# SUMMARY OF CHANGES IN THE BERING SEA-ALEUTIAN ISLANDS SQUID AND OTHER SPECIES ASSESSMENT 

by<br>Sarah Gaichas

Relative to the November 2000 SAFE report, the following changes have been made in the current draft of the squid and other species chapter:

1) Catch and survey biomass data are updated.
2) The recommended ABC for squid in the year 2002 is calculated as 0.75 times the average catch from 1978-1995, or $\mathbf{1 , 9 7 0} \mathbf{~ m t}$; the recommended overfishing level for squid in the year 2002 is calculated as the average catch from 1978-1995, or 2,624 mt.
3) The recommended ABC for the other species complex in the year 2002 is calculated as 0.75 times the average catch from 1978-1995, or $\mathbf{1 9 , 3 2 0} \mathbf{~ m t}$; the recommended overfishing level for the other species complex in the year 2002 is calculated as the average catch from 1978-1995, or $\mathbf{2 5 , 7 6 0} \mathbf{m t}$.
4) Tables with species-group specific alternatives to the status quo other species complex ABC and OFL recommendations given above are included. Options for spatial management of squid are discussed as an example of an alternative to quota management.

Squid and Other Species in the Bering Sea and Aleutian Islands

by<br>Sarah Gaichas

## Response to SSC Comments

From the June, 1999 SSC minutes regarding shark and skate management: During the SSC's discussion of this amendment, it was suggested that the Plan Team review the "other species" category generally to determine if adequate protection is provided for individual species to ensure their conservation.

In Appendix D of the November 1999 SAFE, separate ABC estimates for each species group in the GOA were proposed, both to illustrate how Other species could be restructured to afford better protection to each species group, and so that the SSC may evaluate the extent to which removing sharks and skates would affect allowable catch for the rest of the category. Similar species group management for the BSAI other species complex is illustrated in this assessment.

From the October, 2001 SSC minutes: The SSC received a discussion paper from Jane DiCosimo and Sarah Gaichas on progress towards management of the 'other species' categories for the BS/AI and GOA regions. The SSC is concerned that management based on gross taxonomic groupings will lead to a weakest link problem, where management will be expected to demonstrate "no harm" to species present in low and declining numbers. The development of ABCs and TAC for gross taxonomic groupings has the problem that species are grouped together that are neither ecologically connected, nor similar in their rates of productivity. This is a NMFS-wide problem that may need to be approached at a national level. The SSC recommends continuation of the current approach while a search is conducted for an alternative method.

The ABC and OFL recommendations in this assessment are based on Tier 6 criteria for both squid and the other species complex, which is the current approach. It is difficult to demonstrate "no harm" to individual species when using management measures that are applied to gross taxonomic (or nontaxonomic) groupings. Because there is no control over catches by individual species or even gross taxonomic group under current management of the other species complex, the use of Tier 6 criteria (which result in the lowest possible other species complex ABC and OFL allowed under the current approach) is an attempt to minimize any potential harm to individual species within the complex. While we are searching for more appropriate methods to manage the other species complex, there appears to be no utility in the increased other species ABC and OFL that results from the "step up" approach as applied in 2000 (see the December 2000 SSC minutes; the "step up" approach calculated taxonomic group ABCs using Tier 5 criteria, then summed them into an aggregate ABC , which was then scaled down to be closer to recent TACs for the complex). Therefore, no ABC or OFL based on the "step up" approach is presented here.

For many of the other species, biological and catch information is of questionable quality due to limited sampling, imprecise species identification and other factors. We don't expect significant improvement in our knowledge in the immediate future. Rather than using typical quota setting measures for conservation of other species, other devices, such as restricted area management, should be explored. Survey and observer catch data should be examined to determine if such an approach has promise.

I attempt to characterize the state of our current knowledge in this assessment, which is quite variable within the other species category for a variety of reasons. While this work is ongoing, the outline
presented here may suggest possibilities for improving other species management. An example of restricted area management of squid bycatch is presented in this assessment; similar analyses for different other species groups will be conducted for future assessments.

## INTRODUCTION

Other species are considered ecologically important and may have future economic potential; therefore an aggregate annual quota limits their catch. There is currently little, if any directed fishing on any component of the Other species category in Alaska. In the Bering Sea / Aleutian Islands (BSAI) region, squid is considered separately from the "other species" management group, which includes sculpins, skates, sharks, and octopus. Smelts were removed from the "other species" group and moved to the forage fish group beginning in 1999 as a result of fishery management plan (FMP) amendments 36 and 39 to the Bering Sea and Aleutian Islands and Gulf of Alaska groundfish FMPs.

Individual other species known or suspected to occur in the Bering Sea and Aleutian Islands are listed in Table 14-1. The species list was compiled from AFSC survey and fishery observer catch records, and is considered more comprehensive and up-to-date for the region than the general literature (Hart, 1973; Eschmeyer et al., 1983; Allen and Smith, 1988). However, this list may contain errors because species identification is difficult within this category, and taxonomy for certain groups is not fully resolved.

There is some information indicating which species in this large category are most likely caught in BSAI groundfish fisheries. The predominant species of squid in commercial catches in the EBS is believed to be the red squid, Berryteuthis magister, while Onychoteuthis borealijaponicus, the boreal clubhook squid, is likely the principal species encountered in the Aleutian Islands region. Sharks are the only group in the complex which is consistently identified to species in catches by fishery observers. The three shark species most often encountered in Alaska fisheries are the Pacific sleeper shark, Somniosus pacificus, the piked or spiny dogfish, Squalus acanthias, and the salmon shark, Lamna ditropis.

Skate species are not identified in catches at present, but during cooperative U.S.-Japan surveys from 1979-85, 15 species of skates were identified but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist (Bakkala et al. 1985; Ronholt et al. 1985; Bakkala 1993). In recent AFSC surveys, taxonomic keys have been significantly improved, so that we are now confident of most survey identifications. The most common skate species on the EBS shelf is the Alaska skate, Bathyraja parmifera. This species accounts for about $91 \%$ of the aggregate skate biomass estimated in 1999. The Bering or sandpaper skate (Bathyraja interrupta) was the next most common species in the EBS shelf survey, making up about $6 \%$ of aggregate skate biomass. The other six skate species identified on the shelf survey made up less than $3 \%$ of the aggregate skate complex biomass. Skate species diversity increases on the outer continental shelf and slope, where numerous species were identified in 2000, including the Bering or sandpaper skate Bathyraja interrupta, the Aleutian skate $B$. aleutica, and several deeper dwelling skates including the whitebrow skate $B$. minispinosa, the mud skate $B$. taranetzi (=Rhinoraja longii), the whiteblotched skate B. maculata, and the commander skate $B$. lindbergi. The skate community in the AI appears to be different from that described for the EBS. In the AI, the most abundant species on the 1997 survey was the whiteblotched skate, Bathyraja maculata ( $45 \%$ of aggregate biomass). Alaska and Aleutian skates were also common, composing about $30 \%$ and $15 \%$ of aggregate biomass, respectively. The mud skate, Bathyraja tanaretzi, was relatively common but represented a lower proportion of total biomass ( $\sim 3 \%$ ) because it is a smaller skate. All seven other skate species identified on the 1997 AI survey made up about $7 \%$ of aggregate skate complex biomass.

During the cooperative U.S.-Japan surveys, 41 species of sculpins were identified in the EBS and 22 species in the Aleutian Islands region. Sculpin diversity remains high in recent surveys of both areas. It is likely that the larger sculpin species (Irish lords, Hemilepidotus spp., great sculpin and plain sculpins, Myoxocephalus spp., and bigmouth sculpin Hemitripterus bolini) which contribute to the majority of sculpin biomass on surveys are the ones commonly encountered as bycatch. However, it is unclear which sculpin and skate species are commonly taken in BSAI groundfish fisheries, because observers do not regularly identify animals in these groups to species. It is also unknown which octopus species are caught in BSAI fisheries, although it is assumed that the majority of the catch is of the giant Pacific octopus, Octopus dolfleni (recently renamed Enteroctopus dolfleni, Hochberg 1998 as referenced in $\mathrm{http}: / /$ marine.alaskapacific.edu/octopus/factsheet.html).

Information on distribution, stock structure, and life history characteristics is limited for other species in the Bering Sea and Aleutian Islands. Some life history information is available for the same or similar species in other geographic areas. Given the wide diversity of species represented in this management category, we feel it is important to attempt to describe general life history characteristics at least at the species group level in order to evaluate the potential effects of fishing on other species. Therefore, we summarize the available life history information by group below, with the caveat that this should not substitute for future investigations specific to Bering Sea and Aleutian Islands stocks.

## Sharks

Sharks are long-lived species with slow growth to maturity and large maximum size; therefore the productivity of shark stocks is very low relative to most commercially exploited bony fishes (Compagno, 1990; Hoenig and Gruber, 1990). Shark reproductive strategies are characterized by long ( 6 months - 2 years) gestation periods, with small numbers of large, well-developed offspring (Pratt and Casey, 1990). Many large-scale directed fisheries for sharks have collapsed, even where management was attempted (Anderson, 1990). The three shark species most likely to be encountered in Alaska fisheries are the Pacific sleeper shark, Somniosus pacificus, the piked or spiny dogfish, Squalus acanthias, and the salmon shark, Lamna ditropis. We review life history information for each species below.

Little biological information is available for Pacific sleeper sharks, although they are considered common in boreal and temperate regions of shelf and slope waters of the north Pacific. Sleeper sharks are found in relatively shallow waters at higher latitudes, and in deeper habitats in temperate waters. Pregnant females have not been found, so reproductive mode is unknown, although ovoviviparity is suspected. One individual mature female sleeper shark had 300 eggs. Sleeper sharks grow to large sizes; individuals have been measured to 4.3 m , and lengths to 7 m have been observed under water (Compagno, 1984). Large concentrations of sleeper sharks were found during the 2000 pilot Bering Sea slope survey, while almost none have been encountered in the EBS shelf survey.

Spiny dogfish are demersal, occupying shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the north Pacific, and worldwide in non-tropical waters. They are considered more common off the U.S. west coast and British Columbia than in Alaska (Hart, 1973). This species is commercially fished worldwide, and may be the most abundant living shark. Complex population structure characterizes spiny dogfish stocks in other areas; tagging shows separate migratory stocks that mix seasonally on feeding grounds in the UK, and separate stocks in BC and Washington state, both local and migratory, that don't mix (Compagno, 1984). Dogfish form large feeding aggregations, with schools often segregated by size, sex, and maturity stage. Male dogfish are generally found in shallower water than females, except for pregnant females which enter shallow bays to pup. This species is ovoviviparous with small litters of 1-20, and gestation periods of 18-24 months. While all parameters may vary by population, British Columbia female spiny dogfish are reported to mature at 23 years, and
males at 14. Maximum age estimates range from 25-30 up to 100 years. Eastern north Pacific spiny dogfish stocks grow to a relatively large maximum size of 1.6 m (Compagno, 1984). Directed fisheries for spiny dogfish are often selective on larger individuals (mature females), resulting in significant impacts on recruitment (Hart 1973; Sosebee 1998).

