish habitat are lingering at the population-level.

External State of Alaska Directed Sablefish Fisheries

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been adversely affected by the intensity of the state fisheries. The effects of fishery gear on important sablefish habitat are lingering at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Sablefish recruitment appears to be influenced by water mass movements and temperature (Sigler *et al.* 2001a). Data suggest that sablefish recruitment increases with above average temperature as well as the growth rate of young-of-the-year sablefish (Sigler *et al.* 2002).

External Exxon Valdez Oil Spill

The effects of the EVOS on sablefish habitat suitability are unknown.

Internal JV and Domestic Fisheries (1979-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been adversely affected by the intensity of the past JV and domestic fisheries. The effects of fishery gear on important sablefish habitat are lingering at the population-level. BSAI FMP Amendment 13 closed waters seaward of 3 nm out to 12 nm surrounding the Walrus Islands and Cape Pierce from April 1 through September 30 to all groundfish fishing. Amendments 55 and 65 were proposed to identify EFH, minimize practicable adverse effects on habitat, and encourage conservation.

BSAI/GOA Sablefish Comparative Baseline

Longline surveys were conducted annually in the GOA by the Japan-U.S. cooperative longline survey from 1978 to 1994, and added the Aleutian Islands region in 1980 and the EBS in 1982 (Sasaki 1985, Sigler and Fujioka 1988). The AFSC began conducting annual longline surveys in the upper continental slope in 1987 to continue the U.S.-Japan cooperative survey time series (Sigler and Zenger 1989). The AFSC survey began annual sampling in the GOA in 1987, biennial sampling in the Aleutian Islands region in 1996, and biennial sampling in the EBS in 1997 (Rutecki *et al.* 1997).

Killer whale depredation of the survey's sablefish catches has occurred in the Bering Sea since the beginning of the survey and has been adjusted for by excluding portions of the gear affected (Sasaki 1987). However, sperm whale depredation has not been adjusted for because researchers are uncertain when the depredation began. If depredation began recently, the current survey estimates would underestimate the biomass. However, if adjustments were made and depredation occurred consistently over time, then the biomass would be overestimated. Sperm whale depredation will continue to be monitored; however, no plans have been made to adjust survey estimates (Sigler *et al.* 2001a).

Relative abundance of sablefish has cycled through three major declines and two significant increases between 1970 and 1985. The post-1970 decline has been attributed to heavy fishing, and the 1985 peak has been attributed to high recruitment of late 1970s year-classes. Following 1988, sablefish abundance has decreased significantly, declining faster in the EBS, Aleutian Islands region, and western GOA and slower in the central and eastern GOA (Sigler *et al.* 2002). Geographic differences are probably due to the migration of small sablefish westward, while large sablefish migrate eastward (Heifetz and Fujioka 1991).

Recent important year-classes are 1980-1981, 1984, 1990, 1995, and 1997. Abundance has fallen in recent years because recent recruitment is insufficient to replace strong year-classes from the later 1970s, which are dying off (Sigler *et al.* 2001a).

BSAI Sablefish Cumulative Effects Analysis Status

BSAI sablefish will be brought forward for cumulative effects analysis.

3.5.1.4 BSAI Atka Mackerel

Life History and Distribution

Atka mackerel (*Pleurogrammus monopterygius*) are distributed from the east coast of the Kamchatka Peninsula, Russia, 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 *et al.* 2001, Lowe and Fritz 2001).

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 2001). Adults are semipelagic 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 brightly colored males until hatching occurs (Zolotov 1993). The first *in situ* observations of spawning habitat in Seguam Pass were documented in August 1999 and 2000 (Robert Lauth, NOAA Fisheries AFSC, personal communication). Atka mackerel nests, nest-guarding males, and spawning females were observed and verified with underwater video and SCUBA diving operations. Nichol and Somerton (2002) examined the diurnal vertical migrations of Atka mackerel using archival tags, and related these movements to light intensity and current velocity. Atka mackerel displayed strong diel behavior, with vertical movements away from the bottom occurring almost exclusively during daylight hours and little to no movement at night. A morphological and merisitic study suggests that there may be separate populations of Atka mackerel in the GOA and the Aleutian Islands (Levada 1979). Data from another morphological study conducted in the BSAI and GOA showed some differences between samples, although the differences were not consistent by area for each characteristic analyzed, suggesting a certain degree of reproductive isolation (Lee 1985). More recent genetic analyses show no evidence of discrete stocks in Alaskan waters (Lowe *et al.* 1998). However, the growth rates have been shown to vary extensively among different areas, and the two Aleutian Islands and GOA populations differ significantly in the size, distribution, and recruitment patterns (Kimura and Ronholt 1988, Lowe *et al.* 1998, Lowe and Fritz 2001). Age and size at 50 percent maturity has been estimated at 3.6 years and 33-38 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, as determined by various methods. The current assumed value of natural mortality is 0.30, which is consistent with values of natural mortality derived from methods which do not rely on growth parameters which vary according to area. Table 3.5-8 summarizes biological and reproductive attributes and habitat associations of Atka mackerel in the BSAI and GOA.

Trophic Interactions

The diets of commercially important groundfish species in the Aleutian Islands during the summer of 1991 were analyzed by Yang (1996 and 1999). More than 90 percent of the total stomach content (by weight) of Atka mackerel in the study was made up of invertebrates, with less than 10 percent made up of fish. Euphausiids (mainly *Thysanoessa inermis* and *T.rachii*) were the most important prey items, followed by calanoid copepods. The two species of euphausiids comprised 55 percent of the total stomach contents, and copepods comprised 17 percent. 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 content weight. Squid was another item in the diet of Atka mackerel; it had a frequency of occurrence of 31 percent, but comprised only 8 percent of total stomach content. Atka mackerel are known to eat their own eggs. Yang (1996 and 1999) found that Atka mackerel eggs comprised 3 percent of the total stomach content and occurred in 9 percent of the analyzed Atka mackerel stomachs. Pollock were the second most important prey fish of Atka mackerel, comprising about 2 percent of the total stomach content. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were minor components of the Atka mackerel diet; each category comprised less than one percent of the total stomach content.

Yang (1996 and 1999) found some differences between the diet composition of male versus female Atka mackerel; females were found to cannibalize on eggs more often and preferred calanoids when cannibalism occurred, whereas males preferred euphasiids. Yang (1999) hypothesizes that this difference is due to the egg-guarding behavior of males which deters the males from feeding on their own eggs. The location of the cannibalism (Kiska Island) suggests that this area may be a spawning ground for Atka mackerel.

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, Livingston *et al.* 1993, Fritz *et al.* 1995; as referenced by Yang 1996 and 1999). Atka mackerel are also components in the diets of the following marine mammals and seabirds: harbor seals, Dall's porpoise, thick-billed murres, and horned puffins (as referenced by Yang 1996 and 1999).

BSAI Atka Mackerel Management

In the 2002 assessment for the 2003 fishery, Atka mackerel fell into Tier 3a of the ABC and OFL definitions. According to the definitions of Amendment 56 and current stock conditions, the OFL fishing mortality rate at $F_{35\%}$ is estimated to be 0.84 for Atka mackerel (see Appendix B), which equates to a yield of 99,700 mt. The maximum allowable fishing mortality rate for ABC at $F_{40\%,}$ is estimated to be 0.66 for Atka mackerel in 2003, which translates to a yield of 82,800 mt. A recommendation of 63,000 mt, lower than the maximum permissible ABC, was performed by NPFMC (Lowe *et al.* 2002) (Table 3.5-2).

The BSAI Atka mackerel stock is above its minimum stock size threshold (MSST) and is not overfished or approaching an overfished condition. Under current management, the status determination of Atka mackerel relative to its MSST is made under the auspices of NOAA Fisheries' National Standards Guideline, rather than the groundfish FMPs.

Atka mackerel are a difficult species to survey because they do not have a swim bladder and are therefore 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. The stock assessment in the Aleutian Islands is based on the NOAA Fisheries trawl surveys, as well as total catch and catch-at-age data from the commercial fishery.

In 2002, the BSAI Atka mackerel were assessed using a Stock Assessment Toolbox. This new stock assessment model is designed to better evaluate and estimate assessment uncertainty; to explore alternative models for fishery and to survey selectivities, natural mortality and survey catchability; and to report on abundance and recruitment trends (Lowe *et al.* 2002).

Past/Present Effects Analysis

The geographic scope for the BSAI Atka mackerel past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1970 when the foreign fishery started and ends in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-9 provides a summary of the BSAI Atka mackerel past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI Atka mackerel:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to fishery selectivity, spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to commercial whaling, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, marine pollution and oil spills, introduction to exotic species, and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on Atka mackerel in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the Atka mackerel past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1970-1976)
  - Commercial whaling

  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1991)
  - Domestic groundfish fisheries (1981-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - IWC regulations
  - MMPA of 1972
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the Atka mackerel fishery. Amendments discussed in Section 3.2 which impact on the target fisheries as a whole and Atka mackerel as a component of the fishery, are not repeated here.

Mortality

External Foreign Groundfish Fisheries (1970-1976)

From 1970 to 1979, the Atka mackerel catch was taken exclusively by foreign fleets, including the Soviet Union, Japan, and the Republic of Korea. Catches of Atka mackerel peaked during the 1970s at over 24,000 mt in 1978 (Lowe *et al.* 2001). The Atka mackerel foreign fisheries had been phased out by 1984.

Although large removals of Atka mackerel occurred during the time of the foreign fisheries, there are no observable lingering negative effects on the Atka mackerel population.

Internal Foreign, JV and Domestic Groundfish Fisheries (1976-present)

The U.S. JV fishery began in 1980, and dominated the Atka mackerel catch from 1982-1988. Catches of Atka mackerel declined from their 1970s numbers from 1980-1983, largely due to changes in management and allocations. From 1985-1987, catches again increased, reaching their highest level at 34,000 mt annually. The domestic Atka mackerel fishery began in 1988 and was fully domesticated by 1990. TACs steadily increased from 1992 on in response to evidence of a large exploitable Atka mackerel population in the central and western Aleutian Islands (Lowe *et al.* 2002).

In June of 1997, BSAI FMP Amendment 34 was passed, allocating Atka mackerel catch to jig gear. This amendment was intended to provide an opportunity for local, small-vessel jig gear fleets to fish for Atka mackerel without direct competition from the large, high-capacity trawl fleets. Since that time, little of the jig gear fishery TAC has been harvested.

Although large removals of Atka mackerel have occurred in the past JV and domestic fisheries, there are no observable lingering adverse effects on the population.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1970-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The Atka mackerel fishery is characteristically a highly localized fishery that occurs in the same few locations every year. Foreign catches were made predominantly in the western Aleutian Islands (west of 180°W longitude) during the early 1970s and moved east during the late 1970s and early 1980s. Past foreign fisheries are found to have had an adverse impact on the spatial/temporal distribution of Atka mackerel due to the spatial/temporal concentration of the fishery in the BSAI.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of Atka mackerel. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries.

Internal Foreign, JV and Domestic Groundfish Fisheries (1976-present)

Spatial/Temporal Concentration of Catch/Bycatch

The Atka mackerel fishery is a spatially and temporally concentrated fishery, and occurs primarily in depths less than 200 m. As stated above, the fisheries moved eastward from 180° W longitude in the early 1980s, near Seguam and Amlia Islands. The 1984 and 1985 catches took place primarily from a single 1/2° latitude by 1° longitude block in Seguam Pass. Atka mackerel are not commonly caught as bycatch in other directed fisheries, although the largest amounts occur in the trawl Pacific cod and rockfish fisheries (Lowe *et al.* 2000). Prior to 1998, the highest recorded discard rates were recorded in the western Aleutian Islands (543) and the lowest have been recorded in the eastern (541) (Lowe *et al.* 2002). The JV and past domestic groundfish fisheries have had an adverse impact on the spatial/temporal distribution of Atka mackerel due to the spatial/temporal concentration of the fishery in the BSAI.

Prior to 1993, no mechanism existed to spatially allocate TACs in the Aleutians to minimize the likelihood of localized depletion of Atka mackerel. In mid-1993, however, Amendment 28 to the BSAI FMP became effective, dividing the Aleutian subarea into three districts at 177° W and 177° E longitudes for the purposes of spatially apportioning TACs. Amendment 28 created the western (543), central (542), and eastern (541) Aleutian Districts. The BSAI Atka mackerel ABCs and TACs have been apportioned among areas based on weighted average distribution of biomass from the Aleutian Islands bottom trawl surveys.

Studies on Steller sea lion food habits indicate that Atka mackerel is the most common food item of adult and juvenile Steller sea lions in the summer (NMFS 1995b) and winter (Sinclair and Zeppelin 2002). A 10 nm year-round trawl exclusion zone was established around all rookeries west of 150°W in 1991-1992; and a 20 nm trawl exclusion zone was established around 6 rookeries in 1992-93, two of which included Seguam and Agligadak Islands. In 1993, a 20 nm aquatic zone was established around all rookeries and major haulouts west of 144°W and around three foraging areas, including one located near Seguam Pass.

Due to concerns that the spatial/temporal concentration of Atka mackerel catch could be high enough to affect prey availability for Steller sea lions, NPFMC passed a fishery regulatory amendment in June of 1998 which further dispersed the fishery spatially and temporally and reduced the level of fishing within Steller sea lion critical habitat in the BSAI. These regulations have been superceded by Amendment 70 to the BSAI and GOA FMPs which enacted the current Sea Lion Protection Measures in 2002 (Section 12.2.2 of Lowe and Fritz 1997).

Change in Prey Availability

External Commercial Whaling

Whaling is identified as having a past beneficial effect on prey availability for the Atka mackerel stocks. Atka mackerel have been documented as a prey of certain whale species; therefore, by removing large predators, Atka mackerel recruitment is favored.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. In general, a shift toward colder waters favors recruitment and survival of Atka mackerel. When the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of Atka mackerel.

Change in Important Habitat

External Foreign Groundfish Fisheries (1970-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Due to the schooling, semi-demersal nature of Atka mackerel, this species is readily caught by bottom trawl gear (Lowe *et al.* 2001). Therefore Atka mackerel habitat is also subject to fishery gear impacts associated with bottom trawling. However, data on how fishery gear has specifically affected Atka mackerel habitat is unavailable; therefore, the effects of the past foreign fisheries on habitat suitability for the BSAI stock are unknown.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability in both stocks. In general, a shift toward colder waters favors recruitment and survival of Atka mackerel. When the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of Atka mackerel.

Internal Foreign, JV and Domestic Groundfish Fisheries (1976-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

As stated in the external foreign fisheries section above, data regarding fishery gear impacts specific to Atka mackerel habitat are unavailable; therefore, the effects of the post-MSA foreign, JV, and domestic fisheries on the important habitat of Atka mackerel are unknown.

BSAI FMP Amendment 28, discussed above, helped to guard against reduced habitat suitability by reducing the concentration of Atka mackerel fishing effort spatially and temporally. The June 1998 regulation discussed above also contributed to guarding against reduced habitat suitability by banning trawl fishing within Steller sea lion critical habitat, which is habitat shared by Atka mackerel. Amendment 70, which supercedes the previous Steller sea lion regulations, closes Atka mackerel fishing in the Seguam foraging areas in all critical habitat areas east of 178°W longitude, and within 10 nm of rookeries west of 178°W longitude except Buldir which is closed within 15 nm. Atka mackerel fishing is also prohibited within 3 nm of all haulouts. Further closures have also been initiated in the Bering Sea, although the closures are more complex dependent on the type of fishery, gear used, location, and timing of the fishery. BSAI FMP Amendments 55 and 65 were both designed to identify and conserve EFH and HAPC (see Appendix C).

BSAI Atka Mackerel Comparative Baseline

Survey biomass estimates for Atka mackerel come from the 1986 U.S.-Japan cooperative trawl survey and from domestic trawl surveys in 1991, 1994, 1997, 2000, and 2002. The biomass estimate from 2002 is 772,798 mt, a 51 percent increase from the 2000 survey estimate. Atka mackerel biomass tends to be highly variable over depth (between 1 and 200 m) and area. Virtually all the biomass in the trawl surveys was found between 1 and 200 m. In the 2002 survey, areas with large catches were located north of Akun Island, Seguam Pass, Tanaga Pass, south of Amchitka Island, Kiska Island, Buldir Island, and Stalemate Bank (Lowe *et al.* 2002).

Factors that may affect Atka mackerel distribution, and thus availability to surveys, include bottom water temperatures and tidal cycles. Low bottom temperatures could impact the distribution of Atka mackerel and/or their food source. In 2000, the lowest bottom temperatures were recorded relative to past surveys and the fish during the 2000 survey were also found to weigh less than in the 1994 and 1997 surveys, suggesting a food-related impact. Atka mackerel are also thought to be responsive to tidal cycles; during high tide Atka mackerel may not be as accessible to surveys.

The 2000 survey age composition of Atka mackerel from the fishery is shown in Figure 3.5-4. The age composition is dominated by a strong 1992 and 1995 year-class and a very strong 1998 year-class (2 year-olds). The estimated mean age of the 2000 survey age composition is 5 years (Lowe *et al.* 2001). The current fishery tends to select fish aged 3 to 12 years old (Lowe and Fritz 2001). The 2001 fishery age composition data were dominated by the 1995 and 1998 year-classes (Lowe *et al.* 2002). It is not known how the age composition of the population would look in an unfished population.

BSAI Atka Mackerel Cumulative Effects Analysis Status

The BSAI Atka mackerel will be brought forward for cumulative effects analysis.

3.5.1.5 BSAI Yellowfin Sole

Life History and Distribution

Yellowfin sole (*Limanda aspera*) are distributed from British Columbia to the Chukchi Sea (Hart 1973). In the Bering Sea, they are presently the most abundant flatfish species and are the target of the largest flatfish groundfish fishery in the U.S. While also found in the Aleutian Islands and GOA, the stock is of much smaller size in those areas and is less likely to be commercially exploited there. Adults are benthic and occupy separate winter and spring/summer spawning and 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. The estimated age at 50 percent maturity is 10.5 years at a length of approximately 29 cm (Nichol 1994). The maximum recorded age of a yellowfin sole is 34 years. Table 3.5-10 summarizes biological and reproductive attributes and habitat associations of yellowfin sole in the BSAI and GOA.

Trophic Interactions

Major prey items include bivalves, polychaete and echiuroid worms, euphausiids, and crangon shrimp (Livingston and deReynier 1996). Hafflinger and McRoy (1983) also showed that yellowfin sole will consume bairdi and opilio Tanner crabs and red king crabs at certain areas and times in the EBS. Livingston (1991b) found that yellowfin sole consume small quantities of juvenile bairdi and opilio Tanner crab, and blue king crab.

Groundfish predators of yellowfin sole include Pacific cod, skates, and Pacific halibut, which consume fish ranging from 7 to 25 cm standard length (Livingston and deReynier 1996).

BSAI Yellowfin Sole Management

In the Bering Sea, yellowfin sole are considered one stock for management purposes. The reference fishing mortality rate and ABC for yellowfin sole are determined by the amount of population information available (see Appendix B). Yellowfin sole are currently managed under Tier 3a of NPFMC's ABC and OFL definitions (Appendix C; Amendment 56). Management under Tier 3a requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). The projected yellowfin sole female spawning biomass for 2003 is greater than $B_{40\%}$ (452,800 mt >385,000 mt), leading to an ABC value of 114,000 mt for 2003. The OFL was determined from the Tier 3a formula, equating to a value of 135,000 mt. Model projections indicate that the yellowfin sole stock is neither overfished nor approaching an overfished condition, according to the BSAI groundfish FMP Amendment 56 definitions, although the yellowfin sole stock continues to decline, mainly due to poor recruitment in the last decade (Wilderbuer and Nichol 2002) (Table 3.5-2).

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. Recent stock assessment analyses indicate a positive linear relationship between annual estimates of trawl survey biomass and bottom water temperature. This may be due to the decline in activity at low temperatures of the influence of water temperature on the timing of spawning migrations. As indicated by the 2000 survey, a significant portion of the yellowfin sole biomass appears to lie outside this survey border (Wilderbuer and Nichol 2002).

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.

BSAI Past/Present Effects Analysis

The geographic scope for the yellowfin sole past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign fishery for flounders started and ends in 2002, the most recent year for which a stock assessment is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-11 provides a summary of the yellowfin sole past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on yellowfin sole:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to fishery selectivity, spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery catch/bycatch of prey species, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, marine pollution and oil spills, introduction of exotic species and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on yellowfin sole in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the northwest Pacific to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the yellowfin sole past/present effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1954-1976)
  - State of Alaska crab fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1991)
  - Domestic groundfish fisheries (1987-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the yellowfin sole fishery. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality

External Foreign Groundfish Fisheries (1954-1976)

The first EBS foreign yellowfin sole fishery was conducted by Japan from 1940 to 1941. The catches for these years totaled 9,600 and 12,200 mt, respectively. Japan was not allowed back into Alaska waters until the signing of the peace treaty between the U.S. and Japan in 1952 (NPFMC 2002a).

In 1954, the Japanese again began targeting flounders (primarily yellowfin sole) in the mothership fishery. Fishing occurred mostly off of Bristol Bay. From 1958 to 1963, the Japanese mothership fleet expanded in the Bering Sea. The foreign fisheries overexploited the yellowfin sole stock from 1959 to 1962, with catches averaging 400,000 mt annually, including the Soviet catch. The Soviet flounder fishery did not begin until about 1959, and occurred in areas where the yellowfin sole formed their winter aggregations. The Soviet portion of the flounder catch (made up mostly of yellowfin sole) from 1959 to 1963 ranged between 60,000 and 155,000 mt. Reduced abundance caused a decline in catches to about 100,000 mt annually from 1963 to 1971. By 1973, the Soviet flounder fishery failed to develop and was limited to a two-week period by four trawlers. A small Taiwanese fishery occurred in December of 1974, and was believed to have been targeting pollock and flounders. Yellowfin sole harvests continued to decline to 50,000 mt from 1972 to 1977. However, with an increase in abundance, the foreign and JV harvest increased in the 1980s. Foreign fisheries dominated the yellowfin sole harvest until 1984, and were completely phased-out of the BSAI in 1987 when the domestic and JV fisheries began rapid development (NPFMC 2002a).

Flounders have made up a relatively minor fishery in the Aleutian Islands, and consist of yellowfin sole, Alaska plaice, rock sole and flathead sole. Annual catch remained well under 5,000 mt from 1962 to 1971, increased to about 10,000 mt in 1972, and decreased to previous levels (5,000 mt) by 1976 (NPFMC 2002a).

Although large removals of yellowfin sole occurred during the past foreign fisheries, there are no observable lingering adverse effects on the BSAI yellowfin sole population.

Internal JV and Domestic Groundfish Fisheries (1980-present)

JV fisheries began in 1980 and ended in 1991 when the fishery became fully domesticated. The domestic yellowfin sole fishery began in 1987. Since that time, catches have not exceeded 150,000 mt annually, except for the 1997 harvest at 181,389 mt. In more recent years, the catch has been below 100,000 mt. The fishery is generally limited by Pacific halibut and crab bycatch limits, and market limitations (Wilderbuer and Nichol 2002).

Although large removals of yellowfin sole occurred during the JV and past domestic fisheries, there are no observable lingering adverse effects on the BSAI yellowfin sole population.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1954-1976)

The fishing mortality imposed on the yellowfin sole population by the foreign fisheries operating in the Bering Sea prior to 1976 has had no effect on the reproductive capabilities of the present population. Large removals of yellowfin sole in the early 1960s were followed by sustained above-average recruitment for over a decade in the period from 1966-1976. This level of productivity resulted in high levels of female spawning biomass. Furthermore, the age classes exploited during those years are no longer present in the current population due to natural mortality.

External Climate Changes and Regime Shifts

Patterns of yellowfin sole recruitment do not directly correspond with changes in the climate and the known regime shifts in 1977 and 1989. Following more than a decade of sustained above-average recruitment, the regime shift in 1977 ushered in a period of more variable recruitment success with very large year-classes in 1981 and 1983 interspersed with years of below average recruitment. The 1990s appear to be a less productive decade for recruitment. Because yellowfin sole are late spring/summertime spawners, it is unknown what physical mechanisms influence recruitment success.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The exploitation fraction of the fisheries on yellowfin sole since the MSA has averaged 0.06 and is thus unlikely to have had much effect on the reproductive success of the stock. The fisheries are also characterized as having been spread out over time and space which has caused minimal disruption to spawning concentrations.

Change in Prey Availability

External Foreign Groundfish Fisheries (1954-1976)

The foreign fisheries in the BSAI are unlikely to have directly impacted prey availability for the yellowfin sole stock since these fish eat infaunal and epifaunal invertebrates. The lingering effect in the BSAI yellowfin sole stock is likely due to the natural events related to climate change.

External State of Alaska Crab Fisheries Bycatch of Juvenile Crabs

The bycatch of juvenile crabs (the size consumed by yellowfin sole) is relatively minor in State of Alaska crab fisheries. It is unknown what effect this removal of juvenile crab has on the foraging capabilities of yellowfin sole as juvenile crabs are only one component of yellowfin sole diet. Also the summertime feeding distribution of yellowfin sole is quite extensive over the Bering Sea shelf, whereas these fisheries are quite limited in space.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. Although flatfishes tend to dominate catch during strong Aleutian Lows, on a microclimate scale, community structures changed in some nearshore areas with decreasing populations of shrimps and small forage fish, and increasing populations of the large, fish-eating species, such as Pacific cod, and other flatfishes (see Section 3.10.1.5). Pacific cod, skates, and Pacific halibut are all predators of yellowfin sole.

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of yellowfin sole.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of yellowfin sole.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The bycatch of juvenile crabs occurs in small numbers in domestic trawl fisheries. Crabs less than 25 mm in carapace width are estimated to have a selectivity of 0.001 in domestic fisheries from the snow crab assessment model. Combined with the fact that juvenile crab are only one component of the diet of yellowfin sole, these fisheries are not expected to impact the foraging capabilities of yellowfin sole.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of past foreign fisheries on habitat suitability is either beneficial or adverse; the effects are found to have had a lingering influence in yellowfin sole stocks, and the overall effect is beneficial in the BSAI yellowfin sole assemblage, probably due to climatological effects.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability; depending if habitat suitability is evaluated on a macro- or microscale. In general, when the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Survey biomass estimates of yellowfin sole over the past 15 years show a positive correlation with shelf bottom temperatures (Nichol 1998); estimates have been low during cold years.

(Wilderbuer and Nichol 2001). The lingering beneficial influence in the BSAI yellowfin sole stock is likely due to the natural events related to climate change.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of yellowfin sole.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Recent research by the Resource Conservation Assessment Engineering (RACE) Division of the AFSC has investigated the consequences of lost habitat on juvenile flatfishes. The researchers found that juvenile flatfishes, including Pacific halibut and rock sole, prefer structured habitat (sand with sponges, bryozoans, bivalve shells, and waves). Furthermore, it was found that these structured habitats provide for reduced mortality rates by reducing their encounter rate with predators. Invertebrate bycatch from trawled and untrawled areas northeast of the Crab and Halibut Protection Zone 1 in the EBS inspired this research; invertebrates were more abundant in the non-fished zone versus the fished zone (Stone 2002).

The effect of past JV fisheries on habitat suitability is either beneficial or adverse; the effects are found to have had a lingering influence in yellowfin sole stocks, and the overall effect is beneficial in the BSAI yellowfin sole assemblage, probably largely due to climatological effects.

BSAI Yellowfin Sole Comparative Baseline

AFSC surveys conducted in waters 20-200 m from the Alaska Peninsula north to St. Matthew and Nunivak Islands show a doubling of biomass between 1975 and 1979, with a continued increase till 1981 at 2.3 million mt for fish age-7+ (exploitable biomass). Biomass estimates varied from 1981 to 1990, but levels between 1990 and 1999 have shown an even trend at high levels. 1999 and 2000 biomass estimates are at lower levels, while there is a slight increase in the 2001 and 2002 survey estimates (Wilderbuer and Nichol 2002).

Variations in survey results can be attributed to the availability of the yellowfin sole population in a survey area. Yellowfin sole are known to migrate from wintering areas off the shelf-slope break to spawn in nearshore waters that are not sampled by the AFSC survey (Nichol 1995, Wakabayashi 1989, Wilderbuer *et al.* 1992). Some variability can also be attributed to shelf bottom temperatures; biomass estimates over the past 15 years have shown a positive correlation with shelf bottom temperature: the colder the year, the lower the estimate. This may further reduce the availability of the yellowfin sole population to the survey area (Wilderbuer and Nichol 2001).

Model results suggest that the age-2+ biomass was at low levels during most of the 1960s and 1970s. A peak of 2.5 million mt occurred in 1985 due to sustained above average recruitment from 1967-1976 combined with low exploitation. Since 1985, the population of age-2+ yellowfin sole and female spawning biomass has been in slow decline. Above average recruitment from the 1991 year-class is expected to maintain the abundance of yellowfin sole above the $B_{40\%}$ level in the near future (Wilderbuer and Nichol 2001).

BSAI Yellowfin Sole Cumulative Effects Analysis Status

BSAI yellowfin sole will be brought forward for cumulative effects analysis.

3.5.1.6 BSAI Rock Sole

Life History and Distribution

Rock sole are distributed from southern California northward through Alaska (Wolotira *et al.* 1993). Two species of rock sole occur in the NPO, the northern rock sole (*Lepidopsetta polyxystran* sp.), and the southern rock sole (*L. bilineata*). These species have an overlapping distribution in the GOA, but the northern species primarily comprise the BSAI populations (Wilderbuer and Walters 1997). Their center of abundance occurs off the Kamchatka Peninsula, Russia (Shubnikov and Lisovenko 1964), off British Columbia (Forrester 1969), in the central GOA, and in the southern EBS (Alton and Sample 1976). 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 and 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). Table 3.5-12 summarizes biological and reproductive attributes of rock sole in the BSAI and GOA.

Trophic Interactions

Major prey items include polychaete and miscellaneous worms, amphipods, and miscellaneous fish. Groundfish predators on rock sole include Pacific cod, skates, pollock, yellowfin sole, and Pacific halibut, which primarily consume fish ranging from 5-15 cm standard length. (Livingston and deReynier 1996).

BSAI Rock Sole Management

Northern and southern rock sole are managed as a single unit in the BSAI, and are currently managed under Tier 3a of NPFMC's ABC and OFL definitions. Management under Tier 3a requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected rock sole spawning biomass for 2003 is greater than $B_{40\%}$ (303,000 > 158,000), $F_{40\%}$ (the upper limit on ABC) is recommended as the F_{ABC} harvest reference point for 2003. This equates to a 2003 ABC of 110,000 mt and an OFL of 132,000 mt. Rock sole are abundant on the EBS shelf and also occur in the Aleutian Islands. This species represents a relatively data-rich case (Wilderbuer and Walters 2002) (Table 3.5-2).

Information on the rock sole stock conditions in the BSAI comes primarily from AFSC surveys. The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model as the primary analytical tool. 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 (Wilderbuer and Walters 2001).

BSAI Rock Sole Past/Present Effects Analysis

The geographic scope for the BSAI rock sole past/present effects analysis is the same as the BSAI management units (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign flounder fishery began and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-13 provides a summary of the rock sole past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on rock sole:

- Mortality due to catch/bycatch and marine pollution and oils spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch, the rock sole roe fishery, fishery selectivity and climate changes and regime shifts (indirect effect).
- Change in prey availability due to introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the rock sole fishery. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here. For the BSAI, there are no amendments that specifically mention rock sole.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species by way of ballast water and climate changes and regime shifts has not been brought forward since the impacts on rock sole in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regimes shifts.

The past/present events determined to be applicable to the rock sole past/present effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1954-1976)
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1987-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1954-1976)

Rock sole were first targeted in the Japanese mothership fishery which began in 1954. The rock sole fisheries are the same as the flounder fisheries described in Section 3.5.1.5 that primarily targeted yellowfin sole and include the Japanese and Soviet fisheries. Rock sole were not always identified in catches prior to about 1970. Rock sole catch appears to have remained steady at about 7,000 mt from 1963-1969 and then increased to about 30,000 mt annually between 1970 and 1975. The end of the Soviet flounder fishery in 1973 (due to political reasons) is thought to have had a beneficial effect on the flatfish of the BSAI (NPFMC 2002a).

Flounders have made up a relatively minor fishery in the Aleutian Islands, and consist of yellowfin sole, Alaska plaice, rock sole and flathead sole. Annual catch remained well under 5,000 mt from 1962-1971, increased to about 10,000 mt in 1972 and decreased back down to about 5,000 mt by 1976 (NPFMC 2002a, Wilderbuer and Walters 2002).

Although removals of rock sole occurred during the foreign fisheries, there are no observable lingering adverse effects on the BSAI rock sole populations.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The JV fishery began in 1980 and was phased out of the BSAI by 1990. The JV fisheries averaged 2,000 to 9,000 mt annually from 1980-1983, increasing to nearly 30,000 mt in 1984. Peak harvest occurred in 1988 at about 40,000 mt. The domestic rock sole fishery began in 1987. The domestic harvest ranges from about 25,000 to 63,000 mt annually, with a peak in 1997 at 67,564. The average annual harvest from 1987-2000 is 54,960 mt. Rock sole are also a target of a high value roe fishery in February and March which takes the majority of the annual catch. The rock sole directed fishery tends to be limited due to bycatch of prohibited species (i.e. Pacific halibut and crab) (Wilderbuer and Walters 2001).

Although large removals of rock sole occurred during the JV and past domestic fisheries, there are no observable lingering adverse effects on the BSAI rock sole population.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1954-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effects of the foreign fisheries on the spatial/temporal distribution of BSAI rock sole due to the spatial/temporal concentration of the fishery is unknown. However, any effects would not have had lingering population effects in the population.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of rock sole. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries

Spatial/Temporal Concentration of Catch/Bycatch

The JV and past domestic fisheries effects on the spatial/temporal distribution of the BSAI rock sole due to the spatial/temporal concentration of the fishery is unknown. However, any effects would not have had lingering population effects in the population.

Fishery Selectivity

Large amounts of rock sole are discarded overboard in various Bering Sea trawl target fisheries. Fisheries with the highest discard rates include the rock sole, yellowfin sole, Pacific cod, and the bottom pollock fisheries. Rock sole discard rates have exceeded the amount of rock sole retained since 1987, ranging from 33-45 percent retention from 1990-2000. Recently, percent discards have increased to 66 and 57 percent, respectively, for 2001 and 2002, and the amount discarded was 9,956 mt and 17,291 mt, respectively. Peak discard occurred in 1993 at 45,669 mt, but has generally ranged from 12,000 to 40,000 mt annually based on 1987-2002 (Wildebuer and Walters 2002).

Roe Fishery

The rock sole roe fishery takes a majority of the annual catch of rock sole, although the total catch in recent years has only been 21 percent of the ABC (2000).

Change in Prey Availability

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on and prey availability depending on the frame of reference. In general, when the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of rock sole.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of rock sole.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Recent research by the RACE division of the AFSC has investigated the consequences of lost habitat on juvenile flatfishes. The researchers found that juvenile flatfishes, including Pacific halibut and rock sole, prefer structured habitat (sand with sponges, bryozoans, bivalve shells, and waves). Furthermore, it was found that these structured habitats provide for reduced mortality rates by reducing the flatfish encounter rate with predators. Invertebrate bycatch from trawled and untrawled areas northeast of the Crab and Halibut Protection Zone 1 in the EBS inspired the research; invertebrates were more abundant in the non-fished zone than in the fished zone (Stone 2002).

The effect of these fisheries is either beneficial or adverse; they are found to have had a lingering beneficial influence in the BSAI, probably mostly due to climatological effects.

External Climate Changes and Regime Shifts

The effect of climate changes on habitat suitability is either beneficial or adverse depending on the frame of reference; they are found to have had a lingering beneficial influence in the BSAI. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of rock sole.

Internal JV and Domestic Groundfish Fisheries

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of past JV fisheries on habitat suitability is either beneficial or adverse; they are found to have had a lingering beneficial influence in the BSAI, probably mostly due to climatological effects.

BSAI Rock Sole Comparative Baseline

The AFSC stratified area-swept bottom trawl surveys indicate that rock sole biomass remained stable through 1979, with a substantial increase in abundance to 799,300 mt in 1984. A slight decrease occurred in 1985, but estimates rose again to over 1 million in 1986 and continued to increase throughout the 1990s. The survey estimates peaked in 1994 and thereafter show the stock at a high level with a 2002 estimate of 1.9 million mt (Wilderbuer and Walters 2001).

The stock assessment model abundance estimates indicate that rock sole were at low levels during the mid-1970s through 1982. The population increased from 1982 to 1995, during a period of above-average recruitment and low exploitation, peaking in 1995 at over 1.5 million mt. Current population-levels are 38 percent lower than the peak estimate of 1995, attributable to below-average recruitment of the adult portion of the population during the 1990s, and is projected to decline further in 2003. The female spawning biomass is estimated at a high level, but slightly declining in 2002. Model projections indicate that this stock is neither overfished nor approaching an overfished condition (Wilderbuer and Walters 2002).

Currently, rock sole spawning stock has contributions from a wide range of ages and is well above the $B_{40\%}$ level. Projections for the near future indicate a decline in female spawning biomass due to a lack of good recruitment during the 1990s (Wilderbuer and Walters 2001).

BSAI Rock Sole Cumulative Effects Analysis Status

The BSAI rock sole will be brought forward for cumulative effects analysis.

3.5.1.7 BSAI Flathead Sole

Life History and Distribution

Flathead sole (*Hippoglossus elassodon*) are distributed from northern California northward throughout Alaska. In the northern part of its range, the species overlaps with the related and very similar Bering flounder (*Hippoglossoides robustus*) (Wolotira *et al.* 1993, Hart 1973). Adults are benthic and occupy separate winter spawning and summer feeding distributions. From overwintering 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 late winter/early 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). Age and size at maturity are unknown, but recruitment to the fishery begins at age 3 (Figure 3.5-5). The maximum age from fishery age samples is 28 years. Flathead sole are taken in bottom trawls both as a directed fishery and in pursuit of other bottom dwelling species. Table 3.5-14 summarizes biological and reproductive attributes and habitat associations of flathead sole in the BSAI and GOA.

Trophic Interactions

Flathead sole feed primarily on invertebrates such as ophiuroids, tanner crab, bivalves and polychaetes. Their diet has been shown to include commercially important species such as pollock and tanner crabs. In the EBS, other fish species represented 5 to 25 percent of the diet (Livingston *et al.* 1993). Groundfish predators include Pacific cod, Pacific halibut, arrowtooth flounder, and also cannibalism by large flathead sole, mostly on fish less than 20 cm standard length.

BSAI Flathead Sole Management

Since it is difficult to separate flathead sole and Bering flounder at sea, they are currently managed as a single stock (Walters and Wilderbuer 1997) under Tier 3a of NPFMC's ABC and OFL definitions. Management under Tier 3a 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 2003 (225,000 mt) is greater than $B_{40\%}$, the maximum F_{ABC} is recommended as the harvest reference point for 2003, equating to an ABC of 66,000 mt (Table 3.5-2). The $F_{35\%}$ value (0.37) gives an OFL value of 81,000 mt.

Annual trawl survey biomass results have been the primary data component used to assess stock level since 1982. The assessment model has a length-based formulation, which is underlaid by an age-based model. 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 (Spencer *et al.* 2001a).

BSAI Flathead Sole Past/Present Effects

The geographic scope for the BSAI flathead sole past/present effects analysis is the same as the BSAI management units (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign flounder fishery started and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-15 provides a summary of the flathead sole past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on flathead sole:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).
- Change in reproductive success due to spatial/temporal concentration of catch/bycatch, fishery selectivity, and climate changes and regime shifts (indirect effect).
- Change in prey availability due to climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).
- Change in important habitat due to fishery gear impacts, marine pollution and oil spills, introduction of exotic species and climate changes and regime shifts (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the rock sole fishery. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here. For the BSAI, no amendments specifically mention flathead sole.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on flathead sole in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the flathead sole past/present effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1954-1976)
  - State of Alaska crab fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1987-present)

- Past/Present Management Actions
  - Bilateral agreement
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1954-1976)

Flathead sole were first targeted with other flatfish species in the Japanese mothership fishery which began in 1954. The flathead sole fisheries are the same as the flounder fisheries described in Section 3.5.1.5 that primarily targeted yellowfin sole and include the Japanese and Soviet fisheries. Flathead sole were not always identified in catches prior to about 1970, and were combined into the "other species" category. Flathead sole catch declined from approximately 30,000 mt to under 10,000 mt annually from 1963-1965 and then increased steadily to about 25,000 mt in 1969. A significant increase in catch occurred after 1969, peaking in 1971 at about 51,000 mt. Catches again decreased following 1971 to about 20,000 mt annually and remained relatively stable through 1976. The discontinuation of the Soviet flounder fishery (1973) is thought to have had a beneficial effect on the flatfish of the BSAI (NPFMC 2002a, Spencer *et al.* 2002a).

Flounders have made up a relatively minor fishery in the Aleutian Islands, which consists of yellowfin sole, Alaska plaice, rock sole and flathead sole. Annual catch remained well under 5,000 mt from 1962-1971, increased to about 10,000 mt in 1972 and decreased back down to about 5,000 mt by 1976 (NPFMC 2002a).

Although large removals of flathead sole have occurred in the foreign fisheries, there are no observable lingering negative effects in the BSAI flathead sole population.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The JV fishery began in 1980 and was phased out of the BSAI by 1990. From 1977 to 1989, flathead sole harvests were under 10,000 mt annually, with an average annual catch of 5,286 mt. Catches increased in 1990-2000 to an average of 17,946 mt annually. Flathead sole have remained lightly harvested largely due to prohibited species bycatch restrictions, including halibut and crab limits.

Due to the small removals of flathead sole by the JV and past domestic fisheries, there are no observable lingering adverse effects on the BSAI flathead sole populations.

Prior to 1994, flathead sole and Bering flounder were managed as unit stock *Hippoglossoides sp.* under the "other flatfish" assemblage in the BSAI. At that time NPFMC requested the BSAI Groundfish Plan Team to assign a separate ABC for flathead sole in the BSAI, rather than combining it with the other flatfish assemblage. This request was made to protect the less abundant species of the "other flatfish" category at a time of increased targeting on flathead sole since individual species catch are not distinguished when managing as an assemblage, but rather the ABC is prescribed as a composite of all species.

Recent studies have described the growth and distribution differences between the flathead sole and Bering flounder and have illustrated the possible ramifications of combining the two species as a unit stock (Walters and Wilderbuer 1997). This may lead to separate management in the future.

Change in Reproductive Success

External Foreign Groundfish Fisheries

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the foreign fisheries on spatial/temporal distribution of the BSAI flathead sole stocks is unknown. These fisheries are determined not to have had lingering population effects in the BSAI population. Winter time-area closures in the south EBS, designed pre-MSA for the protection of halibut, also benefitted flathead sole because they form winter concentrations in this area as well. Furthermore, the absence of a directed Soviet fishery on flathead sole after 1972 may have additionally benefitted the stocks (NPFMC 2002a).

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of flathead sole. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1980-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV fisheries on the spatial/temporal distribution of the BSAI flathead sole stock is unknown. These effects are determined not to have had lingering population effects in the BSAI population.

Fishery Selectivity

Significant amounts of flathead sole bycatch occur in the Pacific cod, pollock and rock sole fisheries, although the percentage of retention has increased in recent years from 51 percent in 1995 to 82 percent in 2001. Actual amounts of flathead sole discard have declined from 7,189 mt in 1998 to 3,231 mt in 2001; there has been a slight increase in 2002 at 3,646 mt as of September 21, 2002 (Spencer *et al.* 2002a).

Change in Prey Availability

External Foreign Groundfish Fisheries (1954-1976)

It is unlikely that the foreign fisheries had an effect on the prey availability of flathead sole. Flathead sole are characterized as having both a mixed fish and invertebrate diet. They receive this characterization due to the presence of pollock, brittle stars, crangon shrimp, mysids, and bivalves in their diet. Fish are a relatively small portion (less than 20 cm) of the flathead sole diets, but are increasingly important with size (Livingston and deReynier 1996). Records of past foreign fishery juvenile crab bycatch are unavailable; however, the impacts of these fisheries on flathead sole prey availability are also considered to be minimal.

External State of Alaska Crab Fisheries

The bycatch of juvenile crabs (the size consumed by flathead sole) is relatively minor in the State of Alaska crab fisheries. It is unknown what effect this removal of juvenile crab has on the foraging capabilities of flathead sole as crabs are only one component of their diet and these fisheries are quite limited in space.

External Climate Changes and Regime Shifts

Environmental conditions, such as changes in the Aleutian Low pressure system, may affect flathead sole stock recruitment (Hare and Mantua 2000). Future flathead sole research will take environmental variability into account when performing stock-recruitment analyses. Currently, Wilderbuer *et al.* (in press) are investigating a shift in wind patterns that coincided with below average recruitment of flathead sole in the 1990s.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability depending on the frame of reference. In general, when the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of flathead sole.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of flathead sole.

Internal JV and Domestic Groundfish Fisheries (1980-present)

It is unlikely that the JV and domestic fisheries have had an effect on the prey availability of flathead sole due to the mixed fish and invertebrate diet of flathead sole. Fish make up a relatively small portion of flathead sole diet, although the importance of fish increases with size. The bycatch of juvenile crabs occurs in small numbers in domestic trawl fisheries. Crabs less than 25 mm in carapace width are estimated to have selectivity of 0.001 in domestic fisheries from the snow crab assessment model. Combined with the fact that juvenile crab are only one component of the diet of flathead sole, these fisheries are not expected to impact their forage capabilities.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the foreign fisheries on habitat suitability is either beneficial or adverse; the effects are found to have had a lingering beneficial influence in the BSAI, probably due to climatological effects.

External IPHC Longline and State of Alaska Crab Fisheries

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the IPHC longline and State of Alaska crab fisheries on BSAI flathead sole habitat suitability is expected to be adverse, however, the magnitude of these effects are unknown. The lingering beneficial influence on habitat suitability in the BSAI in likely due to climatological effects.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability depending on the frame of reference. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in the same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of flathead sole.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6 for a discussion of the potential impacts of fishery gear on habitat.

Recent research by the RACE division of the AFSC has investigated the consequences of lost habitat on juvenile flatfishes. The researchers found that juvenile flatfishes, including Pacific halibut and rock sole, prefer structured habitat (sand with sponges, bryozoans, bivalve shells, and waves). Furthermore, it was found that these structured habitats provide for reduced mortality rates by reducing the encounter rate between flatfish and predators. Invertebrate bycatch from trawled and untrawled areas northeast of the Crab and Halibut Protection Zone 1 in the EBS inspired the research; invertebrates were more abundant in the non-fished zone than in the fished zone (Stone 2002).

The effect of the JV fisheries on habitat suitability is either beneficial or adverse; the effects are found to have had a lingering beneficial influence in the BSAI, probably due to climatological effects.

BSAI Flathead Sole Comparative Baseline

Survey biomass estimates indicate that flathead sole increased from low levels in the early 1980s to a high stable level in the mid-1990s. However, values for 1999-2000 were nearly half of the peak value estimated in 1997, with a slight increase in the 2001 and 2002 surveys (Spencer *et al.* 2002a).

Model estimates indicate an increase in age-3+ total biomass from 1977 to a peak in 1991, followed by a steady decline through 2001. Female spawning biomass increased from 1977 to a peak in 1995, also followed by a steady decline through 2001. Model estimates fit the survey biomass estimate data well, except for 1994, 1997, and 1998 estimates. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

BSAI Flathead Sole Cumulative Effects Analysis Status

The BSAI flathead sole will be brought forward for cumulative effects analysis.

3.5.1.8 BSAI Arrowtooth Flounder

Life History and Distribution

Arrowtooth flounder (*Atheresthes stomias*) occur from central California to the Bering Sea, in waters from about 20-800 m (Zimmerman and Goddard 1996). 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). The maximum reported ages are 16 years in the Bering Sea, 18 years in the Aleutian Islands, and 23 years in the GOA (Turnock *et al.* 1997a, Wilderbuer and Sample 1997). Arrowtooth flounder is currently the most abundant groundfish species in the GOA; however, they are currently considered of low value and mostly discarded.

In the Bering Sea, the arrowtooth flounder inhabits the continental shelf waters almost exclusively until age-4, but older ages occupy both shelf and slope waters, with greatest concentrations at depths between 100 and 200 m (Martin and Clausen 1995). The very similar Kamchatka flounder (*Atheresthes evermanni*) also occurs in the Bering Sea. 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). Table 3.5-16 summarizes biological and reproductive attributes and habitat associations of arrowtooth flounder in the BSAI and GOA.

Trophic Interactions

Arrowtooth flounder play an important role in the Bering Sea and GOA ecosystems because they are large, aggressive, and abundant predators of other groundfish species (Hollowed *et al.* 1995, Livingston 1991b, Yang 1993). The majority of prey by weight of arrowtooth flounders larger than 40 cm is pollock, the remainder consisting of herring, capelin, euphausiids, shrimp, and cephlapods (Yang 1993). These fish also consumed salmonids and Pacific cod in the GOA (Yang and Nelson 2000). The percent of pollock in the diet of arrowtooth flounder increases for sizes greater than 40 cm. Arrowtooth flounder 15-30 cm consume mostly shrimp, capelin, euphausiids and herring, with small amounts of pollock and other miscellaneous fish (DiCosimo 1998). Groundfish predators on arrowtooth include Pacific cod and pollock, which feed mostly on small fish (Livingston and deReynier 1996).

BSAI Arrowtooth Flounder Management

Since the Kamchatka flounder is not usually distinguished from arrowtooth flounder in commercial catches, both species are managed as a group. These species are managed under Tier 3a of the ABC/OFL definitions since equilibrium recruitment can be approximated by the average recruitment from the time-series estimated in the stock assessment, and $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ can be estimated. The spawning biomass is above $B_{40\%}$ (436,000 mt >206,000 mt), which leads to an ABC value of 112,000 mt. The 2003 OFL has been established at 139,000 mt (Table 3.5-2). The BSAI Arrowtooth flounder stock is neither overfished nor approaching an overfished condition (Wilderbuer and Sample 2002).

Information on arrowtooth flounder stock conditions in the BSAI comes primarily from the AFSC annual continental shelf trawl survey, the U.S.-Japan cooperative trawl surveys conducted triennially on the continental slope from 1979-1991 (and 1981), and triennial surveys in the Aleutian Island region. The 2002 BSAI SAFE report introduced a new split-sex model for arrowtooth flounder. This model takes into account the high ratio of females to males and estimates a separate natural mortality rate for males. In turn, separate selectivities are calculated for males and females. The abundance, mortality, and recruitment are also evaluated with this model. The outputs include estimates of sex-specific abundance, year-class strengths, length-at-age relationship, 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 (see Appendix B) (Wilderbuer and Sample 2002).

BSAI Past/Present Effects Analysis

The geographic scope for the arrowtooth flounder past/present effects analysis is the same as the BSAI management units (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign fishery for arrowtooth flounder began and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-17 provides a summary of the arrowtooth flounder past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on arrowtooth flounder:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to the spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery bycatch of prey species, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, introduction of exotic species, marine pollution and oil spills, and climate changes and regime shifts (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explains any management actions specific to the arrowtooth flounder. Amendments discussed in Section 3.2 which impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on arrowtooth flounder in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate change or regime shifts.

The past/present events determined to be applicable to the arrowtooth flounder past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1954-1976)
  - State of Alaska groundfish fisheries
  - State of Alaska herring fisheries

  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1986-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1954-1976)

The foreign flatfish fishery began in 1954, mainly targeting yellowfin sole (see Section 3.5.1.5). Catches of Greenland turbot (arrowtooth flounder and Greenland turbot) were relatively high in early years of the EBS fishery ranging over 50,000 mt in 1961 and 1962. Japanese fisheries targeted on arrowtooth flounder from 1961 to 1962 for the production of fishmeal (Takahashi 1976). Catches dropped below 40,000 mt in 1963-1970 as these species were only taken as bycatch in the pollock and other directed fisheries. Annual harvest of arrowtooth flounder reached peak rates between 1974-1976 at levels between 19,000 and 25,000 mt (NPFMC 2002a).

Flounders have formed a relatively small proportion of the total catches in the Aleutian Islands dominated by the Japanese fisheries, although Greenland turbot and arrowtooth flounder have been the main flounder species taken. Reported catches of arrowtooth flounder and Greenland turbot were low until 1970, after which they increased sharply, with Greenland turbot as the primary species taken (NPFMC 2002a).

Although large removals of arrowtooth flounder have occurred during the foreign fisheries, there are no observable lingering adverse effects in the BSAI arrowtooth flounder populations.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The JV arrowtooth flounder fisheries began in 1980 and were phased-out by 1990, when the fishery became fully domesticated. The domestic fisheries began in 1986. With the phasing-out of the foreign fisheries and restrictions placed on Greenland turbot fisheries, harvest rates decreased from the foreign exploitation harvest rates and have remained lightly harvested since that time, averaging 13,500 mt from 1977-2000. Total catch for 2001 (as of September 15, 2001) was 11,230 mt, well below the ABC. Arrowtooth flounder are typically caught in the pursuit of high-value fish and are not a target species in the BSAI (Wilderbuer and Sample 2002).

Prior to 1985, arrowtooth flounder were managed with Greenland turbot as a species complex due to similarities in their life history characteristics, distribution, and exploitation. Greenland turbot were the target species of the fisheries, whereas arrowtooth flounder were caught as bycatch. Because the stock condition of the two species have differed markedly in recent years, management since 1986 has been by individual species.

Discard rates of arrowtooth flounder have been high, ranging from 72 mt in 1985 to 18,841 mt in 1991. Percent retention from 1985-1998 ranged from 4 to 19 percent; however, retention has risen in recent years to 62 percent in 2001. Substantial amounts of discard take place in the BSAI trawl and longline target fisheries, mostly in the Pacific cod, rock sole, "other flatfish," and Greenland turbot fisheries. A developing arrowtooth flounder market is expected to increase retention in coming years (Wilderbuer and Sample 2001).

Although large removals of arrowtooth flounder have occurred in the JV and past domestic fisheries, there are no observable lingering adverse effects in the arrowtooth flounder populations.

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, arrowtooth flounder are primarily caught by bottom trawls as bycatch in high value fisheries. Stocks are lightly exploited and appear to be increasing in both the GOA and the BSAI.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1954-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the direct foreign fisheries on the spatial/temporal distribution of the BSAI arrowtooth flounder is unknown. However, these effects are determined to not have had lingering population effects on the stock.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of arrowtooth flounder. The combination of climate effects and regime shifts on prey availability and habitat suitability influence the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an in-depth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries.

Internal JV and Domestic Groundfish Fisheries (1980-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV and past domestic fisheries on the spatial/temporal distribution of the BSAI arrowtooth flounder is unknown. However, these effects are determined to not have had lingering population effects in either stock.

Change in Prey Availability

External Foreign Groundfish Fisheries (1954-1976)

The past foreign fisheries in the BSAI have had either an adverse or beneficial lingering impact on prey availability. Arrowtooth flounder from 15-30 cm feed mostly on shrimp, euphausiids, capelin, and herring (DiCosimo 1998). Arrowtooth flounder are important as a large and abundant predator of other groundfish species. Adults (fish over 40 cm) are almost exclusively piscivorus and over half their diet can consist of pollock (Hollowed *et al.* 1995, Livingston 1991b, Yang 1993). In turn, the effects of the fisheries could have been beneficial or adverse since pollock also prey on arrowtooth flounder.

Bycatch of forage species in the past foreign BSAI groundfish fisheries is also likely to have been minimal. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that the groundfish fisheries would have had a significantly adverse impact on prey availability.

External State of Alaska Groundfish Fisheries and Herring Fisheries

Bycatch of forage species and juvenile pollock in the BSAI State of Alaska groundfish fisheries is minimal and is unlikely to reduce the prey availability of arrowtooth flounder. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that State of Alaska herring fisheries would have a significantly adverse impact on prey availability.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of arrowtooth flounder.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The past JV fisheries in the BSAI have had either an adverse or beneficial lingering impact on prey availability. However, there are no indications that harvest conditions resulting from arrowtooth flounder management would alter the genetic structure of the populations, the available prey, or the suitability of nursery and/or spawning habitat in a manner that would impede long-term suitability of the stock.

Bycatch of forage species in the BSAI groundfish fisheries is minimal. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that the groundfish fisheries would have a significantly adverse impact on prey availability. BSAI/GOA Amendment 36/36 was established to protect forage fish species from developing in to a fishery market, and limiting the forage fish bycatch.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability for both stocks has been either adversely or beneficially affected by the intensity of the past foreign fisheries, and these effects are considered to have lingering influence at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of arrowtooth flounder.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability for both stocks has been either adversely or beneficially affected by the intensity of the past JV fisheries, and these effects are considered to have lingering influence at the population-level.

There are no indications that harvest conditions resulting from arrowtooth flounder management would alter the genetic structure of the populations, the available prey, or the suitability of nursery and/or spawning habitat in a manner that would impede long-term suitability of the stock.

BSAI Arrowtooth Flounder Comparative Baseline

Estimated biomass from the AFSC surveys on the continental shelf showed a consistent increasing trend from 1975-1995. These estimates remained at high levels from 1992-1997, but declined from 1997-2000 to levels 60 percent below the peak 1994 biomass estimate. 2001 survey biomass estimates are slightly higher than the 2000 estimate; however, the 2002 biomass estimates are down from 2001 (Wilderbuer and Sample 2002).

Continental slope surveys show an increase in biomass estimates between 1982 and 1985. Estimates for 1988 and 1991 are lower; however, the surveys in these years were not as deep as in previous years (200-800 m versus 200-1000 m in previous years). Survey estimates from 1979-1985 indicate that 27-51 percent of the arrowtooth flounder biomass are found in slope waters. The 2002 EBS continental slope survey found over 90 percent of arrowtooth flounder biomass at less than 800 m. Biomass estimates in the Aleutian Island region have remained stable at relatively high values since 1994 (Wilderbuer and Sample 2002).

Stock assessment model estimates indicate a five-fold increase in total biomass from 1980 to 1996, attributed to five strong year-classes. Biomass has since declined 22 percent from the peak of 817,700 mt to the 2002 biomass estimate of 638,000 mt. The decline in abundance can be attributed to a below average recruitment during the late 1990s. Currently the arrowtooth flounder spawning stock has contributions from a wide range of ages, and the stock is considered at a high level but declining. Model projections indicate that this stock is neither overfished nor approaching an overfished condition (Wilderbuer and Sample 2002).

BSAI Arrowtooth Flounder Cumulative Effects Analysis Status

The BSAI arrowtooth flounder will be brought forward for cumulative effects analysis.

3.5.1.9 BSAI Greenland Turbot

Life History and Distribution

Greenland turbot (*Reinhardtius hippoglossoides*) are distributed from Baja California northward throughout Alaska and the Arctic, although they are rare south of Alaska and primarily distributed in the EBS and Aleutian Islands region (Hubbs and Wilimovsky 1964). Juveniles are believed to spend the first three or four years of life on the continental shelf, then move to the continental slope as adults (Alton *et al.* 1988, Templeman 1973). Greenland turbot are demersal to semipelagic. Unlike most flatfish, the Greenland turbot's migrating eye 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 (D'yakov 1982). Juveniles are absent in the Aleutian Islands, 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). Table 3.5-18 summarizes biological and reproductive attributes and habitat associations of Greenland turbot in the BSAI and GOA.

Trophic Interactions

Pelagic fish are the main prey of Greenland turbot, with pollock often a major species in the diet. Other prey items include squid, euphasiids, shrimp, and other fish species inhabiting deepwater, such as Bathylagidae and Myctophidae (Livingston 1991b).

Groundfish predators include Pacific cod, pollock, and yellowfin sole, which feed mostly on fish ranging from 2-5 cm standard length (Livingston and deReynier 1996).

