21. Assessment of the squid stock complex in the Gulf of Alaska

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Executive Summary

Squids in the Gulf of Alaska (GOA) are managed as a single stock complex comprising approximately 15 species. Prior to this assessment, harvest recommendations were based on an historical catch approach setting OFL equal to maximum historical catch during 1997 – 2007. For this assessment, harvest recommendations for squids in the GOA and the Bering Sea/ Aleutian Islands (BSAI) have been reviewed as a result of squid bycatch constraining pollock fisheries in the BSAI, and a new approach has been recommended.

Summary of Changes

1) A number of alternative approaches for harvest recommendations were explored for this assessment and are summarized in Table 7; an alternative similar to a Tier 5 approach is recommended by the author for specifications.
2) Survey data from 2015 has been added and catch data have been updated through October 18, 2015.

Summary of Results

Based on an analysis of multiple alternatives for estimating OFL and ABC, a different approach to harvest recommendations is recommended by the author. The new approach is a Tier 6 approach based on the concept that *F=M* is a sustainable fishing mortality rate, similar to Tier 5, but modifies the way *F* is applied using the Baranov catch equation. The long-term survey average is used for the biomass estimate.

	last year		**this year**	
Quantity/Status	*2015*	*2016*	**2016**	2017
M (natural mortality)	*n/a*	*n/a*	**1.0**	1.0
Specified/recommended Tier	*6*	*6*	**6**	6
Biomass (t)	*n/a*	*n/a*	**6,889**	6,889
average catch 1997-2007	*272*	*272*	**n/a**	n/a
maximum catch 1997-2007	*1,530*	*1,530*	**n/a**	n/a
Recommended OFL	*1,530*	*1,530*	**2,978**	2,978
Maximum ABC	*1,148*	*1,148*	**2,234**	2,234
Recommended ABC	*1,148*	*1,148*	**2,234**	2,234
Status	*As determined last year for:*		As determined this year for:	
	2013	*2014*	2014	2015
Overfishing	*No*	*n/a*	No	n/a
(for Tier 6 stocks, data are not available to determine whether the stock is in an overfished condition)				

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 for determining squid biomass for the purpose of discussion of harvest recommendations.*

Responses to SSC and Plan Team comments specific to this 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: It is unclear whether these recommendations applied to GOA squids as well as BSAI squids. For the GOA, a subset of the analyses performed for the BSAI assessment was conducted, and new alternatives for harvest recommendations, 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: It is unclear whether these recommendations applied to GOA squids as well as BSAI squids. For the GOA, a subset of the analyses performed for the BSAI assessment was conducted, and new alternatives for harvest recommendations, including those requested by the Plan Teams and the SSC, are presented in this assessment.*

Introduction

Description, scientific names, and general distribution
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). The squid assemblage in the BSAI is better understood than in the GOA, so some of the information in this section comes from the BSAI.

In the Gulf of Alaska region 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 *B. magister* and *Gonatopsis borealis* (boreopacific armhook squid) are often found in close proximity to the bottom. The vertical distribution of these three species, as well as the large size of the latter two, are the probable cause of their predominance in the GOA bottom trawl survey relative to other squid species. However no squid species appear to be well-sampled by the GOA survey. Most species are associated with the slope and basin. In the GOA trawl survey the greatest squid biomass is found between 200 m and 300 m (Figure 1), and the spatial distribution is accordingly limited mainly to the continental slope, the Shelikof Sea Valley, and the various canyons that intersect the GOA shelf (Figure 2). 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. *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
Two species from this family are known to occur in the GOA: *Moroteuthis robusta* and *Onychoteuthis borealijaponicus*. *Moroteuthis robusta* is the largest squid in the region, reaching mantle lengths of three feet.

Family Sepiolidae
This family is represented by a single species, *Rossia pacifica*. This small animal is found throughout the Gulf of Alaska 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 GOA 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 the GOA are almost entirely unknown so must 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 Ocean is the magistrate armhook squid, *B. 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 are no directed squid fisheries in Alaskan waters at this time, although squid appear to have been occasionally targeted by foreign vessels in Alaska prior to 1990. Squid in Alaska are generally taken incidentally in target fisheries for pollock. Squids could potentially become targets of Alaskan fisheries, as there are many fisheries directed at squid species worldwide. Most of these fisheries focus on temperate squids in the genera *Illex* and *Loligo* (Agnew et al. 1998, Lipinski et al. 1998). For instance, the market squid *Loligo opalescens* supports one of the largest fisheries in the Monterey Bay area of California (Leos 1998), and has also been an important component of bycatch in other fisheries in that region (Calliet et al. 1979). 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. 1984; Osaka and Murata 1983).

Bycatch and discards

Squids historically represented a small proportion (~1-2%) of the Other Species catch in the GOA (Table 2). This began to change in 2003, when the proportion rose to 5%, and increased to an especially large catch in 2006 (1,530 t, 39% of the Other Species catch; Table 2), which was similar to catch levels in the BSAI during the 2000s (Ormseth and Jorgenson 2007). Since then catches have been relatively low. Analysis of fishery observed data suggests that retention of squids varies considerably; estimates of retention rates range from 19% to 97%, although retention has been high for the last several years (Table 2).

Most squid are caught incidentally in the pollock fishery (Table 3) and in the central GOA (Table 4; Figures 3 & 4). The predominant species of squid in commercial catches in the GOA is believed to be *B. magister*. Starting in 2011 separate catch accounting for squids as a target fishery has been conducted by the Alaska Regional Office. Because squids are delicate and almost certainly killed in the process of being caught, 100% mortality of discards is assumed.

Data

Fishery data

Since 2006 when an unusually high catch of squids occurred, squid catches have ranged from 22 t to 484 t (Table 3). Most of this catch occurs in the pollock fishery (Table 4), and because the pollock fishery is concentrated in Shelikof Strait this is also where most of the squid catch occurs (Table 4; Figures 3 & 4). The catch figures in Tables 2 and 3 include data from NMFS statistical areas 649 and 659, which correspond to inside waters of the GOA (Prince William Sound and Southeast Alaska inside, respectively). Catch in these areas does not count towards the total allowable catch (TAC) but is included here for complete catch accounting. Historically the reported catch in these areas has been minimal, but in 2013 the fishery observer program was restructured. A wider range of vessels now carry observers and the observer coverage in PWS has increased. The apparent increase in squid catches in PWS may be due to this change in observer coverage rather than to actual increase in the catch. Squid length data are collected by fishery observers but these data are sparse. No clear size mode can be observed in the annual length compositions, with most captured squids ranging from 16 cm to 27 cm mantle length (Figure 5). Retention of squids is highly variable (12%-92%; Table 5) and appears to be mainly for bait.