Salmon sharks range in the north Pacific from Japan through the Bering Sea and Gulf of Alaska to southern California and Baja. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures well above ambient water temperatures (Anderson and Goldman, 2001). Salmon sharks have been both considered a nuisance for eating salmon and damaging fishing gear (Macy et al., 1977; Compagno, 1984) and investigated as potential target species in the Gulf of Alaska (Paust and Smith, 1989), although little is known about their life history locally. In the western Pacific, females are estimated mature at 8-10 years and males at 5 years (Tanaka 1980). The reproductive mode for salmon sharks is ovoviviparous and with uterine cannibalism (Gilmore 1993), and litter size in the western North Pacific is up to 5 pups, with a ratio of male to female of 2.2 (Tanaka 1980). Maximum size has been reported at 3.0 m , but average size range seems to be between 2.0 and 2.5 m . This species lives at least 25 years in the western North Pacific (Tanaka 1980). An investigation is currently underway to determine demographics and population parameters for salmon sharks in the eastern North Pacific (K. Goldman, VIMS, personal communication).

## Skates

Skate species are distributed throughout the north Pacific and are common from shallow inshore waters to very deep benthic habitats. Skate life cycles are similar to sharks, with relatively low fecundity, slow growth, and large body sizes. All skate species are oviparous, with one to seven embryos per egg case in locally occurring Raja species (Eschmeyer et al., 1983). The big skate, Raja binoculata, is the largest skate in Alaska, but it is more common in the Gulf of Alaska than in the BSAI. In California, female big skates mature at 12 years ( $1.3-1.4 \mathrm{~m}$ ), and males mature at $7-8$ years ( $1-1.1 \mathrm{~m}$ ). Maximum size is 2.4 m , with 1.8 m and 90 kg common (Martin and Zorzi, 1993). The longnose skate, Raja rhina, achieves a smaller maximum length of about 1.4 m in California, and matures between ages 6 (males) and 9 (females). Maximum age reported for the longnose skate was 13 years, although there are many difficulties with ageing skates (Zeiner and Wolf, 1993). Little information is available on reproductive frequency in skate species, or on any Bathyraja species life history, but Table 14- 2 lists our best information on life history for all species in Alaska. Although little specific life history information exists for most skate species, they are generally thought to have limited reproductive capacity, and thus be vulnerable to overfishing (Sosebee, 1998). Large skate species with late maturation (11+ years) are most vulnerable to heavy fishing pressure, with cases of near-extinction reported in the North Atlantic for the common skate Raja batis and the barndoor skate Raja laevis (Brander, 1981; Casey and Myers, 1998). In the North Atlantic, declines in barndoor skate abundance were concurrent with an increase in the biomass of skates as a group (Sosebee 1998). NMFS surveys identified at least 11 species of skates in the FMP areas. Although it is not determined if any individual skate species have declined in the North Pacific over the course of federal fisheries management, 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.

## Sculpins

Sculpins (Cottidae) are relatively small, benthic-dwelling predators, with many species in the North Pacific. Despite their abundance and diversity, sculpin life histories are not well known in Alaska. In terms of life history, sculpins are different from many target groundfish species in that they lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschemeyer et al, 1983). For example, bigmouth
sculpins lay eggs in vase sponges-it is unknown whether they are completely dependent on finding a particular type of sponge to reproduce. This type of 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. Some larger sculpin species such as the great sculpin, Myoxocephalus polyacanthocephalus, reach sizes of 70 cm and 8 kg in the western North Pacific. There, great sculpins are reported to have relatively late ages at maturity (5-8 years, Tokranov, 1985) despite being relatively short-lived (13-15 years), which suggests a limited reproductive portion of the lifespan relative to other groundfish species. Mean fecundities for great sculpin were 60,000 to 88,000 eggs per gram body weight (Tokranov, 1985). In addition, the diversity of sculpin species in the FMP areas suggests that each sculpin population might react to similar environmental changes (whether natural or fishing influenced) in different ways. 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 population structure (Tokranov, 1985) which is not generally observed in target groundfish stocks. All of these characteristics indicate that sculpins 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 sculpins are different enough from all other members of the other species group to justify their own management category, despite the potential complexity of effective management of a single group as diverse as the sculpins.

## Octopi

In general, short lifespans of 1 to 5 years with a single reproductive period are reported for octopod species (Boyle, 1983). The North Pacific giant octopus, Enteroctopus dofleini, is the largest of all octopods. It ranges from northern California to Japan in nearshore waters from low tide line to 200 m deep. In Japan, where octopus support directed fisheries, its life history has been extensively studied. Seasonal inshore-offshore migrations are reported, with mating occurring during autumn inshore in less than 100 m depth. Male octopus migrate back offshore and die, while females remain inshore, spawning 18,000 to 74,000 eggs in shallow water nests $(<50 \mathrm{~m})$ on rocky or sandy bottom between May and July. Eggs are brooded for 6-7 months; female octopus do not feed during this period, and die soon after the eggs hatch. Hatchlings are about 10 mm long, and are planktonic until growing to $20-50 \mathrm{~mm}$, settling out to benthos in about March of the year following hatching (Roper et al., 1984). Life history in the eastern North Pacific is not as well known, but spawning may be more common in winter months (Hartwick, 1983). It is thought that giant octopus require 3 years to grow to an adult (mature female) size of 10 kg , and that they live 3-5 years. We found no specific information about the life history of the flapjack devilfish, Opisthoteuthis californiana, or the smoothskin octopus, Octopus leioderma. Because at least some octopus species migrate seasonally inshore and offshore, the sexes are often found in separate habitats. Therefore, the timing and location of fishery interactions with octopus populations may have differential effects on the sexes. More information is necessary to develop appropriate management for octopus species in Alaska, but the fact that they already have the highest estimated retention rates of any group in the other species complex suggests that management at the group level may be necessary in the near future.

## Squids

Like octopods, squid species have a single reproductive period; however, most squid lifespans are thought to be 1-2 years. Unlike octopods, squid are generally migratory pelagic schooling species. Squid have been described as "the marine equivalent of weeds," displaying rapid growth, patchy distribution and highly variable recruitment (O'Dor, 1998). Many squid populations are composed of spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski, 1998). Most information on squids refers to Illex and Loligo species which support commercial fisheries in temperate and tropical waters. Of North Pacific squids,
life history is best described for western Pacific stocks (Arkhipkin et al., 1995; Osako and Murata, 1983). The most commercially important squid in the north Pacific is the magistrate armhook squid, Berryteuthis magister. B. magister from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 2 years). Males grew 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. Growth, maturation, and mortality rates varied between seasonal cohorts (Arkhipkin et al., 1995). 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). The essential position of squid within North Pacific pelagic ecosystems, combined with the limited knowledge of the abundance, distribution, and biology of many squid species in the FMP areas, make squid a good candidate for management distinct from that applied to other species (as is already done in the BSAI). Because fishery interactions with squid happen in predictable locations (see below), squid may be a good candidate for management by spatial restriction rather than by quota.

## FISHERY INFORMATION

There is currently little directed fishing for species in this category in Alaska. Squid and other species are taken incidentally in target fisheries for groundfish, and aggregate catches of squid species (Table 143 ) and the other species complex (Table 14-4) are tracked inseason by the Alaska Regional Office.

## Catch estimates by species group

Because annual other species catches are reported in aggregate, catches by species group or individual species must be estimated using data reported by fishery observers. A new method (described below) was used this year to estimate species group catch within the other species complex in the BSAI. This method most closely matches the Regional Office blend catch estimation system, and is considered an improvement over past methods. However, the species group catch estimates presented here may not be identical to those presented in past assessments. Catches for all non-target species were estimated at the lowest practical taxonomic level for the recent domestic fishery, 1997-2000, by simulating the Regional Office's blend catch estimation system as follows. Target fisheries were assigned to each vessel / gear / management area / week combination based upon retained catch of allocated species, according to the same algorithm used by the Regional office. Observed catches of other species (as well as forage and non-specified species) were then summed for each year by target fishery, gear type, and management area. The ratio of observed other species group catch to observed target species catch was multiplied by the blend-estimated target species catch within that area, gear, and target fishery. Total annual catch by species group has been relatively stable between 1997-2000 (Table 14-5). Estimated annual species group catches are reported by target, gear, and area in Tables 14-6 through 14-9 for 1997-2000. Annual estimated total catches for identified shark species are reported within these same tables. Catch patterns for each species group are discussed below.

Estimation of individual species catches within the other species complex depends on the level of identification of those species in the catch. Within the complex, only sharks (especially spiny dogfish, Pacific sleeper, and salmon sharks) are identified to the species level by observers with any regularity. Skates are almost always recorded as "skate unidentified", with very few exceptions between 1990-2000. At least $80 \%$ (by weight) of the observed sculpin catch each year was recorded as "sculpin unidentified," with the remainder of catch identified to the genus level (Hemilepidotus, Myoxocephalus, Gymnocanthus, Triglops). Only small amounts ( $<2 \%$ ) of sculpin catch each year were identified to species. Likewise,
octopus and squid are generally not identified to species in the NORPAC database--there is only one individual species code for squid, Moroteuthis robusta, and all other squid catch falls under the "squid unidentified" species code. Octopus can only be recorded as "octopus unidentified," or "pelagic octopus unidentified." Observers are presently instructed to devote resources to higher-priority target species and prohibited species data collection, so they have limited time to devote to other species identification. At present, fishery observers are not trained to identify skates, sculpins, squid, or octopus to species.

The accuracy of catch estimates for groups or species within the other species complex also depends on the level of observer coverage in a given fishery (no observers, no catch estimates). Observer coverage requirements are based upon vessel size. In general, larger vessels fish in the Bering Sea, such that observer coverage levels in some fisheries approach $100 \%$. Our calculations for 1997-2000 suggest that the BSAI region has approximately $70-80 \%$ observer coverage overall. The size distribution of vessels fishing in the Gulf of Alaska results in approximately $30 \%$ observer coverage overall, although some target fisheries (ie. rockfish) are prosecuted on larger vessels with $100 \%$ observer coverage. Therefore, in making these catch estimates, we are assuming that other species catch aboard observed vessels is representative of other species catch aboard unobserved vessels throughout Alaska. Because observer assignment to vessels in the $30 \%$ coverage class is not at random, there is a possibility that this assumption is incorrect.

## Catch history for BSAI Squid and Other Species

Squid are generally taken incidentally in target fisheries for pollock but have been the target of Japanese and Republic of Korea trawl fisheries in the past. Reported catches since 1977 are shown in Table 14- 3. After reaching $9,000 \mathrm{mt}$ in 1978, total squid catches have steadily declined to only a few hundred tons in 1987-95. 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 $85 \%$ in 1992-1998 (NMFS Regional Office, Juneau, AK).

