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

Olav A. Ormseth
NMFS Alaska Fisheries Science Center

Executive Summary

Summary of changes in assessment inputs

Before this assessment, harvest recommendations for BSAI squids have been made based on the average catch from 1978-1995. In 2014 and particularly 2015, squid catches increased substantially and the current specifications acted as a constraint on the directed pollock fishery, where most squid are captured. In both years a voluntary spatial closure in the Bering Canyon area where squid bycatch was particularly high was adopted by the pollock fleet. This limited fishing access to the fleet and may have interfered with the fleet's ability to avoid chinook and chum salmon. As a result the Plan Teams and the SSC requested that the assessment author revisit the analytic approach and develop a set of harvest recommendations that better reflect a sustainable level of squid removals. This resulted in the following changes to the assessment:

1) The harvest recommendations are based on the years 1977-1981 rather than 1978-1995; OFL is still calculated as average catch.
2) A set of alternative approaches for making harvest recommendations has been explored. The results of this analysis support the change in the time period using for OFL estimation.
3) The random-effects model was used to develop estimates of squid biomass.
4) Catch data have been updated through October 18, 2015 and the results of the 2015 EBS shelf survey have been included in the assessment.

Summary of results

The recommended overfishing level (OFL) for squid in the years 2016-2017 is calculated as the average catch from 1977-1981, or 6,912 t. The recommended allowable biological catch (ABC) for squids in 2016 and 2017 is calculated as 0.75 multiplied by the average catch from 1977-1981, or 5,184 t.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	*2015*	*2016*	**2016**	2017
Tier	6	6	6	6
OFL (t)	*2,620*	*2,620*	**6,912**	6,912
maxABC (t)	*1,970*	*1,970*	**5,184**	5,184
ABC (t)	*1,970*	*1,970*	**5,184**	5,184
	As determined *last* year for:		As determined *this* year for:	
Status	2013	2014	2014	2015
Overfishing	no	n/a	no	n/a

Responses to SSC and Plan Team comments on assessments in general

From the September 2015 Joint Plan Team minutes:
"The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas."

Response: The random effects model was used as one of the methods for determining squid biomass.

Responses to SSC and Plan Team comments specific to this assessment

From the December 2014 SSC minutes:
"The SSC had extensive discussion about whether the [squid catch] period before 1990 should be excluded [from the period used to determine average historical catch]"

Response: After much discussion and exploration of alternatives, the author recommends using ONLY the catch period before 1990 (i.e. the foreign fishery era) for determining average catch and OFL/ABC. The rationale for this decision is included in the report.

"However the SSC believes that the biomass of squid is probably larger, indeed much larger, than the catch, so that a reasonable ABC would be larger"

Response: The author agrees and much of the work in the 2015 SAFE is premised on this belief, which is supported by the included data and analyses.

"For next year, the SSC challenges the author to further investigate existing and additional approaches…reexamination of the historical foreign/ joint-venture information and comparison may shed light on squid spatial distribution. In particular, looking at the historical area, gear, depth and target species of the foreign/ joint-venture fleet would be informative."

Response: Because 2015 is an "off" year for the BSAI squid assessment, the recommended work was planned for 2016. However during the summer of 2015 the squid catch increased dramatically and the need developed for the author to explore new alternatives for harvest specification this year. While the particular analyses suggested by the SSC were not conducted (due to time constraints), a number of alternatives were explored and new harvest recommendations resulted from the analysis. The author plans to further explore the foreign/ joint-venture data for the 2016 squid assessment.

From the September 2015 Joint Plan Team minutes:
"The Teams continue to recommend that consideration be given to moving squid into the Ecosystem Component, and recommend that the squid assessment for November include, at a minimum: 1) the Tier 6 approach using maximum catch; and 2) an approach similar to the Tier 5 approach, using F=M=1 as the estimate of OFL fishing mortality, and using survey biomass as a "minimal" biomass estimate."

Response: A number of approaches, including those requested by the Plan Teams and the SSC, are presented in this assessment.

From the October 2015 SSC minutes:
"The SSC supports the Groundfish Plan Team's suggestion that the squid assessment options brought forward in December include, at a minimum, the current Tier 6 approach, the Tier 6 approach using maximum catch, and an approach similar to the Tier 5 approach, using F=M=1 as the estimate of OFL, fishing mortality, and using survey biomass as a "minimal" biomass estimate.

Response: A number of approaches, including those requested by the Plan Teams and the SSC, are presented in this assessment.

Introduction

<u>Description, scientific names, and general distribution</u>
Squids are marine molluscs in the class Cephalopoda (Group Decapodiformes). 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. 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.

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

Directed fishery

There is some evidence that squids were historically targeted by foreign vessels (from Japan and Korea) in the BSAI, but directed squid fisheries do not currently exist in Alaskan waters. Squids are potential targets for Alaska fisheries, as there are many fisheries directed at squid species worldwide. Most of these focus on temperate squids in the genera *Ilex* and *Loligo* (Agnew et al. 1998, Lipinski et al 1998), but there are fisheries for *B. magister* in the western Pacific, including Russian trawl fisheries with historic annual catches of 30,000 - 60,000 t (Arkhipkin et al., 1995) and coastal Japanese fisheries with catches of 5,000 to 9,000 t (Roper et al. 1982, Osaka and Murata 1983).

Incidental catches and retention

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. Alternatively, the spatial overlap between fisheries and squid distributions may have been greater during the foreign era. 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 *B. magister*. Squids are often retained (Table 2), and even squids that are discarded are unlikely to survive..

Data

Fishery data

Catch

After reaching 9,000 t in 1978, total squid catches steadily declined to only a few hundred tons in 1987-1995 (Table 2 & Figure 1). From 2000-2008 squid catches fluctuated around an average of approximately 1,000 t, with anomalously high catches in some years (Table 2 and Figures 1 & 2). From 2009 to 2013 catches were much smaller, ranging from 360 to 598 t. In 2014, the catch was the highest since 2001, greatly exceeding the TAC which had been set at a low level based on the low catch levels of recent years. The 2015 catch was even higher (2,357 t as of October 18, 2015) and for the first time exceeded the ABC. Most of the squid catch continues to be in the walleye pollock fishery (Table 3). In 2014 and 2015, the majority of the catches occurred in July at the start of the pollock B season (Figure 3). In both years catch rates declined dramatically after the pollock fleet adopted a voluntary special closure in the Bering Canyon area. Retention rates of squid by BSAI groundfish fisheries have ranged between 37% and 67% since 2008, with much of the retained squid being processed for bait.

Catch distribution

The majority of catches occur in the Bering Canyon region of the southeastern Bering Sea (areas 517 & 519; Table 4 & Figures 2 & 4). 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, the outer domain of the EBS shelf, and the Aleutian Islands, the highest catches consistently occurred near the major canyons (Figure 4).

A survey conducted in 2009 in the Bering Canyon region suggested that the density of *B. magister* increases considerably below 200 m (Horne and Parker-Stetter 2010). 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.

