21. Assessment of the squid stock complex in the Bering Sea and Aleutian Islands

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Executive Summary

Summary of changes in assessment inputs

Because reliable biomass estimates do not exist for squids in the Bering Sea and Aleutian Islands (BSAI), harvest recommendations are made using Tier 6 criteria. Under Tier 6 Acceptable Biological Catch (ABC) and Overfishing Level (OFL) are calculated using catch data from 1978-1995, and as a result the harvest recommendations do not change from year to year. However, additional data and analyses are included to improve the understanding of squid biology and their interaction with fisheries. The following changes have been made for the 2012 assessment:

1) Updated catch data, including partial 2012 catch data.
2) Added 2012 EBS shelf and slope survey biomass estimates; added AI survey estimates.
3) Additional discussion of patterns in length compositions.

Summary of results

The recommended allowable biological catch (ABC) for squids in 2013 and 2014 is calculated as 0.75 multiplied by the average catch from 1978-1995, or 1,970 t; the recommended overfishing level (OFL) for squid in the years 2013-2014 is calculated as the average catch from 1978-1995, or 2,624 t.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	*2012*	*2013*	**2013**	2014
Tier	6	6	6	6
OFL (t)	*2,620*	*2,620*	**2,620**	2,620
maxABC (t)	*1,970*	*1,970*	**1,970**	1,970
ABC (t)	*1,970*	*1,970*	**1,970**	1,970
	As determined *last* year for:		As determined *this* year for:	
Status	2010	2011	2011	2012
Overfishing	no	n/a	no	n/a

Responses to SSC and Plan Team comments on assessments in general

There were no general comments relevant to BSAI squids.

Responses to SSC and Plan Team comments specific to this assessment

There were no comments specific to BSAI squids.

Introduction

<u>Description, scientific names, and general distribution</u>
Squids are marine molluscs in the class Cephalopoda (Group Decapodiformes). Squids are considered highly specialized and organized molluscs, with only a vestigial mollusc shell remaining as an internal plate (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 1). Squids are active predators which swim by jet propulsion, reaching swimming speeds up to 40 km/hr, the fastest of any aquatic invertebrate. Squids also hold the record for largest size of any invertebrate (Barnes 1987).

In the Bering Sea/Aleutian Islands regions there are at least 15 species of squid (Table 1). The most abundant species is *Berryteuthis magister* (magistrate armhook squid). Members of these 15 species come from six families in two orders and can be found from 10 m to greater than 1500 m. All but one, *Rossia pacifica* (North Pacific bobtail squid), are pelagic but *Berryteuthis magister* and *Gonatopsis borealis* (boreopacific armhook squid) are often found in close proximity to the bottom. The vertical distribution of these three species is the probable cause of their predominance in the BSAI bottom trawl surveys relative to other squid species, although no squid species appear to be well-sampled by BSAI surveys. Most species are associated with the slope and basin, with the highest species diversity along the slope region of the Bering Sea between 200 – 1500 m. Since most of the data come from groundfish survey bottom trawls, the information on abundance and distribution of those species associated with the bottom is much more accurate than that of the pelagic species.

Family Chiroteuthidae
This family is represented by a single species, *Chiroteuthis calyx*. *Chiroteuthis calyx* is a pelagic, typically deep water squid that is known to mate in the Aleutian Islands region. Larvae are common off the west coast of the US.

Family Cranchiidae
There are two species of this family found in the Bering Sea and Aleutian Islands, *Belonella borealis* (formerly *Taonius pavo*) and *Galiteuthis phyllura*. Mated *Galiteuthis phyllura* have been observed along the Bering Sea slope region and their larvae are common in plankton samples. Mature adults and larvae of *Belonella borealis* have not been identified in the region.

Family Gonatidae
This is the most speciose family in the region, represented by nine species: *Berryteuthis anonychus*, *Berryteuthis magister*, *Eogonatus tinro*, *Gonatus berryi*, *Gonatus madokai*, *Gonatus middendorffi*, *Gonatus onyx*, *Gonatopsis borealis*, and *Gonatopsis* sp. All are pelagic however, *B. magister, G. borealis*, and *Gonatopsis* sp. live very near the bottom as adults. Larvae of all species except the unknown *Gonatopsis* have been found in the Bering Sea. *Gonatus onyx* is known to brood its eggs to hatching, however no evidence of that behavior exists for other members of the family. *B. magister* is known to form enormous spawning aggregations in the Bering Sea, and large schools of late juvenile stages of *B. magister* have been observed elsewhere in the North Pacific Ocean.

Family Onychoteuthidae
Immature adults of two species from this family have been observed in the BSAI: *Moroteuthis robusta* and *Onychoteuthis borealijaponicus*, the latter of which is only known from the Aleutian Islands region. *Moroteuthis robusta* is the largest squid in the region, reaching mantle lengths of three feet. Mature adults, eggs, and larvae of either species have not been collected from the Bering Sea or Aleutian Islands regions.

Family Sepiolidae
This family is represented by a single species, *Rossia pacifica*. This small animal is found throughout the Bering Sea and Aleutian Islands regions to 1000 m. Eggs are deposited on substrate in the summer months and larva are benthic. Adults are believed to live 18 – 24 months and females may lay egg masses more than once in life time. Mature and mated females are common in the summer along the Bering Sea slope.

<u>Management Units</u>
Squids in the BSAI are currently managed as a single stock complex that includes all known squid species in the management area. Although no directed fishery exists for squids, they are caught and retained in sufficiently large numbers for them to be considered as "in the fishery".

<u>Life history and stock structure</u>
The life histories of squids in this area are almost entirely unknown. Of all the species, only *Rossia pacifica* has benthic larvae and only members of the family Gonatidae and Cranchiidae are known to spawn in the Bering Sea region. All other species are likely migrating to the area to feed and possibly mate.

Life history information for BSAI squids can be inferred from data on squid species elsewhere. 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. 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 over a wide geographic area (Lipinski 1998; O'Dor 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. Prior to 2008, most of the information available regarding *B. magister* was from the western Bering Sea. A study completed in 2008 investigated life history and stock structure of this species in the EBS (Drobny 2008). In the EBS, *B. magister* appear to have an approximately 1-year life cycle. This is half the longevity of *B. magister* in the western Bering Sea (Arkhipkin et al., 1995). *B. magister* in the EBS appear to grow and mature more quickly than their conspecifics in Russian and Japanese waters. Squid growth appears to be heavily influenced by ocean temperature (Forsythe 2004), which may account for some of the regional and temporal variability.

Populations of *B. magister* and other squids are complex, being made up of multiple cohorts spawned throughout the year. *B. magister* are dispersed during summer months in the western Bering Sea, but form large, dense schools over the continental slope between September and October. Three seasonal cohorts are identified in the region: summer-hatched, fall-hatched, and winter-hatched. Growth, maturation, and mortality rates vary 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). In the EBS, hatch dates of *B. magister* varied by year but were generally in the first half of the year (Drobny 2008). Analysis of statolith chemistry suggested that adult squids were hatched in at least three different locations, and these locations were different from the capture locations. Juvenile and adult *B. magister* also appear to be separated vertically in the water column.

Fishery

<u>Directed fishery</u>

Historically squid were targeted by foreign vessels (from Japan and Korea) in the BSAI, but directed squid fisheries do not currently exist in Alaskan waters at this time. Squids could potentially become targets of Alaskan fisheries, however. 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 *B. 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>Incidental catches and retention</u>

Catch records for squids exist from 1977 (Table 2) and can be broken into three overlapping periods: “foreign” (1977-1987; when foreign vessels dominated the Alaska fleet), “joint venture” (1981-1989; shared fishing activities between domestic and foreign partners), and “domestic” (1987-present). Since 1990, only domestic vessels have operated in Alaskan waters. The foreign catches are much larger than present-day catches and likely present a mix of directed and incidental catches. Currently in the BSAI, squids are generally taken in target fisheries for pollock. Squid species can be difficult to identify, and fishery observers in the BSAI currently record almost all incidentally-caught squid as “Squid unidentified”. The predominant species of squid in commercial catches in the EBS is believed to be the magistrate armhook squid, *B. magister*. Squids are often retained (Table 2). We assume complete mortality of incidentally caught squids because squids are fragile and are almost certainly all killed in the process of being caught, regardless of gear type or depth of fishing.

Data

<u>Fishery data</u>

Catch

After reaching 9,000 t in 1978, total squid catches steadily declined to only a few hundred tons in 1987-1995 (Table 2 & Figures. 2 & 3). From 2000-2008 squid catches fluctuated around an average of approximately 1,000 t, with anomalously high catches in some years. The 2001 estimated catch of squid, 1,766 t, was the highest in the past ten years and high catches also occurred in 2002 and 2006. Since 2009 squid catches have been much smaller, ranging from 360 to 598 t. Most of this catch continues to be in the walleye pollock fishery (Table 3). Retention rates of squid by BSAI groundfish fisheries have ranged between 43% and 67% since 2008. Squid catches are also highly seasonal, with most catches occurring from May to September (Figure 4). This pattern likely reflects seasonal patterns in the pollock fishery rather than patterns in squid abundance.

Catch size composition
In 2007, fishery observers began collecting data on the mantle length of squids captured in BSAI pollock fisheries. Because squid are so short-lived and fast-growing, examining these data on a seasonal basis may provide insights into the dynamics of cohorts. The data reveal consistent seasonal patterns from 2007 to 2011 (Figure 5). During the 1st quarter there are two distinct size modes at approximately 13 and 21 cm. The relative size of these modes varies among years. In the 2nd and 3rd quarters there is either a single mode or a dominant mode at the approximate 21 cm size. Data from the 4th quarter are sparse and show little evidence of a dominant size mode. These patterns may be due to the species composition of the catch. The mean mantle length of *B. magister* caught during the 2008 AFSC slope survey was 21.2 cm, and the mean mantle length of *Gonatopsis borealis* in the same survey was 13.7 cm. Thus, the observed size composition may result from a mix of these two species. Alternatively, the different size modes and the variability among quarters may reflect the multiple yearly cohorts that are likely to occur in BSAI squid populations. Aggregate length compositions for each year suggest that the representation of the two modes in the catch (whether as a result of differences in species or age) varies among years (Figure 6). Aggregating the catches by quarter and across years suggests that the pollock fishery may be catching a single cohort: the size mode increased slightly during the first 3 quarters of the year (Figure 7).

Catch distribution
The majority of catches occur in the Bering Canyon region of the southeastern Bering Sea (areas 517 & 519; Table 4 & Figure 3). Catches in the Aleutian Islands appear to have increased slightly since 2008. In the EBS, the distribution of squid catch appears to have remained fairly constant over time. While squids were caught throughout the EBS slope and outer domain of the EBS shelf, the highest catches consistently occurred near the major canyons (Figure 8). Bering Canyon, the southernmost, appears to have the highest catches. Large mean catches were also associated with Pribilof Canyon, and particularly the southern part of this canyon. In some years large catches also occurred in Zhemchug Canyon. Analysis of catch by quarter (Figure 9) indicates that catches during the first half of the year occur in the southern portion of the EBS, while in the third quarter catches shift to the north.

A survey conducted in 2009 in the Bering Canyon region suggested that the density of B. magister increases considerably below 200 m (J. Horne, pers. comm.). This is supported by the depth distribution of B. magister in the AI trawl survey. Incidental catches of squids may thus increase when fishing activity occurs at greater depths. These results suggest a possible mechanism for voluntary avoidance of squid bycatch by the pollock fishery.

<u>Survey data</u>

Distribution and abundance
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. Squid records from these surveys tend to appear at the edges of the continental shelf (Figure 10). This is consistent with results from 1988 and 1989 Japanese / U.S. pelagic trawl research surveys in the EBS that indicated 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. It is also consistent with the observation that the largest biomass of squids is found at depths below 200 m (Figure 11). Survey information is included in this assessment for general information only (Table 5 & Figure 12), and the survey biomass estimates cannot be considered reliable measures of squid abundance. Catches of squids in the EBS shelf survey are highly variable and uncertain, and it is likely that few squid inhabit the bottom waters of the shelf (Table 5). The EBS slope survey, which samples the shelf break area and much deeper waters, generally catches greater numbers of squids. *B. magister*, *G. borealis*, and

R. pacifica are the most common squids in the slope survey (Table 5 & Figure 12) . In the AI, *B. magister* is the only squid species captured in abundance (Table 5 & Figure 12).

Size composition
Although some survey-based mean size data exist for several squid species (Table 6 & Figure 13), the only regularly-available length composition data available are for *B. magister* on the EBS slope (Figure 14). The data suggest the presence of at least two cohorts: in 2010 and 2012, two distinct size modes were observed. The presence of only a single mode in the 2008 survey may indicate interannual differences in the timing and growth of individual cohorts.

Analytic approach and results

The available data do not support population modeling for squids in the BSAI, so most of the stock assessment sections are not relevant.

