17. Bering Sea and Aleutian Islands Squids

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16.1.0 Executive Summary

a) 16.1.0.1 Summary of Major Changes

Changes in the input data:

1)Total catch weight for BSAI squids is updated with 2005 and partial 2006 data.

Changes in assessment methodology:

2) There are no changes in the assessment methodology.

Changes in assessment results:

3) There are no changes in assessment results, because BSAI squids remain in Tier 6 as they have for the past several years. The recommended ABC for squid in the year 2007 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 2007 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.

b) 16.1.0.2 Responses to SSC Comments

There were no Squid specific SSC comments to address.

16.1.1 Introduction

Description, scientific names, and general distribution

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 16.1-1). Squids are active predators which swim by jet propulsion, reaching swimming speeds of up to 40 km/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).

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 (http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/squid/default_e.htm). 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. Currently, our bottom trawl surveys do not adequately sample any of the squid species in the BSAI. Therefore, we do not have adequate data to produce spatial distribution maps of squid. Maps of fishery bycatch of squid (unidentified) are included in this assessment.

Management Units

The squid species complex is part of the other species category. In the BSAI, catch of all squid species in aggregate is limited by a TAC (quota), which is based on the average catch of squid between 1978 and 1995 (Fritz, 1999, Gaichas 2003). In 2005 100% of the squid quota was caught, as of 10/21/2006, the 2006 squid quota has been exceeded by 30% or 327 mt. Historically, the squid catch in the BSAI has been problematic within the management of the Community Development Quota (CDQ) program. This is 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 (NMFS 2000). This is more an example of the difficulties with managing very small TACs than with managing squid in particular, because the squid quota is one of the smallest quotas in the BSAI (50 CFR Part 679, February 18, 2000). The NPFMC approved BSAI FMP amendment 66 to remove squid from the CDQ program in June 1999, and was made Final in 2001 (66 FR 13762, March 7, 2001). 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 quota.

Life history and stock structure

Relative to most groundfish, squids are highly productive, short-lived animals. They display 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 rockfish) 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 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*. 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).

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 has been done for forage species in the BSAI and GOA). 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.

16.1.2 Fishery

Directed fishery

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. There are no directed squid fisheries in Alaskan waters at this time. Squids could potentially become targets of Alaskan fisheries, however. While 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 t in the late 1970's-early 1980's (Roper et al. 1982, Osaka and Murata 1983). Therefore, monitoring of catch trends for species in the squid complex is important because markets for squids exist and fisheries might develop rapidly.

<u>Bycatch and discards</u>

Reported catches since 1977 are shown in Table 16.1-1, along with historical ABC and TAC. After reaching 9,000 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). The 2001 estimated catch of squid, 1,766 t (Table 16.1-1), was the highest in the past five years and is much closer to the ABC of 1,970 t than any estimated catch since the 1980's. Catches are more comparable to pre-1999 levels in 2003-2006. 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). The spatial distribution of the observed portion of the squid catch has changed over time; while the Aleutian Islands management areas contributed a measurable portion of observed squid catch between 1990 and 1997, observed squid catch has been almost exclusively from areas 513 and 519 since 2001 (Figure 16.1-2). Some of this redistribution could be due to changes in observer coverage over time, but because the primary fisheries in these areas have high levels of observer coverage, this redistribution could also reflect changing fishing patterns and / or changes in squid distributions.

16.1.3 Data

<u>Fishery Catch</u>

The predominant species of squid in commercial catches in the EBS is believed to be the magistrate armhook squid, *Berryteuthis magister. Onychoteuthis borealijaponicus*, the boreal clubhook squid, is likely the principal species encountered in the Aleutian Islands region. Because observers are not trained to identify individual species of squids, the majority (99%) of squid catch is reported as “squid unidentified”; the remainder is identified as *Moroteuthis* spp, or “giant squid unidentified”. We summarized all available catch information for aggregated squid species, including annual catch and location of catch. We examined fishery data from 1999-2005 to determine total squid catch, catch in different gear types and target fisheries (Table 16.1-2), and observed location of squid catch (see spatial analysis below). Spatial analysis was done only for 1997-1999 because the pollock fisheries changed so much under Steller sea lion management measures since 2000. We assume complete mortality of incidentally caught squids, because squids are rather delicate and are almost certainly all killed in the process of being caught, regardless of gear type or depth of fishing.

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 16.1-3). As will many other non-target species, identification of squids on past surveys was not always attempted, so records labeled as “other squid” may or may not also represent *Berryteuthis magister*. It is clear from Figure 16.1-4 that fisheries catch squids mostly along the outer continental shelf, and that catch is concentrated in certain areas, especially around submarine canyons.

<u>Survey biomass in aggregate and by species</u>

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. Currently, there is no reliable biomass estimate for squids, either in aggregate or by species, for any year in the BSAI at this time. Therefore, there is no way to know whether there are any concerns about biomass trends for any species within the squid complex at this time.

16.1.4 Analytic Approach, and Results

The available data do not support population modeling for squids in the BSAI, so none of these stock assessment sections are relevant.

Projections and Harvest Alternatives

The current harvest specifications and TAC are based on average catch between 1978 and 1995 (Tier 6); however, average catch is likely unrelated to the productivity of a lightly fished stock, and is therefore a suboptimal tool to achieve a harvest policy designed to prevent negative fishing effects on the stock or the ecosystem. The traditional alternative to an average-catch based TAC is one based on biomass. For species in the squid complex, we do not have the minimal information required to set a biologically derived TAC, because we do not have a reliable estimate of biomass. Below, we briefly investigate the costs of obtaining a biomass estimate for squids to determine whether a biologically derived TAC based on biomass or a traditional stock assessment would ever be a cost effective management tool. Then, we suggest alternative management measures which may be more appropriate to an ecologically important species with a spatially and temporally complex life history pattern.

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. There is currently some interest in developing a mesopelagic trawl survey index which might begin this process. 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 basin-wide 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 groundfish 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).