Catch size composition
In 2007, fishery observers began collecting data on the mantle length of squids captured in BSAI pollock fisheries. Examination of past length compositions on a seasonal basis revealed two length modes that might indicate the presence of seasonal cohorts (e.g. Ormseth 2012). Aggregate length compositions for each year (Figure 4) suggest that the representation of the two modes in the annual catch (whether as a result of differences in species or age) varies among years, and that the primary mode occurs consistently at ~21 cm. In the western Bering Sea the size at 50% maturity is 25 cm (Arkhipin et al. 1996), so it is likely that the fishery is capturing mature squids that may soon be spawning.

<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 pelagic squids. Squid records from these surveys tend to appear at the edges of the continental shelf in the eastern Bering Sea and in the Aleutian Islands (Figure 6). 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 (Horne and Parker-Stetter 2010). 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). In the AI, *B. magister* is the only squid species captured in abundance (Table 5).

Survey size composition
The size composition of squids in the combined BSAI trawl surveys is similar to the composition of catches in the fishery (Figure 7). There is a dominant size mode at ~21 cm, which likely corresponds to mature or maturing adults and a secondary mode at ~7 cm that likely corresponds to juveniles of a separate seasonal cohort.

Analytic Approach

Before this assessment, harvest recommendations for BSAI squids have been made based on the average catch from 1978-1995. This approach has been reviewed several times between 2010 and 2015, including by the Center for Independent Experts. While it is problematic, mainly because incidental catches are unlikely to reflect a sustainable level of fishing removals, the consensus has been that it is a precautionary harvest strategy: the OFL is likely to be much higher than the current harvest specifications.

In 2014 and 2015, squid catches increased and the current specifications acted as a constraint on the directed pollock fishery, where most squid are captured. In both years, a voluntary spatial closure in the

Bering Canyon area where squid bycatch was particularly high was adopted by the pollock fleet. This limited fishing access to the fleet and may have interfered with the fleet's ability to avoid chinook and chum salmon (K. Hafflinger, Sea State, pers. comm., August 2015). As a result the Plan Teams and the SSC requested that the assessment author revisit the analytic approach and develop a set of harvest recommendations that better reflect a sustainable level of squid removals.

Numerous methods for developing harvest recommendations were explored, and as has been the case in previous assessments all were found to be problematic in some way. Rather than base recommendations on a new methodology that has not been sufficiently reviewed, the author chose to use an existing methodology (average catch) but based it on a different time period (1977-1981 rather than 1978-1995). The advantages of using this earlier time period are (1) the fishery is consistent during this period (i.e. all fishing was by foreign fleets) and (2) catches during this era are more likely to reflect sustainable catches, either because there was targeting of squid or there was greater overlap between the fisheries and squid. The main problem with using these catch data is that they are relatively old and may not be indicative of sustainable removals for current squid populations. Therefore a number of alternative approaches were explored to examine whether the recommended approach was supported by other data sources and methods. These alternatives and corresponding results are outlined in Table 6 and are summarized as follows:

<u>Maximum catch</u>: In the GOA, maximum catch from 1997-2007 (earlier catch data do not exist) is used instead of average catch. For this assessment two alternatives (a and b in Table 6) using maximum catch and different time periods were used: 1977-1981 and 1997-2007.

<u>Biomass-based approaches- biomass estimates</u>: Alternatives c through i in Table 6 are based on survey biomass estimates. Although the estimates are highly uncertain, we are confident that they are substantial underestimates. The survey data were considered in 3 ways, listed at the bottom of Table 6:

1) **Random-effects model**: A random-effects (RE) model was applied separately to the biomass timeseries from each survey (Table 7 and Figure 8). The 2015 values predicted by the model were combined to produce a BSAI biomass estimate. This estimate was used in alternatives c, f, and i.

2) **Long-term average**: Because squid are short-lived and the annual estimates are likely to be independent of each other the RE model may not be appropriate for estimating current biomass. This is particularly true as squid populations are thought to be highly sensitive to temperature. As a result an average of all of the biomass estimates between 1983 and 2015 may provide a better estimate of squid biomass. This estimate was used in alternatives d and g.

3) **Catchability-corrected RE estimate**: As discussed above the surveys are believed to seriously underestimate squid biomass. This results partially from the vertical distribution of squid relative to the sea floor. *Berryteuthis magister* is the species most often captured in AFSC bottom trawl surveys; this is likely a result of their relatively large size and the fact that adults are often associated with the ocean bottom. However the available information suggests that the majority of squids are distributed off-bottom where they would not be captured in trawls. An acoustic study conducted in 2008 in Bering Canyon was able to resolve near-bottom backscatter from different species (Figure 9). The results indicate that during the day, most squids were located between 10 and 40 m above the bottom. The headrope of the survey trawl is at 6.5 m off the bottom, so unless squid are herded towards the bottom it is likely that the survey misses the bulk of the squid biomass in the areas sampled. For the purposes of this assessment, a conservative catchability of 0.5 was used to

estimate an alternative biomass (i.e. 2x the RE model estimate; alternatives e and h in Table 6).

Biomass-based approaches- parameter estimates: Two alternatives were considered for using biomass to estimate OFL.

1) ***F*=*M*, Baranov equation, *M* = 1.0**: This alternative is based on the NPFMC Tier 5 approach where F_{OFL} is set equal to *M*. *M* is assumed to be 1.0 for squids, although actual *M*s for squid might be considerably higher. Because squid grow, mature, and die so rapidly, the *F*=*M* approach is modified using the Baranov equation to account for mortality during the year. The resulting equations are
$$\mathrm{OFL} = 0.5B_{\mathrm{survey}}(1 - e^{-Z})$$
$$\mathrm{ABC} = 0.375B_{\mathrm{survey}}(1 - e^{-Z})$$
This formulation of *F*=*M* was used for alternatives c-e in Table 6. An *F*=*M* formulation without the catch equation was used in alternative i.

2) **Spawning escapement approach**: This alternative is based on the similarity of the squid life cycle to that of Pacific salmon, i.e. semelparity. As a result, managing for spawning escapement may also be appropriate for squid and squid populations are managed this way in several countries worldwide (e.g. Brodziak 1998). The survey size composition suggests that the biomass estimated by the survey is an index of the adult population, and therefore could be used as an index of spawning biomass. To allow at a minimum 40% of spawning squid to escape, OFL is set at 60% of the biomass estimate. This approach is used in alternatives f-h.

Results

The average catch during 1977-1981was 6,912 t. The alternatives discussed above produced OFLs ranging from 1,766 t to 8,971 t (Table 6). The average OFL among the alternatives was 5,504 t. These results suggest that using average catch 1977-1981 is a reasonable approach and the author recommends that this be used for developing harvest recommendations.

Harvest recommendations

The harvest recommendations are based on the average catch during 1977-1981, with OFL = average catch and ABC = 0.75x average catch:

2016-2017 Tier 6 harvest recommendations for BSAI squids

average catch 1977-1981	6,912 t
OFL (avg. catch)	6,912 t
ABC (0.75 * avg. catch)	5,184 t

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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, 1977-2015, 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			560	560			128	128	688	66%
2013			158	158			141	141	300	37%
2014			1,568	1,568			110	110	1,678	40%
*2015**			*2,276*	*2,276*			*81*	*81*	*2,357*	*55%*

* 2015 catch and retention data are incomplete; retrieved October 18, 2015.