Harvest recommendations
Squids in the BSAI are currently managed under Tier 6, meaning that ABC and OFL are based on average commercial fishery catch between 1978 and 1995:

2013-2014 Tier 6 harvest recommendations for BSAI squids

average catch 1978-1995	2,624 t
ABC (0.75 * avg. catch)	1,970 t
OFL (avg. catch)	2,624 t

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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). The prey and predators of squids depend on their life stage. Adult squid of many species will actively prey upon fish, squid, and crustaceans, while the larvae likely share the same prey items as larval fish, including copepods, euphausiids, and larval fish. Adult squid will be preyed upon by marine mammals, fish, and other squid, whereas, larval and juvenile squids will be taken by fish, squid, and seabirds.

Squids are central in food webs in both the AI (Figure 15, upper panel) and the EBS (Figure 15, 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, upper panel).

In contrast with predation mortality, estimated fishing mortality on squid is currently very similarly low in all three ecosystems. Figure 16 (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 17, 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 17, 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 18). In addition, squids are important constituents of seabird diets (Figure 19). The input data for the AFSC ecosystem models suggests that squids make up nearly half the diet of fulmars, storm petrels, and the albatross/jaegers group (Figure 19; Aydin et al. 2007). These input data are largely based on diet composition and preference data reported by Hunt et al. (2000).

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 do not have significant impacts on 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.

Data gaps and research priorities

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 potential impacts of incidental removal of squids on 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. This research would require a local estimate of squid abundance but would not require a full BSAI population assessment.

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

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Tables

Table 1. Taxonomic grouping of squid species found in the BSAI.

Class Cephalopoda; Order Oegopsida	
Family Chiroteuthidae	
Chiroteuthis calyx	
Family Cranchiidae	"glass squids"
Belonella borealis	
Galiteuthis phyllura	
Family Gonatidae	"armhook squids"
Berryteuthis anonychus	minimal armhook squid
Berryteuthis magister	magistrate armhook squid
Eogonatus tinro	
Gonatopsis borealis	boreopacific armhook squid
Gonatus berryi	Berry armhook squid
Gonatus madokai	
Gonatus middendorffi	
Gonatus onyx	clawed armhook squid
Family Onychoteuthidae	"hooked squids"
Moroteuthis robusta	robust clubhook squid
Onychoteuthis borealijaponicus	boreal clubhook squid
Class Cephalopoda; Order Sepioidea	
Rossia pacifica	North Pacific bobtail squid

Table 2. Estimated total (retained and discarded) catches of squid (t) in the eastern Bering Sea and Aleutian Islands by groundfish fisheries, 1977-2012, and estimated retention rates. JV=Joint ventures between domestic catcher boats and foreign processors.

	Eastern Bering Sea				Aleutian Islands				BSAI	%
Year	foreign	JV	domestic	total EBS	foreign	JV	domestic	total AI	total	retained
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			1,246	1,246			36	36	1,282	
2004			1,000	1,000			14	14	1,014	
2005			1,170	1,170			17	17	1,186	
2006			1,403	1,403			15	15	1,418	
2007			1,175	1,175			13	13	1,188	
2008			1,494	1,494			49	49	1,542	67%
2009			269	269			91	91	360	51%
2010			305	305			105	105	410	63%
2011			237	237			99	99	336	43%
*2012**			*474*	*474*			*125*	*125*	*598*	*66%*

* 2012 catch and retention data are incomplete; retrieved September 28, 2012.

Data Sources: Foreign and JV catches-U.S. Foreign Fisheries Observer Program, AFSC Domestic catches before 1989 (retained only; do not include discards): Pacific Fishery Information Network (PacFIN). Domestic catches 1989-2002: NMFS Alaska Regional Office BLEND. Domestic catches 2003-present: NMFS AKRO Catch Accounting System.

Table 3. Estimated catch (t) of all squid species combined by target fishery, 2003-2012. Data sources as in Table 2.

target fishery	2003	2004	2005	2006	2007	2008	2009	2010	2011	*2012**
walleye pollock	1,226	977	1,150	1,399	1,169	1,452	209	277	178	*426*
arrowtooth flounder	7	6	10	4	3	46	96	104	67	*60*
Kamchatka flounder	0	0	0	0	0	0	0	0	48	*76*
rockfish	12	6	7	6	8	25	18	12	37	*14*
Atka mackerel	21	7	9	9	5	12	14	16	5	*21*
yellowfin sole	1	0	0	0	0	0	0	0	0	*0*
rock sole	0	0	0	0	0	0	0	0	0	*0*
flathead sole	0	4	1	0	0	0	0	0	0	*0*
Pacific cod	9	6	3	1	1	0	0	0	0	*0*
other flatfish	3	2	6	0	2	1	0	0	0	*0*
Greenland turbot	3	6	0	0	0	4	23	1	0	*0*
Alaska plaice	0	0	0	0	0	0	0	0	0	*0*
sablefish	0	0	0	0	0	1	0	0	0	*0*
BSAI total	**1,282**	**1,014**	**1,186**	**1,418**	**1,188**	**1,542**	**360**	**410**	**336**	***598***

* 2012 catch estimate as of September 28, 2012.

Table 4. Estimated catch (t) of all squid species combined by area, 2002-2012*. Data sources as in Table 2.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	***2012****
					AI					
541	9	4	3	2	2	25	66	90	75	*113*
542	10	7	2	6	3	6	5	4	8	*4*
543	17	3	12	7	8	18	20	11	16	*8*
AI total	**36**	**14**	**17**	**15**	**13**	**49**	**91**	**105**	**99**	***125***
					EBS					
508	0	0	0	0	0	0	0	0	0	*0*
509	2	7	5	162	13	25	1	5	3	*16*
513	2	2	0	1	12	9	2	0	1	*1*
514	0	0	0	0	0	0	0	0	0	*0*
516	0	0	0	0	0	0	0	0	0	*0*
517	746	587	539	965	690	1,066	143	133	119	*227*
518	0	0	0	0	0	23	40	17	30	*17*
519	484	398	527	261	419	344	74	145	52	*183*
521	12	5	95	15	26	25	9	5	17	*20*
523	0	0	3	0	0	1	0	1	3	*0*
524	0	0	0	0	15	0	0	0	12	*9*
EBS total	**1,246**	**1,000**	**1,170**	**1,403**	**1,175**	**1,494**	**269**	**305**	**237**	***474***
BSAI total	**1,282**	**1,014**	**1,186**	**1,418**	**1,188**	**1,542**	**360**	**410**	**336**	***598***

*2012 catch estimate as of September 28, 2012.

Table 5. Survey biomass estimates ("bio", in metric tons) and coefficients of variation (CV) for the EBS shelf, EBS slope, and AI. Estimates are included for the principal species caught in each survey. Numerous species occur on the slope and are included in the "total squids" category for that region. Red cells mark CVs in excess of 0.5.

	EBS shelf				**EBS slope**								**AI**	
	R. pacifica		*B. magister*		*R. pacifica*		*B. magister*		*G. borealis*		total squids		*B magister*	
	bio	CV	bio	CV	bio	CV	bio	CV	bio	CV	bio	CV	bio	CV
1983	100	0.32	0	-									9,557	0.33
1984	61	0.30	14	0.94										
1985	4	0.75	13	1.00										
1986	34	0.35	0	-									15,761	0.51
1987	46	0.41	80	1.00										
1988	97	0.63	0	-										
1989	3	1.00	0	-										
1990	5,680	0.99	0	-										
1991	0	-	0	-									28,934	0.89
1992	0	-	0	-										
1993	0	-	0	-										
1994	0	-	0	-									11,084	0.84
1995	6	0.70	0	-										
1996	23	0.42	0	-										
1997	3	1.00	0	-									2,689	0.24
1998	60	0.46	0	-										
1999	19	0.48	0	-										
2000	13	0.45	42	0.82									2,758	0.18
2001	20	0.51	280	0.42										
2002	33	0.39	0	-	52	0.18	1,198	0.12	2	0.74	1,270	0.11	2,088	0.14
2003	27	0.37	16	1.00										
2004	6	0.82	0	-	58	0.19	1,418	0.14	52	0.37	1,642	0.13	3,250	0.37
2005	13	0.67	0	-										
2006	9	0.74	47	1.00									1,468	0.14
2007	11	0.71	0	-										
2008	8	0.52	0	-	36	0.32	1,717	0.10	54	0.41	1,826	0.09		
2009	19	0.41	623	1.00										
2010	42	0.60	9	1.00	72	0.25	1,831	0.10	8	0.32	1,928	0.10	2,444	0.22
2011	25	0.51	1	1.00										
2012	25	0.43	43	1.00	43	0.23	1,298	0.09	13	0.40	1,361	0.09	4,011	0.28

Table 6. Mean lengths (cm) for squid species and species groups caught during the 2008 EBS slope survey conducted by the AFSC. SE = standard error, N = sample size. Mean length for *B. magister* was calculated from extrapolated numbers based on length composition data, so no SE was calculated. Exact N for the *B. magister* data is unknown but is in excess of 1,000 individual measurements.

species	mean	SE	N
Gonatus pyros	6.0		1
Rossia pacifica	6.6	0.3	25
Gonatus onyx	8.0		1
Gonatopsis borealis	13.7	0.2	122
Gonatus berryi	19.0	7.0	3
Berryteuthis magister	21.2	N/A	N/A
Chiroteuthis calyx	25.0		2
Gonatus sp.	21.0	6.0	2
Gonatidae unidentified	4.5	2.5	2
squid unidentified	6.2	0.3	10

Figures

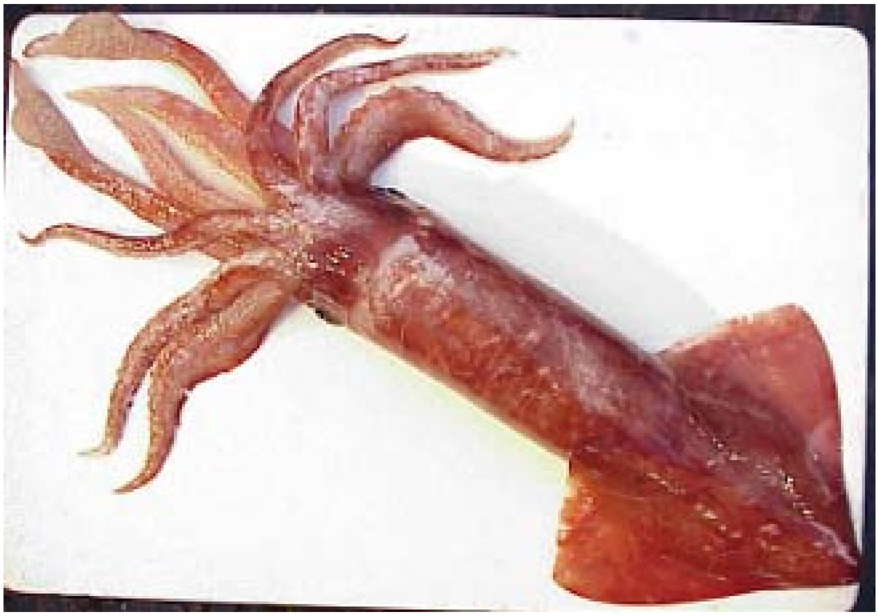


Figure 1. *Berryteuthis magister*, the magistrate armhook or red squid, is a common species in the BSAI and shows the general physical characteristics of species in the Order Teuthoidea.

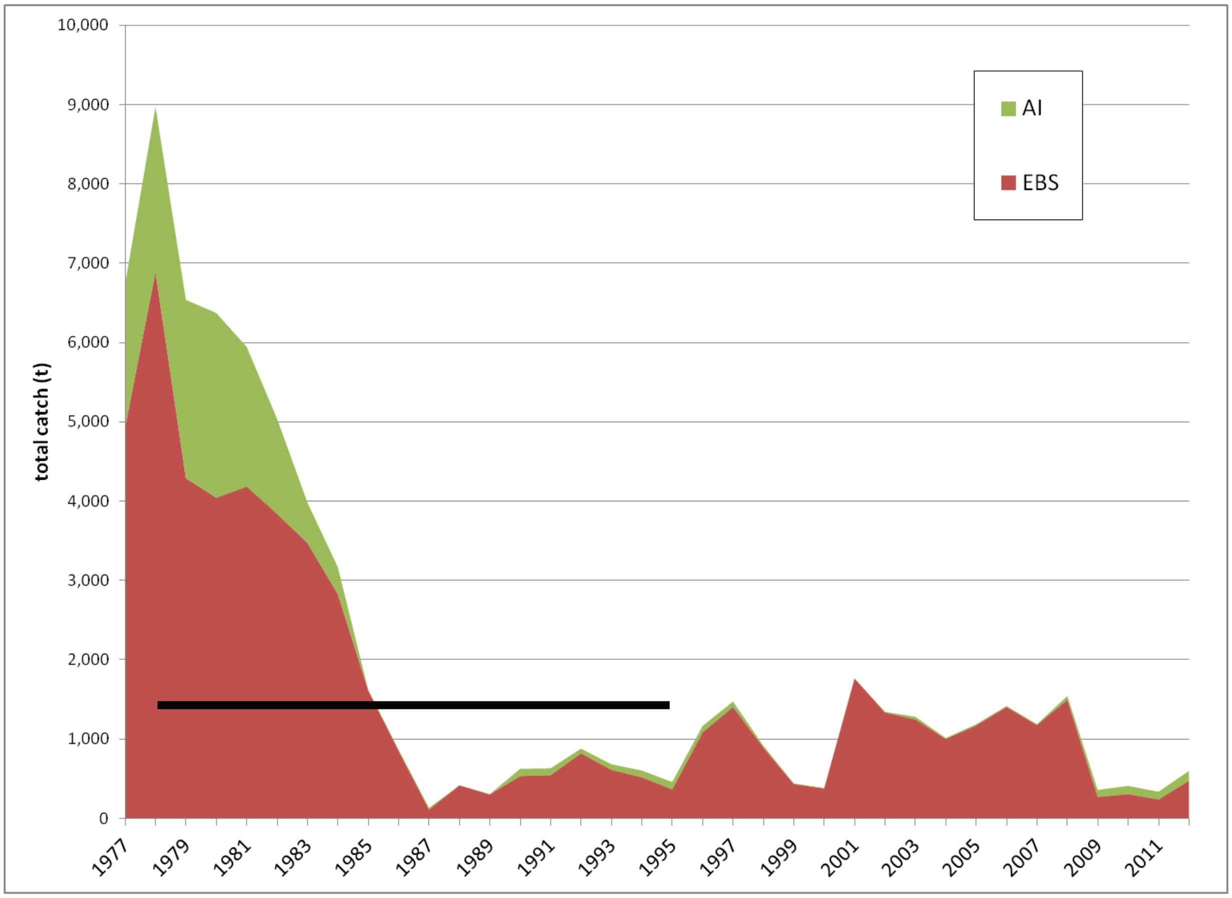


Figure 2. Historical catches of squids in the Bering Sea and Aleutian Islands, 1977-present. Black horizontal line represents the period used for generating harvest recommendations.