BSAI Greenland Turbot Management

Greenland turbot are currently managed as a single stock in the BSAI under Tier 3a of NPFMC's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3a requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). The addition of new slope survey estimates indicate a lower female spawning biomass for 2003 than predicted in the previous year (67,800 mt), which leads to a more conservative ABC. The recommended ABC for 2003 is 5,800 mt based on the recent 5-year average fishing mortality. This conservative ABC value is intended to protect the Greenland turbot stock in light of low recruitment and continued decline in stock abundance. The corresponding OFL is 17,800 mt (Table 3.5-2). Additional slope trawl surveys are necessary to reduce uncertainty in this stock (Ianelli *et al.* 2002a).

Abundance of juvenile and adult Greenland turbot on the EBS shelf is estimated by an annual trawl survey and in the Aleutian Islands by a triennial trawl survey. Abundance of adults and older juveniles were surveyed every three years on the slope cooperatively by the U.S. and Japan from 1979-1991. In the 2002, a biennial bottom trawl survey began in the upper continental slope of the EBS by the AFSC. Data collected provides information on abundance trends and trends in the biological condition of the groundfish and invertebrate resources in that region. As mentioned above, a new continental slope survey also began in the BSAI in 2002 (Ianelli *et al.* 2002a).

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. Recent efforts simplify the model used for Greenland turbot through a two-fishery combined-sexes model. However, further model specification issues will need to be addressed before the model is used extensively (Ianelli *et al.* 2001a).

BSAI Greenland Turbot Past/Present Effects Analysis

The geographic scope for the BSAI Greenland turbot past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign flounder fishery began and ends in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-19 provides a summary of the BSAI Greenland turbot past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI Greenland turbot.

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect)

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery catch/bycatch of prey species, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explains any management actions specific to the Greenland turbot. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on Greenland turbot in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the Greenland turbot past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1954-1976)
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1990)

  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1954-1976)

The flounder foreign fishery began in 1954 and primarily targeted yellowfin sole (see Section 3.5.1.5). Catches of Greenland turbot (combined arrowtooth flounder and Greenland turbot) were high, ranging over 50,000 mt in 1961 and 1962, during which time the Japanese fisheries were targeting arrowtooth flounder for fishmeal (Takahashi 1976). From 1963 to 1970, catches dropped below 40,000 mt as Greenland turbot and arrowtooth flounder were only taken as bycatch in the pollock and other target fisheries. After 1970, Greenland turbot catch increased in both the Japanese and Soviet fisheries, reaching 70,000 mt in 1974 (NPFMC 2002a).

Flounders formed only a minor fishery in the Aleutian Islands region. Combined catches of arrowtooth flounder and Greenland turbot were low until 1970, after which there was a sharp increase in catch dominated by Greenland turbot. Catches from 1972-1975 ranged from 12,000 to 14,000 mt, taken mostly by the Japanese fisheries (NPFMC 2002a).

The large removals of Greenland turbot by the foreign fisheries are determined to have had an adverse effect on the BSAI Greenland turbot population. However, partly due to the longevity of the species, these effects are determined not to have had any observable lingering adverse effects in the population. The current low levels of BSAI Greenland turbot abundance is not attributed to foreign fishery removals.

Internal JV and Domestic Groundfish Fisheries (1968-present)

Following implementation of the MSA in 1976, catches still remained high, ranging from 48,000 to 57,000 mt annually. Catch restrictions placed on the Greenland turbot due to signs of declining abundance caused a decline in annual harvest rates from 1984 to the present. During these years, catches ranged from a high of 23,120 mt in 1984 to a low of 2,689 mt in 1992. Concerns over low recruitment led to a TAC setting at 7,000 mt between 1992-1997 and has resulted in a primarily bycatch-only fishery (Ianelli *et al.* 2001a).

Prior to 1985, Greenland turbot was managed with arrowtooth flounder as a species complex due to similarities in their life history characteristics, distribution, and exploitation. Greenland turbot were the target species of the fisheries, whereas arrowtooth flounder were caught as bycatch. Because the respective stock conditions of the two species have differed markedly in recent years, management since 1986 has been by individual species (Ianelli *et al.* 2002a).

Discard rates of Greenland turbot are significant, ranging from 2,711 mt in 1994 to a low of 729 mt in 1999. Bycatch occurs primarily in the Greenland turbot, sablefish, flathead sole, Pacific cod, and arrowtooth flounder fisheries. The sablefish fishery has the highest discard rate, increasing from 17 percent in 1999 to about 40 percent in 2001 (Ianelli *et al.* 2001a).

The large removals of Greenland turbot by the JV and past domestic fisheries are found to have had an adverse effect on the BSAI Greenland turbot population However, partly due to the longevity and turnover of the species, these effects are determined not to have had lingering population effects in the population. The current low level of BSAI Greenland turbot abundance is not attributed to the JV and past domestic fisheries removals.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1954-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the past foreign fisheries on spatial/temporal distribution of the BSAI Greenland turbot populations is unknown. However, there are no observable lingering adverse effects on the BSAI stock of Greenland turbot.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of Greenland turbot. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Dramatic declines in the number of immature Greenland turbot on the EBS shelf relative to 1970s abundance information have inspired research into possible causes of this decline. One hypothesis is that increased abundance of predators (e.g., Pacific cod, Pacific halibut) in the mid-1980s (possibly due to climatological effects) reduced the survival of juvenile Greenland turbot (Ianelli *et al.* 2001a).

Internal JV and Domestic Groundfish Fisheries (1968-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the past JV fisheries on spatial/temporal distribution of the BSAI Greenland turbot stock is unknown. However, there are no observable lingering adverse effects in the BSAI Greenland turbot population.

Change in Prey Availability

External Foreign Groundfish Fisheries (1954-1976)

The foreign fisheries in Bering Sea could have had lingering adverse or beneficial effects on the availability of prey for Greenland turbot. 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.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes such as Greenland turbot. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes. Greenland turbot and Pacific halibut responded more strongly to longer-term events (such as decadal-scale climate regime patterns). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor in the population.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of Greenland turbot.

Internal JV and Domestic Groundfish Fisheries (1968-present)

The JV fisheries in the Bering Sea could have had lingering adverse or beneficial effects on the availability of prey for Greenland turbot. 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. However, there are no indications that harvest conditions under current management would alter the population genetic structure, the available prey, or the suitability of nursery and/or spawning habitat in a manner that would impede long-term sustainability of the stock in both the BSAI and GOA.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the past foreign fisheries on habitat suitability is either beneficial or adverse; overall, a lingering influence on the population is found in both stocks probably mostly due to climatological effects.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. Another hypothesis to explain the decreased abundance of immature Greenland turbot is that the environmental regime shift that occurred in the late 1970s affected the abundance or shifted the location of Greenland turbot at different life stages due to the changing oceanographic conditions. A Greenland turbot tagging study is being currently being conducted by the NOAA Fisheries Auke Bay Laboratory in an effort to better understand Greenland turbot life history and to develop a multi-species ecosystem model (Ianelli *et al.* 2001a).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of Greenland turbot.

Internal JV and Domestic Groundfish Fisheries (1968-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of these fisheries on habitat suitability is either beneficial or adverse; overall, a lingering influence on the population is found in both stocks, probably mostly due to climatological effects. In 1998, no halibut PSC was apportioned to the Greenland turbot trawl fishery; therefore, no directed trawl fishing occurred, which may decrease the intensity of the fishery on Greenland turbot habitat.

There are no indications that harvest conditions under current management would alter the population genetic structure, the available prey, or the suitability of nursery and/or spawning habitat in a manner that would impede long-term sustainability of the stock in both the BSAI and GOA.

BSAI Greenland Turbot Comparative Baseline

Combined shelf and slope surveys indicate a decline in Greenland turbot abundance between 1979 and 1985. Following 1985, slope and Aleutian Island biomass results are not comparable since surveys were conducted at different depths. However, there is an indication that biomass estimates declined between 1985 and 1991.

The average shelf survey biomass estimate during 1993 and 2001 is 29,968 mt with a declining trend during this period. In the Aleutian Island region, U.S.-Japan cooperative longline surveys suggest an increasing trend from 1980 to 1986, possibly due to the migration of older fish from the EBS (Ianelli *et al.* 2002a).

The stock assessment model estimates biomass in the early 1960s are nearly half of those estimated during the 1970s. Subsequent poor recruitment of young juvenile Greenland turbot led to a decrease in abundance of exploitable stock in the 1980s. However, these biomass estimates may be biased towards low values since the Aleutian Island survey biomass estimates are not included. The Aleutian Island survey biomass estimates typically average about one fourth to one third of the total trawl survey population biomass estimate for the BSAI.

BSAI Greenland Turbot Cumulative Effects Analysis Status

BSAI Greenland turbot will be brought forward for cumulative effects analysis.

3.5.1.10 BSAI Alaska Plaice and Other Flatfish

Life History and Distribution

In the Bering Sea, fifteen flatfish species are managed under the "other flatfish" assemblage: Arctic flounder (*Liopsetta glacialis*), butter sole (*Isopsetta isolepis*), curlfin sole (*Pleuronectes decurrens*), deep-sea sole (*Embassichthys bathybus*), Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), longhead dab (*Limanda proboscidea*), Pacific sanddab (*Citharichthys sordidus*), petrale sole (*Eopsetta jordani*), rex sole (*Glyptocephalus zachirus*), roughscale sole (*Clidodoerma asperrimum*), sand sole (*Psettichthys melanostictus*), slender sole (*Lyopsetta exilis*), starry flounder (*Platichthys stellatus*), and Sakhalin sole (*Pleuronectes sakhalinensis*). Until 2002, Alaska plaice (*Pleuronectes quadriterculatus*) was also a part of the other flatfish assemblage but has since been broken out and managed separately (Spencer *et al.* 2002c).

The species of the "other flatfish" complex are generally found on the EBS continental shelf, with small populations in the Aleutian Islands region. The distribution of many of the flatfish species extends down to Baja California, Mexico (Eschmeyer *et al.* 1983). Arctic flounder has a larger distribution, and can be found in the northeastern Atlantic, Arctic, and North Pacific oceans. In the North Pacific, the Arctic flounder can be found in the Chukchi and Bering seas and northern Okhotsk Sea. Both Arctic flounder and starry flounder are known to enter rivers (Nielsen 1986, Morrow 1980). Flatfish species tend to prefer sandy and/or muddy bottoms. 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). Little is known of the spawning, growth characteristics, or seasonal movements and population age and size structure of the species in the flatfish complex.

Dover sole produce large amounts of slime which may cover other fishes when caught in trawls (Clemens and Wilby 1961). Dover sole can hybridize with starry flounder producing *Inopsetta ischyra*, which can be found in the Bering Sea south to San Francisco, California. Starry flounder also hybridizes with the stone flounder (*Kareius bicoloratus)* (Morrow 1980).

Of the other flatfish species in the Bering Sea, Alaska plaice is the most abundant and commercially important. It is a comparatively long-lived species, and has frequently been aged as high as 25 years. This species is found at depths less than 110 m in the summer, with small juveniles frequenting in the shallower coastal waters and adults in deeper waters.

The other flatfish species complex in the GOA is currently managed as four categories: shallow water flatfish, deepwater flatfish, flathead sole, and rex sole (*Errex zachirus*). In 2002, flathead sole (*Hippoglossoides elassodon*) (see Section 3.5.1.7) was broken out of the flatfish assemblage and managed independently in the GOA. The shallow water flatfish consist of Alaska plaice (*Pleuronectes quadrituberculatus*), starry flounder (*Platichthys stellatus*), yellowfin sole (*Pleuronectes asper*) (see Section 3.5.1.5), English sole (*Pleuronectes vetulus*), butter sole (*Pleuronectes isolepis*), sand sole (*Psettichthys melanostictus*), northern rock sole (*Lepidopsetta perarcuata*) (see Section 3.5.1.6), and southern rock sole (*Pleuronectes bilineatus*) (see Section 3.5.1.6). Deepwater flatfish include Dover sole (*Microstomus pacificus*), Greenland turbot (*Reinhardtius hippoglossoides*) (see Section 3.5.1.9), and deep-sea sole (*Embassichthys bathbius*). Life history and distribution for these benthic species are as described above as in the BSAI or in the individual sections as indicated. Table 3.5-20 summarizes biological and reproductive attributes and habitat associations of selected flatfish in the BSAI and GOA

Trophic Interactions

The information provided below applies for both BSAI and GOA species not previously discussed in other sections.

Alaska plaice appear to feed primarily on polychaetes, marine worms, and other benthic invertebrates (Livingston and deReynier 1996, Livingston *et al.* 1993, Zhang 1988). Although little is known on the feeding habitats of the remaining flatfish species, most seem to prefer benthic invertebrates including small crustaceans, marine worms, mollusks, echinoderms, and small fishes (Hart 1973, Brodeur and Livingston 1988, Pearcy and Hancock 1978, Lamb and Edgell 1986, Nielsen 1986).

A common documented predator of many of the flatfish, including the Dover and English sole and the Pacific sanddab, is the California sea lion (Lowry *et al.* 1990). Other predators of various flatfish species include the Pacific halibut (on Dover sole) (Yang and Nelson 2000), the Pacific staghorn sculpin (on English sole) (Armstrong *et al.* 1995), the Pacific bonito (on Pacific sanddab) (Oliphant 1962), and the blue shark in California waters (on Pacific sanddab) (Harvey 1989). The hydromedusa water jellyfish may also prey upon the larvae and eggs of the English sole and the sand sole as found in a study in British Columbia (Purcell 1989). Predators of Alaska plaice include Pacific halibut, yellowfin sole, beluga whales, and fur seals.

BSAI Alaska Plaice and Other Flatfish Management

Beginning in 2002, Alaska plaice was broken out of the other flatfish assemblage and managed independently (Table 3.5-2). In the past, Alaska plaice dominated the other flatfish assemblage, constituting 87 percent of the 2000-2001 other flatfish catch. Alaska plaice is evaluated under Tier 3a of Amendment 56. Model projections indicate that Alaska plaice stocks are not overfished or approaching an overfished condition. (Spencer *et al.* 2002c).

The time series of fishery and survey age compositions allows the use of an age-based stock assessment model for the Alaska plaice stock. The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass (Spencer *et al.* 2002c).

Although there are fifteen species considered as part of the "other flatfish" complex, only seven species comprise the majority of catch. These species include English sole, Sakhalin sole, Dover sole, butter sole, longhead dab, rex sole and starry flounder. According to 2001 EBS survey results, English sole, Sakhalin sole, and Dover sole constitute less than one percent of the remaining total flatfish biomass (minus Alaska plaice biomass), butter sole constitutes one percent, longhead dab 16 percent, rex sole 28 percent, and starry flounder 55 percent. The other flatfish assemblage is assessed under Tier 5 for 2002, although it has been managed under Tier 4 and 3a in the past. An ABC value for the other flatfish complex is determined at the 0.75 M level, equating to an ABC of 16,000 mt. The 2003 OFL value is 21,400 mt, based on the Tier 5 formula $F = M$ (Table 3.5-2). It is not possible to determine if the other flatfish assemblage is overfished or approaching an overfished condition (Spencer *et al.* 2002b).

Because other flatfish are generally not targeted in the BSAI, commercial catch data are 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. Thus, the annual trawl survey biomass estimates are considered the best information available to determine the stock biomass. Model assessments are not conducted for this group due to lack of sufficient information. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report (Spencer *et al.* 2001b).

BSAI Alaska Plaice and Other Flatfish Past/Present Effects Analysis

The geographic scope for the Alaska plaice and other flatfish assemblage past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1954 when the foreign flounder fishery begins and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-21 provides a summary of the BSAI Alaska plaice and other flatfish assemblage past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on the BSAI Alaska plaice and other flatfish assemblage:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).
- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shift (indirect effect).
- Change in prey availability due to fishery catch/bycatch of prey species, climate changes and regime shifts, introduction of exotic species, and marine pollution and oil spills (indirect effect).
- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, introduction of exotic species, and marine pollution and oil spills (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explains any management actions specific to the other flatfish assemblage. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on the Alaska plaice and the other flatfish assemblage in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the other flatfish assemblage past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1954-1976)
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1988-1991)
  - Domestic groundfish fisheries (1988-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1954-1976)

The flounder foreign fishery began in 1954 and primarily targeted yellowfin sole (see Section 3.5.1.5). Catches of the other flatfish species, including flathead sole increased from 25,000 mt in the 1960s to 52,000 mt in 1971, mostly due to better identification and better reporting of catches during the 1970s (NPFMC 2002a).

Alaska plaice, which has made up the largest portion of catch of the other species assemblage prior to 2002, were probably taken as bycatch in the yellowfin sole fishery (Zhang *et al.* 1998). Following the peak in 1971, annual catch fell below 20,000 mt throughout the rest of the 1970s (Spencer *et al.* 2001b).

Although large removals of Alaska plaice and other flatfish occurred during the foreign fisheries, they are determined not have had any observable lingering adverse effects on the BSAI Alaska plaice and other flatfish populations.

Internal JV and Domestic Groundfish Fisheries (1988-present)

The other flatfish JV fishery began in 1988 and produced the largest catch of Alaska plaice since 1963 at 67,425 mt (Zhang *et al.* 1998). Harvest was drastically reduced in the remaining years of the JV fisheries to below 20,000 mt annually. The JV fisheries were phased-out and the fishery completely domesticated by 1991. The domestic fishery has taken under 20,000 mt in most years, except 1994 and 1997 which were still under 25,000 mt of annual catch. As of November 2, 2002, the Alaska plaice catch has exceeded the OFL of 11,400 mt. In recent years, the other flatfish fishery has been restricted by PSC limits for Pacific halibut and crab (Spencer *et al.* 2002b, Spencer *et al.* 2002c).

Alaska plaice and other flatfish are taken in directed bottom trawl fisheries in the EBS. The discard rates for the other flatfish fishery are significant, ranging from 11,000-19,000 mt from 1993-2000 (discard rates prior to 1995 also include flathead sole). Percent retention is low, with an average retention rate of 27 percent from 1993-2001. Discard occurs primarily in the yellowfin sole, flathead sole, and rock sole fisheries in 2000 (Spencer *et al.* 2002b, 2002c).

Although large removals of Alaska plaice and other flatfish have occurred in the JV and past domestic fisheries, they are determined not to have had any observable lingering adverse effects on the BSAI Alaska plaice and other flatfish populations.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1954-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the foreign fisheries on the spatial/temporal distribution of the BSAI Alaska plaice and other flatfish populations in the BSAI is unknown. However, these fisheries are determined not to have had any observable lingering adverse effects on the BSAI populations.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of the Alaska plaice and other flatfish assemblage. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1988-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV and past domestic fisheries on the spatial/temporal distribution of the BSAI Alaska plaice and other flatfish populations in the BSAI is unknown. However, these fisheries are determined not to have had any observable lingering adverse effects on the BSAI populations.

Change in Prey Availability

External Foreign Groundfish Fisheries (1954-1976)

The foreign fisheries BSAI are unlikely to have directly impacted prey availability for the other flatfish since these fish eat infaunal invertebrates. The lingering beneficial influence in the BSAI flatfish stock is likely due to the natural events related to climate changes.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of Alaska plaice and other flatfish.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of the other flatfish group.

Internal JV and Domestic Groundfish Fisheries (1988-present)

The JV fisheries in the BSAI are unlikely to have directly impacted prey availability for the other flatfish since these fish eat infaunal invertebrates. The lingering beneficial influence in the BSAI flatfish stock is likely due to the natural events related to climate changes.

Change in Important Habitat

External Foreign Groundfish Fisheries (1954-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the foreign fisheries on habitat suitability is either beneficial or adverse; they are found to have had a lingering influence in the BSAI stock, and the overall lingering effect is beneficial on the BSAI other flatfish assemblage, probably mostly due to climatological effects.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of the other flatfish group.

Internal JV and Domestic Groundfish Fisheries (1988-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the JV fisheries on habitat suitability is either beneficial or adverse; they are found to have had a lingering influence in the BSAI stock, and the overall lingering effect is beneficial in the BSAI other flatfish assemblage, probably mostly due to climatological effects.

BSAI Alaska Plaice and Other Flatfish Comparative Baseline

Trawl survey biomass estimates indicate that the abundance of Alaska plaice increased on the EBS continental shelf from 1975 through 1984. A slight decline in the Alaska plaice biomass occurred between 1984 and 1985 and remained relatively stable until an increase in abundance in 1994 and 1997. The 2002 estimate of 424,971 mt is a 27 percent decrease relative to the 2001 biomass estimate, and is very close to the 2000 biomass estimate. It should be noted that there is uncertainty associated with the area-swept method of trawl surveying. Furthermore, there have been changes in gear over time during which the survey has been conducted (Spencer *et al.* 2002c).

Miscellaneous other species in the other flatfish category have shown relatively stable biomass estimates from trawl surveys from 1983-1995. Biomass estimates increased from 1996-2001 with a substantial increase in the 2002 biomass estimate at 97,938 mt in the EBS. The Aleutian Island region generally shows smaller populations of other flatfish, showing slight increases during each survey year since 1991. (Spencer *et al.* 2002b)

BSAI Alaska Plaice and Other Flatfish Cumulative Effects Analysis Status

The BSAI Alaska plaice and the other flatfish assemblage will be brought forward for cumulative effects analysis.

3.5.1.11 BSAI Pacific Ocean Perch

Life History and Distribution

Pacific ocean perch (*Sebastes alutus)* is primarily a demersal species that inhabits the outer continental shelf and slope regions of the NPO and the Bering Sea from southern California to Japan (Allen and Smith 1988). As adults, they live on or near the seafloor, generally in areas with smooth bottoms (Krieger 1993) and generally at depths ranging from 180-420 m. 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). The maximum recorded age of Pacific ocean perch is 100 years (Frimodt 1995). Table 3.5-22 summarizes biological and reproductive attributes and habitat associations of Pacific ocean perch in the BSAI and GOA.

The Pacific ocean perch were found to be genetically similar throughout their range based on allozyme variation (Seeb and Gunderson 1988); however, preliminary analysis using microsatellite deoxyribonucleic acid (DNA) techniques suggests that genetically distinct populations of Pacific ocean perch exist (A.J. Gharrett personal communication, University of Alaska Fairbanks).

Trophic Interactions

During the summer of 1990, the diets of commercially important groundfish species in the GOA 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 Pacific ocean perch (Brodeur and Percy 1984, Yang 1996).

Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it is likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other demersal fish (NMFS 1997).

BSAI Pacific Ocean Perch Management

Pacific ocean perch is the most commercially important rockfish in Alaska's fisheries and is taken mostly with bottom trawls. Reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, therefore qualifying the stock for management under Tier 3. The projected spawning biomass for 2003 is 135,000 mt, placing it into sub-tier "b" of Tier 3. The recommended ABC value for 2003 is 15,100 mt, apportioned between four areas: BS = 2,410 mt; Area 541 = 3,495 mt; Area 542 = 3,330 mt; Area 543 = 5,835 mt. The OFL value of 17,900 mt has been established for the BSAI in 2003 (Table 3.5-2). Model projections indicate that the Pacific ocean perch stock is neither overfished nor approaching an overfished condition.

Previous to 2001, Pacific ocean perch were assessed separately using a model for the EBS and the Aleutian Island region. Beginning with the 2001 stock assessment, the Pacific ocean perch were assessed as one stock, and a single model for the BSAI was used, incorporating the Aleutian Islands trawl survey and the BSAI-wide catches. Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch data and length and age compositions. Survey data are from the NOAA Fisheries triennial trawl groundfish surveys, and the fishery data comes from the Observer Program. The age-structured population model is used to obtain estimates of recruitment, numbers at age, and catch at age. Natural mortality and individual weight-at-age are estimated independent of the model (Spencer and Ianelli 2001).

BSAI Pacific Ocean Perch Past/Present Effects Analysis

The geographic scope for the Pacific ocean perch past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1960 when the foreign Pacific ocean perch fishery begins and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-23 provides a summary of BSAI Pacific ocean perch past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI Pacific ocean perch:

- Mortality due to catch/bycatch, and marine pollution and oil spills (direct effect).
- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes, and regime shifts (indirect effect).
- Change in prey availability due to commercial whaling, climate changes and regime shifts, marine pollution and oil spills, and introduction of exotic species (indirect effect).
- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, marine pollution and oil spills, and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to Pacific ocean perch. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on the Pacific ocean perch in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to Pacific ocean perch past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1960-1976)
  - Commercial whaling
  - IPHC longline fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1990)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1982-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1960-1976)

The Japanese Pacific ocean perch fishery began in 1960 when a mothership operation began fishing for Pacific ocean perch along the continental slope between the Pribilof Islands and Cape Navarin. This fishery expanded in 1963 to Bowers Banks off the Aleutian Islands. Japanese fleets involved in the yellowfin sole fishery also extended their operations to include Pacific ocean perch in 1961-1962 due to the reduced abundance of yellowfin sole. This fishery lengthened the fishing season from one to between four and nine months and began winter fishing. The main target fish of the foreign fisheries was Pacific ocean perch in the Aleutian Islands region. Japanese trawls for Pacific ocean perch concentrated along the shelf edge in the central and western part of the chain, and the fishery took place mostly in the summer or early fall (NPFMC 2002a).

The Soviet Pacific ocean perch fishery also began in 1960 with 25-30 trawlers along the edge of the continental shelf in the eastern and central Bering Sea. Effort shifted to the Aleutian Islands and GOA by 1963, and the directed EBS effort was completely eliminated. However, bycatch of Pacific ocean perch did occur in Soviet pollock fisheries in subsequent years. Soviet harvests of Pacific ocean perch peaked in 1974 and 1975 at 61,000 and 71,000 mt, respectively. In the following years, fishing effort become more sporadic due to reduced abundance of rockfish. Catches in 1973 and 1974 had been reduced to 3,000 and 800 mt, respectively (NPFMC 2002a).

Overall, foreign fishery harvest of Pacific ocean perch and other rockfish species peaked in 1965 in the Aleutian Islands region at 109,100 mt. 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 have increased in the Aleutian Islands and GOA (NPFMC 2002a).

Past foreign fisheries are found to have overfished the BSAI Pacific ocean perch populations; these effects are lingering at the population-level.

Internal JV and Domestic Groundfish Fisheries (1980-present)

A small JV fishery began in 1980 with catches generally under 1,000 mt annually (except in 1988). This fishery was replaced by the domestic fishery in 1990. Domestic Pacific ocean perch fisheries began in 1982 in the EBS and in 1984 in the Aleutian Islands. The EBS fisheries developed rapidly with over 1,000 mt of catch taken by 1984. The Aleutian Islands domestic fishery did not take over 1,000 mt until 1989. Overall, the BSAI Pacific ocean perch domestic fishery reached its peak removal in 1990 at 18,182 mt and has since declined with catches in recent years. The majority of catches take place in the Aleutian Islands region (Spencer and Ianelli 2002).

Discard rates in the Pacific ocean perch fisheries are relatively low, averaging 24.5 percent discard rate in the Bering Sea and a 16.7 percent discard rate in the Aleutian Islands from 1990-1999.

Pacific ocean perch were managed as a complex in association with northern rockfish, rougheye rockfish, shortraker rockfish, and sharpchin rockfish in two distinct areas in the BSAI from 1979-1990. In 1991, NPFMC enacted new regulations that divided the Pacific ocean perch complex into three subgroups in the EBS and two sub-groups in the Aleutian Islands region; Pacific ocean perch, shortraker/rougheye rockfishes, and sharpchin/northern rockfishes in the EBS and shortraker/rougheye and sharpchin/northern rockfishes in the Aleutian Islands region. These groups were established to protect Pacific ocean perch, shortraker rockfish, and rougheye rockfish from possible overfishing. Each group was assigned an individual TAC. Beginning in 1996, the Pacific ocean perch TAC was further subdivided in the Aleutian Islands region. A portion of the Pacific ocean perch TAC (7.5 percent) is allocated to the CDQ group, as well.

The large removals of Pacific ocean perch that occurred in the JV and past domestic fisheries have had an adverse effect on the BSAI Pacific ocean perch population; these effects are lingering at the population-level.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the foreign fisheries on spatial/temporal distribution of the BSAI Pacific ocean perch populations due to the spatial/temporal concentration of the fishery is unknown. However, any possible effects are not expected to have any lingering adverse effects in the populations. Forty-nine percent of the foreign and JV fisheries Pacific ocean perch harvest from 1977-1988 was between 200 and 299 m. Forty-six percent of the past foreign and JV fisheries Pacific ocean perch catch took place in management area 541 (Figure 1.2-2). In the late 1970s, management area 543 contributed a large share of the catch; however, the proportions of total Pacific ocean perch caught by foreign fisheries that were sampled by the observers were quite low prior to 1984 (Megrey and Wespestad 1990).

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of Pacific ocean perch. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1980-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV and past domestic fisheries on spatial/temporal distribution of the BSAI Pacific ocean perch populations is unknown. However, any possible effects are not expected to have any lingering adverse effects in the populations. Forty-nine percent of the foreign and JV fisheries observed fishing depth was from 200-299 m between 1977 and 1988 and forty-six percent of the past foreign and JV fisheries Pacific ocean perch catch took place in management area 541 (Figure 1.2-2). Sixty-six percent of the observed domestic catch took place between 200-299 between 1990-2000; and forty-two percent of the domestic catch came from management area 541. Area 543 contributed a large share of the catch in the mid-1990s to the present.

Change in Prey Availability

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. Populations of Pacific ocean perch have rebounded from low population-levels. The controlling factor for these increases appears to be environmental, with changes in the species composition in nearshore areas linked to an increase in advection in the Alaska current. Increased flow around the GOA may enhance the supply of nutrients and plankton on the shelf and upper slope areas, resulting in an increase in productivity.

External Commercial Whaling

Whaling is identified as having a past beneficial effect on prey availability for all Pacific ocean perch stocks, since 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). A reduction in baleen whale populations could mean that more euphausiids would be available for use by Pacific ocean perch. Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other demersal fish (NMFS 1997).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of Pacific ocean perch.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effects of the past foreign fisheries on habitat suitability are adverse for the BSAI stock and are found to have had a lingering adverse influence in the stocks. The intense trawling of the foreign, JV and past domestic fisheries is the likely cause of this lingering effect.

External IPHC Longline Fisheries

The impacts of IPHC longline gear on Pacific ocean perch habitat have been identified as adverse effects. Longline fishing is likely to have caused Pacific ocean perch habitat degradation and disruption of Pacific ocean perch spawning and/or rearing grounds. This effect is still lingering at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of Pacific ocean perch.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effects of past JV fisheries on habitat suitability are adverse for the BSAI stock; the effects, in combination with climatic changes, are found to have had a lingering adverse influence in the stock. The intense trawling of the foreign, JV and past domestic fisheries is the likely cause of this lingering effect.

BSAI Pacific Ocean Perch Comparative Baseline

The Aleutian Islands survey covers the Aleutian Islands management area, and a portion of the EBS management area; the entire survey biomass is used as an index of Pacific ocean perch abundance in the BSAI. The EBS slope survey is not used in modeling due to its high variability and relatively small population sizes compared to the Aleutian Islands biomass estimates (Spencer and Ianelli 2002).

Survey biomass estimates in the entire survey area show a steady increase from 1980-1997, followed by a decline to the 2000 and 2002 estimates. The portion of the Aleutian Islands survey that occurs in the EBS has produced variable biomass estimates, from 1,501 mt in 1991 to 18,870 mt in 2000. In the Aleutian Islands region, the biomass estimates are less variable (Spencer and Ianelli 2002).

Surveys produce large amounts of biological data, including age determination, length-weight relationships, sex ratio information, and information for estimating the length distribution of the population. Improved age determination methods have determined the maximum age of Pacific ocean perch to be 90 years (Chilton and Beamish 1982).

Modeling results show that estimated survey biomass declined from 1960 to 1978 and increased to 500,933 mt in 2002. Total biomass results show a similar trend as the survey biomass with a 2002 total biomass estimate of 374,809 mt. Recruitment in the EBS and Aleutian Islands tends to be highly variable, although the 1962 year-class appears to be the largest, more than twice as large as any other estimated recruitment (Spencer and Ianelli 2002).

BSAI Pacific Ocean Perch Cumulative Effects Analysis Status

BSAI Pacific ocean perch will be brought forward for cumulative effects analysis.

3.5.1.12 BSAI Rockfish

Life History and Distribution

Northern Rockfish

Northern rockfish (*Sebastes polyspinis*) inhabit the outer continental shelf from the EBS, throughout the Aleutian Islands and the GOA (Kramer and O'Connell 1988). This species is semidemersal and is usually found in comparatively shallower waters off the outer continental slope (from 50-600 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. Like other members of the genus *Sebastes*, they bear live young, and birth occurs in the early spring through summer (McDermott 1994).

Shortrater/Rougheye Rockfish

Shortraker (*Sebastes borealis*) and rougheye rockfish (*S. aleutianus*) inhabit the outer continental shelf of the NPO from the EBS as far south as southern California (Kramer and O'Connell 1988). Adults of both species are semidemersal and are usually found in deeper waters (from 50 m to 800 m) and over rougher bottoms than Pacific ocean perch (Krieger and Ito 1999). 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. Like other members of the genus *Sebastes*, they are viviparous (bear live young), and birth occurs in the early spring through summer (McDermott 1994).

Both species are associated with a variety of habitats, from soft to rocky bottoms, although boulders and sloping terrain appear also to be desirable habitat (Krieger and Ito 1999). Length at 50 percent sexual maturity is about 45 cm for shortraker rockfish and about 44 cm for rougheye rockfish (McDermott 1994). Shortraker and rougheye rockfish are managed as part of the slope rockfish assemblage in the GOA and as part of the other red rockfish assemblage in the BSAI.

Two genetically distinct populations of rougheye rockfish with partially overlapping geographic ranges were found by Hawkins *et al.* (1997) and Gharrett and Gray (1998), and confirmed with recent mitochondrial and microsatellite analyses (A.J. Gharrett, University of Alaska Fairbanks, personal communication).

Other Rockfish

The ‘other rockfish’ management category includes 28 of the *Sebastes* and *Sebastolobus* species. Of these, only eight have ever been confirmed or tentatively identified in fishery catches in the BSAI, and so these eight species only are managed. The two most abundant species are light dusky rockfish (*Sebastes ciliatus* *sp cf*) and shortspine thornyheads (*Sebastolobus alascanus*). Red banded rockfish (*Sebastes babcocki*), dark dusky rockfish (*Sebastes ciliatus*), redstripe rockfish (*Sebastes proriger*), yelloweye rockfish (*Sebastes ruberrimus*), harlequin rockfish (*Sebastes variegatus*), and sharpchin rockfish (*Sebastes zacentrus*) have been identified by U.S. fishery observers and are also included in this group.

Thornyheads in Alaskan waters are comprised of two species, the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis*). Only the shortspine thornyhead is of commercial importance and it is now one of the most commercially valuable rockfish species. Thornyheads are a demersal species found in deepwater, from 94 m to 1,460 m, from the Bering Sea and GOA to Baja California (Gaichas and Ianelli 2001). Little is known about thornyhead life history. Like other rockfish, they are long-lived and slow-growing. The maximum recorded age is in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 years and 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. The shortspine thornyhead is managed as a single stock in its own management group in the GOA; however, this species and the longspine thornyhead are managed as part of the other rockfish assemblage in the BSAI. Table 3.5-26 summarizes biological and reproductive attributes and habitat associations of thornyhead rockfish in the BSAI and GOA.

Light dusky rockfish are only occasionally observed in surveys and are caught as bycatch in other target fisheries. This species is generally caught between 125-200 m, and largely in the Aleutian Islands region. In recent years, bycatch has been highest near Seguam Pass and Petrel Bank; survey catch has been highest at the western tip of Amchitka Island. Light dusky rockfish are rarely found in the EBS, although some bycatch has occurred along the EBS slope, north of Unalaska Island and Akutan Island, the southern part of the EBS and the southern tip of Zhemchung Canyon in the northern EBS. EBS surveys found light dusky rockfish largely near Unalaska Island and Akutan Island (Reuter and Spencer 2003).

Table 3.5-27 summarizes biological and reproductive attributes and habitat associations for selected rockfish species in the BSAI and GOA.

Trophic Interactions

Northern Rockfish

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.

Shortraker/Rougheye Rockfish

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; however, 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).

Other Rockfish

Yang (1993 and 1996) and Yang and Nelson (2000) showed that shrimp, mainly pandalids, were the most important food of the thornyhead. Tanner crabs comprised less than 7 percent by weight of stomach contents, and fish such as pollock, capelin, and sculpins comprised about 15 percent. Other prey items for thornyheads included polychaetes, mysids, amphipods, and other crabs. California sea lion (Lowry *et al.* 1990) and sablefish (Orlov 1997) have both been documented as predators of shortspine thornyhead.

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.

The diet of the other rockfish species (BSAI) for which dietary information exists seems to consist primarily of planktonic invertebrates (Yang 1993 and 1996). Predators of other rockfish are also not well documented, but likely include larger fish, such as Pacific halibut, which are known to prey on other rockfish species.

Management of Rockfish

Northern Rockfish

In 2003, northern rockfish were split out from the BSAI other red rockfish group, which originally included northern, rougheye, and shortraker rockfish. Northern rockfish is now managed under Tier 3 of Amendment 56 to the BSAI groundfish management plan. The projected spawning biomass for 2003 is 43,700 mt, which is greater than the $B_{40\%}$ value, placing it into subtier "a". The recommended ABC value for 2004 is 6,800 mt, apportioned between two areas: EBS = 19 mt and the Aleutian Islands = 6,861 mt. The OFL value of 8,140 mt has been established for the BSAI for 2004 (Table 3.5-2). Model projections indicate that the northern rockfish stock is neither overfished nor approaching an overfished condition (Spencer and Ianelli 2003).

Shortraker/Rougheye Rockfish

Shortraker/rougheye rockfish are now managed as their own group and are managed under Tier 5 of Amendment 56 to the BSAI groundfish management plan, relying on survey biomass estimates for information on population size and to determine ABC and OFL values. ABC values for the BSAI were calculated by $0.75\ M = F_{ABC}$. It is not possible to determine whether these species are overfished or approaching an overfished condition because they are managed under Tier 5.

It has been recommended that shortraker and rougheye be assigned separate TACs in future evaluations to prevent overfishing of one of the species. However, due to poor identification of shortraker and rougheye as separate species, the SSC was unable to establish separate TACs. Although shortraker/rougheye will remain as a single TAC for 2003, changes have been implemented in the Observer Program to improve species identifications and implement separate TACs beginning in 2004 (Spencer and Reuter 2003).

Though shortraker and rougheye rockfish are highly valued, amounts available to the commercial fisheries are limited by relatively small TAC and ABC amounts, which are to support bycatch needs in other groundfish fisheries. As a result, the directed fishery for these species is typically closed at the beginning of the fishing year. The primary methods of harvest for shortraker and rougheye rockfishes are bottom trawls and longline gear. The bulk of the commercial harvest usually occurs at depths between 200 m and 500 m along the upper continental slope.

Other Rockfish

None of the species in the other rockfish assemblage are subject of a directed fishery, but are mainly caught as bycatch in the other BSAI target fisheries. Two species are predominant in both the catch and survey data: light dusky rockfish and shortspine thornyheads. In 2002, sharpchin rockfish were removed from the other red rockfish assemblage to the other rockfish assemblage in the BSAI. Currently, the other species complex is assumed to be two separate stocks in the EBS and Aleutian Islands regions and is assessed as such.

The other rockfish assemblage falls under Tier 5 of Amendment 56 of the BSAI groundfish FMP, relying on biomass estimates to determine ABC and OFL values. ABC is calculated by multiplying 0.75 M by the best estimate of complex-wide biomass. This equates to a 2003 ABC value of 960 mt in the EBS and 634 mt in the Aleutian Islands (Table 3.5-2). The OFL value is determined by setting F_{OFL} = M, equating to a 2003 OFL value of 1,280 mt in EBS and 846 mt in the Aleutian Islands (Reuter and Spencer 2002).

Reuter and Spencer (2002) recommended in the BSAI SAFE that light dusky rockfish be split out of the other rockfish group and assigned a separate ABC due to findings that indicate that light dusky rockfish make up a large amount of the other rockfish catch in the Aleutian Islands and may be disproportionally exploited. Furthermore, Reuter and Spencer (2002) have recommended that EBS and Aleutian Islands biomass estimate for light dusky rockfish be combined for the BSAI. This recommendation comes in light of new catch and survey distribution maps which show continuous spatial distribution of light dusky rockfish along the Aleutian Islands and EBS slope.

Rockfish Past/Present Effects Analysis

This past/present effects analysis discusses northern, shortraker/rougheye and other rockfish groups managed within the BSAI. These species have been discussed together since they have only recently been broken out for management reasons. Refer to Table 3.5-24 for a list of the rockfish occurring in the BSAI and GOA and their associated management groups.

The geographic scope for the BSAI rockfish past/present effects analysis is the same as the BSAI management areas (Figure 1.2-2). The temporal scope for this analysis begins in 1960 when the foreign rockfish fisheries began and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-25 provides a summary of BSAI rockfish past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on BSAI rockfish:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to commercial whaling, climate changes and regime shifts, marine pollution and oil spills and introduction to exotic species (indirect effect).

- Change in important habitat due to climate changes and regime shifts, fishery gear impacts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explains any management actions specific to rockfish. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on other rockfish in the BSAI have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the BSAI as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to rockfish past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1960-1976)
  - IPHC longline fisheries
  - State of Alaska shrimp fisheries
  - Commercial whaling
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1986-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

External Foreign Groundfish Fisheries (1960-1976)

Foreign fisheries for rockfish began in 1960, with the Soviet and Japanese fisheries. These fisheries are the same as were targeting Pacific ocean perch. See Section 3.5.1.11 for more information.

Large removals of rockfish have occurred in the foreign fisheries, although the proportion of removals per species is unavailable due to poor species identification. These removals are identified as having had an adverse effect on the rockfish populations. Moreover, due to the longevity of these species, these fisheries are determined to have had a lingering influence on the these BSAI populations.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The JV fisheries began targeting rockfish in 1980 and were phased-out of the BSAI by 1990 when the fishery became fully domesticated. The domestic rockfish fisheries began in 1986. Removals of rockfish by the JV and past domestic fisheries are determined to have had an adverse effect on the rockfish population, although data regarding the proportion of removals per species is unavailable due to poor species identification. Moreover, due to the longevity of these species, these fisheries are determined to have had a lingering influence on these BSAI rockfish populations.

Northern, Shortraker and Rougheye Rockfish

Catches of rockfish from the EBS and Aleutian Islands are dominated by northern rockfish and shortraker rockfish. The largest catches in the northern rockfish times series have occurred since 1993. Catches of shortraker and rougheye rockfish appear low in the mid-1980s, when the foreign fishery was reduced; however, catches of shortraker rockfish have been relatively high since 1995 (Spencer and Reuter 2002).

Other red rockfish were managed as part of the Pacific ocean perch complex from 1979-1990. In 1991, Pacific ocean perch were separated into two management subgroups; the Pacific ocean perch and the other red rockfish group in the EBS, and into the Pacific ocean perch, shortraker/rougheye rockfishes and sharpchin/northern rockfishes group in the Aleutian Islands region. In 2000, the EBS other red rockfish group was furthered divided into the rougheye/shortraker and sharpchin/northern rockfish groups, as was done in the Aleutian Islands region. Each group was assigned a separate TAC to protect these species from overfishing. In 2002, sharpchin rockfish were removed from the other red rockfish assemblage to the other rockfish assemblage in the BSAI. Finally, in 2003, northern rockfish and shortraker/rougheye rockfish were separated and are now managed as their own group with separate TACs; the other red rockfish assemblage no longer exists.

There are concerns that assigning a TAC for two or more species may allow one of those species to be overfished while still remaining under the group TAC. Separate TACs for each individual species were recommended in the 2002 BSAI SAFE report; however, efforts to establish these levels were hindered by limited observer identification of shortraker and rougheye species (Spencer and Reuter 2001).

Other Rockfish

Prior to 1979, the other rockfish category included northern, rougheye, and shortraker rockfish. Catches prior to 1990 are assumed to include discards, whereas catches from 1999-2000 explicitly account for discards based on Observer Program information. The peak catch of other rockfish occurred in the EBS in 1978 with a removal of 941 mt, and in the Aleutian Islands region, the peak occurred in 1982 with a harvest of 2,114 mt. The bulk of the catch comprises shortspine thornyheads in the EBS and light dusky rockfish in the Aleutian Islands, according to Observer Program data (Spencer and Reuter 2002).

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960-1976)

Spatial/Temporal Concentration of Catch/Bycatch

Effects of the foreign fisheries on spatial/temporal distribution of the BSAI rockfish populations due to the spatial/temporal concentration are identified as either adverse or unknown. When the past effect of the fishery is unknown, it is also unknown whether the effect could be lingering.

External Climate Changes and Regimes Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as a potentially beneficial or adverse on the reproductive success of other rockfish. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Change in Prey Availability

External State of Alaska Shrimp Fisheries

Effects of State of Alaska shrimp fisheries on the prey availability of BSAI rockfish are potentially adverse, however, due to the localized nature of these fisheries, they are unlikely to have a population-level effect.

External Commercial Whaling

The effects of commercial whaling increased the availability of euphausiid prey for northern rockfish and some of the other rockfish species and is therefore noted as a potential beneficial effect.

External Climate Changes and Regimes Shifts

The effects of climate changes and regime shifts are identified as a potentially beneficial or adverse influence on prey availability depending on the frame of reference. Lingering population effects are identified in the these stocks for this category. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important prey species of rockfish.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960-1976)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The impacts of foreign groundfish fishery gear on rockfish and habitat have been identified as adverse effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

External IPHC Longline Fishery

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The impacts of IPHC longline gear on rockfish habitat have been identified as adverse effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

External Climate Changes and Regimes Shifts

The effects of climate changes and regime shifts are identified as a potentially beneficial or adverse influence on habitat suitability depending on the frame of reference. Lingering population effects are identified in the stocks for this category. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the BSAI and what effect these have on the important habitat of rockfish.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.1 (BSAI walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The impacts of JV and domestic groundfish fishery gear on rockfish habitat have been identified as adverse effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

Rockfish Comparative Baseline

Data for determining exploitable biomass estimates come from a number of surveys, including the U.S.-Japan cooperative survey in the EBS on the continental shelf and slope from 1979-1985, and from 1980-1986 in the Aleutian Islands, and domestic trawl surveys in the EBS slope in 1988 and 1991 and in the Aleutian Islands region in 1991, 1994, 1997, 2000, and 2002. In the Aleutian Islands, the exploitable biomass estimate is the average of the most recent surveys; in the 2002 stock assessment those are the 1991, 1994, 1997, 2000, and 2002 Aleutian Islands surveys. The EBS is divided into two areas when determining the biomass of the other red rockfish category. These two areas are: the shelf/slope area and the area that is labeled the Aleutian Islands portion of the EBS, whose 2002 biomass is determined by averaging the three most recent Aleutian Islands surveys.

Surveys from 1991-2002 indicate that the majority of northern rockfish biomass is found in the western Aleutian Islands (72%). Survey biomass estimates show a steady trend in northern rockfish biomass from 1977 at 131,684 mt to 161,984 mt in 1992. The 2003 survey estimate is 137,564 mt. Modeling results estimate total and spawning biomass for 2003 at 143,604 mt and 46,390 mt, respectively (Spencer and Ianelli 2003).

Surveys estimates indicate that rougheye rockfish biomass has declined since the 1980s from approximately 26,277 mt (1980) to 10,379 mt in 2004. Shortraker rockfish biomass estimates have also indicate a decline from the 1980 value of 38,299 mt to 23,379 mt in 2004. Modeling results estimate rougheye rockfish biomass to be 1,503 mt in the EBS and 11,480 mt in the Aleutian Islands for 2004. Shortraker rockfish biomass is estimated at 6,535 mt in the EBS and 27,317 mt in Aleutian Islands for 2004 (Spencer and Reuter 2003).

The recent surveys indicate that shortspine thornyhead, light dusky rockfish, and harlequin rockfish comprise most of the total other rockfish estimated biomass, approximately 90 percent of which is shortspine thornyheads. The discrepancy between the amount of light dusky rockfish catch in the fishery and the light dusky rockfish catch in the survey is attributed to the unequal survey sampling of differing depth zones. For instance, the majority of the light dusky rockfish fishery catch is at depths less than 200 m, whereas the trawl survey targets waters deeper than 200 m. Based on the best available information, the estimated 2003 exploitable biomass for other rockfish is 6,884 mt in the EBS and 12,087 mt in the Aleutian Islands (Reuter and Spencer 2002).

Gulf of Alaska Target Groundfish Species

This section presents descriptions of major target species, summarizing important life history traits, their habitat environment, prey base, past effects, stock management, stock assessment, and current trends of the stocks. Additional information on life history and habitat features for each major groundfish species can be found in the following three documents 1) EA of the EFH (NPFMC 1998a), 2) EFH assessment report for the groundfish resources of the BSAI region (NPFMC 1998b), and 3) EFH assessment report for the groundfish resources of the GOA region (NPFMC 1998c).

Rockfish Cumulative Effects Analysis Status

BSAI northern rockfish, shortraker/rougheye rockfish, and other rockfish will be brought forward separately for cumulative effects analysis.

3.5.1.13 GOA Walleye Pollock

Life History and Distribution

Walleye pollock is the second most abundant groundfish stock, after arrowtooth flounder, in the GOA. In the GOA, the largest spawning concentrations occur in Shelikof Strait and the Shumagin Islands (Kendall *et al.* 1996). Life history of the GOA pollock is similar to those that inhabit the BSAI (refer to Section 3.1.1.1). Olsen *et al.* (2002) found two major spawning areas in the GOA, one occurring in the Shumagin Island area between February 15 and March 1 and the other occurring in the Shelikof Strait between March 15 and April 1.

Trophic Interactions

Larvae, 5 to 20 millimeters (mm) in length, consume larval and juvenile copepods and copepod eggs (Canino 1994, Kendall *et al.* 1987). Early juveniles (25 to 100 mm) of pollock in the GOA primarily eat juvenile and adult copepods, larvaceans, and euphausiids; late juveniles (100 to 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 include as many copepods (Yang 1993). Euphausiids are the dominant prey, constituting a relatively constant proportion of the diet by weight across pollock size groups.

In the GOA, fish prey becomes an increasing fraction of the pollock diet with increasing pollock size. Over 20 different fish species 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, Pacific halibut, and Greenland turbot. Forage fish such as capelin, eulachon, and Pacific sand lance were also found in pollock stomach contents. However, over the period 1993-1996, Yang and Nelson (2000) found that consumption of capelin declined to non-existent as did the consumption of pandalid shrimp. It appears that because of declining pandalid shrimp and capelin populations, pollock in the GOA consumed more euphausiids and copepods in 1996 as compared to 1993.

Dominant groundfish populations 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 predators of pollock include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993) (Figure 3.5-3). As in the EBS, Pacific halibut and Pacific cod tend to consume larger pollock, while arrowtooth flounder consume pollock that are mostly under age 3 years. Unlike the EBS, however, the main source of predation mortality on pollock at present appears to be from the arrowtooth flounder (Livingston 1994a and 1994b). Stock assessment scientists 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 has recently 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, and 1981) (see Sections 3.7 and 3.8). Brodeur and Wilson's review (1996) summarized both bird and mammal predation on juvenile pollock. The main piscivorus birds that consume pollock in the GOA are black-legged kittiwakes, common murres, thick-billed murres, tufted puffins, horned puffins, and probably marbled murrelets. The diets of common murres have been shown to contain around 5 percent to 15 percent age-0 pollock by weight, depending on the season. Both horned puffins and tufted puffins consume age-0 pollock. The tufted puffin diet is more diverse and tends to contain more pollock than that of the horned puffin (Hatch and Sanger 1992).

Pollock is a major prey of Steller sea lions and harbor seals in the GOA (Merrick and Calkins 1996; Pitcher 1980a, 1980b, and 1981). 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 to 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. Harbor seals tend to have a more diverse diet, and the occurrence of pollock in their diet is lower than in the diet of sea lions.

GOA Pollock Management

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). Separation of GOA pollock from the BSAI pollock stocks is supported by analysis of larval drift patterns from spawning locations and microsatellite allele variability (Bailey *et al.* 1997), genetic studies (Grant and Utter 1980), and mitochondrial DNA variability (Mulligan *et al.* 1992, Dorn *et al.* 2001).

Studies conducted by Olsen *et al.* (2002) indicate that there may be two genetically distinct pollock stocks in the GOA: the northern GOA stock that includes PWS and Middleton Island, and the Shelikof Strait stock. Large interannual genetic variations in the PWS stock between 1997 and 1998 were found; however, Olsen *et al.* (2002) suggest that this variation may be caused by variable reproductive success, adult philopatry, source-sink population structure, or utilization of the same spawning areas by genetically distinct stocks with different spawning times (as referenced in Dorn *et al.* 2002).

Under current management, the general impacts of fishing mortality within Amendment 56/56 ABC and OFL definitions discussed in Appendix B, apply to pollock in the GOA (Table 3.5-28). GOA pollock are managed under Tier 3b of the ABC/OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$ and fishing mortality rates $F_{30\%}$ and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawning stock biomass per recruit to 35 percent of its unfished level (the $F_{35\%}$ rate). In the GOA region west of 140°W, the 2003 ABC value of 49,590 mt is recommended, with an OFL of 69,410 mt. This year's ABC value was 35 percent lower than the 2002 ABC, partly due to a reported decrease in the female spawning biomass. In the western, central, and west Yakutat areas, the ABC value has been reduced by 1,720 mt to accommodate the Prince William Sound state pollock fishery (see the past/present effects analysis section for a description of the state pollock fishery). The west Yakutat area receives a 1,078 mt allocation, leaving 46,812 mt ABC for the western and central areas. In the east Yakutat and SEO areas, the 2003 ABC and OFL values are the same as the 2002 ABC and OFL values of 6,460 and 8,610 mt, respectively, due to the lack of new survey data. In southeast Alaska (Area 650), a ban on trawling prevents directed harvest of pollock (Figure 1.2-3; Table 3.5-28).

GOA pollock are 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 compositions. 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 because much of the GOA shelf is untrawlable due to the rough bottom. Fishery catch statistics (including discards) are estimated by the NOAA Fisheries, Alaska Regional Office. These estimates are based on the best blend of observer reported catch and weekly production reports. Age composition data are obtained from several sources, including catch-at-age aggregated over all seasons, nations, vessel classes, and INPFC statistical areas for the years, and catch-at-age from the spring EIT survey and the bottom trawl surveys. Historical information on pollock size composition was 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).

Past/Present Effects Analysis

The geographic scope for the GOA pollock past/present effects analysis is the same as the GOA FMP management areas (Figure 1.2-3). The temporal scope for this analysis begins in 1964 when the GOA foreign groundfish fishery begins and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4. Table 3.5-29 provides a summary of the GOA pollock past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA pollock:

- Mortality due to catch/bycatch and the EVOS (direct effect).
- Change in reproductive success due to removal of predators, fishery selectivity of juveniles, roe stripping, spatial/temporal concentration of catch/bycatch, and climate changes and regime shifts (indirect effect).
- Change in prey availability due to fishery catch/bycatch of prey species, introduction of exotic species, the EVOS, and climate changes and regime shifts (indirect effect).
- Change in important habitat due to fishery gear impacts, the EVOS, introduction of exotic species, and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution was not brought forward for analysis. The NOAA NS&T program has produced a summary of Alaska marine environmental quality through its research and sampling projects, including the Mussel Watch Project and the Benthic Surveillance Project. This report is available on the NOAA website at: http://ccmaserver.nos.noaa.gov/NSandT/BrochurePDFs/Alaska.pdf. Furthermore, international, federal and state laws and enforcement agencies are in place to monitor marine pollution.

Change in prey availability and in important habitat due the introduction of exotic species by way of ballast water and climate changes and regime shifts has not been brought forward since the impacts on pollock in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998) Also, see Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA.

The past/present events determined to be applicable to the pollock past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1964-1976)
  - State of Alaska shrimp fisheries
  - State of Alaska crab fisheries
  - State of Alaska groundfish fisheries
  - IPHC halibut fishery
  - Commercial whaling

  - Seal harvests
  - EVOS
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1979-1991)
  - Domestic groundfish fisheries (1976-present)

- Past/Present Management Actions
  - Bilateral agreements
  - IWC management
  - MMPA of 1972
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - Steller sea lion protection measures
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1964-1976)

Pollock began being targeted in 1964 by the foreign groundfish fisheries, predominately by Japan, the Soviet Union and the Republic of Korea. Most of these foreign groundfish fisheries had started in the GOA targeting Pacific ocean perch and switched to other target species during the late 1960s and early 1970s when Pacific ocean perch was reduced in abundance (NPFMC 2002b).

The Soviet fishing vessels first began in the GOA in 1962 and principally targeted Pacific ocean perch. Following decline of the Pacific ocean perch stock, the Soviet fisheries shifted to pollock, Atka mackerel, and flounders. All fishing by the Soviet fisheries in the GOA has been done by trawls (NPFMC 2002b).

The Japanese fishery began exploratory fishing in 1960, although their full-scale groundfish fishery in the GOA did not start until 1963, possibly precipitated by the start of the Soviet fishery. Like the Soviets, the Japanese targeted Pacific ocean perch and did not focus on other targets, including pollock, Pacific cod, and flounder, until the decline of Pacific ocean perch (NPFMC 2002b).

The Republic of Korea fishery began fishing in the GOA in 1972 and targeted pollock, Pacific cod, flounder, sablefish and Atka mackerel. By 1978, the Republic of Korea relied almost exclusively on trawl gear with pollock being the primary target species. As a result of the expansion of the domestic groundfish fisheries, the Republic of Korea has not received a directed fishing allocation in the GOA since 1985 (NPFMC 2002b).

Smaller scale foreign groundfish fisheries, including Poland, Taiwan, and Mexico, have also been conducted in the GOA. Poland arrived in 1973 and began targeting pollock in 1977. From 1978 to 1981, harvest averaged 39,900 mt per year. Poland has not received a directed fishing allocation since 1985. Taiwan began fishing in the GOA in 1975, but Taiwanese vessels were apprehended for violating the U.S. contiguous fishing zone soon thereafter. By 1977, Taiwan had discontinued fishing within the GOA. Mexico harvested about 10,400 mt of groundfish from the GOA in 1979, of which pollock made up 84 percent (NPFMC 2002b).

In 1973, a bilateral agreement between the U.S. and Japan and the U.S. and the Soviet Union included annual catch quotas, which reduced the catch of pollock in the GOA. However, each country was still responsible for monitoring its catch quotas, the only internationally acceptable arrangement at the time. With the passing of the MSA and the increase of U.S. and JV fisheries, foreign groundfish catch in the GOA was further reduced (NPFMC 2002b).

Although large removals of pollock occurred during the foreign fisheries, there appears to be no lingering effect on the GOA pollock populations.

<u>External State of Alaska Groundfish Fisheries</u>

The directed state pollock fishery began in 1995 and is located in PWS. This fishery is broken into three management sections by ADF&G. These sections are the Port Bainbridge Section (waters west of 148°W), the Knight Island Section (waters between 148°W and 147°20'W) and the Hinchinbrook Section (waters east of 147°20'W). Forty percent of the Guideline Harvest Level (GHL) for the year is allocated to each management area. The GHL is accounted for by the federal ABC limits and is allocated to these state fisheries starting at 1,420 mt in 2000 and increasing to 1,720 mt in 2001 and 2002. The fishery is managed to allow closures due to bycatch, exceeding the GHL, or due to emergency orders to protect Steller sea lions. Furthermore, the fisheries are subject to federal observer coverage and are required to maintain a federal logbook and bycatch data. The state fisheries are also subject to IR/IU (5 Alaska Administrative Code [AAC] 29.079 & 5 AAC 28.075), requiring that all pollock be retained during an open directed pollock fishery and up to the maximum retainable bycatch limits when the directed pollock fishery is closed (ADF&G 2002b).

The Cook Inlet Area pollock fishery is a bycatch only fishery, although opportunities are available for directed pollock fisheries through permitting. These directed fisheries are constrained by the same requirements as the PWS directed pollock fisheries (ADF&G 2002a).

