22. Assessment of the Octopus Stock Complex in the Gulf of Alaska

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Executive Summary

At least seven species of octopus are found in the Gulf of Alaska (GOA). For management purposes, all octopus species are grouped into a single assemblage. Neither the relative abundances of the various species or the species composition of the commercial catch are well documented, but research indicates that the giant Pacific octopus *Enteroctopus dofleini* is the most abundant octopus species in shelf waters and makes up the bulk of octopus catches in commercial fisheries. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the GOA; a portion of the catch is retained or sold for human consumption or bait. The highest octopus catch rates are from Pacific cod pot fisheries in the central and western GOA (NMFS statistical areas 610 and 630).

Through 2010, octopuses were managed as part of the "other species" complex, with catch reported only in the aggregate along with sharks, squids, and sculpins. In 2011, the GOA Fishery Management Plan was amended to provide separate management for sharks, sculpins, squids, and octopuses. In compliance with the reauthorized Magnuson-Stevens Act, each complex has its own annual catch limit. Harvest recommendations for the octopus complex are made using a modified Tier 6 approach, where the overfishing level (OFL) is calculated by multiplying the best available estimate of octopus biomass by the best estimate of natural mortality for *E. dofleini*. Catch limits for octopus for 2011-2014 were set using the average biomass from the last 3 surveys. Beginning in 2015, a random-effects (RE) model is used to provide a minimum biomass estimate.

Summary of Changes in Assessment Inputs

<u>Summary of changes in data</u>

1) All catch data have been updated through October 11, 2017.
2) Results from the 2017 GOA bottom trawl survey have been added to the assessment.
3) The random effects model for estimating survey biomass has been run with 2017 data and the results were used for harvest recommendations.
4) Additional detail regarding survey results and catch information have been added to the assessment, including the reorganization of catch data in the tables and the addition of several tables and figures.

<u>Summary of changes in assessment methods</u>

No changes were made to the assessment methods.

Summary of Results

1) The 2017 trawl survey biomass estimate for the octopus complex is 1,049 t. This is substantially lower than the 2015 estimate of 13,008 t and is the lowest estimate since 2001.

2) The RE-model estimate of 2017 biomass is 1,539 t compared to the 2015 RE-model estimate of 12,270 t.

3) Frequency of occurrence in the survey (5% of hauls) is the lowest since 1996, and the survey CPUE (0.7 kg/hec) is the lowest since 2005.

4) The survey size composition suggests that small animals (≤ 0.5 kg) constituted a much greater proportion of the *E. dofleini* population than in previous years.

5) Although the 2017 catch data are incomplete, the 2017 catch (166 t as of October 11) is on track to be at its lowest level since 2006.

6) **The recommended OFL of 816 t is an order of magnitude lower than the 2016 recommendation of 6,504 t. This is the status quo recommendation based on the approach taken in the previous 2 full assessments. Given the volatility of the harvest recommendations, the Plan Team may wish to consider an alternative approach.**

Harvest Recommendations				
	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2017	2018	2018	2019
Tier 6 (RE model biomass * *M*)				
M	*0.53*	*0.53*	**0.53**	0.53
RE model biomass estimate	*12,270*	*12,270*	**1,539**	1,539
OFL (t)	*6,504*	*6,504*	**816**	816
maxABC (t)	*4,878*	*4,878*	**612**	612
ABC (t)	*4,878*	*4,878*	**612**	612
	As determined *last* year for:		As determined *this* year for:	
Status	2015	2016	2016	2017
Overfishing	no	n/a	no	n/a

Responses to SSC and Plan Team Comments on Assessments in General

The Plan Team and SSC had no general comments that apply to the octopus assessment.

Responses to SSC and Plan Team Specific to this Assessment

From the December 2016 SSC minutes:

The Plan Team expressed concern that the Random Effects model that was applied to survey data appeared to follow the data too tightly given the error. The SSC supports their recommendation that the author examine this.

> *Response*: As of this assessment there is a new stock assessment author for the octopus complex. The RE methodology the new author has used successfully in the past for skates was used here and appeared to provide good results. The way the results are presented (Figure 9) have been changed to make it clear how the survey variance and model output are related.

From the November 2016 Plan Team minutes:

There was concern by the Team about the results of the RE model that was applied to survey data. The model appeared to follow the data too tightly given the error. The analyst will review the data used for the figures depicting RE in the report

> *Response*: See response to similar SSC comment above.

Introduction

Description and general distribution

Octopuses are marine mollusks in the class Cephalopoda. The cephalopods, whose name literally means head foot, have their appendages attached to the head and include octopuses, squids, and nautiluses. The octopuses (order Octopoda) have only eight appendages or arms and unlike other cephalopods, the octopus lack shells, pens, and tentacles. There are two groups of Octopoda, the cirrate and the incirrate. The cirrate have cirri (cilia-like strands on the suckers) and paddle-shaped fins suitable for swimming in their deep oceanic pelagic and epibenthic habitats (Boyle and Rodhouse 2005) and are much less common than the incirrate which contain the more traditional forms of octopus. Octopuses are found in every ocean in the world and range in size from less than 20 cm (total length) to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini* (Wülker, 1910). *Enteroctopus dofleini* is one of at least seven species of octopus found in the GOA (Tables 1 & 2). Members of these seven species represent six genera and can be found in depths from less than 10 m to greater than 1500 m. All but one, *Japetella diaphana*, are benthic octopuses. The state of knowledge of octopuses in the GOA, including the true species composition, is very limited.

In the GOA, octopuses are found from subtidal waters to deep areas near the outer slope (Figures 1-3). The highest species diversity is along the shelf break region of the GOA, although there is a high abundance of octopuses on the shelf. While octopuses are observed throughout the GOA, they are more commonly observed in the central and western GOA (areas 610-630) than in the eastern GOA. Both survey and fishery CPUE suggest concentrations around Kodiak Island and the Shumagin Islands (Figures 1 & 4). These observations are influenced by survey catchability and selectivity, as well as the distribution of fishing effort, and may not reflect true spatial patterns. Octopuses were caught in the fishery at all depths ranging from shallow inshore areas (mostly pot catches) to trawl and longline catches on the continental slope at depths to nearly 1000 meters. The majority of octopus caught with pots in the GOA came from 70-110 meters; catches from longline vessels tended to be in deeper waters of 360-730 meters. AFSC survey data also demonstrate the presence of octopus throughout the GOA and also indicate highest biomass in areas 610 and 630. Octopuses are also common in the eastern Bering Sea and throughout the Aleutian Island chain.

Management units

Through 2010, octopuses were managed as part of the "other species" complex in the GOA. Prior to 2003, catch of other species (squid, octopus, sharks, and sculpins) was reported only in aggregate. Separate catch reporting for different components of the other species complex was initiated in 2003, but octopus was still reported as an aggregate catch for all octopus species. Catch of other species from 2005-2009 was limited by a Total Allowable Catch (TAC) set at $\leq$ 5% of the combined GOA target species TAC. In October 2009, the NPFMC voted unanimously to amend both the BSAI and GOA Fishery Management Plans to eliminate the 'other species' category. Plan amendments were initiated to move species groups formerly included in 'other species' into the target species category and provide for management of these groups with separate catch quotas under the 2007 reauthorization of the Magnuson-Stevens Act and National Standard One Guidelines. These amendments also created an 'Ecosystem Component' category for species not retained commercially. Separate catch limits for groups from the former "other species" category, including octopus, were implemented in January 2011.

National Standard One Guidelines instruct managers to identify core species and species assemblages. Species assemblages should include species that share similar regions and life history characteristics. The GOA octopus assemblage does not fully meet these criteria. All octopus species have been grouped into a species assemblage for practical reasons, as it is unlikely that fishers will identify octopus to species. Octopus are currently recorded by fisheries observers as either "octopus unidentified" or "pelagic octopus unidentified". *Enteroctopus dofleini* is the key species in the assemblage, is the best known, and is most likely to be encountered at shallower depths. The seven species in the assemblage, however, do not necessarily share common patterns of distribution, growth, and life history. One possible approach for the future is to split this assemblage by size, and allow retention of only larger animals. This would restrict harvest to the larger *E. dofleini* and minimize impact to the smaller animals which may be other octopus species.

Life history and stock structure

In general, octopuses are fast growing with a life span generally less than five years. Life histories of seven of the eight species in the Gulf of Alaska are largely unknown. *Enteroctopus dofleini* has been studied extensively in Alaskan, Japanese and Canadian waters and its life history will be reviewed here; generalities on the life histories of the other seven species will be inferred from what is known about other members of the genus.

Enteroctopus dofleini within the Gulf of Alaska have been found to mature between 10 to 20 kg with 50% maturity values of 13.7 kg (95% CI 12.5-15.5 kg) for females and 14.5 kg (95% CI = 12.5-16.3 kg) for males (Conrath and Conners, 2014). *Enteroctopus dofleini* are problematic to age due to a documented lack of beak growth checks and soft chalky statoliths (Robinson and Hartwick 1986). Therefore the determination of age at maturity is difficult for this species. In Japan this species is estimated to mature at 1.5 to 3 years and at similar but smaller size ranges (Kanamaru and Yamashita 1967, Mottet 1975). Within the Gulf of Alaska this species has a protracted reproductive cycle with a peak in spawning in the winter to early spring months. Due to differences in the timing of peak gonad development between males and females, it is likely that females have the capability to store sperm. This phenomenon has been documented in an aquarium study of octopus in Alaska (Jared Gutheridge pers. com.) and British Columbia (Gabe 1975). Fecundity for this species ranges from 40,000 to 240,000 eggs per female with an average fecundity of 106,800 eggs per female. Fecundity is significantly and positively related to the size of the female. The fecundity of this species in Japanese waters has been estimated at 30,000 to 100,000 eggs per female (Kanamaru 1964, Mottet 1975, Sato 1996). Gabe (1975) estimated a female in captivity in British Columbia laid 35,000 eggs. Hatchlings are approximately 3.5 mm. Mottet (1975) estimated survival to 6 mm at 4% while survival to 10 mm was estimated to be 1%; mortality at the 1 to 2 year stage is also estimated to be high (Hartwick, 1983). Since the highest mortality occurs during the larval stage, it is probable that ocean conditions have a large impact on numbers of *E. dofleini* in the GOA and large interannual fluctuations in numbers of *E. dofleini* would be expected.

Enteroctopus dofleini is found throughout the northern Pacific Ocean from northern Japanese waters, throughout the Aleutian Islands, the Bering Sea and the Gulf of Alaska and as far south down the Pacific coast as southern California (Kubodera, 1991, Jorgensen 2009). The stock structure and phylogenetic relationships of this species throughout its range have not been well studied. Three sub-species have been identified based on large geographic ranges and morphological characteristics including *E. dofleini dofleini* (far western North Pacific), *E. dofleini apollyon* (waters near Japan, Bering Sea, Gulf of Alaska), and *E. dofleini martini* (eastern part of their range, Pickford 1964). A recent genetic study (Toussaint et al. 2012) indicate the presence of a cryptic species of *E. dofleini* in Prince William Sound, Alaska and raises questions about the stock structure of this species. There is little information available about the migration and movements of this species in Alaska waters. Kanamaru (1964) proposed that *E. dofleini* move to deeper waters to mate during July through October and then move to shallower waters to spawn during October through January in waters off of the coast of Hokkaido, Japan. Studies of movement in British Columbia (Hartwick et al. 1984) and south central Alaska (Scheel and Bisson 2012) found no evidence of a seasonal or directed migration for this species.

Octopus californicus is a medium-sized octopus with a maximum total length of approximately 40 cm. Very little is known about this species of octopus. It is collected between 100 to 1,000 m depth in Alaska and has been reported in even deeper waters off the coast of California (Smith and Mackenzie 1948). It is believed to spawn 100 to 500 eggs. Hatchlings are likely benthic; hatchling size is unknown. The female likely broods the eggs and dies after hatching.