Survey Data

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 most squids, which are generally pelagic or, if demersal, reside off bottom. Biomass estimates for the GOA have fluctuated considerably since 1984, with the 2015 biomass estimate (14,079 t) the highest ever observed (Table 6). The spatial distribution of squid survey catches (Figure 2) indicates that they are concentrated in waters from 200-500 m depth along the continental slope and in canyons; the majority of the survey biomass occurs between 200 and 300 m. The survey almost certainly underestimates squid biomass. For example, a mass-balance ecosystem model of the GOA estimates the squid population at 369,309 t.

The size composition of squids varies among years and tends to lack a clearly defined size mode (Figure 6), and mantle lengths average less than 20 cm. This is in contrast to data from the BSAI that is consistently dominated by a single size mode at ~21 cm.

Analytic Approach

When squids in the GOA were separated from the “Other Species” group in 2011, a decision was made to make harvest recommendations for squids based on the maximum catch from 1997-2007 (i.e. OFL = maximum catch 1997-2007). While this approach 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 in the BSAI 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 for the BSAI and develop a set of harvest recommendations that better reflect a sustainable level of squid removals. While this effort was focused on the BSAI, the same analysis was conducted for the GOA and new recommendations were made based on the results. The alternatives and corresponding results are outlined in Table 7 and are summarized as follows:

<u>Biomass-based approaches - biomass estimates</u>: Alternatives a, c, and d in Table 7 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 7:

1) **Random-effects model**: A random-effects (RE) model was applied separately to the biomass time series from each depth stratum in the GOA survey (Table 8 and Figures 7 & 8). The 2015 values predicted by the model were combined to produce a GOA biomass estimate. This estimate was used in alternative b.

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 the harvest recommendations and in alternative a in Table 7, the author's recommended alternative.

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. *B. 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 in the BSAI was able to resolve near-bottom backscatter from different species. 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 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; alternative d in Table 7).

<u>Biomass-based approaches- parameter estimates</u>: In the BSAI two alternatives were considered for using biomass to estimate OFL, an F=M approach and a spawning escapement approach. The survey length compositions in the BSAI strongly suggested that the survey was catching mature squid, so that the biomass estimate could be considered as an estimate of spawning biomass. In contrast, the GOA length compositions are diffuse and any length modes probably correspond to immature squids. Therefore the spawning escapement alternative was not explored for the GOA.

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 Ms 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 the harvest recommendations in the author's recommended approach and alternatives b & c.

Results

The estimated OFL for the alternatives varied from 1,503 t (current specifications) to 11,990 t. The author recommends using the alternative using an F=M, Baranov-equation approach applied to the long-term survey average biomass of 6,889 t. This approach provides a reasonable OFL but (based on comparison to the alternatives) is still highly precautionary.

2016 Tier 6 harvest recommendations for GOA squids

F=*M*, Baranov equation, *M*=1.0, long-term average	biomass = 6,889 t
OFL	**2,978**
ABC	**2,234**

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Ecosystem Considerations

Previous assessments (e.g. Ormseth 2011) have included extensive information regarding ecosystem considerations for squids. A brief summary of that information is included in this report. Ecosystem information for squids is highly uncertain due to 2 factors:

1) Much of the information regarding squid predators, particularly marine mammals, is outdated.
2) The squids usually encountered in the trawl survey and commercial fisheries (most of which are *B. magister*) are much larger than those that are predated by birds and fishes. The smaller squids are likely a combination of different species and juveniles of B. magister. As a result, much of the food habits information does not apply to the portion of the squid complex dealt with in this report.

Ecosystem effects on GOA 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			
Salmon	Increased populations since 1977, stable throughout the 1990s to present	Mortality higher on squids since 1977, but stable now	Probably no concern
Toothed whales	Unknown population trend	Unknown	Unknown
Sablefish	Cyclically varying population with a downward trend since 1986	Variable mortality on squids slightly decreasing over time	Probably no concern
Grenadiers	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 <100 tons annually except for 2005, 2006, and 2007	Extremely small relative to predation on squids	No concern
Forage availability for salmon	Depends on magnitude of squid catch taken in salmon foraging areas	Squid catch generally low, small change to salmon foraging at current catch	Probably no concern
Forage availability for toothed whales	Depends on magnitude of squid catch taken in toothed whale foraging areas	Squid catch generally low, small change to toothed whale foraging at current catch	Probably no concern
Forage availability for sablefish	Depends on magnitude of squid catch taken in sablefish foraging areas	Squid catch generally low, small change to sablefish foraging at current catch	Probably no concern
Forage availability for grenadiers	Squid catch overlaps somewhat with grenadier foraging areas along slope	Small change in forage for grenadiers	Probably no 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

Data gaps and research priorities

Clearly, there is little information for stock assessment of the squid complex in the GOA. However, ecosystem models estimate that the proportion of squid mortality attributable to incidental catch in groundfish fisheries in the GOA 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 sensitive species (e.g. toothed whales, albatrosses) is a higher priority for research. Limited data suggest that squids may make up 67 to 85% of the diet (by weight) for toothed whales in the GOA. Research should investigate whether the location and timing of incidental squid removals potentially overlap with foraging seasons and areas of these species, and whether the magnitude of squid catch at these key areas and times is sufficient to limit the available forage.

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Tables

Table 1. Taxonomic grouping of squid species that have been found in the BSAI. It is not known whether all of these species occur in the GOA.

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 catches of squid (t) in the Gulf of Alaska groundfish fisheries, 1990-2015 (1990 is the earliest year for which GOA squid catch data are available). This table also includes annual TACs for the Other Species complex and estimated Other Species catch, 1990-2010, as well as specifications for the squid complex beginning in 2011. **Squid catch reported here includes catch in NMFS statistical areas 649 & 659, which do not count against the squid TAC. For a breakdown of squid catch by area see Table 4.**

	squid catch (t)	Other Species catch (t)	Other Species TAC (t)	squid TAC (t)	squid ABC (t)	squid OFL (t)	management method
1990	60	6,289	n/a				Other Species TAC
1991	117	5,700	n/a				Other Species TAC (incl. Atka)
1992	88	12,313	13,432				Other Species TAC (incl. Atka)
1993	104	6,867	14,602				Other Species TAC (incl. Atka)
1994	39	2,721	14,505				Other Species TAC
1995	25	3,421	13,308				Other Species TAC
1996	42	4,480	12,390				Other Species TAC
1997	97	5,439	13,470				Other Species TAC
1998	59	3,748	15,570				Other Species TAC
1999	41	3,858	14,600				Other Species TAC
2000	19	5,649	14,215				Other Species TAC
2001	91	4,804	13,619				Other Species TAC
2002	43	3,748	11,330				Other Species TAC
2003	97	6,266	11,260				Other Species TAC
2004	162	1,705	12,942				Other Species TAC (no skates)
2005	636	2,513	13,871				Other Species TAC (no skates)
2006	1,530	3,881	13,856				Other Species TAC (no skates)
2007	417	3,035	4,500				Other Species TAC (no skates)
2008	98	2,967	4,500				Other Species TAC (no skates)
2009	345	3,188	4,500				Other Species TAC (no skates)
2010	139	1,724	4,500				Other Species TAC (no skates)
2011	239			1,148	1,148	1,530	squid complex
2012	22			1,148	1,148	1,530	squid complex
2013	361			1,148	1,148	1,530	squid complex
2014	172			1,148	1,148	1,530	squid complex
*2015**	*484*			1,148	1,148	1,530	squid complex

Data sources and notes: squid catch 1990-1996, Gaichas et al. 1999; squid catch 1997-2002, AKRO Blend; squid catch 2003-2015, AKRO CAS; Other Species catch, AKRO Blend and CAS; TAC, AKRO harvest specifications. Other Species catch from 1990-2003 does not include catch of skates in the IFQ Pacific halibut fishery, and after 2003 includes no skate catch at all.