Management alternative

Due to recent bycatch levels of squid, a management scenario involving time and area monitoring of squid catch (e.g., savings area) that has the potential for closure if catches in these areas reach a pre-determined limit should be determined. Given that the majority of squid catches occur in a few clearly defined areas across recent years (Figure 16.1-3), this option seems ideal for squid management. We therefore defined potential squid management areas based on observed squid catches from the years 1997-1999 (Figure 16.1-4). Management within these areas could be applied 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 would be the most conservative measure that would provide protection to all cohorts in the populations of each species that potentially occupies the area, and would minimize squid bycatch overall, but a range of monitoring and management options are available. Given that squid populations do not appear threatened by the current level of fishing mortality, a different management priority may be to maximize prey availability during certain seasons for protected resources. Monitoring and management of squid catch in favored pinniped foraging areas (see below) could be achieved using these same defined squid management areas, as modified by overlap with defined pinniped foraging areas.

16.1.5 Ecosystem Considerations

Fishery management should attempt to prevent negative impacts on squid populations not only because of their potential fishery value, but 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).

Squids are central in food webs in both the AI (Figure 16.1-5, upper panel) and the EBS (Figure16.1-5, lower panel). These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system. The EBS and AI are physically very different ecosystems, especially when viewed with respect to available squid habitat and densities. While direct biomass estimates are unavailable for squids, ecosystem models can be used to estimate squid densities based upon the food habits and consumption rates of predators of squid. The AI has much more of its continental shelf area in close proximity to open oceanic environments where squid are found in dense aggregations, hence the squid density as estimated by predator demand in each system is much greater in the AI relative to the EBS (labeled "BS" in the figures) and GOA (Figure 16.1-6, upper panel).

In contrast with predation mortality, estimated fishing mortality on squid is currently very similarly low in all three ecosystems. Figure 16.1-6 (lower panel) demonstrates the estimated proportions of total squid mortality attributable to fishing vs. predation, according to food web models built based on early 1990's information from the AI, EBS, and the GOA for comparison. Fishing mortality is so low relative to predation mortality that it is not visible in the plot, suggesting that current levels of overall fishery bycatch may be insignificant relative to predation mortality on squid populations. While estimates of squid consumption are considered uncertain, the ecosystem models incorporate uncertainty in partitioning estimated consumption of squid between their major predators in each system. The predators with the highest overall consumption of squid in the AI are Atka mackerel, which consume between 100 and 700 thousand metric tons of squid annually in that ecosystem, followed by "other large demersal species" (mostly grenadiers), which consume a similar range of squid annually (Figure 16.1-7, upper panel). In the EBS, estimated consumption of squid is dominated by "other large demersal species" (grenadiers) taking in the range of 200,000 to over a million metric tons annually, followed by pinnipeds which consume up to 500,000 tons annually (Figure 16.1-7, lower panel). Squid make up about 10% of the diet of AI Atka mackerel, 30% of the diet of EBS fur seals (both adults and juveniles), and between 45 and 50% of the diet of grenadiers in both systems (Figure 16.1-8).

Diets of squids are poorly studied, but currently believed to be largely dominated by euphausiids, copepods and other pelagic zooplankton in the AI and EBS. Assuming these diets are assessed correctly, squids are estimated to consume on the order of one to five million metric tons of these zooplankton species in both systems annually. Squids are also reported to consume forage fish as a small portion of their diet, which could amount to as much as one million metric tons annually in the AI and EBS ecosystems. While there is much uncertainty surrounding the quantitative ecological interactions of squids, as is apparent in the wide ranges of these estimates from food web models, it is clear that squids are intimately connected with both very low trophic level processes affecting secondary production of zooplankton, and in turn they comprise a significant portion of the diet of both commercially important (Atka mackerel) and protected species (pinnipeds) in the AI and EBS.

While overall fishing removals of squid are very low relative to predation at the ecosystem scale, local-scale patterns of squid removals should still be monitored to ensure that fishing operations minimize impacts to both squid and their predators. 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 age, size, and genetic structure of the squid populations themselves (Caddy 1983, O'Dor 1998). Monitoring these fishery interactions with squid could be especially important within the foraging areas for the currently declining Northern fur seals, which rely on squids for a significant portion of their diets. 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 nontarget species complex with little information.

<u>Data gaps and research priorities</u>

Clearly, there is little information for stock assessment of the squid complex in the BSAI. However, ecosystem models estimate that the proportion of squid mortality attributable to incidental catch in groundfish fisheries in the BSAI region is extremely small relative to that attributable to predation mortality. Therefore, improving the information available for squid stock assessment seems a low priority as long as the catch remains at its current low level.

However, investigating any potential interactions between incidental removal of squids and foraging by protected species of concern (pinnipeds, specifically northern fur seals) seems a higher priority for research. Limited data suggest that squids may make up nearly a third of the diet (by weight) for northern fur seals in the EBS. Research should investigate whether the location and timing of incidental squid removals potentially overlap with foraging seasons and areas for northern fur seals (for example, as described in Robeson 2000), and whether the magnitude of squid catch at these key areas and times is sufficient to limit the forage available for these pinnipeds.

Management might consider improvements to the current monitoring of squid species within the complex such as getting observers to measure a subset of the bycatch in order to classify the squid catch by size. A pending change in the observer manual, may allow for collection of these date beginning in 2007. This would be extremely helpful to investigate potential ecosystem effects (e.g., "large" squid the size of *Moroteuthis robusta* are more predator than prey in the ecosystem, while smaller squid species may be most important as prey). Because most squid catch in Alaskan groundfish fisheries is in Bering Sea pollock where there is nearly full observer coverage, it may be feasible for observers to devote time to this task if it becomes a priority. In the future, it might also be important to be able to estimate the species composition of squid complex bycatch to determine relative impacts on marine mammals and other predators that depend on squids for prey, as well as relative impacts to the squid populations themselves.