Octopus rubescens is common along the U.S. west coast and has been reported from Prince William Sound, but its presence in the GOA has not been verified by survey collections. *Octopus rubescens* appears to have a two year life cycle with egg laying occurring in July through September and hatching occurring 5 to 10 months later in February through March. Females of this species are terminal spawners estimated to lay approximately 3,000 eggs (Dorsey 1976). *Octopus rubescens* has a planktonic larval stage.

Octopus sp. A is a small-sized species with a maximum total length < 10 cm. This species has only recently been identified in the GOA and its full taxonomy has not been determined. *Octopus sp. A* is likely a terminal spawner with a life-span of 12 to 18 months. The eggs of *Octopus sp. A* are likely much larger than those of *O. rubescens*, as they have larger benthic larvae. Females of *Octopus sp. A* lay between 80 and 90 eggs that take up to six months or more to hatch.

Benthoctopus leioderma is a medium sized species; its maximum total length is approximately 60 cm. Its life span is unknown. It occurs from 250 to 1400 m and is found throughout the shelf break region. It is a common octopus and often occurs in the same areas where *E. dofleini* are found. The eggs are brooded by the female but mating and spawning times are unknown. Members of this genus in the North Pacific Ocean have been found to attach their eggs to hard substrate under rock ledges and crevices

(Voight and Grehan 2000). *Benthoctopus* tend to have small numbers of eggs (<200) that develop into benthic hatchlings.

Opisthoteuthis californiana is a cirrate octopus; it has fins and cirri (on the arms). It is common in the GOA but is not likely to be confused with *E. dofleini*. It is found from 300 to 1,100 m and is likely common over the abyssal plain. *Opisthoteuthis californiana* in the northwestern Bering Sea have been found to have a protracted spawning period with multiple small batch spawning events. Potential fecundity of this species was found to range from 1,200 to 2,400 oocytes (Laptikhovsky 1999). There is evidence that *Opisthoteuthis* species in the Atlantic undergo 'continuous spawning' with a single, extended period of egg maturation and a protracted period of spawning (Villanueva 1992). Other details of its life history remain unknown.

Japetella diaphana is a small pelagic octopus. Little is known about members of this family. In Hawaiian waters gravid females are found near 1,000 m depth and brooding females near 800 m depth. Hatchlings have been observed to be about 3 mm mantle length (Young 2008). This is not a common octopus in the GOA and not likely to be confused with *E. dofleini*.

Vampyroteuthis infernalis is a cirrate octopus. It is not common in the GOA and is easily distinguishable from other species of octopus by its black coloration. Very little is known about its reproduction or early life history. A hatchling with a mantle length of 8 mm with yolk was captured near the Hawaiian Islands indicating an egg size of around 8 mm for this species (Young and Vecchione 1999).

In summary, there are at least seven species of octopus present in the GOA, and the species composition of both the natural communities and commercial harvest is unknown. At depths less than 200 meters, *E. dofleini* appears to have the highest biomass, but the abundances of *B. leioderma* and *Octopus sp. A.* are also high. The greatest difference in species composition between the Bering Sea Aleutian Islands (BSAI) and the GOA is the presence of *O. californicus* in the GOA.

Fishery

<u>Directed fishery</u>

There is no federally-managed directed fishery for octopus in the GOA. One processor in Kodiak purchases incidentally-caught octopus, primarily for halibut bait. Ex-vessel prices for octopus in Kodiak are typically around $0.50 /lb (Sagalkin and Spalinger, 2011, AKFIN 2015). Recent increases in global market value have increased retention of incidentally-caught octopus in the BSAI and GOA. Overall, only 37% of the 2015 catch in the GOA was retained, but a large fraction (79%) of the catch from area 630 was retained. Because of the relatively large number of small boats in the GOA commercial fleet and recent changes to crab fishing seasons, there is some interest in directed fishing for octopus in the GOA.

The State of Alaska allows directed fishing for octopus in state waters under a special Commissioner's permit. A small directed fishery in state waters around Unimak Pass and in the AI existed from 1988-1995; catches from this fishery were reportedly less than 8 t per year (Fritz 1997). Commissioner's permits are available for targeting octopus but are rarely taken advantage of; two boats fished for octopus on such permits in 2014 with a total catch of approximately 1.5 tons. The majority of octopus catch in state waters is incidental to other fisheries (Bowers et al. 2010, Sagalkin and Spalinger, 2011).

Incidental catch

Octopus are caught incidentally throughout the GOA in both state and federally-managed bottom trawl, longline, and pot fisheries. From 1992-2002 total incidental catch of octopus in federal waters was estimated from observed hauls (Gaichas 2004). Since 2003 the total octopus catch in state and federal waters (including discards) has been estimated using the NMFS Regional Office Catch Accounting System. Incidental catch data are presented in Tables 3-5 and Figure 5 and discussed below in the data section. The majority of incidental catch of octopus comes from Pacific cod fisheries, primarily pot fisheries. Some catch is also taken in trawl fisheries for Pacific cod and other species and in longline fisheries. The overwhelming majority of catch in federal waters occurred in the central and western GOA in statistical reporting areas 610, 620 and 630. In 2014-2015, there were particularly high octopus catches not only in the Shumagin and Kodiak regions (610 and 630), but also in the Chirikof region (620). The species of octopus taken is not recorded, although size distributions suggest that the majority of the catch from pots is *E. dofleini*.

Catch history

Since there has been only a limited market for octopus and no directed fishery in federal waters, there is limited data available for documenting catch history. Historical rates of incidental catch would not necessarily be indicative of future fishing patterns if octopuses were increasingly retained for market catch. Estimates of incidental catch suggest substantial year-to-year variation in abundance, which would result in large annual fluctuations in harvest. This large interannual variability is consistent with anecdotal reports (Paust 1988, 1997) and with life-history patterns for *E. dofleini*.

Data

Fishery

Incidental catch data

From 1997-2007, total incidental catch of octopus in state and federal waters ranged from 88 t to 298 t (Table 3). Catches increased beginning in 2008 and during 2008-2016 did not drop below 300 t. Particularly high catches were observed in 2011, 2014, and 2015. The amount of catch appears to depend primarily on octopus abundance, as catch patterns mirror trends in survey biomass estimates. High rates of incidental catch in 2002, 2004, 2009, 2011, and 2014-15 correspond to high survey catches in 2003, 2009, 2011, and 2015 (Tables 2 & 5).

The vast majority of the incidental catch occurs in the Pacific cod fishery, particularly vessels using pot gear, and in statistical areas 610 and 630 (Tables 4 & 6; Figure 5). Retention rates of captured octopuses during 2003-2016 ranged from 40% to 90%, but in most years approximately half of the catch was retained (Table 3). Retention also varies by area: in 2015, the overall retention rate is estimated at 40% but a large fraction (97%) of octopus caught in area 630 (Kodiak) was retained.

Catches of octopus in the GOA have declined during 2016 and 2017 after two years of relatively high catches in 2014 and 2015 (Table 3). As of October 11, 2017 the catch was 166 t and it appears that the 2017 catch may be the lowest since 2006.

Federal Groundfish Observer Program data

Groundfish observers record octopus in commercial catches as either “octopus unidentified” or “pelagic octopus unidentified”. Observer records do, however, provide a substantial record of catch of the octopus species complex. Figure 4 shows the spatial distribution of observed octopus catch in the GOA (aggregated over 400 km^2 blocks) for the years 2006-2016. The majority of GOA octopus caught by pot gear came from depths of 70-110 meters; catches from longline vessels tended to be in deeper waters (360-730 meters). Unlike data from the Bering Sea, the depth range of octopus catches in the GOA is similar between industry and survey data.

Because of their unique shape measuring octopus size is problematic, and body weight is the most reliable and consistent metric for evaluating size. Not all octopuses are individually weighed in either the trawl surveys or in observed hauls. To evaluate the average size of octopuses captured in surveys and fisheries, data on total weight and number of individuals in fishery hauls was used to estimate a mean weight of octopus in each haul. In most cases only one octopus was sampled and the weight data reflects an exact weight for that individual. The size distribution of captured octopus varies substantially among gear types (Figure 6). Pot gear selects for larger individuals: the size composition has a distinct mode at 14 kg. Based on size alone, these larger individuals are probably *E. dofleini*. Commercial trawls and longlines show size distributions more similar to that of the survey (Figure 7), with a wide range of sizes and a large fraction of octopus weighing 2 kg or less. These smaller octopuses may be juvenile *E. dofleini* or may be any of several species, especially *B. leioderma* or *Octopus* sp. It is apparent that temporal and spatial catch patterns in the pot fishery are primarily determined by seasonal timing and locations of pot fishing for Pacific cod; total observed pot fishing effort varies widely from year to year. Pot fishing in the GOA occurs primarily to the north and east of Kodiak (Chiniak Bay), in Kuprianof Strait, along the west side of Kodiak Island (statistical area 630), and in the western GOA between the Shumagin Islands and Sanak Island (area 610). Octopus catch occurs primarily in January-February and in September.

In order to confirm the recent increases in octopus survey biomass and total catch, observer data was used to construct an estimate of incidental catch-per-unit-effort (CPUE) of octopus (Figure 8). The extrapolated catch of octopus from each haul was divided by the total number of pots fished on each haul and the results were expressed as individuals/pot. The CPUE index was calculated for the entire GOA region and for area 630 only. The GOA-wide and 630 indices display similar trends, but the 630 CPUE is higher in some years: 1999, 2003, 2005-2007, 2009-2010, and particularly 2014. Both indices also parallel the total incidental catch, with a period of fairly stable catch rates from 1998-2007, higher CPUE/catches during 2008 – 2015, and a decreasing trend after 2015.

Survey

<u>AFSC survey data</u>

Catches of octopus are recorded during the biennial NMFS bottom trawl survey of the GOA. In older survey data (prior to 2003) octopus were not consistently identified to species (often being recorded as Octopodidae or *Octopus* sp.) and some individuals may have been occasionally misidentified as *E. dofleini*. Since 2003, increased effort has been put into cephalopod identification and species composition data are considered more reliable; species composition of octopus catch in recent GOA bottom trawl surveys is shown in Table 2. Based on available data, the species with the highest biomass in shelf waters is *E. dofleini*. The size distribution by weight of individual octopus collected by the bottom trawl surveys from 2003 through 2017 is shown in Figure 7. Survey-caught octopus ranged in weight from less than 0.1 kg to over 22 kg, but most individuals weighed 4 kg or less; 38% of all individuals were < 0.5 kg. For most octopus species this likely approximates the size distribution in the population; however for E. dofleini the trawl survey is highly selective for smaller individuals. The basis for this selectivity is unknown but may be related to the distribution of larger octopuses in untrawlable habitat or because they are more adept at avoiding the trawl.

Survey catches of octopus occur throughout the GOA (Figures 1-3). The survey catches octopuses at all depths from 25 to over 900 meters; the most frequent depth of survey catch is in the 100-300 meter range.

The 2009 through 2017 GOA trawl surveys caught primarily *E dofleini, B. leioderma*, and *O. Californiana* (Table 2). The majority of the biomass, however, is *E dofleini*; in 2017 this species made up 96% of the total estimated octopus complex biomass. *Enteroctopus dofleini* occurs more frequently in the central and western GOA and estimated biomass is higher in these regions (Figure 1). *Opisthoteuthis californiana* occurs mainly to the west of Kodiak Island and along the edge of the continental shelf (Figure 2). In contrast, *Benthoctopus leioderma* occurs mainly in survey catches to the east of Kodiak Island (Figure 3).