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

Table 3. Estimated catch (t) of all squid species in the Gulf of Alaska combined by target fishery, 2003-2015. Data source: AKRO CAS.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	*2015**
pollock	68	145	632	1,518	410	92	321	129	209	7	346	143	*438*
rockfish	9	12	2	10	3	5	14	4	12	15	10	19	*23*
ATF	3	1	2	1	2	0	7	2	17	0	0	9	*17*
sablefish	0	4	0	0	1	0	0	0	0	0	1	0	*2*
FHS	0	0	0	0	0	0	0	0	0	0	0	0	*2*
Pcod	14	0	0	0	0	0	0	0	0	0	1	0	*1*
rex sole	2	0	0	0	0	0	2	3	1	0	1	0	*0*
deep flat	0	1	0	0	0	0	0	0	0	0	0	0	*0*
shallow_flat	0	0	0	0	1	0	1	0	0	0	0	0	*0*
total	**97**	**162**	**636**	**1,530**	**417**	**98**	**345**	**139**	**239**	**22**	**361**	**172**	***484***

*2015 data are incomplete; reported October 18, 2015.

Table 4. Estimated catch (t) of all squid species in the Gulf of Alaska combined by NMFS statistical area, 1997-2015. Data are from AKRO CAS.

area	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	***2015****
610	19	15	13	12	3	4	12	3	8	5	1	5	*5*
620	43	129	607	1,485	403	77	315	121	201	6	278	69	*270*
630	13	11	11	14	5	2	10	5	18	5	40	17	*97*
640	2	2	2	5	0	0	1	2	4	2	2	2	*2*
649	20	5	3	14	5	14	7	8	7	4	39	78	*109*
650	0	0	0	0	1	0	0	0	0	0	0	0	*0*
659	0	0	0	0	0	0	0	0	0	0	0	0	*0*
GOA total	**97**	**162**	**636**	**1,530**	**417**	**98**	**345**	**139**	**239**	**22**	**361**	**172**	***484***

*2015 are incomplete; retrieved October 18, 2015.

Table 5. Retention rates of squids in federal groundfish fisheries, 2011-2015. Data source: AKRO CAS. The 2015 data are incomplete; retrieved October 18, 2015.
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year	percent retained
2011	77%
2012	12%
2013	92%
2014	60%
2015	*79%*

Table 6. Biomass estimates (t) of squid species from NMFS GOA bottom trawl surveys, 1984-2015. CV = coefficient of variation.

	miscellaneous squids		*B. magister*		all squids	
year	biomass (t)	CV	biomass (t)	CV	biomass (t)	CV
1984	546	0.35	2,762	0.15	3,308	0.14
1987	577	0.30	4,506	0.34	5,083	0.30
1990	276	0.43	4,033	0.17	4,309	0.16
1993	1,029	0.73	8,447	0.13	9,476	0.14
1996	26	0.28	4,884	0.14	4,911	0.14
1999	254	0.46	1,873	0.13	2,127	0.13
2001	703	0.62	5,909	0.30	6,612	0.27
2003	71	0.23	6,251	0.18	6,322	0.18
2005	249	0.51	4,654	0.18	4,903	0.18
2007	359	0.49	11,681	0.20	12,040	0.20
2009	188	0.61	8,415	0.16	8,603	0.16
2011	392	0.65	4,040	0.13	4,431	0.14
2013	568	0.80	9,675	0.16	10,243	0.16
2015	387	0.65	13,692	0.12	14,079	0.12

Table 7. Alternative approaches for determining squid harvest recommendations in the GOA.

	author's recommendation	
	F=*M*, Baranov equation, *M*=1.0, long-term survey average	
(a)	**OFL**	**2,978**
	ABC	**2,234**
	comparison to other approaches:	
(b)	approach: maximum catch 1997-2007	
	OFL	**1,503**
	ABC	**1,148**
(c)	*F*=*M*, Baranov equation, *M*=1.0, RE estimate	
	OFL	**5,995**
	ABC	**4,496**
(d)	*F*=*M*, Baranov equation, *M*=1.0, 2x RE estimate	
	OFL	**11,990**
	ABC	**8,993**
	RE model biomass estimate	*13,867*
	long-term (1984-2015) average survey biomass estimate	*6,889*
	2X RE model estimate	*28,160*

Table 8. Biomass estimates and coefficients of variation (CV) for all squids combined in 6 depth zones of the GOA. Estimates are annual trawl survey estimates (surv est) or estimates from a random effects model fitted to each survey time series (RE est).