<u>External State of Alaska Crab and Shrimp Fisheries and the IPHC Halibut Fisheries</u>

The GOA bait fishery arose due to the need for bait in the crab and halibut fisheries. The bait fishery occurred from PWS west to the Aleutians, with two-thirds of the catch occurring in Kodiak. The catch consisted largely of pollock, Pacific cod, and various flounder species. Groundfish for bait was taken primarily as bycatch in the Kodiak shrimp fishery during the early to mid-1970s. The bait fishery was later characterized by trawlers and longline vessels which targeted groundfish species. Prior to 1972, unrecorded catch of bait may have equaled or exceeded the recorded groundfish catch since bait was transferred to crab and halibut vessels on the fishing grounds. From 1972 to 1976, the catch of groundfish for bait increased from 96 mt to 303 mt. Catches continued to increase through the late 1970s and by 1982 accounted for 1,059 mt. (NPFMC 2002b). In 1983, GOA FMP Amendment 11 eliminated the bait and personal consumption component of the domestic groundfish fishery. Although past bycatch of pollock has occurred in the shrimp fishery, it does not appear to have had a lingering effect on the GOA pollock populations .

External Exxon Valdez Oil Spill

The number of pollock that suffered direct mortality as a result of the EVOS is unknown, but such mortality has not resulted in population-level effects on GOA pollock.

Internal JV and Domestic Groundfish Fisheries (1976-present)

The domestic pollock fishery began in the GOA in 1976 when a fleet of three trawlers from Petersburg, Alaska trawled for pollock during the winter months. Approximately 60 mt of pollock were landed to shoreside processors. During winter, the fishing effort is targeted primarily on pre-spawning aggregations in the Shelikof Strait and near the Shumagin Islands. Fishing in the summer is more variable, but typically occurs on the east side of Kodiak Island and near-shore waters along the Alaska Peninsula. Kodiak, Sand Point, and Dutch Harbor are all major ports for the GOA pollock fishery, with 53 percent of the 1995-2000 landings occurring in Kodiak. The pollock fishery in the GOA was fully domestic by 1988 (NPFMC 2002b).

The development of JV groundfish fisheries occurred rapidly since their beginning in 1979. GOA FMP Amendment 6 regulations adjusted the DAH and the foreign fishery allocations to reflect the best information available from the observers and domestic processors and to allow for a fully utilized groundfish fishery in the GOA. Pollock became the principle target species of the JV groundfish fisheries in 1980, comprising 99 percent of the total catch. In 1980, GOA Amendment 8 modified the timing of reserve releases to allow for increased catches by domestic groundfish fisheries. However, further FMP amendments were needed to make changes in allocations of fish to domestic groundfish and JV groundfish fishermen, and flexibility was needed for the NOAA Fisheries Regional Administrator to reapportion reserves and domestic allocations to foreign groundfish fishermen if it were projected that domestic groundfish fishermen could not harvest them. The Regional Administrator also needed flexibility to impose on foreign groundfish fisheries such closures for conservation reasons as were in place for domestic groundfish fisheries (NPFMC 2002b).

In response, GOA FMP Amendment 11 in 1983: 1) increased the pollock OY in the central GOA from 95,200 to 143,000 mt, 2) established a framework procedure to annually determine domestic groundfish and JV groundfish processing components of the DAH for each species OY, 3) eliminated the bait and personal consumption component of the DAH, 4) increased the flexibility of the Regional Administrator to reapportion reserves and surplus DAH to foreign groundfish fishing, 5) authorized the Regional Administrator to impose time/area closures on foreign nations to conserve resources, and 6) imposed radio/telephone catch reporting requirements on domestic groundfish vessels leaving state waters to land fish outside Alaska beginning in 1983, thus ensuring that all catches were reported.

In 1984, GOA FMP Amendment 13 combined the western and central GOA pollock OYs into a single OY and increased it from 200,000 to 400,000 mt. It was intended to provide optimum harvest of the pollock resource, to allow the pollock resource in the western and central GOA to be managed as one stock, and to prevent undue restriction and economic hardship on the domestic groundfish fishery, by allowing both the harvest of the increased surplus and the distribution of fishing effort to be based on pollock availability.

In 1985, GOA FMP Amendment 14 modified the management of a number of target species. Under this amendment, OYs were changed for pollock, Pacific ocean perch, other rockfish, Atka mackerel, and other species. A mechanism was also established for timely reporting of catches by domestic groundfish catcher processors that stayed at sea for long periods, and NOAA Fisheries habitat policy was implemented.

The 1992 inshore/offshore amendment (GOA FMP Amendment 23) required that 100 percent of the pollock catch be processed at shoreside plants, completing the phase-out of foreign groundfish and JV fisheries in the GOA. This amendment also moved the fishery from bottom to pelagic trawls to avoid bycatch of prohibited species (i.e., halibut) and closed the factory trawling fisheries of the GOA.

Although large removals have occurred in the JV and domestic fisheries, these fisheries have not had a lingering effect on the GOA pollock population.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1964-1976)

Bycatch in the foreign groundfish fisheries has not been well documented; however, it is assumed that bycatch of pollock consisted mainly of juveniles. Few observers were allowed on Soviet vessels under the bilateral agreements, and the Soviets were well-known for under-reporting their catches of target species and, presumably, bycatch as well.

Foreign groundfish fisheries in the GOA also tended to target younger pollock, with a maximization selection of 5 to 6 years versus the current domestic groundfish fishery which selects fish age-7 to -8 years (Dorn *et al.* 2001).

The effect of the foreign fisheries GOA pollock recruitment due to the foreign fisheries selectivity and bycatch of juvenile pollock is unknown.

External Climate Changes and Regime Shifts

Recruitment of GOA pollock is more variable than EBS pollock. Evidence suggests that spawner productivity is higher at low spawning biomass compared to high spawning biomass. The density-dependence of the survival of eggs corresponds with decadal trends in spawner productivity and have produced a pattern in the GOA pollock population (Dorn *et al.* 2002). Environmental conditions have likely influenced spawner biomass, thus influencing GOA pollock recruitment.

FOCI is used by the SSC to make predictions on the strength of year-classes. These predictions are based on precipitation, wind mixing energy, advection of ocean water, pollock larvae counts, and pollock abundance estimates. Precipitation, wind-mixing and advection are all important factors in the survival and success of pollock larvae.

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of pollock. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an in depth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries.

Internal JV and Domestic Groundfish Fisheries (1976-present)

Fishery Selectivity

GOA pollock are caught as bycatch in other directed fisheries. However, because they occur primarily in well-defined aggregations, the impact of this bycatch is typically minimal. Most of the discards in the pollock fishery are juvenile pollock, or pollock too large to fit filleting machines. In the pelagic trawl fishery the catch is almost exclusively pollock; however in the past bottom trawl pollock fishery the bycatch of other species was higher.

To improve reporting of catch and bycatch, reporting requirements were established for the domestic groundfish fisheries under GOA FMP Amendment 7 in 1979. This amendment created the first domestic groundfish reporting requirements to facilitate better estimates of DAH and processing capabilities, along with other management actions. It also initiated area closures to the JV groundfish fisheries to encourage the growth of the domestic groundfish fishery. GOA FMP Amendment 18 established the domestic Observer Program, designed to estimate bycatch and discard rates, among other things. Additional GOA FMP amendments addressing data collection needs (Amendments 11, 14, 15, 16, 17, 18, 30, and 47) were subsequently approved.

GOA FMP Amendment 49 initiated the IR/IU program to reduce discards of all groundfish target fisheries. This amendment required vessels fishing for groundfish in the GOA to retain all pollock beginning January 1, 1998.

Selectivity in the GOA pollock fishery has changed as the fishery has evolved from a foreign groundfish fishery occurring along the shelf break to a domestic groundfish fishery on spawning aggregations and in nearshore waters. Since 1992, GOA pollock have been managed with time and area restrictions, and selectivity has been fairly stable. As in the BSAI, fishery selectivity increases to a maximum around age 7-8 and then declines.

Like the BSAI, cumulative impacts of fishing mortality on age composition are influenced by the selectivity of the fishery. The current age composition of the stock reflects a fished population with a long catch history under low exploitation rates. The NOAA Fisheries FOCI and Coastal Ocean Programs' SEBSCC regional study focuses research on improving understanding of mechanisms underlying annual production of pollock stocks in the GOA and EBS.

Roe Stripping

Large spawning aggregations of pollock were discovered in the Shelikof Strait in 1981, which initiated the development of the GOA pollock roe fishery (Megrey 1989). By 1990, the growth of the domestic pollock fishery had created competition for the pollock TAC. GOA FMP Amendment 19 was implemented in 1991 to address the following roe stripping issues:

- Roe stripping is a wasteful use of the pollock resource.

- Roe stripping causes an unintended allocation of pollock TAC among seasons and industry sectors.

- Roe stripping may adversely affect the ecosystem.

- Roe stripping may adversely affect the future productivity of the stock.

- Roe stripping increases the difficulty of accurately monitoring the pollock TAC for inseason management.

In 1993, regulations were further tightened to close loopholes that could have potentially undermined the intent of the roe stripping regulations (58 FR 57752).

Spatial/Temporal Concentration of Catch/Bycatch

GOA pollock tend to concentrate along the shelf break at intermediate depths of about 150-200 m and pollock fisheries generally occur from 100-200 m (Hollowed *et al.* 1997). Fisheries concentrate on large concentrations of pollock in the central and western GOA management areas (147°W-170°W), mainly in Shelikof Strait, the trough or gully regions of the east side of Kodiak Island, and Shumagin area. Studies show that the GOA pollock, unlike the BSAI pollock, do not show strong seasonal differences in distribution. Spatial patterns remained consistent from 1984-1996, and shifts in the spatial distribution of pollock reflect the seasonal migrations to spawning locations. In general, the fishery for pollock in the GOA has remained fairly constant in time and space, if not in the amount of biomass removed. Therefore, it is suggested that recent levels of fishing in the GOA may not have had a strong impact on these distributions (Meuter and Norcross 2002).

Management of the pollock fishery has changed recently as NOAA Fisheries and NPFMC have taken measures to reduce the possibility of competitive interactions with Steller sea lions. In 1999, this led to further closures of critical habitat to pollock fisheries in the Aleutian Islands region, the EBS, and the GOA. A total of 210,350 km^2 (54 percent) of critical habitat was closed to the pollock fishery. Following 1998, catches of pollock and the proportion of seasonal TAC caught in the Steller Sea Lion Conservation Area and Steller Sea Lion critical habitat have been reduced (Ianelli *et al.* 2001b).

External Commercial Whaling and Seal Harvests

Whaling is identified as having a past beneficial effect on GOA pollock recruitment. Pollock has been noted as a prey item for fin whales, minke whales, and humpback whales (see Sections 3.8.12, 3.8.14 and 3.8.15). By removing the large predators, pollock recruitment is favored. Whale and seal harvests are no longer of concern. Subsistence and personal use of marine mammals is at such a small scale that it is unlikely to have a population-level effect on the GOA pollock stock.

Change in Prey Availability

External Foreign Pacific Ocean Perch and Pollock Fisheries (1964-1976) and Internal JV and Domestic Pacific Ocean Perch and Pollock Fisheries (1976-present)

Research by Somerton (1979) and Alton *et al.* (1987) has explored the possibility that the rise of pollock in the GOA in the early 1970s was in response to the large biomass removals of Pacific ocean perch, a potential predator for euphausiid prey (Dorn *et al.* 2001). The foreign fishery for Pacific ocean perch started in the GOA in 1962 and peaked in 1966. By 1985, only sufficient quantities for bycatch purposes were allocated by NPFMC. A series of GOA FMP amendments (10, 32, and 38) closed Pacific ocean perch areas to the fisheries and laid out a rebuilding plan.

External Exxon Valdez Oil Spill

The effects of pollution have been found to have reduced pollock prey availability, although it is unlikely that pollution has had a population-level effect on the GOA pollock stocks.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the prey availability of pollock. In general, a shift toward warmer waters favors recruitment and survival of pollock. In 1998/1999, the Pacific Decadal Oscillation shifted to negative, with cooler-than-average northeastern Pacific surface temperature, and warmer-than-average central Pacific surface temperatures.

Changes in Important Habitat

External Foreign Groundfish Fisheries (1964-1976)

Information of the number of trawls that occurred during the pre-MSA GOA foreign fisheries is unavailable. The effects of fishery gear on pollock habitat is potentially adverse, although if so, this does not appear to have had a lingering adverse effect on the GOA pollock populations. See Section 3.6.4 for a discussion of the potential effects of fishery gear on habitat.

A bottom trawling ban was initiated in pollock spawning habitats in pre-MSA fishery management regulations. This initiative reduced the bycatch of juvenile pollock while indirectly reducing the intensity of trawling on pollock spawning habitat. Several of the foreign groundfish fisheries also imposed restrictions on themselves to reduce their effects on pollock spawning habitats.

External Exxon Valdez Oil Spill

This event has been identified as resulting in an adverse effect on pollock spawning habitat; however, this effect has not shown population-level impacts on GOA pollock.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as having potentially beneficial or adverse effects on habitat suitability. In general, a shift toward warmer waters favors recruitment and survival of pollock. As described in Section 3.10.1.5, when the Aleutian Low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian Low was strong, water temperatures were higher, and the catches were dominated by cod, pollock, and flatfishes.

Large fluctuations in pollock abundance without large changes in the direct fishing suggest that the GOA pollock may be strongly influenced by environmental controls and indirect ecosystem effects. This implies a need for conservative management, since adverse population effects by the fisheries may be difficult or impossible to reverse through management measures (Dorn *et al.* 2002).

Internal JV and Domestic Groundfish Fisheries (1976-present)

Very little research regarding the effects of trawling activities in the GOA has been conducted. The greatest bottom trawl effort in the GOA has taken place in the Kodiak Island region, where directed fisheries have targeted Pacific ocean perch, Pacific cod, and flatfish. Over nine years (1990-1998), a total of 57,948 tows were observed in the GOA. If expanded to include unobserved tows, the total number of trawl tows were estimated at 116,288 tows. The total bottom trawl effort measured in 24-hour days was estimated at 11,829 trawl-days. The highest estimated number of bottom trawls in both the GOA and Aleutian Islands occurred on the continental shelf at a depth of 101-200 m. The density value of trawling for the GOA overall was calculated at 0.35/km^2, the highest density in the Kodiak Island region at 1.43/km^2 in an area of 4,657 km^2 at a depth of 301-500 m. The highest bottom trawl duration in the GOA was at a depth of 101-200 m, with the highest number of days trawled per km^2 in the Chirikof Island area at 0.74 days/km^2 at 301-500 m (see Section 3.6 for more information).

For the period 1990-2000, 64,948 bottom trawls were observed in the GOA. The spatial pattern of this effort is much more dispersed than in the Bering Sea region. During 2000 the amount of trawl effort was 3,443 sets. Areas of high fishing effort are dispersed along the shelf edge with high pockets of effort near Chirikof Island, Cape Barnabus, Cape Chiniak and Marmot Flats. Catch in these areas was composed primarily of pollock, Pacific cod, flatfish and rockfish. A larger portion of the trawl fleet in the Kodiak Island area is composed of smaller catcher vessels that require 30 percent observer coverage (see Section 3.6 for more information).

In April 1987, GOA FMP Amendment 15 closed two areas around Kodiak Island to bottom trawling and scallop dredging. These areas were designated as important rearing habitat and migratory corridors for juvenile and molting crabs. The closures are intended to assist rebuilding severely depressed Tanner and red king crab stocks. In addition to crab resources, the closed areas and areas immediately adjacent to them have rich stocks of groundfish including flathead sole, butter sole, Pacific halibut, arrowtooth flounder, Pacific cod, pollock, and several species of rockfish.

GOA FMP Amendment 18 enhanced the protection of target species beginning in 1990. It established the Shelikof Strait area as a management district because the area was found to contain spawning populations of pollock. The amendment also extended the closed areas around Kodiak Island to bottom trawl gear because those closure areas were scheduled to expire at the end of the year.

As mentioned above, GOA FMP Amendment 23 eliminated the domestic bottom trawl fishery for pollock to avoid bycatch of prohibited species and to further reduce the fisheries impacts on benthic habitats. The fishing industry also initiated self-imposed gear modifications to further protect pollock spawning habitat and other benthic habitats.

GOA FMP Amendment 25 established Steller sea lion buffer zones in the GOA. Regulations authorized by this amendment implemented the following measures:

1. Areas are closed year-round to fishing by trawl vessel within 10 nm of key Steller sea lion rookeries.

2. Areas within 20 nm of five sea lion rookeries are closed to directed pollock fisheries during the "A" season.

3. The specified TAC for pollock in the combined western/central area is further divided among three pollock management districts: Area 61, Area 62, and Area 63. The Shelikof Strait District was eliminated. To prevent excessive accumulation of unharvested portions and quarterly allowance of the pollock TAC, a limit of 150 percent of the initial quarterly allowance in each pollock management district was established.

In 1993, NOAA Fisheries extended the no-trawl zone around Ugamak Island out to 20 nm during the pollock roe fishery (58 FR 13561). GOA Amendment 45 further subdivided the areas for pollock fishing; these areas were further modified in June of 1998 (63 FR 31939).

GOA FMP Amendments 55 and 65 were recently passed in order to identify EFH, minimize practicable adverse effects on habitat, and encourage conservation of HAPC.

GOA Pollock Comparative Baseline

AFSC bottom trawl surveys are conducted every three years in the GOA. Starting in 2001, these surveys have been conducted every two years. In 2001, the AFSC survey covered the western and central GOA, which typically accounts for 97 percent of the GOA pollock. The 2001 biomass estimate (216,761 mt) indicates a 65 percent decline in biomass compared to the 1999 biomass survey estimate (Dorn *et al.* 2001).

The Shelikof Strait EIT survey has been conducted annually since 1981 and is used to assess the biomass of pollock in the Shelikof Strait area. Age-2+ abundance estimates were estimated at 229,100 mt, a 38 percent decrease from the 2001 biomass estimates. However, the 2002 age-3 estimated abundance was the third largest on record. EIT surveys were also conducted in the Shumagin Islands spawning areas and the area along the shelf east of the entrance to the Shelikof sea valley in winter of 2002. The 2002 survey results indicate that there may not be a constant ratio of stock spawning in the Shelikof Strait for the total pollock biomass, an assumption used in the modeling of GOA pollock. The GOA pollock stock modeling will be reevaluated in light of these new results (Dorn *et al.* 2002).

The ADF&G crab/groundfish trawl survey is conducted at a fixed number of stations, mostly nearshore from Kodiak Island to Unimak Pass. These surveys have been conducted since 1987. The 2002 biomass estimate (96,237 mt) indicates an increase of 11 percent from the 2001 biomass, in contrast to the steep decline suggested by the Shelikof Strait EIT survey. The ADF&G survey also shows a predominance of older fish (greater than 45 cm) which may be attributed to selectivity of the gear (Dorn *et al.* 2002). The survey biomass estimates from the AFSC, Shelikof Strait EIT and ADF&G trawl surveys for GOA pollock are listed in Dorn *et al.* 2002.

In order to estimate pollock biomass from 1961-1982, a generalized linear model (GLM) was fit to pre-1984 trawl data and post-1984 triennial trawl survey data. This model indicates low biomass estimates between 1961 and 1971, an increase by a factor of 10 in 1974 and 1975, and declining to 900,000 mt in 1978. No consistent trends are noticeable in the GLM following 1978. The coefficients of variation for the GLM-based biomass estimates range between 0.24 and 0.64, larger than the triennial survey biomass estimates (Dorn *et al.* 2001).

Over the last 15 years, NOAA Fisheries' 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 (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. They labeled this hypothesis the *supply dependent multiple life stage control model*. In a parallel study, Megrey *et al.* (1996) reviewed data from FOCI studies and identified several events that are important to pollock survival during the early life history. 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.

The 2002 FOCI predictions were based on information from: 1) observed 2002 Kodiak monthly precipitation, 2) wind mixing energy at 57°N, 156°W, 3) advection of ocean water in the vicinity of Shelikof Strait, 4) rough counts of pollock larvae from May 2002, and 5) estimates of age-2 pollock abundance. By weighting these elements, FOCI forecasted that the 2001 year-class is strong and 2002 year-class is average (Dorn *et al.* 2002).

GOA Pollock Cumulative Effects Analysis Status

GOA pollock will be brought forward for cumulative effects analysis.

3.5.1.14 GOA Pacific Cod

Life History and Distribution

Pacific cod (*Gadus macrocephalus*) 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 GOA and Aleutian Islands. GOA, EBS, and Aleutian Island 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 GOA (Shimada and Kimura 1994). Spawning takes place in the sublittoral–bathyal zone near the bottom, the area of the continental shelf and slope about 40 to 290 m deep. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983). Table 3.5-4 summarizes the biological and reproductive traits and habitat associations of Pacific cod at its different life stages.

Pacific cod reach a maximum recorded age of 19 years. In the BSAI, 50 percent of Pacific cod is estimated to reach maturity by the time they reach 67 cm in length, or an age of about 5 years (Thompson and Dorn 1999). The same length in the GOA stock corresponds to an age of about 7 years (Thompson *et al.* 1999).

Trophic Interactions

Pacific cod is an opportunistic feeder that feeds both in the water column and in benthic areas (Yang and Nelson 2000). In the BSAI and GOA, in terms of percent occurrence in stomach contents, 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 fish, and amphipods. 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 (Livingston 1991b). In studies conducted on GOA Pacific cod, polychaetes and cephalopods were the most frequently found invertebrates in stomach contents. However, pandalid shrimp were more important in terms of percentage of total stomach contents weight. GOA Pacific cod also consumed large amounts of tanner crabs (Yang and Nelson 2000). Predators of Pacific cod include Pacific halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffins (Westrheim 1996).

GOA Pacific Cod Management

Pacific cod in the GOA is managed under Tier 3a. The 2002 assessment projected a 2003 female spawning biomass of 88,300 mt, about 8 percent above 2001 assessment's projection for 2002 and corresponding to a maximum permissible 2003 ABC of 59,900 mt. NPFMC adopted a 2003 ABC of 52,800 mt, down about 8 percent from the 2002 ABC and about 12 percent below the maximum permissible value. The 2003 OFL for the GOA stock is 70,100 mt, down about 9 percent from the 2002 OFL. The 2003 ABC is intended to include all harvest mortality, including catches taken in the State of Alaska Pacific cod fisheries (Table 3.5-28). ABC is allocated among regulatory areas according to the average proportion of trawl survey biomass in each area: western, 39 percent; central, 55 percent; and eastern, 6 percent (Thompson *et al.* 2002) .

Beginning with the 1994 GOA SAFE report (Thompson and Zenger 1994), a length-structured synthesis model (Methot 1990) has formed the primary analytical tool used to assess Pacific cod.

Annual trawl surveys in the EBS and triennial (recently, biennial) trawl surveys in the Aleutian Islands and GOA are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and

Dorn 2002, Thompson *et al.* 2002). Other available data include catch size compositions and biomass by gear, for the years 1978 through the early part of 2002. Within each year, catches are 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 January-May (early) trawl fishery, June-December (late) trawl fishery, the longline fishery, and the pot fishery. In order to account for differences in selectivity between mostly foreign, mostly domestic, and very recent fisheries, the fisheries data were split into pre-1987, 1987-1999, and post-1999 eras in the GOA and pre-1989, 1989-1999, and post-1999 eras in the EBS. 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 Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37 (see Appendix B). Several previous assessments included statistical analyses of the uncertainty surrounding the true values of the survey catchability and natural mortality rate. These analyses of uncertainty led to a risk-averse adjustment factor of 0.87 which is multiplied by the maximum permissible F_{ABC} to obtain the recommended F_{ABC}. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates.

GOA Pacific Cod Past/Present Effects Analysis

The geographic scope for the GOA Pacific cod past/present effects analysis is the same as the GOA FMP management areas (Figure 1.2-3). The temporal scope for this analysis begins in 1867 when the GOA domestic fishery begins and ends in 2002, the most recent year for which a stock assessment is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-30 provides a summary of the GOA Pacific cod past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA Pacific cod:

- Mortality due to catch/bycatch and marine pollutants and oil spills (direct effect).

- Change in reproductive success due to fishery selectivity of juveniles, spatial/temporal concentration of catch, and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery catch/bycatch of prey species, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to impacts of fishery gear, marine pollutants and oil spills, introduction of exotic species and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due the introduction of exotic species by way of ballast water and climate changes and regime shifts has not been brought forward since the impacts on Pacific cod in the GOA has not been directly observed or documented. See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the Pacific cod past effects analysis include the following:

- Past/Present External Events
  - Subsistence and personal use
  - Foreign groundfish fisheries (1962-1976)
  - State of Alaska crab fisheries
  - IPHC longline fisheries
  - State of Alaska groundfish fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1987)
  - JV groundfish fisheries (1978-1988)
  - Domestic groundfish fisheries (1867-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Subsistence and Personal Use

The earliest fisheries for groundfish in the GOA were the Native subsistence fisheries. Catches were traded or sold to the Russians and later to the Americans after the purchase of Alaska by the U.S. in 1867. Groundfish and herring are still important sources of food to many groups of Alaska Natives, although these subsistence harvests are now dwarfed by commercial operations (NPFMC 2002b). Since the overall Pacific cod catch by these groups is relatively small and localized, it is unlikely that these users would have an adverse effect on the GOA Pacific cod populations.

External Foreign Groundfish Fisheries (1962-1976)

The foreign trawl fisheries began in the GOA in 1962 with a Soviet fleet targeting Pacific ocean perch. Japan began fishing the following year, focusing on Pacific ocean perch and sablefish. These fisheries expanded rapidly in the late 1960s, and began targeting other groundfish species, although Pacific cod was not targeted until 1972 by Japan and the Soviet Union, and 1978 by the Republic of Korea. Prior to 1976, the majority of Pacific cod catch was bycatch. Pacific cod became the primary target of Japanese longline vessels in 1978 following the phase-out of foreign fisheries in the sablefish fishery and the expansion of domestic utilization (GOA FMP Amendments 2, 3, and 6). The foreign Pacific cod fishery peaked in 1981 at about 35,000 mt. Foreign fisheries dominated groundfish catch until 1985, when they were limited to only pollock and Pacific cod due to the rapid expansion of domestic fisheries capable of harvesting other species. By 1987, foreign fisheries were eliminated from the GOA (NPFMC 2002b). The past foreign fisheries contributed to fishing mortality in the GOA. Due to the short duration and moderate catch of the past Pacific cod foreign fisheries, there are no observable lingering adverse effects on the GOA Pacific cod populations.

External State of Alaska Groundfish Fisheries

The state-managed Pacific cod fishery began in 1997. Pacific cod fisheries are located in PWS, Cook Inlet, Chignik, Kodiak and the south Alaska Peninsula; each unit is regulated by a state FMP. A portion of the federal ABC is allocated to Pacific cod fisheries as a GHL, similar to the pollock fisheries. The GHLs are then allocated according the location of the fishery and gear type (pot and jig gear) within state waters. In 1999, approximately 14,044 mt of Pacific cod were harvested in the state-managed fisheries (ADF&G 2000b).

The State of Alaska contributed to the fishing mortality of Pacific cod in the GOA. These removals do not appear to have a significantly adverse effect on the GOA Pacific cod populations.

External State of Alaska Crab Bait Fisheries and IPHC Longline Bait Fisheries

The GOA bait fishery arose mainly in response to the need for bait in the growing crab fisheries of Alaska. The halibut fishery also required substantial amount of groundfish for bait. The bait fishery occurred from PWS west to the Aleutians, but some two-thirds of the catch was landed in Kodiak. The catch consisted mainly of pollock, Pacific cod, and various flounder species. The ability to measure the catch of groundfish for bait has been limited due to utilization of large amounts of Pacific cod on board halibut vessels. Therefore, unrecorded catch of bait may equal or exceed the recorded catch of bait. Bait has also been transferred to crab and halibut vessels on the fishing grounds. From 1972 to 1976 the catch of groundfish for bait increased from 96 mt to 303 mt. Catches continued to increase through the late 1970s and by 1982 accounted for 1,059 mt (NPFMC 2002b).

The State of Alaska crab fisheries and the IPHC longline fisheries contributed to fishing mortality in the GOA. The effect of these fisheries consisted of both removals of the fish as bycatch and removals of Pacific cod to be used in the fishery as bait. These past removals may have exerted impacts to the Pacific cod resource, resulting in adverse effects to overall mortality. GOA Amendment 11 was passed in order to eliminate the non-processed portion (bait and personal component) of the domestic fishery.

Internal JV and Domestic Groundfish Fisheries (1867 - present)

The first commercial groundfish fishery in the GOA was a setline fishery for Pacific cod by U.S. Nationals in 1867. Canadians were involved in the groundfish fisheries in the GOA since the beginning of the 20th century, although most of their efforts were focused on Pacific halibut and ended in 1981 as a result of extended jurisdiction (NPFMC 2002b).

Pacific cod have been landed domestically since the late 1950s and early 1960s, although the fishery did not really begin to develop until 1978. In 1985, the foreign fisheries were limited to pollock and Pacific cod in an effort to build the domestic fishery, and by 1987 the GOA had become completely domesticated. A small Pacific cod JV fishery existed through 1988, with a small average catch of approximately 1,400 mt per year. GOA FMP Amendment 8 was proposed to phase out the JV and foreign fisheries. The past JV and pre- and post-MSA domestic fisheries have contributed to the fishing mortality of GOA Pacific cod. There are no observable lingering effects in the GOA Pacific cod populations from these fisheries.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1962-1976)

Fishery Selectivity

In 1969 and 1970, the Soviet groundfish fishery targeted on arrowtooth flounder, sablefish, and pollock with bycatches of Pacific cod, rockfish, and other bottomfish. Data regarding the amount of Pacific cod bycatch and the age of the catch are unavailable; however, it is assumed that the bycatch of juvenile Pacific cod took place. Regardless, there are no observable lingering effects on the GOA Pacific cod population due to past foreign fishery selectivity.

External State of Alaska Groundfish Fisheries

Spatial/Temporal Concentration of Catch/Bycatch

State of Alaska Pacific cod fisheries tend to be spatially concentrated in the separate management areas. In the PWS, a majority of catches occur west of Montague Island and the western part of PWS. In Cook Inlet, catches came predominately from Kachemak Bay. The south Alaska Peninsula fisheries focus on the Sanak and Shumagin Islands area. The Kodiak and Chignik areas are more broadly distributed in space than the other fisheries. Overall, all of the state-managed Pacific cod fisheries tend to be broadly distributed in time, although there is some concentration during the late summer and early fall in certain regions (ADF&G 2000b).

Due to its localized nature, the State of Alaska directed Pacific cod fishery has been noted to have an adverse effect on the spatial distribution of the GOA Pacific cod stock. This effect is determined to have had lingering population effects in that stock.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of Pacific cod. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5 for more details).

Internal JV and Domestic Groundfish Fisheries (1867-present)

Fishery Selectivity

Pacific cod are caught as bycatch and discarded in the Pacific cod fishery and other domestic groundfish trawl fisheries. GOA FMP Amendment 18 established the Observer Program partially in an attempt to reduce target and non-target species bycatch. Since 1998 (GOA FMP Amendment 49), discarding of Pacific cod has been prohibited except for fisheries in which Pacific cod has a bycatch-only status.

Spatial/Temporal Concentration of Catch/Bycatch

The Pacific cod fishery has changed recently due to management measures instituted to reduce possible adverse impacts on the western population of Steller sea lions. Some of these measures attempted to distribute catch more evenly throughout the year. On average during the period 1998-2000, 84 percent of the annual trawl catch, 97 percent of the annual longline catch, and 90 percent of the annual pot catch was taken from January to May. The attempted redistribution of trawl catches appears to have been the most successful, as the proportion taken during January to May was reduced to 63 percent in 2001. Correspondingly, the proportion of trawl catch taken during June to August increased by one percent and the proportion taken during September to December and increased by 20 percent. The longline and pot fisheries saw little change in temporal distribution; although pot gear saw a slight decline in the proportion of the catch taken during January to May with a slight corresponding increase from September to December (Thompson *et al.* 2002).

Change in Prey Availability

External Foreign Groundfish Fisheries (1962-1976)

Past foreign fisheries in the GOA have had an adverse impact on prey availability for large Pacific cod due to large removals of pollock. Large Pacific cod are mainly piscivorus consuming pollock ranging in age from age-0 to greater than age-6 depending on predator size. However, due to the opportunistic nature of Pacific cod, it is unlikely that the fisheries would have had a population-level effect of these populations. No observable lingering effects are apparent in the present GOA Pacific cod populations .

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of Pacific cod.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse with respect to prey availability. In general, a shift toward warmer waters appears to favor recruitment and survival of Pacific cod. As described in Section 3.10.1.5 of this Programmatic SEIS, when the Aleutian Low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian Low was strong, water temperatures were higher, and the catches were dominated by Pacific cod, pollock, and flatfishes.

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of small Pacific cod.

Internal JV and Domestic Groundfish Fisheries (1867-present)

JV and domestic fisheries in the GOA have had an adverse impact on prey availability for large Pacific cod due to large removals of pollock. Large Pacific cod are mainly piscivorus consuming pollock ranging in age from age-0 to greater than age-6 depending on predator size. However, due to the opportunistic nature of Pacific cod, it is unlikely that the fisheries would have had a population-level effect of these populations. No observable lingering effects are apparent in the present GOA Pacific cod populations .

Change in Important Habitat

External Foreign Groundfish Fisheries (1962-1976)

The statistics on the effects of bottom trawling in the GOA pre-MSA is generally unavailable. It is assumbed that habitat suitability has been negatively affected by the intensity of the past foreign fisheries; however, the effects have not shown a lingering influence at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse with respect to habitat suitability. In general, a shift toward warmer waters appears to favor recruitment and survival of Pacific cod. As described in Section 3.10.1.5 of this Programmatic SEIS, when the Aleutian Low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian Low was strong, water temperatures were higher, and the catches were dominated by Pacific cod, pollock, and flatfishes.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of Pacific cod.

Internal JV and Domestic Groundfish Fisheries (1867-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability has been adversely affected by the intensity of the past JV and domestic trawl fisheries; however, the effects are not considered to have a lingering influence at the population-level. GOA FMP Amendments 15, 18, 23, 25 and Steller sea lion protection measures have all contributed to reducing the intensity of bottom trawling by the domestic fishery. GOA FMP Amendments 55 and 65 were proposed to identify EFH, minimize practicable adverse effects on habitat from the fishery, and encourage conservation of HAPC.

GOA Pacific Cod Comparative Baseline

The highest biomass estimate recorded was in the 1984 survey at 571,188 mt and the lowest during the 2001 survey. However, the 2001 survey did not cover the eastern portion of the GOA. The highest number of fish was observed in 1996 with a population estimate of over 315 million fish. Pacific cod distributed throughout the GOA, with 47 percent of the biomass in the western GOA, 45 percent of the biomass in the central GOA, and 8 percent of the biomass in the eastern GOA according to the 2001 survey, using the 1999 eastern GOA survey estimate to approximate the 2001 eastern GOA biomass (Thompson *et al.* 2001).

Modeling indicates an increase in the age-3+ biomass during the early 1980s followed by a period of sustained high abundance through the rest of that decade. A steady decline in survey biomass has occurred from the early 1990s through the present. Female spawning and survey biomass trends also show declines throughout the past decade. Recruitment of age-3 Pacific cod appears to be average for the 1995 year-class and below average for 1998 year-class. Model estimates of age-1 recruitments closely parallel the age-3 recruitment, with the addition of a below average 1999 year-class and an average 2000 year-class (Thompson *et al.* 2002).

GOA Pacific Cod Cumulative Effects Analysis Status

GOA Pacific cod will be brought forward for cumulative effects analysis.

3.5.1.15 GOA Sablefish

Sablefish in the BSAI and GOA are managed as a single stock. Thus, the direct/indirect effects summary and cumulative effects analysis status of BSAI and GOA stocks is presented in Section 3.5.1.3.

3.5.1.16 GOA Atka Mackerel

Life History and Distribution

Atka mackerel existed in the GOA throughout the early 1980s and supported a large foreign fishery. By the mid-1980s, the population had nearly disappeared. This suggests that the Atka mackerel population in the GOA may be the edge of its distribution and that the GOA be populated only during periods of strong recruitment from the Aleutian Islands region. No reliable estimate exists of current Atka mackerel biomass in the GOA. Atka mackerel have not been commonly caught in the GOA triennial trawl surveys and, recently, have been detected by the summer trawl surveys only in the Shumagin (western) area of the GOA (Lowe and Fritz 2001).

Trophic Interactions

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 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. Predators of the GOA Atka mackerel are similar to those encountered in the BSAI, although Atka mackerel appeared only as a minor component in the diet of arrowtooth flounder in the GOA (Yang 1993).

GOA Atka Mackerel Management

GOA Atka mackerel fall into Tier 6 of the ABC and OFL definitions, which define the OFL level as average catch from 1978 to 1995 and ABC as not exceeding 75 percent of OFL. The average annual catch from 1978 to 1995 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 conservative harvest strategy given the uncertainty about GOA Atka mackerel abundance. The 2002 stock assessment for the 2003 fishery recommended an ABC of 600 mt, with the intention of precluding a directed fishery, while providing for bycatch needs in other trawl fisheries (Table 3.5-28). An ABC lower than the maximum prescribed under Tier 6 was recommended since the fishery may have created localized depletions of Atka mackerel. Catch-per-unit-effort (CPUE) data indicate declines in the Atka mackerel population from 1992-1994 and since data indicated that the GOA population is vulnerable to fishing pressure (Lowe 2002).

Atka mackerel have not been commonly caught in the GOA triennial trawl surveys. It has been determined that the general GOA groundfish bottom trawl survey does not assess the GOA portion of the Atka mackerel stock well, and resulting biomass estimates have little value as absolute estimates of abundance or as indices of trend (Lowe and Fritz 2001). Because of this lack of fundamental abundance information, GOA Atka mackerel are not assessed with an age-structured model. The stock assessment, which does not utilize abundance estimates from the trawl survey, consists of descriptions of catch history, length and age distributions from the fishery (1990-1994), and length distributions from the trawl surveys (1996, 1999, and 2001). This information is presented in the GOA Atka mackerel stock assessment, which is incorporated into the GOA SAFE report.

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 population trends for the species in the GOA.

Past/Present Effects Analysis

The geographic scope for the GOA Atka mackerel past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in 1973 when the foreign fishery started and ends in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-31 provides a summary of the GOA Atka mackerel past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA Atka mackerel:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to the spatial/temporal concentration of catch/bycatch, fishery selectivity and climate changes and regime shifts (indirect effect).

- Change in prey availability due to commercial whaling, the introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, introduction of exotic species and marine pollution and oil spills (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on Atka mackerel in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the Atka mackerel past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1973-1976)
  - Commercial whaling
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1986)
  - JV groundfish fisheries (1979-1985)
  - Domestic groundfish fisheries (1979-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - IWC management
  - MMPA of 1972
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the Atka mackerel fishery. Amendments discussed in Section 3.2, which impact on the target fisheries as a whole and Atka mackerel as a component of the fishery, are not repeated here.

Mortality

External Foreign Groundfish Fishery (1973-1976)

Atka mackerel was an important target species of the foreign fishery in the GOA. The past foreign Atka mackerel fisheries participated in the GOA from about 1973 to 1986. Harvests peaked in 1975 at 27,777 mt, and were taken mainly by the Soviet fishery, largely due to a decrease in Pacific ocean perch abundance (NPFMC 2002b). The large removals of Atka mackerel by the foreign fisheries are found to have had a lingering adverse effect on the GOA Atka mackerel population.

Internal JV and Domestic Groundfish Fisheries

The past JV Atka mackerel fishery participated for a short time in the GOA, from 1979 to 1985, although significant catches were not made until 1983. Since 1985, all Atka mackerel landings have been by domestic fleets. The domestic fishery began in 1979 but, like the JV fishery, did not begin catching significant amounts of Atka mackerel until 1983 (NPFMC 2002b). By 1992, catches increased to 14,000 mt (Lowe and Fritz 2001). The Atka mackerel fishery is currently a bycatch only fishery. The large removals of Atka mackerel by the JV and past domestic fisheries (see catch history in Lowe 2002) are found to have had a lingering adverse effect on the GOA population.

An Atka mackerel population existed in the GOA primarily in the Kodiak, Chirikof, and Shumagin areas and supported a large foreign fishery through the early 1980s. By the end of the mid-1980s, this fishery, and presumably the population, had all but disappeared. Atka mackerel were combined with the “other species” category in 1988 (GOA FMP Amendment 16). This regulatory category resulted in the mandatory discard of species of minor commercial importance such as sculpin, skate, squid, smelt, etc. In 1990, a directed fishery resumed when a closure of the Atka mackerel fishery in the BSAI resulted in the movement of vessels into the western regulatory area to continue targeting this species. The fishery had expanded significantly by 1992, and the expansion resulted in the listing of the “other species” category as bycatch only. This closure caused the discard of minor species such as octopus. In 1993, Atka mackerel were again targeted in the GOA, accounting for almost the entire TAC of other species in the western regulatory area. As a result, the “other species” category was closed to directed fishery in the western regulatory area. Since Atka mackerel no longer met the definition of other species (of slight economic importance or containing economically valuable species but insufficient data to allow separate management), Atka mackerel were established as a target species in its own right in the GOA by Amendment 31, and harvest levels were then based on biological stock assessments. Such an action reduced the potential for overfishing Atka mackerel, while allowing for increased harvest of the other species complex, and reduced user conflicts within the western regulatory area of the GOA. Steller sea lion conservation measures in 1991-1993 further restricted the amount of Atka mackerel that could be taken in certain areas. GOA Amendment 44 provided a more conservative OFL definition for Atka mackerel, based on Tier 6, which set the OFL equal to the average catch from 1978 to 1995. However, since 1997, the Atka mackerel has been managed as a bycatch only fishery, with a sufficient level to provide for bycatch in other target fisheries (600 mt annually).

Change in Reproductive Success

External Foreign Groundfish Fishery (1973-1976)

Spatial/Temporal Concentration of Catch/Bycatch

As in the BSAI, the foreign GOA Atka mackerel fishery was a highly localized fishery, occurring in the same locations every year at depths less than 200 m. The past foreign fisheries are found to have had an adverse impact on the spatial/temporal distribution of the GOA Atka mackerel stock due to the spatial/temporal concentration of the fishery. This effect is determined to have a lingering population effect in the GOA stock.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of Atka mackerel. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fishery (1979-present)

Fishery Selectivity

The 1991 to 1994 data show that during certain months on the Davidson Bank and near the Shumagin Islands, more females than males are caught. The presumption is that there is a natural segregation of the population during spawning periods. The Umnak Island fishery ground (1991-1994) represents a more even distribution of males to females in the catch (Lowe and Fritz 2001).

Spatial/Temporal Concentration of Catch/Bycatch

In 1990, the localized Atka mackerel fishery took place near the edge of the continental shelf on Davidson Bank south of Unimak and Sanak Islands, and moved off the southern coast of Umnak Island from 1991-1994. In 1993 and 1994, fishing also took place off the south and east coasts of the Shumagin Islands (Lowe and Fritz 2001).

In 1994, small amounts of Atka mackerel bycatch were caught in the pollock, Pacific cod, and rockfish trawl fisheries in GOA management areas 610 and 620. Bycatch calculations are difficult to obtain for the rockfish fisheries since some vessels “top-off”their hauls with Atka mackerel rather than catch them strictly as bycatch. The 1994 discard rate for the GOA Atka mackerel fishery was about 8 percent (Lowe and Fritz 2001). GOA FMP Amendment 18 (1990) established the Observer Program which was designed to help decrease bycatch and discard rates, among other things.

The past JV fisheries are found to have had an adverse impact on the spatial/temporal distribution of the GOA Atka mackerel stock due to the spatial/temporal concentration of the fishery. This effect has resulted in a lingering population effect.

Change in Prey Availability

External Commercial Whaling

Whaling is identified as having a past beneficial effect on prey availability for the Atka mackerel stocks. Atka mackerel have been recorded as a prey species of certain whales; therefore, by removing large predators, Atka mackerel recruitment is favored.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability in both stocks. In general, a shift toward colder waters favors recruitment and survival of Atka mackerel. When the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of Atka mackerel.

Change in Important Habitat

External Foreign Groundfish Fishery (1973-1976)

Statistics on the number of bottom trawls and the effects of bottom trawling on habitat within the GOA is generally unknown. Due to the schooling, semi-demersal nature of Atka mackerel, this species is readily caught by bottom trawl gear (Lowe and Fritz 2001). The effect of the past foreign fisheries on habitat suitability for the GOA stock is unknown.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability in both stocks. In general, a shift toward colder waters favors recruitment and survival of Atka mackerel. When the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of Atka mackerel.

Internal JV and Domestic Groundfish Fishery (1979-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat. Sex ratio data (1991-1994) suggest that the fisheries frequent habitats inhabited by Atka mackerel, including possible spawning and nesting habitats (Lowe and Fritz 2001). The effects of the JV and past domestic fisheries gear on Atka mackerel habitat are unknown.

Steller sea lion no-trawl or limited trawl zones were established in the BSAI and GOA in 1991, 1992 and 1993. This included a 20 nm aquatic zone around the Shelikof Strait foraging area. From 1991 to 1993, 82 to 89 percent of Atka mackerel were caught between 10-20 nm of Steller sea lion rookeries on islands near Umnak and in the Shumagin Islands. Concerns were raised regarding the localized reduction of food availability to Steller sea lions in those areas. GOA FMP Amendments 55 and 65 were designed to identify, conserve, and mitigate impacts on EFH and HAPC. The effect of the JV fishery on habitat suitability for the GOA stock is unknown.

GOA Atka Mackerel Comparative Baseline

Biomass estimates by survey data are considered unreliable due to high variability in the Atka mackerel distribution and anomalously high single catches. CPUE analyses of Atka mackerel fisheries are the only indicator of recent trends in abundance. These analyses suggest that the Atka mackerel population declined 81 percent between 1992 and 1994 near Umnak Island and declined 58 percent near Shumagin Island in the GOA (Lowe and Fritz 2001).

Fishery age composition data suggests that in 1990, 1992 and 1994, most Atka mackerel were between 3 and 4 years old (1988 year-class). The oldest fish from the 1994 sample was 11 years old from Shumagin Bank (Lowe and Fritz 2001).

GOA Atka Mackerel Cumulative Effects Analysis Status

The GOA Atka mackerel will be brought forward for cumulative effects analysis.

3.5.1.17 GOA Shallow Water Flatfish

Life History and Distribution and Trophic Interactions

Eight flatfish species inhabit shallow waters and are managed in the shallow water flatfish assemblage in the GOA. They include: northern and southern rock sole, yellowfin sole, starry flounder, butter sole, English sole, Alaska plaice and sand sole. The life history, distribution and trophic interactions of these species have been described under the BSAI in Section 3.5.1.5 for yellowfin sole, 3.5.1.6 for rock sole and 3.5.1.10 for the remaining flatfish species.

GOA Shallow Water Flatfish Management

Survey results from 2001 indicate that over half of the estimated biomass (54 percent) of this assemblage are northern and southern rock sole. Rock sole, for which maturity information is deemed adequate, are managed in Tier 4 of the ABC and OFL definitions where $F_{ABC} = F_{40\%}$ (0.17) and $F_{OFL} = F_{30\%}$ (0.209). This equates to on ABC value of 28,351 mt (9,571 mt for northern rock sole and 18,780 mt for southern rock sole) and to an OFL value of 34,214 mt for both species of rock sole; 11,550 mt for northern rock sole and 22,664 mt for southern rock sole (Table 3.5-28) (Turnock 2002b). The rest of the shallow water group is managed as a Tier 5 species in the GOA where ABCs are calculated using $F_{ABC} = 0.75$ M (0.15) and $F_{OFL} =$ M (0.2). The group is managed this way because maturity information for the GOA stock is unavailable (Turnock *et al.* 2001b).

Stock assessment models are not used for any of the shallow water flatfish in the GOA due to the lack of available information (Turnock *et al.* 2001b). Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993, 1996, 1999, and 2001 are considered the best information available to determine stock biomass for all of the flatfish species in the GOA. The 2001 GOA survey effort did not encompass the eastern GOA and resulted in the eastern GOA biomass being approximated using the average of the 1993-1999 GOA biomass estimates. Beginning with the 1996 trawl survey, rock sole was further divided into northern rock sole (*Lepidopsetta sp. cf. bilineata*) and a southern rock sole (*L. bilineata*) Overlapping distributions may lead to separate management in the future (Turnock *et al.* 2001b).

GOA Shallow Water Flatfish Past/Present Effects Analysis

The geographic scope for the GOA shallow water flatfish assemblage past/present effects analysis is the same as the GOA FMP management areas (Figure 1.2-3). The temporal scope for this analysis begins in the 1960s when the GOA shallow water flatfish assemblage foreign fishery began and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-32 provides a summary of the GOA shallow water flatfish assemblage past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA shallow water flatfish assemblage:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch, fishery selectivity and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery prey bycatch, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery impacts, scallop dredging, introduction of exotic species, marine pollutants and oil spills and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on the shallow water flatfish in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the shallow water flatfish assemblage past/present effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1960s-1976)
  - State of Alaska scallop fishery
  - State of Alaska crab bait fisheries
  - IPHC longline bait fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1988)
  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the shallow water flatfish assemblage fishery. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality

External Foreign Groundfish Fisheries (1960s-1976)

The Japanese and Soviet flounder fisheries both started as Pacific ocean perch fisheries in the early 1960s and switched to other target Groundfish following the decline of Pacific ocean perch. Annual harvests were about 15,000 mt taken mostly by Japanese trawlers. By 1981, the Soviet fleets were no longer allowed in the GOA due to political reasons and Japanese catch was minimal. By 1988, only domestic fleets were harvesting flatfish (NPFMC 2002b).

Although removals of shallow water flatfish occurred during the past foreign fisheries, there are no observable adverse lingering effects on the GOA shallow water flatfish population.

External State of Alaska Crab Bait and IPHC Longline Bait Fisheries

The GOA bait fishery targeted pollock, Pacific cod, and various flounder species in order to provide needed bait for the crab and halibut fisheries. Bait fisheries occurred from PWS west to the Aleutians, although the majority of the bait has been landed in the Kodiak area (NPFMC 2002b). Although these fisheries contributed to flatfish mortality, there are no observable lingering effects on the population.

Internal JV and Domestic Groundfish Fishery (1968-present)

The domestic and JV flounder fisheries began in 1968, although catches were minimal until 1986. The JV fisheries were responsible for a large amount of the increase in flatfish catch in 1986-1987, with a four-fold increase in the 1987 catch. JV fisheries were phased-out of the flatfish fishery by 1988; however, the catch continued to increase with the domestic fishery to a high of 43,107 mt in 1996. Flatfish declined in 1998 to 23,237 mt, increased to 37,303 mt in 2000, and declined again in 2001 to 31,734 mt. Shallow water flatfish remained lightly harvested in 2001 at 6,173 mt, a decrease from 6,928 mt in 2000. The flatfish fishery is likely to be limited by the potential for exceeding the Pacific halibut PSC limits in the future (Turnock *et al.* 2002b).

In the GOA, yellowfin sole is managed as part of the flatfish assemblage. In 1990, NPFMC divided the flatfish assemblage into four categories; shallow flatfish, deep flatfish, flathead sole and arrowtooth flounder. Yellowfin sole fell into the shallow flatfish category. This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow water and deepwater flatfish species. Arrowtooth flounder was separated from the other categories due to its high abundance and low commercial value. Flathead sole were separated due to an overlap in depth distribution with the shallow water and deepwater groups.

Rex sole was split out of the deepwater management category in 1993 due the relatively large amounts of Pacific ocean perch bycatch occurring in the rex sole target fishery. Beginning in 1996, rock sole was split into two species, a northern (*Lepidopsetta sp. cf. bilineata*) and a southern rock sole (*Lepidopsetta bilineata*) (personal communication, Jay Orr) due to overlapping distributions.

The large removals of shallow water flatfish by the JV and past domestic fisheries are found to have had a lingering adverse effect on the GOA shallow water flatfish populations.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960s-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the past foreign fisheries on the spatial/temporal distribution of the GOA shallow water flatfish assemblage stock is unknown. However, any effects on the spatial/temporal distribution are not expected to have had a lingering population effect.

External Climate Changes and Regime Shifts

Climate changes and regime shifts are identified as having potentially beneficial or adverse effects on the reproductive success of GOA shallow water flatfish. The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fishery (1968-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the past JV fisheries on the spatial/temporal distribution of the GOA shallow water flatfish assemblage is unknown. However, any effects on the spatial/temporal distribution are not expected to have had lingering population effects.

Change in Prey Availability

External Foreign Groundfish Fisheries (1960s-1976)

The foreign fisheries in the GOA are unlikely to have directly impacted the prey availability for the shallow water flatfish assemblage since these fish eat infaunal and epifaunal invertebrates. The lingering effect in the GOA shallow water flatfish stock is likely due to the natural events related to climate change.

External Climate Changes and Regime Shifts

The lingering adverse effect in the GOA shallow water flatfish stock is likely due to the natural events related to climate change. Although flatfishes tend to dominate catch during strong Aleutian Lows, on a microclimate scale, community structures changed in some nearshore areas with decreasing populations of shrimps and small forage fish, and increasing populations of the large fish-eating species, such as Pacific cod, and other flatfishes. Pacific cod, skates, and Pacific halibut are predators of the species of the shallow water flatfish assemblage.

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of the shallow water flatfish.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of the shallow water flatfish group.

Internal JV and Domestic Groundfish Fishery (1968-present)

The bycatch of juvenile crabs occurs in small numbers in domestic trawl fisheries. Crabs less than 25 mm in carapace width are estimated to have a selectivity of 0.001 in domestic fisheries from the snow crab assessment model. Combined with the fact that juvenile crab are only one component of the diet of yellowfin sole, these fisheries are not expected to impact the foraging capabilities of yellowfin sole.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960s-1976)

The statistics on the number of bottom trawls occurring in the GOA, and their effects on habitat are generally unknown. It is assumed that the effect of the foreign fisheries on habitat suitability is either beneficial or adverse; and the effects are found to have had a lingering influence in shallow water flatfish assemblage stocks.

External State of Alaska Scallop Fishery

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The State of Alaska scallop fishery has a history of being sporadic due to exploitation of limited stocks, market conditions, and availability of more lucrative fisheries. In 1999, only three boats fished for scallops (B. Bechtol, ADF&G, personal communication). While the effects of dredging on benthic habitat are intense, the magnitude of the overall impact of this fishery is likely to be small.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability in both stocks. When the Aleutian Low was strong, water temperatures were higher, and biomass in the catches was dominated by cod, pollock, and flatfishes. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of the shallow water flatfish group.

Internal JV and Domestic Groundfish Fishery (1968-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of these past fisheries on habitat suitability is either beneficial or adverse; and the effects are found to have had a lingering influence in the shallow water flatfish assemblage. The 1998 bottom trawl prohibition in the eastern area of 140°W may have had a beneficial effect on habitat suitability for flatfish in that area.

GOA Shallow Water Flatfish Assemblage Comparative Baseline

The 2001 biomass survey took place only in the central and western Gulf; therefore, the eastern GOA biomass has been estimated using the average of the 1993 through 1999 eastern GOA biomass estimates for all flatfish species except butter sole and English sole. Since the trends for butter sole in the central GOA are similar to their trends in the eastern GOA, the 2001 biomass estimates were obtained by applying the declining trend in biomass from 1999 to 2001 in the central GOA to the 1999 biomass in the eastern GOA. For English sole, the biomass estimate from 1999 was used without adjustment for the 2001 biomass.

Northern rock sole and butter sole have all decreased in 2001 relative to 1990s biomass estimates. Alaska plaice experienced an increase in biomass from 1993-1999; however, 2001 estimates show a decline in biomass. In contrast, southern rockfish and yellowfin sole both showed declines in years previous to 1999 with an increase in 2001 biomass estimates. Starry flounder has shown a continuous increase in biomass since 1990, while English sole increased from 1993-1999 and stabilized from 1999-2001. Sand sole has been variable over the years but has shown a slight increase between 1999 and 2001. Exploitable biomass estimates are assumed to be the same as the 2001 survey biomass results (Turnock *et al.* 2002b). Some experimental evidence indicates that flatfish biomass may be under estimated by the northeastern trawl (Weinberg 2003). Experiments are being conducted to estimate the herding component of catchability.

GOA Shallow Water Flatfish Assemblage Cumulative Effects Analysis Status

The GOA shallow water flatfish assemblage will be brought forward and examined as a group in the cumulative effects analysis.

3.5.1.18 GOA Flathead Sole

Life History and Distribution

Flathead sole (*Hippoglossus elassodon*) are distributed from northern California northward throughout Alaska. In the northern part of its range, the species overlaps with the related and very similar Bering flounder (*Hippoglossoides robustus*) (Wolotira *et al.* 1993, Hart 1973). Adults are benthic and occupy separate winter spawning and summer feeding distributions. From overwintering 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 late winter/early 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). Age and size at maturity are unknown, but recruitment to the fishery begins at age 3 (Figure 3.5-5). The maximum age from fishery age samples is 28 years. Flathead sole are taken in bottom trawls both as a directed fishery and in pursuit of other bottom dwelling species. Table 3.5-14 summarizes biological and reproductive attributes and habitat associations of flathead sole in the BSAI and GOA.

Trophic Interactions

Flathead sole feed primarily on invertebrates such as ophiuroids, tanner crab, bivalves and polychaetes. Their diet has been shown to include commercially important species such as pollock and tanner crabs. In the EBS, other fish species represented 5 to 25 percent of the diet (Livingston *et al.* 1993). Groundfish predators include Pacific cod, Pacific halibut, arrowtooth flounder, and also cannibalism by large flathead sole, mostly on fish less than 20 cm standard length.

GOA Flathead Sole Management

Beginning in 2002, flathead sole were managed independent of the other flatfish complex in the GOA. The projected spawning biomass for flathead sole is estimated above the $B_{40\%}$ biomass (38,163 mt), and is therefore evaluated under Tier 3a. The 2003 ABC equates to 41,390 mt, and the OFL equates to 51,556 mt (Table 3.5-28). The ABC and OFL are further apportioned to western, central, and west and east Yakutat GOA regions (Turnock *et al.* 2002c).

An age-structured model was developed for flathead sole in the 2002 GOA SAFE Report. This model includes age and biomass estimates from the 1984, 1993 and 1996 trawl surveys and length and biomass estimates from the 1987, 1990, 1999, and 2001 trawl surveys. CPUE data from the commercial fisheries was also used from 1985-2002 (Turnock *et al.* 2002c).

GOA Flathead Sole Past/Present Effects Analysis

The geographic scope for the GOA flathead sole past/present effects analysis is the same as the GOA management units (Figure 1.2-3). The temporal scope for this analysis begins in 1960s when the foreign flounder fishery started and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. The following direct and indirect effects were identified as potentially having population-level effects on GOA flathead sole:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery bycatch of prey species, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, marine pollution and oil spills, introduction of exotic species and climate changes and regime shifts (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following section explains any amendments specific to the flathead sole fishery. Amendments discussed in Section 3.2 which impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on flathead sole in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the flathead sole past/present effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (1960s-1976)
  - IPHC longline fisheries
  - State of Alaska scallop fisheries
  - State of Alaska crab fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1988)
  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements

- Industry initiated actions
- Foreign groundfish fishery initiated actions
- Preliminary groundfish FMPs (pre-MSA)
- FMP groundfish fisheries management

For a discussion of the past/present effects on the flathead sole, see the GOA shallow water flatfish past/present effects analysis (Section 3.5.1.5).

GOA Flathead Sole Comparative Baseline

Previous to 1981, flatfish were taken primarily by the foreign fisheries at about 15,000 mt annually. After the passage of the MSA in 1977, catches decreased to a low of 2,441 mt in 1986 and then steadily increased to a high of 43,107 mt in 1996. Flatfish declined in 1998 to 23,237 mt, increased to 37,303 mt in 2000, and declined again in 2001 to 31,734 mt. Flathead sole remain lightly harvested in 2002 at 2,029 mt as of October 5, 2002, a slight increase from 2001. The flatfish fishery is likely to be limited by the potential for high catches of Pacific halibut in the future (Turnock *et al.* 2002c).