Reported catches of "other species" increased during the 1960's and early 1970's and reached a peak of $133,000 \mathrm{mt}$ in 1972 which was the year when total catches of all species of groundfish reached a maximum of 2.3 million mt . The "other species" catch in 1972 represented $6 \%$ of the total groundfish catch. In 1973-76 catches declined to a range of $33,000-70,000 \mathrm{mt}$ annually as total catches of groundfish also declined. Catches of "other species" were relatively high from 1977-1981
( $43,000-73,000 \mathrm{mt}$ ), but thereafter declined to a range of 5,000-13,000 mt in 1984-89 despite increased catches of total groundfish (Table 14-4). Part of the reason may be incomplete reporting of domestic catches before 1990. Since 1990, catches have ranged between 17,000 and $33,000 \mathrm{mt}$, and represented $2 \%$ or less of the total groundfish catches from the Bering Sea and Aleutian Islands. From 1992-1998, between $90 \%$ and $94 \%$ of the "other species" caught were discarded (NMFS Regional Office, Juneau, AK).
Skates and sculpins constitute the bulk of the other species catches, accounting for between $66-96 \%$ of the estimated totals in 1992-1997. This trend has continued in 1997-2000 (Tables 14-5 through 14-9). While skates are caught in almost all fisheries and areas of the Bering Sea shelf, most of the skate bycatch is in the hook and line fishery for Pacific cod, with trawl fisheries for pollock, rock sole and yellowfin sole also catching significant amounts. Sculpins are also caught by a wide variety of fisheries, but trawl fisheries for yellowfin sole, Pacific cod, pollock, Atka mackerel and rock sole catch the most. Most squid have been caught as bycatch in the midwater trawl pollock fishery primarily over the shelf break and slope or in deep waters of the Aleutian Basin (subareas 515, 517, 519, 521 and 522). Bottom trawl pollock and all three of the fisheries for Pacific cod (pots, longlines and trawls) catch almost all of the octopus bycatch. Octopus catches by groundfish fisheries in the BS/AI estimated using observer bycatch rates ranged between 139-1,017 mt in 1992-96. In addition, there is a small directed fishery for
octopus in the Aleutian Islands and southwestern Bristol Bay regions. Directed octopus landings from 1988-95 have been less than 8 mt per year (Skip Gish, Alaska Department of Fish and Game, Dutch Harbor, pers. comm.). Estimates of shark bycatch in the BS/AI groundfish fisheries from 1992-96 have ranged from 308-702 mt. Most of the shark bycatch occurs in the midwater trawl pollock fishery and in the hook and line fisheries for sablefish, Greenland turbot and Pacific cod along the outer continental shelf and slope of the Bering Sea (subareas 517, 515 and 521). Grenadiers, while not part of the other species category, are a significant bycatch species in the sablefish and turbot longline fisheries on the outer shelf and continental slope regions of the Aleutian Islands and eastern Bering Sea. Total bycatch estimates from 1992-96 have ranged between 2,675 mt (in 1992) and 8,885 (in 1993).

## SURVEY DATA

There is currently no reliable estimate of squid abundance in the eastern Bering Sea. Sobolevsky (1996) cites an estimate of 4 million tons for the entire Bering Sea made by squid biologists at TINRO (Shuntov et al. 1993), and an estimate of 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. It is clear that the AFSC bottom trawl surveys greatly underestimate squid abundance.

Data from AFSC surveys provide the only abundance estimates for the various groups and species comprising the "other species" category (Table 14-10). Biomass estimates for the eastern Bering Sea are from a standard survey area of the continental shelf. The 1979, 1981, 1982, 1985, 1988 and 1991 data include estimates from continental slope waters (200-1,000 m in 1979, 1981, 1982, and 1985; 200-800 m in 1988 and 1991), but data from other years do not. Slope estimates were usually $5 \%$ or less of the shelf estimates, except for grenadiers. Stations as deep as 900 m were sampled in the 1980, 1983 and 1986 Aleutian Islands bottom trawl surveys, while surveys in 1991 and 1994 obtained samples only to a depth of 500 m . The actual catches made by research vessels are shown in Table 14-11.

Biomass estimates from AFSC surveys illustrate that sculpins were the major component of the other species complex until 1986, after which the biomass of skates exceeded that of sculpins. The abundance of skates increased between 1985 and 1990 (when a high of $583,800 \mathrm{mt}$ survey biomass was observed), but has since declined to $354,200 \mathrm{mt}$ in 1998; the abundance of sculpins has remained relatively stable over that time period. Biomass estimates for the "other species" complex as a whole have fluctuated considerably since 1975 , possibly because of changes in availability or vulnerability of the various species to the survey trawls, as well as the depths surveyed. This is particularly evident for smelts, sharks and octopus, which are poorly sampled by demersal trawls; abundance of these groups may be underestimated. Until the 2000 pilot slope survey of the EBS, it was thought that bottom trawl surveys did not adequately sample sharks. However, sleeper sharks were the third highest CPUE on this pilot survey, indicating that they can be sampled by bottom trawls. This recent information suggests that it is the location and timing of the EBS trawl survey on the shelf during the summer, and not the use of bottom trawls for sampling which results in the apparently low biomass estimates for sharks in the EBS shelf (Table 14-10). Changes in distribution of particular species may also account for some of the biomass fluctuation of a group. For instance, a cold water sculpin species, the butterfly sculpin (Hemilepidotus papilio), has been found to intrude into the northern portion of the survey area to a greater extent in some years than others, and accounts for some of the fluctuations in biomass of the sculpin group.

## Catch relative to biomass based on survey estimates

Estimated skate and sculpin bycatch in the BSAI groundfish fisheries has ranged between 1-4\% of their respective survey biomass (Table 14-10) between 1990 and 1996. Harvest rates of octopus (defined as
total removals divided by survey biomass) have ranged between 2-10\% for each of the years from 1990-94. However, in 1995, removals of 977 mt of octopus from the eastern Bering Sea alone represented $35 \%$ of the octopus survey biomass of $2,779 \mathrm{mt}$. Octopus biomass in the eastern Bering Sea and Aleutian Islands regions is believed to be underestimated by the bottom trawl surveys due to undersampling in important nearshore, rocky habitats. Due to the lack of deep stations in eastern Bering Sea trawl surveys after 1985, the best biomass estimates of grenadiers may be from the early 1980s in both the eastern Bering Sea (1982) and Aleutian Islands (1983). If this is the case, current (1992-96) bycatch of grenadiers in the BSAI groundfish fisheries represents between 0.5 and $2 \%$ of the grenadier biomass in the BSAI region (Table 14-10).

## ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Please see 1999 GOA SAFE Appendix E for a description of an experimental modeling approach and its results for GOA other species. An analysis of BSAI other species catch and biomass using this approach will appear in next year's assessment.

## PROJECTIONS AND HARVEST ALTERNATIVES

Because other species are currently taken only as bycatch in directed target fisheries, future catches of other species are more dependent on the distribution and limitations placed on target fisheries than on any harvest level established for this category. For example, changes in the allocation of quota by gear type in a major target fishery (i.e., Pacific cod longline vs. trawl) will result in different proportions and species composition of catches within the other species category. With this in mind, no projections are presented, but options for other species "harvest alternatives" are outlined.

The first option is to continue with the status quo of setting other species ABC and OFL at the complex level, and squid ABC and OFL at the species group level. In this assessment, other species complex and squid ABC are set using Tier 6 criteria as $75 \%$ of the average catch of the complex between 1978-1995, and OFL as average catch over the same period:

The average catch of the other species complex between 1978-1995 is 25,760 metric tons. Therefore, the Tier 6 ABC for the BSAI other species complex in the year 2002 is calculated as 0.75 times the average catch from 1978-1995, or $\mathbf{1 9 , 3 2 0} \mathbf{~ m t}$; the Tier 6 overfishing level for the other species complex in the year 2002 is calculated as the average catch from 1978-1995, or $\mathbf{2 5 , 7 6 0} \mathbf{~ m t}$.

Using the same Tier 6 criteria, the recommended ABC for BSAI squid in the year 2002 is calculated as 0.75 times the average catch from 1978-1995, or $\mathbf{1 , 9 7 0} \mathbf{~ m t}$; the recommended overfishing level for squid in the year 2002 is calculated as the average catch from 1978-1995, or $\mathbf{2 , 6 2 4} \mathbf{~ m t}$. (This recommendation is unchanged from previous assessments.)

While this method results in the lowest possible ABC and OFL for the other species complex as a whole, it should be noted that this option does nothing to prevent the entire catch within the ABC or OFL from comprising a single species group or even a single species within the other species category. This may happen if a directed fishery were to develop. In such a situation it is possible that any OFL that might have been established for that single species (or species group) might be exceeded, especially for less productive stocks.

A second alternative is to attempt to estimate an ABC and OFL for each species group within the other species category, based on the extremely limited information available. Although this option will afford better protection to less productive groups within other species (e.g. sharks and skates), it requires that other species catch be monitored at the species group level instead of the current aggregate level. In addition, application of the tier criteria from FMP amendment 56 is difficult for species groups within other species. Tier 6 criteria for establishing ABC and OFL require a reliable catch history from 1978 to 1995. Although a catch history exists for the other species group as a whole during this period, there are no reliable catch estimates by species group prior to 1990 at present. Therefore, we cannot estimate ABC or OFL based on Tier 6 criteria at the species group level.

Tier 5 criteria require reliable point estimates of biomass and natural mortality rate M. Relatively conservative estimates of M were developed for each species group based on literature values (Table 1412). For certain groups within other species (sharks, cephalopods), our current lack of reliable biomass estimates makes ABC and OFL determination difficult using this method, and potentially results in severe underestimates of allowable catch. Several ABC and OFL options are available using the current tier 5 criteria for each species group within the other species category. Within tier 5, ABCs and OFLs are presented which are based on the most recent biomass estimate, the average biomass from the 1990's, and the average biomass over the entire survey time series for each species group (Table 14-13).

These alternative ABCs and OFLs reflect our current understanding of the basic biology for each species group while protecting the less productive components of the category. In addition, they would allow similar levels of bycatch in target fisheries to those observed since 1990, assuming fishing patterns remain stable. We recognize that these taxonomic categories still contain many ecologically unrelated species with different levels of productivity, so that even within these smaller ABCs there is a possibility of overfishing the least productive individual species. However, we think species group ABCs which result in quota management at the species group level are an improvement over an aggregate TAC for this diverse category.

## Alternative management for components of the Other species complex

Because TAC setting may not be equally effective for all "other species", we suggest alternative management measures which might be applied to some of these groups, depending upon the management objective. For instance, if the management objective is simply to reduce bycatch of a given "other species", management tools such as gear restrictions or area management might be more efficient than TAC management. An example of area management to reduce squid bycatch in the EBS pollock fishery is given in the draft Programmatic SEIS (and included here as an appendix to this assessment). Bycatch of squid is reduced by limiting pelagic trawl fishing within relatively small areas of the shelf break; this has already been demonstrated through the indirect effects of closures related to Stellar sea lions. In 1999 and 2000, the pollock fishery was restricted or removed from one area of historically concentrated squid bycatch and squid catch was cut to less than half that observed in 1997-1998 (Table 14-1). Another option for bycatch reduction is the use of specialized gear. Excluder devices designed to reduce halibut bycatch have also been found to be effective in some configurations at releasing skates from trawl nets before they are captured (Craig Rose, NMFS AFSC, and John Gauvin, Groundfish Forum, personal communication). Other configurations may reduce shark bycatch in trawls. For sharks and skates caught on longlines, it is possible that changes in release methods would improve survival, as has also been shown for halibut.