	GOA squids 1-100 m				GOA squids 101-200 m				GOA squids 201-300 m				GOA squids 301-500 m				GOA squids 501-700 m				GOA squids 701-1000 m			
	surv est	surv CV	RE est	RE CV	surv est	surv CV	RE est	RE CV	surv est	surv CV	RE est	RE CV	surv est	surv CV	RE est	RE CV	surv est	surv CV	RE est	RE CV	surv est	surv CV	RE est	RE CV
1984	7	0.66	13	0.66	65	0.33	79	0.32	210	0.22	226	0.21	2,180	0.20	2,176	0.19	381	0.28	274	0.30	464	0.21	430	0.21
1985			34	0.82			115	0.45			409	0.53			2,156	0.39			207	0.30			258	0.50
1986			89	0.78			167	0.45			742	0.56			2,136	0.43			156	0.32			154	0.55
1987	301	0.54	233	0.49	233	0.40	243	0.33	1,797	0.41	1,343	0.37	2,609	0.47	2,117	0.36	75	0.32	118	0.34	69	0.48	92	0.45
1988			335	0.76			371	0.45			1,267	0.57			1,782	0.42			119	0.40			82	0.68
1989			482	0.74			567	0.45			1,195	0.56			1,500	0.38			120	0.45			73	0.82
1990	892	0.39	694	0.39	1,306	0.35	867	0.34	966	0.33	1,127	0.31	1,145	0.18	1,263	0.18			122	0.48			64	0.91
1991			336	0.74			668	0.44			1,799	0.54			1,772	0.37			123	0.49			57	0.97
1992			163	0.78			514	0.41			2,871	0.52			2,486	0.38			124	0.50			51	1.00
1993	41	0.64	79	0.59	359	0.25	396	0.23	4,787	0.16	4,583	0.16	4,289	0.24	3,488	0.24			126	0.50			45	1.01
1994			112	0.80			419	0.41			3,778	0.51			2,643	0.38			127	0.49			40	1.00
1995			160	0.79			444	0.41			3,115	0.52			2,002	0.37			129	0.47			35	0.96
1996	278	0.60	228	0.52	487	0.26	471	0.24	2,648	0.22	2,568	0.21	1,498	0.17	1,517	0.16			130	0.44			31	0.90
1997			222	0.77			451	0.41			1,674	0.53			1,243	0.37			132	0.40			28	0.80
1998			217	0.75			432	0.41			1,090	0.53			1,018	0.37			133	0.33			25	0.66
1999	195	0.45	212	0.42	399	0.24	414	0.23	619	0.27	711	0.26	760	0.20	833	0.19	134	0.26	135	0.23	19	0.43	22	0.41
2000			274	0.79			447	0.43			963	0.57			1,013	0.39			137	0.30			24	0.62
2001			353	0.91			484	0.48			1,305	0.63			1,231	0.44			139	0.33			27	0.72
2002			455	0.86			523	0.44			1,769	0.55			1,496	0.39			142	0.32			31	0.75
2003	1,064	0.75	586	0.63	640	0.27	566	0.25	2,431	0.21	2,397	0.20	2,065	0.20	1,818	0.20	123	0.37	144	0.27			34	0.73
2004			369	0.70			443	0.36			2,871	0.46			1,294	0.32			159	0.27			38	0.64
2005	213	0.43	232	0.39	280	0.26	346	0.25	3,340	0.25	3,438	0.23	855	0.14	920	0.14	163	0.29	175	0.22	53	0.56	43	0.45
2006			201	0.67			498	0.40			4,909	0.46			1,283	0.35			204	0.27			39	0.52
2007	172	0.60	174	0.49	1,064	0.59	717	0.38	7,411	0.20	7,009	0.19	3,017	0.53	1,788	0.35	351	0.41	239	0.27	26	0.52	36	0.43
2008			155	0.68			820	0.42			5,944	0.46			1,804	0.37			238	0.28			47	0.54
2009	123	0.50	138	0.44	1,113	0.33	939	0.29	5,224	0.23	5,041	0.21	1,840	0.23	1,820	0.21	228	0.33	236	0.24	74	0.68	62	0.51
2010			168	0.67			785	0.40			3,304	0.46			1,774	0.32			241	0.29			73	0.66
2011	197	0.50	203	0.44	463	0.46	657	0.35	1,932	0.24	2,165	0.23	1,639	0.16	1,728	0.15	201	0.61	245	0.29			85	0.74
2012			269	0.67			766	0.40			3,056	0.46			2,473	0.33			259	0.29			100	0.75
2013	376	0.52	355	0.45	961	0.34	893	0.28	4,298	0.21	4,312	0.20	4,315	0.28	3,541	0.25	293	0.35	274	0.25			117	0.70
2014			409	0.65			914	0.37			6,245	0.45			3,243	0.34			279	0.27			138	0.59
2015	483	0.36	470	0.35	943	0.23	937	0.22	9,295	0.17	9,045	0.16	2,899	0.22	2,971	0.21	289	0.28	283	0.24	171	0.34	161	0.33

Figures

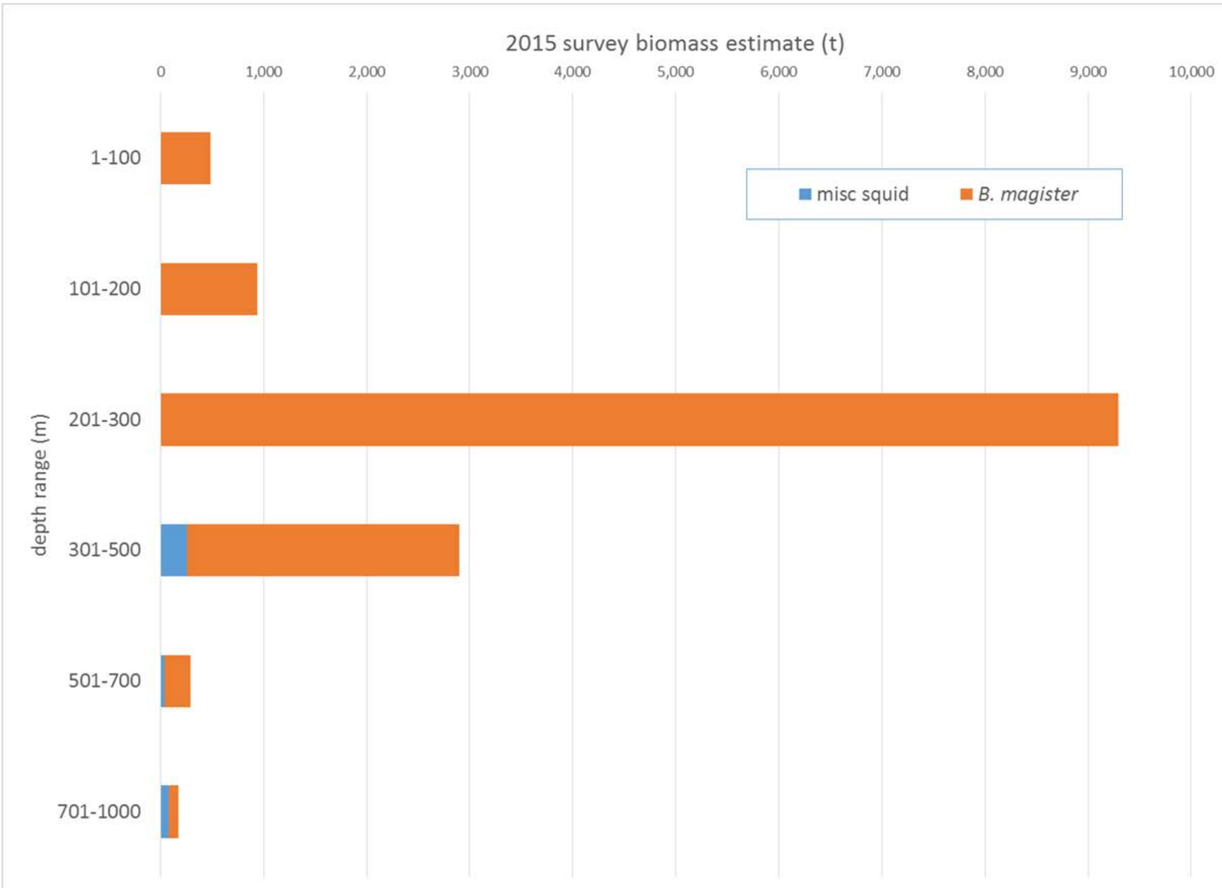

Figure 1. Distribution by depth of squids observed in the GOA bottom trawl survey in 2015.