Many flatfish species exhibited an increasing biomass trend in the 1980s and an decreasing trend in the 1990s. Flathead sole declined from 247,247 mt in 1990 to 170,915 mt in 2001. Exploitable biomass estimates are assumed to be the same as the 2001 survey biomass results (Turnock *et al.* 2002b). Some experimental evidence indicates that flatfish biomass may be underestimated by the northeastern trawl (Weinberg 2003), experiments are being conducted to estimate the herding component of catchability.

GOA Flathead Sole Cumulative Effects Analysis Status

GOA flathead sole will be brought forward for cumulative effects analysis.

3.5.1.19 GOA Arrowtooth Flounder

Life History and Distribution

Arrowtooth flounder (*Atheresthes stomias*) occur from central California to the Bering Sea, in waters from about 20-800 m (Zimmerman and Goddard 1996). 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). The maximum reported ages are 16 years in the Bering Sea, 18 years in the Aleutian Islands, and 23 years in the GOA (Turnock *et al.* 1997a, Wilderbuer and Sample 1997). Arrowtooth flounder is currently the most abundant groundfish species in the GOA; however, they are currently considered of low value and mostly discarded.

In the Bering Sea, the arrowtooth flounder inhabits the continental shelf waters almost exclusively until age-4, but at older ages occupies both shelf and slope waters, with greatest concentrations at depths between 100 and 200 m (Martin and Clausen 1995). The very similar Kamchatka flounder (*Atheresthes evermanni*) also occurs in the Bering Sea. 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). Table 3.5-16 summarizes biological and reproductive attributes and habitat associations of arrowtooth flounder in the BSAI and GOA.

Trophic Interactions

Arrowtooth flounder play an important role in the Bering Sea and GOA ecosystems because they are large, aggressive, and abundant predators of other groundfish species (Hollowed *et al.* 1995, Livingston 1991b, Yang 1993). The majority of prey by weight of arrowtooth flounders larger than 40 cm is pollock, the remainder consisting of herring, capelin, euphausiids, shrimp, and cephlapods (Yang 1993). These fish also consumed salmonids and Pacific cod in the GOA (Yang and Nelson 2000). The percent of pollock in the diet of arrowtooth flounder increases for sizes greater than 40 cm. Arrowtooth flounder 15-30 cm consume mostly shrimp, capelin, euphausiids and herring, with small amounts of pollock and other miscellaneous fish (DiCosimo 1998). Groundfish predators on arrowtooth include Pacific cod and pollock, which feed mostly on small fish (Livingston and deReynier 1996).

GOA Arrowtooth Flounder Management

For the GOA, arrowtooth flounder are also defined in Tier 3a of the ABC and OFL definitions. The 2003 stock assessment ABC (155,140 mt) was based on the $F_{40\%}$ fishing mortality rate because reliable estimates of F_{MSY} and B_{MSY} are unavailable. The 2003 ABC is further apportioned between the western, central, and west and east Yakutat/southeast outside GOA management units. The 2003 OFL value is based on the $F_{35\%}$ value and equates to 181,390 mt (Turnock *et al.* 2002a) (Table 3.5-28).

The stock assessment model used in the arrowtooth flounder assessment uses abundance estimates from IPHC trawl surveys, NOAA Fisheries groundfish surveys, and NOAA Fisheries triennial surveys. Fishery catch and size compositions were also used in the model. 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 an age-based stock assessment model. 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 assessment for 2002 adjusted the population sex ratio so that females were 70 percent of the population. Length frequency data were also incorporated to the 2002 assessment. The stock assessment is updated annually and incorporated into the GOA SAFE report (Turnock *et al.* 2001a).

GOA Arrowtooth Flounder Past/Present Effects Analysis

The geographic scope for the GOA arrowtooth flounder past/present effects analysis is the same as the GOA management units (Figure 1.2-3). The temporal scope for this analysis begins in the 1960s when the foreign fishery for flounders began, and ended in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-33 provides a summary of the arrowtooth flounder past effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on arrowtooth flounder:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery bycatch of prey species, marine pollution and oil spills, climate changes and regime shifts and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, introduction of exotic species and marine pollution and oil spills (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explains any management actions specific to the arrowtooth flounder. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on arrowtooth flounder in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the arrowtooth flounder past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1960s-1976)
  - IPHC longline fisheries
  - State of Alaska crab fisheries
  - State of Alaska groundfish fisheries
  - State of Alaska herring fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1990)
  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1960s-1976)

The Japanese and Soviet flounder fisheries both started as Pacific ocean perch fisheries in the early 1960s and switched to other target groundfish following the decline of Pacific ocean perch (NPFMC 2002b). Catch of arrowtooth flounder remained low from 1964 to 1973, when harvest peaked at 10,007 mt. Catch decreased to between 2,500 and 5,000 mt annually between 1974 and 1976 (Turnock *et al.* 2001a).

Although removals of arrowtooth flounder occurred during the foreign fisheries, there are no observable lingering adverse effects in the GOA arrowtooth flounder populations.

External IPHC Halibut Longline Fisheries and State of Alaska Crab Fisheries

The GOA bait fishery targeted pollock, Pacific cod, and various flounder species in order to provide needed bait for the crab and halibut fisheries. These fisheries took place from PWS west to the Aleutians, although most were landed in the Kodiak area (NPFMC 2002b). The amount of arrowtooth flounder caught in these fisheries is unknown.

Although removal of arrowtooth flounder occurred during the IPHC and crab bait fisheries, there are no observable lingering adverse effects in the GOA arrowtooth flounder populations.

Internal JV and Domestic Groundfish Fisheries (1968-present)

The domestic and JV flounder fisheries began in 1968, although catches of arrowtooth flounder were minimal throughout their duration (catches were dominated by foreign fisheries). From 1980-1990, annual harvest rates remained under 10,000 mt. JV fisheries were phased-out of the arrowtooth flounder fishery by 1990; however, the catch increased with the domestic fishery to a high of 24,252 mt in 2000. The average annual catch from 1990-2001 is approximately 18,000 mt. In 2000, the arrowtooth flounder trawl fishery was limited to bycatch only due to PSC limits for Pacific halibut in the central GOA management region (Turnock *et al.* 2001a).

Arrowtooth flounder is of low value and is typically caught as bycatch in the pursuit of more highly valued target species. Thus, arrowtooth flounder discard rates are high and corresponding percentages of retention are low. From 1991-2000, discard rates averaged 17,000 mt annually, with percent retention ranging from 10 to 43.2 percent. Retention has improved in recent years; 1999 and 2000 percent retention were 26.3 and 43.2 percent, respectively. Marketing efforts for arrowtooth flounder are expected to increase retention rates in coming years (Turnock *et al.* 2001a).

Although removals of arrowtooth flounder have occurred in the JV and past domestic fisheries, there are no observable lingering adverse effects on the GOA arrowtooth flounder populations.

Prior to 1990, arrowtooth flounder was reported as an aggregate of flatfish species. In 1990, NPFMC divided the flatfish assemblage into four categories; shallow water flatfish, deepwater flatfish, flathead sole and arrowtooth flounder. This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow water and deepwater flatfish species. Flathead sole was separated due to an overlap in depth distribution with the shallow water and deepwater groups. Arrowtooth flounder was separated from the other categories due to its high abundance and low commercial value.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960s-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the foreign fisheries on the spatial/temporal distribution of arrowtooth flounder in the GOA is unknown. However, these effects are determined to not have had lingering population effects on the stock.

External Climate Change and Regime Shift

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of arrowtooth flounder. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1968-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the direct JV fisheries on the spatial/temporal distribution of arrowtooth flounder in the GOA is unknown. However, these effects are determined to not have had lingering population effects in the stock.

Change in Prey Availability

External Foreign Groundfish Fisheries (1960s-1976)

Past foreign fisheries in the GOA have had either an adverse or beneficial lingering impact on prey availability. Arrowtooth flounder from 15-30 cm feed mostly on shrimp, euphausiids, capelin, and herring (DiCosimo 1998). Adults (fish over 40 cm) are almost exclusively piscivorus and over half their diet can consist of pollock (Hollowed *et al.* 1995, Livingston 1991b, Yang 1993). Therefore, arrowtooth flounder are important as a large and abundant predator of other groundfish species. In turn, the effects of the fisheries could have been beneficial or adverse since pollock prey on arrowtooth flounder.

Bycatch of forage species in the foreign GOA groundfish fisheries is likely to have been minimal. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that the groundfish fisheries would have had a significantly adverse impact on prey availability.

External State of Alaska Groundfish Fisheries and Herring Fisheries

Bycatch of forage species and juvenile pollock in the GOA State of Alaska groundfish fisheries is minimal and is unlikely to reduce the prey availability of arrowtooth flounder. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that State of Alaska herring fisheries would have a significantly adverse impact on prey availability.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. Arrowtooth flounder and other flatfishes increased with an increase in advection in the Alaska current. The controlling factor for these increases appears to be environmental, with changes seen in the species composition in nearshore areas. Increased flow around the GOA may enhance the supply of nutrients and plankton on the shelf and upper slope areas, resulting in an increase in productivity.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species arrowtooth flounder.

Internal JV and Domestic Groundfish Fisheries (1968-present)

Bycatch of forage species and juvenile pollock in the GOA groundfish fisheries is minimal. Furthermore, since arrowtooth flounder feed on a number of different prey species, it is also unlikely that the groundfish fisheries would have a significantly adverse impact on prey availability. BSAI/GOA Amendment 56/56 was established to protect forage fish species from developing into a fishery market, and to limit the forage fish bycatch.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960s-1976)

The statistics on the number of bottom trawls and their effects on habitat in the GOA pre-MSA are generally unknown. It is assumed that habitat suitability for the GOA stock has been either beneficially or adversely affected by the intensity of the past foreign fisheries, and these effects are considered to have lingering influence at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak

Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of arrowtooth flounder.

Internal JV and Domestic Groundfish Fisheries (1968-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Habitat suitability for the GOA stock has been either adversely or beneficially affected by the intensity of the past JV fisheries, and these effects are considered to have lingering influence at the population-level.

There are no indications that harvest conditions resulting from arrowtooth flounder management would alter the available prey in a manner that would impede long-term suitability of the stock.

GOA Arrowtooth Flounder Comparative Baseline

Small scale, nearshore surveys indicate that arrowtooth flounder may have been at low levels in the 1960s and 1970s. The AFSC gulfwide triennial surveys estimate that biomass increased to about 1,640,000 mt in 1996, declined to 1,262,797 mt in 1999, and is now at a very high and stable level. Since the eastern GOA was not surveyed in 2001, the average biomass in the eastern GOA for 1993-1999 was used to estimate the biomass for 2001 (Turnock *et al.* 2001a).

Age-3+ biomass increased from a low in 1961 to a high of 1,815,500 mt in 2002. The 2001 survey biomass estimate of 1,621,890 mt is slightly higher than the 1999 estimate. There is not enough information available to estimate recruitment of age-3 arrowtooth flounder for 1999-2001; however, model estimates show an increase of age-3 recruits in the 1970s and 1980s with a decrease in the 1990s (Turnock *et al.* 2002a).

GOA Arrowtooth Flounder Cumulative Effects Analysis Status

The GOA arrowtooth flounder will be brought forward for cumulative effects analysis.

3.5.1.20 GOA Deepwater Flatfish

GOA Deepwater Flatfish Assemblage

Greenland turbot, Dover sole, and deep-sea sole are members of the GOA deepwater flatfish assemblage. Section 3.5.1.9 discusses the life history, distribution, and trophic interactions for Greenland turbot in the

BSAI and GOA. Refer to Section 3.5.1.10 for a description of the life history, distribution, and trophic interactions of Dover sole and deep-sea sole, both members of the BSAI other flatfish assemblage.

GOA Deepwater Flatfish Management

The reference fishing mortality rate and ABC for the flatfish management groups are determined by the amount of population information available. ABCs for Dover sole 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 0.1 for Dover sole. Greenland turbot and deepsea sole are in Tier 6 because no reliable biomass estimates exist, where ABC = 0.75 OFL and the OFL = the average catch from 1978 to 1995 (238 mt) (Table 3.5-28). ABC is further apportioned among western, central, west and east Yakutat/southeast outside GOA management areas (Turnock *et al.* 2002b).

Stock assessment models are not used for the deepwater flatfish in the GOA due to the lack of available information. Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993, 1996, 1999, and 2001 are considered the best information available to determine stock biomass for all of the flatfish species in the GOA. The 2001 GOA survey effort did not encompass the eastern GOA and resulted in biomass in the eastern GOA being approximated using the average of the 1993-1999 GOA biomass estimates (Turnock *et al.* 2001b).

GOA Deepwater Flatfish Past/Present Effects Analysis

The geographic scope for the GOA the deepwater flatfish assemblage past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in the 1960s when the foreign flounder fishery began and ends in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-34 provides a summary of the GOA the deepwater flatfish assemblage past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA the deepwater flatfish assemblage:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate change and regime shifts (indirect effect).

- Changes in prey availability due to fishery catch/bycatch of prey species, climate changes and regime shifts, introduction of exotic species and marine pollution and oil spills (indirect effect).

- Changes in important habitat due to fishery gear impacts, climate changes and regime shifts, introduction of exotic species, and marine pollution and oil spills (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to the deepwater flatfish assemblage. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on the deepwater flatfish in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the deepwater flatfish assemblage past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1960s-1976)
  - State of Alaska scallop fisheries
  - State of Alaska crab bait fisheries
  - IPHC longline bait fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1988)
  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1960s-1976)

The Japanese and Soviet flounder fisheries both started as Pacific ocean perch fisheries in the early 1960s and switched to other target groundfish following the decline of Pacific ocean perch abundance (NPFMC 2002b). Previous to 1981, catches were about 15,000 mt annually for the entire flatfish assemblage, including arrowtooth flounder, (Turnock *et al.* 2001b).

Removals of deepwater flatfish by foreign fisheries are determined not to have had lingering adverse effects on the GOA deepwater flatfish populations.

External State of Alaska Bait Crab and IPHC Longline Bait Fisheries

The GOA bait fishery targeted pollock, Pacific cod, and various flounder species to provide needed bait for the crab and halibut fisheries. These fisheries took place from PWS west to the Aleutians, although most were landed in the Kodiak area (NPFMC 2002b). The amount of GOA deepwater flatfish caught in these fisheries is unknown, however there are no observable lingering adverse effects on the deepwater flatfish population.

Internal JV and Domestic Groundfish Fisheries (1968-present)

By 1986, the JV fisheries dominated the flatfish catch in the GOA; however, by 1988, the flatfish fishery was fully domesticated. Annual harvest started at a low of 2,441 mt and increased to the peak of 43,107 mt in 1996. Greenland turbot catch has been variable over the last decade, from 3,012 mt in 1992 to 13 mt in 1997. The most recent catch data current through November 3, 2001, indicates a decline from previous years at only 8 mt. Catches in the deepwater complex declined from 1999 to 985 mt in 2000 and are currently at 805 mt for 2001 (as of November 3). Most of the catch in the deepwater complex is Dover sole, although the catch of Greenland turbot has been variable over the last decade. In 1998 and 1999, the deepwater flatfish fisheries were closed due to PSC limits for Pacific halibut, and in 1999 the entire GOA was closed to trawl fisheries due to PSC limits for Pacific halibut (Turnock *et al.* 2001b).

In the GOA, Greenland turbot is managed as part of the deepwater flatfish assemblage. In 1990, NPFMC divided the flatfish assemblage into four categories; shallow water flatfish, deepwater flatfish, flathead sole and arrowtooth flounder. Greenland turbot fell into the deepwater flatfish category. This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow water and deepwater flatfish species. Arrowtooth flounder were separated from the other categories due to their high abundance and low commercial value. Flathead sole were separated due to an overlap in depth distribution with the shallow water and deepwater groups.

The removals of deepwater flatfish by JV and past domestic fisheries are determined not to have had lingering adverse effects of the GOA deepwater flatfish populations.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960s-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effects of the foreign fisheries on the spatial/temporal distribution of the GOA deepwater flatfish populations are unknown. Furthermore, it is unknown whether these effects are lingering at the population-level.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of the deepwater flatfish. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1968-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effects of the JV and domestic fisheries on the spatial/temporal distribution of the GOA deepwater flatfish populations are unknown. Furthermore, it is unknown whether these effects are lingering at the population-level.

Change in Prey Availability

External Foreign Groundfish Fisheries (1960s-1976)

The foreign fisheries in the GOA could have had lingering adverse or beneficial effects on the availability of prey for the deepwater flatfish assemblage. Pelagic fish are the main prey of these species, with pollock often a major species in the diet (Livingston 1991b). Deepwater flatfish also feed on squid, euphausiids, and shrimp; therefore, foreign fisheries are not expected to have significantly effected prey availability.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock, and flatfishes such as Greenland turbot. Community structure in nearshore areas around Kodiak Island changed in this same period, with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes. Greenland turbot and Pacific halibut responded more strongly to longer-term events (such as decadal-scale climate regime patterns). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor in the population.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of the deepwater flatfish group.

Internal JV and Domestic Groundfish Fisheries (1968-present)

The JV fisheries in the GOA could have had lingering adverse or beneficial effects on the availability of prey for the deepwater flatfish assemblage. However, since deepwater flatfish are found to feed on many species of fish (including pollock), squid, euphausiids, shrimp and some forage species, current management is not expected to alter the available prey in a manner that would impede long-term sustainability of the stocks in the GOA.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960s-1976)

The statistics on the number of bottom trawls and their effects on GOA pre-MSA are generally unknown. It is assumed that the effect of the past foreign fisheries on habitat suitability is either beneficial or adverse; overall, a lingering influence on the population is found in the GOA stock, probably mostly due to climatological effects.

External State of Alaska Scallop Fisheries

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The State of Alaska scallop fishery has a history of being sporadic due to exploitation of limited stocks, market conditions, and availability of more lucrative fisheries. In 1999, only three boats fished for scallops (B. Bechtol, ADF&G, personal communication). While the effect on benthic habitat of the dredging is intense, the magnitude of the overall impact of this fishery is likely to be small.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of deepwater flatfish group.

Internal JV and Domestic Groundfish Fisheries (1968-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the JV fisheries on habitat suitability is either beneficial or adverse; overall, a lingering influence on the population is found in the GOA stock, probably mostly due to climatological effects. Trawl closures (1998 and 1999) due to PSC limits for Pacific halibut reduce the intensity of the fishery on the deepwater flatfish assemblage habitat.

Furthermore, there are no indications that harvest conditions under current management would alter the population genetic structure, the available prey, or the suitability of nursery and/or spawning habitat in a manner that would impede long-term sustainability of the stock in both the BSAI and GOA.

GOA Deepwater Flatfish Comparative Baseline

The 2001 resource assessment trawl survey took place only in the central and western GOA; therefore eastern GOA biomass was estimated using the average of the 1993 to 1999 eastern GOA biomass estimates for all flatfish species except Dover sole. Since the trends in the central GOA for Dover sole are similar to their trends in the eastern GOA, the 2001 biomass estimates were obtained by applying the declining trend in biomass from 1999 to 2001 in the central GOA to the 1999 biomass in the eastern GOA.

Dover sole has decreased in 2001 relative to 1990s biomass estimates. Exploitable biomass estimates are assumed to be the same as the 2001 survey biomass results for Dover sole, but not Greenland turbot or deepsea sole (Turnock *et al.* 2002b). Some experimental evidence indicates that flatfish biomass may be underestimated by the northeastern trawl (Weinberg 2003). Experiments are being conducted to estimate the herding component of catchability.

GOA Deepwater Flatfish Cumulative Effects Analysis Status

The GOA deepwater flatfish assemblage will be brought forward for cumulative effects analysis.

3.5.1.21 GOA Rex Sole

Life History and Distribution and Trophic Interactions

The other flatfish species complex in the GOA is currently managed as four categories: shallow water flatfish, deepwater flatfish, flathead sole, and rex sole (*Errex zachirus*). Life history, distribution and trophic interactions for rex sole is described in the BSAI other flatfish, Section 3.5.1.10. Table 3.5-20 summarizes biological and reproductive attributes and habitat associations of selected flatfish in the BSAI and GOA.

GOA Rex Sole Management

The other flatfish species complex in the GOA is currently managed as four categories with separate ABCs: shallow water flatfish, deepwater flatfish, flathead sole, and rex sole. In 2002, flathead sole were separated from the other flatfish assemblage and assigned a separate ABC due to their overlap in depth distribution of the shallow and deepwater groups (see Section 3.5.1.7). In 1993, rex sole was split out of the deepwater management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery. The flatfish fishery in the GOA mainly targets rock sole (see Section 3.5.1.6), rex sole, and Dover sole. The flatfish catch is limited by halibut bycatch and does not reach the TAC for any species group (Table 3.5-28).

The reference fishing mortality rate and ABC for the rex sole are determined by the amount of population information available. ABCs are 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.

Stock assessment models were not used for this species due to the lack of information. Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993, 1996, 1999, and 2001 are considered the best information available to determine the stock biomass for rex sole (Turnock *et al.* 2002b).

GOA Rex Sole Past/Present Effects Analysis

The geographic scope for the GOA rex sole past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in the 1960s when the foreign flounder fishery began and ends in 2002, the most recent year for which stock assessment information exists.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-35 provides a summary of the GOA rex sole past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA rex sole:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery catch/bycatch of prey species, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to the rex sole. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on rex sole in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to the rex sole past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1960s-1976)
  - IPHC longline fisheries
  - State of Alaska scallop fisheries
  - State of Alaska crab fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1968-1990)
  - Domestic groundfish fisheries (1968-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

External Foreign Groundfish Fisheries (1960s-1976)

The Japanese and Soviet flounder fisheries both started as Pacific ocean perch fisheries in the early 1960s and switched to other target groundfish following the decline of Pacific ocean perch (NPFMC 2002b). Previous to 1981, catches were about 15,000 mt annually for the entire flatfish assemblage, including arrowtooth flounder, with catches dominated by the foreign fisheries. By 1986, the JV fisheries were taking a majority of the flatfish catch (Turnock *et al.* 2001b).

Removals of rex sole by the foreign fisheries are determined to have had an adverse effect on the rex sole population; however, these fisheries are determined not to have had lingering adverse effects on the GOA rex sole populations.

External IPHC Halibut Longline Fisheries and the State of Alaska Crab Fisheries

The GOA bait fishery targeted pollock, Pacific cod, and various flounder species in order to provide needed bait for the crab and halibut fisheries. Bait fisheries occurred from PWS west to the Aleutians, although the majority of the bait has been landed in Kodiak area (NPFMC 2002b). The amount of rex sole caught in these fisheries is unknown.

rex sole population, these fisheries are determined not to have had lingering population effects in the GOA rex sole stocks.

Internal JV and Domestic Groundfish Fisheries (1968-present)

After the passage of the MSA in 1976, catches decreased to a low of 2,441 mt in 1986 and then steadily increased to a high of 43,107 mt in 1996. Flatfish declined in 1998 to 23,237 mt, increased to 37,303 mt in 2000, and declined again in 2001 to 31,734 mt. Catch is currently reported by management areas; catch of each species is estimated by multiplying the fraction of each species observed in a particular group by the total catch for that group. The blend estimate is used as the estimated total catch. The rex sole catches have declined from 1999 to 2,939 mt in 2001 (Turnock *et at.* 2002b). The flatfish fishery is likely to be limited by the potential for high catches of Pacific halibut in the future.

The large removals of rex sole by the JV and past domestic fisheries are determined to have had an adverse effect on the GOA rex sole population and these effects are determined to be lingering at the population-level.

In 1990, NPFMC divided the flatfish assemblage into four categories; shallow water flatfish, deepwater flatfish, flathead sole, and arrowtooth flounder. This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow water and deepwater flatfish species. Arrowtooth flounder were separated from the other categories due to their high abundance and low commercial value. Flathead sole were separated due to an overlap in depth distribution with the shallow water and deepwater groups.

Rex sole were split out of the deepwater management category in 1993. Beginning in 1996, rock sole were split into two species, a northern (*Lepidopsetta sp. cf. bilineata*) and a southern rock sole (*Lepidopsetta bilineata*) (personal communication - Jay Orr as referenced in Turnock *et al.* 2001b) due to overlapping distributions.

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960s-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the past foreign fisheries on spatial/temporal distribution of the GOA rex sole population is unknown. However, these fisheries are determined not to have had any observable lingering adverse effects on the GOA rex sole population.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influence the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of rex sole. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1968-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV and past domestic fisheries on spatial/temporal distribution of the GOA rex sole population is unknown. However, these fisheries are determined not to have had any observable lingering adverse effects on the GOA rex sole population.

Change in Prey Availability

External Foreign Groundfish Fisheries (1960s-1976)

The foreign fisheries in the GOA are unlikely to have directly impacted prey availability for rex sole since these fish eat infaunal invertebrates. The lingering adverse effects in the rex sole GOA stock are likely due to the natural events related to climate changes.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the majority of the diet of rex sole.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of the other flatfish group.

Internal JV and Domestic Groundfish Fisheries (1968-present)

The JV fisheries in the GOA are unlikely to have directly impacted prey availability for rex sole since these fish eat infaunal invertebrates. The lingering adverse effects in the rex sole GOA stock are likely due to the natural events related to climate changes.

Change in Important Habitat

External Foreign Groundfish Fisheries (1960s-1976)

Statistics on the number of bottom trawls and their effects on GOA habitat are generally unknown. It is assumed that the effect of the foreign fisheries on habitat suitability is either beneficial or adverse and is found to have had a lingering influence in the GOA stock.

External IPHC Halibut Longline Fisheries and State of Alaska Scallop Fisheries

See Section 3.5.1.15 (change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of the IPHC halibut longline fisheries on habitat suitability is either beneficial or adverse and is found to have had a lingering influence in the GOA stock. The Alaska scallop fishery has a history of being sporadic due to exploitation of limited stocks, market conditions, and the availability of more lucrative fisheries. In 1999, only three boats fished for scallops (B. Bechtohl, ADF&G, personal communication). While the effect on benthic habitat of the dredging is intense, the magnitude of the overall impact of the fishery is likely to be small.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of the other flatfish group.

Internal JV and Domestic Groundfish Fisheries (1968-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of these fisheries on habitat suitability is either beneficial or adverse and is found to have had a lingering influence in the GOA stock. The 1998 and 1999 trawl closures, due to PSC halibut limits, help to reduce the intensity of the fishery on rex sole habitat.

GOA Rex Sole Comparative Baseline

The 2001 biomass survey took place only in the central and western Gulf; therefore, eastern GOA biomass have been estimated using the average of the 1993 to 1999 eastern GOA biomass estimates for rex sole.

Rex sole has decreased in 2001 relative to 1990s biomass estimates. Exploitable biomass estimates are assumed to be the same as the 2001 survey biomass results (Turnock *et al.* 2002b). Some experimental evidence indicates that flatfish biomass may be underestimated by the northeastern trawl (Weinberg 2003). Experiments are being conducted to estimate the herding component of catchability.

GOA Rex Sole Cumulative Effects Analysis Status

GOA rex sole will be brought forward for cumulative effects analysis.

3.5.1.22 GOA Pacific Ocean Perch

Life History and Distribution

Pacific ocean perch (*Sebastes alutus)* is primarily a demersal species that inhabits the outer continental shelf and slope regions of the NPO and the Bering Sea from southern California to Japan (Allen and Smith 1988). As adults, they live on or near the seafloor, generally in areas with smooth bottoms (Krieger 1993) and generally at depths ranging from 180-420 m. 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). The maximum recorded age of Pacific ocean perch is 100 years (Frimodt 1995). Table 3.5-22 summarizes biological and reproductive attributes and habitat associations of Pacific ocean perch in the BSAI and GOA.

The Pacific ocean perch were found to be genetically similar throughout their range based on allozyme variation (Seeb and Gunderson 1988); however, preliminary analysis using microsatellite DNA techniques suggests that genetically distinct populations of Pacific ocean perch exist (A.J. Gharrett personal communication, University of Alaska Fairbanks).

Trophic Interactions

During the summer of 1990, the diets of commercially important groundfish species in the GOA 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 Pacific ocean perch (Brodeur and Percy 1984, Yang 1996).

Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it is likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other demersal fish (NMFS 1997).

GOA Pacific Ocean Perch Management

In the GOA, Pacific ocean perch are managed as a sub-assemblage of the slope rockfish assemblage. Tier 3a is used to compute ABC and OFL for the Pacific ocean perch stock. The current female spawning biomass is 112,270 mt, leading to an OFL level of 16,240 mt. The ABC value for 2003 is 13,660 mt. The ABC value is apportioned over three areas: 2,700 mt for the western GOA, 8,510 mt for the central GOA, and 2,450 mt for the eastern GOA (Table 3.5-28). The OFL values are: 3,220 mt for the western GOA, 10,120 mt for the central GOA, and 2,900 mt for the eastern GOA. In order to prevent the eastern GOA TAC from being taken between 140° and 147°W, the area left open to trawling following the Amendment 58 trawl ban in the eastern area, a separate TAC of 810 mt has been assigned to the west Yakutat area within the eastern GOA (Heifetz *et al.* 2002).

GOA Pacific ocean perch are assessed with an age-structured model with allowance of size composition data. This model is derived from a generic rockfish model developed in a modeling workshop held in the Auke Bay Laboratory in February 2001. Data used in the model included total catch biomass (1961-2002), fishery size and age compositions, and survey age compositions and biomass estimates (Heifetz *et al.* 2001).

GOA Pacific Ocean Perch Past/Present Effects Analysis

The geographic scope for the Pacific ocean perch past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in 1961 when the foreign Pacific ocean perch fishery begins and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-36 provides a summary of GOA Pacific ocean perch past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA Pacific ocean perch:

- Mortality due to catch/bycatch marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to commercial whaling, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to GOA Pacific ocean perch. Amendments discussed in Section 3.2 which impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on Pacific ocean perch in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to GOA Pacific ocean perch past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1961-1975)
  - Commercial whaling
  - IPHC longline fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1979-1989)
  - Domestic groundfish fisheries (1970-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1961-1976)

The Soviet Union began targeting Pacific ocean perch in 1961, but had shifted to pollock, Atka mackerel, and flounders by the late 1960s and early 1970s due to decline in Pacific ocean perch stocks. The Soviet Union Pacific ocean perch fishery practiced pulse fishing, following the Pacific ocean perch throughout its range in the GOA from around the Shumagin Islands to the eastern area of southeastern Alaska. Soviet Union Pacific ocean perch catch peaked in 1965 at 300,000 mt, and declined thereafter, reaching an all-time low in 1970 at 9,000 mt. By this time, the Soviets had shifted to other target resources; however, catches rose again in 1975. From 1981 on, the Soviet Union was excluded from the GOA for political reasons (NPFMC 2002b).

The Japanese Pacific ocean perch fishery began in 1963 with their North Pacific trawl fishery. Maximum catch occurred in 1966 at 65,200 mt, followed by a decline to 4,948 mt in 1983. By the late 1960s and early 1970s, Japan had switched to other less heavily exploited species since Pacific ocean perch abundance was in a decline (NPFMC 2002b).

The Republic of Korea entered the GOA in 1972 and occasionally targeted Pacific ocean perch although their main target was pollock (NPFMC 2002b).

Past foreign fisheries are found to have overfished the GOA Pacific ocean perch populations, and these effects are lingering at the population-level.

Internal JV and Domestic Groundfish Fisheries (1970-present)

Commercial catch for slope rockfish was not reported separately until 1988. Previously they were listed as part of the Pacific ocean perch complex. Foreign fisheries continued to dominate harvests from 1977 to 1984, with Japan taking a majority of the catch. Catch reached a minimum in 1985 following a ban on foreign trawling in the GOA (NPFMC 2002b).

The past JV fisheries began in 1979, taking relatively small catches throughout their duration. The JV fisheries harvest peak occurred in 1983 at 1,975 mt. The domestic fishery for slope rockfish began in 1970; however, this fishery did not start taking significant amounts of slope rockfish until 1985. By 1989, the GOA slope rockfish fishery had become completely domesticated. The domestic fishery developed rapidly, from 825 mt in 1985 to 21,114 mt by 1990 (Heifetz *et al.* 2002).

The slope rockfish assemblage was divided into three management subgroups in 1991: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, the northern rockfish subgroup was created. These groups were created in order to prevent overfishing of the most desirable species. The groups are assigned separate TACs instead of a single group slope rockfish group TAC, as was done prior to 1991. The TACs are further subdivided into the three management areas within the GOA to avoid spatial/temporal concentration of the catch. These TAC apportionments are based on distributions of exploitable biomass. The GOA domestic fishery catch of Pacific ocean perch has been variable over the years (1991-2001), from a low of 1,853 mt in 1994 to a high of 10,972 mt in 2001 (Heifetz *et al.* 2001). The Pacific ocean perch catch has been constrained in recent years due to PSC limits of halibut and bycatch of other species.

The large removals of Pacific ocean perch that occurred during the JV and past domestic fisheries are found to have had an adverse effect GOA Pacific ocean perch populations. These effects are determined to be lingering at the population-level.

In 1994, GOA FMP Amendment 32 established a rebuilding plan for GOA Pacific ocean perch to minimize mortality. This plan was necessary to maximize the probability of rebuilding success in a realistic time period. As a result of increased concern about the status of Pacific ocean perch stocks, biomass assessment methodology has been improved and domestic harvest levels were reduced during the early to mid-1990s (NPFMC 2002b). After 1995, the Pacific ocean perch biomass began increasing at a fast pace in response to several strong year-classes. The rebuilding plan was revised under GOA FMP Amendment 38 in 1996 to allow the Pacific ocean perch TAC to be set at or below the rebuilding formula, but NPFMC did not invoke that measure because the stock met the rebuilding goal. Pacific ocean perch were considered rebuilt in 1997 and the species biomass has increased steadily through 2001 (Heifetz *et al.* 2002).

Discard rates for Pacific ocean perch have varied over the years (1991-2001), but are relatively low throughout with the exception of 1993 and 1994. In 1993 and 1994, discard rates were 79.2 and 60.3 percent, respectively, due to the bycatch-only status of the fishery. Typically, the discard rate is between about 8-20 percent and has declined in recent years (8.5 percent in 2001). Bycatch rates of Pacific ocean perch are highest in PSR, other slope rockfish, and shortspine thornyhead fisheries (Heifetz *et al.* 2001).

Change in Reproductive Success

External Foreign Groundfish Fisheries (1961-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the foreign fisheries on the spatial/temporal distribution of the GOA Pacific ocean perch populations due to the spatial/temporal concentration of the fisheries is unknown. However, any possible effects are not expected to have lingering effects in the populations.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan et al. (1998), Hollowed et al. (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of Pacific ocean perch. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1970-present)

Spatial/Temporal Concentration of Catch/Bycatch

The effect of the JV and past domestic fisheries on the spatial/temporal distribution of the GOA Pacific ocean perch populations due to the spatial/temporal concentration of the fisheries is unknown. However, any possible effects are not expected to have lingering effects in the populations. 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 (Heifetz *et al.* 2002).

As mentioned above, the apportionment of the TACs into GOA management areas for each slope rockfish subgroup helps to reduce the spatial/temporal concentration of the fishery. In 1998, GOA FMP Amendment 58 was passed prohibiting the use of trawl gear in the eastern area of the GOA east of 140°W longitude. However, there are concerns that the entire eastern TAC for slope rockfish, particularly Pacific ocean perch, could be taken in a small area in the eastern unit that is still open to trawling. As explained under GOA slope rockfish management, the eastern GOA TAC is further apportioned into east and west Yakutat Districts to prevent the entire eastern area TAC from being taken in the east Yakutat/southeast outside unit (Heifetz *et al.* 2002).

Change in Prey Availability

External Commercial Whaling

Whaling is identified as having a past beneficial effect on prey availability for all Pacific ocean perch stocks, since 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). A reduction in baleen whale populations could mean that more euphausiids would be available for use by Pacific ocean perch. Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon and benthic juveniles are eaten by lingcod and other demersal fish (NMFS 1997).

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. Populations of Pacific ocean perch have rebounded from low population-levels. The controlling factor for these increases appears to be environmental, with changes in the species composition in nearshore areas linked to an increase in advection in the Alaska current. Increased flow around the GOA may enhance the supply of nutrients and plankton on the shelf and upper slope areas, resulting in an increase in productivity.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of Pacific ocean perch.

Change in Important Habitat

External Foreign Groundfish Fisheries (1961-1976)

Statistics on the number of bottom trawls and their effects on GOA habitat pre-MSA is generally unknown. However, the effect of the foreign fisheries on habitat suitability is negative for the GOA stock and is found to have had a lingering adverse influence in the stocks. The intense trawling of the foreign, JV and past domestic fisheries is the likely cause of this lingering effect. Prior to 1996, more than 90 percent of slope rockfish were taken by large factory-trawlers.

External IPHC Longline Fisheries

The impacts of IPHC longline gear on Pacific ocean perch habitat have been identified as adverse effects. Intense longline fishing is likely to have caused Pacific ocean perch habitat degradation and disruption of Pacific ocean perch spawning and/or rearing grounds. This effect is still lingering at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of Pacific ocean perch.

Internal JV and Domestic Groundfish Fisheries (1970-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The effect of past JV fisheries on habitat suitability is adverse for the GOA stock and is found to have had a lingering adverse influence in the stocks. The intense trawling of the foreign, JV and past domestic fisheries is the likely cause of this lingering effect. Prior to 1996, more than 90 percent of the slope rockfish were taken by large factory-trawlers. After 1996, smaller shore-based trawling began taking a larger catch. From 1993-2000, longline catches of shortraker/rougheye rockfish have increased to 30 to 48 percent of the annual catch and a larger portion of Pacific ocean perch have been taken by pelagic trawls. The percentage of Pacific ocean perch taken by pelagic trawls has increased from 2 to 8 percent in 1990-1995 to 14 to 20 percent in 1996-1998.

GOA Pacific Ocean Perch Comparative Baseline

Triennial trawl surveys have been conducted in the GOA since 1984 and are now conducted biennially starting in 2001. The 2001 trawl survey did not survey the eastern GOA; therefore, biomass estimates for that area are based on an average of 1993, 1996 and 1999 biomass estimates. The 2001 trawl survey indicates that Pacific ocean perch was the most abundant species with an estimated biomass of 858,982 mt, 61.9 percent of the total slope rockfish biomass. The 2001 biomass estimates for Pacific ocean perch are greatly influenced by large catches in one or two hauls, resulting in higher variance of biomass.

When comparing the trawl surveys from 1984-2001, Pacific ocean perch biomass estimates were relatively low in 1984-1990, increased in 1993 and 1996. and remained high in 1999 and 2001. Variance in biomass estimates is attributed to anomalously large individual hauls (as in 1999 and 2001), and to a change in availability of rockfish to the survey caused by unknown behavioral or environmental factors. Causes of changes in biomass estimates can not be determined until more is known about rockfish behavior.

GOA Pacific Ocean Perch Cumulative Effects Analysis Status

GOA Pacific ocean perch will be brought forward for cumulative effects analysis.

3.5.1.23 GOA Thornyhead Rockfish

Life History and Distribution

Thornyhead rockfish in Alaskan waters are comprised of two species, the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis*). Only the shortspine thornyhead is of commercial importance and it is now one of the most commercially valuable rockfish species. Thornyheads are a demersal species found in deepwater, from 94 m to 1,460 m, from the Bering Sea and GOA to Baja California (Gaichas and Ianelli 2001). Little is known about thornyhead life history. Like other rockfish, they are long-lived and slow-growing. The maximum recorded age is in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 years and 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. The shortspine thornyhead is managed as a single stock in its own management group in the GOA; however, this species and the longspine thornyhead are managed as part of the other rockfish assemblage in the BSAI (see Section 3.5.1.13). Table 3.5-26 summarizes biological and reproductive attributes and habitat associations of thornyhead rockfish in the BSAI and GOA.

Trophic Interactions

Yang (1993 and 1996) and Yang and Nelson (2000) showed that shrimp, mainly pandalids, were the most important food of the thornyhead. Tanner crabs comprised less than 7 percent by weight of stomach contents, and fish such as pollock, capelin, and sculpins comprised about 15 percent. Other prey items for thornyheads included polychaetes, mysids, amphipods, and other crabs. California sea lion (Lowry *et al.* 1990) and sablefish (Orlov 1997) have both been documented as predators of shortspine thornyhead.

GOA Thornyhead Rockfish Management

Up until 2003, thornyhead rockfish were managed under Tier 3 of the GOA groundfish FMP. Due to uncertainty associated with model estimates of natural mortality and other parameters, GOA thornyhead rockfish estimates of ABC and OFL were based on Tier 5. The recommended ABC is 1,940 mt (Table 3.5-28). ABC and OFL have been further apportioned to the western, central, and eastern GOA (Gaichas and Ianelli 2002).

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 to 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 determination on this species has not been done.

Biologically, the greatest area of uncertainty for this species is in their longevity and natural mortality rate. Currently, NOAA Fisheries scientists believe they are slow-growing and long-lived fish that are relatively sedentary on the ocean floor. Recent research based on reproductive information of west coast and Alaska populations indicates that shortspine thornyheads are very long-lived (Pearson and Gunderson in review) with lower natural mortality rates than previously predicted and higher maximum ages (250-350 years). Radiometric analysis suggests that the maximum age is between 50-100 years (Kastelle *et al.* 2000, Cailliet *et al.* 2001), although these are high-variance estimates. Alternative models to estimate natural mortality rates were run during the 2001 and 2002 stock assessments using radiometric and conventional analyses (Kline 1996) and the Kastelle *et al.* (2000) analysis; however, none of the models was a substantial improvement from the base model.

GOA Thornyhead Rockfish Past/Present Effects Analysis

The geographic scope for the thornyhead rockfish past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in the late 1800s when the U.S. and Canadian trawl fisheries began exploiting deepwater demersal communities, and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-37 provides a summary of GOA thornyhead rockfish past/present effects analysis presented below. The following direct and indirect effects were identified as potentially having population-level effects on GOA thornyhead rockfish:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).

- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).

- Change in prey availability due to fishery bycatch of prey species, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

- Change in important habitat due to fishery gear impacts, climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to GOA thornyhead rockfish. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here. Sections 3.5.1.11 and 3.5.1.12 discuss management measures for Pacific ocean perch and rockfish, respectively.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on thornyhead rockfish in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regimes shifts.

The past/present events determined to be applicable to GOA thornyhead rockfish past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (late 1800s-1976)
  - State of Alaska shrimp fisheries
  - IPHC longline fisheries
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1983-1990)
  - Domestic groundfish fisheries (1983-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (late 1800s-1976)

Thornyheads have been fished in the northeastern Pacific ocean since the late 1800s as part of the deepwater demersal fish community. U.S. and Canadian trawls were the first to fish thornyheads commercially. Soviet, Japanese, and Republic of Korea vessels began fishing for thornyheads in the mid-1960s (Chitwood 1969). Thornyheads have been lightly exploited throughout the history of the fishery. From 1967 to 1977, annual harvest never exceeded 2,000 mt. Catches were made by trawl and hook and line gear, although trawl gear has taken the majority of catch. Foreign harvest peaked in 1973 at 1,565 mt. Catch data from 1967-1980 are based on U.S. Foreign Observer Program reports, Pacific Fishery Information Network reported landings, and reports compiled by French *et al.* (1977) and Wall *et al.* (1978-1981) (Gaichas and Ianelli 2001).

Removals of thornyhead rockfish by the foreign fisheries are determined to have had an adverse effect on the GOA thornyhead rockfish populations; furthermore, these effects are lingering at the population-level.

External IPHC Longline Fisheries

Thornyhead rockfish have been and continue to be caught as bycatch in the IPHC longline fishery. The amount of this bycatch is unknown, although it is expected to be minimal. The IPHC longline fishery is not expected to have a significant impact on the GOA thornyhead rockfish population.

Internal JV and Domestic Groundfish Fisheries (1983-present)

Since 1983, the Observer Program has monitored thornyhead rockfish as part of the JV fisheries, and thornyheads have been monitored as a separate group in the domestic fisheries since 1984. Foreign fishery catch continued to exceed JV and domestic catch until 1985. By 1989, the domestic fishery had reached its peak catch of 3,080 mt. Average catch from 1996-2000 is about 1,260 mt annually (Gaichas and Ianelli 2001).

Thornyhead rockfish are caught primarily as bycatch in other target fisheries. 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 in the rockfish and combined flatfish fisheries.

The removals of thornyhead by the JV and past domestic fisheries are found to have had an adverse effect on the GOA thornyhead population; however, it is uncertain whether the removals by these fisheries have had a lingering adverse effect on the GOA thornyhead populations.

Change in Reproductive Success

External Foreign Groundfish Fisheries (late 1800s-1976)

Spatial/Temporal Concentration of Catch/Bycatch

The effects of the foreign fisheries on the spatial/temporal distribution of the GOA thornyhead rockfish populations due to the spatial/temporal concentration of the fishery are unknown. Although, historical removals of thornyhead rockfish appear to be more concentrated in the central region of the GOA, there do not appear to be any observable lingering adverse effects on the population (Ianelli and Ito 1995).

External IPHC Longline Fisheries

Thornyhead rockfish have been and continue to be caught as bycatch in the IPHC longline fishery. The amount of this bycatch is unknown, although it is expected to be minimal. The IPHC longline fishery is not expected to have a significant impact on the GOA thornyhead rockfish population.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influences the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of thornyhead rockfish. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (1983-present)

Spatial/Temporal Concentration of Catch/Bycatch

Based on foreign historical trends, the concentration of thornyhead rockfish catch appears to be in the central GOA region. Researchers have recommended further apportionment of thornyhead TAC into management units to avoid concentration of catch in the future. Furthermore, the trawl closure of part of the eastern area east of 140°W in 1998 (GOA FMP Amendment 58) may led to concentration of catch in the small area of the eastern management area that has not been closed to trawl gear.

Change in Prey Availability

External Foreign Groundfish Fisheries (late 1800s-1976)

Effects of the foreign fisheries on prey availability in the stock are unknown. However, it is unlikely that the foreign groundfish fisheries have had an adverse impact on thornyhead rockfish prey availability since the majority of thornyhead prey is pandalid shrimp.

External State of Alaska Shrimp Fisheries

Effects of State of Alaska shrimp fisheries on the prey availability of thornyhead rockfish are potentially adverse; however, due to the localized nature of these fisheries, they are unlikely to have a population-level effect.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5). Due to the ambiguity in the effects related to climate change, the overall lingering influence on competition for prey is unknown.

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes the part of the diet of thornyhead rockfish.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of thornyhead rockfish.

Internal JV and Domestic Groundfish Fisheries (1983-present)

The effects of the JV and domestic groundfish fisheries on thornyhead rockfish prey availability is unknown, however the effects are expected to be minimal since the majority of thornyhead rockfish prey is made up of pandalid shrimp.

Change in Important Habitat

External Foreign Groundfish Fisheries (late 1800s-1976)

Statistics on the number of bottom trawls and their effects on GOA habitat pre-MSA is generally unknown. Effects of the foreign fisheries on habitat suitability in the stock are not identified.

External IPHC Longline Fisheries

The IPHC longline fishery has and continued to overlap with thornyhead rockfish habitat. IPHC longline fishery gear may negatively contribute to GOA thornyhead rockfish degradation, although the magnitude of this effect is unknown.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5). Due to the ambiguity in the effects related to climate change, the overall lingering influence on habitat suitability is unknown.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of thornyhead rockfish.

Internal JV and Domestic Groundfish Fisheries (1983-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

Closure of the eastern management area east of 140°W in 1998 to trawl gear may reduce the intensity of the fishery on thornyhead rockfish habitat. However, those areas in the eastern region not closed to trawl gear may become more intensely fished, or there may be a shift to greater use of longline gear in the areas closed to trawl.

GOA Thornyhead Rockfish Comparative Baseline

Survey and fishery catch rates indicate that shortspine thornyheads are relatively evenly distributed within their habitat and, like many other groundfish species, do not tend to form dense aggregations. 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 (for further information on surveys see Appendix B). Fishery data include estimates of the total catch and size distribution information by gear type.

Longline surveys have also been used to estimate abundance of thornyheads in the GOA since 1979. However, the use of the longline survey has been questioned since data show there is an interaction between sablefish and thornyhead abundance. Sigler and Zenger (1994) found that as thornyhead abundance decreased, sablefish abundance increased. Research is underway to evaluate the hook competition between thornyheads and sablefish, and a thornyhead tagging study is being conducted to learn about the movement and growth rates of these species (Gaichas and Ianelli 2001).

Modeling results indicate that the abundance of shortspine thornyheads has remained relatively stable since 1970. Recruitment is highly variable, although several strong year-classes are apparent. Since thornyheads are long-lived and slow growing it is difficult to determine the precise strong year-classes.

GOA Thornyhead Rockfish Cumulative Analysis Status

GOA thornyhead rockfish will be brought forward for cumulative effects analysis.

3.5.1.24 GOA Rockfish

Life History and Distribution

Northern rockfish (*Sebastes polyspinis*) inhabit the outer continental shelf from the EBS, throughout the Aleutian Islands and the GOA (Kramer and O'Connell 1988). This species is semidemersal and is usually found in comparatively shallower waters off the outer continental slope (from 50-600 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. Like other members of the genus *Sebastes*, they bear live young, and birth occurs in the early spring through summer (McDermott 1994). Northern rockfish are managed as part of the slope rockfish assemblage in the GOA.

Table 3.5-27 summarizes biological and reproductive attributes and habitat associations for selected rockfish species in the BSAI and GOA.

Shortraker (*Sebastes borealis*) and rougheye rockfish (*S. aleutianus*) inhabit the outer continental shelf of the NPO from the EBS as far south as southern California (Kramer and O'Connell 1988). Adults of both species are semidemersal and are usually found in deeper waters (from 50 m to 800 m) and over rougher bottoms than Pacific ocean perch (Krieger and Ito 1999). 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. Like other members of the genus *Sebastes*, they are viviparous (bear live young), and birth occurs in the early spring through summer (McDermott 1994).

Both species are associated with a variety of habitats, from soft to rocky bottoms, although boulders and sloping terrain appear also to be desirable habitat (Krieger and Ito 1999). Length at 50 percent sexual maturity is about 45 cm for shortraker rockfish and about 44 cm for rougheye rockfish (McDermott 1994). Shortraker and rougheye rockfish are managed as part of the slope rockfish assemblage in the GOA.

Numerous other rockfish species of the genus *Sebastes* have been reported in the GOA (as managed as other slope rockfish) and BSAI (managed as other rockfish) (Eschmeyer *et al.* 1984), and several are of commercial importance. Most are demersal or semidemersal, with different species occupying different depth strata (Kramer and O'Connell 1988). Other slope rockfish inhabit waters of the outer continental shelf and continental slope of the GOA as adults at depths greater than 150-200 m. All are viviparous (Hart 1973). Life history attributes of most of these rockfish are poorly or virtually unknown. Because they are long-lived and slow-growing, natural mortality rates are probably low. 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, 6 species alone make up 95 percent of the catch and estimated abundance. These six species include the sharpchin, redstripe, harlequin, silvergrey, yellowmouth, and redbanded rockfishes. In the BSAI, the other rockfish species assemblage comprises 28 species, several of which are classified in different groups in the GOA. Shortspine thornyheads are managed as part of the other rockfish species in the BSAI; however, it is managed as part of the thornyhead rockfish assemblage in the GOA (see Section 3.5.1.12).

Genetic studies are currently underway assessing the genetic stock structure of some species of slope rockfish. Some studies examining the differences among areas in age composition, growth, fecundity, and prevalence of parasites suggest that separate populations exist in the adult stage of some rockfish (Leaman and Kabata 1987, Moles *et al.* 1998). Two genetically distinct populations of rougheye rockfish with partially overlapping geographic ranges were found by Hawkins *et al.* (1997) and Gharrett and Gray (1998), and confirmed with recent mitochondrial and microsatellite analyses (personal communication, A.J. Gharrett, University of Alaska Fairbanks).

The GOA PSR group includes: dusky rockfish (*Sebastes ciliatus*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelys*). Dusky rockfish is by far the most important species in the group, both in terms of abundance and commercial value. PSR inhabit waters of the continental shelf of the GOA and typically exhibit midwater, schooling behavior. The dusky rockfish has the northernmost distribution of all the rockfish species in the Pacific Ocean, ranging from British Columbia north to the Bering Sea and west to Hokkaido Island of Japan, but is most abundant in the GOA. Studies are underway that indicate the occurrence of two distinct species of dusky rockfish in the GOA, a dark-colored and light-colored variety (Seeb 1986 and 2000, Orr and Blackburn 2000). In the GOA, nearly all dusky rockfish considered are of the light-colored variety. These species are managed as the PSR assemblage in the GOA and as part of the other rockfish species assemblage in the BSAI.

GOA DSR include seven species of nearshore, bottom-dwelling rockfish: canary rockfish (*Sebastes pinniger)*, China rockfish (*S. nebulosus)*, copper rockfish (*S. caurinus)*, quillback rockfish (*S. maliger)*, rosethorn rockfish (*S. helvomaculatus)*, tiger rockfish (*S. nigrocinctus)*, and yelloweye rockfish (*S. ruberrimus*). DSR are nearshore, bottom-dwelling species that occur on the continental shelf and are generally associated with rugged, rocky habitat. 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 inhabit areas of rugged, rocky relief, and adults appear to prefer complex bottoms with the presence of "refuge spaces" (O'Connell and Carlile 1993). All of the DSR are slow-growing and very long-lived; the yelloweye rockfish have been estimated to reach an age of 118 years (Adams 1980, Gunderson 1980, Archibald *et al.* 1981). DSR are classified as ovoviviparous (eggs hatch within the females body). Rockfish have internal fertilization and several months separating copulation, fertilization, and parturition (giving birth). Parturition typically occurs from February through September with most species extruding larvae in late winter and spring. Yelloweye rockfish extrude larvae over an extended period, with the peak occurring in April and May (O'Connell 1987). Demersal rockfish have a closed swim bladder, which makes them susceptible to embolism mortality when brought to the surface from depth. Therefore, most species are fatally injured even when caught as discard in other fisheries. The DSR are managed as an assemblage in the GOA; the canary rockfish, copper rockfish, rosethorn rockfish, and tiger rockfish are managed as part of the other rockfish assemblage in the BSAI.

Trophic Interactions

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.

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; however, 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).

The diet of the other slope rockfish (GOA) and other rockfish species (BSAI) for which dietary information exists seems to consist primarily of planktonic invertebrates (Yang 1993 and 1996). Predators of other slope rockfish are also not well documented, but likely include larger fish, such as Pacific halibut, which are known to prey on other rockfish species.

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.

Yelloweye rockfish are large, predatory fishes that usually feed 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, sand lance, and Puget Sound rockfish (*S. empheaus*) were particularly dominant. Shrimp are also an important prey item (Rosenthal *et al.* 1988).

GOA Rockfish Management

In the GOA, northern rockfish are managed as a sub-assemblage of the slope rockfish assemblage. Tier 3a is used to compute the ABC and OFL values for northern rockfish. The current female spawning biomass for 2002 is 40,070 mt, greater than the $B_{40\%}$ value. The ABC value for 2003 equates to 5,530 mt, and the OFL value equates to 6,560 mt. ABC was apportioned in the western and central areas of the GOA. Northern rockfish are combined with other slope rockfish in the eastern GOA (Heifetz *et al.* 2002).

The northern rockfish group is assessed based on an age-structure model. Data used in this model include triennial survey biomass estimates and fishery catch, age, and size compositions. Natural mortality was fixed at an independently estimated value, and a single selectivity was assumed for the fishery and the survey.

In the GOA, shortraker and rougheye rockfish are managed as a sub-assemblage of the slope rockfish assemblage. GOA shortraker rockfish are managed in Tier 5 and rougheye rockfish are managed under Tier 4, but both have their own TAC-setting processes separate from other rockfish species in the other slope rockfish assemblage. The average exploitable biomass for the shortraker/rougheye and other slope rockfish groups is estimated by the unweighted average of the last three trawl survey results, excluding biomass in the 1-100 m depth stratum. The exploitable biomass for 2003 is 66,830 mt for the shortraker/rougheye group and 107,962 mt for other slope rockfish. According to ABC and OFL definitions, other slope rockfish are placed in Tier 5 where ABC is determined by $F = 0.75M$. Sharpchin are assessed under Tier 4 where OFL is calculated by $F = M$. This equates to an ABC value of 5,050 mt and an OFL value of 6,610 mt for the other slope rockfish group (Heifetz *et al.* 2002). Table 3.5-28 shows the ABC and OFL values for the more common species in the slope rockfish group. For management information on Pacific ocean perch as a member of the slope rockfish assemblage, see Section 3.5.1.11.Efforts have been made to assess rougheye rockfish using an age-structured model; however, development of this model is still in preliminary stages.

The PSR group includes dusky rockfish, yellowtail rockfish and widow rockfish. Beginning with the 2001 stock assessment, dusky rockfish were assessed separately from the larger PSR group since dusky rockfish compose nearly all the biomass. In 2003, dusky rockfish were moved up to Tier 3a, with an age-structured model, while yellowtail and widow rockfish are still managed under Tier 5. The dusky rockfish ABC value is computed using an $F = M$ strategy rather than $F_{40\%}$ due to concerns of unreliable biomass estimates. This equates to an ABC value of 5,070 mt. Yellowtail and widow rockfish ABC values were computed using $F = 0.75M$, equating to an ABC value of 415 mt (Table 3.5-28). These ABC values are apportioned over the western, central and eastern GOA. The Plan Team has recommended that the eastern ABC values be further apportioned over the west Yakutat and the east Yakutat/southeast outside regions at 640 mt and 860 mt, respectively (Clausen *et al.* 2002).

The DSR assemblage includes seven species of rockfish: canary rockfish, China rockfish, copper rockfish, quillback rockfish, rosethorn rockfish, tiger rockfish, and yelloweye rockfish. The yelloweye rockfish is the dominant species in this assemblage. These species are managed jointly by the NOAA Fisheries and the State of Alaska as a distinct assemblage only off the SEO east of 140°W, an area that is further divided into four management units along the outer coast: the south SEO, central SEO, north SEO, and east Yakutat. Two internal state water subdistricts (north southeast Inside District and south southeast Inside District) are managed entirely by the state. Yelloweye rockfish comprise 90 percent of the catch and will be the focus of this section. DSR 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 is set aside for bycatch.

DSR falls into Tier 4 of the ABC and OFL definitions. Under these definitions, the OFL mortality rate is $F_{35\%} = 0.028$ (540 mt), and the maximum allowable fishing mortality rate for ABC is $F_{40\%} = 0.025$. 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 DSR species, the recommended 2003 ABC is 390 mt. The total exploitable biomass estimate for 2003 is 17,510 mt, a 10 percent increase from the 2002 estimate. Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates (O'Connell *et al.* 2002).

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, the ADF&G is continuing research to develop and improve a stock assessment approach for them. As part of that research, a manned submersible, Research Vessel (R/V) *Delta*, has been used to conduct line transects (Burnham *et al.* 1980). Density estimates are limited to adult yelloweye, because it is the principal species targeted and caught in the fishery; therefore, ABC and 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 DSR habitat (O'Connell and

Carlile 1993). Both transect line lengths and total area of rocky habitat are difficult to estimate, resulting in some uncertainty in the biomass estimates.

GOA Rockfish Past/Present Effects Analysis

The past/present effects analysis for all species of GOA rockfish are presented in this section and in Table 3.5-38. Species-specific information in noted when applicable. The geographic scope for the rockfish past/present effects analysis is the same as the GOA management areas (Figure 1.2-3). The temporal scope for this analysis begins in 1962, when the foreign rockfish fisheries began and ends in 2002, the most recent year for which stock assessment information is available.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. The following direct and indirect effects were identified as potentially having population-level effects on GOA rockfish species:

- Mortality due to catch/bycatch and marine pollution and oil spills (direct effect).
- Change in reproductive success due to spatial/temporal concentration of catch/bycatch and climate changes and regime shifts (indirect effect).
- Change in prey availability due to climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).
- Change in important habitat due to climate changes and regime shifts, marine pollution and oil spills and introduction of exotic species (indirect effect).

Section 3.2 contains brief explanations of all the FMP amendments that impact the target species. The following sections explain any management actions specific to GOA rockfish. Amendments discussed in Section 3.2 that impact the target fisheries as a whole are not repeated here.

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on rockfish in the GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the Pacific Northwest to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section 3.10.1.5 for documentation of occurrences of unusual species in the GOA as influenced by climate changes and regime shifts.