Ecosystem Effects on Stock and Fishery Effects on the Ecosystem: Summary

In the following table, we summarize ecosystem considerations for BSAI squids and the entire groundfish fishery where they are caught incidentally. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how the fishery trend affects the ecosystem (fishery effects on the ecosystem). The evaluation column indicates whether the trend is of: *no concern, probably no concern, possible concern, definite concern,* or *unknown.*

Ecosystem effects on BSAI Squids *(evaluating level of concern for squid populations)*

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton Forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Predator population trends			
Pinnipeds	Fur seals declining, Steller sea lions level	Possibly lower mortality on squids	No concern
Atka mackerel (AI)	Cyclically varying population with slight upward trend overall 1977-2005	Variable mortality on squids slightly increasing over time	Probably no concern
Grenadiers (BSAI)	Unknown population trend	Unknown	Unknown
Changes in habitat quality			
North Pacific gyre	Physical habitat requirements for squids are unknown, but are likely linked to pelagic conditions and currents throughout the North Pacific at multiple scales.	Unknown	Unknown

Groundfish fishery effects on ecosystem via squid bycatch *(evaluating level of concern for ecosystem)*

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Squid catch	Stable, generally <2000 tons annually	Extremely small relative to predation on squids	No concern
Forage availability for Atka mackerel (AI)	Minor pollock fisheries in AI so very little squid catch in Atka mackerel foraging areas	Little change in forage for Atka mackerel	Probably no concern
Forage availability for grenadiers (BSAI)	Squid catch overlaps somewhat with grenadier foraging areas along slope	Small change in forage for grenadiers	Probably no concern
Forage availability for pinnipeds (EBS)	Depends on magnitude of squid catch taken in pinniped foraging areas, most catch in fur seal foraging area at shelf break by Pribilofs	Mixed potential impact (fur seals vs Steller sea lions)	Possible concern
Fishery concentration in space and time	Bycatch of squid is mostly in shelf break and canyon areas, no matter what the overall distribution of the pollock fishery is	Potential impact to spatially segregated squid cohorts and squid predators	Possible concern
Fishery effects on amount of large size target fish	Effects of squid bycatch on squid size are not measured	Unknown	Unknown
Fishery contribution to discards and offal production	Squid discard an extremely small proportion of overall discard and offal in groundfish fisheries	Addition of squid to overall discard and offal is minor	No concern
Fishery effects on age-at-maturity and fecundity	Effects of squid bycatch on squid or predator life history are not measured	Unknown	Unknown

16.1.6 Summary

The squid complex in both the BSAI and GOA is an assemblage which is both ecologically important and has potential fishery value. Management with TACs has been problematic in the past, both due to a lack of biomass estimates and to small TAC management issues associated with the CDQ program in the BSAI. Concerns with squid bycatch are likely to surround the ecological relationships of squids rather than squid population dynamics, as current levels of squid catch appear to contribute very little to total squid mortality relative to predation mortality in the BSAI. Squid bycatch occurs in the same areas year after year, so any potential ecosystem effects of squid catch could be monitored in those areas where interactions with protected predator species foraging on squid are likely. If squid bycatch becomes a management concern for squid themselves or for squid predators, pollock or other pelagic fisheries could be excluded from designated shelf break and canyon regions during certain times of the year, all year, or only after a certain threshold level of squid complex catch had been reported by fishery observers. Management might consider improvements to the current monitoring of squid species within the complex such as getting observers to measure a subset of the bycatch to classify the squid catch by size. This would be extremely helpful to investigate potential ecosystem effects (e.g., "large" squid the size of *Moroteuthis robusta* are more predator than prey in the ecosystem, while smaller squid species may be most important as prey). Because most squid catch in Alaskan groundfish fisheries is in Bering Sea pollock where there is nearly full observer coverage, it may be feasible for observers to devote time to this task if it becomes a priority. It might be important to be able to estimate the species composition of squid complex bycatch to determine relative impacts on marine mammals and other predators that depend on squids for prey, as well as relative impacts to the squid populations themselves.

> Using Tier 6 criteria, the recommended ABC for BSAI squid in the year 2007 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 2007 is calculated as the average catch from 1978-1995, or **2,624 mt**. (This recommendation is unchanged from previous assessments.)

16.1.7 Literature Cited

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Table 16.1-1. Estimated total (retained and discarded) catches of squid (mt) in the eastern Bering Sea and Aleutian Islands by groundfish fisheries, 1977-2006. 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			432	432			9	9	441
2000			375	375			8	8	384
2001			1,761	1,761			5	5	1,766
2002			1,334	1,334			10	10	1,344
2003*			1,171	1,171			35	35	1,206
2004*			879	879			14	14	893
2005*			1,087	1,087			17	17	1,101
2006**			1,294	1,294			6	6	1,300

*Updated total catch data from NMFS AK Regional Office Catch Accounting System.
**2006 catch as reported through August 10, 2006.

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 1989-2002: NMFS Regional Office BLEND database, Juneau, AK 99801. Domestic catches 2003-present: NMFS Regional Office Catch Accounting System, Juneau, AK 99801

Table 16.1-2. Estimated catch (t) of all squid species combined by target fishery, gear, and area, 1999-2005.