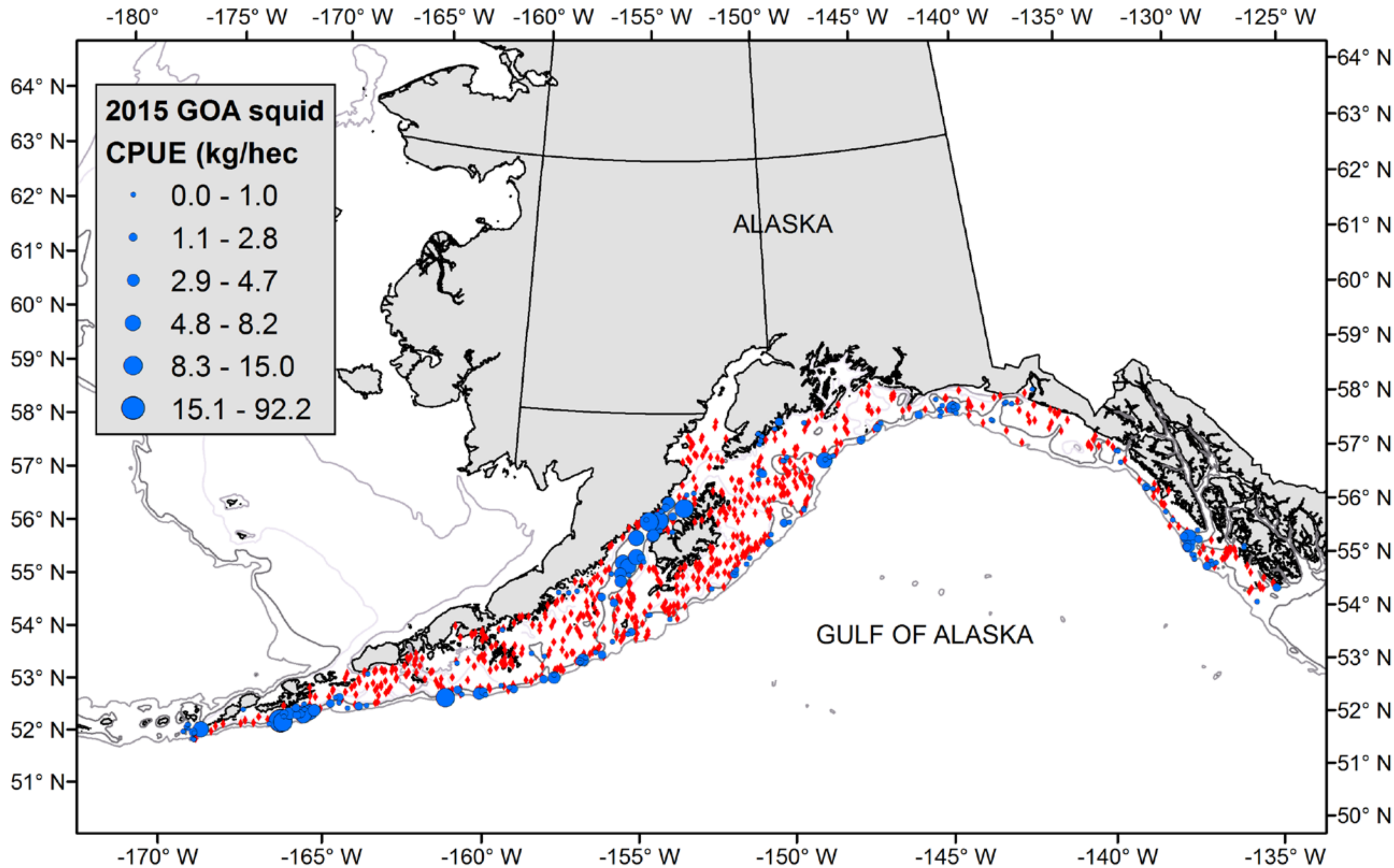

Figure 2. Distribution of survey catches of all squids in the GOA during 2015. Red diamonds indicate hauls with no squid catch.

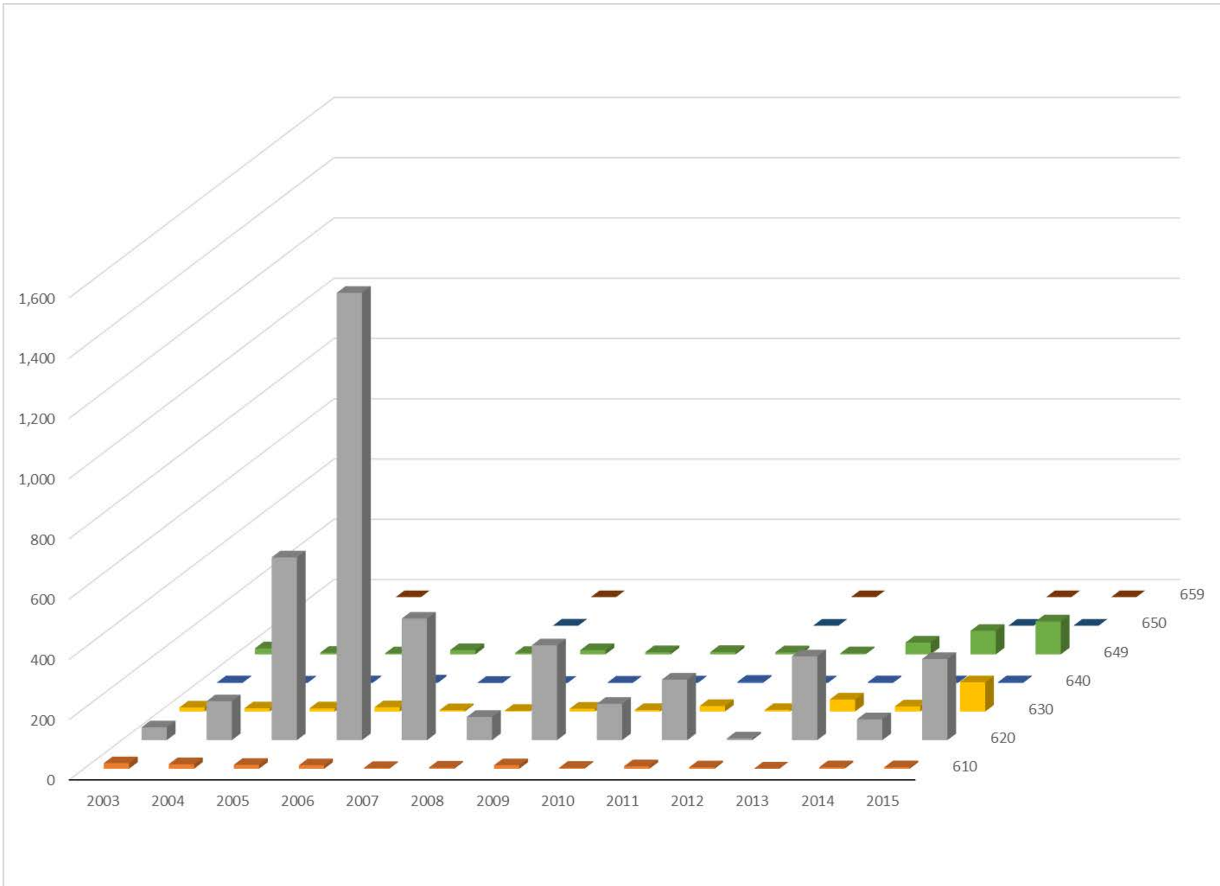

Figure 3. Estimated catch (t) of all squid species combined in the Gulf of Alaska by NMFS statistical area, 2003-2015. Data source: AKRO CAS. 2015 data are incomplete; retrieved October 18, 2015.