For more sedentary species, there are also ways to combine catch information with survey information in applying area-specific TACs to achieve individual species management without individual species TACs. While there are several species within each sculpin genus in the EBS, there is reasonably good
geographic separation of these species according to AFSC bottom trawl survey data. It is therefore possible to have only identification to genus in the catch, along with location, and determine which species were in the catch with a reasonable degree of certainty. A sculpin genus-level TAC (e.g. "Irish lords") applied within a given area where species do not overlap would then be species specific. This might result in fewer area-specific group TACs to manage as opposed to many area-wide species TACs to track. It may also be possible to apply this type of area-specific TAC at the assemblage level, and estimate which species are in the assemblage using survey data. These management measures may be incorporated into these plan amendments or developed in future amendments.

## OTHER CONSIDERATIONS

Understanding other species population dynamics is fundamental to describing ecosystem structure and function in Alaska, because each group in other species plays an important ecological role. The species groups in this category occupy all marine habitats from pelagic to benthic, nearshore to open ocean, and shallow to slope waters. Sharks are top predators, so fluctuations in their populations may have significant effects on community structure. Squid and octopus are highly productive, voracious predators which are in turn important prey for commercially important groundfish, sharks, and marine mammals. Smelts and other forage fishes are essential components in the diets of marine mammals, seabirds, and commercially important groundfish. Sculpins and skates are important benthic predators, and sculpins serve as prey for many groundfish species. Grenadiers, while not included in the other species category, may be the dominant fish in deeper habitats. They are caught in sufficient numbers to warrant additional attention, especially because they may be very long lived species (Andrews et al., 1999).

## SUMMARY

Catches of other species have been very small compared to those of target species in Alaska. However, it should be clear from this assessment that data limitations are severe, and that further investigation is necessary to be sure that all components of other species are not adversely affected by groundfish fisheries. Furthermore, if target fisheries develop for any component of the other species group, effective management will be extremely difficult with the current limited information. Regardless of management decisions regarding TAC and the future structure for other species, it is essential that we continue to improve species identification, survey sampling, and biological data collection for the species in this group if we hope to ensure their continued conservation.

## ACKNOWLEDGMENTS

We gratefully acknowledge Gary Walters' timely and efficient work in estimating biomass and variance of biomass for each other species group from all Eastern Bering Sea trawl surveys back to 1975, including the historical slope surveys. Likewise, Mark Wilkins kindly provided species specific and group specific "biomass estimates" from the pilot Bering Sea slope survey conducted in 2000. Jerry Hoff provided references on sculpin species. Ken Goldman (VIMS) provided information and references on shark species. Jay Orr and Jerry Hoff edited species lists from racebase and provided insights into the difficulties of species identification. Sheryl Corey and Jennifer Ferdinand clarified past and current observer training procedures.

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## TABLES

Table 14-1. Other species and squids in the Bering Sea-Aleutian Islands, by scientific and common name; compiled from the AFSC survey database RACEBASE. This list should be considered preliminary.

BSAI Other Category
115 species codes

| Scientific name | Common name shark unident. |
| :---: | :---: |
| Lamna ditropis | salmon shark |
| Squalus acanthias | spiny dogfish |
| Somniosus pacificus | Pacific sleeper shark |
| Rajidae unident. | skate unident. <br> skate egg case unident. |
| Bathyraja sp. egg case |  |
| Raja sp. |  |
| Bathyraja sp. |  |
| Bathyraja spinosissima | white skate |
| Bathyraja abyssicola | deepsea skate |
| Raja binoculata | big skate |
| Bathyraja interrupta | Bering skate |
| Raja rhina | longnose skate |
| Raja stellulata | starry skate |
| Bathyraja taranetzi (=Rhinoraja longii) | mud skate |
| Bathyraja trachura | black skate |
| Bathyraja parmifera | Alaska skate |
| Bathyraja aleutica | Aleutian skate |
| Bathyraja lindbergi | commander skate |
| Bathyraja maculata | whiteblotched skate |
| Bathyraja minispinosa | whitebrow skate |
| Bathyraja smirnovi | golden skate |
| Bathyraja violacea | Okhotsk skate |
| Cottidae | sculpin unident. |
| Zesticelus profundorum | flabby sculpin |
| Thyriscus anoplus | sponge sculpin |
| Icelinus borealis | northern sculpin |
| Icelinus tenuis | spotfin sculpin |
| Gymnocanthus sp. |  |
| Gymnocanthus pistilliger | threaded sculpin |
| Gymnocanthus tricuspis | Arctic staghorn sculpin |
| Gymnocanthus galeatus | armorhead sculpin |
| Radulinus asprellus | slim sculpin |
| Clinocottus acuticeps | sharpnose sculpin |
| Gymnocanthus detrisus |  |
| Artediellus sp. |  |
| Artediellus miacanthus | bride sculpin |
| Artediellus pacificus | Pacific hookear sculpin |
| Artediellus scaber | hamecon |
| Artediellus uncinatus | Arctic hookear sculpin |
| Bolinia euryptera |  |
| Malacocottus sp. |  |
| Malacocottus kincaidi | blackfin sculpin |

Table 14-1 Continued BSAI Other Category

## Scientific name

Malacocottus zonurus
Hemilepidotus sp.
Hemilepidotus gilberti
Hemilepidotus spinosus
Hemilepidotus zapus
Hemilepidotus hemilepidotus
Hemilepidotus jordani
Hemilepidotus papilio
Archistes plumarius
Triglops sp.
Triglops forficata
Triglops metopias
Triglops scepticus
Triglops pingeli
Triglops macellus
Microcottus sellaris
Myoxocephalus verrucosus
Myoxocephalus niger
Myoxocephalus polyacanthocephalus
Myoxocephalus jaok
Myoxocephalus stelleri
Myoxocephalus sp.
Megalocottus platycephalus
Myoxocephalus quadricornis
Myoxocephalus scorpioides
Leptocottus armatus
Gilbertidia sigalutes
Enophrys sp.
Enophrys bison
Enophrys lucasi
Enophrys diceraus
Dasycottus setiger
Psychrolutes sp.
Psychrolutes paradoxus
Psychrolutes phrictus
Blepsias bilobus
Nautichthys pribilovius
Nautichthys oculofasciatus
Nautichthys robustus
Hemitripterus bolini
Hemitripterus villosus
Eurymen gyrinus
Triglops xenostethus
Icelus spiniger
Icelus canaliculatus
Icelus euryops
Icelus spatula
Icelus uncinalis
Rastrinus scutiger
Jordania zonope
Icelus sp.

## Common name

darkfin sculpin
Irish lord
banded Irish lord brown Irish lord longfin Irish lord red Irish lord yellow Irish lord butterfly sculpin
scissortail sculpin crescent-tail sculpin spectacled sculpin ribbed sculpin roughspine sculpin brightbelly sculpin warty sculpin warthead sculpin great sculpin plain sculpin frog sculpin
belligerent sculpin fourhorn sculpin Arctic sculpin Pacific staghorn sculpin soft sculpin
buffalo sculpin
leister sculpin
antlered sculpin
spinyhead sculpin
tadpole sculpin
blob sculpin
crested sculpin
eyeshade sculpin sailfin sculpin shortmast sculpin bigmouth sculpin sea raven
smoothcheek sculpin
thorny sculpin
porehead sculpin
spatulate sculpin
uncinate sculpin
roughskin sculpin
longfin sculpin

## Table 14-1 Continued BSAI Other Category

Scientific name
Paricelinus hopliticus
Cephalopoda unident.

Octopus leioderma
Opisthoteuthis californiana
Octopus dofleini
Benthoctopus sp.
Vampyroteuthis infernalis

Rossia pacifica
Loligo opalescens
Gonatus sp.
Gonatus onyx
Berryteuthis magister
Gonatopsis sp.
Gonatopsis borealis
Moroteuthis robusta
Taonius pavo

Common name
thornback sculpin
cephalopod unident. cuttlefish unident.
octopus unident. pelagic octopus unident. smoothskin octopus flapjack devilfish giant octopus
squid unident.
eastern Pacific bobtail
California market squid
clawed armhook squid magistrate armhook squid
boreopacific armhook squid
robust clubhook squid

Table 14-2. Life history information available for BSAI and GOA skate species.

| Species | Common | Max <br> Length (cm) ${ }^{1}$ | $\begin{gathered} \text { Max } \\ \text { Age } \end{gathered}$ |  | Feeding mode ${ }^{3}$ | $\begin{gathered} \text { n/ } \\ \text { egg }_{\text {case }}{ }^{1} \end{gathered}$ | Depth range (m) ${ }^{4}$ | $\begin{gathered} \text { Est. } \\ \text { of } \\ \text { M } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Raja <br> binoculata | big skate | 180-240 | ? | $\begin{gathered} 8-12 \mathrm{yrs} \\ 109-130 \mathrm{~cm} \end{gathered}$ | predatory ${ }^{1}$ | 1-7 | $3-800^{5}$ | 0.10 |
| Raja rhina | longnose skate | 137 | ? | $\begin{gathered} 7-10 \mathrm{yrs} \\ 74-100 \mathrm{~cm} \end{gathered}$ | ? | 1 | 25-675 ${ }^{5}$ | 0.10 |
| Bathyraja interrupta | Bering skate | 86 | ? | ? | benthophagic | 1 | 50-1380 | 0.10 |
| Bathyraja tanaretzi | mud skate | 70* | ? | ? | ? | 1 |  | 0.10 |
| Bathyraja trachura | black skate | 89 | ? | ? | ? | 1 | 800-2050 | 0.10 |
| Bathyraja parmifera | Alaska skate | $\begin{aligned} & \text { 61-91, } \\ & \text { 113* } \end{aligned}$ | ? | ? | predatory | 1 | 25-300 | 0.10 |
| Bathyraja aleutica | Aleutian skate | 120-150 | ? | ? | predatory | 1 | 300-950 | 0.10 |
| Bathyraja lindberghi | commander skate | 93* | ? | ? | ? | 1 | 175-950 | 0.10 |
| Bathyraja maculata | whiteblotched skate | 120* | ? | ? | predatory | 1 | 175-550 | 0.10 |
| Bathyraja minispinosa | whitebrow <br> skate | 82* | ? | ? | benthophagic | 1 | 100-1400 | 0.10 |
| Bathyraja violacea | Okhotsk skate | 150* | ? | ? | benthophagic | 1 | 25-500 | 0.10 |