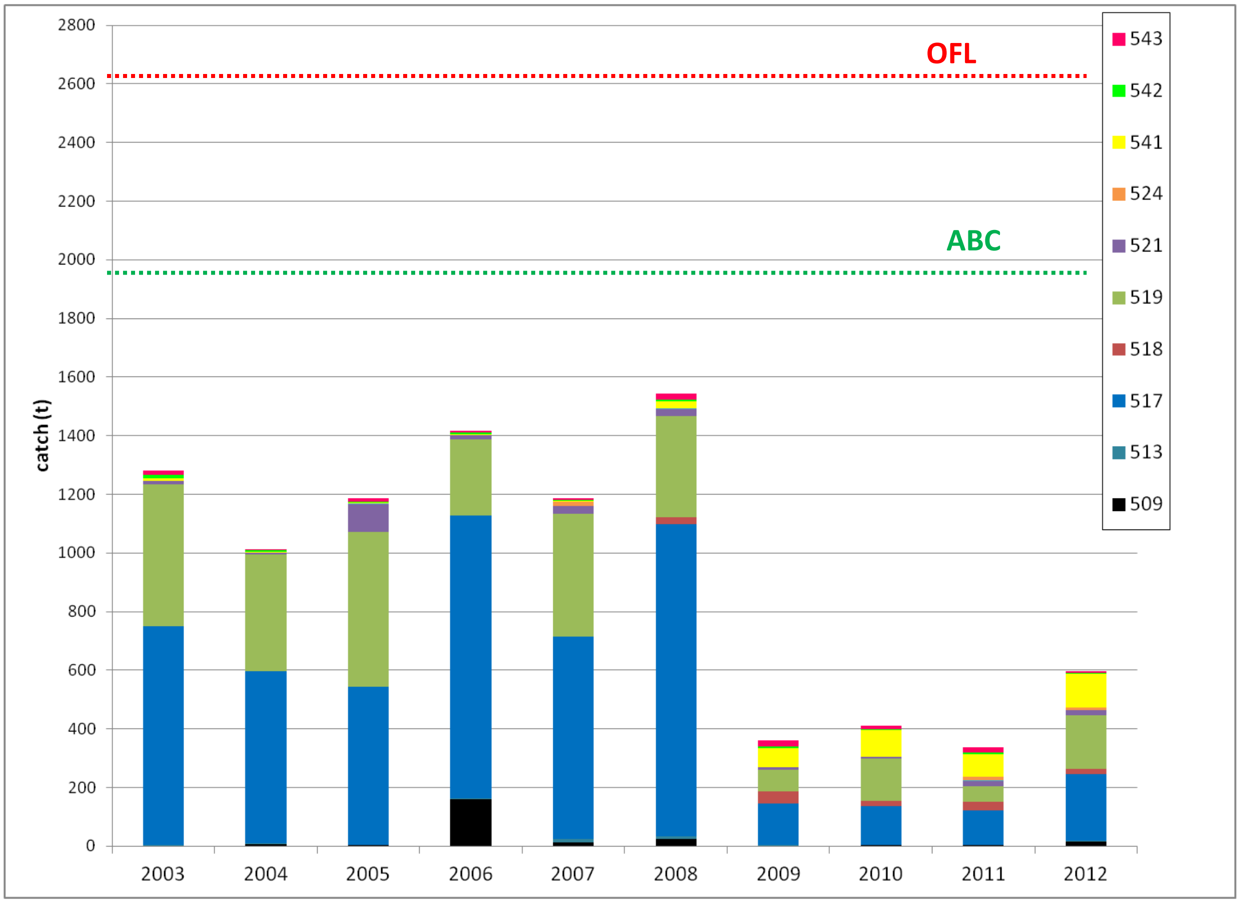


Figure 3. Estimated total fishery catch (t) of all squid species in NMFS management areas of the BSAI region, 2003-2012 (2012 data as September 28, 2012). Numbers in legend refer to management area. The recommended OFL and ABC for 2013 are indicated on the plot.

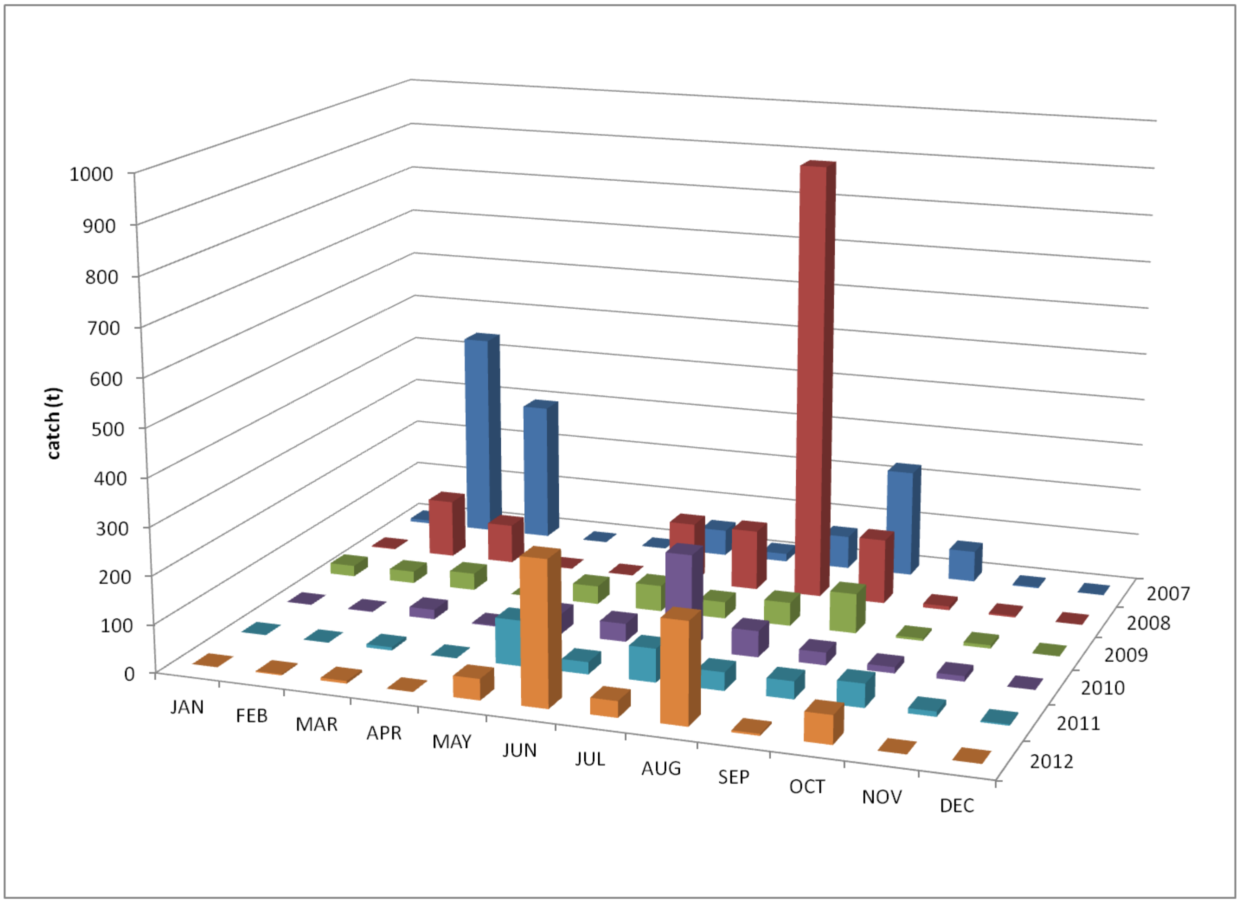


Figure 4. Catches (t) of squids in the BSAI by month and year, 2007-2012. 2012 data are incomplete; retrieved October 28, 2012.

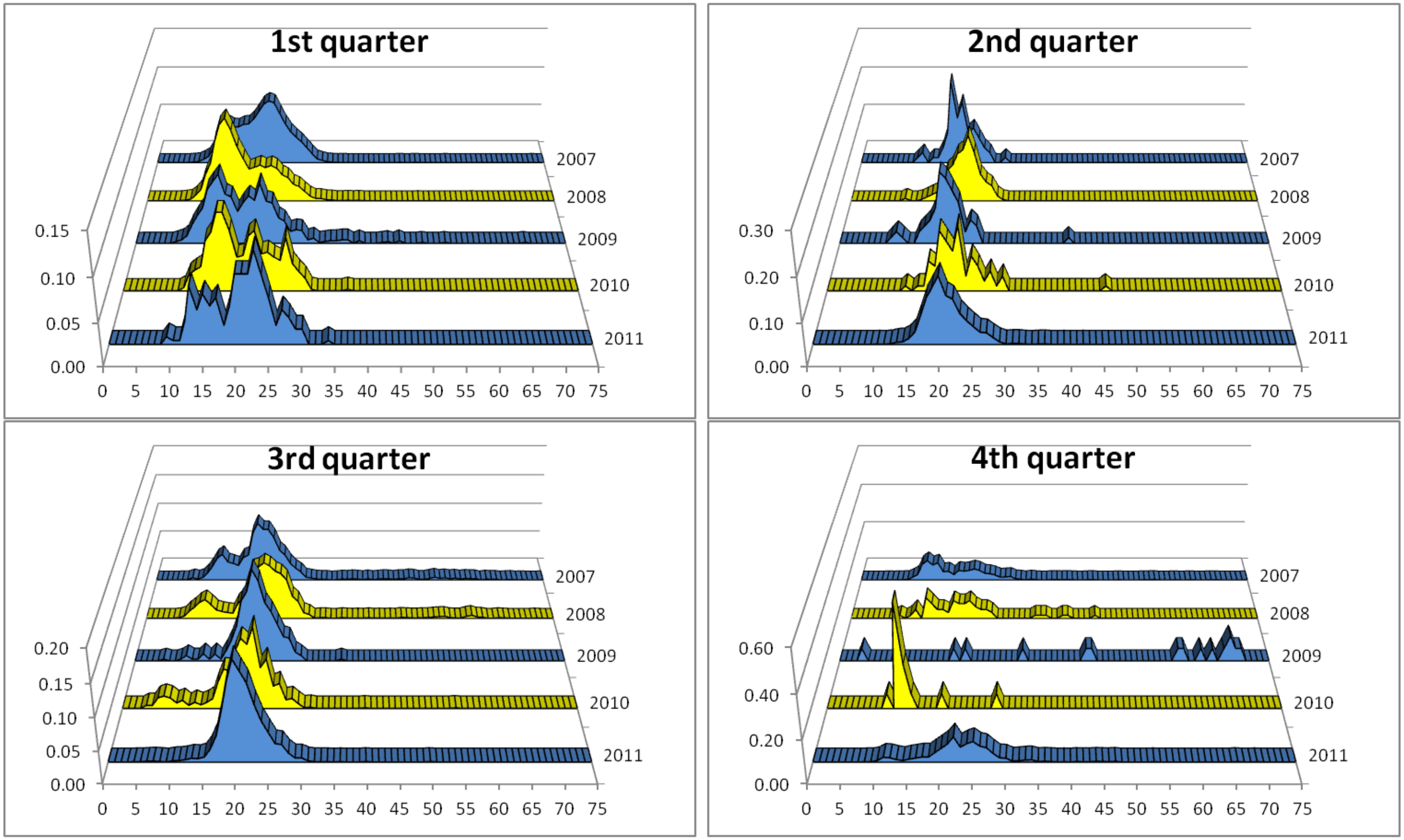


Figure 5. Length compositions, by year and quarter, of squids captured in BSAI federal fisheries, 2007-2011. Data are from the AFSC's Fishery Monitoring and Analysis program.