In contrast to the very large octopus biomass estimated by the trawl survey in 2015, the 2017 biomass estimate of 1,049 t is the lowest since 2001 (Table 5 and Figure 9). The mean CPUE (0.7 kg/hec) was the lowest since 2005 (Table 2) and the frequency of occurrence (5% of survey hauls) was the lowest since 1996 (Table 5). The coefficient of variation (CV) for octopus biomass estimates is typically high but was especially high for the 2017 estimated at 0.43. Very little of the octopus biomass occurs in the eastern GOA (Figure 10); since 2011 the proportion of the biomass in the western GOA has been increasing to the point that biomass is now approximately equal between the western and central areas. Relative to previous years, the 2017 survey catch included more small *E. dofleini*, with the majority of individuals weighing 0.5 kg or less (Figure 11).

Biomass estimation

Estimates of octopus biomass based on the biennial GOA trawl surveys (Table 5) represent total weight for all species of octopus, and are calculated using the sample procedures used for estimating groundfish biomass (National Research Council 1998, Wakabayashi et al. 1985). The positive aspect of these estimates is that they are founded on fishery-independent data collected by proper design-based sampling. The standardized methods and procedures used for the surveys make these estimates the most reliable biomass data available. The survey methodology has been carefully reviewed and approved in the estimation of biomass for other federally-managed species. There are, however, some drawbacks to using the trawl survey biomass estimates for octopus.

As noted earlier, the survey trawl may not be suitable gear for sampling octopus. The bottom trawl net used for the GOA survey has roller gear on the footrope to reduce snagging on rocks and obstacles and may allow benthic organisms, including octopus, to escape under the net. Given the tendency of octopus to spend daylight hours near dens in rocks and crevices, it is entirely likely that the actual capture efficiency for benthic octopus is poor (D. Somerton, AFSC, personal communication, 7/22/05). Trawl sampling is not conducted in areas with extremely rough bottom and/or large vertical relief, exactly the type of habitat where den spaces for octopus would be most abundant (Hartwick and Barringa 1989). The survey also does not sample in inshore areas and waters shallower than 30 m, which may contain sizable octopus populations (Scheel 2002). The estimates of biomass in Table 3 assume a catchability coefficient (q) of 1, which is probably not realistic for octopus. For this reason the survey probably underestimates octopus biomass in the regions covered by the survey. The large numbers of survey tows with no octopus also tend to increase the sampling variability of the survey estimates; in many years, octopus were present in less than 10% of the survey tows.

There is a considerable difference in size selectivity between survey trawl gear and industry pot gear that catches most of the octopus harvested. The average weight for individual octopus in survey catches from 2006–2016 was 3.8 kg; 38% of survey-collected individuals over this period weighed 0.5 kg or less. Larger individuals are strong swimmers and may be more adept at escaping trawl capture. In contrast, the average weight of individuals from commercial pot gear was over 12 kg (Figure 6). Pot gear is probably selective for larger, more aggressive individuals that respond to bait, and smaller octopus can easily escape commercial pots while they are being retrieved. Unlike the BSAI, the depth range of octopus catches in the GOA is similar between industry and survey data, although pot fisheries tend to be concentrated in shallower shelf waters. There is also a seasonal difference between summer trawl surveys and the fall and winter cod seasons, when most octopus are harvested.

Due to these limitations the trawl survey should be considered an imprecise minimum estimate of octopus biomass in the GOA. Before the 2015 assessment, survey biomass for use in generating harvest recommendations was calculated as the average of the 3 most recent surveys. Beginning in 2015, a random effects (RE) model developed by the Plan Teams is used to generate a biomass estimate (Figure 9).

Species-specific methods of biomass estimation are needed for octopus and are being explored. Octopus are readily caught with commercial or research pots. An index survey of regional biomass in selected areas of the Kodiak and Shumagin regions would be appropriate and is highly feasible. It may also be feasible to estimate regional octopus biomass using mark-recapture studies or depletion methods (Caddy 1983, Perry et al. 1999). These options could be explored with a small experimental fishery and industry support. A size-based stage-structured model is currently being explored, but will need a sufficient time-series index of abundance and size frequency data to be predictive.

Analytic Approach

Model Structure

The available data do not support population modeling for either individual species of octopus in the GOA or for the multi-species complex. As better catch and life-history data become available, it may become feasible to manage the key species *E. dofleini* through a size-based model. For the last few years, the GOA Plan Team has elected to use a modified approach under Tier 6 where the overfishing level (OFL) is equal to the best available biomass estimate multiplied by the best available natural mortality rate (*M*), and the allowable biological catch is equal to 75% of the OFL. This is very similar to the Tier 5 approach specified in the FMP; because the Tier 5 language requires "reliable" estimates of biomass and *M*, the method for octopus is specified as Tier 6.

Parameter Estimates

Natural mortality rate (*M*)

It is important to note than not all species of octopus in the GOA have similar fecundity and life history characteristics. This analysis is based on *E. dofleini*, which probably make up the majority of the harvest. Since *E. dofleini* are terminal spawners, care must be taken to estimate mortality for the intermediate stage of the population that is available to the fishery but not yet spawning (Caddy 1979, 1983). If detailed, regular catch data from a directed fishery are available, the natural mortality could be estimated from catch data (Caddy 1983). When this method was used by Hatanaka (1979) for the West African *O. vulgaris* fishery, the estimated mortality rates were in the range of 0.50-0.75. Mortality may also be estimated from tagging studies; Osako and Murata (1983) used this method to estimate a total mortality of 0.43 for the squid *Todarodes pacificus*. Empirical methods based on the natural life span (Hoenig 1983, Rikhter and Efanov 1976) or von Bertalanffy growth coefficient (Charnov and Berrigan 1991) have also been used. While these equations have been widely used for finfish, their use for cephalopods is less well established. Perry et al. (1999) and Caddy (1983) discuss their use for invertebrate fisheries.

If we apply Hoenig's (1983) equation to *E. dofleini*, which have a maximum age of five years, we get an estimated *M* = 0.86. Rikhter and Efanov's (1976) equation gives a mortality rate of 0.53 based on an age of maturity of 3 years for *E. dofleini*. The utility of maturity/mortality relationships for cephalopods needs further investigation, but these estimates represent the best available data at this time. The Rikhter and Evanov estimate of M=0.53 represents the most conservative estimate of octopus natural mortality, based on information currently available. If future management of octopus is to be based on Tier 5 methods, a direct estimate of octopus natural mortality in the GOA, based on either experimental fishing or tagging studies, is desirable.

Results

Harvest Recommendations

Harvest recommendations are made using a modified approach under Tier 6, which uses a minimum biomass estimate and a natural mortality rate based on life history parameters, similar to the Tier 5 approach. The 2017 RE-model biomass estimate for all octopuses was 1,539 t. This is slightly higher than the survey biomass estimate of 1,049 t and much less than the 2015 RE-model estimate of 12,270 t. Assuming an M of 0.53, the 2018 and 2019 harvest recommendations are as follows:

- OFL = 1,539 t * 0.53 = 816 t
- ABC = 816 * 0.75 = 612 t

Because of the overall lack of biological data and the large uncertainty in abundance estimates, we do not recommend a directed fishery for octopus in federal waters at this time. We anticipate that octopus harvest in federal waters of the GOA will continue to be largely an issue of incidental catch in existing groundfish fisheries. If interest in a directed octopus fishery increases, we recommend using an experimental fishery to obtain depletion-based regional biomass estimates and to develop an octopus-specific index survey using pot gear specialized for capturing octopuses.

Because the 2016 catch was below the 2016 OFL, GOA octopus are not being subject to overfishing. Gulf of Alaska octopus are managed in Tier 6 and it is not possible to make a status determination of whether the stock is *overfished* or *approaching* an overfished condition.

Ecosystem Considerations

Ecosystem Effects on the Stock

Little is known about habitat use and requirements of octopus in Alaska. In trawl survey data, sizes are depth stratified with larger (and fewer) animals living deeper and smaller animals living shallower. However, the trawl survey does not include coastal waters less than 30 m deep, which may include large octopus populations. Hartwick and Barriga (1989) reported increased trap catch rates in offshore areas during winter months. Octopus require secure dens in rocky bottom or boulders to brood their young until hatching, which may be disrupted by fishing effort. Activity is believed to be primarily at night, with octopus staying close to their dens during daylight hours. Hartwick and Barriga (1989) suggest that natural den sites may be more abundant in shallow waters but may become limiting in offshore areas. In inshore areas of Prince William Sound, Scheel (2002), noted highest abundance of octopus in areas of sandy bottom with scattered boulders or in areas adjacent to kelp beds. Distributions of octopus along the shelf break are related to water temperature, so it is probable that changing climate is having some effect on octopus, but data are not adequate to evaluate these effects. Survey data are not yet adequate to determine depth and spatial distributions of the minor octopus species; spatial patterns about the most abundant species (*E. dofleini*) may be inferred only by combining data over several years.

Fishery Effects on the Ecosystem

Very little is known about the role of octopus in North Pacific ecosystems. In Japan, *E. dofleini* prey upon crustaceans, fish, bivalves, and other octopuses (Mottet 1975). Food habit data and ecosystem modeling of the GOA (Livingston et al. 2003) indicate that octopus diets in the GOA are dominated by epifauna such as snails and crabs and infauna such as mollusks. The Ecopath model (Figure 12) indicates that octopus in the GOA are preyed upon primarily by grenadiers, Pacific cod, halibut, and sablefish. In the GOA, Steller sea lions and other marine mammals are not significant predators of octopus (Figure 13). Model estimates show octopus comprise less than 0.5% of the diet of both juvenile and adult Steller sea lions. This is in contrast to the Bering Sea, where Steller sea lions and other marine mammals are significant predators of octopus. At least 20% of the estimated overall mortality of octopus in the GOA cannot be explained by the model (Aydin et al. 2007).

Analysis of scat data (Sinclair and Zeppelin 2002) shows unidentified cephalopods are a frequent item in Steller sea lion diets in both the Bering Sea and Aleutian Islands, but much less so in the western GOA. This analysis does not distinguish between octopuses and squids. The frequency of cephalopods in sea lion scats averaged 8.8% overall, and was highest (11.5-18.2%) in the Aleutian Islands and lowest (<1 – 2.5%) in the western GOA. Proximate composition analyses from Prince William Sound in the GOA (Iverson et al. 2002) show that squid had among the highest high fat contents (5 to 13%), but octopus had among the lowest (1%).

Data Gaps and Research Priorities

A volume on cephalopod taxonomy and identification in Alaska has been published (Jorgensen 2009). Efforts to improve octopus identification during AFSC trawl surveys will continue, but because of seasonal differences between the survey and most fisheries, questions of species composition of octopus incidental catch may still be difficult to resolve. Genetic analysis of tissue samples could be used to identify octopus species.

Because octopuses are semelparous, a better understanding of reproductive seasons and habits is needed to determine the best strategies for protecting reproductive output. *Enteroctopus dofleini* in Japan and off the US west coast reportedly undergo seasonal movements, but the timing and extent of migrations in Alaska is unknown. The distribution of octopus biomass and extent of movement between federal and state waters is unknown and could become important if a directed state fishery develops.

Fishery-independent methods for assessing biomass of the harvested size group of octopus are feasible, but would be species-specific and could not be carried out as part of existing multi-species surveys. Pot surveys are effective both for collecting biological and distribution data and as an index of abundance; mark-recapture methods have been used with octopus both to document seasonal movements and to estimate biomass and mortality rates. These methods are currently being researched; priorities for funding and staffing for a dedicated octopus survey needs to be addressed.

Tagging studies are needed to obtain a complete understanding of the migratory patterns of *Enteroctopus dofleini*. Additional genetic and/or tagging studies are needed to clarify the stock structure of this species in Alaska waters.