Target fishery	gear	1999	2000	2001	2002	2003	2004	2005
Arrowtooth	trawl	3	3	7	11			
Flatheadsole	trawl	2	9	10	5			
OtherFlats	trawl	5	2	>1	1			
Rock sole	trawl	0	0	1	>1			
Turbot	hook n line		>1	0				
	pot	0	0					
	trawl	4	9	2	1			
Yellowfinsole	trawl	>1	>1	>1	>1			
Flatfish	Trawl					14	18	18
Atka mackerel	trawl	5	3	3	7	20	7	9
Pacific cod	hook n line	0	0	0	0	>1	>1	>1
	pot	0	0	>1		0	0	>1
	trawl	>1	2	6	5	8	5	2
Pollock	Trawl*	475	379	1,776	1,702	1,150	855	1,066
Rockfish	trawl	6	6	2	9	12	6	7
Sablefish	hook n line	>1			>1	0	0	0
	trawl	>1		>1		0	>1	>1
BSAI Total		**500**	**413**	**1,807**	**1,742**	**1,206**	**891**	**1,102**

* Pelagic trawl

FMP area	area	1999	2000	2001	2002	2003	2004	2005
AI	541	1	4	2	6	8	3	3
	542	1	2	2	5	10	7	2
	543	8	2	3	5	17	3	11
AI Total		**10**	**8**	**7**	**16**	**35**	**13**	**16**
EBS	509	>1	2	>1	1	2	7	5
	513	>1	1	>1	2	2	2	>1
	516			>1		0	0	>1
	517	435	282	792	1,083	719	555	502
	518	>1	>1	>1		>1	0	0
	519	8	94	994	638	436	309	482
	521	47	20	14	2	12	5	95
	523	>1		1	>1	>1	>1	2
	524	>1	6	>1	0	>1	>1	>1
EBS Total		**490**	**405**	**1,801**	**1,726**	**1,171**	**878**	**1,086**
BSAI Total		**500**	**413**	**1,808**	**1,742**	**1,206**	**891**	**1,102**
BSAI ABC		1,970	1,970	1,970	1,970	1,970	1,970	1,970
BSAI TAC		1,970	1,970	1,970	1,970	1,970	1,275	1,275

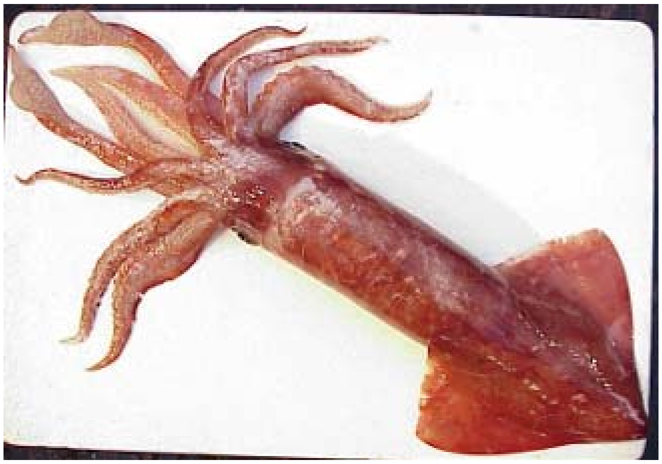

Figure 16.1-1. *Berryteuthis magister*, the magistrate armhook or red squid, is a common species in the BSAI and shows the general physical characteristics of species in the Order Teuthoidea.

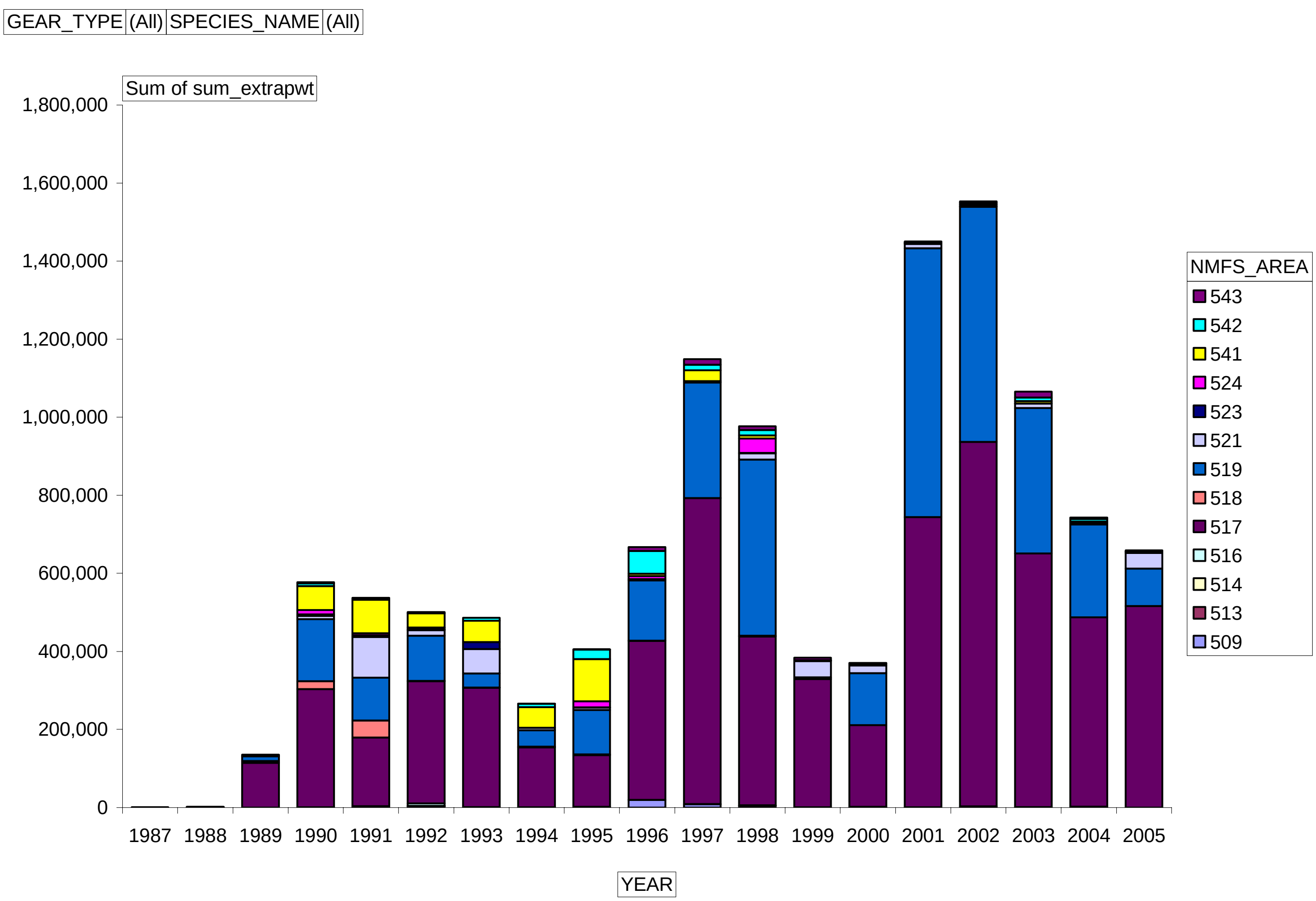

Figure 16.1-2. Observed catches (extrapolated weight in kg) of all squid species in all gear types by NMFS management areas in the BSAI region, 1987-2005 (as of October 4, 2005).