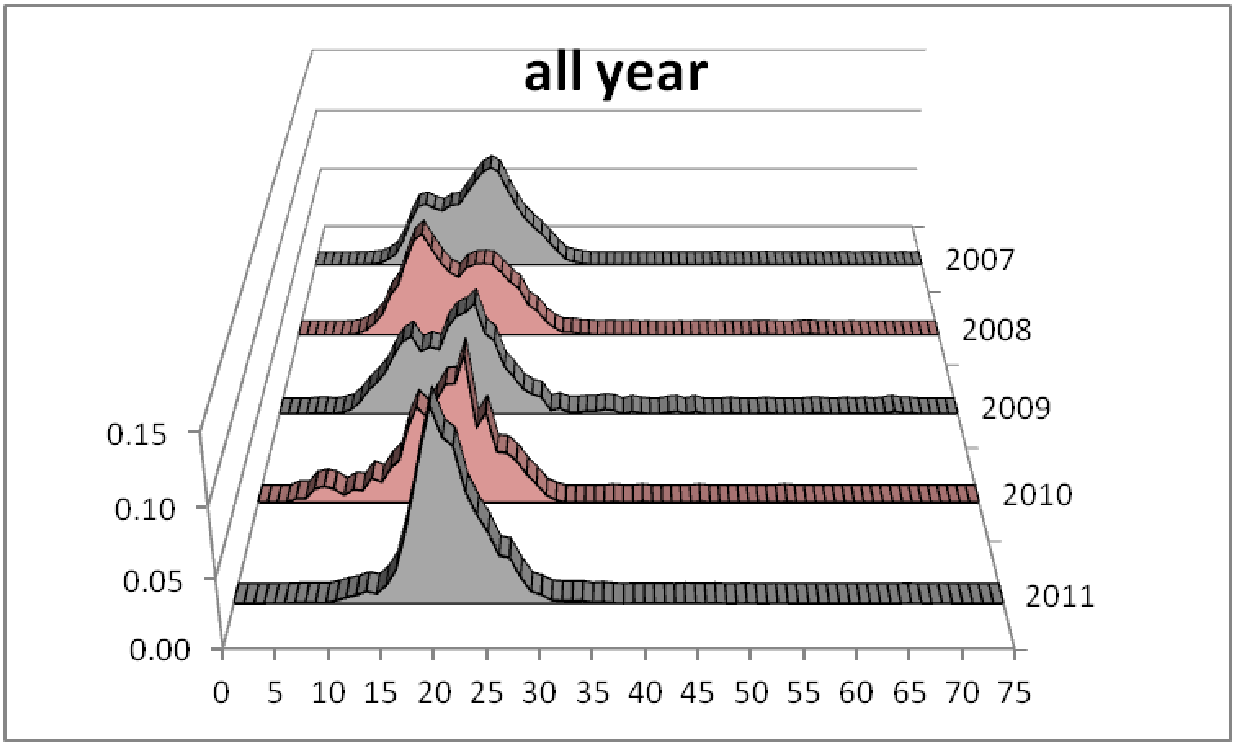


Figure 6. Length compositions by year, of squids captured in BSAI federal fisheries, 2007-2011. Data are from the AFSC's Fishery Monitoring and Analysis program.

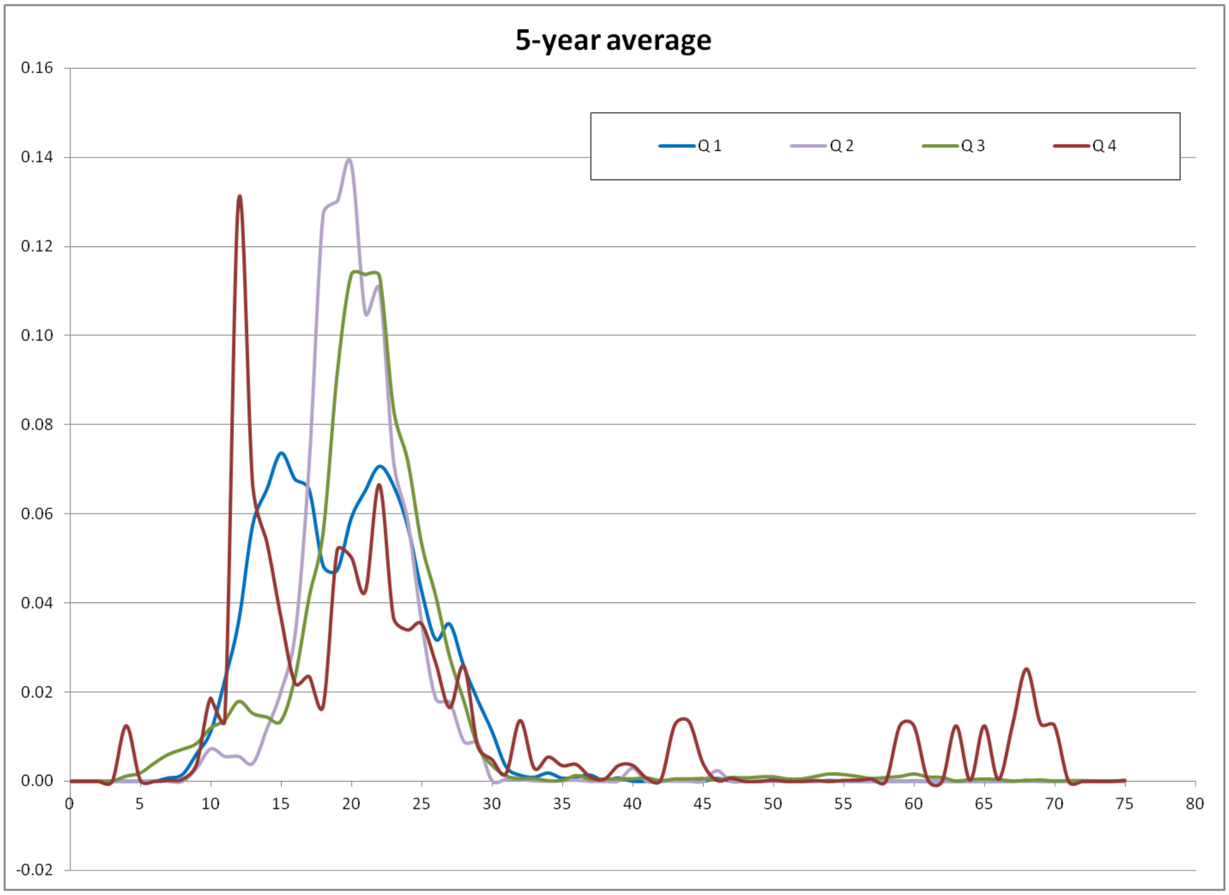


Figure 7. Five-year average length compositions,by quarter, of squids captured in BSAI federal fisheries, 2007-2011. Data are from the AFSC's Fishery Monitoring and Analysis program.

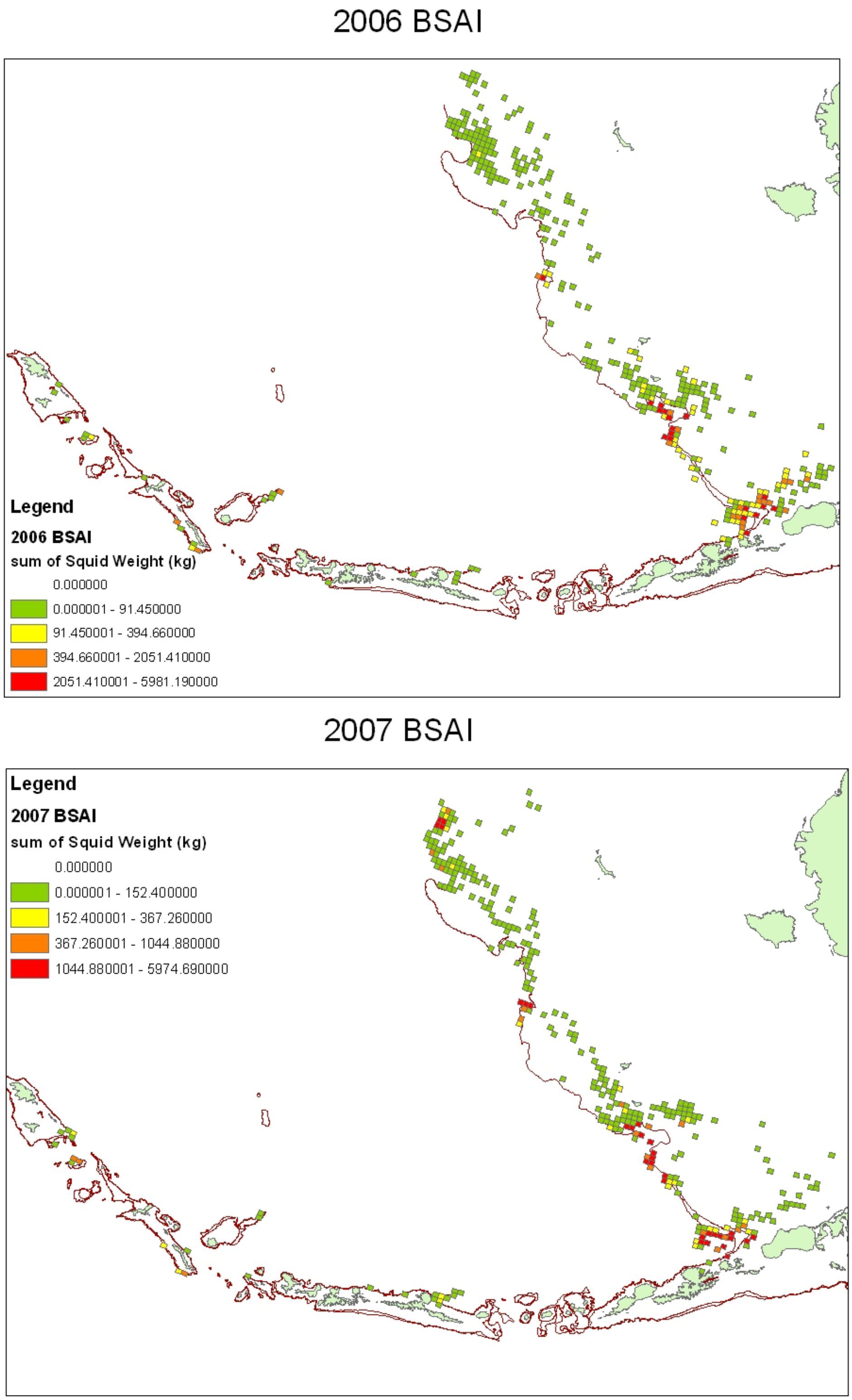
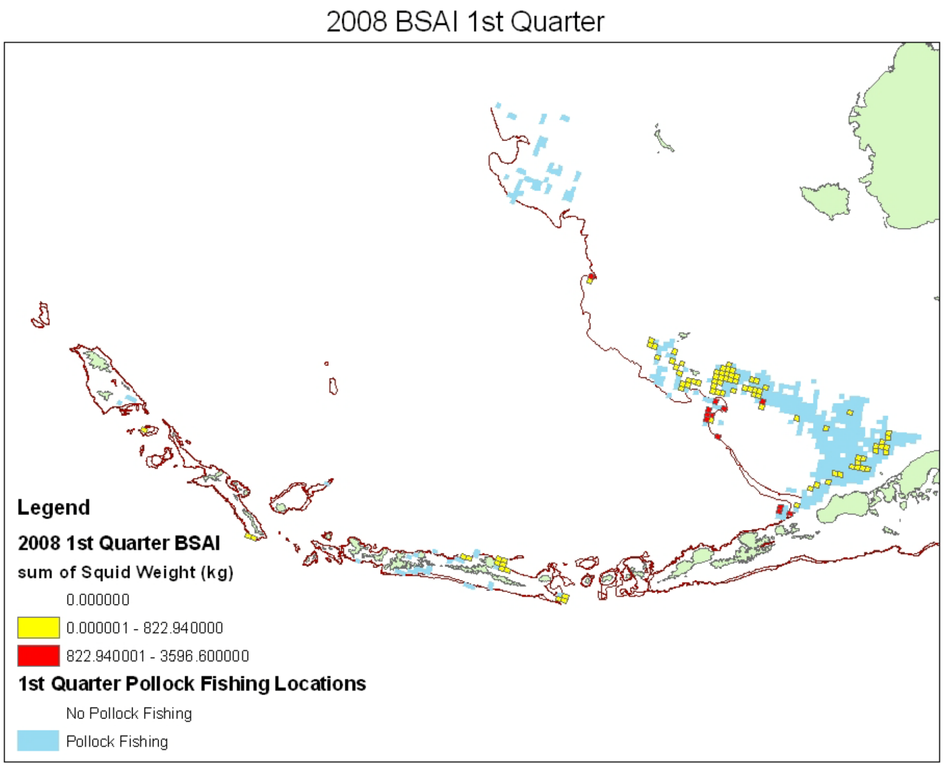


Figure 8. . Distribution of annual squid catches from 2006-2007. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.