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Table 1. Octopus species found in the Gulf of Alaska.

Taxonomy		Common Name	General Distribution	Age at Maturity	Size at Maturity
Class	Cephalopoda				
Order	Vampyromorpha				
Genus	*Vampyroteuthis*				
Species	***Vampyroteuthis infernalis***		GOA; > 300 m	unknown	unknown
Order	Octopoda				
Group	Cirrata				
Family	Opisthoteuthidae				
Genus	*Opisthoteuthis*				
Species	***Opisthoteuthis californiana***	flapjack devilfish	GOA; > 300 m	unknown	unknown
Group	Incirrata				
	Bolitaenidae				
	Japetella				
	Japetella diaphana	pelagic octopus	pelagic; over the shelf break	unknown	< 300 g
Family	Octopodidae				
Genus	*Benthoctopus*				
Species	***Benthoctopus leioderma***	smoothskin octopus	GOA; > 250 m	unknown	< 500 g
Genus	*Enteroctopus*				
Species	***Enteroctopus dofleini***	giant octopus	all GOA; 10 - 1400 m	3 - 5 yr	>10 kg
Genus	*Octopus*				
Species	***Octopus californicus***		E. GOA; 100 - 1000 m	unknown	1 -2 kg
	Octopus rubescens	red octopus	N Pacific, Prince Wm. Sound	1 yr	unknown
	***Octopus* sp. A**		GOA shelf , 10 - 300 m	unknown	< 250 g

Table 2. Mean catch per unit effort (CPUE; kg/hec) of octopus species in AFSC GOA bottom trawl surveys, 1984-2017. “Miscellaneous octopuses” includes *Vampyroteuthis infernalis* and all octopus species except *Enteroctopus dofleini*.

	1984	**1987**	**1990**	**1993**	**1996**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**
Enteroctopus dofleini		1.6	0.7	2.0	1.4	2.4	1.2	2.4	0.5	1.5	1.8	2.4	1.2	3.4	1.0
Opisthoteuthis californiana	0.8	0.1	0.7	0.4		0.6		0.3	0.5	0.3	0.6	0.2	1.0	0.4	0.4
Octopus sp								0.6	1.7	0.02	0.2		0.01	0.7	0.3
Benthoctopus sp								0.1	0.02		0.1	0.6			0.03
Benthoctopus oregonensis														0.02	0.02
Benthoctopus leioderma	0.01	0.03	0.2	0.04		0.2	0.2	0.1	0.1	0.01	0.05	0.3	0.05	0.03	0.01
octopus unID	0.6	1.6	1.0	0.6	1.5	0.3	1.3	0.1		0.02	0.1	0.004	0.01	0.001	0.001
Japatella diaphana								0.01	0.01	0.03			0.04	0.03	
Octopus californicus									0.05						
Octopus rubescens								0.02							
Vampyroteuthis infernalis		0.4				0.3		0.8				0.002			
miscellaneous octopus	0.6	1.3	0.6	0.5	1.5	0.4	1.1	0.3	0.5	0.1	0.2	0.2	0.2	0.2	0.1
all octopuses	0.6	1.3	0.6	0.7	1.5	0.5	1.2	1.6	0.5	1.1	1.4	2.0	0.9	2.9	0.7

Table 3. Estimated total catches of octopuses (all species) and estimated retention rates in Gulf of Alaska groundfish fisheries, 1997-2017. This table also includes annual TACs for the Other Species (OS) complex and estimated OS catch, 1997-2010, as well as specifications for the octopus complex beginning in 2011. **Octopus catch reported here does not include catches in NMFS statistical areas 649 & 659, which do not count against the octopus TAC. For a breakdown of octopus catches by area, including 649 & 659, see Table 4.**

	octopus catch	% retained	Other Species catch (t)	Other Species TAC (t)	octopus TAC (t)	octopus ABC (t)	octopus OFL (t)	management method
1997	232		5,439	13,470				OS TAC
1998	112		3,748	15,570				OS TAC
1999	166		3,858	14,600				OS TAC
2000	156		5,649	14,215				OS TAC
2001	88		4,804	13,619				OS TAC
2002	298		3,748	11,330				OS TAC
2003	212	21%	6,266	11,260				OS TAC
2004	283	57%	1,705	12,942				OS TAC (no skates)
2005	149	68%	2,513	13,871				OS TAC (no skates)
2006	166	86%	3,881	13,856				OS TAC (no skates)
2007	266	90%	3,035	4,500				OS TAC (no skates)
2008	339	82%	2,967	4,500				OS TAC (no skates)
2009	321	83%	3,188	4,500				OS TAC (no skates)
2010	330	82%	1,724	4,500				OS TAC (no skates)
2011	927	42%			954	954	1,273	octopus complex
2012	415	66%			1,455	1,455	1,941	octopus complex
2013	444	49%			1,455	1,455	1,941	octopus complex
2014	1,300	41%			1,507	1,507	2,009	octopus complex
2015	967	40%			1,507	1,507	2,009	octopus complex
2016	382	54%			4,878	4,878	6,504	octopus complex
*2017**	*166*	*79%*			4,878	4,878	6,504	octopus complex

Data sources and notes: Octopus catch 1997-2002, AKRO Blend; octopus catch 2003-2017, AKRO CAS; Other Species catch, AKRO Blend and CAS; specifications, AKRO harvest specifications. Skates were removed from the Other Species group in 2004.
*2017 catch as of XX

Table 4. Estimated catches of octopuses (all species) in state and federal fisheries by NMFS reporting area. **Catches in NMFS statistical areas 649 & 659 (inside waters; Prince William Sound and Southeast Alaska, respectively) do not count against the octopus TAC**. Data are from Alaska Regional Office Catch Accounting System.

	catch (t) in NMFS reporting areas							**GOA catch w/o inside waters**	**GOA catch with inside waters**
	610	**620**	**630**	**640**	**650**	**649**	**659**		
2003	149	13	48	0.34	2	0.40	1	212	214
2004	200	6	76	0.11	0.46	0.03	0.13	283	283
2005	58	3	88	0	0.04	0	0	149	149
2006	37	9	119	0.27	0.17	0.06	0.08	166	166
2007	64	22	179	0.04	0.10	0.03	0.17	266	266
2008	125	28	186	0	0.07	0.08	0.12	339	339
2009	141	33	146	0.24	0.30	0.38	0.26	321	321
2010	142	49	139	0.22	0.08	0.09	0.23	330	331
2011	565	92	268	1	2	1	0.48	927	929
2012	177	25	212	0.08	0.03	0.07	0.06	415	415
2013	240	30	143	17	15	5	6	444	454
2014	496	170	627	4	3	1	2	1,300	1,303
2015	215	366	383	1	2	1	1	967	968
2016	170	85	126	1	0.47	1	0.38	382	384
2017*	*42*	*42*	*82*	*0.24*	*0.18*	*0.16*	*0.20*	*166*	*166*

*Data for 2017 are as of October 11, 2017.

Table 5. Biomass estimates and percent occurrence in survey hauls for *Enteroctopus dofleini*, miscellaneous octopuses, and all octopus species combined from the Alaska Fisheries Science Center GOA bottom trawl surveys. CV = coefficient of variation.

		Enteroctopus dofleini				**miscellaneous octopuses**				**all octopuses**			
	total survey hauls	**hauls w/ *E. dofleini***		**biomass (t)**	**CV**	**hauls w/ misc. octopus**		**biomass (t)**	**CV**	**hauls w/ any octopus**		**biomass (t)**	**CV**
		#	%			#	%			#	%		
1984	929	-	-	-	-	89	10%	1,498	0.23	89	10%	1,498	0.23
1987	783	2	0%	172	0.82	33	4%	2,049	0.47	35	4%	2,221	0.43
1990	708	3	0%	163	0.94	31	4%	866	0.42	34	5%	1,029	0.38
1993	774	6	1%	437	0.57	36	5%	771	0.41	42	5%	1,208	0.33
1996	807	6	1%	222	0.60	28	3%	1,738	0.51	34	4%	1,960	0.46
1999	764	3	0%	293	0.70	45	6%	701	0.27	48	6%	994	0.28
2001	489	14	3%	571	0.43	15	3%	423	0.65	29	6%	993	0.37
2003	809	50	6%	3,590	0.22	22	3%	177	0.41	72	9%	3,767	0.22
2005	837	29	3%	382	0.31	29	3%	743	0.46	58	7%	1,125	0.32
2007	816	55	7%	2,155	0.23	18	2%	159	0.38	73	9%	2,314	0.22
2009	823	60	7%	3,496	0.20	21	3%	296	0.38	81	10%	3,791	0.19
2011	670	58	9%	4,743	0.19	11	2%	154	0.35	69	10%	4,896	0.18
2013	548	48	9%	2,420	0.20	19	3%	266	0.46	67	12%	2,686	0.18
2015	771	108	14%	12,642	0.15	11	1%	366	0.43	119	15%	13,008	0.14
2017	536	16	3%	1,009	0.44	9	2%	40	0.54	25	5%	1,049	0.43

Table 6. Estimated catches (t) of octopuses (all species) in the Gulf of Alaska by target fishery, 2003-2017. Octopus catch reported here does not include catches in NMFS statistical areas 649 & 659, which do not count against the octopus TAC. ATF = arrowtooth flounder. Data source: AKRO CAS.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	***2017****
Pacific cod	193	250	139	151	249	327	307	267	861	408	320	1,184	901	358	*158*
ATF	1	0.01	6	9	2	4	0.23	1	3	1	0.17	22	7	2	*2*
IFQ halibut	9	1	1	2	1	2	5	5	54	1	97	51	31	9	*2*
sablefish	3	0.08	0.22	0.32	2	1	1	1	1	1	16	7	4	4	*2*
rockfish	1	0.43	0.19	0.47	0.06	3	1	4	1	1	2	7	11	2	*1*
shallow flatfish	6	1	1	0.02	9	3	5	10	2	0.18	6	16	6	3	*0.39*
pollock	0	0	0.06	3	1	0.03	0.06	1	2	0.43	0.33	7	4	5	*0.03*
deep flatfish	0.04	0.35	0	0	0	0	0	0	0	0	0	0	0	0	*0*
flathead sole	0.03	0.04	0	0	0	0	0	1	1	2	0.05	0.31	0.36	0.01	*0*
other target	0.06	30	2	0.16	1	0.08	1	42	1	0	0.01	6	0	0.27	*0*
rex sole	0.21	0	0	0	0.03	0.13	0.46	0.04	0.25	1	3	0	3	0	*0*
all fisheries	212	283	149	166	266	339	321	330	927	415	444	1,300	967	382	*166*