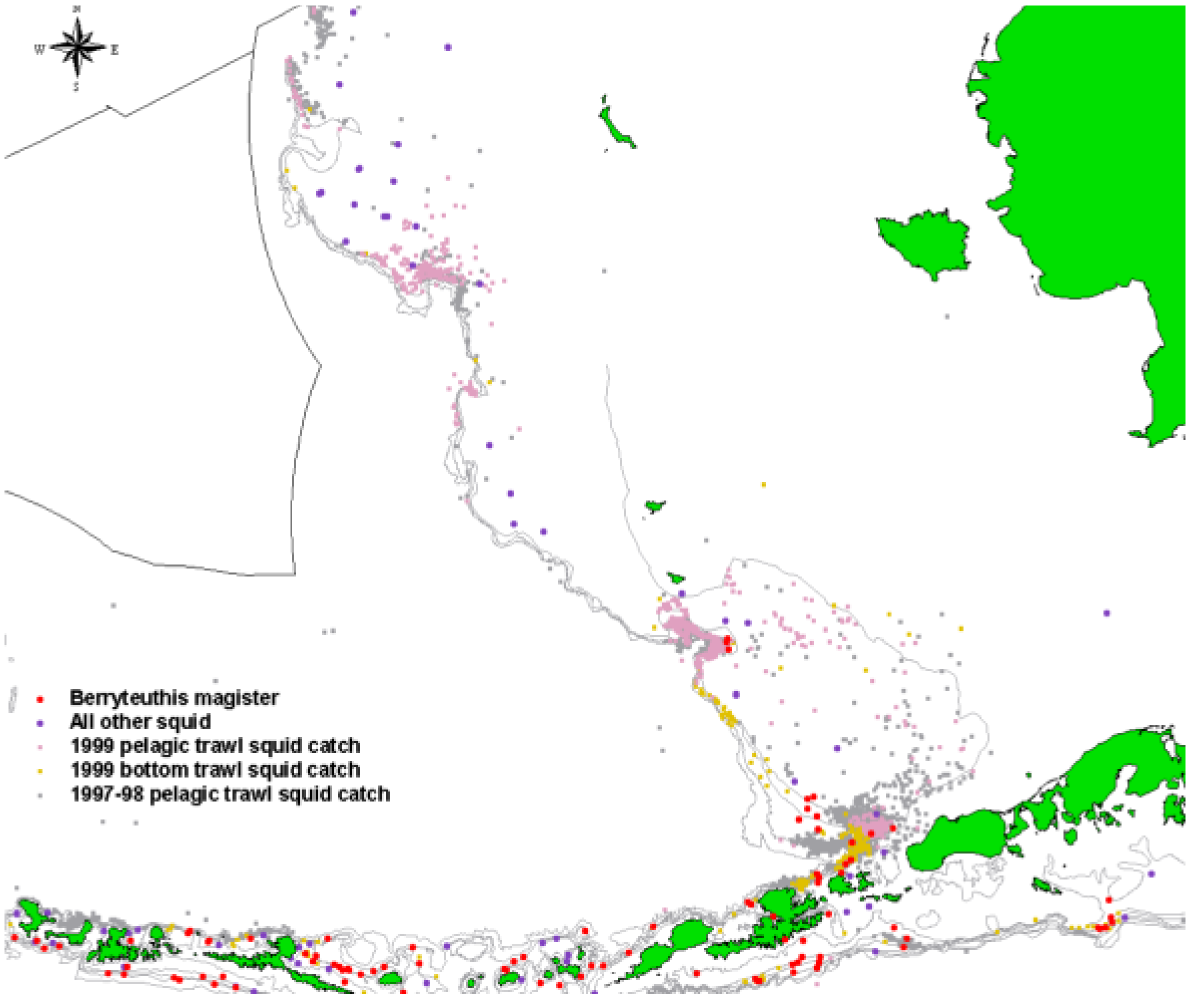

Figure 16.1-3. Distribution of squid species from bottom trawl surveys and catch, 1997-1999.