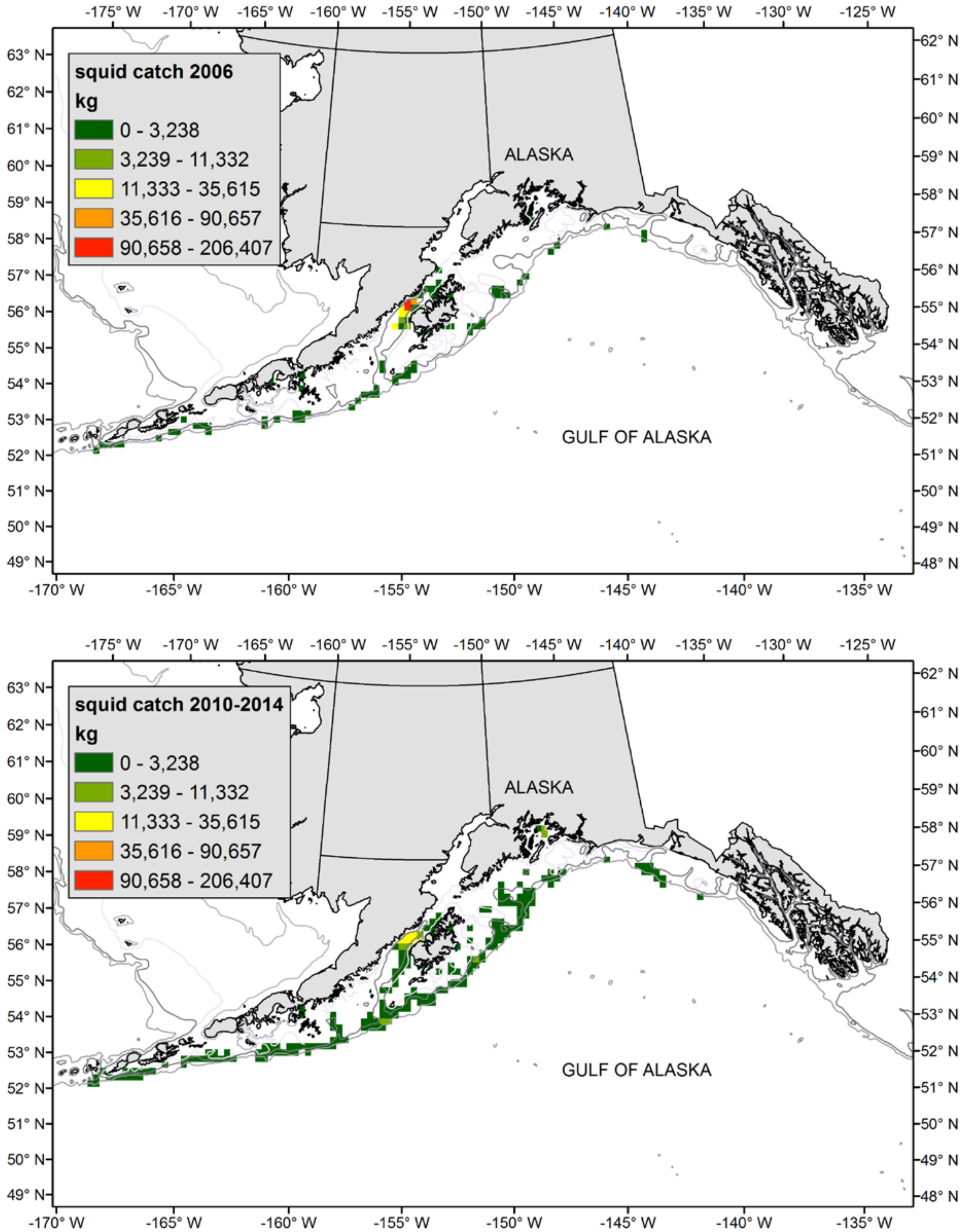

Figure 4. Distribution of squid catches in the GOA in 2006 (top panel) and during 2010-2014 (bottom panel). Data are total catch per 20 km x 20 km grid cell.