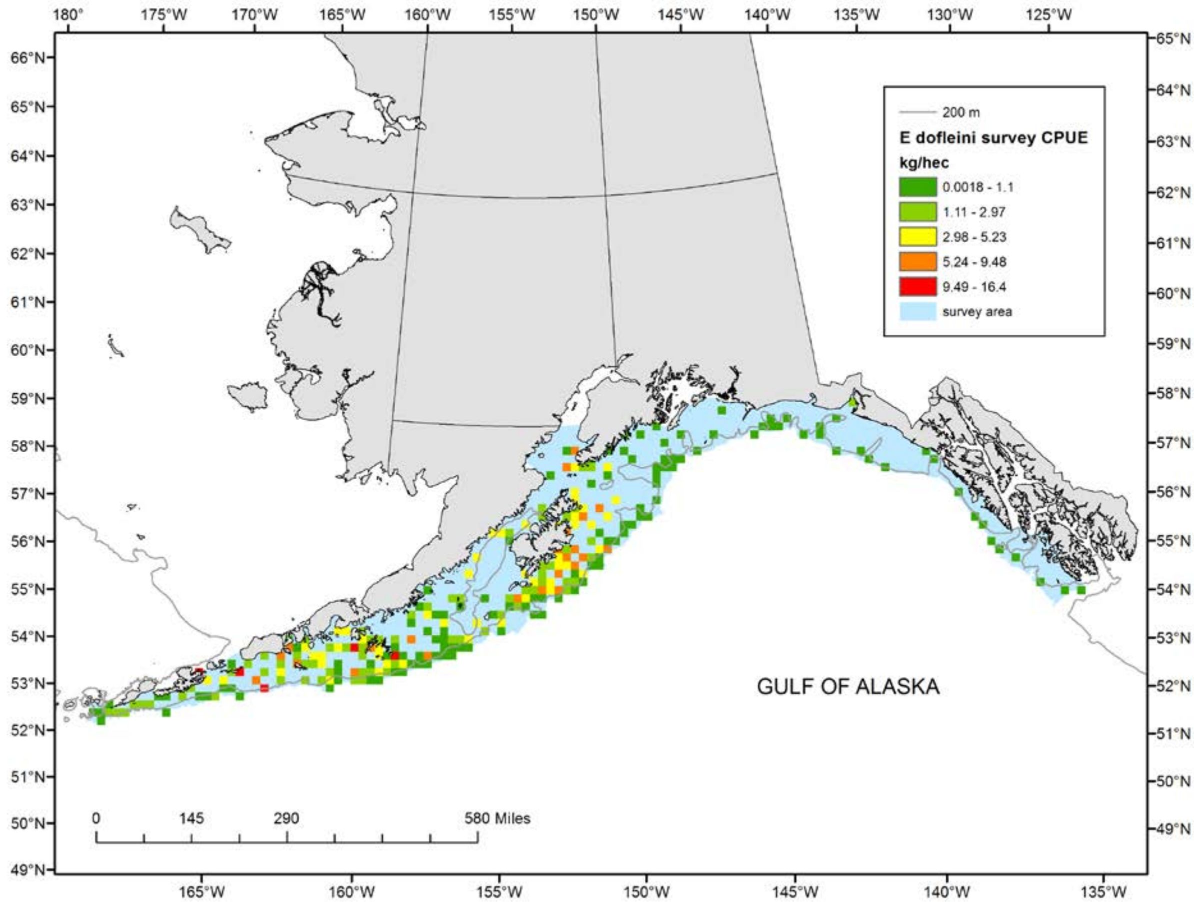

Figure 1. Mean catch-per-unit-effort (CPUE; kg/hec) of giant Pacific octopus *Enteroctopus dofleini* in AFSC bottom trawl surveys conducted in the Gulf of Alaska during 2003-2017. Data are aggregated into 20 km X 20 km grid cells to clarify areas of high CPUE. Light blue shading indicates the spatial extent of the survey; note that no sampling occurs in Prince William Sound or inside waters of southeast Alaska.

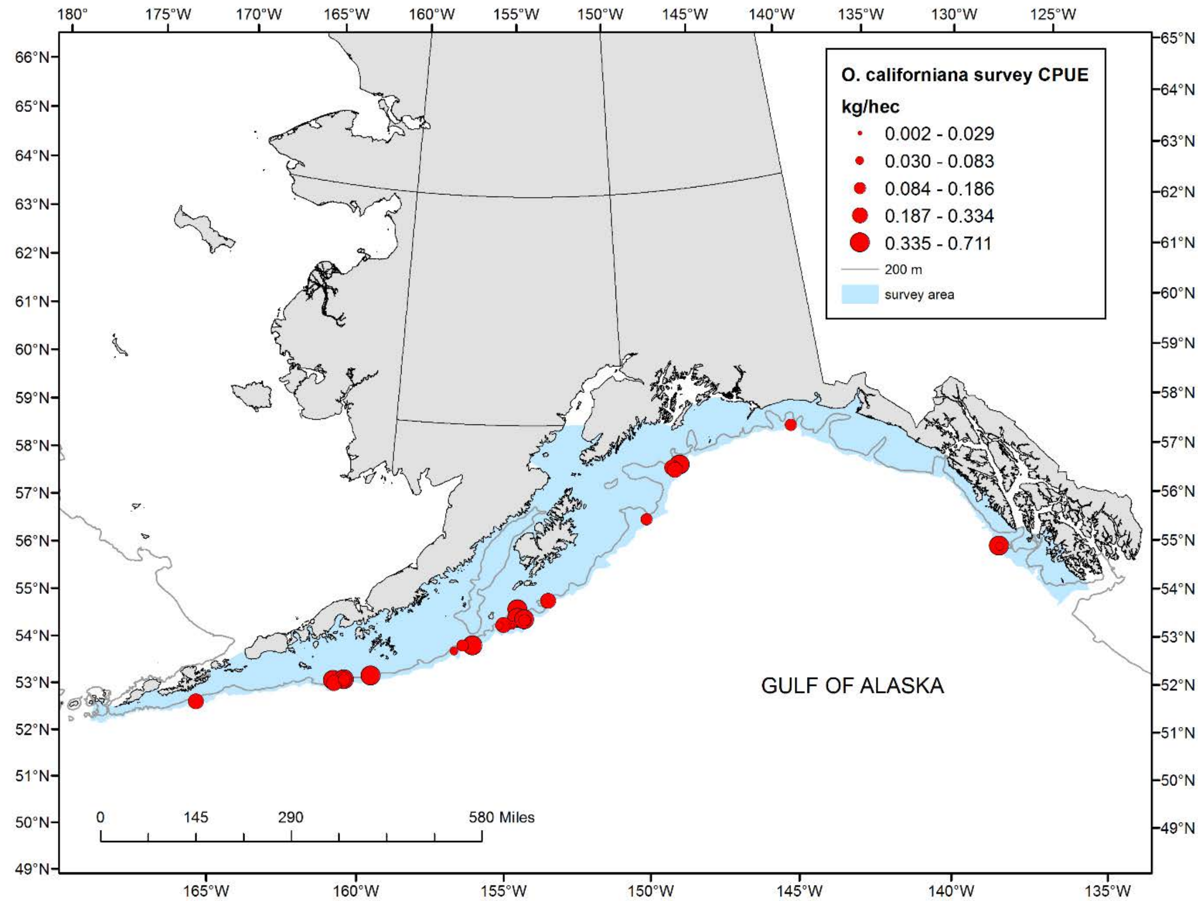

Figure 2. Mean catch-per-unit-effort (CPUE; kg/hec) of flapjack devilfish *Opisthoteuthis californiana* in AFSC bottom trawl surveys conducted in the Gulf of Alaska during 2003-2017. Light blue shading indicates the spatial extent of the survey; note that no sampling occurs in Prince William Sound or inside waters of southeast Alaska.

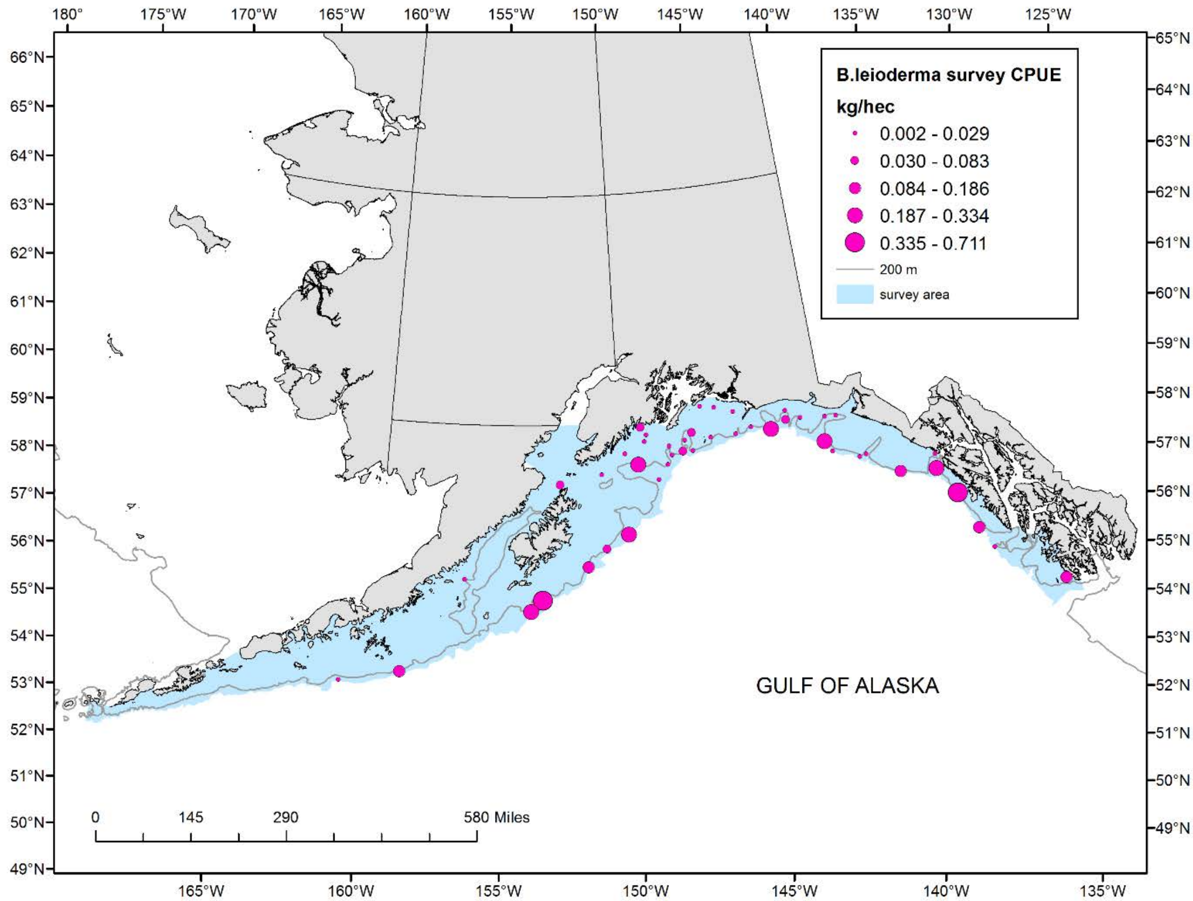

Figure 3. Mean catch-per-unit-effort (CPUE; kg/hec) of smoothskin octopus *Benthoctopus leioderma* in AFSC bottom trawl surveys conducted in the Gulf of Alaska during 2003-2017. Light blue shading indicates the spatial extent of the survey; note that no sampling occurs in Prince William Sound or inside waters of southeast Alaska.