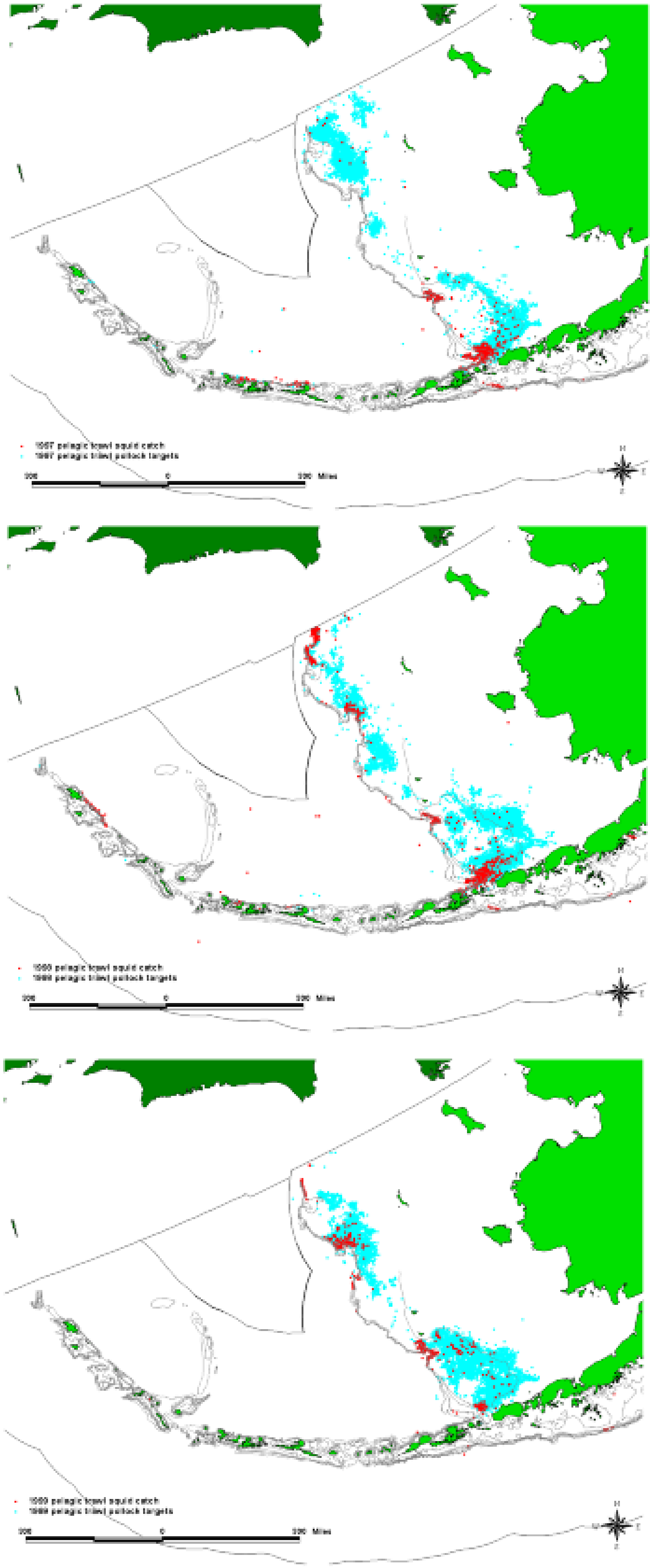

Figure 16.1-4. Eastern Bering Sea pollock fishery in light blue, areas of squid catch in dark red. Top--1997, center--1998, bottom--1999. Note that squid catches occur in the same places regardless of where the fishery operates.

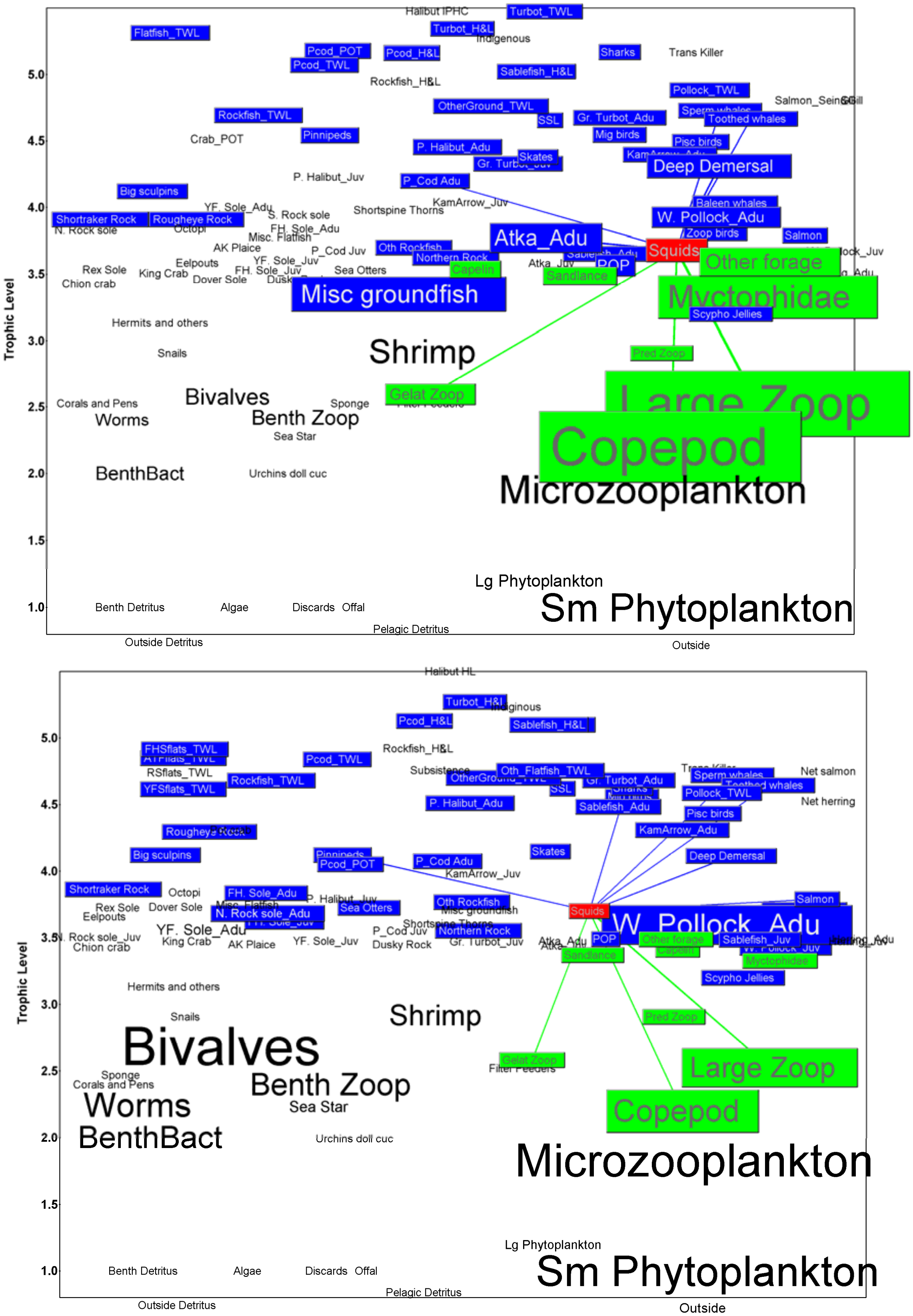

Figure 16.1-5. AI (upper) and EBS (lower) food webs of squids (red), predators (blue), and prey (green).