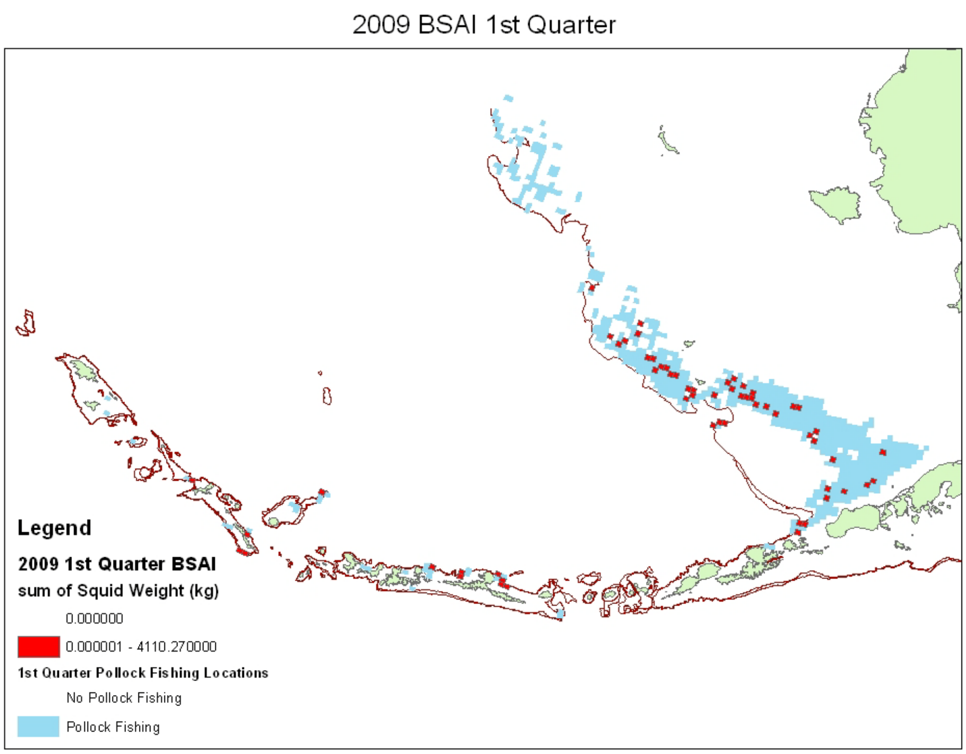
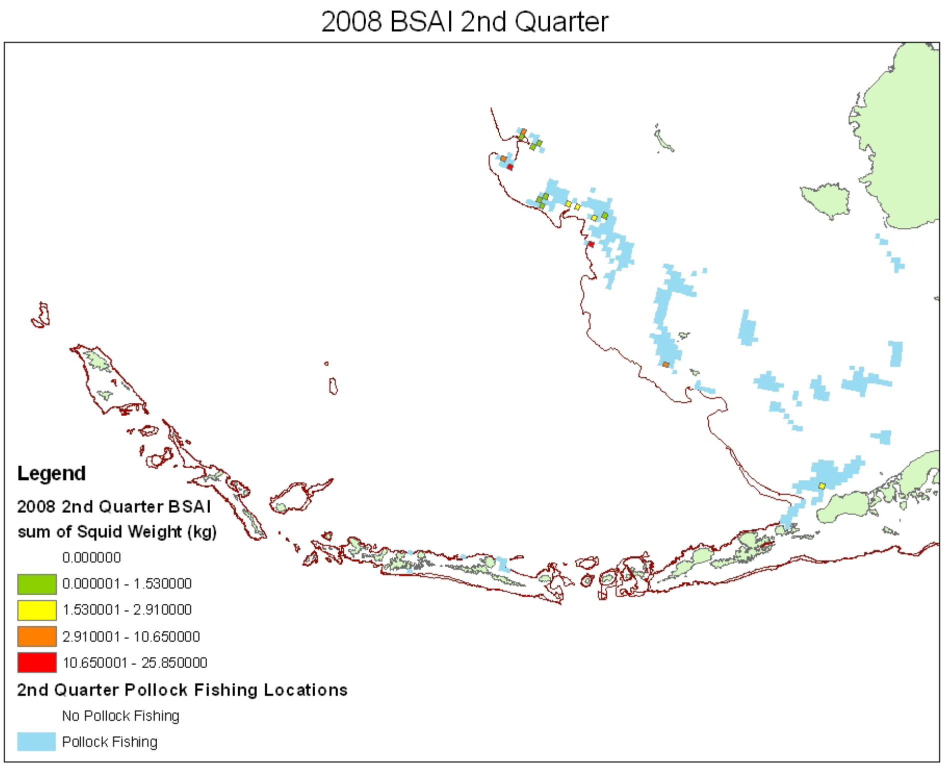


Figure 9. Distribution of squid catches by quarter, 2008-2009. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.



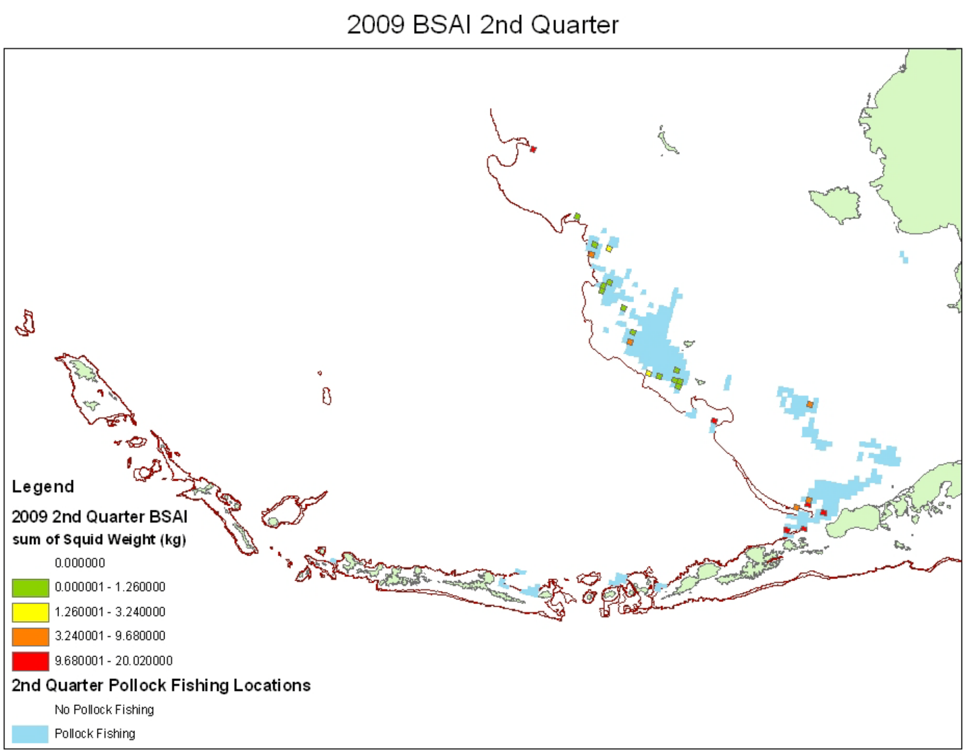
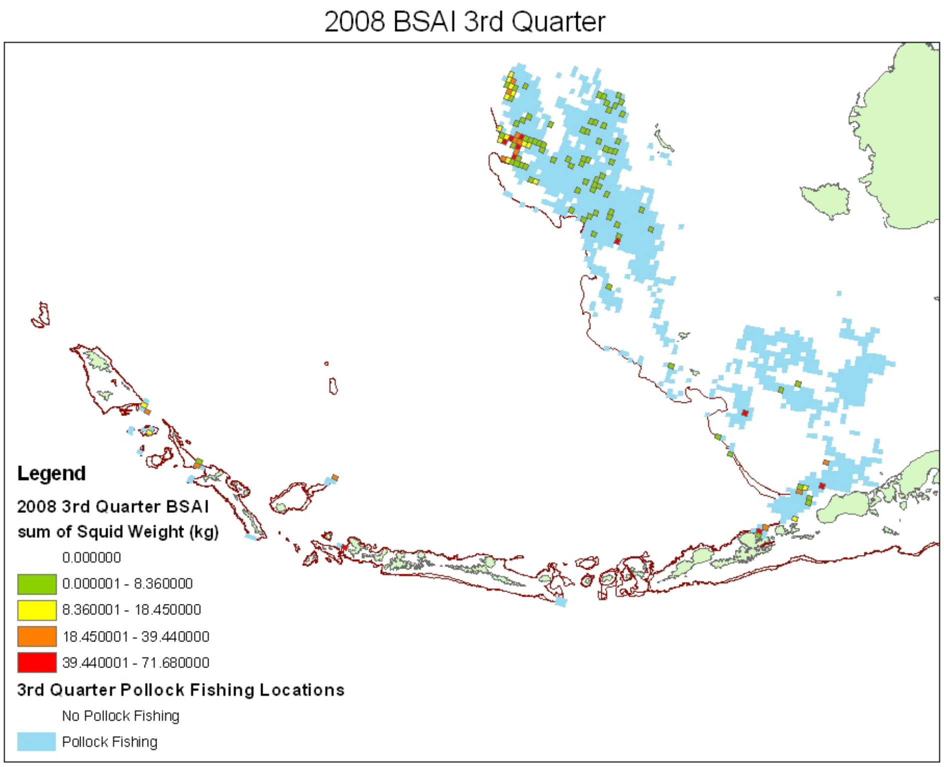


Figure 9 (continued). Distribution of squid catches by quarter, 2008-2009. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.



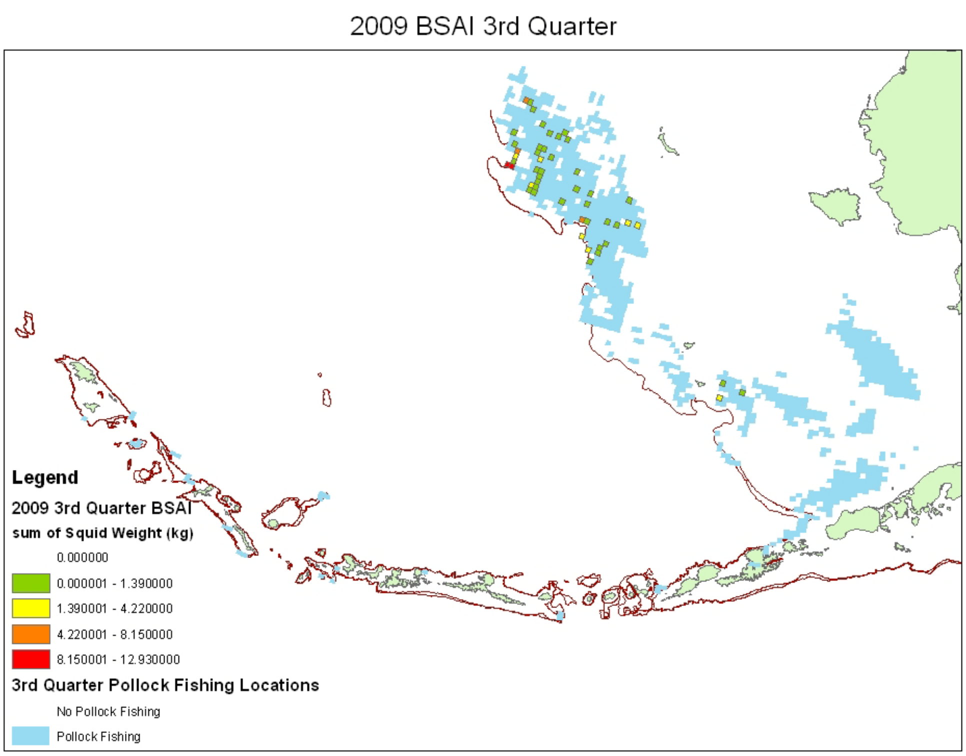
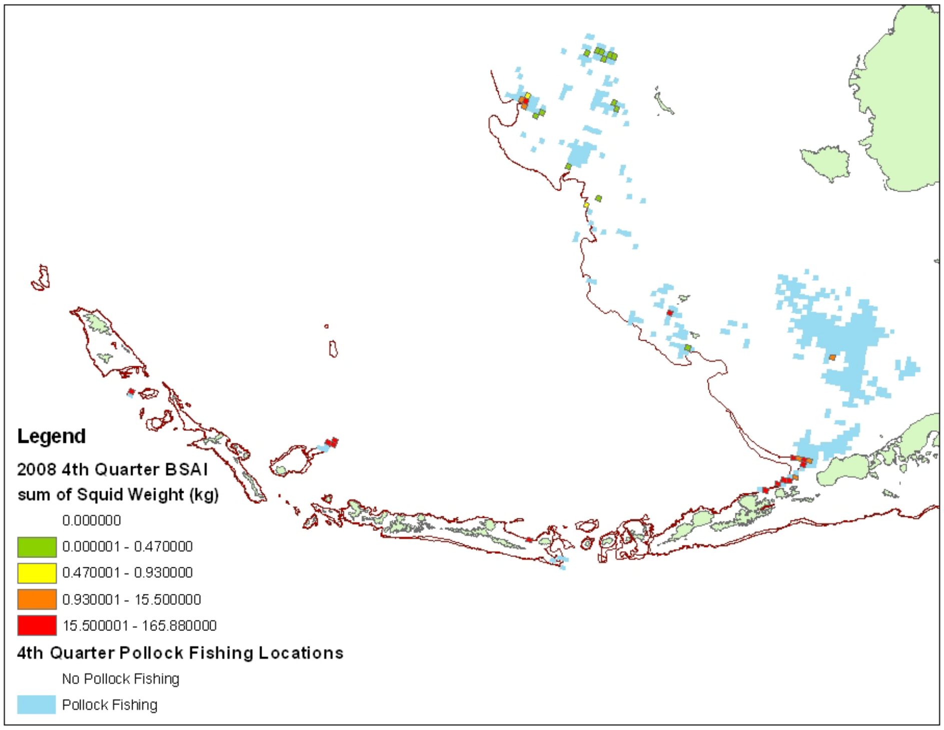


Figure 9 (continued). Distribution of squid catches by quarter, 2008-2009. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.