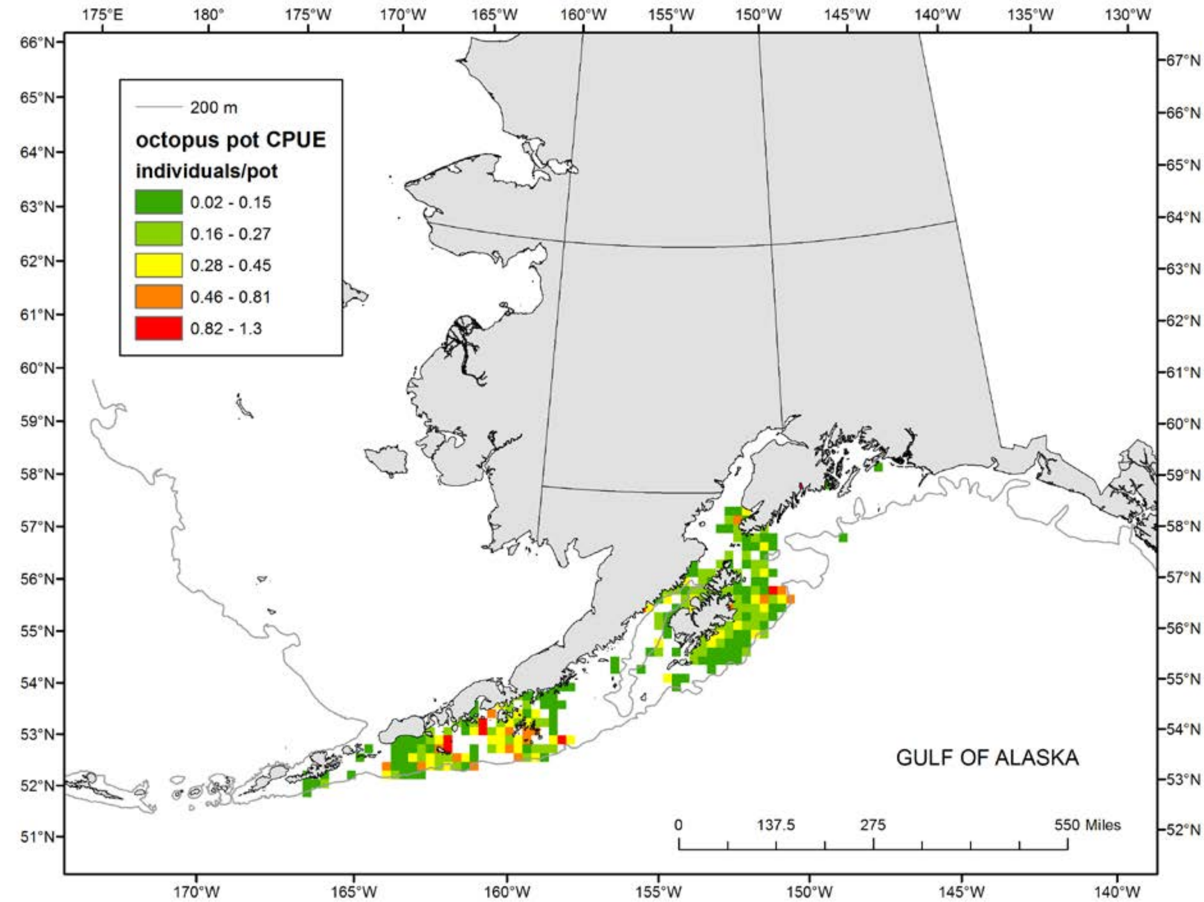

Figure 4. Mean catch-per-unit-effort (CPUE; kg/hec) of octopuses (all species combined) in observed catches by fisheries using pot gear in the Gulf of Alaska during 2006-2016. Data are aggregated into 20 km X 20 km grid cells to clarify areas of high CPUE.

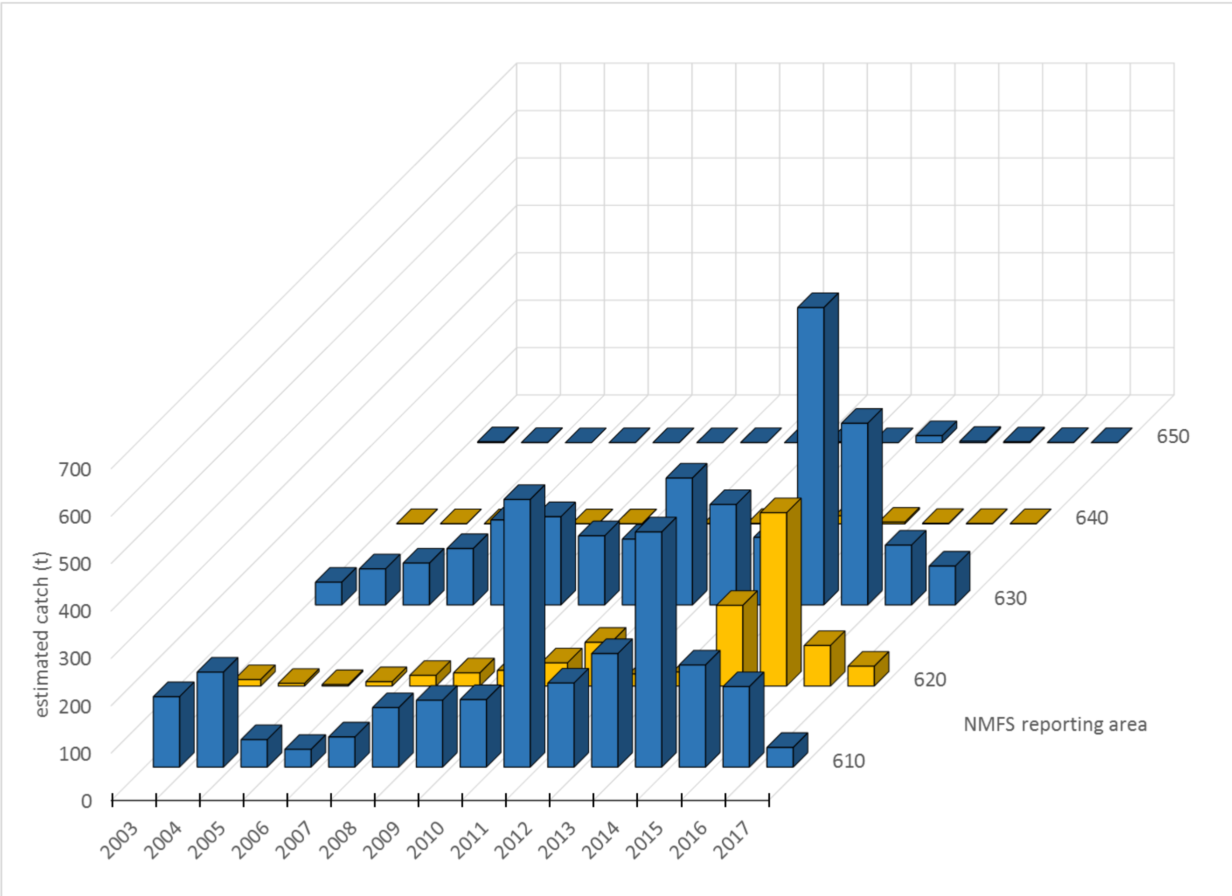

Figure 5. Incidental commercial catch of octopuses (all species), 2003-2017, by NMFS reporting area.

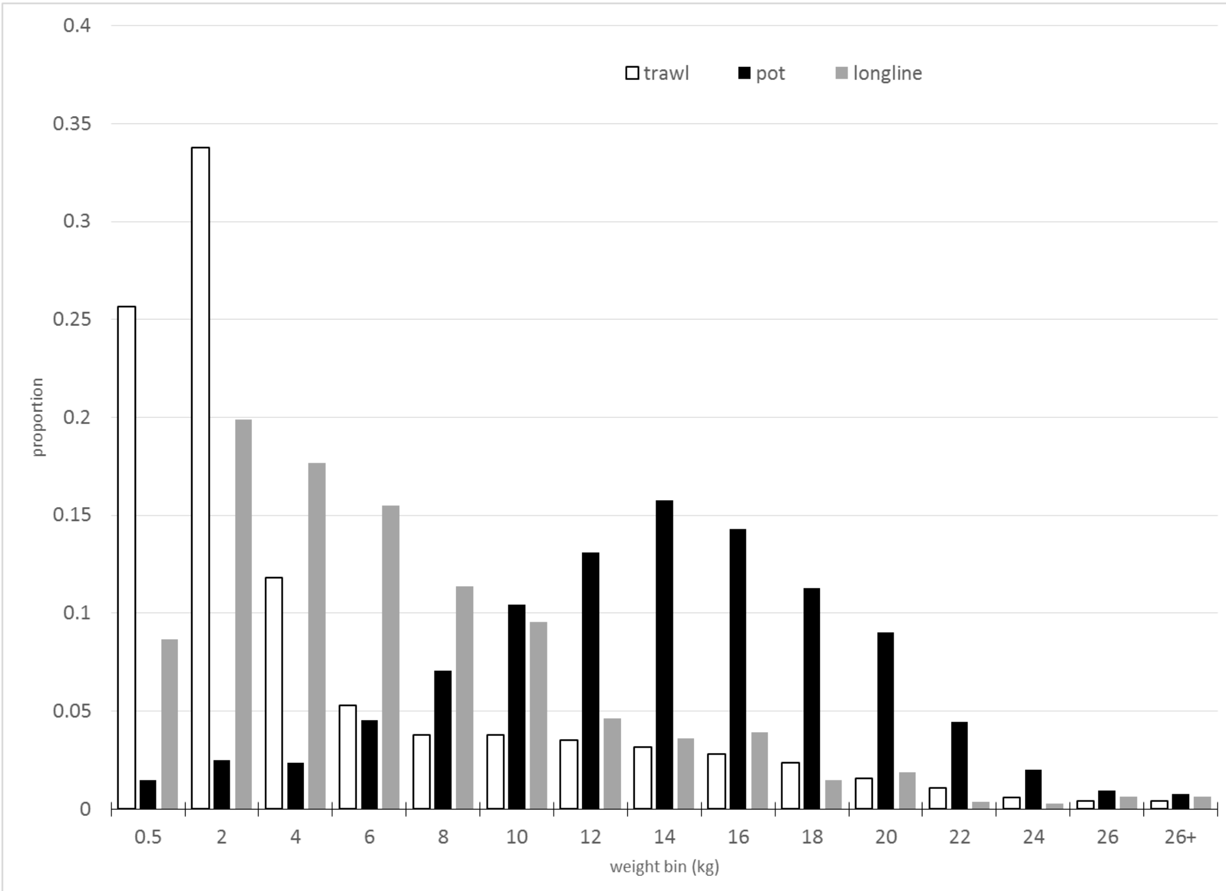

Figure 6. Estimated size composition (kg body weight) of octopuses (all species combined) in observed commercial catches in the Gulf of Alaska during 2006-2016. Data are separated by gear type.

