18c. Assessment of the Octopus Complex in the Bering Sea and Aleutian Islands

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Executive Summary

Through 2010, octopuses were managed as part of the BSAI “other species” complex, along with sharks, skates, and sculpins. Historically, catches of the other species complex were well below TAC and retention of other species was small. Due to increasing market values, retention of some other species complex members is increasing. Beginning in 2011, the BSAI fisheries management plan has been amended to provide separate management for sharks, skates, sculpins, and octopus. In compliance with the reauthorized Magnuson-Stevens act, each group will have its own annual catch limit. This is the first assessment of the octopus complex independent from the other species group, and provides recommendations for annual catch limits for 2011 and 2012.

All octopus species will continue to be grouped into one species assemblage. At least seven species of octopus are found in the BSAI. The species composition of the octopus community is not well documented, but recent research indicates that the Giant Pacific octopus *Enteroctopus dolfleini* is most abundant in shelf waters and predominates in commercial catch. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the BSAI; a portion of the catch is retained or sold for human consumption or bait. The highest octopus catch rates are from Pacific cod fisheries in the three reporting areas around Unimak Pass. The Bering Sea and Aleutian Island trawl surveys produce estimates of biomass for octopus, but these estimates are highly variable and do not reflect the same sizes of octopus caught by industry. Examination of size frequency from survey and fishery data shows that both commercial and survey trawls catch predominantly small animals (<5 kg), while commercial pot gear catches or retains only larger animals (10-20 kg). In general, the state of knowledge about octopus in the BSAI is poor. A number of research studies and special projects have been initiated in recent years to increase knowledge for this assemblage; results of these studies are summarized.

Summary of Changes in Assessment Inputs

There have been no changes to the assessment methods for this assemblage. Previous assessments have included both Tier 6 catch limits based on incidental catch rates and an approximate Tier 5 limit based on trawl survey biomass for comparison; this practice is continued in this document. Survey data have been updated with the 2010 Bering Sea shelf, slope, and Aleutian Island survey results; species composition and size ranges by species from the most recent surveys are presented. Observer special project data have also been updated; in particular data from 2009 on the condition of octopus at discard are presented. The table of incidental catch rates has been updated to include estimated catch for the entirety of 2009 and the first part of 2010. The estimated total catch for 2009 was low, only 72 tons. Incidental catch through fall 2010 was 126 tons. Text has been added summarizing new research underway on octopus, and the life history section has been updated. Other report sections are largely unchanged from the 2009 SAFE.

Summary of Results

The current data are not sufficient for a model-based assessment. From 2006 through 2009, preliminary stock assessments of octopus were prepared that presented both Tier 5 and Tier 6 estimates of OFL and ABC. The SSC and plan teams have discussed the difficulties in applying groundfish methodologies to octopus and have agreed to treat octopus as a Tier 6 species, owing to inadequate data for estimating Tier 5 parameters. There are no historical catch records for octopus. Estimates of incidental catch rate from 1997-2007 are used as a baseline for Tier 6 assessment. Due to an update of the catch accounting system, catch estimates for this assessment differ slightly from last year's numbers. Percentiles of incidental catch are presented, along with catch limits from two alternative Tier 6 methods. Using the revised catch data, the average incidental catch rate of octopus for 1997-2007 was 314 mt; if this is used as the Tier 6 OFL, the ABC would be 235 tons. The maximum incidental catch over that period was 528 tons; if this is used the Tier 6 OFL would be 528 tons and the ABC would be 396 tons. The authors and plan teams feel that a standard Tier 6 approach based on the average incidental catch results in an overly conservative limit, because most of these data are from a period in which there was very little market or directed effort for octopus.

There is insufficient data to determine whether the complex is being subjected to overfishing, is currently overfished, or is approaching a condition of being overfished.

	Last year		**This year**	
Quantity/Status	2010	2011	**2011**	2012
Specified/recommended Tier (alternative)	6(average)	6(average)	6(average)	6(average)
Specified/recommended OFL (t)	311	311	314	314
Specified/recommended ABC (t)	233	233	235	225
Specified/recommended Tier (alternative)	6(max)	6(max)	**6(max)**	6(max)
Specified/recommended OFL (t)	516	516	**528**	528
Specified/recommended ABC (t)	387	387	**396**	396
(for Tier 6 stocks, data are not available to determine whether the stock is being subjected to overfishing or is in an overfished condition)				

Responses to SSC comments

Comments from the September 2010 SSC meeting indicated that the SSC agrees with the authors and plan team that trawl survey biomass estimates are unreliable for octopuses in the BSAI, and agrees with continuation of Tier 6 management based on a maximum catch in the base years of 1997 to 2007. The SSC requested clarification from NOAA general council on the level of economic activity that would exceed the "minimal" amounts of sale for octopus to be considered an Ecological Component species. Comments form the October 2010 meeting indicated support for percentile methods, so this information has been included in this assessment. The SSC disagreed with a suggestion to set ABC at the average catch; it instead,recommended using the default formula of ABC = 0.75 x OFL."