2008 BSAI 4th Quarter



2009 BSAI 4th Quarter

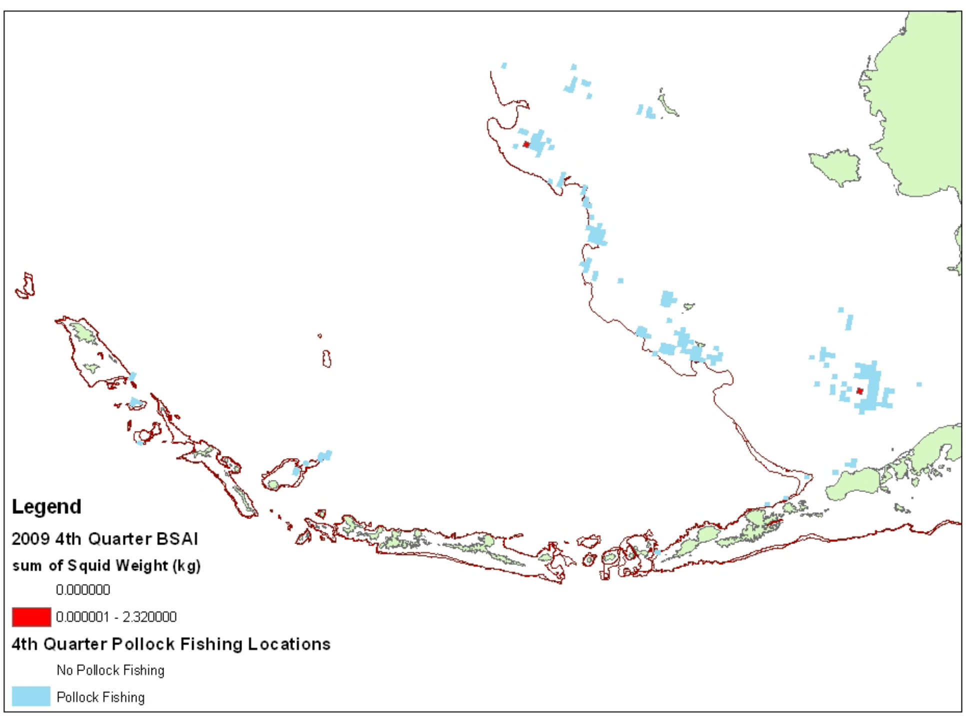


Figure 9 (continued). Distribution of squid catches by quarter, 2008-2009. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.

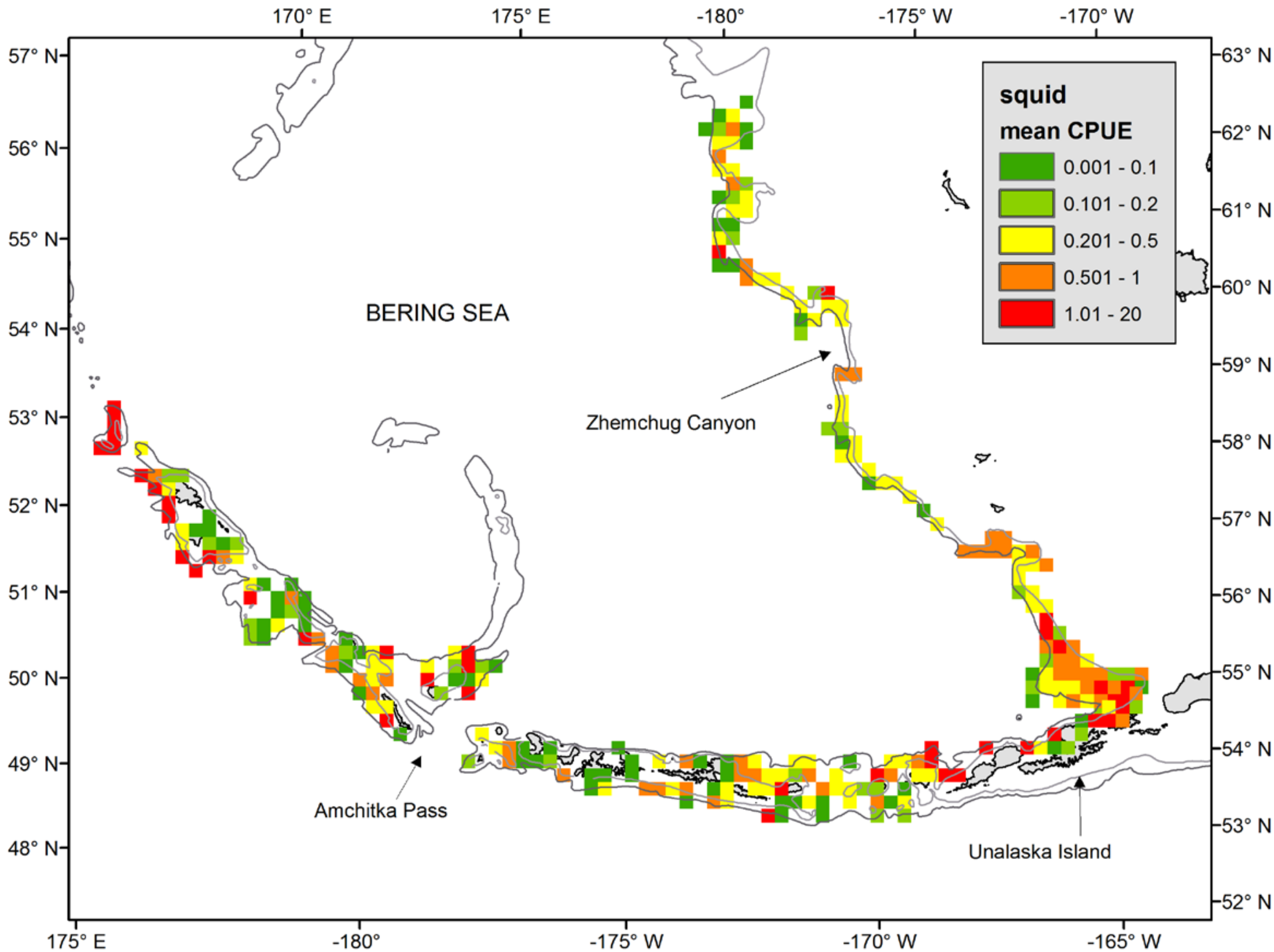


Fig. 10. Mean trawl survey CPUE of all squid species combined in the BSAI, 2000-2012. Grid cells are 20 km X 20 km.

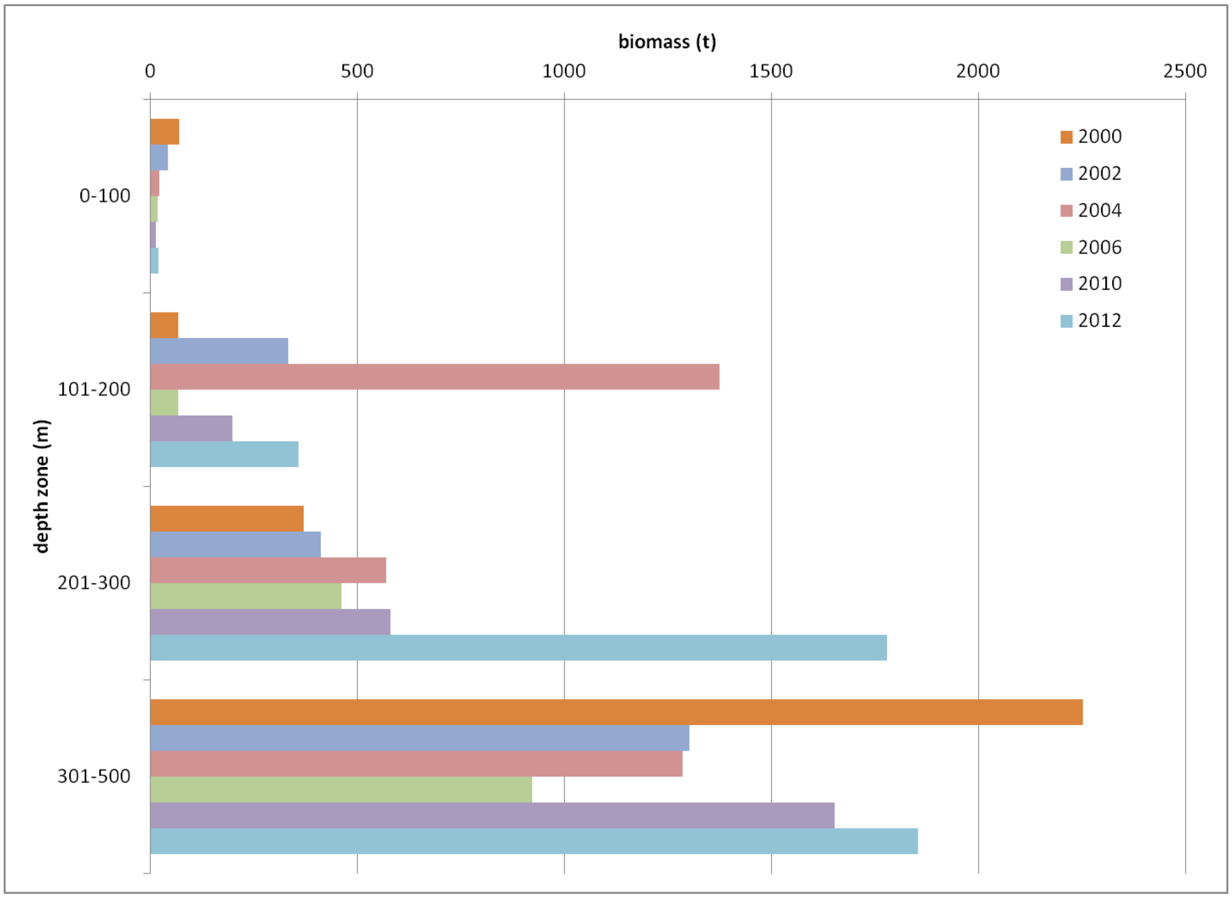


Figure 11. Depth distribution of *Berryteuthis magister* survey biomass estimates in the AI, 2000-2012.