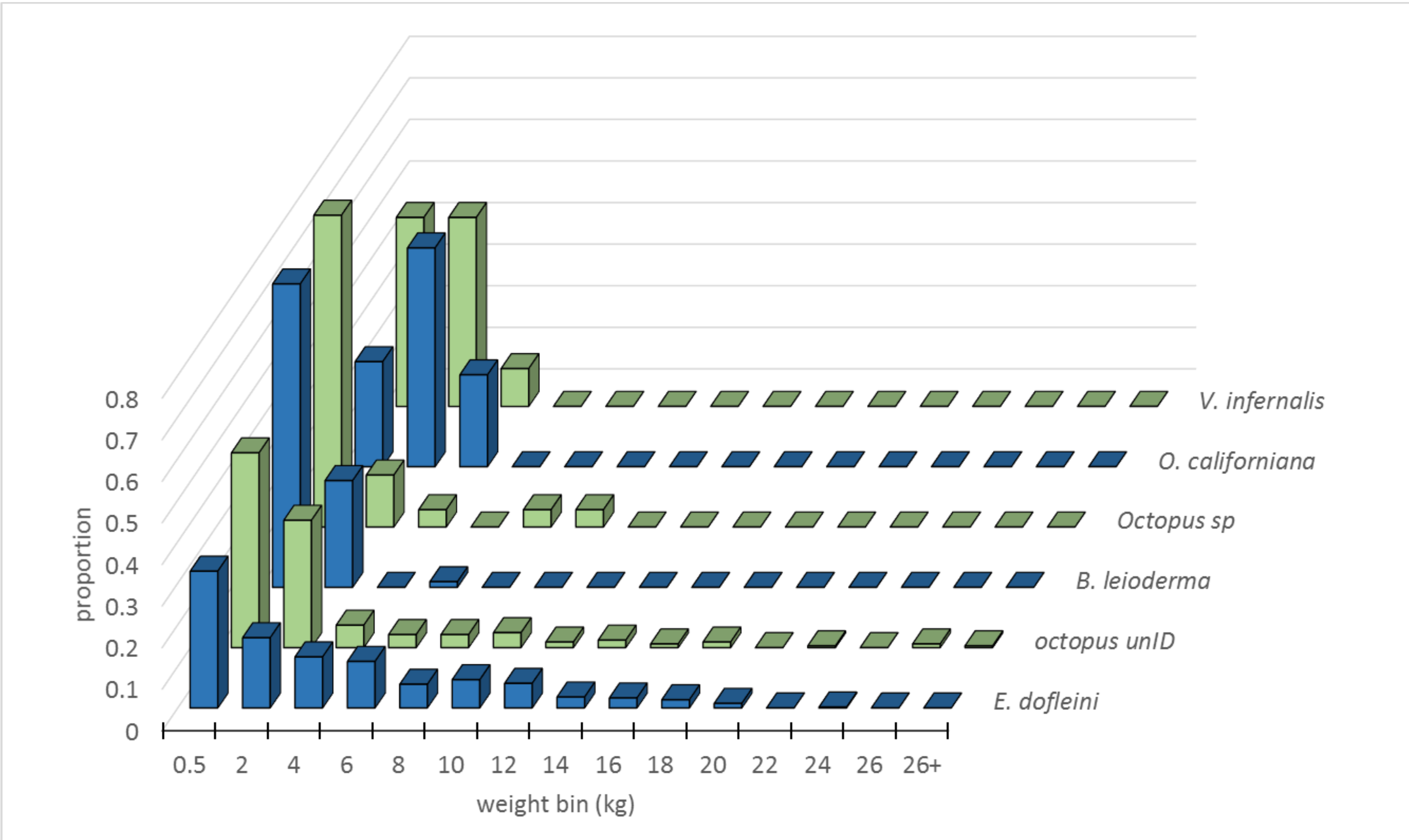

Figure 7. Mean size compositions (kg body weight) of octopuses captured in AFSC bottom trawl surveys in the Gulf of Alaska. Data are aggregated over the years 2003-2017.

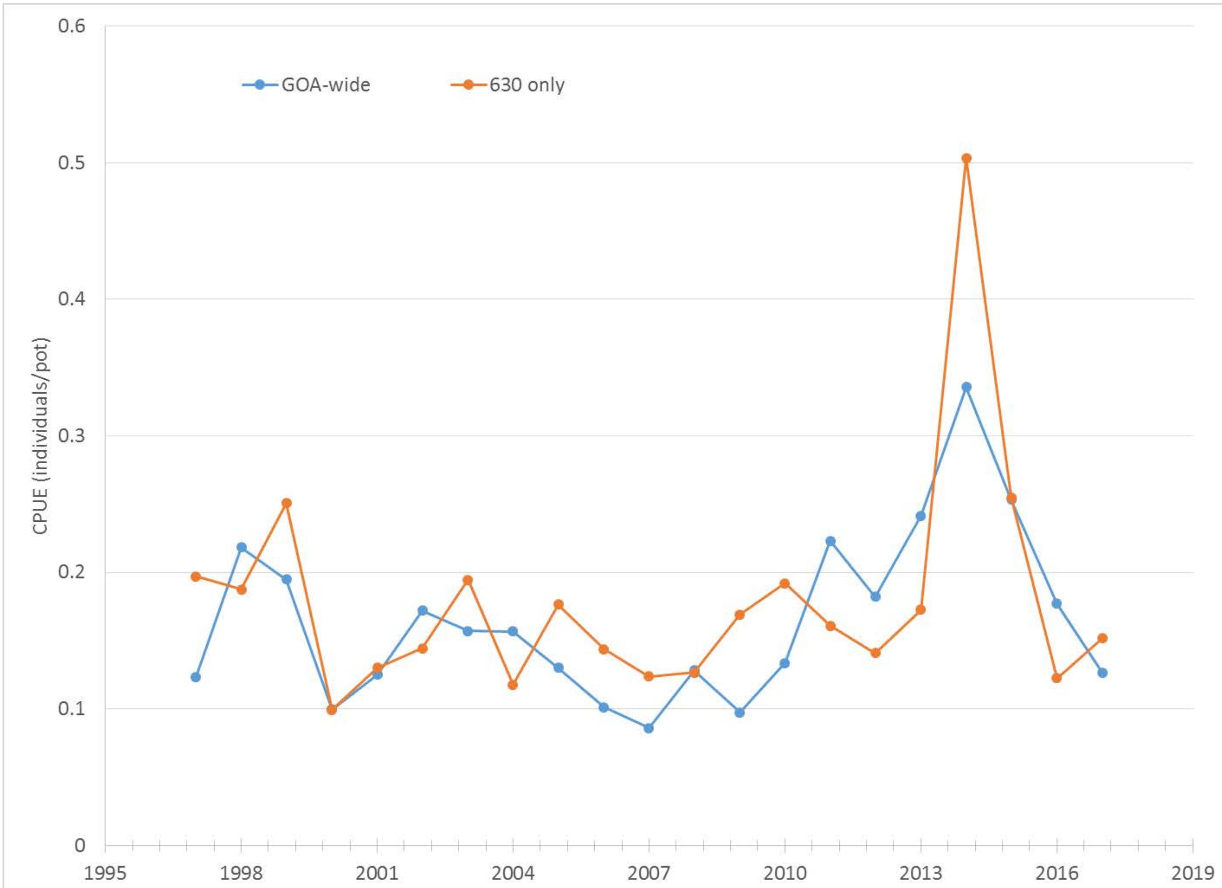

Figure 8. Time series of catch-per-unit-effort (CPUE; individuals/pot) of octopuses (all species combined) in observed catches by fisheries using pot gear in the Gulf of Alaska (GOA) during 2006-2016. Data are shown for GOA-wide catches as well as catches only in statistical area 630.

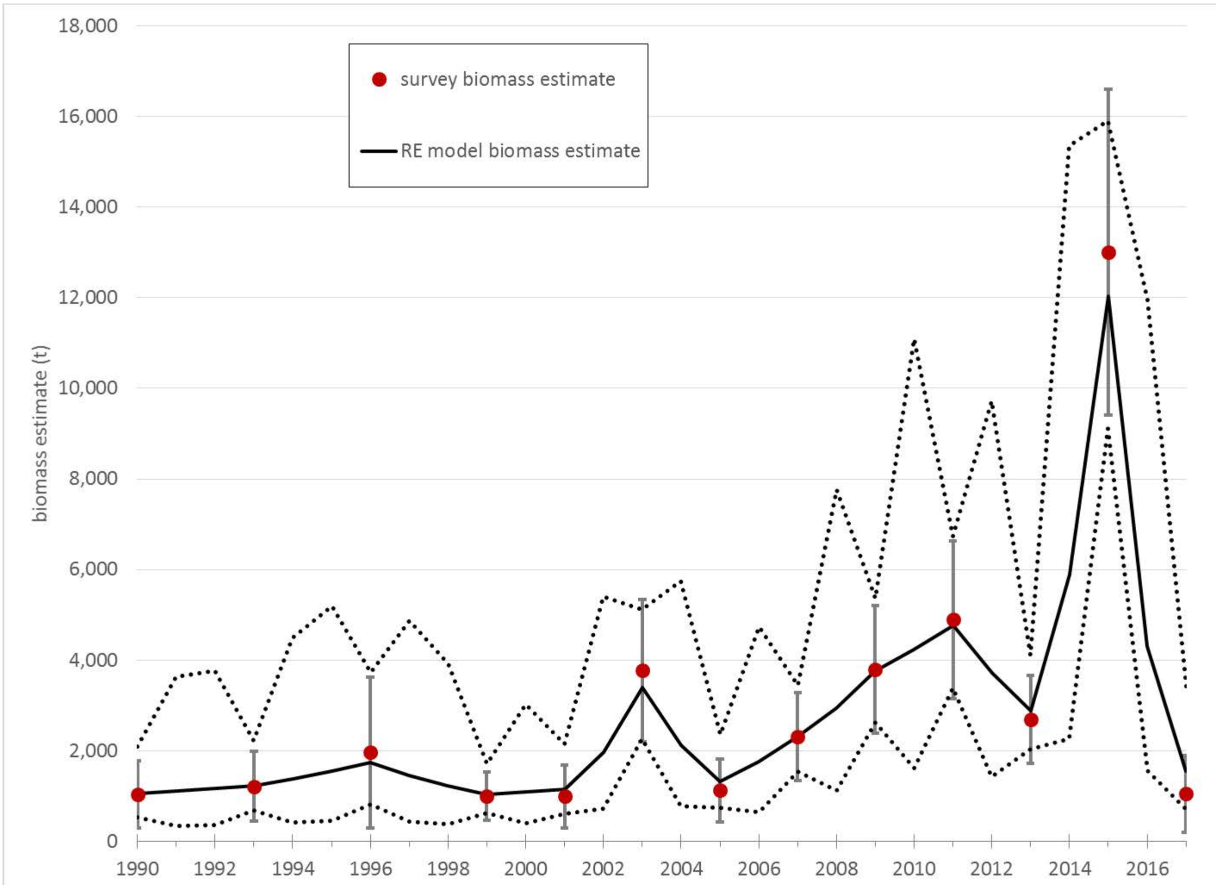

Figure 9. Biomass estimates for the Gulf of Alaska octopus complex from the random-effects model (solid black line) and the trawl survey (red dots). Confidence intervals are shown as dashed black lines for the random effects model and gray error bars for the survey biomass estimates.

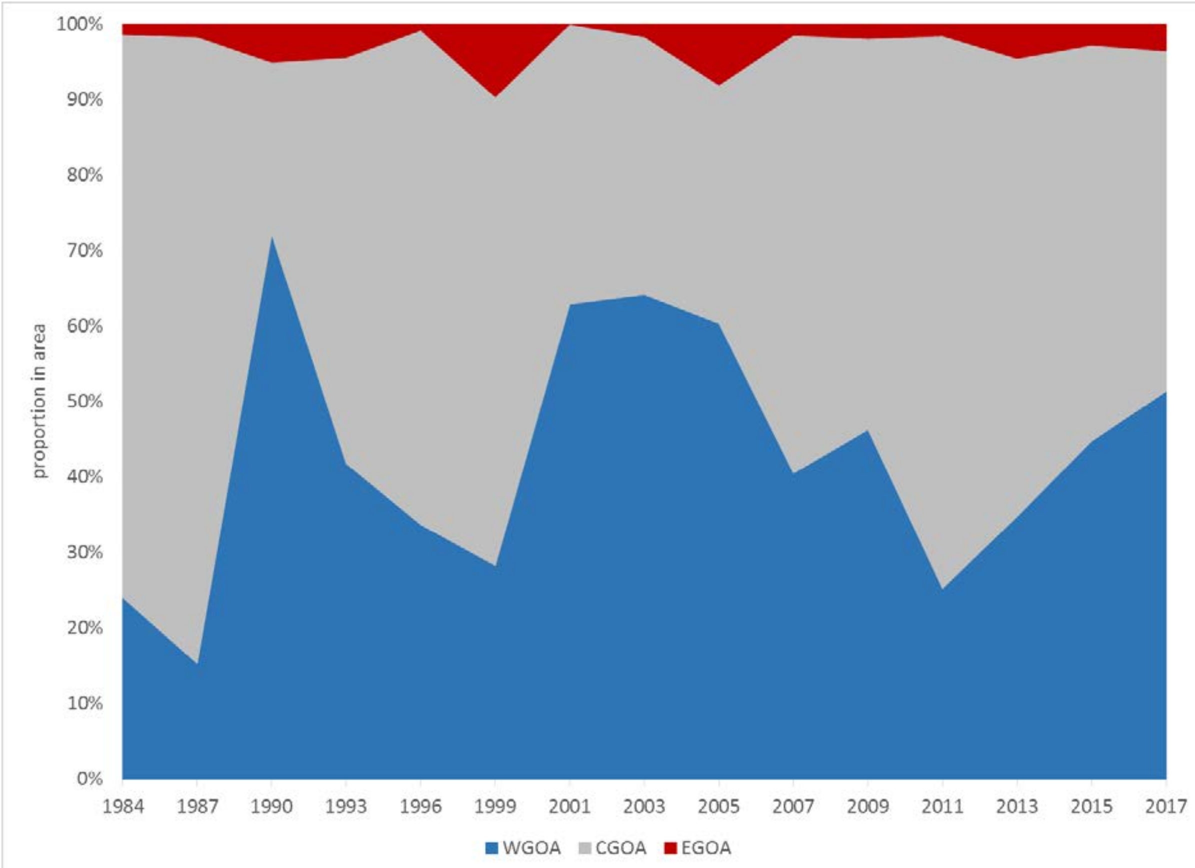

Figure 10. Proportion of octopus survey biomass estimates (all species) in each Gulf of Alaska regulatory area, 1984-2017.