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, 2003-2015. Data sources as in Table 2.

target	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	***2015****
pollock	1,226	977	1,150	1,399	1,169	1,452	209	277	178	495	118	1,478	*2,206*
rockfish	12	6	7	6	8	25	18	12	37	33	60	56	*59*
Kamchatka	0	0	0	0	0	0	0	0	48	76	36	42	*52*
arrowtooth	7	6	10	4	3	46	96	104	67	60	68	69	*24*
Atka	21	7	9	9	5	12	14	16	5	23	15	31	*12*
flathead sole	0	4	1	0	0	0	0	0	0	0	1	0	*1*
other flatfish	3	2	6	0	2	1	0	0	0	0	1	0	*1*
Pacific cod	9	6	3	1	1	0	0	0	0	0	0	1	*1*
yellowfin sole	1	0	0	0	0	0	0	0	0	0	0	0	*0*
Greenland turbot	3	6	0	0	0	4	23	1	0	0	0	1	*0*
sablefish	0	0	0	0	0	1	0	0	0	0	0	0	*0*
total BSAI	**1,282**	**1,014**	**1,186**	**1,418**	**1,188**	**1,542**	**360**	**410**	**336**	**688**	**299**	**1,678**	***2,357***

* 2015 catch estimate as of October 18, 2015.

Table 4. Estimated catch (t) of all squid species combined by area, 2003-2015. Data sources as in Table 2.

	area	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	***2015****
EBS	509	2	7	5	162	13	25	1	5	3	16	5	19	*9*
	513	2	2	0	1	12	9	2	0	1	2	1	0	*1*
	517	746	587	539	965	690	1,066	143	133	119	308	63	938	*1,495*
	518	0	0	0	0	0	23	40	17	30	17	2	43	*42*
	519	484	398	527	261	419	344	74	145	52	187	41	548	*579*
	521	12	5	95	15	26	25	9	5	17	20	33	13	*59*
	523	0	0	3	0	0	1	0	1	3	0	1	3	*90*
	524	0	0	0	0	15	0	0	0	12	9	11	5	*2*
AI	541	9	4	3	2	2	25	66	90	75	114	107	76	*31*
	542	10	7	2	6	3	6	5	4	8	6	5	13	*11*
	543	17	3	12	7	8	18	20	11	16	8	30	21	*38*
EBS total		**1,246**	**1,000**	**1,170**	**1,403**	**1,176**	**1,494**	**269**	**305**	**237**	**560**	**158**	**1,568**	***2,276***
AI total		**36**	**14**	**17**	**15**	**12.73**	**49**	**91**	**105**	**99**	**128**	**141**	**110**	***81***
BSAI total		**1,282**	**1,014**	**1,186**	**1,418**	**1,188**	**1,542**	**360**	**410**	**336**	**688**	**299**	**1,678**	***2,357***

* 2015 catch estimate as of October 18, 2015.

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
2013	146	0.84	28	1.00										
2014	21	0.49	0	-									6,178	0.30
2015	91	0.40	61	0.66										

Table 6. Alternative approaches for determining squid harvest recommendations in the BSAI.

	author's recommendation	
	approach: average catch 1977-1981	
	OFL	**6,912**
	ABC	**5,184**
	alternative approaches:	
(a)	maximum catch 1977-1981	
	OFL	**8,971**
	ABC	**6,728**
(b)	maximum catch 1997-2007 (same as in GOA)	
	OFL	**1,766**
	ABC	**1,325**
(c)	*F*=*M*, Baranov equation, *M*=1.0, RE estimate	
	OFL	**2,941**
	ABC	**2,206**
(d)	*F*=*M*, Baranov equation, *M*=1.0, long-term average	
	OFL	**3,987**
	ABC	**2,990**
(e)	*F*=*M*, Baranov equation, *M*=1.0, 2x RE estimate	
	OFL	**5,882**
	ABC	**4,412**
(f)	40% spawning escapement, RE estimate	
	OFL	**4,082**
	ABC	**3,061**
(g)	40% spawning escapement, long-term average	
	OFL	**5,533**
	ABC	**4,149**
(h)	40% spawning escapement, 2x RE estimate	
	OFL	**8,164**
	ABC	**6,123**
(i)	*F*=*M*, *M*=1.0, RE estimate	
	OFL	**6,803**
	ABC	**5,102**
	average of alternatives	
	OFL	5,504
	ABC	4,128
	RE model biomass estimate	*6,803*
	long-term (1983-2015) average survey biomass estimate	*9,221*
	2X RE model estimate	*13,606*

Table 7. Biomass estimates and coefficients of variation (CV) for all squids combined (excluding *R. pacifica*) from 3 regions of the BSAI. Estimates are annual trawl survey estimates ("surv est") or estimates from a random effects model fitted to each survey timeseries (RE est).

	EBS slope					AI					EBS shelf			
	surv est	surv CV	RE est	RE CV		surv est	surv CV	RE est	RE CV		surv est	surv CV	RE est	RE CV
1983						9,557	0.32	10,302	0.29					
1984								10,996	0.36		15	0.80	15	0.72
1985								11,736	0.38		13	0.83	16	0.72
1986						15,761	0.48	12,527	0.36		80	0.83	32	1.22
1987								12,230	0.43				65	0.78
1988								11,940	0.48				64	1.64
1989								11,657	0.50				64	2.10
1990								11,380	0.50				63	2.40
1991						28,934	0.76	11,111	0.49				62	2.61
1992								9,362	0.49				62	2.74
1993								7,888	0.46				61	2.80
1994						11,084	0.73	6,646	0.41				61	2.79
1995								5,139	0.38				60	2.73
1996								3,973	0.33				59	2.60
1997						2,689	0.24	3,072	0.21				59	2.38
1998								2,940	0.29				58	2.07
1999								2,814	0.28				58	1.59
2000						2,758	0.18	2,693	0.16		42	0.71	57	0.66
2001								2,410	0.24		280	0.40	235	0.39
2002	1,270	0.11	1,349	0.11		2,088	0.14	2,156	0.13				75	1.17
2003			1,454	0.12				2,240	0.26		16	0.83	24	0.77
2004	1,642	0.13	1,568	0.10		3,250	0.36	2,327	0.25				31	1.38
2005			1,621	0.13				1,913	0.26				40	1.38
2006			1,677	0.14		1,468	0.14	1,572	0.14		47	0.83	51	0.77
2007			1,734	0.13				1,775	0.28				84	1.38
2008	1,826	0.09	1,794	0.08				2,004	0.32				139	1.39
2009			1,794	0.11				2,263	0.30		623	0.83	231	0.83
2010	1,928	0.10	1,794	0.09		2,444	0.22	2,555	0.19		9	0.83	13	0.70
2011			1,609	0.11				3,139	0.26		1	0.83	3	0.80
2012	1,361	0.09	1,443	0.09		4,011	0.27	3,857	0.22		43	0.83	24	0.70
2013			1,443	0.15				4,522	0.29		28	0.83	29	0.71
2014			1,443	0.20		6,178	0.29	5,302	0.26				41	1.18
2015			1,443	0.23				5,302	0.40		61	0.60	58	0.58