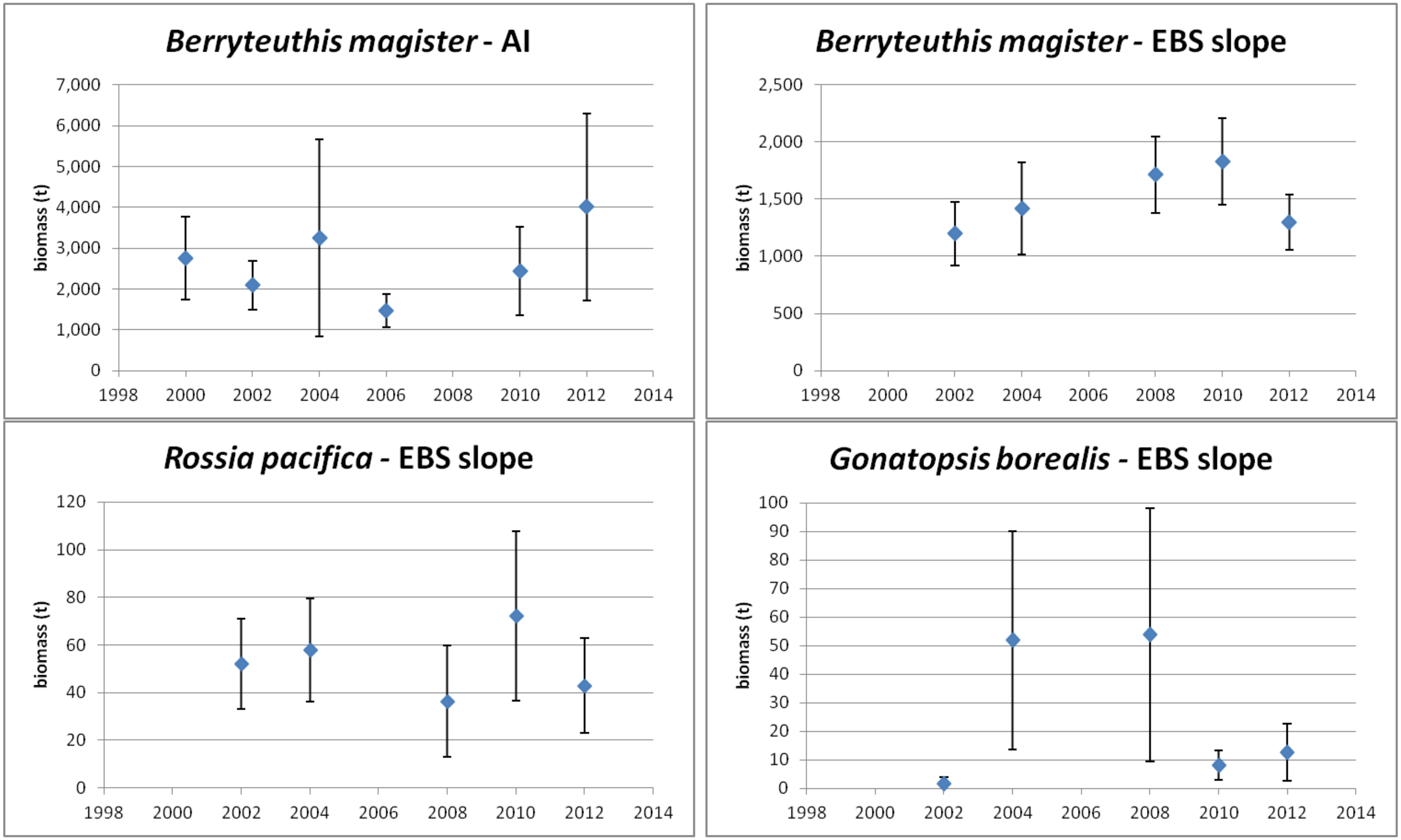


Figure 12. Timeseries of biomass estimates (t) for selected squid species in the Aleutian Islands (AI) and on the eastern Bering Sea (EBS) slope, 1998-2012. Error bars show 95% confidence intervals.

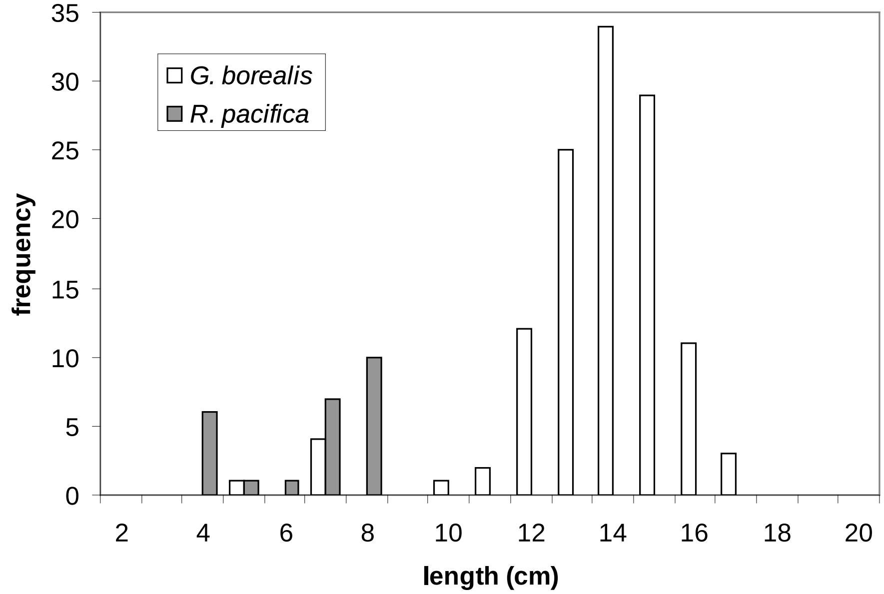


Figure 13. Length compositions of *G. borealis* and *R. pacifica* caught during the 2008 EBS slope survey conducted by the AFSC. Data shown are numbers of individuals observed at each length.

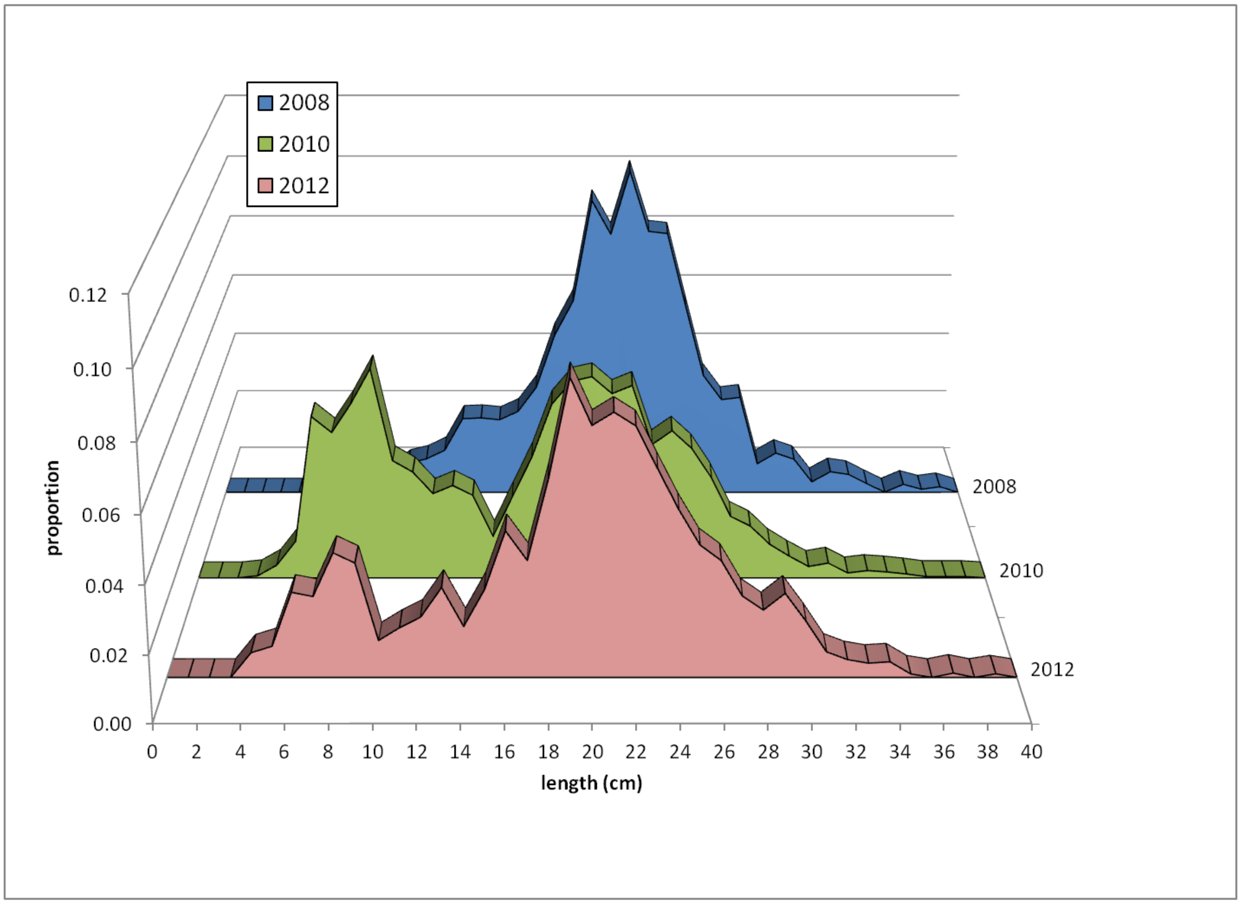


Figure 14. Length composition of *B. magister* caught during the 2008-2012 EBS slope surveys conducted by the AFSC. Proportions were calculated from extrapolated numbers at length.

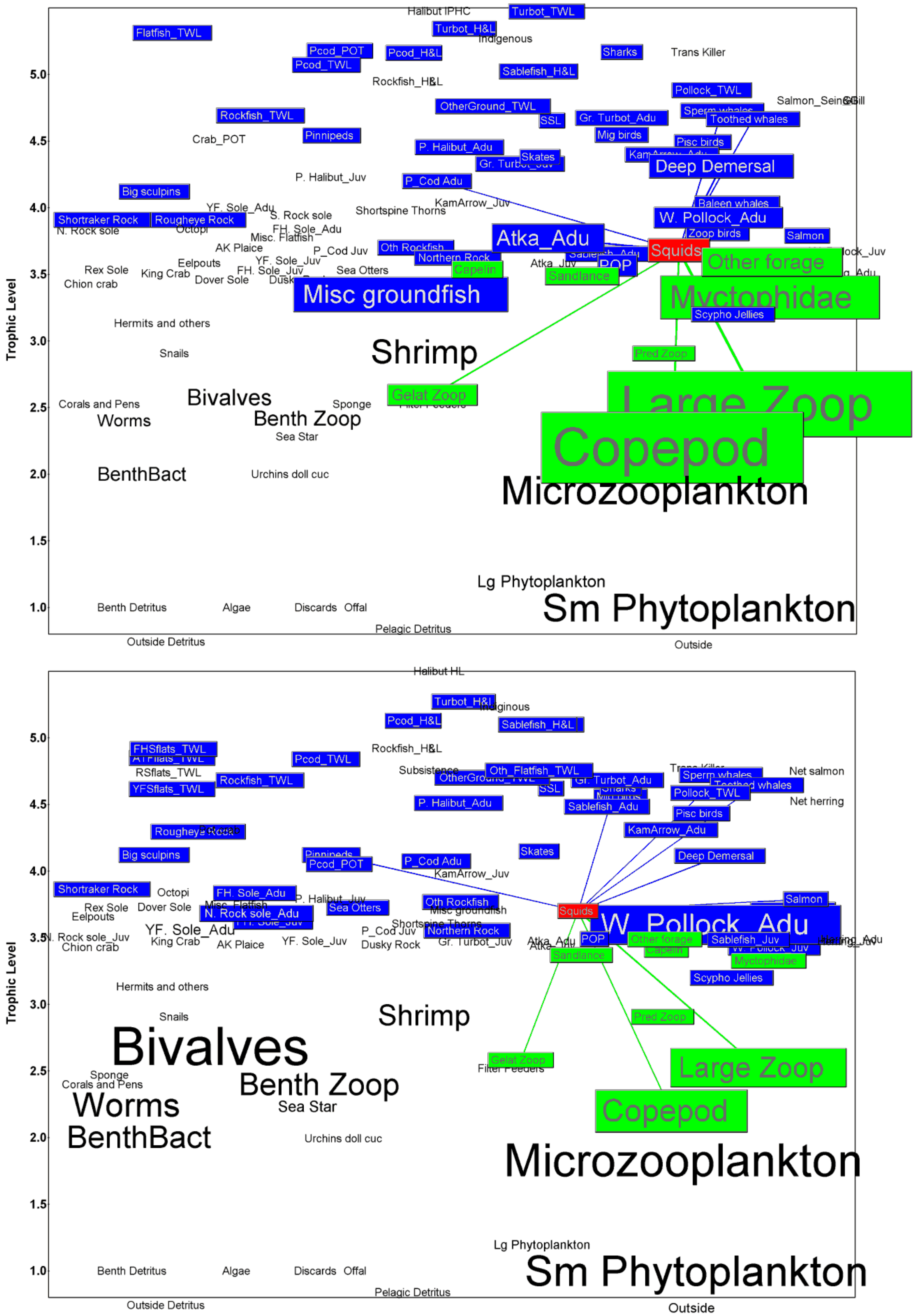


Figure 15. AI (upper) and EBS (lower) food webs of squids (red), predators (blue), and prey (green).