The past/present events determined to be applicable to GOA rockfish past/present effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (1962-1976)
  - State of Alaska groundfish fisheries (DSR and some slope rockfish species, i.e. rougheye and yelloweye rockfish)

  - IPHC longline fishery
  - State of Alaska shrimp fisheries (pelagic and DSR and some slope rockfish species)
  - State of Alaska herring fishery (DSR)
  - Commercial whaling
  - Marine pollution and oil spills
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (1976-1985)
  - JV groundfish fisheries (1980-1990)
  - Domestic groundfish fisheries (1981-present)

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - Foreign groundfish fishery initiated actions
  - Preliminary groundfish FMPs (pre-MSA)
  - FMP groundfish fisheries management

Mortality

External Foreign Groundfish Fisheries (1962-1976)

Foreign fisheries for rockfish (with the exception of the DSR fishery) began in 1962, with the Soviet and Japanese fisheries. These fisheries are the same as were targeting Pacific ocean perch. See Section 3.5.1.11 for more information.

Foreign fishery removals of GOA rockfish are found to have had an adverse effect on the GOA rockfish populations. Furthermore, due to the longevity of these species, the effects are determined to be lingering at the population-level.

External State of Alaska Directed Groundfish Fisheries

Slope Rockfish

Directed State of Alaska rockfish fisheries take place in PWS, Cook Inlet and the south Alaska Peninsula fisheries. In 1999, 31.3 mt of rockfish were taken from the PWS area of which approximately 42 percent were slope rockfish. The Cook Inlet and south Alaska fisheries tend to focus largely on black and blue rockfish that are now under the State of Alaska jurisdiction. Yelloweye rockfish (part of the demersal rockfish group) is also targeted in the PWS fishery. These fisheries operate under a 68 mt annual harvest cap and are bycatch-only when the directed fishery is closed (ADF&G 2000b).

Internal Joint Domestic and State of Alaska Southeast Groundfish Fisheries

Demersal Shelf Rockfish

The directed DSR fishery began in 1979 by a hook and line fishery in southeast Alaska. Fishing occurred within 110 m, near-shore and targeted the entire DSR complex. Today, the directed DSR fishery is conducted by longliners and focuses mostly on yelloweye rockfish within 75-150m.

Catch rates increased from 106 mt in southeast in 1982 to a peak of 803 mt in 1987. In 1993, catch exceeded 900 mt, but has since decreased to 183 mt in 2000. The lava fields off Cape Edgecumbe in the central southeast area and the offshore Fairweather Ground in the east Yakutat area are the most important fishing areas. A small amount of DSR are taken as bycatch in jig and troll fisheries. Trawling is prohibited in the eastern GOA (GOA FMP Amendment 58). 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 (O'Connell *et al.* 2002).

GOA FMP Amendment 14 separated out and protected DSR from the more general other rockfish category by establishing a central SEO with 600 mt OY for the complex. In the early 1980s, all *Sebastes* species other than Pacific ocean perch and four associated slope rockfish species were managed as other rockfish on a gulfwide basis, and yet a domestic fishery harvesting DSR in the southeastern area was expanding very rapidly by 1984. Yelloweye and quillback rockfish were the primary targets of this longline fishery. Other actions under this amendment 1) changed OYs for Pacific ocean perch and other rockfish, 2) established a mechanism for timely reporting of catches by domestic catcher processors that stayed at sea for long periods; and 3) implemented NOAA Fisheries habitat policy. In 1991, GOA FMP Amendment 21 modified the FMP language that allows DSR in southeast Alaska to be managed by the State of Alaska and modified the overfishing definition.

In 1998, an FMP amendment was passed by NPFMC requiring full retention of DSR. This amendment is still under review by NOAA Fisheries. In July of 2000, the State of Alaska enacted a regulation requiring full retention of DSR and requiring that they be reported on fish tickets. DSR in excess of legal sale limits are forfeited to the State of Alaska fishery fund. The new regulation has substantially increased the estimated amount of yelloweye rockfish landed.

Internal JV and Domestic Groundfish Fisheries (1980-present)

The JV fisheries began targeting rockfish in 1980 and were phased-out of the GOA by 1990 when the fishery became fully domesticated. The domestic rockfish fisheries began in 1981. Past effects on these rockfish are not well characterized, but generally consist of the foreign, JV and domestic fisheries. These fisheries are identified as having contributed to rockfish mortality and are found to have had a lingering adverse effect on the rockfish population.

Pelagic Shelf Rockfish

Catch data for PSR are only available from 1988-2001. Prior to 1988, PSR were managed as a larger aggregate rockfish group "other rockfish" in the GOA. Annual harvest rates of rockfish have been subject to variability mostly due to management action. From 1988-1992, catches generally increased; however, beginning in the early1990s, TACs became more restrictive. In recent years, area closures have created a decrease in catch, while preventing the PSR TAC from being exceeded or preventing excessive bycatch of Pacific ocean perch or Pacific halibut (Clausen *et al.* 2002).

In 1998, GOA FMP Amendment 46 removed black and blue rockfishes from the FMP to enhance their management by the State of Alaska by providing more responsive management and preventing localized overfishing of their stocks. Expansion of a fishery for these species in the central regulatory area in the mid-1990s was believed to possibly result in unsustainable black and blue rockfish catches. Two problems with federal management of black and blue rockfish were identified. First, the TAC for all PSR species was based on a triennial trawl survey. Survey catches are dominated (93 to 99 percent) by the under exploited dusky rockfish. This information led to the calculation of ABC levels for the PSR assemblage as a whole, but managers were concerned that the survey bias caused by dusky rockfish could result in an ABC that was inappropriate for less abundant black and blue rockfish stocks. The second problem with federal management was that the trawl survey samples only fish on or near a smooth bottom; most black and blue rockfish occur in rocky nearshore reef habitats that cannot be sampled by this survey.

Slope Rockfish

As in the BSAI, the Pacific ocean perch were highly sought by the Soviet Union and Japanese fisheries beginning in the early 1960s. Catch of Pacific ocean perch peaked in 1965 at 350,000 mt, followed by a continuous decline into the 1970s, reaching low catch of 8,000 mt in 1978. Commercial catch for slope rockfish was not reported separately until 1988; previously they were listed as part of the Pacific ocean perch complex. Foreign fisheries continued to dominate from 1977 to 1984, with Japan taking a majority of the catch. Catch reached a minimum in 1985 following a ban on foreign trawling in the GOA. The domestic fishery entered the slope rockfish fishery in 1985 and expanded until 1991 when restrictions were placed on the fishery that lowered the TAC of Pacific ocean perch stocks, established the management of the four slope rockfish subgroups, and closed fisheries to avoid exceeding TAC through the rockfish trawl fleet. Since 1996, catches of Pacific ocean perch have increased due to increases in TAC levels, although catch of northern rockfish has remained below TAC.

Current data (1992-2000) available from the Observer Program indicate that harlequin, sharpchin, redstripe, silvergrey, and yellowmouth rockfish are the predominant species in the other slope rockfish group caught in the commercial fishery. The data are based only on trips that had observers on board and may be biased towards larger vessels that had more complete observer coverage. A substantial increase in these five species occurred following the removal of northern rockfish from the other slope rockfish group, apparently since removing northern rockfish allowed for an expansion in the fishery for other species. However, from 1994 to 1998, estimated catch for these five species decreased, partly due to lower TACs established for the other slope rockfish group. Since 1998, the catch for these species has remained low. In the shortraker/rougheye rockfish group, shortraker rockfish has always dominated the commercial catch and also has a higher market value than rougheye rockfish (Heifetz *et al.* 2002).

Change in Reproductive Success

External Foreign Groundfish Fisheries (1960s-1976)

Slope Rockfish

Effects of the foreign fisheries on spatial/temporal distribution of slope rockfish due to the spatial/temporal concentration of the fisheries are identified as either adverse or unknown. When the past effect of the fishery is unknown, it is also unknown whether the effect could be lingering.

External Climate Changes and Regime Shifts

The combination of climate effects and regime shifts on prey availability and habitat suitability influence the reproductive success of species. Research on climate shifts as a forcing agent on species and community structure of the NPO can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). See Section 3.10.1.5 for an indepth discussion of the various effects on climate changes and regime shifts on the NPO ecosystem.

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on the reproductive success of PSR. In general, stronger recruitment would be expected under more favorable climatic conditions because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected (although not perfectly) in the strength and weaknesses of the affected age groups within future fisheries (see Section 3.10.1.5).

Internal Joint Domestic and State of Alaska Southeast Groundfish Fisheries

Demersal Shelf Rockfish

Although management of this assemblage has been conservative, and overall the population appears stable, a decline in the density estimates in the Fairweather Grounds may be an indication that localized overfishing is occurring (Heifetz *et al.* 2002). The TAC for the eastern GOA is partitioned by management district based on biomass density and known habitat. The current harvest strategy indicates that 2 percent of the exploitable biomass is taken per year and that this level of exploitation is sustainable. However, fishing effort on the Fairweather Grounds appears to be concentrated in areas of best habitat and high density and it may be that local overfishing occurs. If occurring, such localized overfishing could have a long-term adverse effect on DSR stocks due to their longevity and slow growth rate (Heifetz *et al.* 2002). Rockfish stocks typically require long periods to recover from high fishing pressure.

Change in Prey Availability

External State of Alaska Shrimp Fisheries

Effects of State of Alaska shrimp fisheries on the prey availability of GOA rockfish (i.e. rougheye rockfish, dusky rockfish and other rockfish species) is potential adverse, however due to the localized nature of these fisheries, they are unlikely to have a population-level effect.

External State of Alaska Herring Fisheries

The State of Alaska herring fisheries effects on the prey availability of GOA DSR are identified as potential negative contributions, however due to the localized nature of these fisheries, they are unlikely to have a population-level effect.

External Commercial Whaling

The effects of commercial whaling increased the availability of euphausiid prey for northern rockfish (as part of the other slope rockfish complex) and some of the other rockfish species and is therefore noted as a potential beneficial effect.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Research has not been done on the effects of climate on the benthic community (polychaete worms, clams, etc.), which constitutes part of the diet of some GOA rockfish species.

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important prey species of other rockfish.

Change in Important Habitat

External Foreign Groundfish Fisheries (1962-1976)

Statistics on the number of bottom trawls and their effects on GOA habitat pre-MSA is generally unknown. However, the impacts of foreign groundfish fishery gear on GOA rockfish habitat have been identified as negative effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

External State of Alaska Directed Groundfish Fisheries

Slope Rockfish

Statistics on the number of bottom trawls and their effects on GOA habitat pre-MSA is generally unknown. However, the impacts of JV and domestic groundfish fishery gear on DSR habitat have been identified as negative effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

External IPHC Longline Fishery

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The impacts of IPHC longline gear on GOA rockfish habitat have been identified as negative effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

External/Internal Marine Pollution and Oil Spills

It is unknown to what extent marine pollution and oil spills from vessels occur in the GOA and what effect these have on the important habitat of other rockfish.

Internal JV and Domestic Groundfish Fisheries (1980-present)

See Section 3.5.1.15 (GOA walleye pollock past/present effects: change in important habitat) for statistics on the number of bottom trawls occurring in these areas and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat.

The impacts of JV and domestic groundfish fishery gear on rockfish habitat have been identified as adverse effects. Intense trawling is likely to have caused rockfish habitat degradation and disruption of rockfish spawning and/or rearing grounds. This effect is still lingering at the population-level.

Pelagic Shelf Rockfish

PSR are caught almost exclusively by bottom trawls. Light dusky rockfish are typically caught in relatively shallow (100-149 m) offshore banks of the continental shelf (Reuter 1999). They are found in large concentrations in the "W" grounds west of Yakutat, Portlock Bank northeast of Kodiak Island, and around Albatross Bank south of Kodiak Island. The trawlers that target Pacific ocean perch and northern rockfish typically target dusky rockfish, as well, fishing for dusky rockfish after they have filled their quota for the other two species. From 1988-1995, large factory trawlers took over 95 percent of the dusky rockfish catch; however, following 1996, smaller shore-based trawlers began taking larger portions of the PSR catch, taking 58 percent in 2001 in the central area (Clausen *et al.* 2002). HAPC biota bycatch analysis from 1997-1999 ranks the dusky rockfish trawl fisheries fourth among all fisheries in the amount of coral taken as bycatch and sixth in the amount of sponges taken. Research is being conducted to investigate the habitat associations of these species and any detrimental effect in trawl fisheries may have on their associated habitat (see Section 3.6).

GOA Rockfish Comparative Baseline

The Japan-U.S. cooperative survey and the NOAA Fisheries domestic longline survey are conducted on the continental slope of the GOA and provide data on the relative abundance of slope rockfish. Rougheye and shortraker rockfish are the primary species caught; however, caution should be taken when viewing data from both surveys since the analyses do not take into account possible effects of competition for hooks with other species caught on the longline (Heifetz *et al.* 2002).

Data from the Japan-U.S. cooperative survey for 1979-1987 indicate that the abundance of rougheye and shortraker rockfish remained stable in the GOA for those years (Sasaki and Teshima 1988, Clausen and Heifetz 1989). Data also suggest that rougheye and shortraker rougheye are most abundant in the eastern GOA. Domestic longline survey data from 1988-2002 show fluctuations in relative population numbers and relative population weight for shortraker and rougheye rockfish. However, the five highest annual gulfwide relative population numbers and relative population weights for shortraker and rougheye rockfish were seen in the most recent five surveys (1997-2001). This survey also shows the highest abundance of shortraker/rougheye rockfish in the eastern GOA with the Yakutat area having the highest relative population number and relative population weight values for shortraker rockfish and the southeastern area with the best rougheye rockfish values. Relative population numbers and relative population weights for rougheye and shortraker rockfish are slightly lower relative to 2001 estimates (Heifetz *et al.* 2002).

Triennial trawl surveys have been conducted in the GOA since 1984, and are now conducted biennially starting in 2001. The 2001 trawl survey did not survey the eastern GOA, therefore biomass estimates for that area are based on an average of 1993, 1996 and 1999 biomass estimates. The 2001 trawl survey indicates that Pacific ocean perch was the most abundant species with an estimated biomass of 858,982 mt, 61.9 percent of the total slope rockfish biomass. Northern rockfish comprised 25.6 percent of the total biomass. Other slope rockfish were poorly represented since the eastern GOA was not sampled, the area where a large percentage of the other slope rockfish species are located. The 2001 biomass estimates for Pacific ocean perch and northern rockfish are greatly influenced by large catches in one or two hauls, resulting in higher variance of biomass for both species (Heifetz *et al.* 2002).

When comparing the trawl surveys from 1984-2001, high variability in biomass estimates can be seen in nearly all species. Of the other slope species, biomass estimates for rougheye rockfish have been most consistent. Northern rockfish biomass estimates were relatively stable from 1987-1996, however underwent a large increase in population in 1999 and 2001. Biomass estimates for silvergrey rockfish steadily increased from 1984-1999. Variance in biomass estimates is attributed to anomalously large individual hauls (as in 1999 and 2001), and change in availability of rockfish to the survey caused by unknown behavioral or environmental factors. Causes of changes in biomass estimates can not be determined until more is known about rockfish behavior (Heifetz *et al.* 2002).

Comparative biomass estimates over the past seven triennial surveys show that dusky rockfish abundance varies. Total biomass increased from 1984 to 1987 and dropped 50 percent by 1990. Abundance again increased in 1993 and 1996, but has since decreased. None of the changes in biomass are statistically significant and may be attributed to changes in the availability of rockfish to survey gear or the imprecision of sampling methods for these species. In 2001, the eastern GOA was not sampled; therefore, 2001 eastern GOA biomass estimates are based on an average of the 1993, 1996, and 1999 estimates for each species in each region. Light dusky rockfish appear to dominate the PSR assemblage from 1996 to 1999; however, a large biomass of yellowtail rockfish was also seen in the southeastern area in 1999. The Kodiak area shows the highest biomass of dusky rockfish in all survey years (except 1984) and the southeastern area has shown the lowest biomass (except 1999) (Clausen *et al.* 2002).

Current exploitable biomass is based on the average of the three most recent surveys (1996, 1999, and 2001). This equates to 62,489 mt for the PSR assemblage, 56,336 mt for dusky rockfish and 6,153 for widow and yellowtail rockfish (Clausen *et al.* 2002).

Survey age compositions are available from the 1984, 1987, 1990, 1993, 1996, and 1999 surveys, and these show that recruitment of dusky rockfish appears to be highly variable. In 1999, aged 12-13 (1986-1987 year-classes) are most prominent. Fish under age-10 make up a much smaller portion of the population.

Biomass of adult yelloweye rockfish is derived as a product of estimated density, estimated rocky habitat within the 200 m contour, and average weight of fish for each management area. Estimation of the line length for the transects used in the submersible survey and the total area of rocky habitat is difficult; therefore, there is uncertainty in the biomass estimates. Only the north SEO section was surveyed during 2001, and only six transects were run due to poor weather. Consequently, the distance sampling model did not fit the data well. The density estimate for these data was 1,420 adult yelloweye/km^2. This is a 40 percent increase over the 1994 survey data and is more similar to the density estimates from the rest of the SEO region (O'Connell *et al.* 2002).

The age and size distributions of yelloweye rockfish are discussed in O'Connell *et al.* (2001) and O'Connell and Funk (1987). Estimated length and age at 50 percent maturity for yelloweye collected in the central SEO in 1988 are 45 cm and 21 years for females and 50 cm and 23 years for males. The most recent age data is from the 2000 commercial catch samples. In the central SEO, the area with the longest catch history, 2001 age data depicts the average age at 36 years. The older ages have declined in frequency over time, and the average age continues to decline over time. In the south SEO, the 2001 age data shows is bimodal, strongly at 23 and weaker at 44-45 years. In east Yakutat District, the 2001 age distribution is somewhat bimodal, with the largest mode is at 32-34 years, and a smaller mode at 44-45, with a mean age of 42 years. The maximum age recorded for 2001 was 110 years in the east Yakutat and central SEO (O'Connell *et al.* 2002).

An August 1998 sidescan sonar survey was conducted in Fairweather Ground to determine the gross bottom type. In the 1997 survey, the estimate total area of rocky habitat of the Fairweather Ground was reduced from 1,132 km^2 to 448 km^2. Although the 1998 survey did not cover the entire Fairweather area, by comparing techniques, the rock habitat of the east Yakutat area was reestimated at 617 km^2. Estimates of rock habitat in the SEO were also revised, down 46 percent overall to 3,095 km^2. Estimates are likely to continue to change as further information is gathered. Total exploitable biomass for 2003 equates to 17,510 mt, a slight increase from the 2002 estimate due to the addition of average weight data and revised estimates of the area of yelloweye habitat (O'Connel *et al.* 2002).

GOA Rockfish Cumulative Effects Analysis Status

The GOA northern rockfish, shortraker/rougheye rockfish, other slope rockfish, PSR DSR will be brought forward separately for the cumulative effects analysis.

3.5.2 Prohibited Species

Retention of prohibited species is forbidden in the BSAI and GOA groundfish fisheries. These species were typically utilized in domestic fisheries prior to the passage of the MSA in 1976. Retention was prohibited in the foreign, joint venture, and domestic groundfish fisheries to eliminate any incentive that groundfish fishermen might otherwise have to target these species. The prohibited species include:

- Pacific halibut (*Hippoglossus stenolepis*).
- Pacific salmon and Steelhead trout (*Oncorhynchus mykiss*).
- Pacific herring (*Clupea pallasi*).
- Red king crab (*Paralithodes camtschaticus*), blue king crab (*P. Platypus*), golden or brown king crab (*Lithodes aequispinus*), bairdi Tanner crabs (*Chionoecetes bairdi*), and opilio Tanner crabs (*C. opilio).*

3.5.2.1 Pacific Halibut

The geographic scope for the Pacific halibut past/present effects analysis is the same as the IPHC regulatory areas. The temporal scope for this analysis begins in 1910 when the commercial Pacific halibut fishery started in southeast Alaska and ends in 2001.

Life History and Distribution

Pacific halibut range from Santa Barbara, California to Nome, Alaska, along the North American Pacific coastline. Pacific halibut are considered to be a single stock from the Pacific west coast to the Bering Sea. During the summer Pacific halibut are found along the northeast continental shelf, with a patchy distribution at the northern and southern ends of the range (IPHC 1998). Males can grow to exceed 36 kg and can live up to 27 years, and females can grow to over 225 kg and can live up to 42 years.

Adults make seasonal migrations from the summer feeding grounds on the continental shelf to deeper spawning grounds. Spawning takes place from December through February. Most spawning takes place off the continental shelf edge at depths of 400 to 600 m. Male halibut become sexually mature at 7 or 8 years of age, females mature at 8 to 12 years. The number of eggs a female produces is related to its size. Females over 113 kg may produce up to 4 million eggs annually (IPHC 1998). Fertilized eggs float free for about 15 days before hatching; the larvae and postlarvae drift westward on the prevailing currents for up to another six months. The currents eventually carry the young halibut to shallower waters that serve as nursery grounds (IPHC 1998).

Juvenile halibut spend five to seven years in shallow water nursery grounds before beginning a migration to "home areas." The migration of halibut from their western nursery grounds to home areas appears to be a unidirectional clockwise movement (IPHC 1998). Juvenile halibut marked in the northern GOA have been recovered after migration in the northern GOA and to the south, but rarely from the western GOA or BSAI. Similarly, juvenile halibut marked in British Columbia waters are typically recovered in the British Columbia area or farther south, and very rarely in Alaskan waters (IPHC 1998). It is not known if returning juveniles are the descendants of spawners of a given home area (IPHC 1998).

Trophic Interactions

Halibut are strong swimming apex predators. The diet of Pacific halibut varies with size. Halibut feed on plankton in their larval stage (IPHC 1998). Halibut less than 30 cm are known to feed on hermit crabs (pagurids), small shrimp-like organisms, and small fish (Yang and Nelson 2000, IPHC 1998). Fish become a larger component of the diet as halibut increase in size. Species frequently observed in the stomachs of halibut >50 cm include capelin, Pacific sand lance, eulachon, cod, Pacific salmon, sole species, sablefish, pollock, rockfish, flatfish species (including juvenile Pacific halibut), poachers (agonids), pricklebacks (stichaeids), eelpouts (zoarcids), and sculpins (cottids); and in addition octopi, crabs, clams, and other crustaceans (Yang and Nelson 2000, IPHC 1998).

Due to their size, active nature, and bottom dwelling habit, there are few predators of Pacific halibut aside from humans (IPHC 1998). Occasionally, conflicts have arisen between human predators and marine mammals, which have been observed foraging on halibut hooked on longlines (Bell 1981).

Pacific Halibut Management

Pacific halibut fisheries are managed by the IPHC, a treaty between the U.S. and Canada. The IPHC management process and stock assessments take all removals into account (bycatch in the federal and state groundfish fisheries and catch in the IPHC regulated commercial, subsistence, and sport fisheries) when issuing halibut allocations to the directed halibut fisheries. In addition, migration rates of juvenile halibut are used in concert with bycatch information for the groundfish fisheries to estimate appropriate yield reductions for the directed halibut fishery in each IPHC management area (Clark and Hare 1998).

Bycatch Management in the Federal Groundfish Fisheries

In addition to designating salmon, crab, herring, and halibut as prohibited species, NOAA Fisheries annually sets PSC limits under 50 CFR 679.21 through the annual TAC-setting process. PSC limits are further allocated to fishery categories, gear groups, or seasons to create more refined PSC limits.

Groundfish fishery PSC rates are calculated by dividing the sum of the weights or counts of PSC in a set of observer data by the sum of the weight of groundfish in the dataset. For rates from observed vessels that will be applied to unobserved vessels, a minimum of three different weekly observer reports is required before an average rate is used. For some rates, this threshold is set at a higher number of reports. This process is discussed in detail in Appendix B.

NOAA Fisheries monitor PSC limits for the general and CDQ groundfish fisheries using PSC rate estimates. Reaching a PSC limit can result in closure of an area or a fishery season, even if the groundfish quota (e.g., TAC) remains unharvested. When it is determined that a PSC limit will be reached, NOAA Fisheries publishes a notice in the *Federal Register* closing the associated area or fishery. Bycatch of Pacific halibut constrains the groundfish fisheries in both the BSAI and GOA, preventing the TAC of many groundfish target species from being harvested.

Past/Present Effects Analysis

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-40 provides a summary of the Pacific halibut past effects analysis presented below.

Nutritional stress due to the catch/bycatch of prey species was not brought forward for analysis because halibut have flexible feeding habits. Pacific halibut are apex feeders that can respond to short-term localized shortages of one prey species by substituting another.

The following direct and indirect effects were identified as potentially having population-level effects on Pacific halibut:

- Mortality due to catch/bycatch (direct effect).
- Spawning disruption due to fishing in spawning habitat (indirect effect).
- Reduced recruitment due to spatial/temporal concentration of catch/bycatch (indirect effect).

The past/present events determined to be applicable to the Pacific halibut past effects analysis include the following:

- Past/Present External Events
  - IPHC regulated Pacific halibut fishery
  - Foreign fisheries (pre-MSA)
  - Decadal oscillations

- Past/Present Internal Events
  - Foreign fisheries (post-MSA)
  - JV fisheries
  - Domestic fisheries

- Past/Present Management Actions
  - IPHC fisheries management
  - Industry initiated actions
  - FMP groundfish fisheries management

Past/Present Events and Management Actions

External Mortality- Catch in the IPHC Regulated Pacific Halibut Fishery

Pre-World War I fisheries targeting halibut in the North Pacific were relatively small. Market demand for halibut began to grow once technology was developed to ice and preserve the catch. Fishermen began to explore for Pacific halibut resources, and a small GOA halibut fishery began in 1910. The fishery rapidly expanded both north and south and into offshore waters. Early in the fishery, the stock of Pacific halibut was recognized as being rapidly reduced in areas that had been consistently fished (IPHC 1948).

The U.S. and Canada began discussing international management of halibut in 1913. Conservation of the stocks was not a major consideration until annual landings declined in 1915 despite increase in exploitation of new fishing grounds (IPHC 1948). By 1923, a halibut conservation treaty ratified and established an International Fisheries Commission with limited regulatory powers. The Commission engaged a staff to begin practical scientific investigations of Pacific halibut biology, stock status, and the fishery. The initial results of these investigations indicated that landings were only being maintained by constant increases in fishing intensity (IPHC 1948). The treaty was renegotiated during subsequent years granting the Commission increased regulatory power over the fishery. The regulations governing the Pacific halibut fishery, guided by scientific programs and investigations, stopped the decline of the fishery and allowed for the rebuilding of Pacific halibut stocks.

The halibut fleet remained relatively stable until the 1970s when the Pacific halibut fleet dramatically increased in size due to the rise in halibut price, declining crab stocks, and limited entry salmon fisheries (Coughenower and Blood 1997). By the late 1980s the fishing season had decreased from a five-month season in 1970 to just two 24- to 48-hour openings (Coughenower and Blood 1997).

External Mortality: Bycatch in the pre-MSA Foreign Fisheries

Pacific halibut bycatch mortality in the groundfish fisheries was relatively low until the 1960s when it increased due the development of the foreign fisheries (Williams 2001; see Appendix B for details on the development of the foreign fisheries.) Total bycatch mortality for IPHC regulatory areas:

- Peaked in 1965 at approximately 21 million pounds.
- Decreased in the late 1960s to approximately 15 million pounds.
- Increased to approximately 20 million pounds by the early 1970s.
- Decreased through the late 1970s with an increase to approximately 18 million pounds in 1980.

A detailed discussion of U.S. fisheries management prior to the MSA is presented in Appendix B and summarized in Table 3.5-40. The U.S. had virtually no authority to impose regulations beyond its territorial sea (3 miles prior to 1966, then expanded to 12 miles by public law) and relied primarily on multilateral and bilateral international agreements. Japan instituted some conservation and management measures independently, including a LLP and area restrictions to ease U.S. and Canadian concerns about the Japanese trawl fisheries impact on Pacific halibut (Appendix B).

Internal Mortality: Bycatch in the Post-MSA Groundfish Fisheries

By 1985, the JV operations and growing U.S. domestic fleet had entered the scene and continued the harvest of groundfish species. Federal groundfish fisheries have been prosecuted by an all-domestic fleet since 1987 in the GOA and 1991 in the BSAI. Bycatch of Pacific halibut is associated with all historical groundfish fisheries to varying degrees. The majority of the Pacific halibut bycatch was taken in the Bering Sea foreign and JV groundfish fisheries in the 1980s (Clark and Hare 1998). By 1985, Pacific halibut bycatch mortality had declined to 7.2 million pounds, the lowest level since the IPHC began its monitoring, and peaked again at 20.3 million pounds in 1992 (Williams 2001). The estimate of Pacific halibut bycatch mortality in 2002 of 12.7 million pounds is the lowest seen since 1987 but is consistent with estimates for the past several years (Williams 2002, Williams 2003). Bycatch mortality of legal-sized halibut (80+cm) was 6.73 million pounds in 2001, which remains consistent with the bycatch mortality of legal-sized halibut reported annually since 1995 (Clark and Hare 2002).

The bycatch of Pacific halibut in the groundfish fisheries decreases the amount that can be taken by fishermen in the directed IPHC fishery. Figure 3.5-6 shows Pacific halibut bycatch by area and gear from 1998-2001 (Hiatt *et al.* 2002). Bycatch has been controlled by FMP management measures, but not without cost to groundfish fisheries. In particular, Pacific halibut bycatch management measures have constrained groundfish harvests. Typically, all Pacific halibut bycatch mortality (4,665 mt) allocated to trawl and longline fisheries is taken, along with lesser amounts from pot fisheries and fisheries within Alaska state waters (Williams 1997). Longline fisheries have also been constrained by Pacific halibut bycatch, and careful release requirements have been implemented to improve survival of halibut discards (Smith 1995). Implementation of an IFQ system for Pacific halibut and sablefish longline fisheries in 1995 allowed for more selective longline fisheries with lower bycatch (Adams 1995). An indirect effect of changes in fishery scheduling and fishing ground closures to protect Steller sea lion has been a further reduction of halibut bycatch (Williams 2001).

Reducing halibut bycatch has also been the objective of numerous industry-initiated proposals in recent years. Several trawlers voluntarily use bycatch reduction devices in their nets to release incidentally caught halibut with minimal harm, and testing of these devices is ongoing.

External Spawning Disruption

The early directed Pacific halibut fisheries took place year-round. Pacific halibut caught during spawning season were of poor quality (IPHC 1948). A winter season fishery closure was proposed as a result of the 1913 U.S. and Canada discussions on international halibut management. This closure was proposed in order to eliminate a period of dangerous fishing when poor quality fish were caught and to provide a time frame for sales of accumulated frozen fish inventories (IPHC 1948). The Commission established the proposed three-month winter closed season in 1923.

Internal Spawning Disruption: Post-MSA Groundfish Fisheries

Pacific halibut spawn in very deep waters (400 to 600 m) off the continental shelf edge, and most bottom trawl groundfish fisheries take place in shallower areas of the continental shelf. Most bottom trawl groundfish fisheries occur between March and November, while Pacific halibut spawning takes place from December through February . The largest major spawning ground identified by IPHC is off Yakutat and is currently closed to all groundfish trawling. Typically, the IPHC halibut fishery closes annually from November 16 to March 15 to protect spawning halibut.

External/Internal Reduced Recruitment: Spatial/Temporal Concentration of Bycatch

Alaska groundfish fisheries take the majority (more than 90 percent) of Pacific halibut bycatch (Clark and Hare 1998). Bycatch contains both adult (> 81 cm) and juvenile fish (< 81 cm). Juveniles may or may not have completed their migrations from the nursery ground to home areas. Their capture has the potential effect of reducing recruitment to adult stock in the home area to which they would have migrated (Clark and Hare 1998). Adult fish caught as bycatch have completed their migration back to home areas. Therefore, bycatch of adult fish can be expected to affect only the stock in the area where the bycatch is taken (Clark and Hare 1998). Approximately 50 to 60 percent of Pacific halibut bycatch is below the directed fishery size limit of 81 cm, with differences in bycatch by gear type. The projected halibut bycatch in each major gear type is assumed to follow the general pattern observed from 1997 to 1999 (Figure 3.5-7). While there are more data from the BSAI than the GOA, bottom trawls generally appear to catch a higher proportion of smaller halibut than longlines in both areas.

External Reduced Recruitment: Decadal Oscillations

Climate variability can have both beneficial and adverse effects on Pacific halibut stocks. Positive Pacific Decadal Oscillations are currently thought to enhance the recruitment of Pacific halibut which spawn and rear mainly in Alaska waters (Clark and Hare 2001, see Section 3.3.4 of this Programmatic SEIS for a discussion of decadal oscillations). An analysis conducted by Clark and Hare (2001) indicated that Pacific halibut recruitment is strongly influenced by climatic regime and weather in the year of spawning. The importance of environmental conditions in the year of spawning suggests that regulation of year-class strength occurs in that year. The dependence could be either on available transport of eggs and larvae to nursery grounds by ocean currents, or on planktonic production that varies strongly with climate and weather (Clark and Hare 2001).

Pacific Halibut Comparative Baseline

The assessment of the Pacific halibut stock status was revised in 1996 due to the observed changes in individual growth rates that affected fishing selectivity by gear. The new analyses showed that the exploitable portion of the Pacific halibut stocks apparently peaked at 326,520 mt in 1988 (Sullivan and Parma 1998). The population has since declined slightly and has maintained a biomass in the range of 270,000 to 277,000 mt. The long-term average reproductive biomass for the Pacific halibut resource was estimated at 118,000 mt (Parma 1998). Long-term average yield was estimated at 26,980 mt, round weight (Parma 1998).

Average catches from 1995 to 1999 were 29,325 mt for the U.S. and 6,935 mt for Canada, for a combined total of 36,260 mt for the entire Pacific halibut resource. This catch was 34 percent higher than long-term potential yield, which reflects the good condition of the Pacific halibut resource. The 1999 coastwide catch totaled 58,026 mt (round weight). The breakdown by fishery was: commercial fisheries, 43,270 mt, or 75 percent; recreational fisheries, 5,502 mt (9 percent); personal use, 440 mt (1 percent); bycatch in other fisheries, 7,779 mt (13 percent); and wasted mortality due to fishing by lost gear and discards, 1,035 mt (2 percent). The 2002 commercial catch totaled 33,748 mt (net weight). Removals of Pacific halibut for 2002 totaled 44,453 mt (net weight), similar to annual removals for the past six years. The breakdown by fishery is as follows: commercial catch, 33,748 mt (76 percent); sport catch, 3,946 mt (9 percent); incidental bycatch mortality, 5,806 mt (13 percent); personal use, 363 mt (1 percent); and wastage, 726 mt (2 percent) (Gilroy 2003). At its 2003 annual meeting, the IPHC recommended commercial catch limits totaling 33,975 mt for the 2003 U.S. and Canadian commercial catch which is identical to the catch limits put in place for 2002 (IPHC 2003).

Pacific halibut have shown a decrease in size at age over time, with fish today weighing approximately a third of what fish of the same age weighed 20 years ago (Clark and Hare 2001). It is currently hypothesized that this change may be due to a density dependent factor, and not to removal of prey by groundfish fisheries (Clark *et al.* 1999). It is not yet clear how Pacific halibut density affects growth. However, it has been widely observed that flatfish growth rates tend to increase under exploitation (Clark and Hare 2001).

The nature of the Pacific halibut commercial fisheries has changed in recent years. Both Canadian and U.S. fisheries have moved from an open access fishery with short fishing seasons to an IFQ fishery that lasts eight months each year. In addition, quota allocations have been implemented for Native American treaty, commercial, and recreational fisheries for waters from Washington to California. With closer management of quota allocations, an overall decrease in fleet size has occurred. Vessels licensed to fish in Canada remained at 435, while 1,850 vessels fished in the U.S. fisheries in 1999, a reduction from 3,400 vessels in 1993.

Currently the Pacific halibut resource is considered to be healthy, and the total catch has been near record levels. It is inferred that any direct or indirect effects of bycatch on Pacific halibut in past groundfish fisheries were taken into account under the IPHC management process and mitigated by the numerous BSAI and GOA FMP management measures to reduce bycatch in the federal groundfish fisheries.

Pacific Halibut Cumulative Effects Analysis Status

FMP 2.1 proposes to eliminate the groundfish fishery PSC limits. This in itself might not affect Pacific halibut biomass since the IPHC takes into account the groundfish fishery bycatch as part of their management process. However, if bycatch increased, it would lower the IPHC catch limit and could impose an economic hardship in the directed fishery. Therefore, Pacific halibut will be carried forward for the proposed alternative cumulative effects analysis.

3.5.2.2 Pacific Salmon and Steelhead Trout

Five species of Pacific salmon , pink *(Oncorhynchus gorbuscha)*, chum *(O. keta)*, sockeye *(O. nerka)*, coho *(O. kisutch)*, and chinook salmon *(O. tshawytscha)*, as well as steelhead trout (*O. mykiss*) occur in Alaska. With some important variations, all species have a similar appearance and anadromous life history. Salmon spawn in freshwater and during the fall their eggs incubate, hatch, and go through several developmental stages taking several months to several years depending on species, then migrate to the ocean as fry or smolt. The young salmon feed and grow to maturity in saltwater, ranging widely over the North Pacific Ocean and Bering Sea. They return to freshwater, often migrating tremendous distances to reach their natal streams where they spawn. This adaptation to spawning in freshwater has resulted in the tremendous seasonal abundance of spawning salmon, that is easily harvested, and has sustained human populations for millennia. Adult salmon do not compete directly with juveniles for the food resources found in freshwater environments. Carcasses left in the streams after spawning fertilize the freshwater environment, ultimately providing food for the developing young.

No stocks of Pacific salmon originating from freshwater habitat in Alaska are listed under the ESA. The ESA- listed species that migrate into marine waters off Alaska originate in freshwater habitat in Washington, Oregon, Idaho, and California. Threatened and endangered salmon species are discussed in further detail in Section 3.4.2 of this Programmatic SEIS.

Steelhead trout populations are generally stable throughout Alaska. No commercial fishery is held for steelhead trout. Steelhead trout are very rarely taken in GOA groundfish fisheries; no catch was observed in the GOA groundfish fisheries between 1997 and 1999. Most incidentally caught steelhead are taken in the commercial salmon fisheries where the state requires that steelhead be treated as a prohibited species and released (ADF&G 1998). Steelhead are managed by the state exclusively as a recreational sport fish. Steelhead trout will not be analyzed in this document due to their rare occurrence in the BSAI groundfish fisheries.

NOAA Fisheries group salmon species into two categories: chinook salmon and other salmon. The other salmon category includes chum, pink, coho, and sockeye salmon species. The analysis in this section will follow this practice.

Pacific Salmon Life History and Distribution

Chinook Salmon

These are the largest salmon, often exceeding 14 kg. The largest sport-caught chinook salmon was a 44-kg fish taken from the Kenai River. Some chinook salmon outmigrate to the ocean soon after hatching in late winter or early spring (ocean-type), while others remain in freshwater for over one year before outmigrating to the ocean as smolts (stream-type). Chinook salmon become sexually mature in 2 to 7 years; females tend to be older than males at maturity. Fish in any spawning run vary greatly in size; a mature three-year-old will weigh less than 2 kg, while a mature seven-year-old may exceed 23 kg. Chinook salmon often make extensive freshwater migrations to their natal steams in some of the larger river systems. Yukon River chinook salmon bound for the headwaters in the Yukon Territory, Canada, and will travel more than 2,000 miles in 60 days (Groot and Margolis 1991).

Chinook salmon occur from California through the North Pacific Ocean, Bering, and Chukchi seas, to the Anadyr River in Siberia and Hokkaido, Japan. Marine distribution data indicate that stream-type chinook move offshore early in their ocean life and maintain a mostly offshore distribution throughout their ocean life (some stream-type chinook are found in coastal waters). The reverse is found for the ocean-type chinook, which are more common in coastal waters and less common in offshore waters (Healey 1991). Only stream-type chinook occur in Asia and western Alaska.

Information on the oceanic distribution of chinook salmon in relation to their area of origin comes from two sources: tagging studies and analysis of scale patterns. Neither source provides an adequate picture of oceanic distribution for many chinook stocks. Oceanic distribution of Asian and Alaskan stream-type chinook is not clearly defined; however, some general ideas have been put forth. Asian stream-type chinook are likely distributed throughout the BSAI , but concentrated west of 180°W. In the North Pacific Ocean, the Asian stocks appear to be distributed as far east as 175°W. Their southern distribution limit is not known (Healey 1991).

Western Alaska and Canadian Yukon stream-type chinook are distributed throughout the Bering Sea, probably with higher concentrations in the central and eastern areas. Western Alaskan chinook also travel into the North Pacific south of the Aleutian Islands, but the limits of their distribution are not known. Central Alaskan chinook are also thought to be widely distributed in the central and western North Pacific as well as in the Bering Sea. Chinook stocks from southeastern Alaskan/British Columbia, as well as those from Washington, Oregon, and California, are rare in the Bering Sea and western North Pacific. Their main oceanic distribution is thought to be in the eastern North Pacific, with the greatest concentrations occurring over the continental shelf waters (Healey 1991).

Chum Salmon

Chum salmon are the second largest of the Pacific salmon after chinook salmon. Chum salmon are the most important commercial and subsistence species in Alaska's arctic, northwest, and interior. Chum salmon vary in size from 2 to over 13 kg, but usually range from 3 to 8 kg, with females usually smaller than males. Chum salmon spend little time in freshwater as juveniles, and are therefore thought to be more affected during the juvenile stage by estuarine and marine conditions than by freshwater conditions relative to other salmon species. Chum salmon generally return to freshwater to spawn after 3 to 5 years at sea (Johnson *et al.* 1997).

Chum salmon have the widest distribution, ranging from California to Japan. In the Arctic Ocean, they range from the Mackenzie River in Canada to the Lena River in Siberia. Research conducted by the North Pacific Fisheries Commission has contributed to the understanding of chum salmon distribution during the high-seas phase of their life. At-sea migrations of Asian and North American immature chum salmon overlap in the North Pacific Ocean during the winter, but the salmon appear to migrate independently in the following spring and summer (Salo 1991). The known winter distribution of Asian age-1 chum salmon extends as far east as the central Aleutian Islands. Western Alaskan chum salmon, by comparison, leave the Bering Sea to join North American immatures from more southerly locations in the GOA. Western Alaska chum salmon are not thought to re-enter the Bering Sea prior to returning as mature fish (Salo 1991). There is evidence that immature Asian chum salmon from the northwestern Bering Sea also migrate to the GOA. By age-2 there is a more pronounced intermingling between the Asian and North American chum salmon. The Asian stock moves eastward and southeastward into the northeastern Pacific Ocean, and the North American stocks move to the north and west from the GOA region (Salo 1991).

Maturing chum salmon are widely distributed in the GOA and in the northeastern Pacific Ocean along the Aleutian Islands. The formation of aggregations for inshore movement to spawning grounds is not well understood. Typically Asian stocks with extensive distances to travel begin their spawning migration into the Bering Sea in April and May. Asian chum continue to migrate from the North Pacific Ocean in a northwestern pattern into the Bering Sea through June (Salo 1991). Maturing Alaskan chum salmon begin their homeward migrations from June through July. Western chum salmon begin their migrations from as far east as the British Columbia coast and as far west as the central Aleutian Islands. Typically their spawning migrations through the Aleutian passes begin in June and peak in July. GOA chum stock begin their homeward migrations from May to July.

Pink Salmon

Pink salmon are the smallest salmon species; adults average 1.6 to 2 kg with an average length of 50 to 65 cm. In Alaska, adult pink salmon enter spawning steams between June and mid-October. Most pink salmon spawn within a few miles of the coast, and spawning within the intertidal zone or stream terminuses is very common. The female carries 1,500 to 2,000 eggs and digs a nest, or redd, with her tail and releases the eggs into the nest. Eggs are immediately fertilized by one or more males. After spawning, both males and females die, usually within two weeks. The eggs hatch sometime in early to midwinter. In late winter or spring, the fry emerge from the gravel and quickly migrate to the ocean, usually during the darkness (Groot and Margolis 1991). Pink salmon grow rapidly while at sea, with mature fish typically returning to spawning areas after 18 months (Heard 1991). Pink salmon have a fixed two-year life span. Therefore, pink salmon spawning in the same freshwater system are reproductively isolated during even and odd years, developing into different genetic lines (Heard 1991).

Pink salmon occur from northern California to Russia and Korea and are the most common species in Alaska. Large spawning populations of pink salmon occur in southeastern, central, and western Alaskan coastal waters. Smaller concentrations of pink salmon occur north of the Bering Strait, in the Chukchi Sea coast, and along the Beaufort Sea coast (Heard 1991).

Coho Salmon

Adults average between 3.6 and 5.4 kg, but may reach as much as 13.6 kg. Spawning coho enter freshwater from July to November. The fry remain in the gravel, feeding on the yolk sac until they emerge in May or June. Coho spend from one to five years in freshwater streams and lakes before migrating to the sea. The amount of time spent at sea varies greatly, but most coho spend 18 months feeding and growing before returning as full-size adults (Groot and Margolis 1991).

Coho salmon occur from California through the North Pacific Ocean and southern Bering Sea to Siberia, Japan, and Korea. In the spring and early summer, Asian coho are generally distributed in the southern part of the western Pacific Ocean (Sandercock 1991). As water temperatures warm during the summer months, Asian coho move progressively northward throughout the North Pacific Ocean and the Bering Sea (Sandercock 1991). The known eastern limit of Asian coho distribution is about 177°W and 45°N. Asian and North American coho stocks intermingle near the end of the Aleutian chain. The known western limit of Alaskan coho is 177°30'E and 44°30'N. Immature Alaskan coho from streams along the EBS begin to migrate south to the Aleutian Islands and some into the GOA when temperatures begin to decline in late summer. When temperatures begin to increase in the spring, coho from the Bering Sea tributaries begin their migration northward to their spawning streams (Sandercock 1991).

Sockeye Salmon

Sockeye are the most important commercial species in Alaska. Adults average from 2 to 3.6 kg. After hatching, juvenile sockeye may spend one to four years in freshwater before migrating to the ocean as smolt, weighing only about 5 g. Sockeye grow quickly and spend one to four years feeding and growing to maturity in the ocean before returning to spawn. Those fish returning to spawn after only one year in the ocean—called jacks—are almost all males. Although sexually mature, they are much smaller in size (often less than 25 cm in length and 250 g in weight) than adult males that have spent several more years feeding in the ocean. Jacks are also common in chinook and coho salmon populations (Groot and Margolis 1991).

Sockeye salmon occur widely through the North Pacific Ocean and the Bering and Chukchi seas, from California to northern Hokkaido in the Pacific, and from Bathurst Inlet in Canada to the Anadyr River in Siberia. Asian and North American sockeye distributions in the North Pacific Ocean and Bering Sea have broad areas of overlap. Asian sockeye distribution bounds are generally west of 175°W (Burgner 1991). The bounds of North American sockeye, particularly western Alaskan stocks, are found in the North Pacific Ocean to 160°E and in the Bering Sea they are found to 170°E (Burgner 1991). The center of abundance for Asian stocks is generally west of 175°E, and the North American stocks are concentrated east of this longitude (Burgner 1991).

Pacific Salmon Trophic Interactions

The composition of prey for salmon species depends on life stage, availability, and relative abundance of prey, which vary with season and location. Chinook salmon feed on small fish (particularly herring), pelagic amphipods, and crab megalopa, with fish being the largest single contributor to their diet (Healey 1991). Chum salmon diets are composed of amphipod, euphausiid, pteropod, copepod, fish, and squid larvae (Salo 1991). Pink salmon are opportunistic and generalized feeders and are known to feed on epibenthic harpacticoid copepods, pelagic copepods, barnacle nauplii, mysids, eggs of invertebrates and fishes, and fish larvae (Heard 1991). Coho salmon are also opportunistic feeders with diets consisting of marine invertebrates, chum and pink salmon fry, smelts, sand lance, sticklebacks, squid, and crab larvae (Sandercock 1991). Sockeye are known to feed on euphausiids, amphipods, and small fish (lantern fish and juvenile cod in central North Pacific Ocean; in the EBS larval caplin, sand lance, and herring; in GOA sand lance, herring, pollock and capelin) (Burgner 1991).

A wide variety of predators feed on migrant salmon smolts. Predators of large salmon include all toothed whales, seals, sea lions, and shark (Sandercock 1991).

Pacific Salmon Management

Pacific salmon off the Alaska coast are managed under a complex mixture of domestic and international bodies, treaties, regulations, and other agreements. Federal and state agencies cooperate in managing salmon fisheries. The ADF&G manages salmon fisheries within state jurisdictional waters, where the majority of harvest occurs. Management in the EEZ is the responsibility of NPFMC. Under Amendment 4 of the Federal Salmon FMP, regulation of the directed salmon fishery occurring in the EEZ off southeast Alaska is deferred to the State of Alaska (NPFMC 1990). The EEZ off central and western Alaska is closed to directed salmon fisheries. Management of Alaska salmon fisheries is based primarily on regional stock groups of each species and on time and area harvesting by specific types of fishing gear. Over 25 different commercial salmon fisheries in Alaska are managed with a special limited-entry permit system that specifies when and what type of fishing gear can be used in each area. These fisheries, extending from Dixon Entrance in southeast Alaska to Norton Sound in the Bering Sea, are allowed to catch salmon in different fisheries, either with drift gillnets, set gillnets, beach seines, purse seines, hand troll, power troll, or fish wheel harvest gear. Sport fishing is limited to hook-and-line, while subsistence fishermen may use gillnets, dipnets, or hook-and-line. Some subsistence harvesting of salmon is also regulated by special permits.

Salmon fisheries are managed by ADF&G to meet an escapement goal of a certain number of spawners for each river system. Meeting escapement goals is considered equivalent to maintaining healthy stocks. In general, spawners are counted on their way upstream, after their numbers have already been reduced by natural mortality at sea, bycatch at sea, and directed fisheries downstream.

The well-being of salmon in Alaska is also directly influenced by land management practices. The quality of freshwater habitats determines the success of reproduction and initial rearing of juveniles. Several agencies, entities, and groups have significant influence on the quality of freshwater spawning and rearing habitats for salmon throughout Alaska. Included among these are the U.S. Forest Service (in the U.S. Department of Agriculture); the U.S. Bureau of Land Management, National Park Service, and National Wildlife Refuges (in the U.S. Department of the Interior); state parks and forests, Alaska Native regional and village corporations; and various municipalities, boroughs, and private land owners that exert some control over watersheds used by salmon.

International Management

Some fisheries, including the southeast Alaska chinook, coho, and sockeye fisheries, have harvest limits that are subject to negotiations with Canada under the Pacific Salmon Treaty. This treaty also covers salmon that are intercepted in fisheries that are returning to Idaho, Oregon, and Washington. This treaty was signed in 1983, but, in recent years, the treaty process was stalled due to disagreements between the two countries on allocations for certain fisheries and species. On June 30, 1999, a new agreement was signed by the negotiators and agreed to by both countries in December 1999. These new treaty agreements will expire in 2008. The extended time span of the new agreements should add stability to the fisheries of both countries. The agreements are complex, however, and will require continuous coordination between both countries to be successful. Fisheries in the Yukon River are covered under a separate agreement, but a treaty has not been signed. However, joint research and management programs in that large transboundary river system are nearing final agreement.

On a broader international scope, the management of salmon harvest in the high seas of the North Pacific Ocean from 1957 to 1992 was authorized by the INPFC, and via bilateral and multilateral agreements and negotiations with Taiwan and the Republic of Korea (South Korea). In 1993, the NPAFC was formed to replace INPFC. This four-country commission (Canada, Japan, the Russian Federation, and the U.S.) now provides a framework for international cooperation in salmon management and research in the North Pacific Ocean. The NPAFC Convention prohibits high seas salmon fishing and trafficking of illegally caught salmon. Coupled with United Nations General Assembly Resolution 46/215, which bans large-scale pelagic driftnet fishing in the world's oceans, the NPAFC has eliminated legal harvesting of Pacific salmon on the high seas. This allows for effective management control to fully return to the salmon-producing nations.

NOAA Management

There are no GOA FMP amendments that directly limit salmon bycatch. However, in the GOA, the timing of seasonal openings for the pollock fishery in the central and western GOA has been adjusted to avoid periods of high historical chinook and chum salmon bycatch.

In the BSAI, a PSC limit of 48,000 chinook salmon between January 1 and April 15 was established for trawl gear in the Chinook Salmon Savings Area (Figure 3.5-18) (50 CFR 679.21 (e)(1)(v)) and a limit of 42,000 non-chinook salmon between August 15 and October 15 was established in the Catcher Vessel Only Area (50 CFR 679.21 (e)(1)(vi). In 1999, NPFMC reduced the cap to 41,000. This cap was further reduced annually thereafter and currently stands at 29,000, applicable only to pelagic pollock fishing. In the event that these PSC limits are reached, no further groundfish trawling in the specified area is allowed for the remainder of the year.

Salmon bycatch limits are expected to trigger closures only during years when exceptionally high bycatch rates are encountered by the trawl fleet. During the first year of implementation in 1994, the Chum Salmon Savings Area was closed to all trawling from August 20 through November 12 (Figure 3.5-8).

Past/Present Effects Analysis

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-42 provides a summary of the Pacific salmon past effects analysis presented below.

Groundfish fisheries take place at sea, not in the freshwater spawning habitat occupied by spawning aggregations of anadromous Pacific salmon. While other human activities may affect spawning salmon and their habitat, federal groundfish fisheries do not. The quality of salmon spawning habitat is influenced by land management practices (e.g., logging, mining, and oil and gas developments) and climatic events (e.g., flooding that scours streams). Several agencies, entities, and groups exert control over watersheds used by spawning salmon. A relationship between the groundfish fisheries and salmon spawning habitat that could have the potential to cause population-level effects was not identified during screening.

The following direct and indirect effect indicators were identified as potentially having population-level effects on Pacific salmon:

- Mortality due to catch/bycatch of salmon (direct effect).
- Mortality associated with spatial/temporal concentration of salmon bycatch (indirect effect).
- Bycatch mortality of prey species (indirect effect).
- Salmon mariculture (indirect effect).
- Climatic influences (indirect effect).
- Oil pollution (indirect effect).

The past/present events determined to be applicable to the Pacific salmon past effects analysis include the following:

- Past/Present External Events
  - State of Alaska directed salmon fisheries
  - Subsistence fisheries
  - Foreign fisheries (pre-MSA in U.S. EEZ)

  - Foreign fisheries (outside U.S. EEZ)
  - Salmon mariculture (Canada)
  - Climatic shifts
  - EVOS

- Past/Present Internal Events
  - Pollock trawl fisheries

- Past/Present Management Actions
  - ADF&G management
  - Foreign fisheries management
  - Industry self-imposed management
  - FMP groundfish fisheries management

Mortality: State of Alaska Directed Salmon Fisheries

Federal management of Alaska salmon in the pre-statehood era was weak and heavily influenced by the processing sector. The state took over salmon management after statehood in 1959. By the 1970s, state managers realized that salmon stocks were being over prosecuted by an ever-growing fleet and initiated a limited entry system. Hatchery enhancement programs were also initiated to augment commercial salmon harvests (ADF&G 2000b).

Mortality: Subsistence Fisheries

Alaska Native peoples have a bond with salmon that is part of their heritage, as an economic, cultural, and subsistence necessity. Salmon are harvested and used by Alaskan Native populations along the coast of southeastern and southwestern Alaska, comprising the most highly developed aboriginal fishing complex on the continent (Cooley 1961).

Mortality: Foreign Fisheries (pre-MSA in U.S. EEZ)

Direct catch and bycatch of salmon are both associated with past pre-MSA foreign fisheries. U.S. bilateral agreements with Japan and Russia attempted to reduce gear conflicts between State of Alaska salmon fisheries and foreign fisheries and allocate salmon resources to the state fisheries. It is inferred that the past foreign fisheries bilateral agreements were marginal management measures at best and probably did not provide any significant benefit to salmon stocks.

Mortality: Foreign Fisheries (outside US EEZ)

Salmon have a transboundary nature; hence western Bering Sea stocks have the potential to be caught in high-seas and Russian EEZ fisheries. The NPAFC coupled with the United Nations General Assembly Resolution 46/214, both established in 1993, prohibit high seas salmon fishing and ban large-scale pelagic driftnet fishing, respectively. In 1992, the U.S. and Russia signed a bilateral agreement calling for a ban on direct salmon fishing within both country's EEZs, but allowed for directed salmon fishing within 25 nm of the baseline from which the EEZ is measured (Pautzke 1997). With the exception of the occasionally-caught illegal fishing vessel, these measures are thought to provide effective management for salmon catch and bycatch outside the U.S. EEZ.

Mortality: Salmon Mariculture (Canada)

Salmon mariculture began in the Pacific Northwest in the 1970s. By the 1980s, salmon farms raising Atlantic salmon were established in British Columbia and Washington State. Fish farming is perceived as having the potential to increase disease in wild stocks, cause marine water pollution in localized areas, displace wild stock with escaped farm fish, and to lead to interbreeding between wild stocks and escaped farm fish. Studies conducted in British Columbia indicate that farm Atlantic salmon are able to spawn successfully in the wild (Gaudet 2002). Storms, tides, marine mammals, and/or accidents can damage the floating net pens used in fish farms and allow for the escapement into the marine environment of farm fish of all life stages (Gaudet 2002). Sexually mature Atlantic salmon can currently be found in both freshwater and marine environments throughout the Pacific Northwest and Alaska (Gaudet 2002). Alaska banned the farming of finfish in 1990 in order to protect Alaska wild stocks. In 2002, ADF&G proposed that British Columbia phase out their marine fish farms and allow only land-based lake rearing farms to eliminate risks to marine environments while minimizing disruption of local economies (Gaudet 2002).

Mortality: Climatic Influences

Climate variability can have an influence on salmon populations and their prey, both beneficial and adverse. Ocean conditions that have favored high marine survivals in recent years; however, fluctuate due to interdecadal climate oscillations (Mantua *et al.* 1997). Recent evidence suggests that a change in ocean conditions in the North Pacific Ocean may be under way, possibly reflecting the downturn in abundance of Alaska salmon runs in 1996 and 1997. Studies indicate that salmon have improved marine survival during periods of warmer than normal ocean temperatures (Salo 1991).

Pacific salmon prey also respond to climatic conditions. For example, capelin and eulachon, two species of smelts, have been observed to shift abundance and/or distribution during climate changes. Capelin have shown abrupt declines in occurrence in small-mesh trawl survey samples in the GOA (Piatt and Anderson 1996, Anderson and Piatt 1999). In survey data from both NOAA Fisheries and ADF&G, capelin first declined along the east side of Kodiak Island and bays along the Alaska Peninsula. Subsequent declines took place in the bays along the west side of Shelikof Strait. These declines happened quickly, and low abundance has persisted for over a decade. The decline corresponded with increases in water temperature of the order of 2°C, which began in the late 1970s. Capelin have fairly narrow temperature preferences and probably were very susceptible to the increase in water column temperatures (Piatt and Anderson 1996, Anderson *et al.* 1997). Mapping of relative densities of capelin showed defined areas of relative high abundance. The Shelikof Strait region showed relatively high catches in Kujulik, Alitak, and Olga bays. Most catches of capelin were closely associated with bays, except for high catches offshore of Cape Ikolik at the southwest end of Kodiak Island. Isolated offshore areas east of Kodiak Island showed some high catches, with most of the high catches associated with Ugak and Kazakof Bays. Only isolated catches of less than 50 kg were evident in the database from PWS, the Kenai Peninsula, and lower Cook Inlet.

Furthermore, evidence from fishery observers and survey data suggests that eulachon abundance declined in the 1980s (Fritz *et al.* 1993). This data should be interpreted with caution because surveys were not designed to sample small pelagic fishes such as eulachon, and fishery data were collected primarily to estimate total catch of target groundfish. Causes of this presumed decline are unknown, but may be related to variability in year-class strength, as noted for capelin. Small-mesh shrimp trawl surveys in the GOA coastal areas suggest that eulachon have remained at a low level of relative abundance since 1987. Eulachon are currently at the lowest recorded level in the survey series (1972–1997) at 0.01 kg/km (Anderson and Piatt 1999) (see Appendix B).