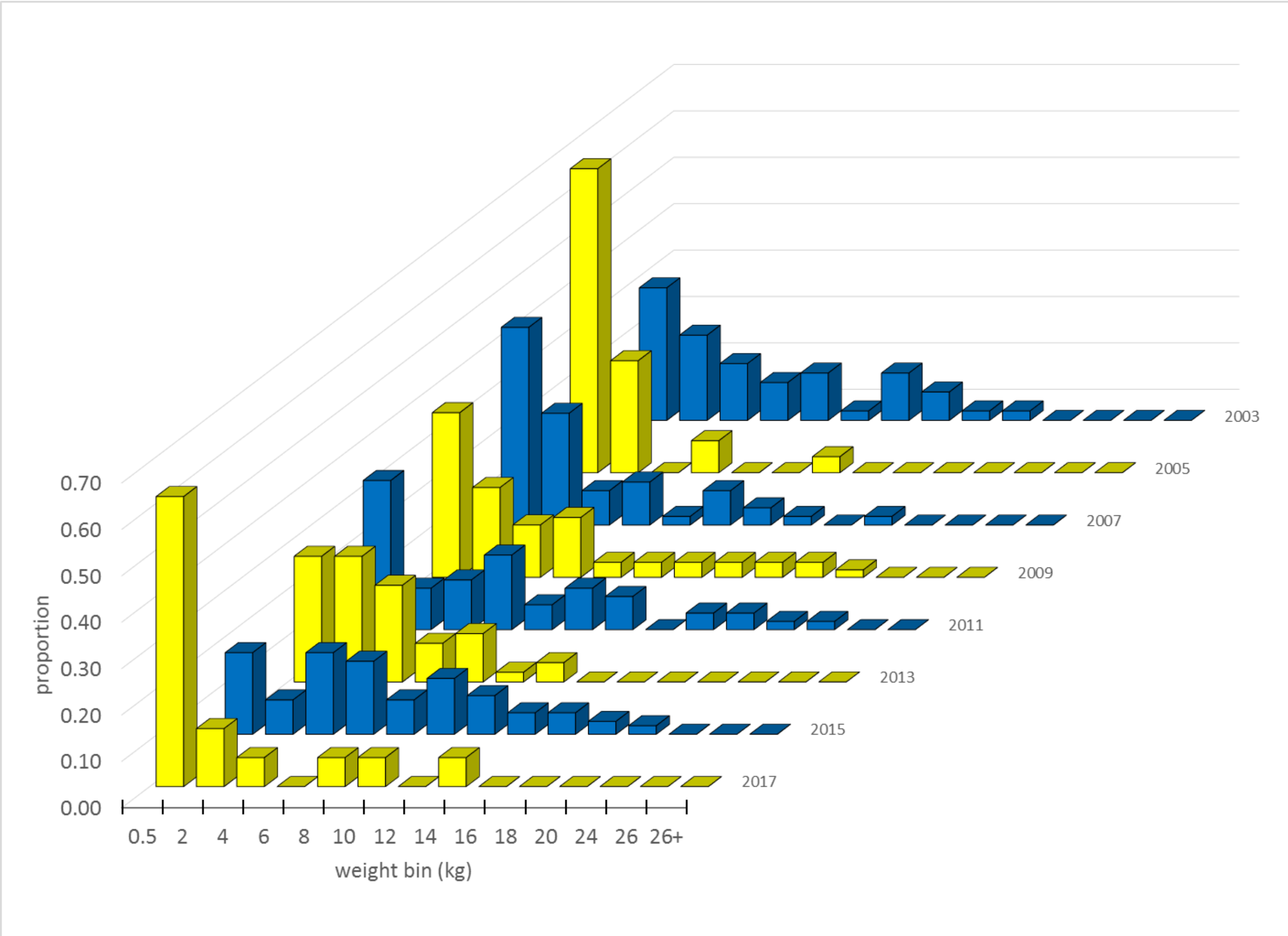

Figure 11. Size compositions (kg body weight) of *Enteroctopus dofleini* captured in AFSC bottom trawl surveys in the Gulf of Alaska, 2003-2017.

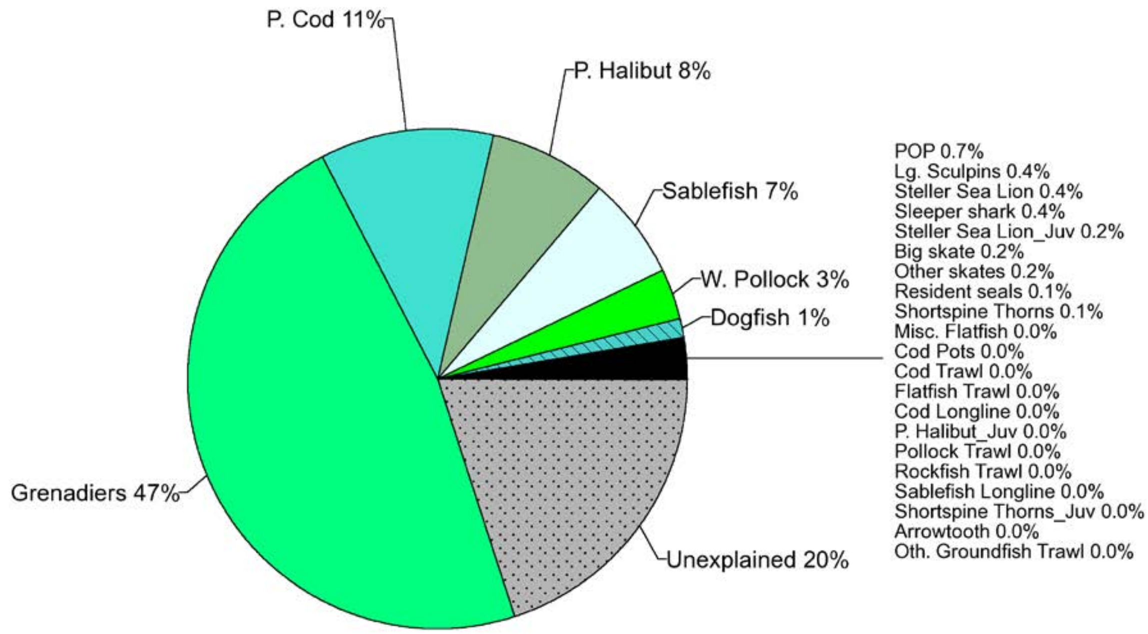

Figure 12. Ecopath model estimates of total consumption of octopus in the GOA (based on average 1990-1993 biomass and catch estimates).

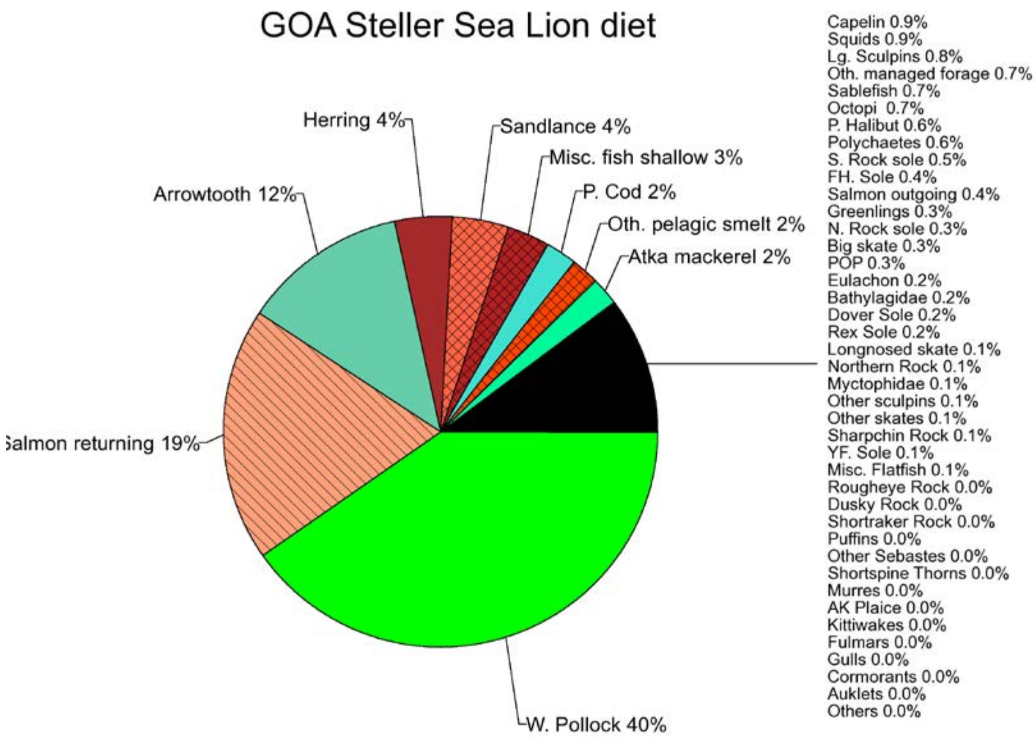

Figure 13. Ecopath model estimates of prey of Steller sea lions in the GOA (based on average 1990-1993 biomass and catch estimates).

Appendix A: Non-commercial catches (kg) of octopuses in the Gulf of Alaska, 1982-2016.

agency	ADFG						IPHC	NMFS				total
source of catch	Golden King Crab Pot Survey	Large-Mesh Trawl Survey	Scallop Dredge Survey	Small-Mesh Trawl Survey	Spot Shrimp Survey	Subsistence Fishery	IPHC Annual Longline Survey	Annual Longline Survey	Gulf of Alaska Bottom Trawl Survey	Salmon EFP 13-01	Shelikof Acoustic Survey	
1982						3,113						3,113
1983						168						168
1984						1,403						1,403
1985						376						376
1986						1,301						1,301
1987						9,074						9,074
1988						2,005						2,005
1989						998						998
1990								63				63
1991						4,590		13				4,603
1992						3,837		6				3,844
1993						3,426		19				3,445
1994								25				25
1995								25				25
1996						1,426		19				1,445
1997						2,363		50				2,413
1998		6				453		44				504
1999		41	0					6				48
2000		78	1	7		1,475						1,561
2001		18						6				25
2002		9						38				47
2003		135		16		1,427		76				1,653
2004	9	34						63				106
2005		88		32				6				127
2006		75	0	13	12			13				112
2007		213		10	1			6				230
2008		89						44				133
2009		56	0					25				81
2010		879		36			1,629	139			1	2,683
2011		695	6	39	42		1,444	69	0			2,295
2012		543		24			498	76				1,141
2013		279	21	8			1,697	44	0			2,049
2014		1,160		68	32		1,828	183		21		3,291
2015		1,410		15	33		1,402	429	0			3,289
2016		538	2		17		311	25				893