${ }^{1}$ Eschemeyer, 1983 (assuming that B. kincaidii = B. interrupta) and *species id notes by Jay Orr (AFSC)
${ }^{2}$ Zeiner and Wolf, 1993.
${ }^{3}$ Orlov, 1998 \& 1999 (benthophagic eats mainly amphipods, worms. Predatory diet primarily fish, cephalopods)
${ }^{4}$ McEachran and Miyake, 1990b
${ }^{5}$ Allen and Smith, 1988

Table 14- 3. Estimated total (retained and discarded) catches of squid (mt) in the eastern Bering Sea and Aleutian Islands by groundfish fisheries, 1977-2001. JV=Joint ventures between domestic catcher boats and foreign processors.

| Year | Eastern Bering Sea |  |  |  | Aleutian Islands |  |  |  | Grand Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Foreign | JV | Domestic | Total | Foreign | JV | Domestic | Total |  |
| 1977 | 4,926 |  |  | 4,926 | 1,808 |  |  | 1,808 | 6,734 |
| 1978 | 6,886 |  |  | 6,886 | 2,085 |  |  | 2,085 | 8,971 |
| 1979 | 4,286 |  |  | 4,286 | 2,252 |  |  | 2,252 | 6,538 |
| 1980 | 4,040 |  |  | 4,040 | 2,332 |  |  | 2,332 | 6,372 |
| 1981 | 4,178 | 4 |  | 4,182 | 1,763 |  |  | 1,763 | 5,945 |
| 1982 | 3,833 | 5 |  | 3,838 | 1,201 |  |  | 1,201 | 5,039 |
| 1983 | 3,461 | 9 |  | 3,470 | 509 | 1 |  | 510 | 3,980 |
| 1984 | 2,797 | 27 |  | 2,824 | 336 | 7 |  | 343 | 3,167 |
| 1985 | 1,583 | 28 |  | 1,611 | 5 | 4 |  | 9 | 1,620 |
| 1986 | 829 | 19 |  | 848 | 1 | 19 |  | 20 | 868 |
| 1987 | 96 | 12 | 1 | 109 |  | 23 | 1 | 24 | 131 |
| 1988 |  | 168 | 246 | 414 |  | 3 |  | 3 | 417 |
| 1989 |  | 106 | 194 | 300 |  | 1 | 5 | 6 | 306 |
| 1990 |  |  | 532 | 532 |  |  | 94 | 94 | 626 |
| 1991 |  |  | 544 | 544 |  |  | 88 | 88 | 632 |
| 1992 |  |  | 819 | 819 |  |  | 61 | 61 | 880 |
| 1993 |  |  | 611 | 611 |  |  | 72 | 72 | 683 |
| 1994 |  |  | 517 | 517 |  |  | 87 | 87 | 604 |
| 1995 |  |  | 364 | 364 |  |  | 95 | 95 | 459 |
| 1996 |  |  | 1,083 | 1,083 |  |  | 84 | 84 | 1,167 |
| 1997 |  |  | 1,403 | 1,403 |  |  | 71 | 71 | 1,474 |
| 1998 |  |  | 891 | 891 |  |  | 25 | 25 | 915 |
| 1999 |  |  |  |  |  |  |  |  | 411 |
| 2000 |  |  |  |  |  |  |  |  | 333 |
| 2001* |  |  |  |  |  |  |  |  | 1,400 |

*2001 catch reported through October 6, 2001.
Data Sources: Foreign and JV catches-U.S. Foreign Fisheries Observer Program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, BIN C15700, Bld.4, 7600 Sand Point Way NE, Seattle, WA 98115. Domestic catches before 1989 (retained only; do not include discards): Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Portland, OR 97201. Domestic catches since 1989: NMFS Regional Office BLEND database, Juneau, AK 99801.

Table 14-4. Estimated total (retained and discarded) catches of other species (mt) in the eastern Bering Sea and Aleutian Islands by groundfish fisheries, 1977-2001. JV=Joint ventures between domestic catcher boats and foreign processors. Estimated catches of other species from 1977-98 include smelts.

| Year | Eastern Bering Sea |  |  |  | Aleutian Islands |  |  |  | Grand <br> Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Foreign | JV | Domestic | Total | Foreign | JV | Domestic | Total |  |
| 1977 | 35,902 |  |  | 35,902 | 16,170 |  |  | 16,170 | 52,072 |
| 1978 | 61,537 |  |  | 61,537 | 12,436 |  |  | 12,436 | 73,973 |
| 1979 | 38,767 |  |  | 38,767 | 12,934 |  |  | 12,934 | 51,701 |
| 1980 | 33,955 | 678 |  | 34,633 | 13,028 |  |  | 13,028 | 47,661 |
| 1981 | 32,363 | 3,138 | 100 | 35,651 | 7,028 | 246 |  | 7,274 | 42,925 |
| 1982 | 17,480 | 720 |  | 18,200 | 4,781 | 386 |  | 5,167 | 23,367 |
| 1983 | 11,062 | 1,139 | 3,264 | 15,465 | 3,193 | 439 | 43 | 3,675 | 19,140 |
| 1984 | 7,349 | 1,159 |  | 8,508 | 184 | 1,486 |  | 1,670 | 10,178 |
| 1985 | 6,243 | 4,365 | 895 | 11,503 | 40 | 1,978 | 32 | 2,050 | 13,553 |
| 1986 | 4,043 | 6,115 | 313 | 10,471 | 1 | 1,442 | 66 | 1,509 | 11,980 |
| 1987 | 2,673 | 4,977 | 919 | 8,569 |  | 1,144 | 11 | 1,155 | 9,724 |
| 1988 |  | 11,559 | 647 | 12,206 |  | 281 | 156 | 437 | 12,643 |
| 1989 |  | 4,695 | 298 | 4,993 |  | 1 | 107 | 108 | 5,101 |
| 1990 |  |  | 16,115 | 16,115 |  |  | 4,693 | 4,693 | 20,808 |
| 1991 |  |  | 16,261 | 16,261 |  |  | 938 | 938 | 17,199 |
| 1992 |  |  | 29,994 | 29,994 |  |  | 3,081 | 3,081 | 33,075 |
| 1993 |  |  | 20,574 | 20,574 |  |  | 3,277 | 3,277 | 23,851 |
| 1994 |  |  | 23,456 | 23,456 |  |  | 1,099 | 1,099 | 24,555 |
| 1995 |  |  | 20,923 | 20,923 |  |  | 1,290 | 1,290 | 22,213 |
| 1996 |  |  | 19,733 | 19,733 |  |  | 1,706 | 1,706 | 21,440 |
| 1997 |  |  | 23,656 | 23,656 |  |  | 1,520 | 1,520 | 25,176 |
| 1998 |  |  | 23,077 | 23,077 |  |  | 2,455 | 2,455 | 25,531 |
| 1999 |  |  |  |  |  |  |  |  | 20,584 |
| 2000 |  |  |  |  |  |  |  |  | 24,030 |
| 2001* |  |  |  |  |  |  |  |  | 18,955 |

*2001 catch reported through October 6, 2001.
Data Sources: Foreign and JV catches-U.S. Foreign Fisheries Observer Program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, BIN C15700, Bld.4, 7600 Sand Point Way NE, Seattle, WA 98115. Domestic catches before 1989 (retained only; do not include discards): Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Portland, OR 97201. Domestic catches since 1989: NMFS Regional Office BLEND database, Juneau, AK 99801.

Table 14-5. Estimated total catch ( t ) of non-target species groups by FMP category and area, 1997-2000. Source: NORPAC observer database and year-end estimates of target species catch from the NMFS Regional Office BLEND database (see text for estimation methods).

| Species group | BSAI |  |  |  | GOA |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 |
| Other squid | 1573.4 | 1255.8 | 501.8 | 412.9 | 97.5 | 59.2 | 40.7 | 18.6 |
| skates | 17747.4 | 19317.9 | 14079.8 | 18876.5 | 3119.8 | 4476.2 | 2000.4 | 3238.4 |
| sculpin | 7477.8 | 6285.5 | 5470.0 | 7086.5 | 906.6 | 540.8 | 544.4 | 943.0 |
| dogfish | 4.1 | 6.4 | 5.0 | 8.9 | 657.5 | 864.9 | 313.6 | 397.6 |
| salmon shark | 6.8 | 18.0 | 30.0 | 23.3 | 123.8 | 71.0 | 131.6 | 37.8 |
| sleeper shark | 304.1 | 336.0 | 318.7 | 490.4 | 135.9 | 74.0 | 557.7 | 608.2 |
| unid shark | 52.8 | 136.1 | 176.4 | 67.6 | 123.5 | 1379.9 | 33.0 | 73.6 |
| octopus | 248.4 | 189.7 | 326.1 | 418.1 | 232.2 | 112.0 | 166.3 | 175.9 |
| Other Total | 27414.7 | 27545.3 | 20907.7 | 27384.3 | 5396.7 | 7577.9 | 3787.6 | 5493.3 |
| Forage smelts | 29.8 | 36.6 | 45.3 | 51.7 | 23.1 | 122.7 | 26.1 | 123.8 |
| sandfish | 1.1 | 0.4 | 3.3 | 20.3 | 3.7 | 2.2 | 0.5 | 0.3 |
| sticheidae | 0.4 | 0.2 | 0.0 | 0.1 | 0.3 | 0.0 | 3.5 | 0.5 |
| lanternfish | 0.4 | 0.4 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| sandlance | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 |
| gunnel | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| Forage Total | 31.8 | 37.6 | 48.7 | 72.2 | 27.2 | 125.0 | 30.2 | 124.9 |
| Non-specified grenadier | 5851.6 | 6589.0 | 7388.2 | 7320.9 | 12029.4 | 14683.1 | 11387.7 | 11610.0 |
| otherfish | 1569.2 | 1362.7 | 1327.3 | 1458.2 | 575.9 | 8400.3 | 819.0 | 979.3 |
| jellyfish | 8849.2 | 7147.5 | 7153.3 | 10491.2 | 36.0 | 166.6 | 107.2 | 37.9 |
| starfish | 6191.0 | 3287.2 | 3051.5 | 3174.0 | 987.1 | 1244.5 | 1510.4 | 894.2 |
| invert unid | 1608.6 | 638.3 | 140.1 | 1121.4 | 8.1 | 42.9 | 1.3 | 15.2 |
| tunicate | 1793.7 | 728.1 | 372.0 | 1055.7 | 1.6 | 1.2 | 0.0 | 3.6 |
| sponge | 530.1 | 500.8 | 321.8 | 164.9 | 3.6 | 3.7 | 12.9 | 4.3 |
| benthic invert | 672.7 | 531.4 | 226.4 | 366.0 | 24.6 | 31.3 | 25.2 | 10.3 |
| crabs | 303.8 | 185.9 | 108.9 | 142.7 | 15.4 | 25.1 | 10.9 | 12.4 |
| anemone | 183.0 | 113.7 | 171.5 | 347.2 | 17.6 | 15.7 | 17.4 | 16.2 |
| echinoderms | 44.9 | 24.3 | 30.3 | 42.4 | 22.5 | 32.4 | 8.5 | 7.0 |
| birds | 28.7 | 43.5 | 24.4 | 27.0 | 2.0 | 5.6 | 6.4 | 3.3 |
| coral | 38.9 | 27.7 | 52.5 | 43.1 | 4.1 | 7.9 | 1.2 | 10.2 |
| seapen/whip | 2.6 | 2.4 | 5.0 | 5.0 | 0.6 | 2.9 | 2.7 | 0.9 |
| shrimp | 2.7 | 1.7 | 1.2 | 3.7 | 3.7 | 2.3 | 0.6 | 1.4 |
| Non-specified Total | 27670.5 | 21184.2 | 20374.4 | 25763.5 | 13732.4 | 24665.4 | 13911.4 | 13606.2 |
| Grand Total | 55117.0 | 48767.1 | 41330.7 | 53220.0 | 19156.2 | 32368.3 | 17729.2 | 19224.4 |