Figures

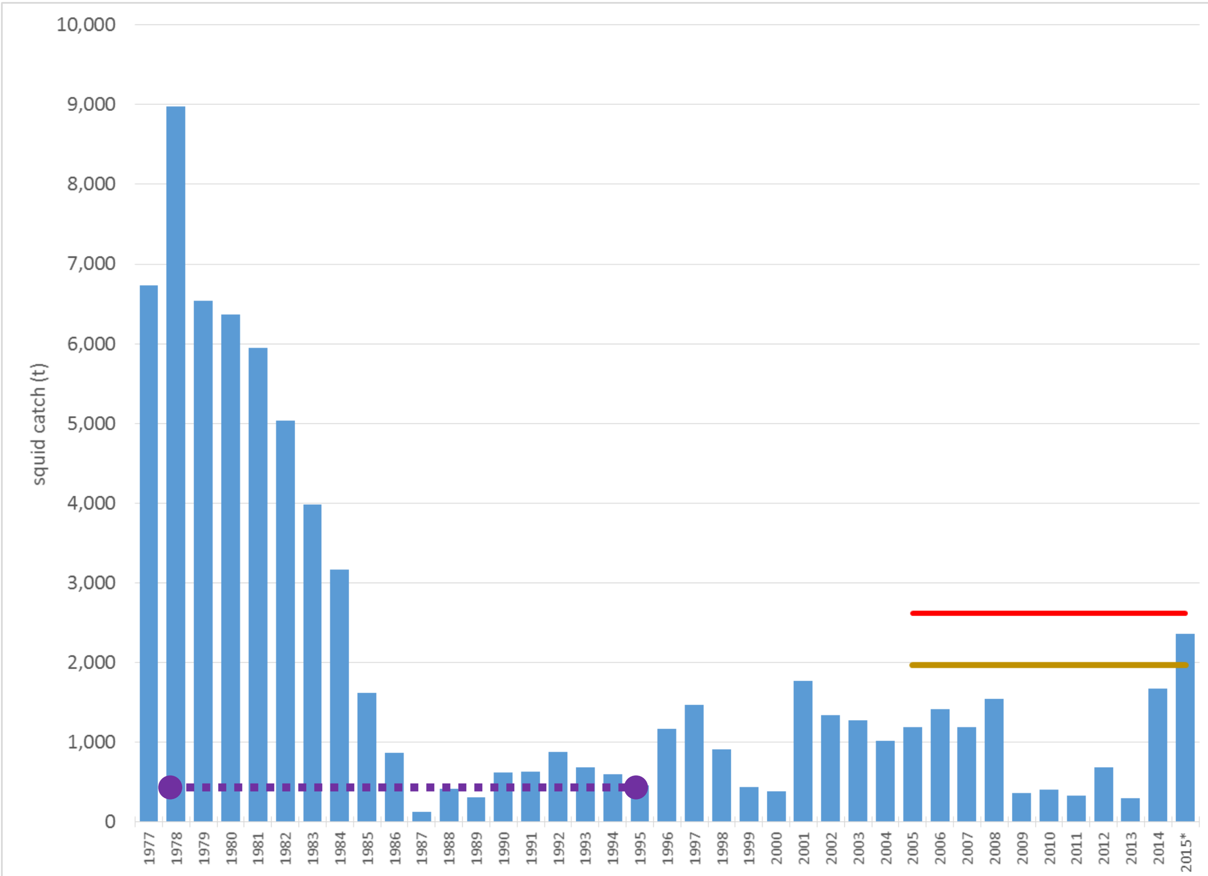

Figure 1. Historical catches of squids in the Bering Sea and Aleutian Islands, 1977-2015 (**2015 data as of October 18, 2015**). Red and brown horizontal lines indicate current OFL and ABC, respectively. Dashed purple line indicates period currently used for developing harvest recommendations.

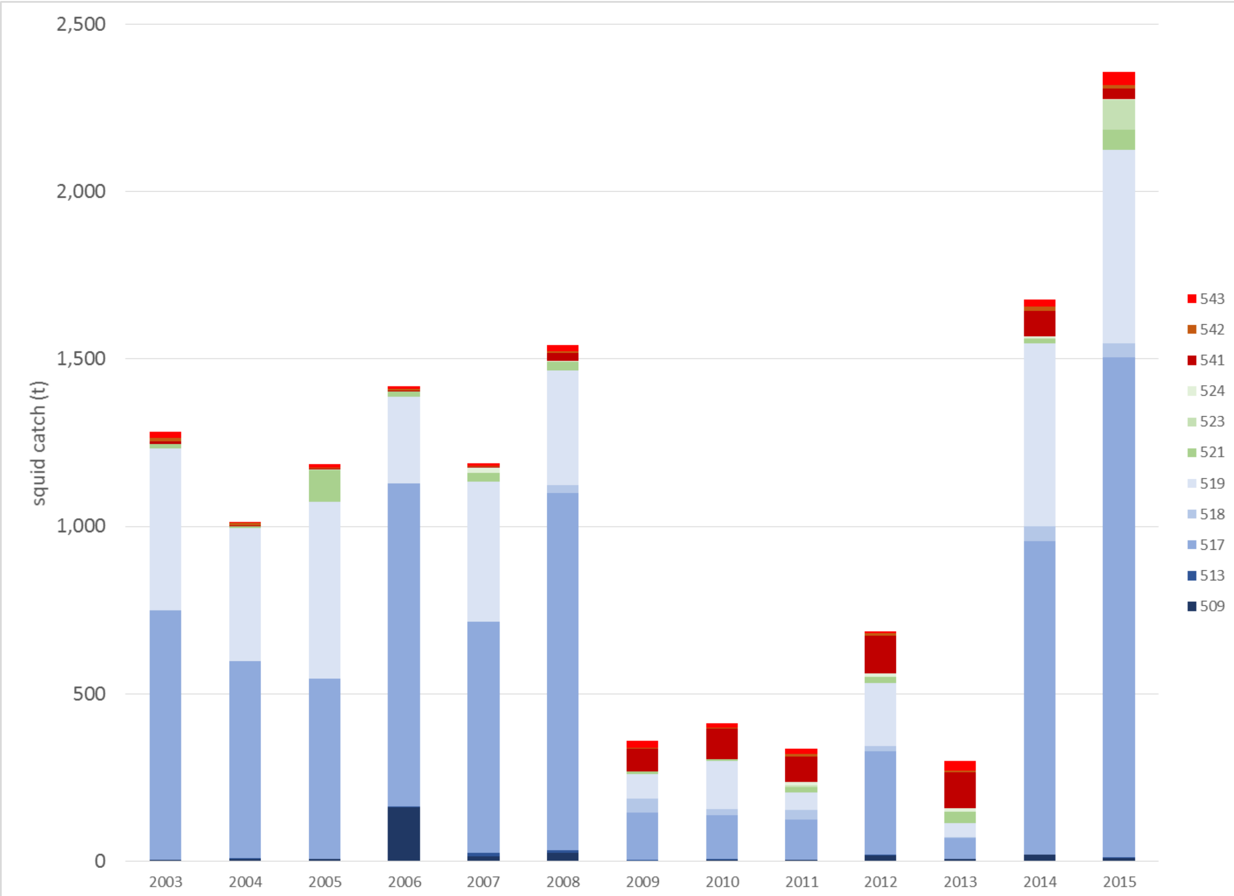

Figure 2. Estimated total fishery catch (t) of all squid species in NMFS management areas of the BSAI region, 2003-2015 (**2015 data as of October 18, 2015**). Numbers in legend refer to management area. Blue and green colors indicate EBS areas; red indicates AI areas.