Mortality: Oil Pollution

The EVOS affected pink salmon in PWS and sockeye salmon in the Kodiak Island area (EVOS Trustee Council 2002a and 2002b). Commercial salmon fishing was closed in PWS, portions of the Cook Inlet, and near Kodiak in 1989 as a result of the spill to avoid possibility of contaminated fish being sent to market. The recovery goal for affected pink and sockeye stocks was a return to stock conditions that would have existed prior to the spill. The EVOS Trustee Council considers both of these species to be recovered from effects of the EVOS (EVOS Trustee Council 2002a and 2002b).

Mortality: Bycatch in MSA Groundfish Fisheries

Although all groundfish fisheries in the Bering Sea and the GOA are prohibited from retaining any salmon they catch, they do encounter them as bycatch. Most salmon bycatch is taken by vessels using pelagic trawl gear targeting pollock. Chinook salmon seem most vulnerable to trawl gear, accounting for 36 to 44 percent of total numbers of salmon bycatch. Chum salmon is next in vulnerability and can reach bycatch proportions as large as those for chinook. Figures 3.5-9 and 3.5-10 show chinook and other salmon bycatch trends by area and gear type from 1998-2001.

The highest bycatch rates for chum salmon occur during August, September, and October, with almost no chum salmon taken in other months (NPFMC 1995a). According to groundfish fishery observer data in the BSAI, the overwhelming majority (96 percent between 1997 and 1999) of other salmon bycatch is chum salmon. Chum salmon from Asia account for a significant part of the chum bycatch in the Bering Sea. Bycatch percentages of coho, sockeye, and pink salmon are small (less than 1 or 2 percent of total salmon bycatch). Chum salmon dominate other salmon bycatch in the GOA as well (56 percent between 1997 and 1999, but higher in prior years).There are also catches of coho salmon (14 percent), pink salmon (3 percent), and sockeye salmon (1 percent) in the GOA. The recent history of salmon bycatch is listed in Table 3.5-43.

Chinook salmon bycatch appears to be concentrated somewhat relative to the overall distribution of pollock fishing (Figure 3.5-11). Although some amount of chinook salmon bycatch occurs throughout the year, it is higher in September and October (pollock B season during 1997 to 1999). Chinook salmon bycatch in the Bering Sea is likely composed mainly of western Alaska and Canadian Yukon stocks (Healey 1991).

Regulations implemented under the BSAI FMP amendment process successfully reduced the foreign fisheries bycatch of salmon. The foreign fisheries salmon bycatch reductions were offset by increased salmon bycatch in the growing JV operations and domestic groundfish fisheries. Establishment of new salmon bycatch limits were issued to address the increase in JV and domesticbycatch levels.

Trawling is prohibited in the Chinook Salmon Savings Areas upon attainment of a bycatch limit of 48,000 chinook salmon in the BSAI under FMP Amendment 21b (NPFMC 1995b, Figure 3.5-18). Currently, an other salmon bycatch level of 42,000 fish is set in the BSAI, and a Chum Salmon Savings Area has been established, which is closed to all trawling during the period of high chum salmon bycatch(August 1 to 31 of each year) (Figure 3.5-8). These measures were implemented under BSAI FMP Amendment 35 (NPFMC 1995a). Like the chinook salmon bycatch level, the other salmon action level serves as a trigger to close the Chum Salmon Savings Area seasonally if that level is reached in a given year, and not as an absolute limit on chum salmon catch. Unlike the chinook salmon bycatch level, catch of other salmon only counts toward the limit of 42,000 fish if it is taken within a limited area of the BSAI, the catcher vessel operation area. Thus, catch of other salmon generally exceeds 42,000 fish per year, and the Chum Salmon Savings Area has never been closed to fishing outside of August 1 to 31. However, catch of other salmon has been considerably lower since these management measures were implemented in 1995 than in the years immediately prior to implementation.

Salmon are always prohibited species in any groundfish fishery; however, they only accrue against the PSC limit when caught with trawl gear from January 15 to April 15 for chinook salmon and within the catcher vessel operational area from August 15 to October 14 for non-chinook salmon. Accrued CDQ trawl salmon PSC catch must be retained and delivered to a shoreside processor, where it is sorted by species, counted, and reported to NOAA Fisheries by the shoreside processor on a CDQ delivery report. Although observer data are not used directly to estimate salmon PSC limits, they are used to verify the species reported on the CDQ delivery report.

Mortality: Bycatch of Salmon Prey Species in MSA Groundfish Fisheries

Bycatch of Pacific salmon prey species, such as sand lance, capelin and euphausiids (i.e., forage fish), in the BSAI and GOA groundfish fisheries tends to be minimal, remaining under 75 mt in the BSAI and 130 mt in the GOA in recent years and would likely have no effect on prey availability to Pacific salmon (Section 3.4.2).

Spatial/Temporal Concentration of Bycatch

The spatial/temporal concentration of bycatch could cause overharvesting of a distinct genetic component of a stock. Current spatial/temporal concentration of salmon bycatch in the BSAI seems to be relative to the distribution of the pollock fishery (Figure 3.5-12). Potential impacts to salmon from past and current BSAI and GOA groundfish fisheries bycatch distribution have not been determined due to the uncertainty of bycatch stock composition; therefore, the magnitude of any such influences is unknown.

Spatial/temporal salmon bycatch is also controlled by non-regulatory means. Many measures have been embraced by the trawl and longline fleet to control and reduce bycatch of Pacific halibut, crab, and salmon. A GIS application has been used by the BSAI trawl and longline fleet to identify hotspots by using bycatch rates reported by individual vessels (Gauvin *et al.* 1995; Smoker 1996). Bycatch rate information from individual vessels is received at a central location, aggregated daily, and then quickly relayed back to the entire fleet in the form of maps, so that hotspot areas can be avoided. PSC rates are reduced and correspondingly higher groundfish catches can then be realized by the fleet. Unfortunately, because this is a voluntary program, non-participating vessels with high bycatch rates may keep the fleet as a whole from catching the entire quota of flatfish. Some bycatch reduction may also come in the form of peer pressure. Individual vessel bycatch rates are now published on the Internet. Vessels with high bycatch rates may face pressure to lower their bycatch.

Comparative Baseline

All five species of Alaska salmon are fully utilized, and stocks in most regions of the state generally have been rebuilt to or beyond previous levels (Table 3.5-44). The high abundance of Alaska salmon up to 1995 should not be interpreted as an absence of some of the same factors affecting declines of salmon in the Pacific Northwest. Unspoiled habitats, favorable oceanic conditions, and adequate numbers of spawning salmon are likely the paramount issues positively affecting current Alaska salmon abundance. Alaska salmon management continues to focus on maintaining pristine habitats and ensuring adequate escapements.

Alaska commercial salmon harvests have generally increased over the last three decades, but may have peaked in 1995 (Figure 3.5-13). After reaching record low catch levels in the 1970s, most populations have rebounded, and fisheries are now at or near all-time peak levels in many regions of the state (Burger and Wertheimer 1995, Wertheimer 1997). The record-high commercial landing of 217 million salmon in 1995 was 11 percent higher than the previous record of 196 million in 1994. However, significant declines in the commercial catches followed in both 1996 and 1997 (Figure 3.5-13). The 1998 Alaska commercial salmon harvest was 151 million salmon (322,055 mt), distributed as 22.6 million sockeye (57,607 mt), 18.9 million chum (73,937 mt), 105 million pink (169,646 mt), 4.6 million coho (16,284 mt), and 563 thousand chinook (4,581 mt). Recreational fishermen caught over 1.8 million salmon in Alaska in 1995 (Howe *et al.* 1996), and subsistence fisheries for salmon in 1994, the most recent year available, harvested over 1 million fish (ADF&G 2001a). Based on preliminary data, the 2002 Alaska commercial salmon harvest (exvessel values) totaled approximately 130 million salmon (275,987 mt). This total was distributed among species as follows: 539,000 chinook (4,064 mt), 22.5 million sockeye (61,914 mt), 4.8 million coho (16,717 mt), 87.6 million pink (135,509 mt), and 15 million chum (57,783 mt) (ADF&G 2003).

The annual commercial harvest of chinook salmon in Alaska has averaged between 500,000 and 700,000 fish in recent years. The statewide 10-year (1988-1997) average annual harvest was 627,000 fish (Savikko 1997). Spawning escapements of chinook and other salmon in southeast Alaska are stable or increasing in 99 percent of the management units, indicating that stocks are healthy (NOAA Fisheries 2003). Of the 407 chinook stocks harvested in the southeast, 81 percent are classified as not threatened, and 15 percent are special concern or at risk (Slaney *et al.* 1996). Large portions of the southeast chinook harvest originate from the Columbia river upriver bright chinook, Middle Columbia River bright chinook, and north-migrating Oregon coastal chinook; these stocks are considered stable (NOAA Fisheries 2003). Chinook stocks listed under the ESA make up a small portion of the southeast harvest, and nearly all coho salmon harvested originate from Alaskan streams (Weitkamp *et al.* 1995).

An exception to the above stock status summary resides in the AYK region of Alaska. After two previous years of very low runs, the summer 2000 chinook and chum salmon runs in the Yukon and Kuskokwim River drainages (ADF&G Region 3, Figure 3.5-14) were so low that even subsistence fishing was prohibited, resulting in a federal disaster declaration. A subsistence closure emphasizes the serious concern for the health of salmon stocks in this region.

Pacific Salmon Cumulative Effects Analysis Status

Chinook salmon and other salmon will be carried forward for the cumulative effects analysis based on the current depressed status of some stocks and the lack of recovery shown to date.

3.5.2.3 Pacific Herring

Life History and Distribution

Pacific herring (*Clupea pallasii)* occur from California through the GOA and Bering Sea to Japan. Pacific herring may grow to a length of 45 cm with a weight of over 500 grams but average 23 cm and about 225 grams. Pacific herring migrate in schools. In Alaska, Pacific herring begin spawning in mid-March in southeastern Alaska and as late as June in the Bering Sea. The timing of spawning is related to water temperatures (NPFMC 1998a). Spawning occurs in shallow, vegetated intertidal and subtidal areas. The eggs are adhesive, and survival is greater for those eggs that stick to vegetation than for those that fall to the bottom. Milt released by the males drifts among the eggs, fertilizing them. The eggs hatch in about two weeks, depending on water temperature. Herring spawn every year after reaching sexual maturity at 3 or 4 years of age. The average life span of herring is about 8 years in southeastern Alaska and 16 years in the Bering Sea. The young larvae drift and swim with the ocean currents. After developing to their juvenile form, they rear in sheltered bays and inlets and appear to remain segregated from adult populations until they mature. After spawning, most adults leave inshore waters and move offshore to feed. They are seasonal feeders and accumulate fat reserves for periods of relative inactivity. Herring schools often follow a diel vertical migration pattern, spending daylight hours near the bottom and moving upward during the evening to feed (Hart 1973). Following spawning, Bering Sea herring move clockwise along the Alaska Peninsula to feed. They typically reach the Unimak Pass area by mid-summer. In late summer, Bering Sea herring move to overwintering areas in the vicinity of the Pribilof Islands (NPFMC 1998a).

In the GOA, spawning concentrations occur mainly off southeastern Alaska, in PWS, around Kodiak Island, and in Cook Inlet. However, little is known about GOA herring overwintering locations.

Trophic Interactions

Pacific herring feed on zooplankton, larvae of pollock, sand lance, and smelt during all their life stages (Schweigert 1997, Livingston 1985, ADF&G 1985). Herring eggs and young larvae are preyed upon extensively by other vertebrate and invertebrate predators (Funk 1994). Juvenile and adult herring are also important prey for other fish, marine mammals, and seabirds.

Management Overview

A draft FMP for BSAI herring was prepared in the early 1980s, but never finalized because herring was deemed fully utilized in Alaska state waters. Management authority was delegated to the State of Alaska. Pacific herring are managed by the ADF&G with annual quotas allocated by the Alaska Board of Fisheries. All directed herring fisheries occur in state waters from Dixon Entrance north to Norton Sound. The fishery fluctuates depending on market demands. Alaska herring fishing quotas are based on a variable exploitation rate of 20 percent. Lower exploitation rates are used when stocks decline to near-threshold levels. Herring fisheries are managed by regulatory stocks (i.e., geographically distinct spawning aggregations). Herring fisheries include the following:

- Subsistence harvest of spawn on kelp or artificial substrate.
- Herring spawn on open pound spawn-on-kelp and wild spawn-on-kelp.

- Purse seine and gillnet fisheries sac roe harvest.

- Food and bait harvest.

Past/Present Effects Analysis

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-45 provides a summary of the Pacific herring past effects analysis presented below.

The following direct and indirect effects were identified as potentially having population-level effects on Pacific herring:

- Mortality due to catch/bycatch (direct effect).

- Nutritional stress due to climatic influence on prey species (indirect effect).

- Reduced recruitment due to oil pollution (EVOS; PWS population) (indirect effect).

The past/present events determined to be applicable to the Pacific herring past effects analysis include the following:

- Past/Present External Events
  - Alaska State directed herring fisheries
  - Foreign fisheries (pre-MSA)
  - Climatic shifts
  - EVOS

- Past/Present Internal Events
  - Pollock trawl fisheries

- Past/Present Management Actions
  - ADF&G management
  - FMP groundfish fisheries management

Federal groundfish fisheries do not take place in the nearshore shallow environments where herring congregate to spawn, so no impacts to herring spawning habitat or aggregations are predicted as a result of these fisheries. Herring prey on zooplankton, including larvae of pollock, sand lance, and smelt. Zooplankton are not caught in groundfish fisheries. The only way groundfish fisheries might possibly have any impact on herring prey would be severe overfishing of species such as pollock to an extent that limited pollock larval abundance. This level of groundfish overfishing has not been observed over the course of FMP management, and is not likely to occur in the future. The spatial/temporal concentration of bycatch could have adverse effects by overharvesting a distinct genetic herring stock. GOA herring are considered to be genetically distinct from EBS herring. BSAI herring bycatch appears to be evenly spread throughout the federal pollock fishery (Figure 3.5-15). Herring bycatch in the GOA groundfish fisheries is very small compared to the bycatch in the BSAI. Examples of indirect impacts to Pacific herring would be spatial and temporal concentrations of bycatch resulting in the overharvest of a distinct genetic component of the stock, destruction of spawning habitat and disruption of spawning aggregations, and competition for prey. Herring bycatch does not appear to be concentrated in space, but rather is spread throughout the pollock fishery under status quo management (Figure 3.5-15). Although there is some amount of herring bycatch throughout the year, it is higher in September and October (pollock B season during 1997 to 1999). No significant impacts to herring stocks from spatial or temporal concentration of herring bycatch have been identified.

Past/Present Events and Management Actions

External Mortality: Catch in the State Directed Herring Fisheries

During the 1920s herring was valued for oil and meal. Reduction plants sprang up all over Alaska from Craig to Kodiak to process herring into oil and meal. Reduction and food herring harvests peaked in the 1920s and 1930s (Figure 3.5-16). By the 1950s, Peruvian anchoveta harvest had severely impacted the Alaska herring oil and meal markets due to lower costs (ADF&G 2000). Herring reduction plants began closing and by1966 the last herring reduction plant in Alaska had closed. The herring for bait fishery began in the early 1900s and has remained relatively stable to the present time with a slight increase in demand due to the development of the crab fisheries in the 1970s (Figure 3.5-16). Herring fisheries continue to occur; however, they are highly managed by the state. Annual stock assessments from trawl surveys are conducted with quota setting processes responsive to fluctuations in herring biomass.

External Mortality: Catch in the pre-MSA Foreign Fisheries

A foreign fishery for herring food products existed in the Bering Sea during the 1960s and 1970s (Figure 3.5-16). Foreign harvesting of herring was discontinued around 1980 under the provisions of the MSA when inshore domestic fisheries began to fully utilize Bering Sea herring (ADF&G 2000b).

Internal Mortality: Bycatch in Groundfish Fisheries

Herring bycatch is taken primarily in the trawl pollock fisheries. Herring caught as bycatch in trawl fisheries do not survive. Overall herring bycatch is higher in the BSAI than the GOA. It is estimated that herring bycatch may have been as high as 7,300 to 9,100 mt in the late 1980s. JV operations peaked in 1987, giving way to a rapidly developing domestic fishery. Bycatch further increased with development of the fully domestic fleet, but was quickly limited by regulation. By 1989, unrestrained bycatch in the trawl fisheries had jumped to high levels relative to exploitable biomass. Past federal groundfish fisheries bycatch combined with the state fisheries direct take have exceeded the state's herring harvest policy in the past. (Appendix C, BSAI FMP Amendment 16a).

Pacific herring bycatch limitations in the groundfish fisheries apply to trawl gear in the Bering Sea. The PSC limit for trawl gear is determined each year when TAC specifications are reset. Amendment 16a, implemented on July 12, 1991, established a herring bycatch cap of one percent of the estimated EBS herring biomass, which is further apportioned by target fishery (50 CFR 679.21 (e)(1)(iv)) (Funk 2003). Should the PSC limit for any groundfish fishery be reached during the fishing year, one or all of the three designated Herring Savings Areas close, depending on the time of year (Figure 3.5-17) (50 CFR 679.21 (e)(7)(v)). Three time and area closures were established, taking into account herring migration patterns. Area 1 closes from June 15 to July 1, Area 2 from July 1 to August 15, and Area 3 from September 1 through March 1. Areas with relatively high bycatch rates of herring were identified from data collected by observers on foreign and joint venture vessels. Pacific herring closures have been effective at maintaining an acceptable level of bycatch in years when herring are abundant on the fishing grounds. This situation occurred in 1992, 1993, 1994, and 1995, when herring savings areas 2 and 3 were closed to trawling for fisheries directed at pollock, rock sole, yellowfin sole, and other flatfishes. Area 3 experienced a total closure from November 4, 1994 to March 1, 1995, for the pollock midwater trawl fishery. From 1993 to present, the pollock fishery has primarily driven herring bycatch rates with the yellowfin sole fishery playing a secondary role (Figure 3.5-19) (Funk 2003).

PSC bycatch is also controlled by non-regulatory means. Many measures have been embraced by the trawl and longline fleet to control and reduce bycatch of Pacific halibut, herring, crab, and salmon. A GIS application has been used by the BSAI trawl and longline fleet to identify hotspots by using bycatch rates reported by individual vessels (Gauvin *et al.* 1995, Smoker 1996). Bycatch rate information from individual vessels is received at a central location, aggregated daily, and then quickly relayed back to the entire fleet in the form of maps, so that hotspot areas can be avoided. PSC rates are reduced and corresponding higher groundfish catches can then be realized by the fleet. Unfortunately, because this is a voluntary program, non-participating vessels with high bycatch rates may keep the fleet as a whole from catching the entire quota. Some bycatch reduction may also come in the form of peer pressure. Individual vessel bycatch rates are now published on the Internet. Vessels with high bycatch rates may face peer pressure to lower their bycatch.

External Nutritional Stress: Climatic Influence on Prey Species

Climate variability can have an influence on herring prey. However, these interactions are not fully understood nor defined and research on climatic effects is ongoing.

External Reduced Recruitment: EVOS Contamination (PWS)

Herring spawning habitat in PWS was contaminated by oil from the EVOS in 1989. Subsequent laboratory studies have indicated that larval and adult herring exposure to oil can cause increased rates of egg mortality, larval deformities, and compromise adult herring immune systems. In 1993, there was a crash in the PWS herring population. This crash was correlated with a viral disease, increasing biomass, and lowering plankton production. The extent that exposure to oil contributed to the disease outbreak and consequent population crash is uncertain (EVOS Trustee Council 2002c). The EVOS Trustee Council continues to monitor the recovery of the PWS herring population.

Comparative Baseline

ADF&G makes herring biomass projections for each regulatory stock using postseason escapement estimates, historical mean rates of survival, and current mean weights and assumed recruitment rates for each age class.

Herring fisheries continue to occur; however, they are closely managed by the state. Although most herring are harvested in the sac-roe season in spring, fall seasons are also designated for food and bait harvesting. The ADF&G regulates and monitors the resource by 20 separate fisheries. Annual stock assessments from trawl surveys are conducted and quota setting processes are responsive to fluctuations in herring biomass.

In the Bering Sea, catches peaked dramatically in 1970 at more than 108,000 mt and fell to 19,050 mt in 1977 (Figure 3.5-20, NMFS 1999d). Since then, catches have risen slowly but steadily, reflecting improving stock conditions. A portion of the Bering Sea harvest is taken as bycatch in the groundfish fishery. Regulations now limit bycatch to about 1,000 mt. In more recent years, statewide herring harvests have averaged about 45,000 mt. The majority of the harvest was roe-bearing herring (about 90 percent) and the remainder was food-and-bait herring (about 10 percent). The herring roe-on-kelp harvest (about 150 mt) is minuscule in percentage terms.

Herring populations, like those of other small pelagic fish species, are subject to wide fluctuations in abundance. The causes suggested for these fluctuations range from natural causes to overfishing (and underfishing), pollution effects (including the 1989 EVOS), disease, climate variability, and combinations of factors (Pearson *et al.* 1999). From catch records (Figure 3.5-20), it is evident that herring biomass fluctuates widely due to influences of strong and weak year-classes. The period since the mid-1970s seems to be one of low-to-moderate herring abundance. Abundance of the stocks depends mostly on highly variable year-class strengths. A strong 1988 year-class, which dominated the stock, declined rapidly in abundance, and was replaced by another strong year-class (1992), which should sustain abundance levels in the near future. In PWS, herring collections in 2002 indicate that a large proportion of this population (over 30 percent) is now comprised of 3-year olds. If this trend holds up through successive sampling, it could signal that recovery is underway for the PWS herring stock (EVOS Trustee Council 2002c).

Pacific Herring Cumulative Effects Analysis Status

FMP 2.1 proposes to eliminate the groundfish fishery PSC limits and inseason bycatch triggered closures. These measures have the potential to affect herring biomass levels and could impose further economic hardship on the state herring fisheries. Therefore, Pacific herring will be carried forward for the alternative cumulative effects analysis.

3.5.2.4 Crab

The commercially important crab species are red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), golden king crab (*L. aequispinus;* also called brown king crab), bairdi Tanner crab (*Chionoecetes bairdi*), and opilio Tanner crab *(C. opilio;* also called snow crab). King and Tanner crab share a similar life cycle, although particular life cycle traits are distinct for each species. After males and females mate, the female carries the eggs for approximately a year, at which time the eggs hatch into free-swimming larvae. After drifting with the currents and tides and undergoing several development changes, the larvae settle to the ocean bottom and molt into non-swimmers, looking very much like miniature adult crab. The juvenile crab settle on preferred habitat, where they continue to molt and grow for several years until they become sexually mature. Each life stage of crab stocks is concentrated at some combination of depth, habitat, geographic area, and time of year.

Crab, being benthic organisms, depend on specific habitat types throughout their life stages. Settlement on habitat with adequate shelter, food, and temperature is imperative to the survival of first settling crab. Young-of-the-year red and blue king crab require nearshore shallow habitat with significant protective cover (e.g., sea stars, anemones, microalgae, shell hash, cobble, shale) (Stevens and Kittaka 1998). Early juvenile stage bairdi and opilio Tanner crab also occupy shallow waters and are found on mud habitat (Tyler and Kruse 1997).

King and Tanner Crab Life History and Distribution

Red king crab are widely distributed throughout the BSAI, GOA, Sea of Okhotsk, and along the Kamchatka shelf up to depths of 250 m. King crab molt several times per year through age three, and annually thereafter. At larger sizes, king crab may skip molt as growth slows. Females grow more slowly and do not get as large as males. In Bristol Bay, males attain 50 percent maturity at 120-mm carapace length and females at 90-mm carapace length (about 7 years). Ages of crab referred to in this document are inferred from tagging and growth, since currently crab cannot be aged. For crab which undergo a terminal molt, radiometric aging of the shell has provided estimates of age since the last molt (Nevissi *et al.* 1996). Maximum age for the largest red king crab caught near Kodiak may be about 24 years based on growth and tagging data(Stevens and Kittaka 1998). Mean age at recruitment into the fishery is eight to nine years. Red king crab in Norton Sound mature at smaller sizes and do not attain the maximum sizes found in other areas. In Bristol Bay, red king crab mate when they enter shallower waters (less than 50 m), generally beginning in January and continuing through June. Males grasp females just prior to female molting, after which the eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female's abdomen. The females carry the eggs for 11 months before they hatch, generally in April. Red king crab spend two to three months in larval stages before settling to the benthic life stage. Young-of-the year crab occur at depths less than 50 m. They are solitary and need high-relief habitat or coarse substrate, such as boulders, cobble, shell hash, and living substrates, such as bryozoans and stalked ascidians (Stevens and Kittaka 1998). At 1.5 to 2 years, crab form pods consisting of thousands of crab. As crab grow, they migrate to deeper water.

Blue king crab have a discontinuous distribution throughout their range and tend to form discrete populations along rocky coasts, rocky islands, and fjord-like areas. In the Bering Sea, discrete populations exist around the Pribilof Islands, Saint Matthew Island, Saint Lawrence Island, and Little Diomede Island in the Bering Straight. Smaller populations have been found around Nunivak and King Islands. Adult male blue king crab occur at an average depth of 70 m and an average water temperature of 0.6 °C. Blue king crab molt multiple times as juveniles. Skip molting occurs with increasing probability for males larger than 100-mm carapace length. In the Pribilof Islands, males attain 50 percent maturity at 108-mm carapace length, and females attain 50 percent maturity at 96-mm carapace length (about five years) (Somerton and MacIntosh 1983). Blue king crab in the Saint Matthew Island area mature at smaller sizes (50 percent maturity at 77-mm carapace length for males and 81-mm carapace length for females) and do not get as large overall. Blue king crab have a biennial ovarian cycle and a 14-month embryonic period before hatching in late spring. Juveniles require cobble habitat with shell hash. These habitat areas have been found at 40 to 60 m around the Pribilof Islands. Unlike red king crab, juvenile blue king crab do not form pods, but instead rely on cryptic coloration for protection from predators.

Golden king crab, also called brown king crab, range from the Japan Sea to the northern Bering Sea, around the Aleutian Islands, on various sea mounts, and as far south as northern British Columbia. In the BSAI, golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island passes on extremely rough bottom strata. Size at sexual maturity depends on latitude, with crab in the northern areas maturing at smaller sizes. In the Saint Matthew Island area, males attain 50 percent maturity at 92-mm carapace length and females at 98-mm carapace length. In the Pribilof Islands and western Aleutian Islands, males attain 50 percent maturity at 107-mm carapace length and females at 100-mm carapace length. Further south, in the eastern Aleutian Islands, males attain 50 percent maturity at 130-mm carapace length and females at 111-mm carapace length.

Bairdi Tanner crab are distributed on the continental shelf of the North Pacific Ocean and Bering Sea from Kamchatka to Oregon. Off Alaska, bairdi Tanner crab are concentrated around the Pribilof Islands and immediately north of the Alaska Peninsula, and are found in lower abundance in the GOA. After molting many times as juveniles, bairdi tanner crab reach sexual maturity at about age-6 with an average carapace width of 110 to 115 mm for males and 80 to 110mm for females (Tyler and Kruse 1997). At maturity, females undergo a terminal molt. Molting frequency for males decreases after maturity; however, terminal molt for males has not been determined (Zheng *et al.* 1998). Male bairdi Tanner crab reach a maximum size of 190-mm carapace width and have a maximum age of at least 15 years (Donaldson *et al.* 1981). Males of commercial size may range between 9 and 11 years old and vary in weight from 1 to 2 kg (Adams 1979). Bairdi Tanner crab females are known to form high-density mating aggregations, or pods, consisting of hundreds of crab per mound. These mounds may provide protection from predators and attract males for mating. Research shows that female bairdi Tanner crab prefer mating with large, old-shell males (Paul and Paul 1996, Paul *et al.* 1995). Mating occurs from January through June. Some females can retain viable sperm in spermathecae for up to two years. Females carry clutches of 50,000 to 400,000 eggs for one year after fertilization. Hatching occurs between April and June (Tyler and Kruse 1997). Spawning habitat for bairdi Tanner crab in the BSAI has not been identified.

Opilio Tanner crab are distributed on the continental shelf of the Bering Sea, the Arctic Ocean, and in the western Atlantic Ocean as far south as Maine. Opilio Tanner crab are not present in the GOA. In the Bering Sea, they are common at depths of no more than 200 m. The EBS population within U.S. waters is managed as a single stock; however, the distribution of the population extends into Russian waters to an unknown degree. Opilio Tanner crab reach sexual maturity at about age 5 to 8, with 50 percent mature at carapace width of 79 mm for males and 49 mm for females. The mean size of mature females varies from year to year over a range of 63-mm to 72-mm carapace width. Females cease growing with a terminal molt upon reaching maturity, and rarely exceed 80-mm carapace width. Males may also cease growing upon reaching a terminal molt when they acquire the large claw characteristic of maturity. Male opilio Tanner crab reach a maximum size of 150-mm carapace width and may live up to 19 years. Large, old -shelled males out-compete new-shell adolescent and small adult males in mating with females (Sainte-Marie *et al.* 1999). Commercial-sized males may range between 9 and 11 years old and average about 0.6 kg (Saint-Marie *et al.*1999). Female opilio Tanner crab are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two groups of eggs can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known (Sainte-Marie *et al.* 1997). In Bristol Bay, podding behavior is unique to red king crab and incorporates male and female crab of different ages. These pods may result in a patchy distribution of red king crab in this region as opposed to a random or continuous distribution often observed for other species (Dew and McConnaughey in review).

King and Tanner Crab Trophic Interactions

In the trophic structure, crab are members of the inshore benthic infauna consumers guild (NPFMC 1994). During each life stage, crab consume different prey and are consumed by different predators. Planktonic larval crab consume phytoplankton and zooplankton. Post settlement juveniles feed on diatoms, protozoa, hydroids, crab, and other benthic organisms.

Food eaten by king crab varies with size, depth inhabited, and species, but includes a wide assortment of worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, fish parts, and algae. Bairdi and opilio Tanner crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, other crustaceans, polychaetes and other worms, gastropods, and fish (Lovrich and Sainte-Marie 1997).

Planktonic larval crab are prey for pelagic fish, such as pollock, salmon, and herring. King crab fall prey to a wide variety of species including Pacific cod, Pacific halibut (Alaska plaice, yellowfin sole, flathead sole) arrowtooth flounder, octopus, and large king crab (Livingston *et al.* 1993). Bairdi and opilio Tanner crab are consumed by a wide variety of predators including groundfish, walrus, bearded seals, sea otters, octopi, Pacific cod, Pacific halibut and other flatfish, eelpouts, sculpins, and adult tanner crab (Tyler and Kruse 1997). Opilio Tanner crab comprise a large portion of the diet of many skate species (Orlov 1998).

King and Tanner Crab Management

Alaska king, bairdi Tanner crab, and opilio Tanner crab (also called snow crab) fisheries are managed by the State of Alaska, with federal oversight and following guidelines established in the BSAI king and Tanner crab FMP (NPFMC 1989). Annual trawl surveys for crab stock assessments are conducted by the NOAA Fisheries in the BSAI. A length-based analysis, developed by ADF&G, incorporates survey, commercial catch, and observer data into more precise abundance estimates (Zheng *et al.* 1998, Zheng *et al.* 1995). Abundance estimates generated by this model are used to set guideline harvest levels for the crab fisheries. Catches are restricted by GHLs, seasons, permits, pot limits, and size and sex limits that restrict landings to legal-sized male crab. Fishing seasons are set at times of the year that avoid molting, mating, and softshell periods, both to protect crab resources and to maintain product quality. Observers are required on all vessels processing king and tanner crab. Crab are captured with baited pots, and most of the catch is landed in Dutch Harbor, Alaska. Most crab vessels target different crab species during different seasons, and many crab vessels also participate in the groundfish fisheries.

King crab along with bairdi and opilio Tanner crab are prohibited species for the state scallop and groundfish fisheries and federal groundfish fisheries, meaning that any crab bycatch must be discarded. Although crab are always prohibited species in any groundfish fishery, they accrue against a CDQ PSC limit only when caught with trawl gear in Zone 1 for red king crab, Zone 1 and 2 for bairdi Tanner crab, and the opilio Tanner Crab Bycatch Limitation Zone for opilio Tanner crab (Figure 3.5-8). PSC limits are set for each species by zone for each fishery. When the PSC limit is reached the fishery closes for the remainder of the season .

The PSC limit for red king crab is based on abundance of the Bristol Bay red king crab stock as follows:

- When the number of mature female red king crab is equal to or below the threshold number of 8.4 million crab, or the effective spawning biomass is less than 14.5 million pounds, the Zone 1 red king crab PSC limit is 35,000 crab.

- When the number of mature female red king crab is above threshold, and the effective spawning biomass is equal to or greater than 14.5, but less than 55 million pounds, the Zone 1 red king crab PSC limit is 100,000 crab.

- When the number of mature female red king crab is above threshold, and the effective spawning biomass is equal to or greater than 55 million pounds, the Zone 1 red king crab PSC limit is 200,000 crab.

BSAI FMP Amendment 57 modified the red king crab bycatch by reducing the limits by an additional 3,000 crab as part of the conversion of the pollock fishery to pelagic trawling only.

Based on the 2002 abundance estimate of the effective spawning biomass at 37.7 million pounds (NPFMC 2002e; Appendix B - Prohibited Species Catch in the BSAI), the current PSC limit is 97,000 crab. The red king crab cap has generally been allocated among several groundfish fisheries. Once a fishery exceeds its red king crab PSC limit, Zone 1 is closed to that fishery for the remainder of the year, unless further allocated by season.

Bairdi tanner crab PSC limits are set separately for Zone 1 and Zone 2. PSC limits in both zones are based on total abundance of tanner crab as determined by the annual NOAA Fisheries trawl survey, as follows:

	Abundance	PSC Limit
Zone 1	0-150 million crab	0.5 percent of abundance
	150-270 million crab	750,000 crab
	270-400 million crab	850,000 crab
	Over 400 million crab	1,000,000 crab

	Abundance	PSC Limit
Zone 2	0-175 million crab	1.2 percent of abundance
	175-290 million crab	2,100,000 crab
	290-400 million crab	2,550,000 crab
	Over 400 million crab	3,000,000 crab

These PSC limits are further reduced by 50,000 crab as part of BSAI FMP Amendment 57.

Based on the 2002 abundance estimate of 464.9 million crab, the 2003 PSC limit is 980,000 crab in Zone 1 and 2.97 million crab in Zone 2 (NPFMC 2002e; Appendix B - Prohibited Species Catch in the BSAI). The bairdi tanner crab cap may be further allocated among several groundfish fisheries. When a fishery exceeds its bairdi tanner crab PSC limit in a zone, trawling is closed in that zone for the remainder of the year.

PSC limits for opilio tanner crab also are based on their total abundance as estimated by the NOAA Fisheries trawl survey. The opilio tanner crab PSC limit is set at 0.1133 percent of total opilio tanner crab abundance, with a minimum PSC of 4.5 million opilio tanner crab and a maximum of 13 million crab. PSC limits are further reduced through BSAI FMP Amendment 57 by 150,000 crab. Based on the 2002 abundance estimate of 1.49 billion crab (NPFMC 2002e; Appendix B - Prohibited Species Catch in the BSAI), the 2003 PSC limit is 4.35 million crab. The opilio tanner crab PSC limit applies to the *C. opilio* Bycatch Limitation Zone. The total PSC limit is allocated among several groundfish trawl fisheries. Upon attainment of a opilio crab PSC limit for a particular trawl target fishery, that fishery is prohibited from fishing within the *C. opilio* Bycatch Limitation Zone.

NOAA Fisheries Management

Crab regulations have been based on concerns that trawling impacts crab populations directly in terms of trawl-induced mortality and indirectly through habitat degradation. Observed mortality, as measured by crab bycatch, has accounted for a small percentage of crab populations. For example, bycatch amounted to only

0.5 percent of the red king crab, 1.2 percent of the bairdi Tanner crab, and 0.1 percent of the opilio Tanner crab population on average, for 1992 through 1995 (NPFMC 1996). Because bycatch is currently considered to be minor relative to other sources of mortality, time and area closures are thought to be more effective than PSC limits in reducing impacts of trawling on crab stocks (Witherell and Harrington 1996). As such, numerous trawl closure areas have been instituted to address concerns about unobserved mortality (crab wounded or killed but not captured), and possible habitat degradation due to trawling and dredging.

BSAI Crab Closures

Nearshore Bristol Bay Closure

BSAI FMP Amendment 10 prohibits all trawling at all times in the EEZ within the area east of 162°W with the exception of an area bounded by 159° to 160°W and 58° to 58°43'N which remains open April 1 to June 15; this amendment addresses concerns that commercial trawl fishing was contributing to increased mortality of crab due to incidental capture and mutilation.

Bristol Bay Red King Crab Area

BSAI FMP Amendment 37 closed this area seasonally to non-pelagic trawling to protect important red king crab habitat and rebuild the red king crab stock. The red king crab commercial fishery was closed in 1994 and 1995.

Pribilof Islands Habitat Conservation Area

BSAI FMP Amendment 21a closed trawling year-round in important habitat areas for blue king crab and Korean hair crab.

Crab Protection Zones

Zone A closed to trawling year-round; Zone B closed to trawling March 15 to June 15.

Crab Bycatch Limitation Zones

Closed to specified trawl fisheries when limits are reached.

C. Opilio Bycatch Limitation Zones

BSAI FMP Amendment 40 closed this area to specified trawl fisheries when limits are reached.

GOA Crab Closures

Permanent Kodiak Crab Protection Zones

GOA FMP Amendment 15 and 26 established Type I, II, and III areas for special bottom trawl within the GOA region to protect king crab, rebuild crab stocks, and protect habitat. Alitak Flats/Towers and Marmot

Flats are closed to non-pelagic trawls year-round, Chirikof Island and Barnabas are closed to non-pelagic trawls from February 15 to June 15.

Past/Present Effects Analysis

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-46 provides a summary of the king and Tanner crab past effects analysis presented below.

Crab species prey on a wide assortment of organisms that varies with life stages. fisheries bycatch of crab prey species ranges from very low (e.g., worms, snails, brittle stars, et cetera) to none (e.g., phytoplankton and zooplankton). A relationship between the groundfish fisheries minor bycatch of crab prey and prey availability for crab that could have the potential to cause population-level effects on crab species was not identified during screening. Therefore, effects on crab prey species will not be part of the analysis.

The following direct and indirect effect indicators were identified as potentially having population-level effects on crab:

- Catch/bycatch mortality (direct effect).
- Mortality from predation (direct effect).
- Climatic influences on marine survival (indirect effect).
- Mortality associated with spatial/temporal concentration of bycatch (indirect effect).

The past/present events determined to be applicable to the crab past effects analysis include the following:

- Past/Present External Events
  - Foreign fisheries (pre-MSA in U.S. EEZ)
  - Alaska State directed crab fisheries
  - Alaska State groundfish and scallop fisheries
  - Subsistence fisheries
  - Predation
  - Climate variability
- Past/Present Internal Events
  - FMP groundfish fisheries
- Past/Present Management Actions
  - Bilateral agreements
  - ADF&G management
  - Industry self-imposed management
  - FMP groundfish fisheries management

Mortality: Foreign Fisheries Direct Catch and Bycatch

Directed Japanese (1953 to 1975) and Russian (1959 to 1972) red king crab fisheries were conducted in the EBS and Bristol Bay. By the mid-1960s, there were signs that exploitation rates were at or approaching limits. Bristol Bay data showed that increased catches were being maintained by increases in the number of tangle nets being fished and in the average time the nets were being soaked. The Bristol Bay red king crab stock began to decline in 1964 after peak catches not related to crab biomass increases. Declines in the Kodiak and GOA crab fisheries led to a renewed interest of the domestic crab fleet in the Adak and Bering seas. The Adak fishery declined in the early 1970s and has never fully recovered.

During the mid-1960s, foreign fleets in the BSAI took record numbers of yellowfin sole and Pacific ocean perch. Crab bycatch is associated with both of these fisheries. Crab bycatch and unobserved mortality also occurred due to interactions with the foreign fleet's bottom trawl gear and state crab fixed gear fisheries. In the mid-1960s, the U.S. initiated several bilateral agreements with Japan and Russia to reduce gear conflicts between State of Alaska fixed gear crab fisheries and foreign fisheries and to allocate crab resources between the foreign fisheries and state fixed gear crab fisheries. The Japanese pot sanctuary area was established as a no-trawl zone in the early 1960s but was eliminated in 1976 with the implementation of the MSA. This area coincided with the distribution of mature female red king crab brood stock in the Bering Sea (Dew and McConnaughey in review). Although the MSA effectively eliminated trawling by foreign vessels, it did not provide for observers on domestic vessels (roughly between 1977-1990). Thus, the lack of observer coverage aboard vessels fishing in Bristol Bay may have led to inaccurate bycatch numbers being reported to managers who in turn, evaluated the potential impacts of trawling on red king crab (Dew and McConnaughey in review).

Mortality: Direct catch and Bycatch in State Directed Crab Fisheries

Bycatch consists of females and sublegal-sized males of the target species and non-target crab species. In the crab fisheries, this bycatch may comprise up to 60 percent of the total catch (Zhou and Shirley 1997a, Zhou and Shirley 1997b). The main concern of bycatch in the crab fishery is handling mortality of discarded crab, which leads to some reduction in fishery production (MacIntosh *et al.* 1995, Murphy and Kruse 1995). Mortality of crab bycatch is not well known, but is estimated to be 20 percent, although, handling mortality may be higher in winter fisheries when crab are exposed to low air temperatures and wind (NMFS 2004). Research is being conducted to reduce the amount of bycatch in the crab fisheries, such as improving pot design (Zhou and Shirley 1997a, Zhou and Shirley 1997b). Crab FMP regulations prohibit the landing of females and sublegal-sized males. State crab fisheries continue to occur and are closely managed by the state in cooperation with NOAA Fisheries. Quota setting processes are responsive to fluctuations in crab stocks but are limited in their ability to account for other factors possibly affecting crab populations such as changes in sex-ratio and spawning-recruitment success. Crab bycatch in the state and federal groundfish fisheries is taken into account under the state management processes.

Mortality: Bycatch in State Groundfish and Scallop Fisheries

Crab bycatch and unobserved mortality due to interactions with bottom trawl gear is associated with past state groundfish fisheries and state scallop fisheries. In the domestic groundfish fisheries, bycatch of red king crab and bairdi Tanner crab have been kept in check with PSC limits for trawl and scallop fisheries.

Mortality: Egg Mass Predation

Egg masses of king crab are often infested by a variety of symbionts and predators. Of particular importance is the nemertean worm, *Carcinonemertes regicides* (which means "king killing crab worm"). These worms have been observed in egg masses of king crab from multiple locations in Alaska (Kuris *et al.* 1991). Prevalence of worms (the proportion of crab infested with worms) was 100 percent in crab collected from southeastern Alaska, Cook Inlet, and many Kodiak sites. The worms were essentially absent from crab collected in the Bering Sea. Almost 100 percent of eggs were killed by worm predation in crab collected from Kachemak Bay, near Homer, Alaska, from 1983 to 1984. This predator could be responsible for limiting recruitment of crab populations in southcentral Alaskan waters, but does not seem to be a major factor in the Bering Sea.

Mortality: Climate Variability

Climate can have an influence on crab populations and their prey, both beneficial and adverse. Wind speed and duration can affect coastal upwelling of colder water from deeper depths. This process of upwelling promotes primary and secondary production, thus affecting the production of food for crab larvae. At the present time a causal relationship between phytoplankton and larval crab abundance and survival has not been established. However, it is thought that community composition and relative abundance of various phytoplankton species, in particular specific diatoms, could potentially be critical to the survival of red king crab larvae. Current regimes over the EBS influence the transport of crab larvae during their planktonic life, and eventual deposition on appropriate or non-appropriate settlement habitat for post-settlement juvenile survival (NMFS 2004).

Mortality: Bycatch in MSA Groundfish Fisheries

Crab bycatch in past foreign fisheries was replaced with increased crab bycatch in the JV fisheries until 1987 when new bycatch limits were put into effect. As the JV fisheries were being phased out and the domestic fisheries phased in, crab bycatch increased once again, but was quickly addressed by the establishment of new crab bycatch limits. Bycatch of opilio Tanner crab was unconstrained through 1996. Overall crab bycatch has been a function of crab abundance and PSC limits. High bycatch of king and Tanner crabs (mostly opilio Tanner crab) were taken in the 1970s by foreign fisheries. However, regulations and incentives implemented with the groundfish FMP in 1982 reduced crab bycatch to much lower levels. Bycatch of opilio Tanner crab increased drastically in the early 1990s, corresponding to an expanding crab population, so opilio Tanner crab PSC limits were established in 1996. Figures 3.5-21, 3.5-22, 3.5-23, and 3.5-24 show bycatch trends for red king crab, other king crab, bairdi Tanner crab, and other Tanner crab by area and gear during 1998-2001 (Hiatt *et al.* 2002).

Bycatch of prohibited species is also controlled by non-regulatory means. Many measures have been embraced by the trawl and longline fleet to control and reduce bycatch of crab, herring, Pacific halibut, and salmon. A GIS application has been used by the BSAI trawl and longline fleet to identify hotspots by using bycatch rates reported by individual vessels (Gauvin *et al.* 1995; Smoker 1996). Bycatch rate information from individual vessels is received at a central location, aggregated daily, and then quickly relayed back to the entire fleet in the form of maps, so that hotspot areas can be avoided. PSC rates are reduced and corresponding higher groundfish catches can then be realized by the fleet. Unfortunately, because this is a voluntary program, non-participating vessels with high bycatch rates may keep the fleet as a whole from catching the entire quota. Some bycatch reduction may also come in the form of peer pressure. Individual vessel bycatch rates are now published on the internet and vessels with high bycatch rates may face pressure to lower their bycatch.

Habitat Destruction

Major spawning areas have been identified for BSAI red king crab and western GOA red king crab. These important habitats are protected by trawl closures and conservation zones. Areas currently closed to non-pelagic trawling in the Bering Sea to protect crab species are the Red King Crab Savings Area, the nearshore Bristol Bay No Trawling Zone, and the Pribilof Islands Habitat Conservation Area. Blue and golden king crab habitat areas are protected by conservation zones in the Pribilof Islands and indirectly by the lack of groundfish effort near Saint Matthew Island. It has been hypothesized that the elimination of the Japanese pot sanctuary in Bristol Bay in 1976, with the subsequent establishment of a major trawling area amidst a large broodstock of red king crab, resulted in adverse impacts to important inshore crab habitat (Dew and McConnaughey in review). The importance of living and non-living habitat to various life stages of crab populations throughout the BSAI and GOA has not been determined to date. However, habitat research continues.

Comparative Baseline

Red King Crab

The 2002 length based analyses show mature female crab abundance has decreased slightly from the 2001 level; however, legal males show a slight increase and pre-recruit males have decreased in abundance. Legal male abundance in Bristol Bay increased from 7.5 million crab in 1997 to 9.4 million crab in 1999, decreased to 8.3 million crab in 2001, then increased slightly to 8.6 million crab in 2002 (NPFMC 2002f). Mature females (>89 mm) declined from 28.2 million crab in 1997 to 18.9 million crab in 2000, increased slightly in 2001 to 21.8 million crab, then declined to 18.6 million crab in 2002. Due to the decrease in abundance of mature females, ADF&G decreased the 1999 GHL from a 15 percent to a 10 percent exploitation rate; this rate has continued to be used for the 2001 and 2002 fishery (NPFMC 2002f). The Bristol Bay red king crab stock remains depressed compared to past abundance levels. Survey estimates of Pribilof Islands red king crab have been highly variable over the last ten years and have a high degree of uncertainty due to the patchy distribution of the animals. Model estimates of mature male abundance shows a decline from about 2 million in 1992 to 1 million in 1997, and then an increase to about 1.7 million in 2002. Legal male abundance was estimated at 1.36 million in 2002 (NPFMC 2002f). The red king crab Pribilof Islands fishery was closed in 1999 and has continued to be closed into 2002 due to uncertainty in the abundance estimates. A small Aleutian Island red king crab fishery occurs, with a 2002 GHL of 0.5 million pounds. Norton Sound also supports a small summer red king crab fishery (Bowers *et al.* 2002).

Blue King Crab

The blue king crab population in the Pribilof Islands is low, and population trends are not easily detectable (NMFS 1998a). Blue king crab female abundance is considered imprecise because trawling does a poor job of sampling the inshore, rocky substrate preferred by females (Morrison *et al.* 1998). The 2002 NOAA Fisheries survey estimated legal male abundance in the Pribilof Islands at 0.38 million crab, a decrease from the 2001 estimate (NPFMC 2002f). Pribilof Islands blue king crab were declared overfished in 2002 (64 FR

62212). A rebuilding plan is currently has been developed and was passed as BSAI Crab FMP Amendment 17 on March 18, 2004 (NPFMC 2004). Blue king crab in the Saint Matthew Island area have increased from 0.8 million crab in 2000 to 1.1 million crab in 2001. However, spawning biomass is still estimated to be below the minimum stock size threshold (Bowers *et al.* 2002). The Saint Matthew Island blue king crab stock was declared overfished and the fishery was closed in 1999 and has continued to be closed into 2002 (64 FR 54791). A rebuilding plan has been developed for the Saint Matthew Island stock and was passed as BSAI Crab FMP Amendment 15 on November 29, 2000 (NMFS 2000b).

Golden King Crab

Population estimates are not available from the NOAA Fisheries trawl survey for golden king crab. Golden king crab are found primarily near the Aleutian Islands. ADF&G conducts the Aleutian Islands golden king crab pot survey; however, there are no absolute estimates of abundance. ADF&G and NOAA Fisheries do not make annual abundance estimates for Bering Sea golden king crab, and commercial harvest is allowed by ADF&G permit (Morrison *et al.* 1998). Catches have declined from the early years of the fishery, as the initial stock was exploited and recruitment was unable to sustain the fishery at its initial harvest levels (Morrison *et al.* 1998). In 1995, the State of Alaska mandated observer coverage for all vessels targeting golden king crab in the Aleutian Islands. Small fisheries for golden king crab exist in the Pribilof Island area and in the Northern District of Saint Matthew Island (Bowers *et al.* 2002).

Bairdi Tanner Crab

In 1996, the bairdi Tanner crab was declared overfished in the Bering Sea. Following this declaration, the bairdi Tanner crab fishery was closed from 1997 to 2002 due to low abundance. During the 1997 survey, 95 percent of legal males encountered were old-shelled and not expected to molt again, and few young males in the 50- to 115-mm carapace width range were surveyed. In the 1998 survey, most legal males encountered were in the eastern district, with the highest abundance in central Bristol Bay. The cohort which began recruiting into the fishery in 1988 to 1992 has declined as a result of natural mortality and fishery removals. Given these two factors, it is likely that the Bering Sea bairdi Tanner crab population will continue to decline for years (Morrison *et al.* 1998). The 2001 survey abundance estimates for large males (135-mm carapace width) and large females have decreased from the 2000 estimates (Bowers *et al.* 2002). NPFMC considers the stock overfished and its crab plan team has developed a rebuilding plan (64 FR 15308). The bairdi Tanner crab rebuilding plan was passed as BSAI Crab FMP Amendment 11 on June 8, 2000 (NPFMC 1999b).

Opilio Tanner Crab (snow crab)

Large male opilio Tanner crab were estimated at 94 million crab in 1999, a decline of 63 percent from 1998. The mature biomass declined below the minimum stock size threshold of 460 million lbs, and the stock was declared overfished on September 24, 1999 (64 FR 54791). A rebuilding plan has been developed by NPFMC's crab plan team. This rebuilding plan was passed as BSAI Crab FMP Amendment 14 on December 28, 2000 (NPFMC 2000a). Since 1999, snow crab abundance has increased; the 2001 NOAA Fisheries survey estimates 77.5 million crabs, 2 percent above the 2000 estimate. A harvest of 33.5 million lbs was landed in 2000, based on a reduced harvest rate from past years. The 2002 Bering Sea opilio Tanner crab GHL is established at 31 million pounds (Bowers *et al.* 2002).

GOA Crab Stocks

GOA crab stock status is limited due to the lack of survey information. GOA red king crab stocks in the vicinity of Kodiak Island remain depressed. The last good year-class produced was in 1973 to 1974, and recent surveys failed to detect signs of rebuilding. No Kodiak red king crab fishery has occurred since 1983. Due to relative low abundance, all GOA direct red king crab fisheries are currently closed with the exception of a sporadic fishery in a few small areas off southeast Alaska. A golden king crab fishery occurs in the Kodiak region, although no more than two boats have participated in the fishery since 1988, with no fishing occurring during most years. The Kodiak bairdi Tanner crab population has been assessed by ADF&G trawl surveys since 1980. The 2001 survey estimates the Tanner crab population to be the highest on record at 175.9 million crab, although the number of legal crab remains similar to the 2000 estimate of 2.6 million crab. A commercial fishery took place in the Northeast and eastside sections of Kodiak Island in 2001 and 2002 (Ruccio *et al.* 2002).

King and Tanner Crab Cumulative Effects Analysis Status

All BSAI and GOA King and Tanner crab species mentioned here will be carried forth for cumulative effects analysis based on declining stock assessments and lack of information regarding current population status of some stocks.

3.5.3 Squid, Skates and Other Species

The other species category was established to monitor and manage groundfish species groups that are not currently economically important in BSAI and GOA groundfish fisheries, but are perceived to be ecologically important and of potential economic importance as well.

Marine species other than fish, including hard and soft deep sea corals, sea pens, sea fans and sea whips, are considered HAPC. They are discussed separately in Section 3.6 of this Programmatic SEIS.

BSAI/GOA Other Species Management

With the exception of squid in the BSAI and skates in the GOA, an aggregate TAC limits the catch of species in the other species category. Although the composition of this category has varied over the course of FMP management, the current configuration has been relatively stable:

- Squid (order Teuthoidea): target species in the BSAI.
- Sculpin (family Cottidae).
- Shark (*Somniosus pacificus, Squalus acanthias, Lamna ditropis*).
- Skate (genera *Bathyraja and Raja*): target species in the GOA.
- Octopi (*Octopus dofleini,Opistholeutis california,* and *Octopus leioderma*).

With the exception of squid and skate species, none of the species in the other species category is currently targeted by the BSAI and GOA groundfish fisheries. As such, they are only caught as bycatch by fisheries targeting groundfish. In the BSAI FMP, squid are managed in a combined squid and other species category, which is composed of squid (considered separately) and sculpin, skate, shark, and octopi (which compose the true other species category). Because data are insufficient to manage each of the other species groups separately, they are considered collectively. Currently, squid are a target species under the BSAI FMP and skate are target species in the GOA, pending the adoption of Amendment 63 (68 FR 67390).

A single estimate of M for this diverse assemblage is not feasible. The SSC believes that M is conservatively estimated at 0.2 OFL for the other species assemblage and is set using the criteria in Tier 5 (as described in FMP Amendment 44; Appendix C), where $F_{OFL} = M$, and OFL = $M \times$ (total other species survey biomass). Using Tier 5 criteria, ABC is capped at 75 percent of OFL. However, rather than use this method, since 1978 the other species ABC has been calculated as the average annual catch in order to avoid potential five-fold increases in other species catches that could occur if ABC were set at 75 percent of OFL. In 1998 (for the 1999 fishery), NPFMC began a 10-step increase toward full $F = M$ exploitation strategy for the other species complex by implementing the first 10 percent of the difference between that strategy and average catch since 1978. For the 2000 fishery, NPFMC stopped the stepwise increase and kept the ABC at a level approximately 10 percent higher than the stock assessment author's recommendation. BSAI other species TAC has been set equal to the other species ABC by NPFMC. 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 (561,600 mt from 1997 to 1999), and adding the most recent Aleutian Islands bottom trawl estimate (48,800 mt from 1997). A TAC for other species in the GOA is set at 5 percent of the sum of target species TACs each year, although a preliminary stock assessment was conducted for GOA other species in 1999 (Gaichas *et al.* 2003).

Adoption of Amendment 63 by NPFMC would result in the separation of GOA skate species from the other species complex. In turn, they would be added to the target species category with an ABC and TAC set for skates and skate complexes (NPFMC 2003). The NPFMC has requested a separate OFL and ABC for combined big and longnose skates in the Central GOA due to concerns regarding a developing fishery. Efforts to address existing data gaps for skate species are underway and improved collection of data is expected under this amendment.

BSAI/GOA Other Species Past/Present Effects Analysis

The geographic scope for the BSAI and GOA other species past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the availability of bycatch estimates of other species and ends in 2002, the most recent year of which stock assessment information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. The following direct and indirect effects were identified as potentially having population level effects on BSAI/GOA other species (including BSAI squid and GOA skate species):

- Mortality due to catch/bycatch (direct effect).

- Reduced recruitment due to habitat/feeding/spawning disruption and spatial/temporal concentration of bycatch (indirect effect).

The following past/present effects determined to be applicable to the squid past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska groundfish fisheries
  - Directed fisheries

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

A past/present effects analysis is conducted for the other species category as a whole and for the individual taxonomic groups where information is available. Any information presented here for the entire group is not repeated in the subsections.

External Mortality: Foreign Groundfish Fisheries (Pre-MSA)

Reported catches of other species increased in the late 1960s and early 1970s with the increase in groundfish harvests. Similarly, other species catch peaked in 1972 at 133,000 mt, the same year that target groundfish harvest peaked.

External Mortality: Directed Fisheries

Directed fisheries have existed for squid, octopi and some species of shark in the past, and some fisheries persist today. See the subsections of these taxonomic groups for further details.

External Mortality: State of Alaska Groundfish Fisheries

See the subsections of specific other species groups for further details.

External Mortality: State of Alaska Crab Fisheries

See the subsections of specific other species groups for further details.

Internal Mortality: JV and Domestic Groundfish Fisheries

Beginning in 2000, a new method was used to estimate species group catch within the other species complex in the BSAI. The new method is similar to the NOAA Fisheries, Regional Office blend catch estimation system; the ratio of observed other species group catch to observed target species catch was multiplied by the blend-estimated target species catch within each area, gear, and target fishery to obtain the total annual catch by species group between 1997-2001 (Gaichas 2002).

Within the other species group, only shark are identified to the species level by fishery observers. Observers are currently instructed to concentrate on higher-priority target and prohibited species for data collection. Furthermore, accuracy of catch estimates depends on the level of coverage in each fishery. Estimates of observer coverage in the BSAI are 70 to 80 percent, whereas the GOA has only approximately 30 percent observer coverage. Coverage can also vary for certain target fisheries and vessel sizes (Gaichas 2002).

Other species catch occurs largely in the flatfish bottom trawl, Pacific cod longline and bottom trawl and pollock fisheries in the BSAI and in the sablefish and Pacific cod fisheries in the BSAI. Other species catch is made up mostly of skate and sculpin (66-96 percent from 1992 to 1997) and can vary from year to year (Gaichas 2002).

Recommendations have been made by the AFSC staff to reduce other species bycatch. For squid, limiting pelagic trawl fishing in areas with high squid abundance has shown successful reduction in bycatch. Steller sea lion closures have reduced squid bycatch in recent years, demonstrating the effectiveness of area closures on squid bycatch. In 1999 and 2000, the pollock fishery was limited in an area of historically concentrated squid bycatch, cutting squid bycatch to less than half than was observed in 1997-1998 (NPFMC 2002e). Shark and skate bycatch can be reduced through the use of specialized gear; excluder devices that are used to avoid halibut bycatch may be effective and improve survival by releasing skates from trawl nets before they are captured (Craig Rose, AFSC, NMFS, and John Gauvin, The Groundfish Forum, personal communication). A similar configuration could be used to release sharks before capture. For sculpin, by determining the general location of certain genuses, management may be able to incorporate area-specific TACs to achieve individual species management (Gaichas 2002). Estimated total catch of other species in the EBS and the Aleutian Islands from 1977-2002, and in the GOA from 1977-2001 is listed in Gaichas (2002) and Gaichas *et al.* (2003).