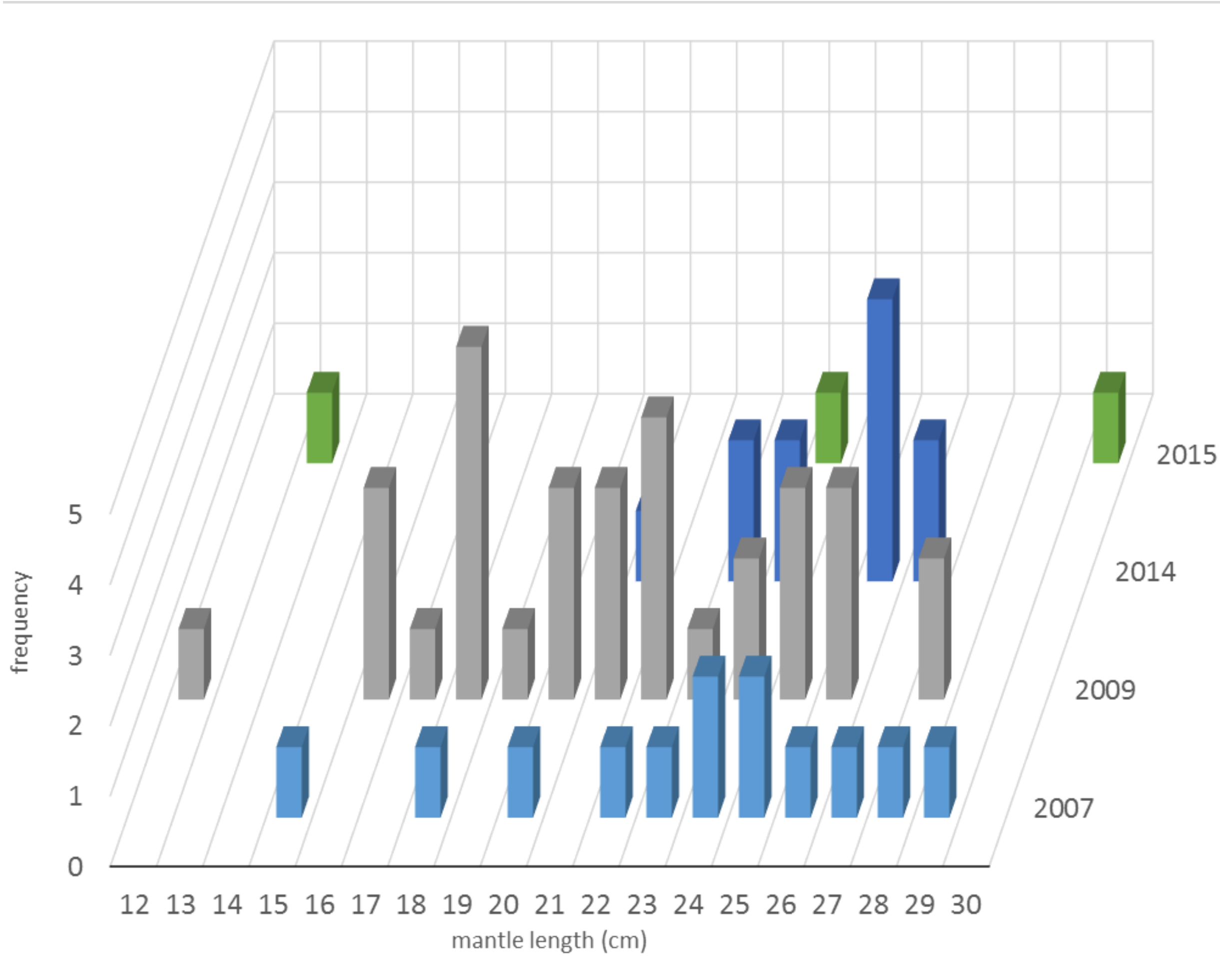

Figure 5. Size composition of squids in GOA fishery catches.

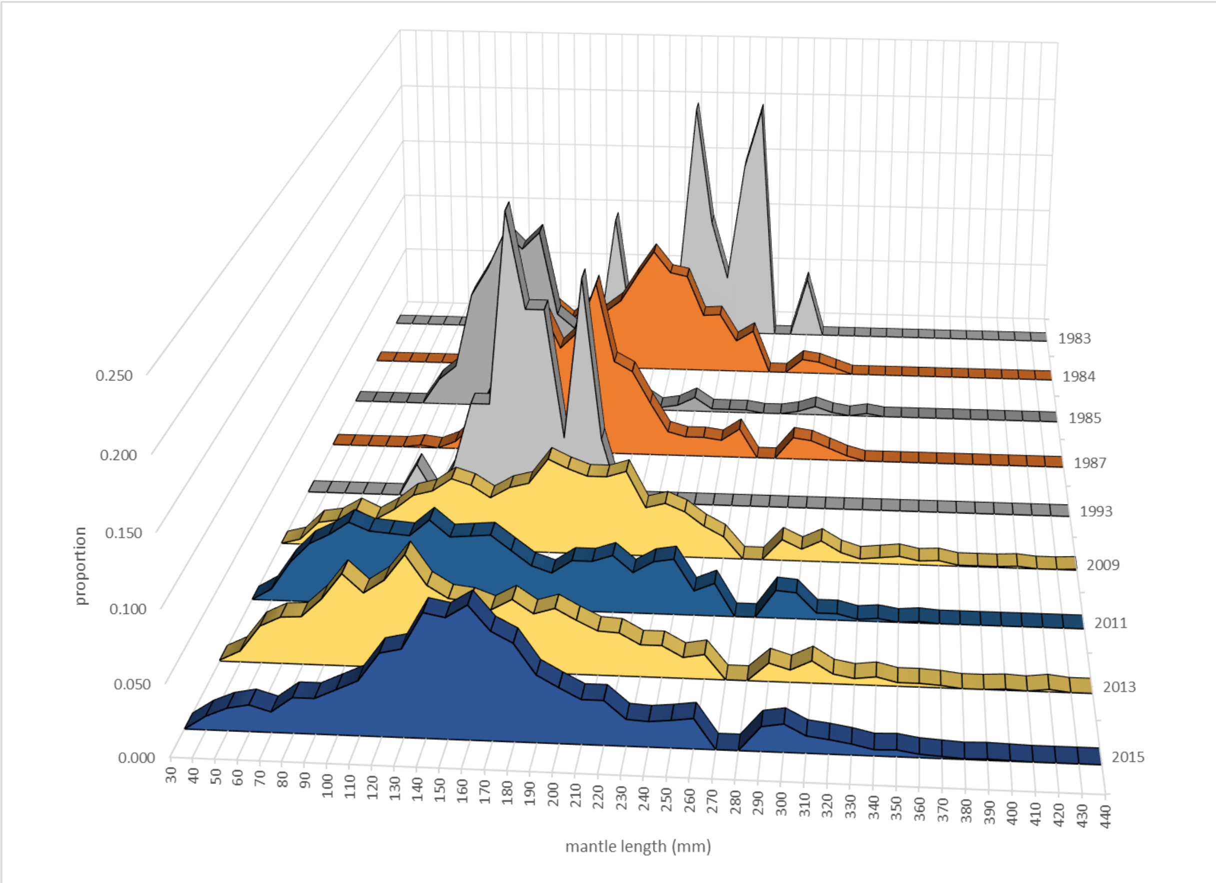

Figure 6. Size composition of *B. magister* in GOA survey catches.