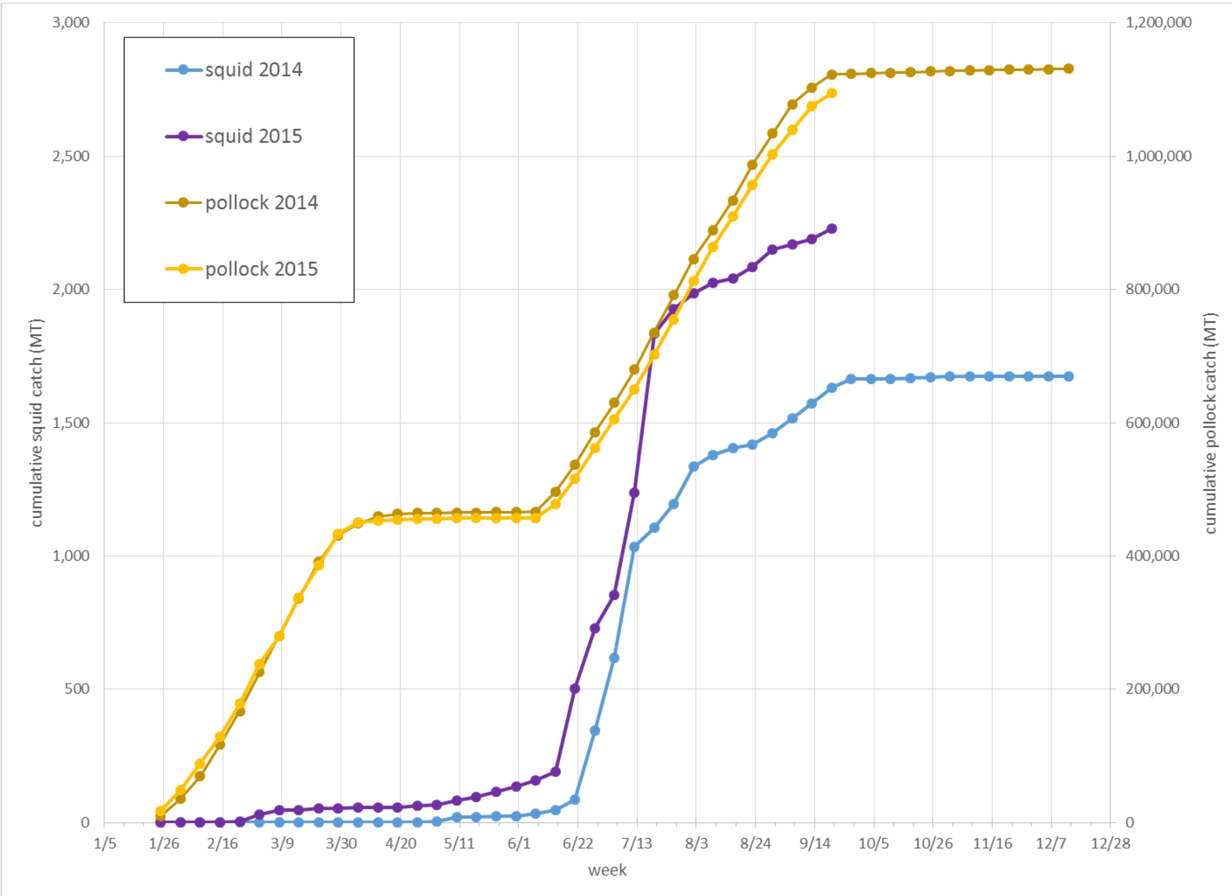

Figure 3. Cumulative catch of squids and pollock in the BSAI by week, 2014 & 2015.