Table 14-6. 1997 BSAI Squid and Other species and grenadier catches $(\mathrm{t})$ by fishery and gear ( $1=$ bottom trawl, $2=$ pelagic trawl, $6=$ pot, $8=$ longline).

| Year | Area | Target fishery | Gear | Squid | Skates | Sculpins | Shark unid | Salmon shark | $\begin{gathered} \text { Dogfis } \\ \text { h } \end{gathered}$ | Sleeper shark | Octopus | Grenadier |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1997 |  | Atka mackerel | 1 | 15.82 | 110.51 | 290.39 | 0 | 0.14 | 0 | 0 | 1.20 | 9.80 |
|  |  | Pacific cod | 1 | 1.06 | 36.89 | 107.27 | 0 | 0 | 0 | 0 | 2.19 | 0 |
|  |  |  | 6 | 0 | 0 | 7.30 | 0 | 0 | 0 | 0 | 24.14 | 0 |
|  |  |  | 8 | 0 | 338.07 | 333.96 | 0.11 | 0 | 0.10 | 0 | 10.39 | 396.74 |
|  | Pacific cod Total Pollock |  |  | 1.07 | 374.95 | 448.53 | 0.11 | 0 | 0.11 | 0 | 36.72 | 396.74 |
|  |  |  | 1 | 6.07 | 1.64 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0.33 |
|  |  |  | 2 | 45.51 | 0.03 | 0.05 | 0.03 | 0.07 | 0 | 0.06 | 0.06 | 16.23 |
|  | Pollock Total Rockfish |  |  | 51.57 | 1.68 | 0.08 | 0.03 | 0.07 | 0 | 0.06 | 0.06 | 16.57 |
|  |  |  | 1 | 6.52 | 30.05 | 31.61 | 0 | 0 | 0 | 0 | 0.36 | 149.45 |
|  |  |  | 8 | 0 | 108.88 | 0.09 | 0 | 0 | 0 | 0.87 | 0.37 | 231.43 |
|  | Rockfish Total |  |  | 6.52 | 138.93 | 31.70 | 0 | 0 | 0 | 0.87 | 0.73 | 380.88 |
|  | Sablefish |  | 8 | 0 | 231.07 | 0.32 | 0 | 0 | 0 | 26.87 | 0.12 | 2,083.48 |
|  | $\begin{array}{r} \text { AI } \\ \text { Total } \\ \hline \end{array}$ |  |  | 74.99 | 857.15 | 771.03 | 0.14 | 0.21 | 0.11 | 27.79 | 38.83 | 2,887.46 |
|  | BS Flatfish |  | 1 | 1.36 | 2,708.07 | 4,014.53 | 0.40 | 0 | 0 | 0.94 | 85.52 | 4.05 |
|  |  |  | 2 | 0 | 0.14 | 11.45 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | Flatfish Total Pacific cod |  |  | 1.36 | 2,708.21 | 4,025.98 | 0.40 | 0 | 0 | 0.94 | 85.52 | 4.05 |
|  |  |  | 1 | 6.78 | 678.22 | 1,505.94 | 0.19 | 0 | 0 | 7.90 | 29.00 | 0.73 |
|  |  |  | 2 | 0 | 0.12 | 2.36 | 0 | 0 | 0 | 0 | 0 | 0 |
|  |  |  | 6 | 0 | 1.50 | 351.25 | 0 | 0 | 0 | 0 | 79.34 | 0.07 |
|  |  |  | 8 | 0 | 12,960.74 | 705.96 | 26.53 | 0 | 3.97 | 66.88 | 14.54 | 437.37 |
|  | Pacific cod TotalPollock |  |  | 6.78 | 13,640.58 | 2,565.52 | 26.72 | 0 | 3.97 | 74.78 | 122.88 | 438.17 |
|  |  |  | 1 | 27.38 | 37.45 | 29.20 | 0.02 | 1.36 | 0 | 15.14 | 0 | 0 |
|  |  |  | 2 | 1,459.25 | 310.60 | 79.70 | 15.54 | 5.25 | 0 | 89.99 | 1.01 | 19.66 |
|  | Pollock Total |  |  | 1,486.63 | 348.05 | 108.90 | 15.56 | 6.61 | 0 | 105.13 | 1.01 | 19.66 |
|  | Rockfish |  | 8 | 0 | 1.39 | 0 | 2.48 | 0 | 0 | 0 | 0 | 0.21 |
|  | Sablefish |  | 8 | 0 | 34.93 | 1.30 | 1.16 | 0 | 0 | 18.43 | 0.03 | 225.68 |
|  | Turbot |  | 1 | 3.65 | 16.13 | 3.20 | 0 | 0 | 0 | 6.48 | 0.04 | 49.18 |
|  |  |  | 8 | 0 | 140.82 | 0.61 | 6.30 | 0 | 0.02 | 70.51 | 0.04 | 2,227.12 |
|  | Turbot Total |  |  | 3.65 | 156.95 | 3.81 | 6.30 | 0 | 0.02 | 76.99 | 0.08 | 2,276.30 |
|  | Unknown |  | 1 | 0 | 0 | 0.32 | 0 | 0 | 0 | 0 | 0 | 0 |
|  |  |  | 8 | 0 | 0.11 | 0.98 | 0 | 0 | 0 | 0 | 0.02 | 0.02 |
|  | Unknown Total |  |  | 0 | 0.11 | 1.30 | 0 | 0 | 0 | 0 | 0.02 | 0.02 |
|  | $\begin{array}{r} \text { BS } \\ \text { Total } \end{array}$ |  | 1,498.41 |  | 16,890.22 | 6,706.81 | 52.62 | 6.61 | 3.99 | 276.28 | 209.54 | 2,964.09 |
| $\begin{aligned} & \hline 1997 \\ & \text { Total } \end{aligned}$ | BSAI |  |  | 1,573.40 | 17,747.37 | 7,477.84 | 52.77 | 6.82 | 4.09 | 304.07 | 248.37 | 5,851.55 |

Table 14-7. 1998 BSAI Squid and Other species and grenadier catches $(\mathrm{t})$ by fishery and gear ( $1=$ bottom trawl, $2=$ pelagic trawl, $6=$ pot, $8=$ longline).


Table 14-8. 1999 BSAI Squid and Other species and grenadier catches $(\mathrm{t})$ by fishery and gear ( $1=$ bottom trawl, $2=$ pelagic trawl, $6=$ pot, $8=$ longline).


Table 14-9. 2000 BSAI Squid and Other species and grenadier catches $(\mathrm{t})$ by fishery and gear ( $1=$ bottom trawl, $2=$ pelagic trawl, $6=$ pot, $8=$ longline).


Table 14-10. Estimated biomass ( t ) of BSAI squid and other species from various AFSC surveys.

| EBS shelf survey biomass estimates |  |  |  |  | EBS slope survey biomass estimates |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Year | Sharks | Skates | Sculpins | Octopi | Year | Sharks | Skates | Sculpins | Octopi |
| 1975 | 0 | 24,349 | 111,160 | 6,129 |  |  |  |  |  |
| 1976 |  |  |  |  |  |  |  |  |  |
| 1977 |  |  |  |  |  |  |  |  |  |
| 1978 |  |  |  |  |  |  |  |  |  |
| 1979 | 692 | 58,147 | 284,228 | 30,815 | 1979 | 0 | 3,056 | 4,555 | 729 |
| 1980 |  |  |  |  |  |  |  |  |  |
| 1981 |  |  |  |  | 1981 | 1 | 2,743 | 5,372 | 234 |
| 1982 | 0 | 164,084 | 340,877 | 12,442 | 1982 | 23 | 2,723 | 3,261 | 180 |
| 1983 | 379 | 161,041 | 292,025 | 3,280 |  |  |  |  |  |
| 1984 | 0 | 186,980 | 252,259 | 2,488 |  |  |  |  |  |
| 1985 | 47 | 149,576 | 182,469 | 2,582 | 1985 | 314 | 3,329 | 2,316 | 152 |
| 1986 | 0 | 251,321 | 303,671 | 480 |  |  |  |  |  |
| 1987 | 223 | 346,691 | 195,501 | 7,834 |  |  |  |  |  |
| 1988 | 4,058 | 409,076 | 233,169 | 9,846 | 1988 | 1,967 | 3,271 | 4,944 | 138 |
| 1989 | 0 | 410,119 | 215,666 | 4,979 |  |  |  |  |  |
| 1990 | 0 | 534,556 | 219,020 | 11,564 |  |  |  |  |  |
| 1991 | 0 | 448,458 | 272,653 | 7,990 | 1991 | 2,635 | 4,031 | 2,449 | 61 |
| 1992 | 2,564 | 390,466 | 239,947 | 5,326 |  |  |  |  |  |
| 1993 | 0 | 375,040 | 215,922 | 1,355 |  |  |  |  |  |
| 1994 | 5,012 | 414,235 | 260,994 | 2,183 |  |  |  |  |  |
| 1995 | 1,005 | 391,768 | 218,693 | 2,779 |  |  |  |  |  |
| 1996 | 2,804 | 423,913 | 187,817 | 1,746 |  |  |  |  |  |
| 1997 | 37 | 393,716 | 215,766 | 211 |  |  |  |  |  |
| 1998 | 2,378 | 354,188 | 197,675 | 1,225 |  |  |  |  |  |
| 1999 | 2,079 | 370,543 | 146,185 | 832 |  |  |  |  |  |
| 2000 | 1,487 | 325,292 | 161,350 | 2,041 | 2000 | pilot surv | no officia | l biomass | mate |
| 2001 | 0 | 419,508 | 143,368 | 5,357 |  |  |  |  |  |

## AI trawl survey estimates

| Year | Sharks | Skates | Sculpins | Octopi | Squid | Grenadiers |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| 1980 | 800 | 10,123 | 33,624 | 757 | 16,461 | 322,409 |
| 1983 | 0 | 16,259 | 24,570 | 440 | 20,786 | 364,110 |
| 1986 | 0 | 19,491 | 32,211 | 781 | 25,982 | 618,102 |
| 1991 | 2,927 | 14,987 | 15,904 | 1,148 | 28,935 | 24,597 |
| 1994 | 421 | 24,964 | 17,192 | 1,728 | 11,082 | 33,669 |
| 1997 | 2,497 | 28,902 | 13,680 | 1,219 | 2,677 | 71,505 |
| 2000 | 2,663 | 29,206 | 13,037 | 775 | 2,675 | 219,694 |

Table 14-11. Research catches of squid and other species in the BSAI, 1977-1998 (tons).