It is possible under current other species management that a species or even a species group could be disproportionately exploited while the overall aggregate other species TAC is not reached. This potential is a concern because the other species category includes groups with extremely diverse habitats and life history strategies. In addition, data limitations plague different groups within this category. The lack of biomass estimates for cephalopods (squid and octopi) has been a source of difficulty for determining stock status relative to bycatch, and the lack of adequate species identification in catch data hampers the analysis of catch trends for skate and sculpin species. Moreover, the highest observed catches of non-target species are within the categories receiving the least intensive management under the current FMP: other species and non-specified species. It is difficult to determine how much protection is afforded by a TAC set with the use of these data-poor criteria.

Stock assessments are conducted for other species, including squid (in the BSAI) and skates (in the GOA), although TACs are established separately for other species and squid in the BSAI (Fritz 1999), and skates in the GOA (pending adoption of Amendment 63). An aggregate TAC limits the catch of species in the other species category.

In 1999, FMP Amendments 63/63 were initiated to remove the shark and skate species groups from other species in both the BSAI and GOA to better protect these vulnerable, long-lived species (NPFMC 1999a). Based on the 1999 stock assessments for other species (discussed below), the Plan Teams recommended that all other species be considered in an expanded FMP amendment to establish TACs at the species group level. While this amendment was being revised, NPFMC recommended to NOAA Fisheries that other species be placed on bycatch only status to prevent a directed fishery from developing in the interim. NOAA Fisheries determined that it did not have regulatory authority for such an action; therefore, aggregate other species TACs remain in place in the BSAI and the GOA despite efforts to limit directed fisheries and develop more protective management within this category. Final action on the revised plan amendments to set other species as bycatch only and to redefine the GOA TAC setting process will be scheduled in the future.

Beginning in 1999, smelt was removed from the other species category and placed—along with a wide variety of other fish and crustaceans including krill, deep-sea smelt, and lantern fishes—in the forage fish category. This action was accomplished through Amendments 36 and 39 to the BSAI and GOA groundfish FMPs (see Appendix C and D)

Management Tier/Stock for Sculpin, Shark, Skate and Octopi

BSAI/GOA Other Species Comparative Baseline

Reliable biomass estimates exist for two groups (skate and sculpin) that comprise the bulk of the biomass and fishery catches in the other species category. Survey biomass estimates for shark, smelt, and octopi, while not reliable, represent the best data available on the abundance of these species. Fluctuations of biomass have been shown within the other species group. This may be a result of changes in distribution of particular species among regions and during various times of the year (NPFMC 2002c).

Data from NOAA Fisheries surveys in both the BSAI and GOA 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 NOAA Fisheries survey area of the continental shelf. The 1979, 1981, 1982, 1985, 1988, and 1991 data include estimates from continental slope waters (200 to 1,000 m in 1979, 1981, 1982, and 1985; 200 to 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 (see Section 3.5.5). 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 to a depth of only 500 m. Trends in the biomass of GOA other species were investigated using the NOAA Fisheries triennial trawl survey data from 1984 through 1999. There are inconsistencies associated with some of these studies. Thus, some of the GOA data is not as comprehensive as the data for the BSAI.

Since the BSAI 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 EBS surveys in 1997, 1998, and 1999 is 561,600 mt; adding the estimate from the 1997 Aleutian Islands survey (48,975 mt) yields a total BSAI other species biomass estimate of 610,575 mt. The average biomass of other species from the last three EBS shelf and slope surveys (2000, 2001, and 2002) is 637,578 mt; adding the estimate from the 2002 Aleutian Islands survey (51,600 mt) results in a current total BSAI other species biomass estimate of 689,178 mt (NPFMC 2002e).

Trends in the biomass of GOA other species (shark, skate, sculpin, smelt, octopi, and squid) were investigated using the NOAA Fisheries triennial trawl survey data from 1984 through 1999. GOA biomass trend discussion should be viewed with the following caveats in mind:

- Survey efficiency may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Robin Harrison, AFSC, NMFS, personal communication).

- 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 in the GOA, using all six survey biomass estimates (from 1984 to 1990), is 160,000 mt; much less than the average of the more recent BSAI surveys. The most recent estimate of other species biomass (1999) is 213,000 mt. Skate represent 30 to 40 percent of the other species biomass from all surveys and are the most common species in each year except 1984 when sculpin biomass was highest within the category. Total biomass for the other species category 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. Biomass estimates of other species in the EBS and Aleutian Islands, from various AFSC surveys, are included in Gaichas (2002).

BSAI/GOA Other Species Cumulative Effects Status

It is possible under current other species management that a species or even a species group could be disproportionately exploited while the overall aggregate other species TAC is not reached. This potential is a concern because the other species category includes groups with extremely diverse habitats and life history strategies. In addition, data limitations plague different groups within this category. The lack of biomass estimates for cephalopods (squid and octopi) has been a source of difficulty for determining stock status relative to bycatch, and the lack of adequate species identification in catch data impedes the analysis of catch trends for skate and sculpin species. It is difficult to determine how much protection is afforded by a TAC set with the use of these data-poor criteria.

Trophic Interactions of Other Species

Many species in the squid and other species category are important prey for marine mammals and birds, as well as commercial groundfish species. Squid and octopi 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), Pacific white-sided dolphins (Morris *et al.* 1983), and beaked whales (Loughlin and Perez 1985). Sculpin have also been found in the diet of harbor seals (Lowry *et al.* 1982). Squid are important prey for albatross, especially during nesting season.

3.5.3.1 Squid

Life History and Distribution

Squid (order Teuthoidea) are cephalopod mollusks that are related to octopi. Squid are considered highly specialized and organized mollusks, with only a vestigial mollusc shell remaining as an internal plate called the pen, or gladius. They are streamlined animals with 10 appendages (2 tentacles and 8 arms) extending from the head, and lateral fins extending from the rear of the mantle. Squid are active predators that swim by jet propulsion, reaching swimming speeds of up to 40 km/hour, the fastest of any aquatic invertebrate. Members of this order (*Archeteuthis* species) also hold the record for largest size of any invertebrate (Barnes 1987).

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. Squid are characterized by their rapid growth, patch distribution and high variable recruitment; being described as the "marine equivalent of weeds" (O'Dor 1998). Squid travel in schools of similarly sized individuals. Lipinski (1998) conjectured that these schools may migrate, forage and spawn at different times of the year. The importance of squid to the North Pacific ecosystem and our limited knowledge of their life history, distribution and abundance makes squid a good case study to illustrate management of an important resource with little information.

The most commercially important (and therefore best studied) squid in the western North Pacific is the magistrate armhook squid, *(Berryteuthis magister)* (Figure 35-25). It is abundant over continental slopes throughout the North Pacific Ocean from Oregon to southern Japan (Nesis 1987). It is the basis of fisheries in both Russian and Japanese waters. The maximum size reported for *B. magister* is 28-cm mantle length. The internal vestigial shell, or gladius, and statoliths (similar to otoliths in fish) were compared for aging this species (Arkhipkin *et al.* 1996). *B. magister* from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 2 years). Males grow more slowly to earlier maturation than females. *B. magister* were dispersed during summer months in the western Bering Sea, but formed large, dense schools over the continental slope between September and October. Stock structure in this species is complex, with three seasonal cohorts identified in the region: summer-hatched, fall-hatched, and winter-hatched. Growth, maturation, and mortality rates varied between seasonal cohorts, with each cohort using the same areas for different portions of the life cycle. For example, the summer spawned cohort used the continental slope as a spawning ground only during the summer, while the fall spawned cohort used the same area at the same time primarily as a feeding ground, and only secondarily as a spawning ground (Arkhipkin *et al.* 1996). There are many fisheries directed at squid species worldwide, although most focus on temperate squid in the genus *Ilex* and *Loligo* (Agnew *et al.* 1998, Lipinski 1998).

Trophic Interactions

Squid are important components in the diets of many seabirds, fish, and marine mammals, as well as being voracious predators of zooplankton and larval fish (Caddy 1983, Sinclair *et al.* 1999). Squid 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), Pacific white-sided dolphins (Morris *et al.* 1983), and beaked whales (Loughlin and Perez 1985). Perez (1990) estimated that squid 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.

BSAI/GOA Squid Management

In the BSAI, squid are managed within their own category under a species complex TAC, which is set each year based on Tier 6 criteria at 75 percent of the average catch of squid over the period 1978 to 1995. This criteria has been used for establishing ABC for squid in 2003 as well (BSAI SAFE 2002) Squid bycatch is taken almost entirely (97 percent) in the pelagic pollock fishery (NMFS 2001a) . The estimated total catch of squid in the BSAI for 2001 reached 1,801 mt, being the highest in the past five years (Gaichas, BSAI SAFE 2002).

In the GOA, squid are managed as part of the other species category. The 14,270 mt TAC for this complex is set at 5 percent of all target species TACs for the GOA. When combined with the predicted catch of all animals in this category (about 5,400 mt) this catch would not exceed the other species TAC for the GOA. As in the BSAI, squid bycatch in the GOA is taken primarily in pollock fisheries (74 percent), although small amounts are from bottom trawl fisheries such as those targeting the deepwater flatfish complex (10 percent).

The catch of individual squid species cannot be estimated because they are not identified to species in the catch at present. In contrast with the skate and grenadier, reasonable assumptions about the catch composition within the squid complex cannot be developed and analyzed because of the lack of biomass estimates by species.

BSAI/GOA Squid Past/Present Effects Analysis

The geographic scope for the BSAI and GOA squid past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in 1977 when the Japanese squid fishery begins and ends in 2002, the most recent year of which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS. Table 3.5-47 provides a summary of the BSAI and GOA squid past effects analysis presented below. The following direct and indirect effects were identified as potentially having population level effects on BSAI/GOA squid:

- Mortality due to catch/bycatch (direct effect).
- Reduced recruitment due to habitat/feeding/spawning disruption and spatial/temporal concentration of bycatch (indirect effect).

The following past/present effects determined to be applicable to the squid past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)

  - State of Alaska groundfish fisheries
  - State of Alaska shrimp fisheries
  - Directed squid fisheries

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

External Mortality: Foreign Groundfish Fisheries

Due to poor identification and incomplete reporting, bycatch rates for squid are unknown for the foreign fisheries prior to 1977, however they are assumed to have increased from the 1960s and 1970s and then decreased following the peak other species catch in 1972, similar to the other species complex trends discussed above.

External Mortality: Directed Fisheries

The Japanese and the Republic of Korea conducted a directed fishery on squid from 1975-1987 in the EBS and the Aleutian Islands. Catches were limited by the 1973 U.S. and Japan bilateral agreement and were further limited by the passing of the MSA.

External Mortality: State of Alaska Groundfish Fisheries and Shrimp Fisheries

Currently, catch data for squid is incomplete for State of Alaska groundfish fisheries and shrimp fisheries for the BSAI and GOA regions. Due to this lack of data, reliable estimates cannot be drawn at this time.

Internal Mortality: Foreign, JV and Domestic Groundfish Fisheries (post-MSA)

Foreign fishery catch of squid peaked in the EBS in 1978 at 6,886 mt and steadily dropped until the foreign fisheries were phased out by the domestic fisheries in 1987. In the Aleutian Islands, foreign catch peaked in 1980 at 2,332 mt. Presumably, these catch statistics reflect both directed catch by Japan and the Republic of Korea, and incidental catch in the foreign target fisheries (Gaichas 2002).

JV target fisheries began reporting squid bycatch in 1981 in the EBS and in 1983 in the Aleutian Islands region. Reported bycatch of squid remained low throughout the duration of these fisheries, at less than 200 mt annually. The domestic fisheries entered in the EBS and Aleutian Islands in 1987, with squid bycatch ranging from 1 to 1,500 mt annually, combined for both regions. Bycatch peaked in 1997, declined, and peaked again in 2001 at 1,766 mt.

Squid represent a low proportion of non-target groundfish bycatch relative to other species. Squid are primarily caught in pelagic trawl fisheries along the outer continental shelf and slope, especially around submarine canyons or in deep waters of the Aleutian Basin. Squid do not survive capture. Squid bycatch is higher in EBS than GOA. In the EBS pollock trawl domestic fishery (1990-2001) the squid bycatch ranged from 364 to 1,761 mt. In the Aleutian Islands pollock trawl domestic fishery (1990-2001) the squid bycatch ranged from 5 to 95 mt/year (Gaichas 2002). In the GOA, squid are caught as bycatch mostly in the pollock fisheries, and in small amounts from bottom trawl fisheries such as rockfish and the deepwater flatfish complex. Estimated catch between 1997-2000 ranged from 14 to 98 mt (NPFMC 2002c).

In 1980, GOA FMP Amendment 8 created four species management categories (target, other species, unallocated, and non-specified) and three regulatory districts for sablefish in southeast Alaska. Its purpose was to make the GOA FMP conform to the newly adopted BSAI FMP, enhance target species management, and protect incidentally caught species. Information on squid, rockfish, and several other species was found insufficient to warrant OYs for the three main regulatory areas in the GOA; therefore, their management was changed to a Gulf-wide management strategy.

Reported catches of squid in the EBS and Aleutian Islands since 1977 show that after reaching 9,000 mt in 1978, total squid catches have steadily declined to only a few hundred tons in 1987-1995. Thus, squid stocks have been comparatively lightly exploited in recent years. Discard rates of squid (discards/total squid catch) by the BSAI groundfish fisheries have ranged between 40 and 85 percent in 1992-1998 (NOAA Fisheries Regional Office, Juneau, personal communication). The 2001 estimated catch of squid, 1,810 mt, is the highest in the past five years and much closer to the ABC of 1,970 mt than any estimated catch since the 1980s. The recommended ABC for squid in 2003 is calculated as 0.75 times the average catch from 1978-1995, or 1,970 mt; the recommended overfishing level for squid in the year 2002 is calculated as the average catch from 1978-1995, or 2,624 mt. The rationale for a Tier 6-based ABC recommendation is that there is no reliable biomass estimate for squid (Gaichas 2002).

External Reduced Recruitment: Foreign Groundfish fisheries (pre-MSA)

Data is not available to determine whether the foreign fisheries disrupted spawning, feeding, and/or habitat of squid and squid aggregations. However, it is assumed that the foreign fisheries may have had similar impacts on squid recruitment as the current domestic fisheries.

External Reduced Recruitment: Directed Fisheries

Data is not available to determine whether the directed fisheries disrupt spawning, feeding, and/or habitat of squid and squid aggregations. However, it is assumed that they may have similar impacts on squid recruitment as the domestic fisheries.

External Reduced Recruitment: State of Alaska Groundfish fisheries

Data is not available to determine whether the State of Alaska groundfish fisheries disrupt spawning, feeding, and/or habitat of squid and squid aggregations. However, it is assumed that they may have similar impacts on squid recruitment as the domestic fisheries. Timing and location of fishery interactions with squid spawning aggregations may affect both the squid population and availability of squid as prey for other animals (Caddy 1983, O'Dor 1998).

Internal Reduced Recruitment: Foreign, JV and domestic fisheries (post-MSA)

Timing and location of fishery interactions with squid spawning aggregations may affect both the squid population and availability of squid as prey for other animals (Caddy 1983, O'Dor 1998). Whereas the proportion of overall squid complex biomass that is caught in groundfish fisheries cannot be determined, there are some hints as to the potential indirect impacts of bycatch on squid stocks. The concentration of squid bycatch in certain areas over the continental shelf edge (Figure 3.5-26) may indicate that these regions are important to squid stocks for spawning, feeding, or both. In western Bering Sea stocks of *Berryteuthis magister*, these localized aggregations appear to be composed of a single seasonal cohort of related squid. Groundfish bycatch may not represent a significant impact on the basinwide population of squid, but may damage stock structure even with relatively small amounts of bycatch if all bycatch is from a single seasonal cohort in one area. Groundfish fisheries may also disturb squid aggregations or disrupt important habitat, in addition to the direct effect of catch. More information on squid biology in the EBS and GOA is needed to determine whether any of these indirect impacts on the squid complex would occur and whether they represent significantly adverse impacts.

BSAI/GOA Squid Comparative Baseline

Squid are found throughout the Pacific Ocean. Squid species are not well sampled by bottom trawl surveys, and historically, acoustic surveys have not been directed at squid in the FMP areas. At least 7 squid species have been identified in the FMP areas by AFSC surveys, whereas 18 species were identified in the mesopelagic regions off the slope of the EBS (Sinclair *et al.* 1999).

Assessment data are not available for squid from NOAA Fisheries 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 is generally lacking. Red armhook squid (*Berryteuthis magister*) predominates in commercial bycatch in the EBS and GOA, and *Onychoteuthis borealijaponicus* is the principal species encountered in the Aleutian Islands.

As a group, squid represent a relatively low proportion of non-target species catch (about 2 percent), however they serve a crucial role in marine ecosystems. No reliable biomass estimates or stock assessments for squid exist. Sobolevsky (1996) cites an estimate of 4 million tons for the entire Bering Sea made by squid biologists at the Pacific Research Institute of Fisheries and Oceanography (Shuntov 1993), and an estimated 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. NOAA Fisheries bottom trawl surveys almost certainly underestimate squid abundance. Squid catches and ABCs are a very small percentage of the total squid biomass in the EBS and GOA.

In theory, a squid survey could be conducted with midwater trawls and or hydroacoustics. There is such a survey for pollock, but the existing survey would need to extend out across shelf break, at least, which would greatly expand the scope of the current survey. As far as seasonality, squid appear in the catch data during all pollock seasons in the areas around the shelf break. The highest observed fishery CPUE of squid might indicate when a survey would be most efficiently conducted. According to fishery information from 1997 to 1999, a peak in squid CPUE occurs in January; however, it is also all in one location (Pribilof Canyon), making it difficult to tell if the high CPUEs are seasonally or spatially related. The life history information reported for western Bering Sea *Berryteuthis magister* suggests that any survey for squid would have to occur over multiple seasons to fully assess the biomass available in a given year and would require significant information on the life cycles and migratory routes of local squid to maximize efficiency.

Lacking this information, a survey to provide the biomass estimates would have to cover so much territory and so many seasons as to be prohibitively expensive, especially considering that there is no target fishery for squids in the FMP areas at this time. A more realistic approach might be to initiate smaller scale surveys, perhaps coordinated with the existing pollock surveys, to conduct squid species identification and life history investigations in the area to determine how a larger scale survey might be conducted in the future.

BSAI/GOA Squid Cumulative Effects Status

Assessment data is limited for squid from NOAA Fisheries surveys and no reliable biomass estimates or stock assessments for squid exist. However, they will be brought forward as part of the other species complex for cumulative effects analysis due to their ecological importance and essential role as prey species.

3.5.3.2 Sculpin

Life History and Distribution

Despite their abundance and diversity, sculpin life histories are not well known in Alaska.Forty-one sculpin species have been identified in the EBS and 22 species in the Aleutian Islands (Bakkala 1993, Bakkala *et al.* 1985, Ronholt *et al.* 1985). Sculpin are small, bottom-dwelling fish that lay adhesive eggs in nests and exhibit parental care for eggs (Eschemeyer *et al.* 1983). Life history information varies for each species in this group; the great sculpin is the largest sculpin species reaching 70 cm in length and 8 kg in weight in the western North Pacific. These species appear to be relatively short-lived with late maturity; the great sculpin does not reach maturity until 5-8 years (Tokranov 1985) and lives only 13 to 15 years.

Trophic Interactions

Little is known of the trophic interactions of sculpin. Sculpin are important benthic predators and serve as prey for many groundfish species such as halibut (*Hippoglossus stenolepis*), salmon (*Onchorynchus gorbuscha*), and hakes/burbots (*Brosme brosme*) (Gaichas 2002). Currently, data relating to the trophic interactions of sculpin in the BSAI is unavailable.

In the GOA, the main prey items for sculpin are shrimp and small flatfish. They also feed on crab, eelpouts, other sculpin, and smelt. Sculpin are prey for numerous species of marine life including: Steller sea lions, halibut, cod, other sculpin, toothed whales, seals, skate, sablefish, arrowtooth flounder, thornyhead rockfish, pollock, and small flatfish (Aydin *et al.* 2002, Gaichas 2003).

BSAI/GOA Sculpin Management

See above in the BSAI/GOA Other Species Management section.

BSAI/GOA Sculpin Past/Present Effects Analysis

The geographic scope for the BSAI and GOA sculpin past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the availability of bycatch estimates of other species and ends in 2002, the most recent year of which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this document. Table 3.5-48 provides a summary of the BSAI and GOA sculpin past effects analysis presented below. The following direct effect was identified as potentially having population level effects on BSAI/GOA sculpin:

- Mortality due to bycatch (direct effect).

The following past/present effects determined to be applicable to the sculpin past effects analysis include the following:

- Past/Present External Events
    - Foreign groundfish fisheries (pre-MSA)
    - State of Alaska groundfish fisheries

- Past/Present Internal Events
    - Foreign groundfish fisheries (post-MSA)
    - JV groundfish fisheries
    - Domestic groundfish fisheries

- Past/Present Management Actions
    - FMP groundfish fisheries management
    - Data limitations

External Mortality: Foreign Groundfish Fisheries (pre-MSA)

Bycatch data from the foreign fisheries in the BSAI and GOA is non-existent for sculpin. It is assumed that the sculpin foreign bycatch is comparable to the current level of bycatch; bycatch tends to increase with increase in target groundfish catch.

External Mortality: State of Alaska Groundfish Fisheries

It is inferred that proportionally similar sculpin bycatch could occur in the state groundfish fisheries as compared to the current federal groundfish fisheries. Since sculpin are taken incidentally from the Pacific cod and pollock federal fisheries, it is assumed that sculpin would also be taken in the State of Alaska Pacific cod and pollock fisheries. Although amount of sculpin bycatch may be similar between state and federal groundfish fisheries, the species mix of sculpin within this bycatch may differ between nearshore state fisheries and federal fisheries.

Internal Mortality: Foreign, JV and domestic fisheries (post-MSA)

Past JV fisheries bycatch of sculpin for the BSAI and GOA is non-existent. It is assumed that the bycatch is comparable to domestic bycatch levels; bycatch tends to increase with increase in target groundfish catch.

Skate and sculpin make up the bulk of the other species bycatch (66-96 percent from 1992-1997). This trend continued from 1997-2001 as well. Sculpin are caught largely in the Pacific cod hook and line fishery and trawl fisheries for pollock, yellowfin sole, Atka mackerel and rock sole occurring over the shelf break and slope or in deep waters of the Aleutian Basin (Gaichas 2001).

Internal Reduced Recruitment: JV and Domestic Fisheries

Habitat suitability/Spawning disruption

The sculpin nest-laying reproductive strategy may make sculpin populations more sensitive to changes in benthic habitats than other groundfish species such as cod and pollock, which are broadcast spawners with pelagic eggs. Moreover, the limited information on sculpin species suggest that species may react differently to similar environmental conditions. Within each sculpin species, the spatial effects of fishing may still be important, because observed differences in fecundity, egg size, and other life history characteristics suggest local populations (Tokranov 1985), which are not generally observed in target groundfish stocks. All of these characteristics indicate that sculpin as a group might be managed differently than other groundfish stocks, perhaps most efficiently within a spatial context rather than with a global annual aggregate TAC. It seems clear that sculpin are significantly different from all other members of the other species category as to justify their own management category, despite the potential complexity of effective management of a single group as diverse as the sculpin (Gaichas 2001).

BSAI/GOA Sculpin Comparative Baseline

Sculpin in the BSAI were the major component of other species group until 1986 according to the EBS AFSC surveys, after which skate biomass exceeded that of sculpin. In the EBS, sculpin abundance remained stable through 1998, but has since declined, with a slight increase in the 2002 survey at 181,200 mt (slope and shelf surveys). The Aleutian Islands survey show a decline since 1980, averaging around 13,000-14,000 mt in recent years (Gaichas 2002). Estimated total catch of sculpin in the BSAI from 1997-2000 ranged from 5,470 to 7,670 mt (Gaichas 2002). In the GOA, estimated total catch for the same years ranged from 541 to 943 mt (NORPAC and year-end estimates of target species catch from the NMFS Regional Office blend database).

In the GOA, individual sculpin species display divergent biomass trends between 1984 and 1999. While the biomass of bigmouth sculpin (*Hemitripterus bolini*) decreased over the survey period, great sculpin (*Myoxocephalus polyacanthocephalus*) biomass remained relatively stable, and yellow Irish lord (*Hemiliepidotus jordani*) biomass increased. Yellow Irish lord biomass appears to have increased over time despite general stability in the number of hauls where the species occurred, whereas bigmouth sculpin were encountered in fewer hauls each year. Uncertainty in these estimates varies between years.

BSAI/GOA Sculpin Cumulative Effects Status

Assessment data is limited for sculpin and no reliable biomass estimates or stock assessments for sculpin exist. Thus, they will be brought forward for cumulative effects analysis due to their ecological importance and essential role as prey species.

3.5.3.3 Shark

Life History and Distribution

The three shark species most commonly encountered in the North Pacific are the sleeper shark, *Somniosus pacificus*, the piked or spiny dogfish, *Squalus acanthias*, and the salmon shark, *Lamna ditropis* (Gaichas 2002). Generally, shark are more K-selected species; long-lived, long gestation periods (6 months to 2 years) and few, well-developed offspring (Pratt and Casey 1990).

The Pacific sleeper shark are not well known, but are found often in the shelf and slope waters of the North Pacific. Dense aggregations of sleeper shark were found during the 2000 Bering Sea slope survey, although none have yet been found on the EBS shelf survey. The reproductive mode of the sleeper shark is unknown.

The spiny dogfish can be found from the Bering Sea to the Baja Peninsula in shelf and upper slope waters, and are most common off the U.S. west coast and British Columbia (Hart 1973). Separate stocks of spiny dogfish have been found off the coast of British Columbia and Washington that do not mix (Compagno 1984). Dogfish form feeding aggregations segregated by size, sex and maturity; males are often found in shallower water than females. Females bear small litters of 1-20 pups following a gestation period of 18-24 months, females travel to shallow bays to bear their young. Average age recorded range from 25-30 years, with a maximum up to 100 years; and maximum size of 1.6 m in the eastern North Pacific (Compagno 1984).

Salmon shark are found from Japan, throughout the BSAI and GOA and down to Baja California, most commonly in coastal littoral and epipelagic waters both inshore and offshore. Salmon shark are oviporous bearing an average of 5 pups in the western North Pacific. Uterine cannibalism has been found (Gilmore 1993). Average size ranges from 2 to 2.5 m, with a maximum size of 3.0 m. Salmon shark live to an average age of 25 years in the western North Pacific; females generally reach maturity from 8-10 years and males at 5 years (Tanaka 1980). Little is known about the eastern North Pacific salmon shark population, although research is being conducted to determine the demographics and population parameters (K. Goldman, VIMS, personal communication as referenced by Gaichas 2002).

Trophic Interactions

In recent years, numbers of shark in Alaskan waters seem to be increasing while a decline in pinnipeds (specifically Steller sea lions) has occurred. Although it may be possible that shark predation could introduce a source of mortality to pinnipeds in certain areas of Alaska, much more research is needed to address uncertainty in data collected thus far. Little is known of the trophic interactions of shark in the BSAI. Thus, only GOA will be discussed here.

In the GOA, sleeper shark prey primarily on arrowtooth flounder. Additionally, they may eat salmon, cephalopods, small flatfish, and fishery offal. Salmon shark prey mostly on salmon and cephalopods as well as sablefish, herring, smelt, few rockfish, and flatfish. Dogfish eat large zooplankton, herring, shrimp, small flatfish, cephalopods, smelt, sandlance, and other demersal fish. Shark in the GOA have no known predators. However, salmon shark will prey upon spiny dogfish (Gaichas 2002).

BSAI/GOA Shark Management

See above in the BSAI/GOA Other Species Management.

BSAI/GOA Past/Present Effects Analysis

The geographic scope for the BSAI and GOA shark past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the availability of bycatch estimates of other species intensity and ends in 2002, the most recent year of which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS. Table 3.5-49 provides a summary of the BSAI and GOA shark past effects analysis presented below. The following direct and indirect effects were identified as potentially having population level effects on BSAI/GOA shark:

- Mortality due to catch/bycatch (direct effect).

- Increased recruitment due to increased habitat suitability (indirect effect).

The following past/present effects determined to be applicable to the shark past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska groundfish fisheries
  - IPHC halibut longline fisheries
  - Sport fisheries
  - Climate changes and regime shifts

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

External Mortality: Sport Fisheries

There are currently no directed commercial fisheries for shark in Alaska State or federal waters. The state prohibited directed commercial fishing for shark in 1998 and set limits for the modest sport fishery that currently exists (2 shark per person per year, 1 on any given day). This made Alaska the first state ever to implement precautionary management before allowing a commercial fishery or large sport fishery to develop (Camhi 1999).

External Mortality: IPHC Halibut Longline Fisheries

Currently, the IPHC does not report shark bycatch specific to fishery. Total catch of shark (dogfish and sleeper) is recorded during IPHC setline surveys in Alaska, but does not reflect accurate bycatch estimates for halibut fisheries in general. Most likely, shark bycatch is lower in the fisheries compared to catch rates that IPHC surveys report because commercial vessels often fish in areas lacking high populations of shark.

External Mortality: State of Alaska Groundfish Fisheries

It is assumed that proportionally similar shark bycatch could occur in the state groundfish fisheries as compared to the current federal groundfish fisheries. Although the amount of shark bycatch may be similar between state and federal groundfish fisheries, the species mix of shark within this bycatch most likely differs between nearshore state fisheries and federal fisheries. Catch of Pacific sleeper shark in the sablefish longline surveys from 1997-2000 in the BSAI and GOA ranged from 9 to 11 sharks (NPFMC 2002c).

Internal Mortality: Foreign, JV and Domestic Groundfish Fisheries (Post-MSA)

Shark bycatch varies for species by region. All shark bycatch tends to be higher in the GOA region, whereas sleeper shark bycatch has been similar between regions. Table 3.5-50 shows estimated total catch of sharks in the BSAI and GOA from 1997-2001. In 2001, sleeper shark bycatch for BSAI showed a large reduction compared to years past of 17.3 mt, while dogfish bycatch seemed to significantly increase at 697 mt (NPFMC 2002c). A possible explanation for these shifts is that observer identification for these two species has improved. Regional shifts in shark abundance could also be occurring.

The majority of bycatch for unidentified shark in 2000 and 2001 was taken by sablefish and Pacific cod longline fisheries (79 percent) while salmon shark bycatch was predominantly taken by pollock pelagic trawl fisheries (90 percent in 2001 and 84 percent in 2000). Total amount of dogfish bycatch increased in 2001 for the BSAI with Pacific cod and flathead sole longline fisheries and pollock pelagic trawl fisheries being primary takers (90 percent). In contrast to dogfish, sleeper shark bycatch decreased in 2001. According to 2000 survey data, sablefish, turbot, and Pacific cod longline fisheries in addition to pollock pelagic trawl fisheries accounted for the majority of the total bycatch in BSAI (90 percent) (NPFMC 2002c).

In the GOA region during 1999 surveys, Pacific cod longline fisheries accounted for the majority of sleeper shark, spiny dogfish, and unidentified shark bycatch. Pelagic trawl pollock fisheries took the largest portion of salmon shark bycatch in 1999 for the GOA. Salmon sharks have been both considered a nuisance for both eating salmon and damaging fishing gear (Macy *et al.* 1978, Compagno 1984).

Due to sharks slow growth to maturity and low productivity of the stocks (Compagno 1990, Hoenig and Gruber 1990), many large-scale directed fisheries for sharks have collapsed, even where management was attempted (Anderson 1990). An EA/RIR for BSAI/GOA FMP Amendments 63/63 has been developed by NPFMC outlining a shark and skate management program in Alaskan federal waters. This amendment would remove shark and skate from the other species complex in an effort to better protect this long-lived species. Salmon shark have been considered as a potential target species in the GOA (Paust and Smith 1989).

Increased Recruitment: Climate Changes and Regime Shifts

It has been speculated that warmer waters in the PWS have lead to an increase in abundance of certain shark species. However, there is limited evidence to support the theory and the effects of climate change and regime shifts on shark remain unknown.

BSAI Shark Comparative Baseline

Until a pilot survey was conducted in 2000 of the EBS, it was thought that bottom trawl surveys did not accurately sample shark. However, sleeper shark were the third highest CPUE on the survey. Thus, showing the ability for this shark to be successfully surveyed by bottom trawls (NPFMC 2002c). During the 2002 EBS slope survey, sleeper shark biomass was estimated and shown to be substantial (NPFMC 2002c). This new information suggests that location and timing of EBS trawl surveys on the shelf during summer months may play a significant role in estimating biomass of shark (NPFMC 2002c). Shark are rarely taken during demersal trawl surveys in the Bering Sea; however, spiny dogfish *(Squalus acanthias*) is a species usually caught, and the Pacific sleeper shark (*Somniosus pacificus*) has been taken on occasion.

Much of the catch and landing data for shark in Alaska is not useful for assessing relative abundance because species are lumped into a single category of "shark". However, in recent years the NOAA Fisheries groundfish Observer Program, the IPHC, and the ADF&G have documented shark catch by species making preliminary estimates of relative abundance possible. The NOAA Fisheries Observer database contains estimated weights (in mt) for species, while the IPHC and ADF&G databases contain data on shark bycatch from fishery independent halibut and sablefish surveys respectively (Goldman 2001).

IPHC setline surveys in Alaska have reported total catch for dogfish and sleeper shark from 1997-2002 within specific IPHC areas including: southeast Alaska, central GOA, western GOA, eastern Aleutians, and western Aleutians. Although these surveys used varying numbers of skates (one skate containing one hundred hooks) within different IPHC areas from year to year, it is possible to obtain a rough estimate of average stock density for these two shark species in the areas mentioned above over time. Figures 3.5-27 and 3.5-28 show average stock densities of dogfish and sleeper shark estimated by IPHC Setline Surveys throughout five IPHC areas from 1997-2002, respectively (Dykstra *et al.* 2003).

GOA Shark Comparative Baseline

In the GOA, individual species biomass trends were evaluated for the more common and easily identified shark and sculpin species encountered by the triennial trawl surveys. In general, the increasing biomass trend for the shark species is a 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 shark is 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 (Gaichas 2001).

BSAI/GOA Shark Cumulative Effects Status

Assessment data is limited for shark and no reliable biomass estimates or stock assessments for shark exist despite recent improvements in their identification. This species group will be brought forward for cumulative effects analysis due to their ecological importance.

3.5.3.4 Skate

Life History and Distribution

NOAA Fisheries surveys have recorded 15 skate species, but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist (Figures 3.5-29, 3.5-30, and 3.5-31). Species that have been consistently identified during surveys are the Alaska skate (*Bathyraja parmifera*), big skate (*Raja binoculata*), longnose skate (*rhina*), and Aleutian skate (*B.aleutica*). Biomass estimates of sculpin and skate from demersal trawl surveys serve as valuable indices of their relative abundance (Gaichas 2001). A summary of the identified species is shown in Table 3.5-51.

Although little specific life history information exists for most skate species, they are generally thought to have limited reproductive capacity relative to gadids, pleuronectids, and other exploited groundfish and may be vulnerable to overfishing (Sosebee 1998). Skate are oviparous with one to seven embryos per egg in local species (Eschmeyer *et al.* 1983). Skate are similar to shark in that they are long-lived species, have low fecundity and low productivity. Size varies per species; the big skate, *Raja binoculata*, is the largest skate in the GOA. The California big skate reaches a maximum size of 2.4 m, with 1.8 m and 90 kg common (Martin and Zorzi 1993). The longnose skate, *Raja rhina*, is smaller, reaching maximum length of about 1.4 m in California. Maximum age reported for the longnose skate was 13 years, however there are difficulties associated with ageing skates (Zeiner and Wolf 1993).

The most important life history parameter for our purposes is *M*. Natural mortality provides an approximation of the amount of fishing mortality a stock can withstand, so that fractions of *M* are often used to set upper limits on *F* (Clark 1991). The natural mortality rate can be estimated from information on the maximum age attained by a species (in the absence of fishing mortality). We used a relationship developed from data on many marine species including fish, molluscs and marine mammals to estimate *M* for skate using all the information available to us. Admittedly, little is known about the lifespan of many shark and skate species, but some ichthyologists speculate that in larger chondrichhyan fish "maximum ages of 70-100 years or more are likely". We chose to estimate *M* conservatively at 0.10, a low but reasonable number for larger skate (reflecting a potential maximum age of 40 years), in an attempt to account for the longer-lived species within the complex. We must assume the same natural mortality rate for all skate species in our area until better information is available. (NPFMC 2000c). Life history information available for skate in the BSAI and GOA is presented in Table 3.5-52.

Trophic Interactions

Limited information is available regarding the trophic interactions of skate in the BSAI. Thus, only GOA will be discussed here.

In the GOA, skate prey mainly on pollock, shrimp, crab, and other benthic epifauna. To a lesser degree, small flatfish, sculpin, eelpouts, smelt, and benthic detritus serve as prey for skate as well. Predators of skate include: toothed whales, Steller sea lions, seals, halibut, and Pacific cod.

BSAI/GOA Skate Management

In the BSAI, skate species are managed within the other species category with a TAC specified for the entire complex (see above).GOA Amendment 63 is scheduled for secretarial approval (NPFMC) on March 3, 2004 and will result in skate species being moved from the other species category to the target species category in the GOA. Upon adoption of this amendment, OFL, ABC, and TAC limits with be established. In addition, the NPFMC has suggested that a separate OFL and ABC for combined big and longnose skates be implemented for the central GOA region (NPFMC 2003) . It is presumed that data collection and research will improve for GOA skate species after this amendment has been implemented.

BSAI/GOA Skate Past/Present Effects Analysis

The geographic scope for the BSAI and GOA skate past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the availability of bycatch estimates of other species and ends in 2002, the most recent year in which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS. Table 3.5-53 provides a summary of the BSAI and GOA skate past effects analysis presented below. The following direct effect was identified as potentially having population level effects on BSAI/GOA skate:

- Mortality due to bycatch (direct effect).

The following past/present effects determined to be applicable to the skate past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska groundfish fisheries
  - IPHC halibut longline fisheries
  - State of Alaska sport halibut fishery

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries

  - Domestic groundfish fisheries

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

External Mortality: Foreign Groundfish Fisheries (Pre-MSA)

Pre-World War II foreign fisheries were relatively small with an expansion of large scale fishing operations in the post-war period, ultimately leading to increases in the catches of groundfish in the BSAI and GOA. By 1985, the JV operations and growing U.S. domestic fleet had entered the scene, and continued the harvest of groundfish species. Federal groundfish fisheries have been prosecuted by an all domestic fleet since 1987 in the GOA and 1991 in the BSAI.

Unfortunately, bycatch data from the foreign fisheries' BSAI and GOA FMP foreign fishery Observer Program is non-existent at the level necessary to distinguish skate from other species. It is inferred that the past foreign fisheries had proportionally similar bycatch rates for skate as the current federal groundfish fisheries.

External Mortality: IPHC Halibut Longline Fisheries

The IPHC halibut fisheries do not keep bycatch records (IPHC, personal communication). Since halibut and skate are caught incidentally in the federal sablefish fisheries, it is inferred that skate would also be taken incidentally in the IPHC halibut fishery.

The IPHC halibut fishery continues to occur, and for reasons stated above are considered to have potential external effects on skate in the present and future. Since none of these fisheries record bycatch, the magnitude of the potential effects on skate populations cannot be determined due to lack of pertinent information.

External Mortality: State of Alaska Groundfish Fisheries and State of Alaska Sport Halibut Fishery

The State of Alaska groundfish fisheries do not keep bycatch records (ADF&G, personal communication). It is inferred that proportionally similar skate bycatch could occur in the state groundfish fisheries as compared to the current federal groundfish fisheries.

State of Alaska groundfish fisheries continue to occur, and for reasons stated above are considered to have potential external effects on skates in the present and future. Since none of these fisheries record bycatch, the magnitude of the potential effects on skate populations cannot be determined due to lack of pertinent information.

Internal Mortality: Foreign, JV and Domestic Groundfish Fisheries

Skate are caught about 71 percent of the time by longline gear, 26 percent of the time by bottom trawls, and 3 percent of the time by pelagic trawls; skate catch in pot gear is negligible. Most of this skate catch is taken in the longline fishery directed at Pacific cod (69 percent). They are generally discarded (and may survive depending upon catch handling practices), although skate caught incidentally are sometimes retained and processed. Markets for skate products are currently limited in the North Pacific, but skate is subject to directed fisheries in other areas of the world (Martin and Zorzi 1993, Agnew *et al.* 1998).

Skate species catch may not be proportional to its biomass, for a number of reasons. In particular, the BSAI skate biomass is measured with a bottom trawl survey which takes place in the summer and covers the entire continental shelf. In contrast, most of the skate bycatch is taken by longline fisheries for Pacific cod, which occur in the spring and fall on the outer portion of the continental shelf. Figure 3.5-29 shows a comparison between the locations of EBS fisheries and survey skate catch. There is no information to determine whether the distribution of skate species changes seasonally or whether different skate species have different catch abilities in different gear types. However, these are both viable possibilities. Both longline and trawl fisheries tend to catch skate in the area where the two most common Bering Sea skate, the Alaska skate *(Bathyraja parmifera)* and the Bering or sandpaper skate *(B. interrupta),* are caught together in the survey. Thus, the relative catch rates of these two species in the survey areas may represent relative catch rates in the fishery, which occur in the area of species overlap (NMFS 2001a).

Using the average catch rate of *B. parmifera* to *B. interrupta* from the 1999 EBS survey, the potential catch of each species was estimated. On average, *B. parmifera* were about 4 times more common than *B. interrupta* in terms of weight in the areas where both species are present. In addition, *B. interrupta* were about 50 times more common than any other species of skate when they were caught together. Based on this survey data, the catch composition of skate species in the EBS was assumed on average to consist of about 80 percent *B. parmifera*, 20 percent *B. interrupta*, and negligible amounts of all other skate species in areas where the groundfish fishery occurs. When the high end of the predicted catch range (14,000 mt) is proportioned using this ratio, the catch of *B. parmifera* would be 11,200 mt, which is 3.6 percent of the 1999 estimated biomass for this species (338,000 mt). Assuming this average observed catch rate, the catch of *B. interrupta* would be approximately 2,800 mt, which is 11.7 percent of the estimated biomass of this species (24,000 mt). When the low end of the predicted catch range (12,000 mt) is proportioned, the exploitation rates are 2.8 percent for *B. parmifera* and 10 percent for *B. interrupta.* Under this generally realistic assumption of disproportional catch of rarer species, the fishing mortality rate for *B. interrupta* could potentially equal or exceed the rate estimated to be the OFL (10 percent) with December 6, 2000 information. More extreme assumptions about disproportional catch would, of course, result in even higher estimated rates of fishing mortality relative to OFL for the rarer skate species (NMFS 2001a).

It is unknown which skate species are caught as bycatch in GOA groundfish fisheries; therefore, the catch of each of the nine skate species found in the area cannot be estimated. In the GOA, average catch rates are difficult to determine because of the more diverse skate complex combined with less information regarding skate catch location due to lower observer coverage. There is less information in the GOA to determine whether fisheries take place in areas of skate species overlap or in single-species areas; therefore, average catch rates cannot be estimated from survey information. Because most skate (99 percent) are referred to as "unidentified" in the catch, skate catch is estimated at the family level (Rajidae). Most of this catch is taken in the longline fishery directed at sablefish (39 percent), followed by the Pacific cod longline fishery (21 percent), the Pacific cod trawl fishery (13 percent), and the shallow water flatfish trawl fishery (7 percent).

In the North Atlantic, declines in barndoor skate abundance were concurrent with an increase in the biomass of skate as a group (Sosebee 1998). NOAA Fisheries surveys identified at least 11 species of skate in the FMP areas. Although it is not determined if any individual skate species have declined in the North Pacific during the timeframe of the FMPs, it is determined that there is adequate evidence that fisheries can affect skate populations and that stable or rising aggregate skate biomass does not necessarily indicate that no impact is occurring at the species level (Gaichas 2002).

Skate are presently managed within the other species category in both the BSAI and GOA FMPs through an aggregate TAC set for all other species combined. Management of the skate species within aggregate complexes and the apparent population stability for skate species in aggregate has masked the decline of individual skate species in European fisheries (Dulvy *et al.* 2000). Estimated total catch of skate in the BSAI from 1997-2001 averaged 18, 119 mt (Gaichas 2002) In the GOA, estimated total catch of skate over the same period averaged 2,932 mt (NORPAC and year–end estimates of target species catch from the NMFS Regional Office blend database). The current management of skate within an aggregate other species category TAC could mask declines in individual skate species and therefore lead to overfishing of a given skate species. Due to this reason and the fact that the majority of skate bycatch is taken in the BSAI groundfish fisheries, the current management is considered to have had a lingering adverse effect on skate species in the BSAI.

BSAI/GOA Skate Comparative Baseline

As opposed to aggregate skate biomass, biomass for each individual skate species is more difficult to assess. The knowledge of the number and identity of skate species in an area is developing concurrently with research. Skate have been described as unique among Chondrichthyes for their relatively high species diversity combined with morphological conservatism; in other words, there are lots of species that look alike (NMFS 2001a). For this reason, species identification has been variable over the course of surveys, ranging from skate unidentified to identification of over 10 different species in each area. In addition, skate taxonomy has changed over the course of surveys, with two new species described in the North Pacific; *Bathyraja hubbsi and Bathyraja pseudoisotrachys* (Ishihara and Ishiyama 1985). Therefore, any apparent trends in species abundance within the skate complex over the period of the surveys are not likely to be reliable. In recent years (1996 to present) training with increased emphasis on consistent skate species identification has improved this situation dramatically so that individual skate species may be assessed in the future. Distribution data is also affected by species identification issues. For these reasons, we evaluate biomass and distribution of individual skate species only for recent years where survey scientists are confident of species identification (NMFS 2001a).

Bottom trawl surveys conducted by the AFSC provide reliable estimates of aggregate skate biomass within the timeframe of the FMPs (Gaichas 2002). Bottom trawl gear designed to assess flatfish and demersal groundfish is expected to catch skate at least as well as target species. There are also longline surveys conducted by the IPHC and the AFSC for halibut and sablefish, respectively. These surveys are not used to index the abundance of skate at this time, because they are more specialized, being designed for individual target species, whereas the trawl surveys are designed to assess all groundfish species (NMFS 2001a).

The EBS skate complex is dominated by a single skate species, the Alaska skate (*Bathyraja parmifera*) (Table 3.5-54). This species accounted for about 91 percent of the aggregate skate biomass estimated in 1999. The Bering or sandpaper skate (*Bathyraja interrupta*) was the next most common species in the EBS, making up about 6 percent of the aggregate skate biomass. The other six skate species identified in the survey (Table 3.5-51) made up less than 3 percent of the aggregate skate complex biomass (NMFS 2001a).

The GOA skate complex is more diverse than that found on the Bering Sea shelf. Four skate species were considered common, with an additional five uncommon species. The big skate (*Raja binoculata*) composed nearly 50 percent of the aggregate skate biomass, followed by the longnose skate (*Raja rhina*) at about 30 percent of aggregate biomass. Two *Bathyraja* species, the Aleutian skate (*B. aleutica*) and the Bering skate (*B. interrupta*) were next in abundance, representing about 10 percent, and 3 percent of the aggregate biomass, respectively. All five other skate species identified on the 1999 GOA survey made up about 3 percent of the aggregate skate complex biomass (NMFS 2001a).

The skate community in the Aleutian Islands appears to be different from that described for both the EBS and the GOA. In the Aleutian Islands, the most abundant species in the 1997 survey was the white blotched skate (*Bathyraja maculata*) making up 45 percent of aggregate biomass. Alaska and Aleutian skate were also common, composing about 30 percent and 15 percent of the aggregate biomass, respectively. The mud skate, (*Bathyraja tanaretzi*), was relatively common but represented a lower proportion of total biomass (approximately 3 percent) because it is a smaller skate. All seven other skate species identified in the 1997 Aleutian Islands survey made up approximately 7 percent of the aggregate skate complex biomass.

The biomass of all skate species combined as estimated by the AFSC bottom trawl surveys has generally increased in all FMP areas over the past 15 to 20 years, although it has declined somewhat from the 1990 peak in the EBS (NPFMC 1999c). In 2002, AFSC EBS shelf and slope surveys for skate showed a biomass estimate of 434,525 mt. Skate biomass estimate for the 2002 AFSC AI trawl survey was 34,412 mt, being the highest estimate since 1980.

Skate, as a group, represented the highest proportion of estimated non-target species catch weight (28 percent) from 1997 to 1999 in both FMP areas combined. In the BSAI, skates are by far the highest proportion of non-target species catch at 35 percent of total estimated non-target catch weight. Table 3.5-55 shows estimated skate bycatch rates in BSAI and GOA.

BSAI/GOA Skates Cumulative Effects Status

Although it is not determined if any individual skate species have declined in the North Pacific during the timeframe of the FMPs, there is adequate evidence that fisheries can affect skate populations and that stable or rising aggregate skate biomass does not necessarily indicate that no impact is occurring at the species level (Gaichas 2002). Due to the vulnerability of certain or all skate species to overfishing and lack of accurate bycatch estimates, they will be carried forth for cumulative effects analysis. GOA Amendment 63 is scheduled for secretarial approval on March 3, 2004 which will result in skate species being moved from the other species complex to the target species complex. Upon the adoption of this amendment, OFL, ABC, and TAC levels will be established for skates and skate complexes in the GOA region. The direct and indirect effects analysis as well as the cumulative effects analysis presented in this document will consider skate species as part of the other species complex. As data and research improves for these species, future analyses will incorporate the proposed changes to the GOA FMP.

3.5.3.5 Octopi

Life History and Distribution

Three octopi species have been recorded: the giant Pacific octopus, *Enteroctopus dolfeni* (the principal species), the flapjack devilfish, *Opisthoteuthis california,* and the smoothskin octopus*, Octopus leioderma* (which appears only intermittently). The giant Pacific octopus is found from California to Japan in waters from low tide line to 200 m. In general, the giant Pacific octopi have short life spans ranging from only 1 to 5 years, averaging 3 to 5 years, during which they have only one reproductive period (Boyle 1983). Mating occurs in autumn inshore at less than 100 m in depth; females spawn 18,000-74,000 eggs in May and July in rocky or sandy bottom nearshore nests, while males return offshore and die. The female octopi brood their eggs for 6 to 7 months without feeding, dying soon after the eggs hatch. Hatchling are planktonic at first, settling to the bottom around March of the following year after hatching (Roper *et al.* 1984). The giant Pacific octopus is the largest of the octopods, reaching 10 kg at maturity (3 years for females). Less information is available for eastern North Pacific giant Pacific octopi, although it is thought that spawning occurs more often in the winter months (Hartwick 1983). Little is known of the flapjack devilfish or the smoothskin octopus.

Trophic Interactions

Information on trophic interactions for octopi in the BSAI and GOA regions is lacking. Thus, no further discussion will be presented here.

BSAI/GOA Octopi Management

In the BSAI and GOA, octopi species are managed within the other species category with a TAC specified for the entire other species complex.

BSAI/GOA Octopi Past/Present Effects Analysis

The geographic scope for the BSAI and GOA octopi past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the availability of other species bycatch information and ends in 2002, the most recent year in which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS. Table 3.5-56 provides a summary of the BSAI and GOA octopi past effects analysis presented below. The following direct and indirect effects were identified as potentially having population level effects on BSAI/GOA octopi:

- Mortality due to catch/bycatch (direct effect).

- Reduced recruitment due to spatial/temporal concentration of catch/bycatch (indirect effect).

The following past/present effects determined to be applicable to the octopi past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska groundfish fisheries
  - State of Alaska Crab fisheries
  - Directed fisheries

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

External Mortality: Foreign Groundfish Fisheries (Pre-MSA)

Unfortunately, bycatch data from the foreign fisheries' BSAI and GOA FMP foreign fishery Observer Program is non-existent at the level of octopi. It is inferred that past foreign fisheries had proportionally similar octopi bycatch to the current federal groundfish fisheries (NMFS 2001a).

External Mortality: Directed Fisheries

In the Bering Sea, the last directed octopus fishery was in 1995. Since then, there have been no directed fisheries for octopus. Directed octopus fishing is prohibited in the Aleutian Islands area as well (Funk 2003). No vessels applied for directed octopus fishing permits in the Alaska Peninsula area in 2001 (Ruccio *et al.* 2002).

The seasonal migrations of octopi for spawning purposes segregates the sexes in different habitats at certain times of the years. Therefore, there is some concern that fisheries could pose different effects on the sexes of octopi. More information is necessary to develop appropriate management for octopus species in Alaska (Gaichas 2001).

External Mortality: State of Alaska Groundfish Fisheries

Prior to 2001, vessels registered for groundfish or shellfish could also register for octopus fishing in addition to the target species. This allowed for 100 percent of octopi to be retained as bycatch in target fisheries. In 2001, ADF&G prohibited this dual registration and placed a retention limit of 20 percent for octopus bycatch (Funk 2003).

In 2000, harvest of octopi in the Alaska Peninsula area was 3.1 mt (state and federal waters) with no vessels formally registering for octopus harvest. In the groundfish fisheries, vessels targeting Pacific cod using pot gear accounted for the majority of the octopus bycatch (Funk 2003). During the 2000 season in the Bering Sea, 7.4 mt of octopus bycatch was reported and 64 percent was taken by pot gear in groundfish fisheries (Funk 2003). Non-pelagic bottom trawl gear accounted for 48 percent of octopus bycatch while pot gear made up 47 percent during the 2001 season in the Bering Sea (Bowers *et al.* 2002). Almost 100 percent of the 2000 and 2001 landings of octopi in the Aleutians area were taken from Pacific cod or other groundfish vessels using pot gear (Funk 2003; Bowers *et al.* 2002).

External Mortality: State of Alaska Crab Fisheries

From 1977 to 1984, a substantial amount of octopus was caught incidentally by Tanner crab pots (Funk 2003). Information regarding current status of octopus bycatch is lacking.

Internal Mortality: Foreign, JV and Domestic Groundfish Fisheries

Octopi bycatch tends to be slightly less in the GOA than in the BSAI, ranging from 88 to 232 mt in the GOA and from 190-418 mt in the BSAI from 1997-2001 (Gaichas 2002). Bycatch is taken largely in the Pacific cod fisheries, mainly the Pacific cod pot fishery. Octopi also have higher estimated retention rates of any group in the other species category, suggesting that a separate management group may be necessary in the future (Gaichas 2002).

BSAI/GOA Octopi Comparative Baseline

Octopi biomass estimates are limited and show large fluctuations from year to year in the BSAI and GOA. The 2002 AFSC shelf and slope surveys for the EBS estimated octopi biomass at 3,400 mt with Aleutian Islands trawl surveys totaling 1,380 mt. Octopi appear to be poorly sampled by demersal trawls and their biomass may be underestimated. Furthermore, biomass may be underestimated due to lack of sampling in important, nearshore, rocky habitats preferred by octopi (Gaichas 2002). Stock assessments are not conducted on octopi by ADF&G for the westward region of Alaska, thus, population status is unknown to date (Ruccio *et al.* 2002).

BSAI/GOA Octopi Cumulative Effects Status

Accurate biomass estimates and bycatch data for octopi are limited. Current population status for octopi in the BSAI and GOA regions cannot be determined at this time. Cumulative effects analysis will be carried forth in order to address uncertainty and data gaps associated with this species group.

3.5.4 Forage Species

Forage fishes, as a group, occupy a nodal or central position in the North Pacific Ocean food web, being consumed by a wide variety of fish, marine mammals, and seabirds. Many forage species undergo large, seemingly unexplainable, fluctuations in abundance. Most of these are r-selected species (e.g., capelin and sand lance), which generally have higher reproductive rates, are shorter-lived, attain sexual maturity at younger ages, and have faster individual growth rates than K-selected species (e.g., rockfish and many flatfish, which are generally long-lived, reach sexual maturity at an older age, and grow slowly). Predators that feed on r-selected fish species (marine mammals, birds, and other fish) have evolved in an ecosystem in which fluctuations and changes in relative abundance of these species have occurred. Consequently, most of them, to some degree, are generalists who are not dependent on the availability of a single species to sustain them, but instead rely on a suite of species, any one (or more) of which is likely to be abundant each year. However, differences in energy content exist among forage species, with herring, sand lance, and capelin containing higher energy content per unit mass than other forage species such as juvenile pollock (Payne *et al.* 1997). It is possible that changes in availability of higher energy content forage may influence growth and survival of the upper-trophic-level species reliant on forage species as their main prey.

Table 3.5-57 shows the biology and habitat attributes of a few of the forage fish species in the BSAI and GOA.

Trophic Interactions

In the EBS, forage fish, as defined here, are found in the diets of walleye pollock, Pacific cod, arrowtooth flounder, Pacific halibut, Greenland turbot, yellowfin sole, rock sole, Alaska plaice, flathead sole, and skates. However, forage fish do not represent a large portion of the diet, by weight, of these predators, with the exception of shelf rock sole (14.3 percent) and slope pollock (12.6 percent). Tables 3.5-58 and 3.5-59 present the ten most important prey, by weight, in the diets of each predator for the EBS shelf and slope regions, respectively. All forage fish species are italicized. Forage fish found in the diet, but not in the top ten prey by weight are also listed. The miscellaneous fish category represents all fish prey not included as one of the ten most important prey categories, primarily unidentified fish. All groundfish diet data are from the AFSC Resource Ecology Fishery Management Division, groundfish food habits database. Tables 3.5-63, 3.5-64, and 3.5-65 depict forage fish species found in the diets of seabirds and marine mammals occurring in the BSAI and GOA regions.

EBS Shelf

Despite the generally piscivorus diet of cod, arrowtooth flounder, Pacific halibut, Greenland turbot, and skates, forage fish are not principal components, by weight, in the diets of EBS groundfish (Table 3.5-58). Sand lance are the most prevalent forage fish in the diet of cod (0.8 percent) while capelin, osmerids, bathylagids, myctophids, and eulachon each represent 0.1 percent or less of the diet by weight. In the diet of arrowtooth flounder, capelin and eulachon each represent 0.2 percent of the diet by weight, while osmerids, myctophids, and sand lance each constitute 0.1 percent or less. The diet of Pacific halibut contains 2.2 percent sand lance and 1.8 percent capelin; osmerids and eulachon each represent 0.1 percent or less. Myctophids represent 0.2 percent of the diet of Greenland turbot; bathylagids, osmerids, and sand lance represent 0.1 percent or less. Sand lance are the most important forage fish in the diet of skates (0.7 percent); capelin, sandfish, and myctophids each represent 0.1 percent or less. Sand lance is the most prevalent forage fish species in the diet of walleye pollock (0.5 percent); osmerids, bathylagids, myctophids, and eulachon each represent less than 0.1 percent of the diet by weight. The total contribution (0.6 percent) of forage fishes to the diet of yellowfin sole is primarily due to sand lance; bathylagids and capelin each represent less than 0.1 percent by weight. Sand lance are the second most important prey in the diet of rock sole, 14.3 percent by weight; osmerids are the only other forage fish present in the diet (less than 0.1 percent). Sand lance are the only forage fish found in the diet of Alaska plaice, representing 0.5 percent of the diet. Flathead sole consume capelin (1.3 percent), sand lance (0.5 percent), osmerids (0.1 percent) and myctophids (less than 0.1 percent).

EBS Slope

Lang and Livingston (1996) studied the diets of groundfish in the EBS slope region. In this region, forage fish are relatively unimportant in the diets of Greenland turbot, flathead sole, arrowtooth flounder, and cod (Table 3.5-59). However, 12.6 percent of the diet of pollock on the slope consists of forage fishes. Greenland turbot consume bathylagids (0.4 percent) and myctophids (0.4 percent) as the only forage fish in their diet. Flathead sole also consumed bathylagids (0.3 percent) and myctophids (0.1 percent). Myctophids (0.2 percent) are the only forage fish found in the diet of arrowtooth flounder. Pollock consume bathylagids (7.0

percent), myctophids (5.5 percent), osmerids (0.1 percent), and sand lance (less than 0.1 percent). Forage fish are negligible in the diet of cod; bathylagids represent less than 0.1 percent of the diet by weight.