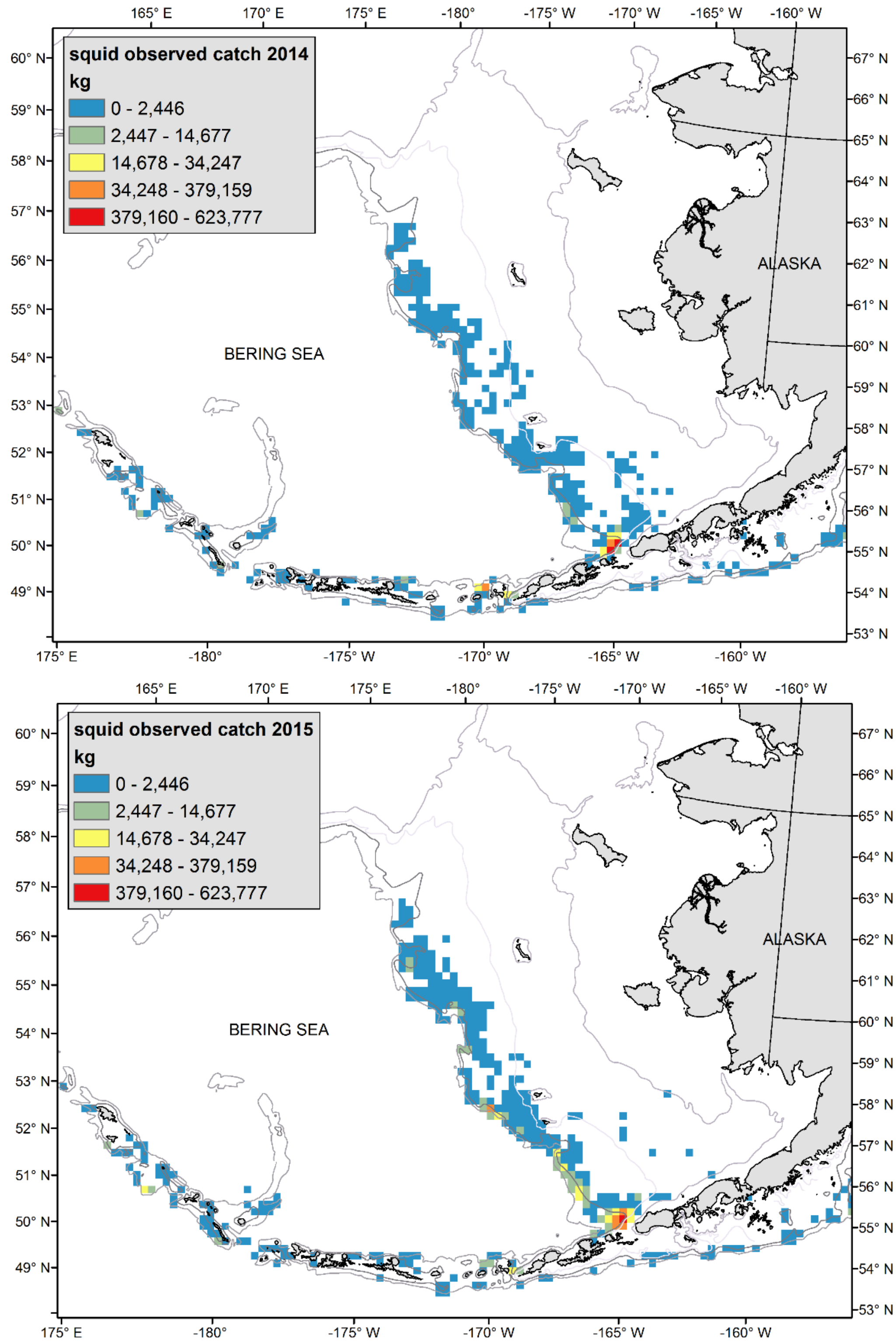

Figure 4. Distribution of observed annual squid catches during 2014 (top) and 2015 (bottom). Each 400 km^2 grid cell depicts the total observed catch in kg. Data are from the AFSC Fisheries Monitoring and Analysis program.

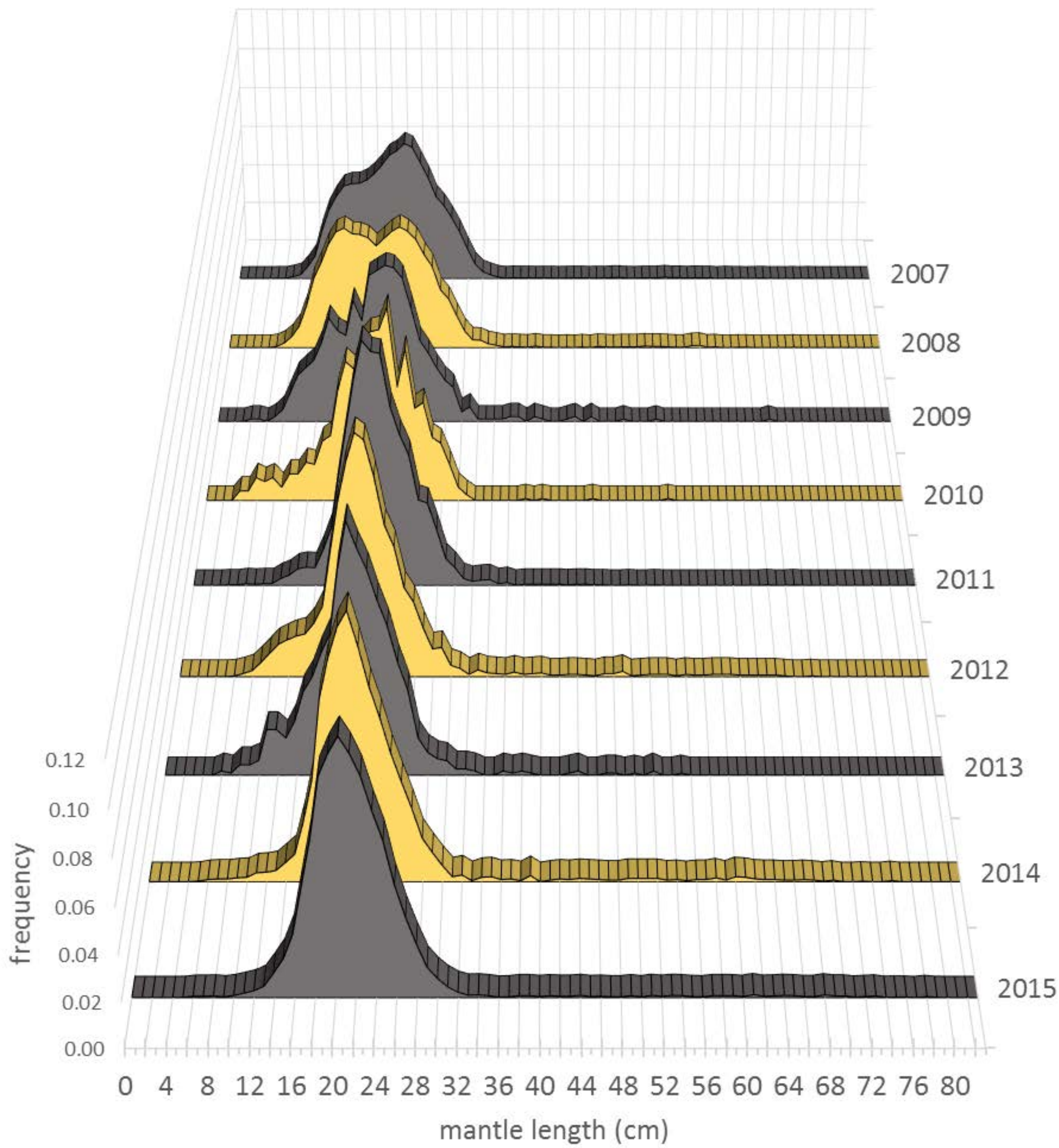

Figure 5. Length compositions by year, of squids captured in BSAI federal fisheries, 2007-2015. Data are from the AFSC's Fishery Monitoring and Analysis program. The 2015 data are provisional because not all 2015 has been collected and/or checked for quality.