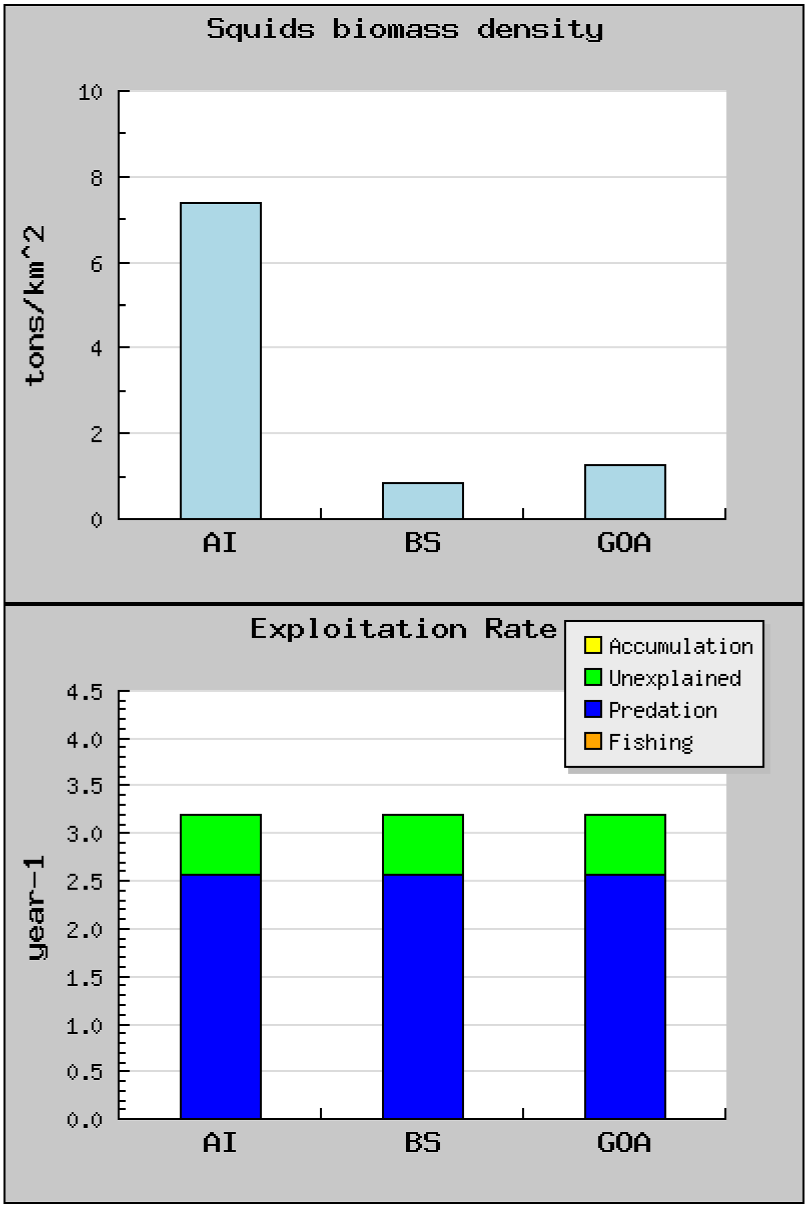

Figure 16-1.6. (upper) Biomass density (tons per square kilometer) come from direct estimates of consumption by groundfish of the AI, EBS, and GOA, and (lower) Exploitation rates partitioned into mortality due to predation, fishing, and unexplained sources. (Fishing mortality has been included in this calculation, but is too small to show on the plot.)

Disclaimer: Figures generated in October 2005, we are currently awaiting updated figures. The calculation for this is Equation 1.1 in Appendix 1 of the Ecosystem Assessment (page 83).