Aleutian Islands

Yang (1996) studied the diets of groundfish in the Aleutian Islands during summer. He found that main fish prey of groundfish in the Aleutian Islands included Atka mackerel, walleye pollock, Pacific herring, capelin, myctophids, bathylagids, Pacific sand lance, and eulachon (Table 3.5-60). Although Atka mackerel and walleye pollock were important fish prey of arrowtooth flounder, Pacific halibut, and Pacific cod, other forage fish species comprised from 1 to 37 percent of groundfish diets. Most of the Atka mackerel consumed by the groundfish were located near Attu, Agattu, Amchitka, Tanaga, Atka, and Unalaska Islands. Myctophids were an important forage fish. Large amounts of myctophids were found in the diets of Greenland turbot, walleye pollock, Pacific ocean perch, and shortraker rockfish. They were also found in arrowtooth flounder, Pacific cod, rougheye rockfish, Atka mackerel, and northern rockfish. Most myctophids consumed by the groundfish were located near Kiska, Adak, Seguam, and Yunaska Islands. It is notable that nine out of eleven groundfish species shown in Table 3.5-60 consumed myctophids as food. If the abundance of the myctophids declines dramatically, it could impact the growth of Aleutian Islands groundfish, which depend on myctophids for a main food resource. Bathylagids were found in the diets of Greenland turbot and walleye pollock. Capelin were found in the diet of Pacific halibut and walleye pollock collected in the Akutan Island area, but they contributed only 5 percent and less than one percent of the diets of Pacific halibut and walleye pollock, respectively. Pacific sand lance were food of arrowtooth flounder, Pacific halibut, Pacific cod, and walleye pollock, but they contributed less than one percent of these diets. Only a small amount (less than one percent) of eulachon was found in the diet of walleye pollock. Pacific sandfish was not found in the diets of the groundfish in the Aleutian Islands area.

Gulf of Alaska

Yang and Nelson (2000) studied the diets of groundfish in the GOA shelf during summer. They found that the main fish prey of groundfish in the GOA included pollock, Pacific herring, capelin, Pacific sand lance, eulachon, Atka mackerel, bathylagids, and myctophids (Table 3.5-61). Although walleye pollock was the most important fish prey of arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and walleye pollock in the GOA, other forage fish species comprised 1 to 23 percent of the diet of groundfish. Capelin was important food of arrowtooth flounder and pollock, comprising 23 and 7 percent of the diet, respectively in 1990. The consumption of capelin by walleye pollock gradually decreased to 3 percent in 1993; to 0 percent in 1996. Compared to 1990, arrowtooth flounder also consumed less capelin in 1993 (4 percent) and in 1996 (10 percent). The capelin consumed by these groundfish were mainly located northeast and southwest of Kodiak Island. Eulachon comprised 6 percent of the diet of sablefish. Myctophids were important forage fish for shortraker rockfish, comprising 18 percent of the diet of shortraker rockfish. Pacific sand lance were found in the stomachs of arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and walleye pollock, but their contribution to these diets was small (1 percent or less). Bathylagids were only found in the diet of walleye pollock, and they contributed less than one percent. Pacific sandfish was not found in the diet of the groundfish in the GOA.

In the Atlantic, strong interactions between cod and capelin have been recorded (Akenhead *et al.* 1982). Even though Pacific cod did not feed so heavily on capelin in the GOA, capelin was an important fish prey of several groundfish species. The distribution and the abundance of forage fish in the GOA are not well known.

However, a series of years with poor forage fish recruitment, which decreases the availability of small prey fish, may have a large impact on piscivorus groundfishes.

BSAI and GOA Forage Fish Management

The BSAI and GOA FMPs were amended in 1998 to establish a forage species category to prevent the development of directed fisheries on these ecologically important non-target species. This category consists of many fish families (Osmeridae [smelts], Myctophidae, Bathylagidae, Ammodytidae, Trichodontidae, Pholidae, Stichaeidae, Gonatostomatidae, and the order Euphausiacea). These families were removed from the non-specified species category with the smelt species, (dominated by capelin, *Mallotus villosus* and eulachon, *Thaleichthys pacificus*), which were previously removed from the other species category. The forage species rule restricts all species in this category to bycatch only status and establishes a maximum retainable bycatch (MRB) rate (explained in Appendix B) of 2 percent for these species in aggregate. In addition, commerce in forage species is currently prohibited except for the small amounts retained under the MRB rates and for artisanal or subsistence uses.

BSAI and GOA Past/Present Effects Analysis

The geographic scope for the BSAI and GOA forage fish past/present effects analysis is the same as the BSAI and GOA FMP management areas (Figures 1.2-2 and 1.2-3). The temporal scope for this analysis begins in the 1960s with the increase in intensity of the foreign fisheries, and ends in 2002, the most recent year of which information is available on the resource category.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events screened for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS. Table 3.5-62 provides a summary of the BSAI and GOA forage fish past effects analysis presented below. The following direct and indirect effects were identified as potentially having population level effects on BSAI forage fish:

- Mortality due to bycatch and marine pollution and oils spills (direct effect).

- Change in reproductive success due to predator removal and climate changes and regime shifts (indirect effect).

- Change in prey availability due to introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

- Change in important habitat due to fishery gear impacts, introduction of exotic species, marine pollution and oil spills and climate changes and regime shifts (indirect effect).

Mortality caused by marine pollution and change in prey availability and important habitat due to the introduction of exotic species and climate changes and regime shifts by way of ballast water has not been brought forward since the impacts on forage fish in the BSAI and GOA have not been directly observed or documented. However, researchers are attempting to link recent warming trends in the northwest Pacific to an increase in abundance of tropical predators (Northwest Fisheries Science Center 1998). See Section

3.10.1.5 for documentation of occurrences of unusual species in the BSAI and GOA as influenced by climate changes and regime shifts.

The past/present event determined to be applicable to the BSAI and GOA forage fish past effects analysis include the following:

- Past/Present External Events
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska directed capelin fishery
  - Subsistence and personal use fisheries
  - Regime shifts and climate changes

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries
  - State groundfish fisheries bycatch

- Past/Present Management Actions
  - FMP groundfish fisheries management
  - Data limitations

Mortality

External Foreign Groundfish Fisheries (pre-MSA)

It is inferred that past foreign fisheries had forage fish bycatch rates that are proportionally similar to the current domestic fisheries. It is likely that effects on the populations have occurred; however, magnitude of the effects is unknown due to the lack of pertinent bycatch information.

External State of Alaska Directed Capelin Fishery

Although little commercial fishing occurs on forage fish species, documentation exists of a small and sporadic commercial fishery on capelin as early as the 1960s (ADF&G 1993). The largest harvest of capelin was taken in 1984 (489 mt, sorted), and in 1993, 31 mt of capelin were harvested in Nunavachuk Bay. Data reveal that no more than three vessels per year participated in a capelin fishery. Data from 1992 and 1994 indicate that less than 1 mt of capelin was commercially harvested by one boat. The limited annual harvest of capelin in the North Pacific Ocean is due to sporadic market conditions, processing limitations, and fluctuation of available capelin biomass. However, declining Atlantic stocks have the potential to change the market interest for capelin.

Presently, commercial fishing for capelin is in state waters open by regulation, not managed by emergency order, and is restricted by few regulations. The opportunity for a directed fishery on capelin or the other forage fish species exists under the current management system. Presently, species contained in the proposed forage fish category are not actively managed by the State of Alaska; however, cooperative state and federal management would be necessary for those forage fish that may be distributed in state waters during spawning times.

External Subsistence and Personal Use Fisheries

The ADF&G Subsistence Division conducts household surveys to determine subsistence use of forage fish species. Data from these surveys show that smelt are reported harvested in a large number of coastal communities in the southeast, southcentral, southwest, west, and arctic regions of Alaska. Reported smelt harvests range from a few pounds to several thousand pounds per community, depending on place and year.

In the southeast, southcentral, and southwest regions, eulachon are the smelt most commonly taken. Rainbow smelt, capelin and unknown smelt are also reported harvested in communities in the arctic, west, southwest, and southcentral regions. The ADF&G database contains no records of subsistence harvests of other forage fish categories; however, it is possible that, in particular communities, some subsistence harvests of other forage fish species may occur (B. Wolfe, ADF&G, Subsistence Division, personal communication).

Internal JV and Domestic Groundfish Fisheries (post-MSA)

Forage fish bycatch has been a minimal component of the commercial fisheries, remaining under 75 mt in the BSAI and under 130 mt in the GOA, although in 2001, bycatch exceeded 500 mt in the GOA. Osmerids (smelts) make up the largest portion of the bycatch and tend to be caught in the pollock fishery in both the BSAI and GOA. While it is not known what percentage these values are of their actual biomasses in the BSAI or GOA, this bycatch amount probably has little effect on the reproducibility of each species, nor does it represent significant competition with other apex predators (marine mammals, birds, and other fish).

It is inferred that past JV and domestic fisheries had forage fish bycatch rates that are proportionally similar to the current domestic fisheries. It is likely that effects on the populations have occurred; however, magnitude of the effects is unknown due to the lack of pertinent bycatch information.

Recent changes in predator abundance and significant declines in seabirds (and marine mammals) in the BSAI and GOA have raised concerns that a decrease in the forage fish biomass may contribute to the further decline of seabird, marine mammal, and commercially important fish populations. The previous regulatory regime allowed for the retention of forage fish under the other species category TAC or as a non-specified species, but there was no measure in place to prevent the development of a directed fishery.

In April 1997, NPFMC adopted Amendment 36 to the BSAI FMP and Amendment 39 to the GOA FMP to prevent the development of commercial fisheries for forage fish. NOAA Fisheries published the final rule implementing the regulations on March 17, 1998 (63 FR 13009). Amendments 36/39 defined a forage fish species category and prevented the development of a commercial directed fishery for forage fish. The amendment established a 2 percent MRB amount in other directed fisheries and prohibited the selling, bartering, trading, or receiving any other remuneration for forage fish species. However, within the 2 percent limit, forage fish could be reduced to fish meal and sold.

While NPFMC considered options that would have put forage fish in the other species category or the prohibited species category, the alternative chosen was more effective in that it explicitly prohibited a directed fishery and the sale and barter of forage fish. The amendment also reduced waste by allowing retention (up to the 2 percent MRB amount) and processing (into fishmeal) of those forage fish caught incidentally in groundfish fisheries.

This action is appropriately precautionary and proactive to protect these ecologically important species from the development of target fisheries. However, protection from overfishing and maintenance of healthy stocks for species in this category might be better achieved if limits were set on total catch of these species in addition to MRB rates. These limits are difficult to set at present because biomass estimates are lacking for most of these species.

Change in Reproductive Success

External Foreign Groundfish Fisheries (pre-MSA)

Forage fish are a large prey item of several target species, removal of these predators by the fisheries could potentially have had a beneficial population level effect on forage fish abundance, favoring forage fish recruitment. However, the magnitude of these potential benefits are unknown.

External Climate Changes and Regime Shifts

Some evidence exists that osmerid abundance (see below for life history and distribution information), particularly capelin and eulachon, have significantly declined since the mid-1970s. Evidence for this comes from marine mammal food habits data from the GOA (Calkins and Goodwin 1988), as well as from data collected in GOA biological surveys not designed to sample capelin (Anderson *et al.* 1997) and EBS commercial fisheries bycatch (Fritz *et al.* 1993). It is not known, however, whether smelt abundance has declined or whether the populations have redistributed vertically, presumably due to warming surface waters in the region beginning in the late 1970s. This conclusion could also be drawn from the data presented by Yang (1993), who documented considerable consumption of capelin by arrowtooth flounder, a demersal lower-water-column feeder, in the GOA.

Research by Brodeur *et al.* (1999) has shown some spatial separation of some forage fish species and some changes in distribution in a cold versus warm year. Capelin were associated with colder temperatures in the northen part of the Bering Sea, while age-0 pollock were associated with warmer temperatures than the overall measured temperature. Eulachon were found only in the warmer temperatures at the southernmost part of the sampling area. Although this study did not find any long-term trends in forage fish abundance in the Bering Sea, the study period began in 1982, which is generally considered to be a warmer period in the Bering Sea. Analysis of 36 years of Russian pelagic trawl data indicates different periods of fish abundance, depending on environmental conditions. In the western Bering Sea and Okhotsk Sea, herring and capelin appear to alternate in abundance with pollock. Such a pattern has not been definitively identified for the EBS.

Internal JV and Domestic Fisheries (post-MSA)

Forage fish are a large prey item of several target species; removal of these predators by the fisheries could potentially have a beneficial population level effect on forage fish abundance, favoring forage fish recruitment. However, the magnitude of these potential benefits are unknown.

Change in Prey Availability

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Change in Important Habitat

External Foreign Groundfish Fisheries (pre-MSA)

See Sections 3.5.1.1 and 3.5.1.13 (past/present effects analysis: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat. The specific effects of foreign fishery gear on forage fish habitat are unknown.

External Climate Changes and Regime Shifts

The effects of climate changes and regime shifts are identified as potentially beneficial or adverse on habitat suitability and prey availability. For example, when the Aleutian Low is strong, water temperatures are higher, and biomass in the catches is dominated by cod, pollock and flatfishes. Community structure in nearshore areas around Kodiak Island changes in this same period with decreasing populations of shrimps and small forage fish, and increasing populations of large, fish-eating species, such as Pacific cod, and flatfishes (see Section 3.10.1.5). Since both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support environmental variance as an important controlling factor for the population (see Section 3.10.1.5).

Internal JV and Domestic Groundfish Fisheries (post-MSA)

See Sections 3.5.1.1 and 3.5.1.13 (past/present effects analysis: change in important habitat) for statistics on the number of bottom trawls occurring in these areas, and also see Section 3.6.4 for a discussion of the potential impacts of fishery gear on habitat. The specific effects of JV and domestic fishing gear on forage fish habitat are unknown. However, trawling efforts in forage fish habitat have been reduced in recent years due to Steller sea lion habitat conservation measures.

BSAI and GOA Forage Fish Comparative Baseline

Most of the fisheries catch is composed of target species, which are rigorously managed under an elaborate system of data collection, inseason management, and stock assessment. The management emphasis on target species, though arguably justified given the observed catch composition, leaves little time and resources for the management of non-target species. Historically, non-target species have been given relatively low priority in both fishery-dependent and fishery-independent data collection programs because of limitations on management resources. Although this has changed in recent years in the North Pacific, data limitation remains the primary assessment and management problem for most non-target species in the forage species, other species, and non-specified species categories (see Appendix B for more information on methods used to assess non-target species).

BSAI and GOA Forage Fish Cumulative Effects Status

The following sections describe the life history, distribution and baseline information for each forage species group where information is available. However, forage fish are only assessed as a group, not as the separate species groups in the past/present effects as discussed above and in the cumulative effects analysis of Chapter 4.

3.5.4.1 Osmeridae

Life History and Distribution

Smelts (capelin, rainbow smelt, and eulachon, family Osmeridae) are slender schooling fishes that can be either marine, such as capelin (*Mallotus villasus*) or anadromous, such as rainbow smelt (*Osmerus mordax dentex*) and eulachon (*Thaleichthys pacificus*). Figure 3.5-32 shows a generalized distribution of these three smelt species in the south EBS based on data collected by NOAA Fisheries summer groundfish trawl surveys and by fisheries observers.

Capelin

Capelin are distributed along the entire coastline of Alaska and south along British Columbia to the Strait of Juan de Fuca. In the North Pacific Ocean, capelin can grow to a maximum of 25 cm at age-4. Most capelin spawn at age-2 or -3, when they are only 11 to 17 cm (Pahlke 1985). Spawning occurs in spring in intertidal zones of coarse sand and fine gravel, especially in Norton Sound, northern Bristol Bay, and around Kodiak Island. Very few capelin survive spawning. The age of maturity of capelin in the Barents Sea has been shown to be a function of growth rate, with fast-growing cohorts reaching maturity at an earlier age than slow-growing cohorts. Thus, it is possible to have slow- and fast-growing cohorts mature in the same year, resulting in large spawning biomasses one year preceded and potentially followed by small spawning biomasses.

In the Bering Sea, adult capelin are only found nearshore during the months surrounding the spawning run. During other times of the year, capelin are found far offshore in the vicinity of the Pribilof Islands and the continental shelf break. The seasonal migration may be associated with the advancing and retreating polar ice front, as it is in the Barents Sea. In the EBS, winter ice completely withdraws during the summer months. If migration follows the ice edge, the bulk of the capelin biomass in the Bering Sea could be located in the northern Bering Sea, beyond the area worked by the groundfish fisheries and surveys. Very few capelin are found in surveys, yet they are a major component of the diets of marine mammals feeding along the winter ice edge (Wespestad 1987), and of marine birds, especially in the spring. In the GOA, which remains ice-free year-round, capelin overwinter in the bays of Kodiak Island and in Kachemak Bay.

Rainbow smelt

Rainbow smelt ascend rivers to spawn in spring shortly after the ice breakup. After spawning, they return to the sea to feed. Surveys have found concentrations of rainbow smelt off Kuskokwim Bay, Togiak Bay, and Port Heiden (Figure 3.5-32), but they also probably occur near many river mouths. Rainbow smelt mature at ages 2 or 3 (19 to 23 cm), but can live to be as old as 9 years and as large as 30 cm. Little is known about abundance trends of this species.

Eulachon

Eulachon also spawn in spring in rivers of the Alaska Peninsula, and possibly other rivers draining into the south EBS. Eulachon live to age-5 and grow to 25 cm, but most die following their first spawning at age-3. Eulachon are consistently found by groundfish fisheries and surveys between Unimak Island and the Pribilof Islands in the Bering Sea (Figure 3.5-32), and in Shelikof Strait in the GOA.

Trophic Interactions

Capelin

The diet of capelin in the North Pacific Ocean, as summarized by Hart (1973) and Trumble (1973), is primarily planktivorous. Small crustaceans such as euphausiids and copepods are common to the diet of capelin, although marine worms and small fish are also part of their diet. In the Bering Sea, adult capelin consume copepods, mysids, euphausiids, and chaetognaths. Juveniles primarily consume copepods (Naumenko 1984). The largest capelin (over 13 cm) consume euphausiids nearly exclusively. Capelin feed throughout the year in the Bering Sea. However, the diet exhibits seasonal variation that is due in part to spawning migration and behavior.

Eulachon

The diet of eulachon in the North Pacific Ocean generally consists of planktonic prey (Hart 1973, Macy *et al.* 1978). As larvae they primarily consume copepod larvae; post-larvae consume a wider variety of prey, including phytoplankton, copepod eggs, copepods, mysids, ostracods, barnacle larvae, cladocerans worm larvae, and larval eulachon. Juvenile and adult eulachon feed almost exclusively on euphausiids, with copepods and cumaceans occasionally in the diet.

The primarily planktivorous diets of eulachon, sand lance, and capelin reduce the potential for dietary competition with the piscivorus and benthic diets of most groundfish. However, the potential for dietary competition is greater between pollock and osmerids due to the importance of planktonic prey, such as euphausiid and copepod in their diets.

BSAI Osmeridae Comparative Analysis

Smelts make up the majority of the forage fish bycatch. Catches tend to be more erratic in the GOA; ranging from 23.1 to 534.8 mt per year from 1997 to 2001. In the BSAI, total bycatch ranges from 29.8 to 80.1 mt from 1997 to 2000. Smelt bycatch drastically increased in 2001in both the BSAI and GOA regions (Mark Nelson, personal communication, 22 January 2003). The cause of this increase is unknown at this time.

In the BSAI, the majority (64 percent - 94 percent) of the smelt bycatch occurs in the pollock fishery. Most of the remainder of the bycatch occurs in various flatfish fisheries. In the GOA, smelt bycatch is almost exclusively (92 percent to >99 percent) attributed to the pollock fishery.

GOA Osmeridae Comparative Baseline

Capelin

Capelin have shown abrupt declines in occurrence in small-mesh trawl survey samples in the GOA (Piatt and Anderson 1996, Anderson and Piatt 1999). In both NOAA Fisheries and ADF&G survey data, capelin first declined along the east side of Kodiak Island and bays along the Alaska Peninsula. Subsequent declines took place in the bays along the west side of Shelikof Strait. These declines happened quickly, and low abundance has persisted for over a decade. The decline was coincident with increases in water temperature of the order of 2°C, which began in the late 1970s. Capelin have fairly narrow temperature preferences and probably were very susceptible to the increase in water column temperatures (Piatt and Anderson 1996, Anderson *et al.* 1997). Mapping of relative densities of capelin showed defined areas of relative high abundance. The Shelikof Strait region showed relatively high catches in Kujulik, Alitak, and Olga bays. Most catches of capelin were closely associated with bays, except for high catches offshore of Cape Ikolik at the southwest end of Kodiak Island. Isolated offshore areas east of Kodiak Island showed some high catches, with most of the high catches associated with Ugak and Kazakof Bays. Only isolated catches of less than 50 kg were evident in the database from PWS, the Kenai Peninsula, and lower Cook Inlet.

Eulachon

Evidence from fishery observer and survey data suggests that eulachon abundance declined in the 1980s (Fritz *et al.* 1993). These data should be interpreted with caution because surveys were not designed to sample small pelagic fishes such as eulachon, and fishery data were collected primarily to estimate total catch of target groundfish. Causes of the decline, if real, are unknown, but may be related to variability in year-class strength, as noted for capelin. Small-mesh shrimp trawl surveys in the GOA coastal areas suggest that eulachon has remained at a low level of relative abundance since 1987. Eulachon are currently at the lowest recorded level in the survey series (1972 to 1997) at 0.01 kg/km (Anderson and Piatt 1999).

3.5.4.2 Myctophidae

Life History and Distribution

Lantern fishes (family Myctophidae) are distributed pelagically in the deep sea throughout the world's oceans. Most species in this family occur at depth during the day and migrate to near the surface to feed (and be fed upon) at night. A common myctophid in the Bering Sea and GOA is the northern lampfish (*Stenobrachius leucopsarus*), which has a maximum length of approximately 13 cm. Lanternfish are important forage fishes for marine birds and mammals.

Trophic Interactions

Because of their large mouth, relatively sparse and denticulate gill rakers, well-developed stomach, and short intestine, lantern fishes mostly consume actively swimming animals such as copepods and euphausiids (Balanov *et al.* 1995).

BSAI and GOA Myctophidae Comparative Baseline

Because they are rarely caught in survey or fishery trawls, nothing is known of recent trends in Myctophidae abundance. Lanternfish make a minor portion of the BSAI and GOA forage fish bycatch (Nelson 2002), less than half a metric ton between 1997-2001.

3.5.4.3 Bathylagidae

Life History and Distribution

Deep-sea smelts (family Bathylagidae) are distributed pelagically in the deep sea throughout the world's oceans. Most species in this family occur at depth during the day and migrate to near the surface to feed (and be fed upon) at night. Deep-sea smelt of the North Pacific Ocean include blacksmelt (*Bathylagus* spp.) and northern smoothtongue (*Leuroglossus stilbius schmidti*), each of which has maximum length of 12 to 25 cm. Deep-sea smelt are important forage fishes for marine birds and mammals.

Trophic Interactions

Because deep-sea smelts have a small mouth, dense flat gill rakers, a small stomach, and long intestine, they consume weak-swimming, soft-bodied animals such as pteropods, appendicularia, ctenophores, chaetognaths, polychaetes, and jellyfishes. Deep-sea smelts in the epipelagic zone can also feed on euphausiids and copepods at night when they are abundant (Balanov *et al.* 1995, Gorelova and Kobylyanskiy 1985).

BSAI and GOA Bathylagidae Comparative Baseline

Because they are rarely caught in survey or fishery trawls, nothing is known of recent trends in Bathylagidae abundance.

3.5.4.4 Ammodytidae

Life History and Distribution

Pacific sandlance (*Ammodytes hexapterus*, family Ammodytidae) are usually found on the sea bottom, at depths between 0 and 100 m except when feeding (pelagically) on crustaceans and zooplankton. Spawning is believed to occur in winter. Sand lance mature at 2 to 3 years and lengths of 10 to 15 cm. Little is known of their distribution and abundance; they are rarely caught by trawls. Given the sand lance’s short life span, and the large number of species that prey on it, mortality, fecundity, and growth rates are probably high.

Sand lance in the Kodiak Island region undergo an extensive migration that is counter to the normal pattern found with many inshore species. Spawning takes place in the late fall and winter, and usually is completed in January. Hatching of larvae continues over an extended time, until March and perhaps April (Blackburn *et al.* 1983, Blackburn and Anderson 1997), and some larval fish may spend up to several months in beach sediments. Newly hatched larval sand lance and adults start migrating offshore in the early spring and spend some time in offshore bank areas, where they can often be abundant (Clemens and Wilby 1961). Offshore ichthyoplankton surveys in the GOA indicated high larval abundance, first appearing in early March and remaining high until early July, but then disappearing. In the late summer, massive schools of fish start migrating inshore to suitable beach habitat for spawning and overwintering. These inshore migrating schools provide important forage for species such as offshore migrating seabirds during late summer and early fall. Hence, sand lance are among one of the few fish that migrate inshore during the late summer months to overwinter near-shore while most other fish migrate offshore prior to winter months.

Trophic Interactions

Hart (1973) and Trumble (1973) summarized the diet of sand lance in the North Pacific Ocean as primarily planktivorous, their primary prey changing with ontogeny. Larval sand lance consume diatoms (microscopic one-celled or colonial algae) and dinoflagellates (photosynthetic marine organisms); post-larvae prey upon copepods and copepod nauplii. More recent information on the food habits of age-0 and age-1 sand lance shows a dominance of calanoid copepods in the diet, with barnacle nauplii, larvaceans, and shrimp larvae as other important prey (Blackburn and Anderson 1997). Adult sand lance prey upon chaetognaths, fish larvae, amphipods, annelids, and common copepods. Sand lance exhibit seasonal and diurnal variation in feeding activity and are opportunistic feeders upon abundant plankton blooms.

In the Bering Sea, sand lance are common prey of salmon, northern fur seals, and many marine bird species. Thus, they may be abundant in Bristol Bay and along the Aleutian Islands and Alaska Peninsula. In the GOA, sand lance are prey of harbor seals, northern fur seals, and marine birds, especially in the Kodiak Island area and along the southern Alaska Peninsula.

BSAI and GOA Ammodytidae Comparative Baseline

Little is known about the historical abundance of Pacific sandlance in the BSAI or GOA. Sandlance are not effectively sampled in current NOAA Fisheries surveys and make a very minor portion of the forage fish bycatch (Nelson 2002).

3.5.4.5 Trichodontidae

Life History and Distribution

The Pacific sandfish (*Trichodon trichodon*, family Trichodontidae) lives in shallow inshore waters to about 50 m depth and grows to a maximum length of 30 cm. Some evidence shows sandfish exhibit burrowing behavior in which they bury themselves in the sand and come to rest with only their dorsal surface showing. Nothing is known of trends in their abundance.

Trophic Interactions

In the EBS, the diet of Pacific sandfish is primarily (95 percent by weight) fish, especially gadids (Brodeur and Livingston 1988). They are fed upon by salmon and other fish, as well as pinnipeds.

In the GOA, the diet of sandfish consists of small crustaceans such as mysids, amphipods, and cumaceans (Kenyon 1956, Mineva 1955). More recent information from the GOA shows that sandfish consume sand lance, several types of shrimp, crab larvae, cumaceans, and polychaetes (Paul *et al.* 1997). They are fed upon by salmon and other fish, as well as pinnipeds.

BSAI and GOA Trichodontidae Comparative Baseline

Pacific sandfish make up the second largest portion of the forage fish bycatch, after smelts; however, they are still lightly exploited in both the BSAI and GOA, generally ranging between 0.4 and 3.7 mt in recent years (Mark Nelson, personal communication, 22 January 2003). In 2000 the catch in the BSAI reached a peak of 20.3 mt. This unusually high bycatch came primarily from the flathead sole fishery (14.3 mt). At this time, the cause of this anomalous catch is unknown.

3.5.4.6 Pholidae

Life History and Distribution

Gunnels (family Pholidae) are long, compressed, eel-like fishes with long dorsal fins often joined with the caudal fin. Gunnels have flexible dorsal fin rays; they differ from pricklebacks in that the anal fin is smaller (the distance from the tip of the snout to the front of the anal fin is shorter than the length of the anal fin). Most species in this family live in shallow nearshore waters among seaweed and under rocks and are mostly less than 45 cm in length. Approximately 5 species of pholids occur in Alaska. Nothing is known about their abundance, and little is known about growth rates, maturity, and trophic relationships, although they are believed to grow quickly.

Trophic Interactions

The diets of gunnels (family Pholidae) consist primarily of benthic and epibenthic prey. Amphipods, isopods, polychaete worms, harpacticoid copepods, cumaceans, munid crabs, insects, mysids, algae, ostracods, bivalves, crustacean larvae, and tunicates have been described as their main prey (Simenstad *et al.* 1979, Williams 1994). Juvenile fish prey (English sole, *Parophry vetulus*, and sand lance, *Ammodytes hexapterus*) have also been described as infrequent components of its diet in Puget Sound, Washington (Simenstad *et al.* 1977).

Pholids (saddleback gunnel) were found in Pacific cod stomachs in the Aleutian Islands, but their contribution was less than one percent by weight of the total stomach content. Pholids were not found as a significant portion of the diets of EBS shelf or slope groundfish. Pholids are probably not important prey of the GOA groundfish area because they were not found in a study of groundfish diets in that area (Yang 1993).

BSAI and GOA Pholidae Comparative Baseline

Gunnels make up a very minor portion of the forage fish bycatch in the BSAI and GOA (Nelson 2002).

3.5.4.7 Stichaeidae

Life History and Distribution

Pricklebacks (family Stichaeidae, including warbonnets, eelblennys, cockscombs and shannys) are long, compressed, eel-like fishes with long dorsal fins often joined with the caudal fin. Pricklebacks are so named because of the spiny rays in the dorsal fin in most species (some have soft rays at the rear of the dorsal fins). Most species of this family live in shallow nearshore waters among seaweed and under rocks and are mostly less than 45 cm in length. Approximately 14 species of stichaeids occur in Alaska. Nothing is known about their abundance, and little is known about growth rates, maturity, and trophic relationships, although they are believed to grow quickly. Some cockscombs in British Columbia attain sexual maturity at age-2 years.

Trophic Interactions

The longsnout prickleback (*Lumpenella longirostris*) eats copepods almost exclusively (Barraclough 1967). Young ribbon pricklebacks (*Phytichthys chirus*) eat copepods and oikopleura (Robinson *et al.* 1968). The food of the adults of this species includes crustaceans and red and green algae. Black pricklebacks (*Xiphister atropurpureus*) consume copepods, copepod nauplii, and clam larvae (Barraclough *et al.* 1968). It has also been reported that an important food of high cockscomb (*Anoplarchus purpurescens*) is green algae. Other food of this species include polychaete worms, amphipods, mollusks, and crustaceans.

Stichaeids represent a minimal portion of the diets of several groundfish species in the EBS shelf region. Pacific cod (Livingston 1991b), arrowtooth flounder (Yang 1996), and flathead sole (Pacunski 1991) consume unidentified stichaeids as less than one percent of their diets by weight. Greenland turbot consume a combination of unidentified stichaeids and daubed shanny (*Lumpenus maculatus*) as a small portion (less than one percent) of their diet. Stichaeids represent a small portion (less than one percent by weight) of the diet of Pacific cod, arrowtooth flounder, and Greenland turbot in the EBS slope region (Lang and Livingston 1996). Yang (1996) studied the diets of groundfish in the Aleutian Islands and found that stichaeids comprised 2 percent of the stomach contents weight of arrowtooth flounder. Stichaeids comprised less than one percent of the diets of Pacific cod, walleye pollock, and Atka mackerel.

Yang (1993) also studied the diets of the groundfish in the GOA during summer and found that stichaeids comprised about one percent of the stomach content weight of arrowtooth flounder, Pacific cod, and walleye pollock, respectively. Pacific halibut, sablefish, and Pacific ocean perch also consumed stichaeids, but their contribution to the diets was small less than one percent).

BSAI and GOA Stichaeidae Comparative Baseline

Pricklebacks make up a minor portion of the BSAI and GOA forage fish bycatch (Nelson 2002), ranging between 0 and 0.4 mt in the BSAI from 1997-2001, and 0 and 4.7 mt in the GOA for the same period (Mark Nelson, personal communication, 22 January 2003).

3.5.4.8 Gonostomatidae

Life History and Distribution

This is a large and diverse family (Gonostomatidae) of small (to about 8 cm), mesopelagic and bathypelagic fish that are rarely observed except by researchers. They can be abundant at depths of up to 5,000 m. As many as six species may occur in the North Pacific Ocean and Bering Sea. Bristleworms, lightfishes, and anglemouths have large gill openings and well-developed gill rakers, characteristics of zooplankton feeders.

Trophic Interactions

The primary zooplankton prey of gonostomatids are calanoid copepods. Other food includes ostracods and euphausiids. Some larger gonostomatids also consume some fish (Gorelova 1980).

Gonostomatids were not found to be a significant portion of the diets of EBS shelf or slope groundfish (Livingston and deReynier 1996). However, they were found in pollock stomachs in the Aleutian Islands, but contributed less than one percent by weight of the total stomach content (Yang 1996). Gonostomatids are probably not important prey of GOA groundfish because they were not found in a study of groundfish diets in that area (Yang 1993).

BSAI and GOA Gonostomatidae Comparative Baseline

Members of the Gonostomatidae family are found in mesopelagic waters around the world. Due to their distribution and scope of their habitat members of the genus *Cyclothone* are thought to be the most abundant fish in the world (Moyle and Cech 1988). Nothing is known about the abundance of these fish in the BSAI or GOA region.

3.5.4.9 Euphausiacea

Life History and Distribution

Along with many copepod species, the euphausiids (*Euphausiacea*) form a critical zooplanktonic link between the primary producers (phytoplankton) and all upper pelagic trophic levels. These crustaceans, also known as krill, occur in large swarms in both neritic (nearshore) and oceanic (offshore) waters. Members of at least 11 genera of euphausiids are known from the North Pacific Ocean, the most important (in terms of numbers of species) being *Thysanopoda, Euphausia, Thysanoëssa,* and *Stylocheiron* (Boden *et al.* 1955, Ponomareva 1963).

Euphausiids are generally thought to make diurnal vertical migrations, remaining at depth (usually below 500 m) during the day and ascending at night to 100 m or less to feed. However, this is complicated by the fact that as euphausiids grow they are found at deeper depths, except during spawning, which occurs in surface waters.

Spawning occurs in spring to take advantage of the spring phytoplankton bloom, and the hatched nauplii larvae live near the surface (down to about 25 m). By fall and winter, the young crustaceans are found mainly at depths of 100 m or less, and make diurnal vertical migrations. Sexual maturity is reached the following spring at age-1. After spawning, adult euphausiids gradually descend to deeper depths until fall and winter, when they no longer migrate daily to near-surface waters. In their second spring, they again rise to the surface to spawn; euphausiids older than 2 years are very rarely found. This classical view of euphausiid life history and longevity was recently questioned by Nichol (1990), who reported that Antarctic euphausiids may live as long as 6 to 10 years; annual euphausiid production, then, would be much lower than if they lived only 2 years.

While euphausiids are found throughout oceanic and neritic waters, their swarms are most commonly encountered in areas where nutrients are available for phytoplankton growth. This occurs primarily in areas where upwelling of waters from depths into the surface region is a consistent oceanographic feature. Areas with such features are at the edges of the various domains on the shelf or at the shelf-break, at the heads of submarine canyons, on the edges of gullies on the continental shelf (e.g., Shumagin, Barnabus, Shelikof gullies in the GOA), in island passes (on certain tides) in the Aleutian Islands (e.g., Seguam Pass, Tanaga Pass), and around submerged seamounts (e.g., west of Kiska Island). It is no coincidence that these are also prime fishing locations used by commercial fishing vessels seeking zooplanktivorous groundfish, such as pollock, Atka mackerel, sablefish, and many rockfish and flatfish species (Fritz *et al.* 1993, Livingston and Goiney 1983, Yang 1993).

Trophic Interactions

The species comprising the euphausiid group occupy a position of considerable importance within the North Pacific Ocean food web. Euphausiids are eaten by almost all other major taxa inhabiting the pelagic realm. The diet of many fish species other than the groundfish listed previously, including salmon, smelt (capelin, eulachon, and other osmerids), gadids such as Arctic cod and Pacific tomcod, and Pacific herring, is composed, to varying degrees, of euphausiids (Livingston and Goiney 1983). They are also the principal item in the diet of most baleen whales (e.g., minke, fin, sei, humpback, northern right, and bowhead whales) (Perez 1990). While copepods generally constitute the major portion of the diet of planktivorous birds (e.g., auklets), euphausiids are prominent in the diets of some predominantly piscivorus birds in certain areas (e.g., kittiwakes on Buldir Island in the Aleutian Islands, Middleton Island in the GOA, and Saint Matthew Island in the Bering Sea) (Hatch *et al.* 1990). Euphausiids are not currently sought for human use or consumption from the North Pacific Ocean on a scale other than local, but large (about 500,000 mt per year) krill fisheries from Japan and Russia have been operating in Antarctic waters since the early 1980s (Swartzman and Hofman 1991).

The diets of euphausiids in the North Pacific Ocean consist of planktonic prey. Species of the genus *Euphausia* consume diatoms, dinoflagellates, tintinnids, chaetognaths, echinoderm larvae, amphipods, crustacean larvae, ommatidians, and detritus (Mauchline 1980). Species of the genus *Thysanoessa* consume diatoms, dinoflagellates, tintinnids, radiolarians, foraminiferans, chaetognaths, echinoderm larvae, mollusks, crustacean larvae, ommatidians and detritus (Mauchline 1980). In the GOA, several species of *Thysanoessa* also consume walleye pollock eggs (Brodeur and Merati 1993).

Euphausiids represent a significant portion of the diet of walleye pollock in the EBS shelf region (Livingston 1991a). Euphausiids represent as much as 70 percent of the diet in the winter and spring and are generally more important to larger pollock than smaller ones. Euphausiids are also the primary prey of small (less than 35 cm) Greenland turbot in the EBS shelf, but are of little importance to larger fish (Livingston and deReynier 1996). Small (less than 35 cm) arrowtooth flounder also consume euphausiids as a large (50 percent by weight) portion of their diet; euphausiids are of little importance to the larger ones (Livingston and deReynier 1996). Euphausiids were not found to be a significant diet component of any other EBS shelf groundfish. In the EBS slope region, euphausiids were found in the diets of several groundfish species. They represent 26 percent of the overall diet by weight of walleye pollock, but are more important by season (80 percent by weight in winter) and to smaller fish (less than 50 cm) fish (Lang and Livingston 1996). Euphausiids also play a small role (less than one percent by weight) in the diets of Pacific cod, flathead sole, and arrowtooth flounder (Lang and Livingston 1996). In the Aleutian Islands, euphausiids also comprised 43, 55, 51, and 50 percent of the stomach contents of walleye pollock, Atka mackerel, Pacific ocean perch, and northern rockfish, respectively. Euphausiids were also in the diets of arrowtooth flounder (5 percent), rougheye rockfish (2 percent), shortspine thornyhead (1 percent), and shortraker rockfish (1 percent) in the Aleutian Islands (Yang 1996).

Euphausiids are an important food item of many groundfish species in the GOA and Aleutian Islands. Yang (1993) showed that the diets of plankton-feeding groundfish in the GOA, such as dusky rockfish, Pacific ocean perch, and northern rockfish had large percentages (more than 65 percent) of euphausiids. Euphausiids also comprised 39 percent of the diet of walleye pollock in the GOA.

BSAI and GOA Euphausiacea Comparative Baseline

There are no current data available on the abundance of Euphausiacea in the BSAI or GOA.

3.5.5 Non-Specified Species

The non-specified species category contains a huge diversity of species, including invertebrates, that are not defined in the FMP as target, other, forage, or prohibited species, except for animals protected under the MMPA or the ESA. There is currently no management or monitoring of any species in this category, and the retention of any non-specified species is permitted. No reporting is required for non-specified species, and there are no catch limitations or stock assessments. Most of these animals are not currently considered commercially important and are not targeted or retained in groundfish fisheries.

The complete lack of reporting requirements may be problematic because it allows a species to slip through the system unnoticed. For example, bycatch of grenadiers, a non-specified species group, is higher in the GOA than the catch of all species in the other species category combined (Gaichas *et al.* 1999), and yet bycatch of grenadiers is not regulated. The current non-management of grenadiers could mask declines in individual grenadier species and therefore, lead to overfishing of a given grenadier species. Grenadiers are long-lived species (e.g., Andrews *et al.* 1999) that may be extremely vulnerable to and slower to recover from heavy fishing pressure, similar to rockfish and elasmobranch populations. Information and scientific data regarding the grenadier are very minimal in comparison to other species such as halibut. Due to the lack of information on other species within the non-specified category, grenadier is the only species that will be discussed in this document.

3.5.5.1 Grenadier

Life History and Distribution

Grenadiers (family Macrouridae) are deep-sea fishes that are related to hakes and cods. They have large heads and elongated bodies that taper to a thin pointed tail. Grenadiers are found throughout the North Pacific as far east as the Okhotsk Sea near Japan, north to the Bering Sea and down the west coast of the U.S. to Mexico. There are at least three common species in the BSAI and GOA: the giant grenadier (*Albatrossia pectoralis*) (Figure 3.5-33), the Pacific grenadier (*Coryphaenoides acrolepis*), and the popeye grenadier (*Coryphaenoides cinereus*). An additional eight species from the Pacific Ocean are known, and may be present in the North Pacific. Grenadiers dominate the fish fauna of continental slopes worldwide and may be pelagic or demersal, but are found only in deep waters (Eschmeyer *et al.* 1984).

The grenadiers found in the GOA are very long-lived animals, despite the fact that some do not grow large. The maximum reported age for the giant grenadier is 56 years, and for the Pacific grenadier is 73 years. Giant grenadiers are appropriately named, as they are the largest of all macrourid species. They are usually found between 140 and 1,740 m deep. According to research in Russian waters, giant grenadiers form sex-specific aggregations, with females found in shallower water than males, and they migrate seasonally between shallower and deeper waters according to the timing of ovarian maturation and spawning (Novikov 1970, as referenced in Burton 1999). Giant grenadiers are oviparous, with a planktonic larval stage (Ambrose 1996). The giant grenadier has a pelagic juvenile stage, with settlement to benthic habitats thought to coincide with the onset of maturity (Noikov 1970). This life history strategy may protect immature giant grenadiers from fishing pressure (Burton 1999).

Pacific grenadiers are approximately one-half the size of the giant grenadiers. They are a benthopelagic mid-slope species, usually found in a depth range of 155 to 2500 m, that may wander off slope bottoms into midwater (Ambrose 1996). Pacific grenadier are oviparous, with a planktonic larval stage (Ambrose 1996). According to research near the Oregon and California coasts, spawning depth is not known. Larval stages, however, have been captured in the water column in waters less than 200 m, while older larvae and juveniles are known to occur deeper. Pacific grenadier of the northeast Pacific ocean appear to be a relatively sedentary species, as no migrations have been documented. Iwamoto and Stein (1974) noted that larger Pacific grenadier are found in deeper water off the coast of Oregon, suggesting that the species may move to deep water as they grow.

Popeye grenadier are a benthopelagic species, usually found between 225 and 2,832 m in depth, whose size is approximately two-thirds that of the Pacific grenadier. Because there are no current age and growth information for the popeye grenadier, it is assumed that it has a lifespan similar to the giant grenadier, based on preliminary information (J. Hoff, AFSC, personal communication). Grenadiers dominate the biomass in many deep-sea habitats and are suspected to play an important ecological role in energy transfer, either as pelagic predators, benthic predators, and/or as scavengers on detritus. There is much to learn about grenadier ecology.

Grenadier life history is summarized in Table 3.5-66. There are no distribution maps to date for the grenadier, but there are documented harvest areas for the sablefish, a species with which grenadier bycatch is primarily associated in the GOA (see discussions following). Since the two species share similar habitats and ranges (bathydemersal, deep water, GOA) it can be inferred that the distribution of grenadiers in the GOA would mimic the distribution of sablefish in the harvest area map from the east Yakutat area to the western GOA area (Figure 3.5-34).

Trophic Interactions

Grenadiers that inhabit the upper continental slope generally prey on locally abundant fish and invertebrates and scavenge for carcasses (Okamura 1970, Pearcy and Ambler 1974, Drazen *et al.* In press). The popeye grenadier is the most numerically abundant grenadier in this region (Bohle 1988), and it likely has this type of feeding strategy. The giant grenadier feeds on myctophids, squid, and a variety of benthic and mesopelagic animals in the EBS (Novikov 1970): eelpouts, other fish, and shrimp were identified as its dominant prey from samples taken in the 1980s (Brodeur and Livingston 1988). Pacific grenadier feed on small fish, euphuasiids, prawns, amphipods and cephalopods (Cohen *et al.* 1990). Cannibalism is not uncommon in Pacific grenadier off the coast of Oregon, according to Stein (1978), and may be responsible for high larval and juvenile mortality.

Predators of the grenadier include sablefish (*Anaplopoma fimbria*) and skates (*Bathyraja maculata*), both bathydemersal fishes like the grenadier.

Grenadier Management

There is currently no management or monitoring of grenadiers in either the BSAI or GOA. This complete lack of reporting requirements and protection within the existing non-specified species category can lead to overexploitation of the species. The Pacific grenadiers may be extremely vulnerable to unregulated fishing due to the species' very low resilience, the minimum population doubling time is more than 14 years (Cohen *et al.* 1990).

The original GOA FMP (1978) included three management categories: target species, prohibited species, and other species. The other species category contained all species that are in the current other species category, plus all that are now in the non-specified species category. Each category, including other species, had a MSY/OY cap. It became clear that the inclusion of grenadiers in the other species category could cause the MSY/OY cap for other species to be reached before foreign fisheries had caught their allocations of target species, because bycatch of grenadiers was high even then. In 1979, GOA FMP Amendment 5 established a separate management category and TAC of 13,200 mt for grenadiers to avoid premature closure of target fisheries due to grenadier bycatch. However, they were moved to the non-specified species FMP category in 1980 (Amendment 8), where they have remained ever since. Within the non-specified species FMP category, there are no requirements for reporting catch of grenadiers, and their catch is not monitored, but retention of grenadiers is permitted. Unfortunately, the highest observed catches of non-target species are within the categories receiving the least intensive management under the status quo: other species and non-specified species.

Right now, grenadiers are taken only as bycatch in fisheries directed at target species; consequently, catches of grenadiers are dependent on the distribution and limitations placed on target fisheries. In deep-water longline fisheries, the catch of non-specified species may approach that of target species, due solely to the bycatch of grenadiers (Table 3.5-67), the species which accounts for the higher proportion of non-target species catch in the GOA (Figure 3.5-35). Only PSCs are limited by status quo management of non-target species. At the November 1999 GOA Plan Team meeting, GOA grenadier catches were reviewed, and there was interest in initiating management for grenadier species, at least as part of the other species category. This action is being considered within the revision of the proposed FMP amendment to change the management of sharks, skates, and the rest of the other species category (NPFMC 1999a).

It was attempted to determine which species were likely to be caught in the fisheries by combining species distribution information from surveys with the observed fishery catch information from 1997 to 1999. In this case, information on depth distribution of grenadier species from surveys separated species more clearly than location of catch, because all three species appear to be distributed all along the GOA slope. This depth distribution information is only useful if the depths are known where fisheries catch grenadiers. Fortunately, there is average depth information available associated with each observed catch location which may indicate which species are caught.

Because observers are not trained to identify individual species of grenadiers, the majority (100 percent in 1997–1998 and 90 percent in 1999) of grenadier catch is reported as "grenadier unidentified." The other 10 percent of grenadier catch from 1999 were identified as giant grenadier, (*A. pectoralis*). All available catch information is summarized for aggregated grenadier species, including annual catch and location of catch. Fishery data were examined from 1997–1999 to determine total grenadier catch, and catch in different gear types and target fisheries (Table 3.5-68), and the location and depth of grenadier catch were observed (see latter test regarding spatial analysis). Unlike skates, grenadiers are almost all killed when caught and brought to the surface from the depths they inhabit.

If all grenadier species are caught in proportion to their estimated biomass in the GOA, then bycatch would remove approximately 3.4 percent of the biomass of each grenadier species. The available information on the maximum age of grenadier species indicates that the natural mortality rate M for each species might be 0.074 for giant grenadier (*Albatrossia pectoralis*) and 0.057 for the Pacific grenadier (*Coryphaenoides acrolepis*). The life history of the popeye grenadier (*C. cinereus*) was assumed to be most similar to the giant grenadier, and M was estimated accordingly at 0.074 for this species. If these estimates are correct for each species, current management Tier 5 criteria for establishing ABC would allow taking up to 5.5 percent of the biomass of giant and popeye grenadiers, and the OFL would be reached if 7.4 percent of the biomass of each species were caught in groundfish fisheries, because OFL = M × biomass, and ABC is 75 percent of OFL. Similarly, the ABC for Pacific grenadier would be reached when 4.3 percent of biomass was removed by fishing, and the OFL would be reached at 5.7 percent of estimated biomass.

The information available on the depth distribution of fisheries as compared to survey estimates of the depth distribution of grenadier species from the 1999 GOA trawl survey indicates that the fisheries likely catch giant grenadiers much more frequently than any other grenadier species. Therefore, the proportional catch assumption may be reasonable for grenadiers. However, the least common grenadier species according to our surveys, the Pacific grenadier (*C. acrolepis*), is also the longest lived, and, therefore, has the lowest OFL of 5.7 percent of biomass. The proportional catch assumption would mean that 2 percent of the grenadier catch is Pacific grenadiers, but if this proportion increased slightly to only 4 percent of catch, the take of Pacific grenadiers would increase to 6.8 percent of estimated biomass, over what we would establish as an OFL for this species using current management Tier 5 criteria. More extreme assumptions about disproportional catch would, of course, result in even higher estimated rates of fishing mortality relative to OFL for the rarer grenadier species.

If a disproportional catch assumption about the species composition of the grenadier complex catch in the GOA is true, then there would be very different impacts on each grenadier species. The impact on the common species in the complex, the giant grenadier (*Albatrossia pectoralis*), would be non-significant because the catch would not even approach the OFL based on $M = 0.074$. However, the catch of the less common species in the complex, the Pacific grenadier (*Coryphaeniodes acrolepis*), could be at or above the OFL based on current management Tier 5 criteria; therefore, the impact could be significantly adverse for this species. The actual proportion of each species in the catch is unknown, and in this case there is additional uncertainty associated with the biomass of Pacific grenadiers. Unfortunately, even with very good recent biomass data from the GOA, it has been impossible to determine whether Pacific grenadiers are truly rare in the GOA, or if the survey simply did not sample deep enough habitats to fully assess the population size of Pacific grenadiers. Given the longevity of the species and the unregulated nature of grenadier catch in general, the impacts of current management would be conditionally significantly adverse for Pacific grenadiers in the GOA.

Past/Present Effects Analysis

The geographic scope for the grenadier past/present effects analysis includes the Bering Sea, Aleutian Islands, and GOA. The temporal scope for this analysis begins in 1978 when the original GOA FMP was initiated and ends in 2002.

A discussion of the direct/indirect effects, external human controlled and natural events, and internal groundfish fishery events for the past effects analysis is presented in Section 3.1.4 of this Programmatic SEIS, Table 3.5-69 provides a summary of the grenadier past effects analysis presented below. The following direct and indirect effects were identified as potentially having population level effects on grenadiers:

- Mortality due to bycatch (direct effect)

- Reduced recruitment due to spatial/temporal concentration of bycatch (indirect effect)

The following past/present effects determined to be applicable to the grenadier past effects analysis include the following:

- Past/Present External Effects
  - Foreign groundfish fisheries (pre-MSA)
  - State of Alaska groundfish fisheries

- Past/Present Internal Events
  - Foreign groundfish fisheries (post-MSA)
  - JV groundfish fisheries
  - Domestic groundfish fisheries

- Past/Present Management Actions
  - Bilateral agreements
  - Industry initiated actions
  - FMP groundfish fisheries management
  - Lack of information

External Mortality: Bycatch in the pre-MSA Foreign Fisheries

Pre-World War II foreign fisheries were relatively small with an expansion of large scale fishing operations in the post-war period, ultimately leading to increases in the catches of groundfish in the BSAI and GOA. By 1979, grenadier bycatch comprised as much as 66 percent of the total foreign fishery sablefish catch in the GOA and was recognized as a significant bycatch problem (GOA FMP Amendment 5, see Appendix D). By 1985, the JV operations and growing U.S. domestic fleet had entered the scene and continued the harvest of groundfish species.

External Mortality: State of Alaska Groundfish Fisheries

State sablefish fisheries do not keep records of grenadier (ADF&G, personal communication). However, since grenadier bycatch is associated with the federal sablefish fisheries, it is inferred that grenadier bycatch would also be associated with the state sablefish fisheries.

Internal Mortality: Foreign, JV and domestic Groundfish fisheries (post-MSA)

Federal groundfish fisheries have been prosecuted by an all-domestic fleet since 1987 in the GOA and since 1991 in the BSAI. Information is lacking with regard to mortality effects on grenadiers from post-MSA groundfish fisheries. Bycatch of grenadier is primarily associated with the sablefish and Greenland turbot longline fisheries on the outer shelf and continental slope regions of the Aleutian Islands and EBS. Bycatch estimates of grenadier have ranged between 2,675 mt (in 1992) and 8,885 mt (in 1993) (Gaichas 2000). Bycatch of grenadiers is higher in the GOA than the catch of all species in the other species category combined (Gaichas *et al.* 1999).

During the period 1997 to 1999, the average estimated bycatch of grenadiers from the GOA sablefish fishery was 92 percent of the total average of grenadier bycatch for all 16 target species fisheries included in the study. The bycatch of grenadiers from the BSAI sablefish and turbot fisheries combined was 84 percent of the total average of grenadier bycatch for all 16 target species fisheries during this same period (Table 3.5-68). In the GOA, grenadiers comprised approximately 55 percent by weight of the total estimated non-target groundfish catch during 1997 and 1999. As has been discussed previously, since grenadier bycatch is not recorded by species, there is the potential for a species to become overexploited.

Internal Reduced Recruitment: Foreign, JV and Domestic Groundfish Fisheries

Since it has been found that the giant grenadier forms sex-specific aggregations (Novikov 1970, as referenced in Burton 1999), there is a potential for fisheries to overexploit a certain sex, thus possibly leading to reduced recruitment. Although bycatch composition estimates the impact on the common species, impact on giant grenadier would be non-significant because the catch would not approach the OFL based on $M = 0.074$. However, if it is found that the long-lived, rarer Pacific grenadier also forms sex-specific aggregations, this species may be more vulnerable to fishery-related impacts.

Grenadier Comparative Baseline

The reliability of grenadier biomass estimates depends on whether AFSC bottom trawl surveys included sampling of deep water strata. Deep strata were sampled in the EBS in 1979, 1981-1982, 1985, 1988, and

1991; in the Aleutian Islands in 1980, 1983, and 1986; and in the GOA in 1984, 1987, and 1999. Aggregate biomass estimates were reported from these bottom trawl surveys only, as others may severely underestimate the biomass of these deep water species. Recent biomass estimates are available for all three common grenadier species from the 1999 GOA bottom trawl survey (Table 3.5-70).

According to the observed depth distribution of biomass from the 1999 GOA survey, almost all grenadiers caught shallower than 700 m are giant grenadiers. This depth distribution also suggests that the surveys do not sample deep enough to fully assess all three common grenadier species found in the GOA; for example, there are indications that the maximum density of Pacific grenadiers occurs at a depth of approximately 1,500 m (Andrews *et al.* 1999). Catch by average depth and gear type indicates that all three species may be caught in longline fisheries, but the predominant catch in trawl fisheries in the GOA is most likely the giant grenadier, (*Albatrossia pectoralis*). The depth distribution of longline catch suggests that much of this catch may also be giant grenadiers; however, the interpretation of the longline depth data is complicated by the use of an average depth without any indication of the potential depth range. It is possible for a longline set at an average depth of 400 to 500 m to extend into waters deep enough to catch species other than giant grenadiers.

There had been no slope surveys in the EBS since 1991 and none in the Aleutian Islands since 1986. A few studies were conducted recently, beginning in 1997 to present. Sablefish longline surveys were conducted in deeper water strata (approximately 200 to 1,000 m) of the GOA and EBS annually from 1997 to 2001. The 2002 bottom trawl survey in the EBS and upper continental slope were also conducted in deep water strata (approximately 200 to 1,000 m). The 2000 and 2002 bottom trawl surveys in the Aleutian regions, however, were conducted in much shallower waters; the depths ranged from approximately 20 to 471 m. While these recent Aleutian studies confirmed the presence of giant grenadiers (grenadier biomass 2000: 219,693 mt, 2002: 22,851 mt) , the sampling most likely did not occur at depths great enough to fully assess all three grenadier species of interest in this document, and so will not be discussed. The results of the sablefish longline and 2002 EBS studies are outlined below.

The sablefish longline surveys were conducted annually from 1997-2001 at approximately the same depths (200 to 1,000 m) using the same sampling stations from year to year. The combined results from both the GOA and EBS areas showed that giant grenadier consistently accounted for 22 percent of the total number of fish caught and recorded (average of 232,000 fish). The giant grenadier followed only the sablefish (35 to 40 percent of the catch) as the second-most frequently caught species (1997-2001).

The 2000 bottom trawl survey of the Aleutian Islands region (western, central, and eastern Aleutians and southern Bering Sea) groundfish resources also resulted in grenadier catch as well. However, the bottom trawl survey was conducted in much shallower water than the sablefish survey with a depth range from 20 to 471 m. The giant grenadier was the third most abundant species (219,693 mt) of the 12 species captured in the four sample areas combined; following only the Atka mackerel (512,511 mt) and Pacific ocean perch (511,706 mt). The giant grenadier was most abundant in the eastern Aleutian region, where its biomass estimate was 203,727 mt, and non-existent in the southern Bering Sea area (AFSC 2000). According to groundfish assessment surveys in the Aleutian region, the catch of giant grenadier has increased approximately eight fold from 1991 to 2000, from an estimated 24,594 to 219,693 mt. This upward trend may have been influenced by survey factors such as improved sampling techniques and possibly survey timing; the 2000 survey was conducted 3 weeks earlier than the 1997 and 1994 surveys, which were 7 weeks earlier than the 1991 survey (AFSC 2000).

The 2002 bottom trawl survey of the EBS upper continental slope groundfish resources was conducted along the EBS from Akutan Island northwest to the International boundary, between depths of 200 and 1,200 meters. The giant grenadier was the dominant species in overall biomass collected, with a total biomass of 81.5 mt. Pacific ocean perch weighed a total of 13.0 mt followed by the popeye grenadier total of 9.2 mt.

The 2002 bottom trawl survey of the Aleutian Islands region was conducted in approximately the same areas and at the same depths as the 2000 study. The giant grenadier was the fifth most abundant species in the three Aleutian areas, following the Atka mackerel, Pacific ocean perch, northern rockfish, and the walleye pollock, respectively. There were no grenadier found in the southern Bering Sea area. The grenadiers are again most abundant in the eastern Aleutian region, where their biomass estimate was 20,908 mt, compared with the combined biomass total in all three Aleutian regions being 22,851 mt.

The species most commonly encountered in the trawl surveys mentioned above was the giant grenadier (*Albatrossia pectoralis*). The Pacific grenadier (*Coryphaenoides acrolepis*) and the popeye grenadier (*Coryphaenoides cinereus*) were also present, but with much lower estimated biomass in all years. Survey coverage of deeper strata is particularly important to grenadier biomass estimates; therefore, the 1990-1996, 2000, and 2002 bottom trawl survey estimates are considered to be of little use for detecting trends in grenadier abundance. Because the 2000 sablefish longline survey and the 2002 bottom trawl surveys were both conducted in deeper strata, the data may be helpful in determining grenadier abundance.

BSAI and GOA Grenadier Cumulative Effects Status

Reliable biomass estimates are limited for grenadier, and species-specific information within the complex is almost non-existent. Since grenadier bycatch is not recorded by species, there is the potential for a species to become overexploited by fishing activities. This lack of information prevents discussion of the mortality effects of grenadiers due to post-MSA groundfish fisheries. Due to the potential vulnerability of this species group to overfishing, they will be brought forth for cumulative effects analysis.