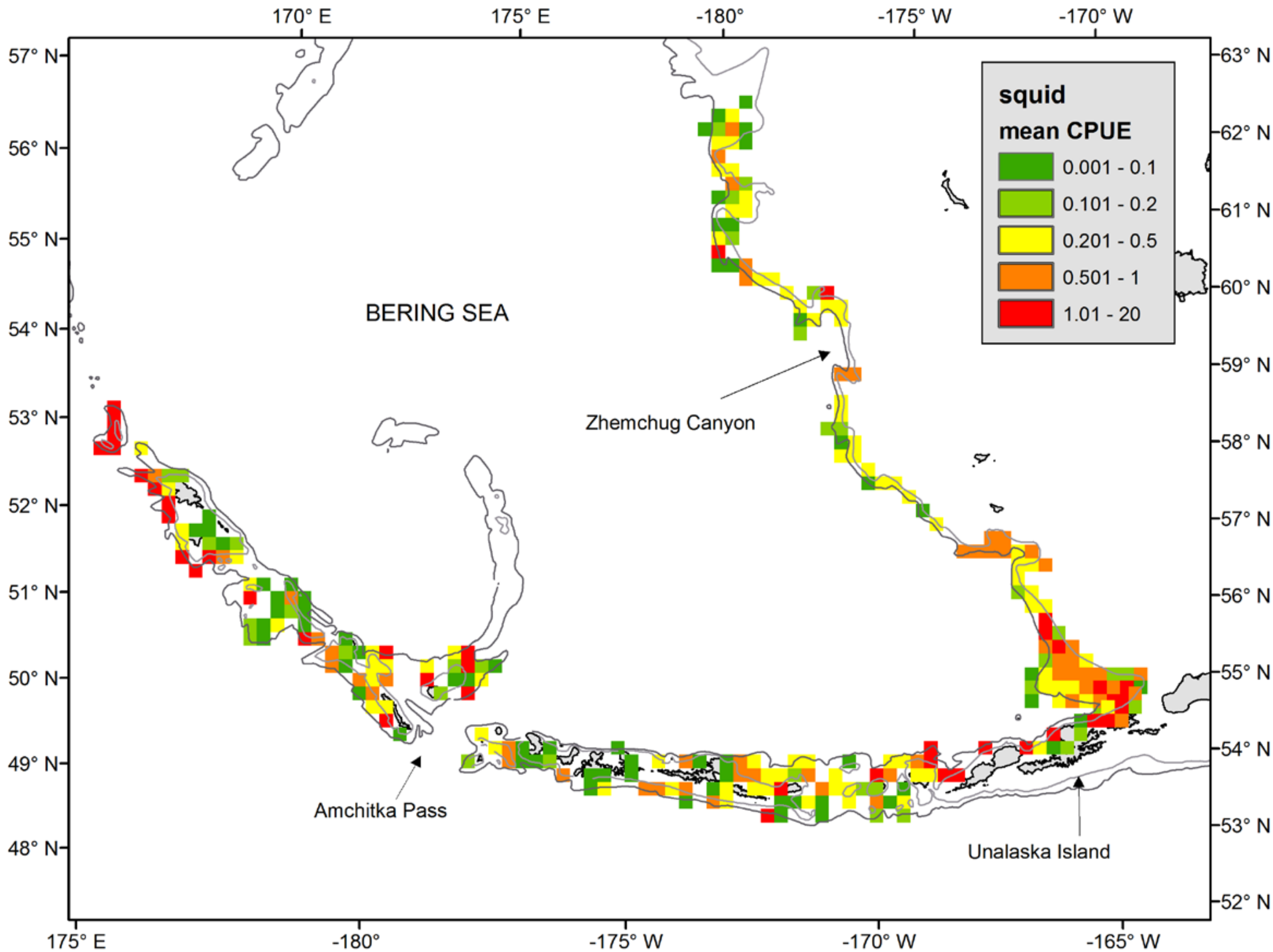

Fig. 6. Mean trawl survey CPUE of all squid species combined in the BSAI, 2000-2012. Grid cells are 20 km X 20 km.

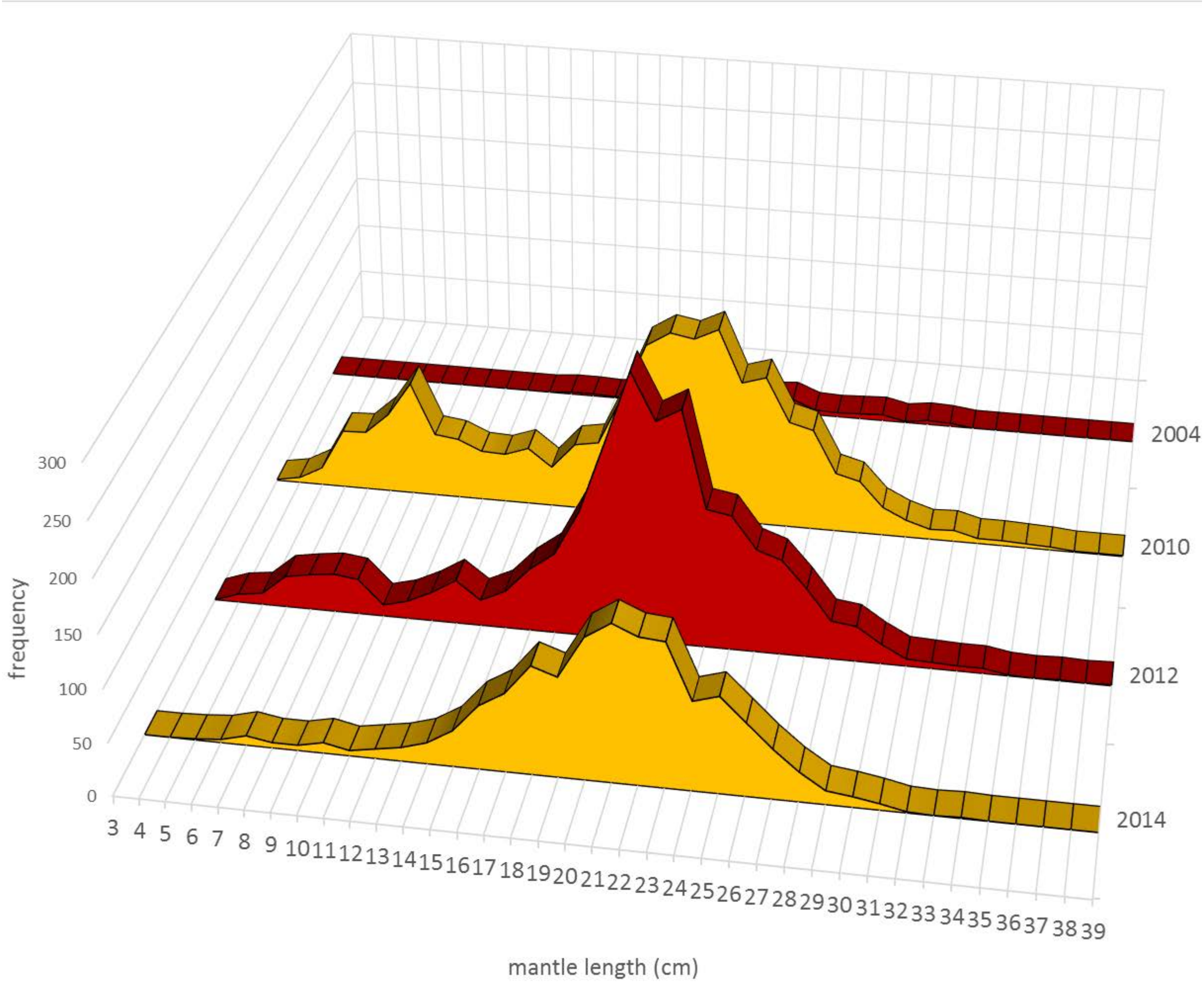

Figure 7. Size compositions of *B. magister* captured in the BSAI trawl surveys conducted by the AFSC, 2004-2014. The 2014 size composition does not include data from the EBS slope as there was no survey in that year.