Table 14-12. Published annual natural mortality (M) estimates for other species groups

| group | species | estimate | reference |
| :--- | :--- | :--- | :--- |
| squid | Todarodes pacificus | 0.4308 | Osako and Murata, 1983 |
| octopus | Octopus vulgaris | 0.5 | Sato and Hatanaka, 1983 |
| smelt | Mallotus villosus | 0.42 | Anderson, 1990 |
| sculpin |  |  | none found |
| skate | Raja erinacea | 0.4 | Sosebee, 1998 |
| shark | Squalus acanthias | 0.094 | Anderson, 1990 |
|  | Lamna nasus | 0.09 | Sosebee, 1998 |
|  |  | 0.18 | Anderson, 1990 |

Table 14-13. Potential BSAI ABC and OFL by species group for "other species" and grenadiers. (Squid would remain the same as at present, for now; we plan to add model estimated biomass as an additional option for ABC OFL estimation in the BSAI in next year's assessment).

EBS estimated group ABCs based on Tier 5 criteria

|  | Sculpins | Skates | Sharks | Octopi | Grenadiers |
| :--- | ---: | ---: | ---: | ---: | ---: |
| group estimate of M | 0.15 | 0.1 | 0.09 | 0.3 | 0.07 |
| biomass avg all years | 232,461 | 316,405 | 1,207 | 7,350 | 82,300 |
| ABC avg all | $\mathbf{2 6 , 1 5 2}$ | $\mathbf{2 3 , 7 3 0}$ | $\mathbf{8 1}$ | $\mathbf{1 , 6 5 4}$ | $\mathbf{4 , 3 2 1}$ |
| OFL avg all | $\mathbf{3 4 , 8 6 9}$ | $\mathbf{3 1 , 6 4 0}$ | $\mathbf{1 0 9}$ | $\mathbf{2 , 2 0 5}$ | $\mathbf{5 , 7 6 1}$ |
| biomass avg 90s | 211,859 | 407,036 | 1,782 | 3,391 | 38100 |
|  |  |  |  |  |  |
| ABC avg 90s | $\mathbf{2 3 , 8 3 4}$ | $\mathbf{3 0 , 5 2 8}$ | $\mathbf{1 2 0}$ | $\mathbf{7 6 3}$ | $\mathbf{2 , 0 0 0}$ |
| OFL avg 90s | $\mathbf{3 1 , 7 7 9}$ | $\mathbf{4 0 , 7 0 4}$ | $\mathbf{1 6 0}$ | $\mathbf{1 , 0 1 7}$ | $\mathbf{2 , 6 6 7}$ |
|  |  |  |  |  |  |
| most recent biomass | 161,350 | 325,500 | 1,500 | 2,000 |  |
| ABC most recent | $\mathbf{1 8 , 1 5 2}$ | $\mathbf{2 4 , 4 1 3}$ | $\mathbf{1 0 1}$ | $\mathbf{4 5 0}$ |  |
| OFL most recent | $\mathbf{2 4 , 2 0 3}$ | $\mathbf{3 2 , 5 5 0}$ | $\mathbf{1 3 5}$ | $\mathbf{6 0 0}$ |  |

AI estimated group ABCs based on the same Tier 5 criteria

|  | Sculpins | Skates | Sharks | Octopi | Grenadiers |
| :--- | ---: | ---: | ---: | ---: | ---: |
| group estimate of M | 0.15 | 0.1 | 0.09 | 0.3 | 0.07 |
| biomass avg all years | 21,457 | 20,557 | 1,271 | 857 | 434,867 |
| ABC avg all |  |  |  |  |  |
| OFL avg all | $\mathbf{2 , 4 1 4}$ | $\mathbf{1 , 5 4 2}$ | $\mathbf{8 6}$ | $\mathbf{1 9 3}$ | $\mathbf{2 2 , 8 3 1}$ |
| biomass avg 90s | 14,950 | 24,500 | 2,025 | 1,200 |  |
| ABC avg 90s |  |  |  |  |  |
| OFL avg 90s | $\mathbf{1 , 6 8 2}$ | $\mathbf{1 , 8 3 8}$ | $\mathbf{1 3 7}$ | $\mathbf{2 7 0}$ |  |
| most recent biomass | 13,000 | 29,100 | 2,300 | 800 |  |
| ABC most recent | $\mathbf{1 , 4 6 3}$ | $\mathbf{2 , 1 8 3}$ | $\mathbf{1 5 5}$ | $\mathbf{1 8 0}$ |  |
| OFL most recent | $\mathbf{1 , 9 5 0}$ | $\mathbf{2 , 9 1 0}$ | $\mathbf{2 0 7}$ | $\mathbf{2 4 0}$ |  |

APPENDIX: Example of spatial management of squid bycatch if the management goal is a $75 \%$ reduction in squid bycatch from current levels. Note that this case study was developed for the draft programmatic SEIS (January 2001) to illustrate management of squid catch if nontarget species bycatch reduction were prioritized over all other management goals; obviously this example would be modified when all management priorities were considered.

### 4.1.3.3.3 Squids

What are squids? Which species are found in the FMP areas?
Squids (order Teuthoidea) are cephalopod molluscs which are related to octopus. Squids are considered highly specialized and organized molluscs, with only a vestigal mollusc shell remaining as an internal plate called the pen or gladius. They are streamlined animals with ten appendages ( 2 tentacles, 8 arms) extending from the head, and lateral fins extending from the rear of the mantle (Figure 4.1.3.3.3-1).
Squids are active predators which swim by jet propulsion, reaching swimming speeds of up to $40 \mathrm{~km} / \mathrm{hr}$, the fastest of any aquatic invertebrate. Members of this order (Archeteuthis spp.) also hold the record for largest size of any invertebrate (Barnes 1987).


Figure 4.5.8 The magistrate armhook squid, Berryteuthis magister.

The 18 squid species found in the mesopelagic regions of the Bering Sea represent 7 families and 10 genera (Sinclair et al. 1999). Less is known about which squid species inhabit the GOA, but the species are likely to represent both EBS species and more temperate species in the family Loligo, which are regularly found on the U.S. West Coast and in British Columbia, Canada, especially in warmer years (BC squid fishery thing). Squid are distributed throughout the North Pacific, but are common in large schools in pelagic waters surrounding the outer continental shelf and slope (Sinclair et al, 1999). The most common squid species in the Eastern Bering Sea are all in the family Gonatidae. Near the continental shelf, the more common species are Berryteuthis anonychus and Berryteuthis magister. Further offshore,
the likely common species are Gonatopsis borealis, Gonatus middendorfi and several other Gonatus species, according to survey information collected in the late 1980's (Sinclair et al. 1999). In addition, marine mammal food habits data and recent pilot studies indicate that Ommastrephes bartrami may also be common, in addition to Berryteuthis magister and Gonatopsis borealis (B. Sinclair, ASFC, personal communication). Much more research is necessary to determine exactly which species and life stages are present seasonally in the BSAI and GOA.

How are squids managed under status quo?
Squids are part of the Other species FMP category. In the BSAI, catch of all squid species in aggregate is limited by a TAC, which is based on the average catch of squid between 1978 and 1995 (Fritz, 1999). In the GOA, catch of squids is reported within the category "other" along with skates, sharks, sculpins, and octopus, and is limited by a TAC set for the entire complex. This GOA TAC for other species has been established as $5 \%$ of the sum of the TACs for all other assessed target species in the GOA (Gaichas et al., 1999). The squid TAC in the BSAI and the other species TAC in the GOA have never been exceeded. However, squid catch in the BSAI became a potential problem within the management of the Community Development Quota (CDQ) program. Because each CDQ group receives an allocation of groundfish which is $7.5 \%$ of the TAC set for each species, the groups would be required to restrict squid catch to a low level, potentially constraining target fisheries (Sally's EA). This is more an example of the difficulties with managing very small TACs than with managing squid in particular, because the squid TAC is one of the smallest TACs in the BSAI (ref 2000 harvest specifications for BSAI groundfish). The NPFMC approved BSAI FMP amendment 66 to remove squid from the CDQ program in June 1999, and the Final Rule is pending (Federal Register, May 30, 2000). Under this rule, the catch of squid within the CDQ program is still monitored, and still counts against overall BSAI squid TAC, but CDQ groups will not be restricted to $7.5 \%$ of the squid TAC.

## Development of Squid Management Under Alternative 4

## Step 1. Prioritization

Although there are no directed squid fisheries in the Eastern North Pacific, there are many fisheries directed at squid species worldwide, although most focus on temperate squids in the genera Ilex and Loligo (Agnew et al. 1998, Lipinski et al 1998). There are fisheries for Berryteuthis magister in the Western Pacific, including Russian trawl fisheries with annual catches of 30,000-60,000 metric tons (Arkhipkin et al., 1995), and coastal Japanese fisheries with catches of 5,000 to $9,000 \mathrm{t}$ in the late 1970'searly 1980's (Roper et al. 1982, Osaka and Murata 1983). In addition to the fishery potential of North Pacific squids, they were selected for analysis because of the crucial role they play in marine ecosystems. Squid are important components in the diets of many seabirds, fish, and marine mammals, as well as voracious predators themselves on zooplankton and larval fish (Caddy 1983, Sinclair et al. 1999). Many squid populations are composed of spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski, 1998). The timing and location of fishery interactions with squid spawning aggregations may affect the availability of squid as prey for other animals as well as the squid populations themselves (Caddy 1983, O'Dor 1998). The essential position of squids within North Pacific pelagic ecosystems combined with our limited knowledge of the abundance, distribution, and biology of squid species in the FMP areas make squids a good case study to illustrate management of an important resource with little information.

Step 2. Evaluate available data

## Fishery catch

Because observers are not trained to identify individual species of squids, the majority (99\%) of squid catch is reported as "squid unidentified". No species codes for the likely common species, Berryteuthis magister and Gonatopsis borealis, have been established for observers to use even if they did identify these species. We summarize all available catch information for aggregated squid species, including annual catch and location of catch. We examined fishery data from 1997-1999 to determine total squid catch, catch in different gear types and target fisheries (Table 4.1.3.3.3-1), and observed location of squid catch (see spatial analysis below). Unlike skates, squids are rather delicate are almost certainly all killed in the process of being caught, regardless of gear type or depth of fishing.

Squid catch in the FMP areas is low relative to the catch of skates and grenadiers, and relative to the reported catches of squid from directed fisheries in the western Bering Sea. The majority of squid catch in all areas occurs in the pelagic trawl fishery directed at pollock in the EBS (Table 4.1.3.3.3-1). In the GOA, catches of squid are estimated to be low overall, but most squid catch comes from the pollock fishery in this area as well. Squids are also caught in smaller amounts in bottom trawl fisheries in both areas, while catches are negligible in fixed gear fisheries. We focus on squid catch in EBS pollock pelagic trawl fisheries for the remainder of this case study, since this represents the majority of squid catch in areas covered by the FMPs.