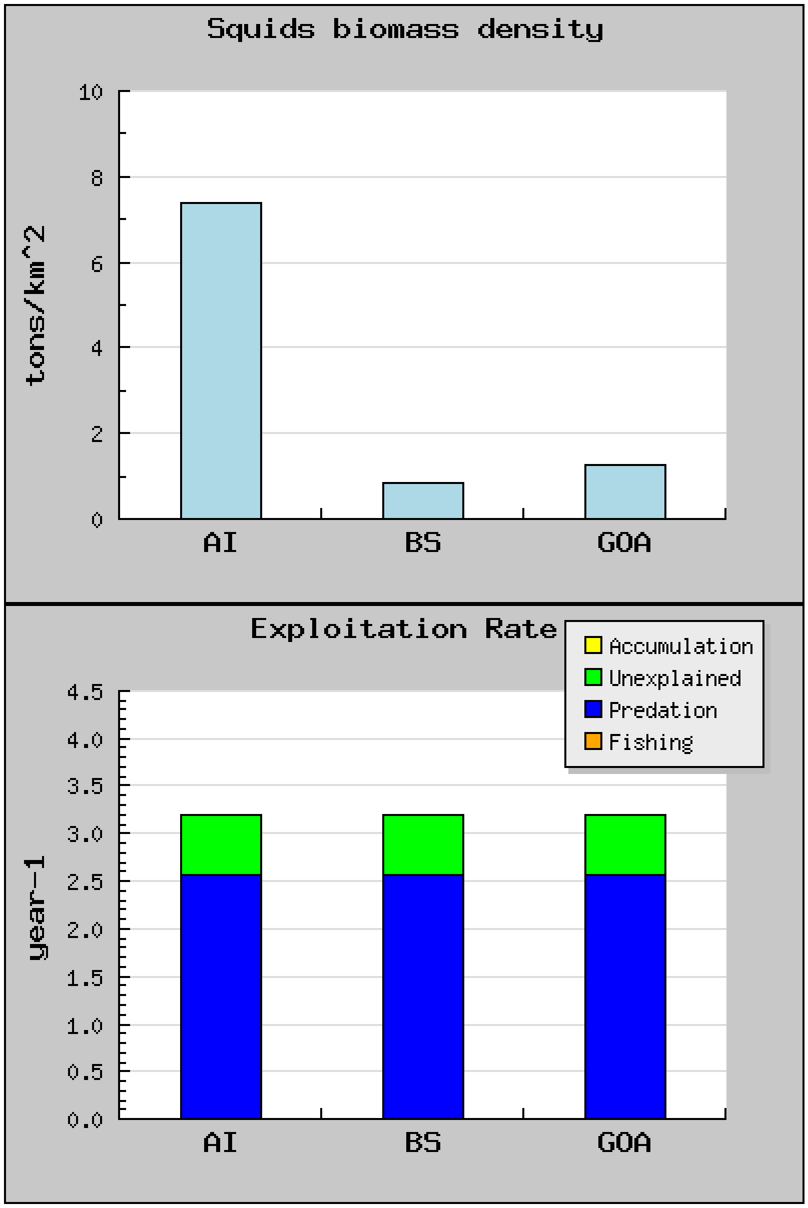


Figure 16. Biomass density (tons per square kilometer) come from direct estimates of consumption by groundfish of the AI, EBS, and GOA (upper panel), and exploitation rates partitioned into mortality due to predation, fishing, and unexplained sources (lower panel). Fishing mortality has been included 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).

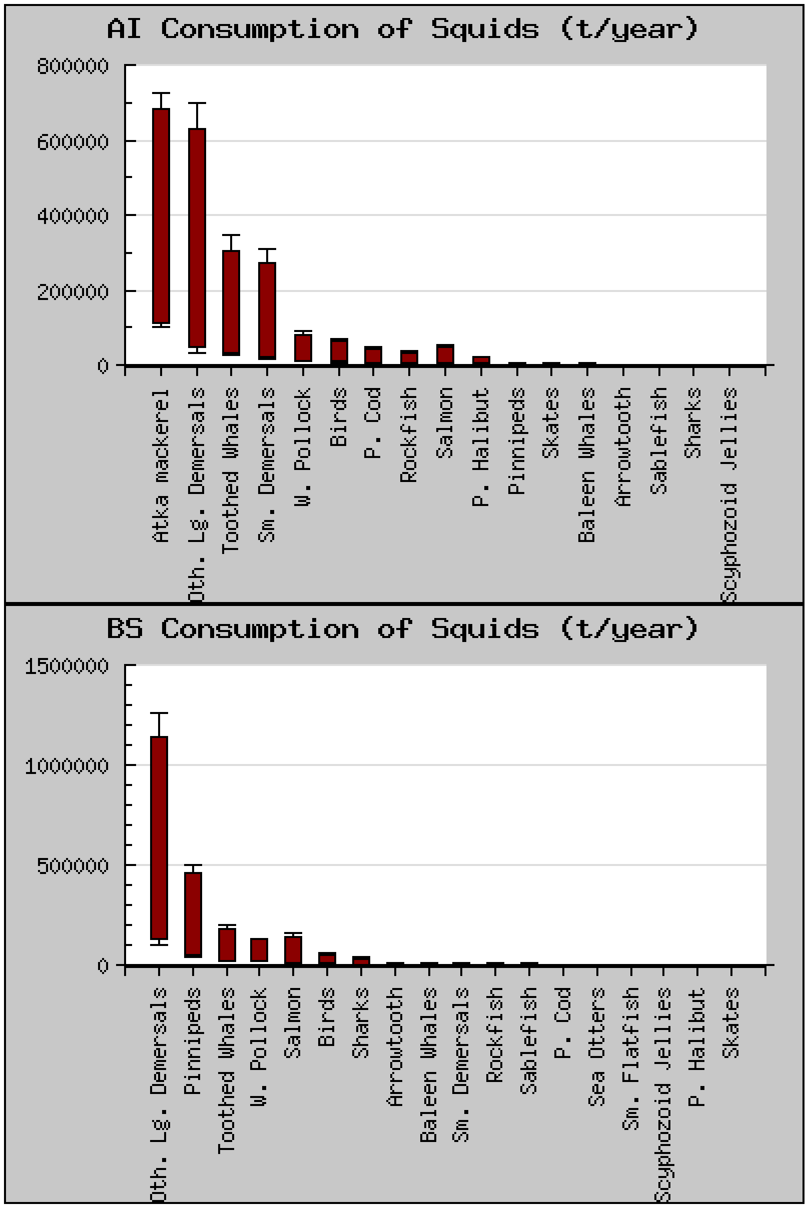


Figure 17. Consumption of squids estimated from ecosystem models for the AI (upper) and EBS (lower), based on early 1990's data and incorporating uncertainty. "Other large demersals" is primarily grenadiers (Macrouridae) in both ecosystems.
Disclaimer: Figures generated in October 2005, we are currently awaiting updated figures. Description of method is in an appendix of the Ecosystem considerations chapter.

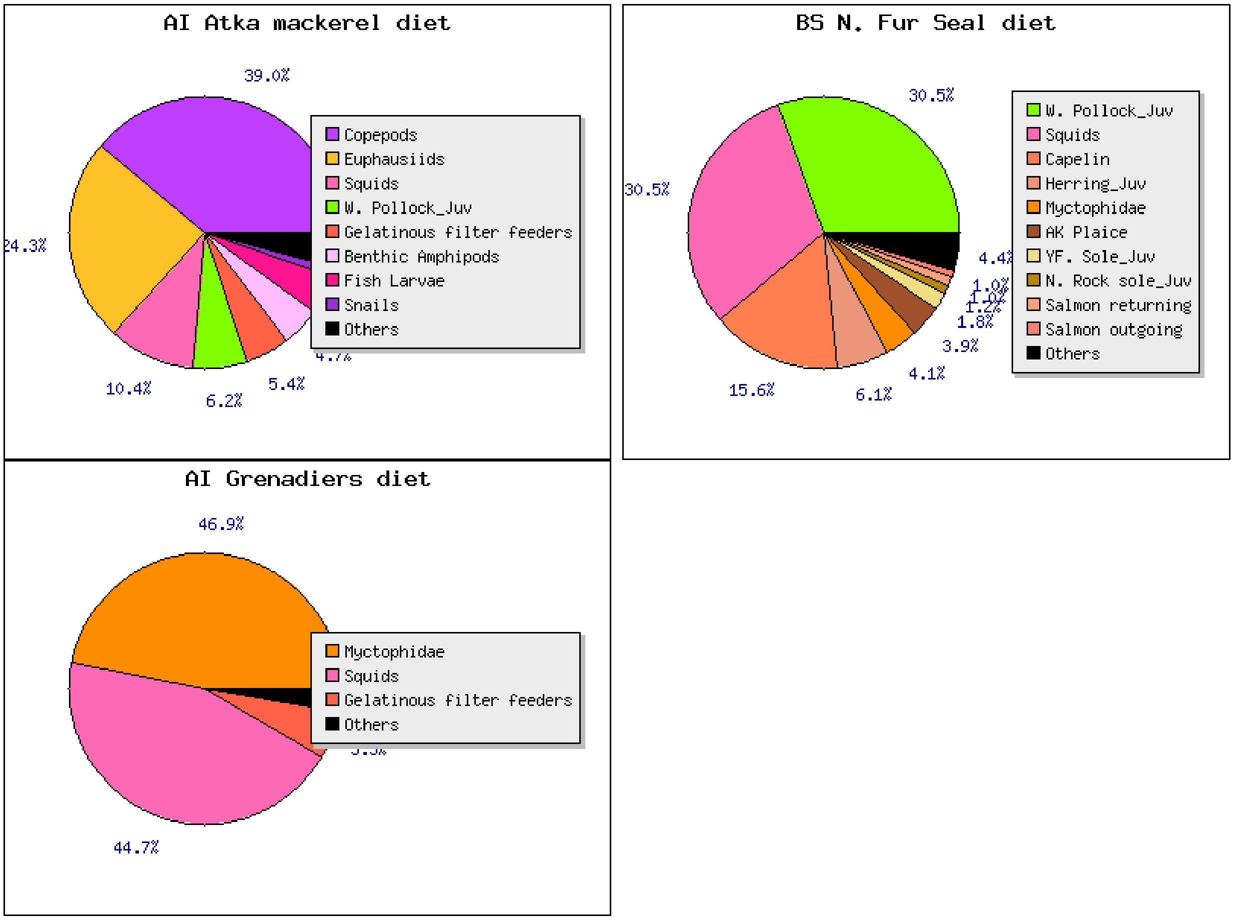


Figure 18. Proportion of squids in diets of major squid consumers in BSAI: Atka mackerel (top), northern fur seals (center), and grenadiers (bottom). EBS grenadier diets (not shown) are similar to AI.
Disclaimer: Figures generated in October 2005, we are currently awaiting updated figures. Description of method is in an appendix of the Ecosystem considerations chapter.

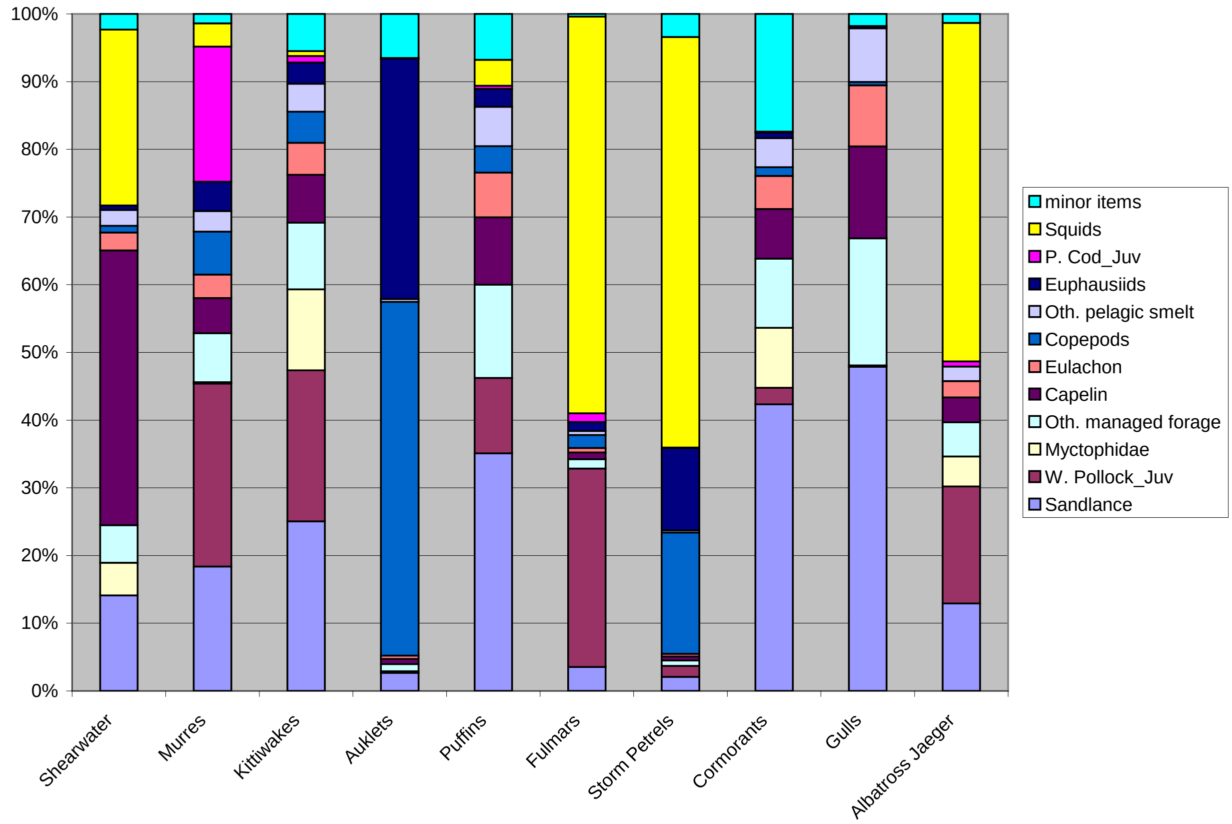


Figure 19. Estimated diet composition of seabirds in the GOA. Data are the inputs used in ecosystem modeling performed at the AFSC (Aydin et al. 2007) and are based largely on Hunt et al. (2000). Albatrosses and jaegers are considered a single functional group for modeling purposes.