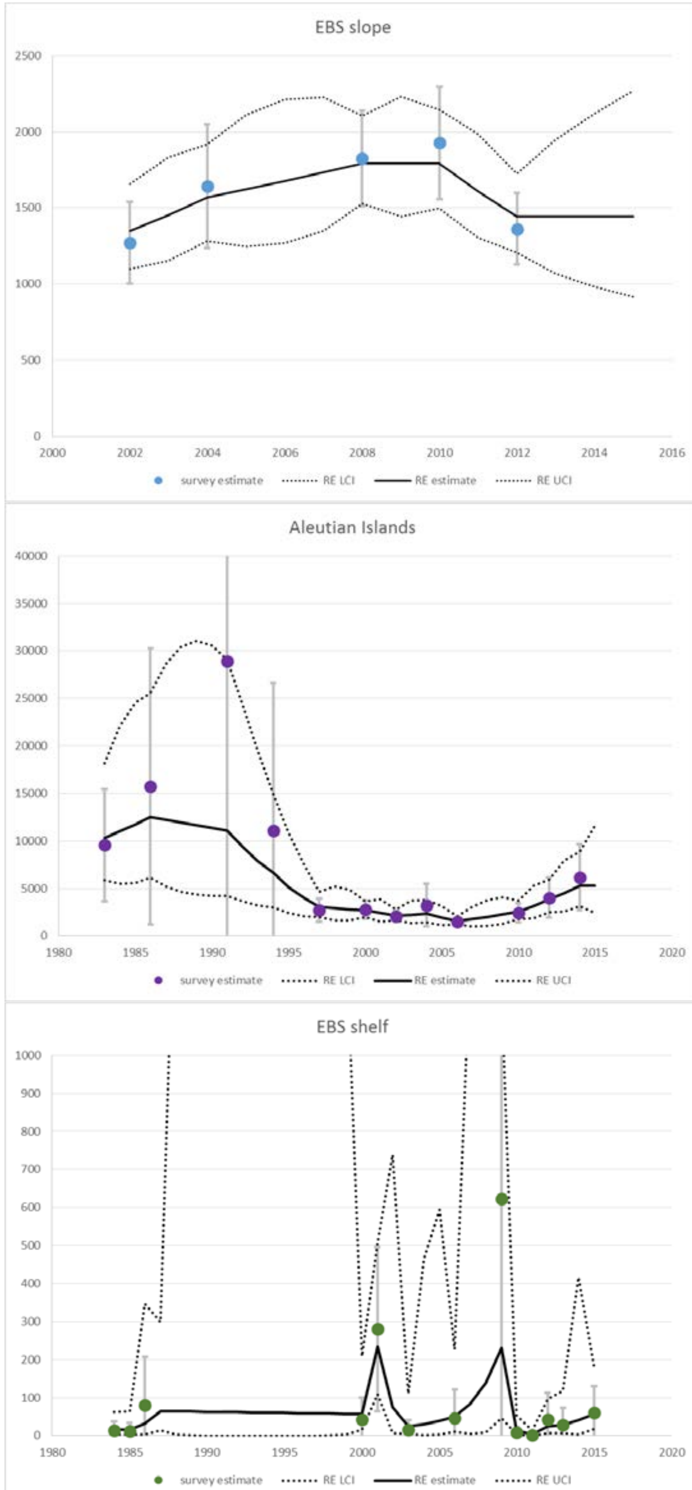

Figure 8. Survey biomass estimates (t; colored dots) and results from a random-effects model of survey biomass (t; black line) for squids in 3 regions in the BSAI. Confidence intervals are marked by grey bars (survey estimates) and dashed black lines (model estimates). Time periods and vertical scale differ among plots.

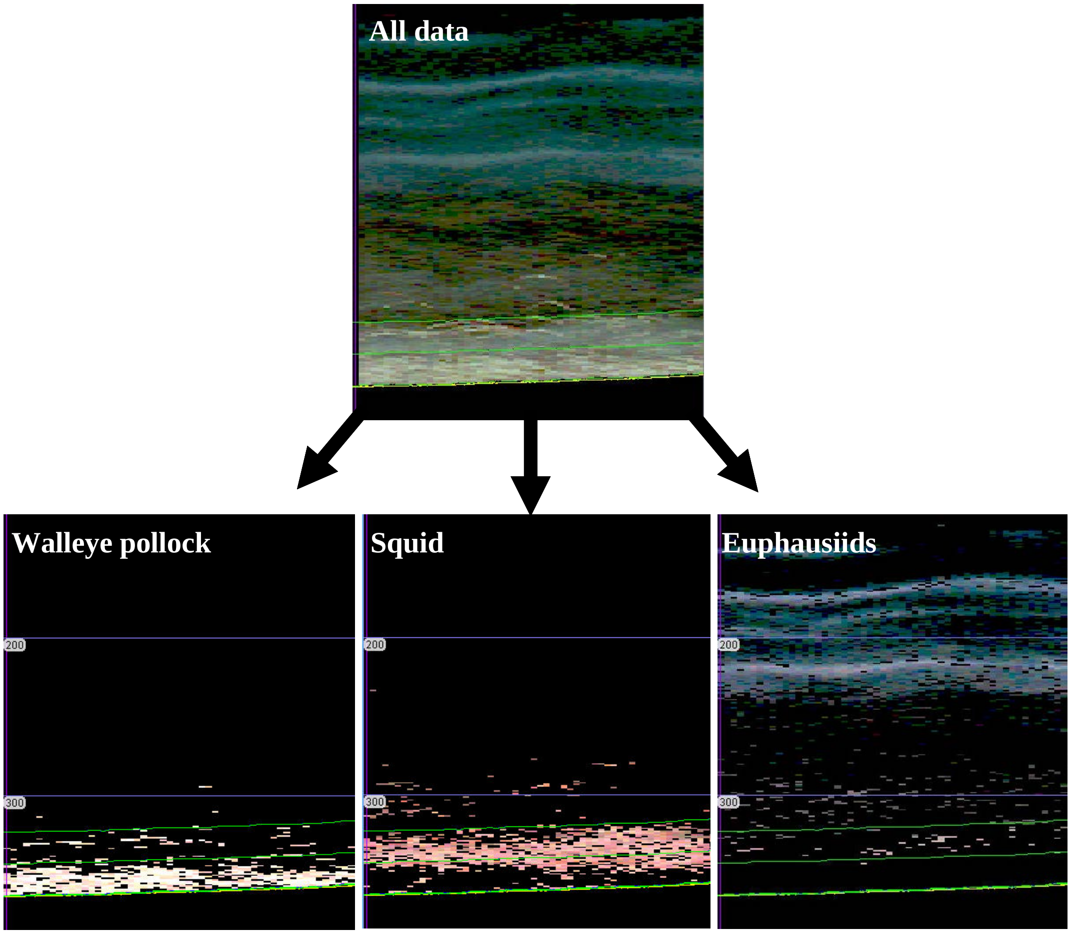

Figure 9. Echogram of squid, pollock, and euphausiid aggregations in the southeastern Bering Sea.

Appendix 1. Non-commercial catches (kg) of squids in the BSAI, 2010-2014. Data are from the Alaska Regional Office.

Source of removal	2010	2011	2012	2013	2014
Aleutian Island Bottom Trawl Survey	1.9		4.0		29.5
Aleutian Islands Cooperative Acoustic Survey					
Bering Sea Acoustic Survey	6.5				
Bering Sea Bottom Trawl Survey	1.4				
Bering Sea Slope Survey	16.3		9.4		
Bogoslof EIT Survey with Northern Extensions			6.8		
Eastern Bering Sea Bottom Trawl Survey		0.8	0.8	5.3	0.7
Gulf of Alaska Bottom Trawl Survey		0.0			
Large-Mesh Trawl Survey			1.1	1.2	
Pollock EFP 11-01			12,143.3		
total	**26.1**	**0.8**	**12,165.4**	**6.5**	**30.2**