Table 4.1.3.3.3-1 Estimated catch (t) of all squid species combined by gear and target fishery.

| Bering Sea Aleutian Islands |  |  |  |  | Gulf of Alaska |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Gear | 1997 | 1998 | 1999 | average | Gear | 1997 | 1998 | 1999 | average |
| bottom trawl | 69 | 23 | 28 | 40 | bottom trawl | 17 | 13 | 18 | 16 |
| pelagic trawl | 1,505 | 1,233 | 473 | 1,070 | pelagic trawl | 80 | 46 | 20 | 49 |
| pot | 0 | - | 0 | 0 | pot | 0 | 0 | 0 | 0 |
| longline | 0 | 0 | 0 | 0 | longline | 0 | 0 | 2 | 1 |
| Total | 1,573 | 1,256 | 502 | 1,110 | Total | 97 | 59 | 41 | 66 |
| Target fishery | 1997 | 1998 | 1999 | average | Target fishery | 1997 | 1998 | 1999 | average |
| Arrowtooth | 0 | 3 | 3 | 2 | Arrowtooth | 1 | 3 | 1 | 1 |
| Atka | 16 | 8 | 5 | 10 | Cod | 1 | 1 | 1 | 1 |
| Cod | 8 | 2 | 0 | 3 | Deepwater flats | 5 | 3 | 6 | 5 |
| Flathead | 1 | 2 | 2 | 2 | Demersal shelf rockfish | 0 |  | 0 | 0 |
| Other flats | 0 | 1 | 5 | 2 | Flathead sole | 1 | 0 |  | 1 |
| Other rockfish | 0 | 0 | 0 | 0 | Northern rockfish | 1 | 1 | 0 | 1 |
| Other species |  | 0 | 0 | 0 | Other species | 14 | 0 | 0 | 5 |
| Pollock B | 92 | 28 | 4 | 41 | Pelagic shelf rockfish | 2 | 1 | 2 | 2 |
| Pollock P | 1,446 | 1,208 | 471 | 1,042 | Pollock B | 0 | 0 | 1 | 1 |
| POP | 7 | 1 | 6 | 4 | Pollock P | 66 | 45 | 19 | 43 |
| Rock sole | 0 | 0 | 0 | 0 | POP | 4 | 4 | 5 | 4 |
| Sablefish | 0 | 0 | 0 | 0 | Rex sole | 1 | 1 | 4 | 2 |
| Shortraker / rougheye |  | 0 | 0 | 0 | Sablefish | 0 | 0 | 2 | 1 |
| Turbot | 4 | 3 | 4 | 3 | Shallow flats | 0 | 0 | 0 | 0 |
| Yellowfin sole | 0 | 0 | 0 | 0 | Shortraker / rougheye | 0 |  | 0 | 0 |
| Other targets | 0 | 0 | 0 | 0 | Thornyheads | 0 |  |  | 0 |
| Total | 1,573 | 1,256 | 502 | 1,110 | Total | 97 | 59 | 41 | 66 |

Survey biomass in aggregate and by species
The AFSC bottom trawl surveys are directed at groundfish species, and therefore do not employ the appropriate gear or sample in the appropriate places to provide reliable biomass estimates for the generally pelagic squids. Although midwater acoustic and trawl surveys are conducted in the EBS annually by the AFSC, all sampling on these surveys is directed at pollock. Squid records from these surveys tend to appear at the edges of the continental shelf, which is at the margin of the sampling strata defined for these surveys. The available information from 1988 and 1989 Japanese / U.S. pelagic trawl research surveys in the EBS indicates that the majority of squid biomass is distributed in pelagic waters off the continental shelf (Sinclair et al. 1999), beyond the current scope of the AFSC surveys. These midwater surveys provided the information we have to indicate which species might be found in the EBS, but they were characterized by extreme variability in species abundance between years. The bottom line is, there is no reliable biomass estimate for squids, either in aggregate or by species, for any year in any FMP area at this time.

## Spatial aspects of Fishery catch and Survey distribution by species

As with skate and grenadier catch, we attempted to resolve which squid species are likely to be caught in the EBS pollock fishery by combining species distribution information from surveys with the observed fishery catch information from 1997-1999. While the surveys do not cover enough area to provide biomass estimates for squids, they do cover many of the areas where pollock fisheries catch squids. This analysis confirms that Berryteuthis magister is likely to be present in at least some fishery catches of squid (Figure 4.1.3.3.3-2). As will many other non-target species, identification of squids on past surveys was not always attempted, so records labeled below as "other squid" may or may not also represent Berryteuthis magister. It is clear from Figure 4.1.3.3.3-2 that fisheries catch squids mostly along the outer continental shelf, and that catch is concentrated in certain areas, especially around submarine canyons.


Figure 4.1.3.3.3-2 Distribution of squid species from bottom trawl and midwater surveys (dots) and catch (shaded squares), 1997-99.

## Life history information

In contrast with the previous case study species, squids are highly productive, short-lived animals. They have been described as "the marine equivalent of weeds," displaying rapid growth, patchy distribution and highly variable recruitment (O'Dor 1998). Unlike most fish, squids may spend most of their life in a juvenile phase, maturing late in life, spawning once, and dying shortly thereafter. Whereas many groundfish populations (including skates and grenadiers) maintain stable populations and genetic diversity over time with multiple year classes spawning repeatedly over a variety of annual environmental conditions, squids have no such "reserve" of biomass over time. Instead, it is hypothesized that squids maintain a "reserve" of biomass and genetic diversity in space with multiple cohorts spawning and feeding throughout a year and over a wide geographic area across locally varied environments (O'Dor 1998). Many squid populations are composed of these spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski 1998). Most information on squids refers to Illex and Loligo species which support commercial fisheries in temperate and tropical waters. Of North Pacific squids, life history is best described for western Pacific stocks (Arkhipkin et al. 1995; Osako and Murata 1983).

The most commercially important (and therefore best studied) squid in the western north Pacific is the magistrate armhook squid, Berryteuthis magister. This species is distributed from southern Japan throughout the Bering Sea, Aleutian Islands, and Gulf of Alaska to the U.S. West coast as far south as Oregon (Roper et al. 1984). The maximum size reported for $B$. magister is 28 cm mantle length. The internal vestigal shell, or gladius, and statoliths (similar to otoliths in fish) were compared for ageing this species (Arkhipkin et al., 1995). B. magister from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 2 years). Males grew 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., 1995).

## Step 3. Selection of management tools

TAC setting is the preferred management tool under this alternative regime to increase protection to nontarget species. For squids, we do not have the minimal information required to set a TAC, because we do not have a reliable estimate of biomass. (While we set a TAC right now under status quo management for squid in the BSAI, this TAC is based on average catch, which is not necessarily related to the productivity of squid stocks. Under this alternative management regime we set slightly higher standards for TAC setting, so that our TACs would be biologically derived.) The management regime which we outlined in section 4.1.3.2 would now require us to investigate the costs of obtaining a biomass estimate for squids, so that we could eventually set a TAC.

In theory, a squid survey could be conducted with midwater trawls and or hydroacoustics. We have 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 squids might indicate when a survey would be most efficiently conducted. According to fishery information from 1997-1999, a peak in squid CPUE occurs in January, but it is also all in one location
(Pribilof canyon), so it is 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 squids 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 necessary for squid TAC setting 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 our area to determine how a larger scale survey might be conducted in the future.

The rapid dynamics reported for squid species and their subpopulations indicates that the temporal and spatial scales for assessment of squids are different from the annual and basinwide scales we apply to most groundfish. Therefore, even if we had a reliable estimate of biomass, we would have to understand the relative composition of cohorts and their movements and different mortality rates in order to apply TAC management effectively. If we used a previous year's biomass estimate to set a TAC for the following year for squids (as we do for Target species), there would be a significant probability that this TAC would be far too high or low relative to the current year's biomass due to the great interannual variability of squid stocks (Caddy 1983). To avoid this problem, biomass would have to be estimated for a given species and TAC set and taken within a very short time period, potentially less than one year. Even this intensive management scenario would leave open the possibility that an entire seasonal cohort could be eliminated by fishing unless additional temporal or spatial management measures ensured that fishing pressure was distributed between cohorts. Both effort controls and closed areas and seasons have been suggested as more effective management tools than TAC setting for maintaining adequate levels of squid spawning stock biomass (Caddy 1983, O’Dor 1998). An understanding of the biology and dynamics of squid life cycles at the species level is essential for the application of any management tool (Lipinski et al 1998).

## Step 4. Application of management tools

Our fallback option for management under this alternative regime is to reduce fishery interactions with squids by at least $75 \%$ using time and area closures. Given that majority of squid catches occur in a few clearly defined areas across recent years (Figure 4.1.3.3.3-2), this option seems ideal for squid management. We therefore defined squid closed areas are based on observed squid catches from the years 1997-1999 (Figure 4.1.3.3.3-3). These closures apply only to pelagic trawl gear in the Bering Sea (almost exclusively the pollock fishery). Squid catch in each of these areas occurs in distinct seasons, but there is not enough fishing year round to determine if squids would be caught in each area in all seasons. Squids migrate throughout the area and populations are composed of multiple cohorts with different spawning seasons. Year-round closures in these areas is a conservative measure that will provide protection to all cohorts in the populations of each species that potentially occupies the area, so there is no time element to these closures. We estimated the total pollock fishery catch in each year (1997-1999) that would have been displaced by these closures, and reduced the pollock TAC by $18.5 \%$, the average proportion of displaced catch from these three years (Table 4.1.3.3.3-2). This was to reduce the probability that the fishery would displace effort into other areas to take the entire TAC, potentially catching just as much squid outside the closures as they would have inside. This could still happen, but is less likely with a TAC reduction than without one.

We note that area closures for squid and TAC reductions in the pollock fishery apply under both
alternatives 4.1 and 4.2 , so that they can be analyzed in conjunction with the other management measures implemented to increase protection to these high priority case study non-target species groups.

Table 4.1.3.3.3-2 Proportion of pelagic pollock fishery total catch inside closed areas for squid.

| Pollock fishery (pelagic trawl only) | $\mathbf{1 9 9 7}$ | $\mathbf{1 9 9 8}$ | $\mathbf{1 9 9 9}$ | average |
| :--- | ---: | ---: | ---: | ---: |
| Total catch (metric tons) | $1,026,738$ | 928,368 | 838,708 |  |
| Foregone catch in squid closures (metric tons) | 194,128 | 206,029 | 117,405 |  |
| Foregone $\%$ of total | $18.9 \%$ | $22.2 \%$ | $14.0 \%$ | $18.5 \%$ |



Figure 4.1.3.3.3-3 Squid closures (inside black outlines) applied to pelagic trawl gear, all seasons.