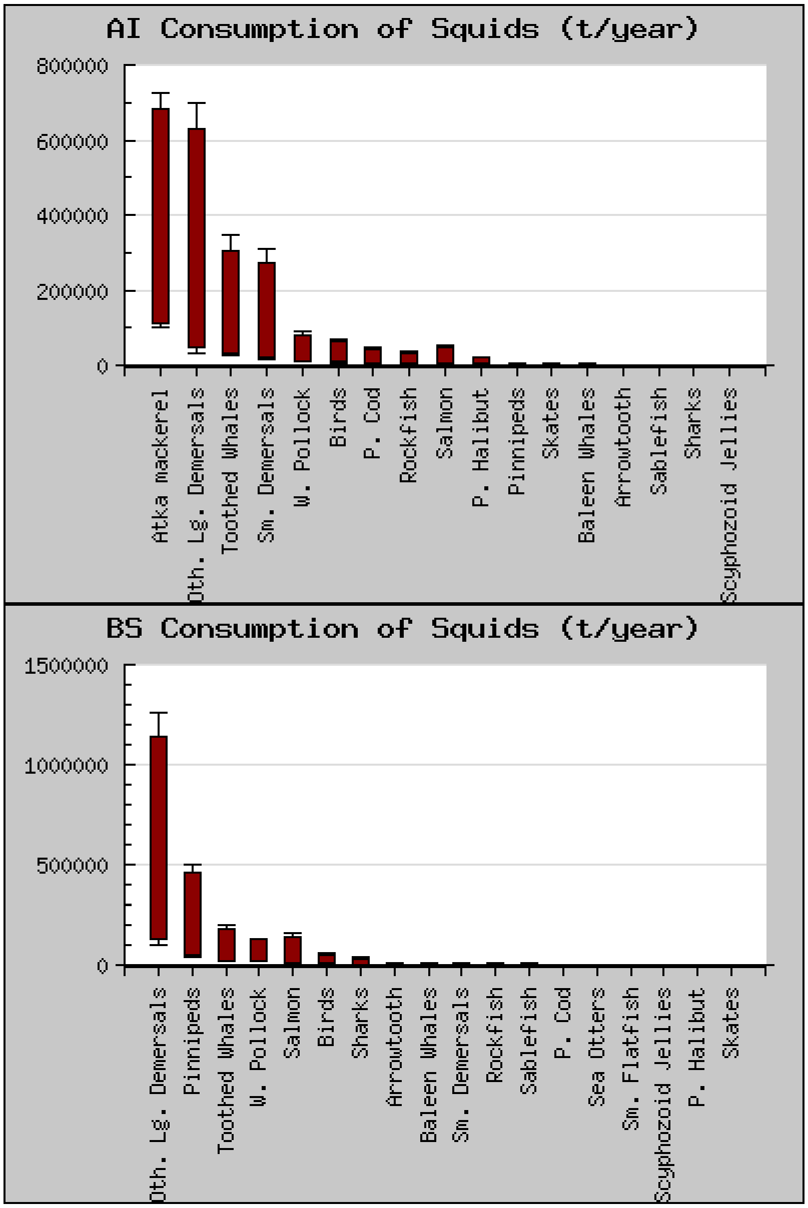

Figure 16.1-7. Consumption of squids estimated from ecosystem models for the AI (upper) and EBS (lower), based on early 1990's data and incorporating uncertainty. "Other large demersals" is primarily grenadiers (Macrouridae) in both ecosystems.

Disclaimer: Figures generated in October 2005, we are currently awaiting updated figures. Description of method is in an appendix of the Ecosystem considerations chapter.

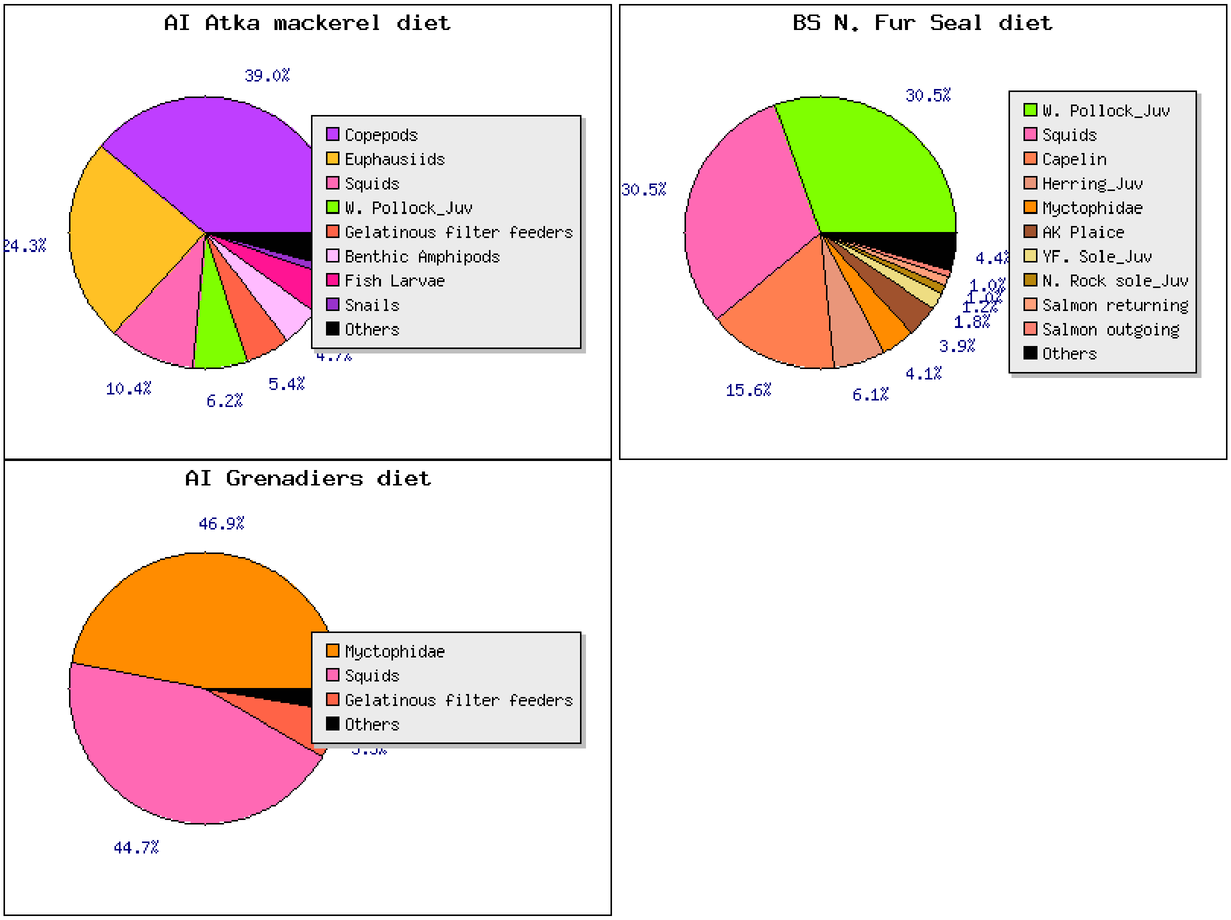

Figure 16.1-8. Proportion of squids in diets of major squid consumers in BSAI: Atka mackerel (top), northern fur seals (center), and grenadiers (bottom). EBS grenadier diets (not shown) are similar to AI. *Disclaimer: Figures generated in October 2005, we are currently awaiting updated figures. Description of method is in an appendix of the Ecosystem considerations chapter.*