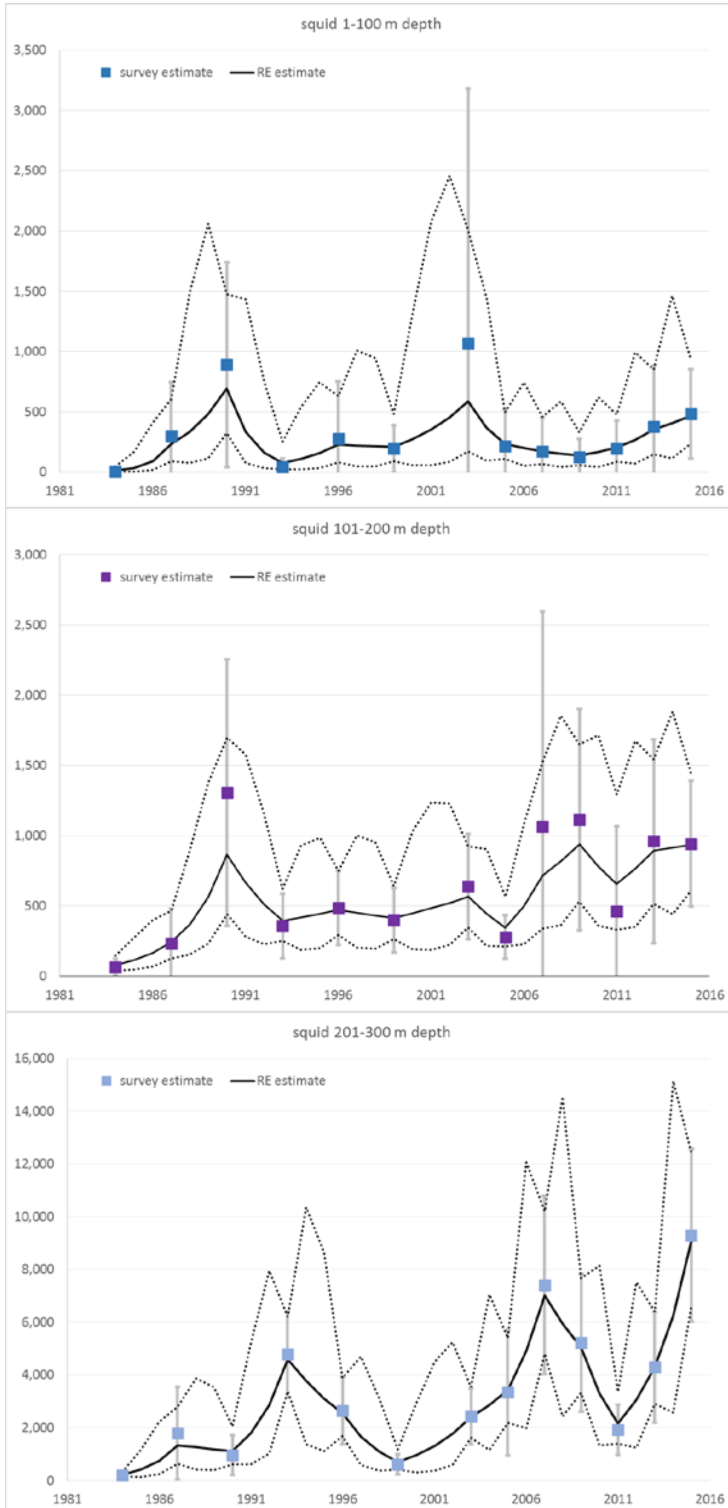

Figure 7. Survey biomass estimates (t; colored squares) and results from a random-effects model of survey biomass (t; black line) for squids in 3 depth zones of the GOA. Confidence intervals are marked by grey bars (survey estimates) and dashed black lines (model estimates). Vertical scales differ among plots.

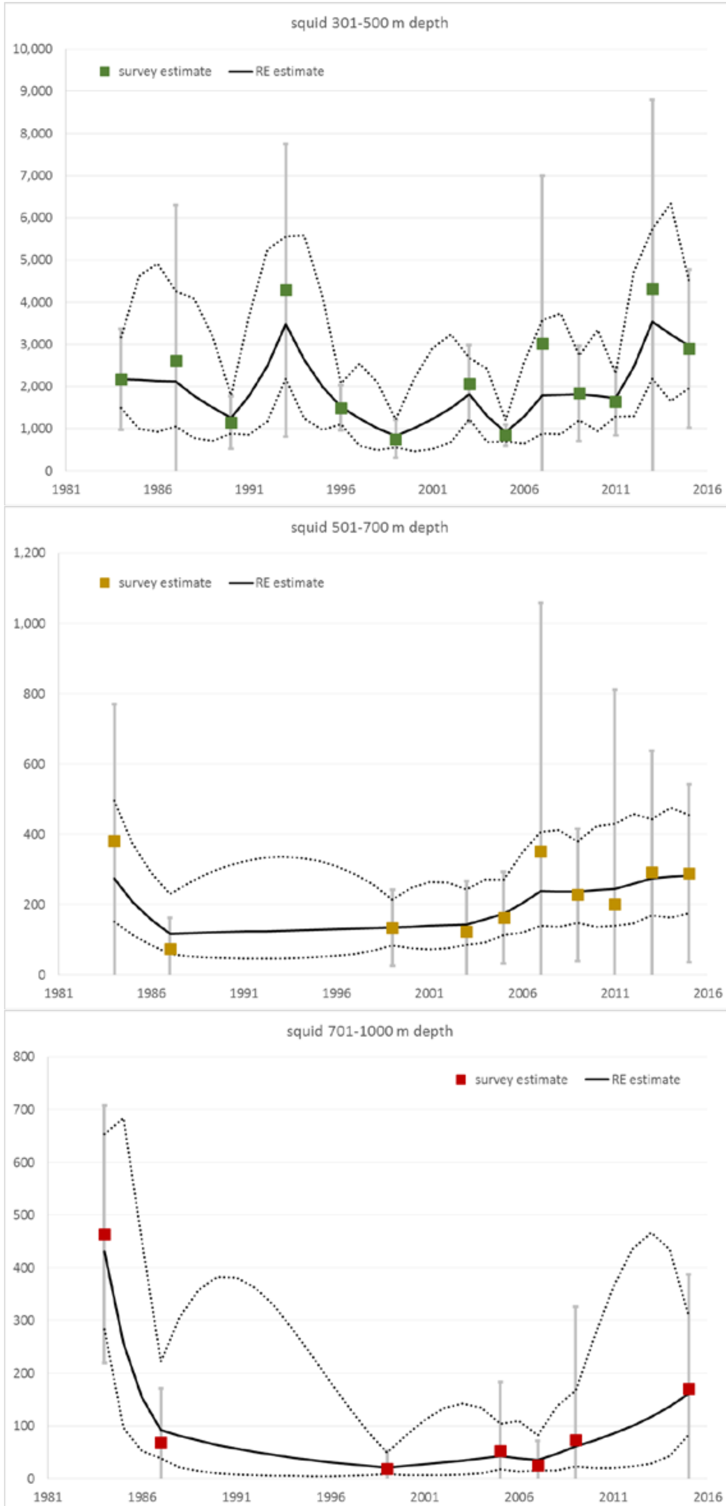

Figure 8. Survey biomass estimates (t; colored squares) and results from a random-effects model of survey biomass (t; black line) for squids in 3 depth zones of the GOA. Confidence intervals are marked by grey bars (survey estimates) and dashed black lines (model estimates). Vertical scales differ among plots.

Appendix: Summary of non-commercial catches. Data are from the Alaska Regional Office.

	Annual Longline Survey	Gulf of Alaska Bottom Trawl Survey	Large-Mesh Trawl Survey	Salmon EFP 13-01	Shelikof Acoustic Survey	Shelikof and Chirikof EIT	Shumigans Acoustic Survey	Small-Mesh Trawl Survey	Subsistence Fishery	Western Gulf of Alaska Pollock Acoustic Cooperative Survey	**total**
agency	NMFS	NMFS	ADFG	NMFS	NMFS	NMFS	NMFS	ADFG	ADFG	NMFS	
1988									103		103
1991									1,672		1,672
1993									41		41
1996									10		10
1997									147		147
1999			73								73
2000								0.31	20		20
2001			45								45
2003			16								16
2004								0.42			0
2005			32					37			69
2006								38			38
2007			29					15			44
2009			18								18
2010					13		1	57		0.01	72
2011		34	40					51			125
2012			24			9		39			71
2013		29	124	21,641				135			21,929
2014	3		28	716				46			794

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