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, they 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 possess paddle-shaped fins suitable for swimming in their deep ocean 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). *E. dofleini* is one of at least seven species of octopus (Table 1) found in the Bering Sea, including one newly identified species. Members of these seven species represent six genera and can be found from less than 10 m to greater than 1500 m depth. All but one, *Japetella diaphana*, are benthic octopuses. The state of knowledge of octopuses in the BSAI, including the true species composition, is very limited.

In the Bering Sea octopuses are found from subtidal waters to deep areas near the outer slope (Figure 1). The highest diversity is along the shelf break region between 200 – 750 m. The observed take of octopus from both commercial fisheries and AFSC RACE surveys indicates few octopus occupy federal waters of Bristol Bay and the inner front region. Some octopuses have been observed in the middle front, especially in the region south of the Pribilof Islands. The majority of observed commercial and survey hauls containing octopus are concentrated in the outer front region and along the shelf break, from the horseshoe at Unimak Pass to the northern limit of the federal regulatory area. Octopus have been observed throughout the western GOA and Aleutian Island chain. The spatial distribution of commercial octopus catch and the distribution of trawl survey octopus by species are discussed in the data section of this report.

Management Units

Through 2009, octopuses were managed as part of the BSAI “other species” complex, with catch reported only in the aggregate with sharks, skates, and sculpins. In the BSAI, catch of other species was limited by a Total Allowable Catch (TAC) based on an Allowable Biological Catch (ABC) estimated by summing estimates for several subgroups (Gaichas 2004). Historically, catches of other species were well below TAC (Table 2) and retention of other species was small. Due to increasing market value of skates and octopuses, retention of other species complex members is increasing. In 2004, the TAC established for the other species complex was close to historical catch levels, so all members of the complex were placed on “bycatch only” status at the beginning of the year, with retention limited to 20% of the weight of the target species. By October 2004, the other species complex TAC was reached and all members of the complex were placed on discard only status for the remainder of the year. The “other species” group remained on bycatch-only status with 20% retention through 2007, since the expected incidental catch for this category is close to the TAC.

In October 2009, the North Pacific Fisheries Management council voted unanimously to amend both the BSAI and GOA fishery Management plans to eliminate the ‘other species’ category. Plan amendments 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. At present, the Council is reviewing proposals to consider including octopus in the 'Ecosystem Component' category or to add a discard mortality factor to catch accounting for the octopus assemblage.

Draft revisions to guidelines for National Standard One instruct managers to identify core species and species assemblages. Species assemblages should include species that share similar regions and life history characteristics. The BSAI 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". *E. 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 avenue being explored for possible future use is to split this assemblage by size, allowing retention of only larger animals. This could act to 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, octopus life spans are either 1-2 years or 3-5 years depending on the species. Life histories of six of the seven species in the Bering Sea are largely unknown. *Enteroctopus dofleini* has been studied extensively (primarily in waters of northern Japan and western Canada), and its life history will be reviewed here. General life histories of the other six species are inferred from what is known about other members of the genus.

E. dofleini are estimated to mature at 1.5 – 3 years in Japanese waters (Kanamaru and Yamashita 1967, Motett 1975). In Japan, females weigh between 10 – 15 kg at maturity while males are 7 – 17 kg (Kanamaru and Yamashita, 1967). In British Columbia male *E. dofleini* were found to mature at around 12.5 kg with females thought to mature at larger sizes (Robinson 1983). *E. 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. *E. dofleini* in Japan move to deeper waters to mate during July – October and move to shallower waters to spawn during October – January (Kanamaru 1964). It is assumed female *E. dofleini* store sperm with a delay between mating and spawning (Kanamaru 1964) and this phenomenon has been documented in an aquarium study of octopus in British Columbia (Gabe 1975). *E. dofleini* is a terminal spawner, females die after the eggs hatch while males die shortly after mating. The fecundity of this species in Japanese waters has been estimated at 30,000 to 100,000 eggs per female (Kanamaru 1964, Motett 1975, Sato 1996). Gabe estimated a female in captivity in British Columbia laid 35,000 eggs and it appears likely fecundity is similar in this region. 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 – 2 year stage was also estimated to be high (Hartwick 1983). Large numbers of planktonic larvae of this species have been captured in offshore waters of the Aleutian Islands during June through August. These juveniles were assumed to be hatched out in the coastal waters along the Aleutian Islands and transported by the Alaska Stream (Kubodera 1991). Since the highest mortality occurs during the larval stage it is likely that ocean conditions have the largest effect on the number of *E. dofleini* in the Bering Sea and large fluctuations in numbers of *E. dofleini* should be expected. Based on larval data, *E. dofleini* is the only octopus in the Bering Sea with a planktonic larval stage.

Sasakiopus salebrosus is a small benthic octopus recently identified from the Bering Sea slope in depths ranging from 200–1,200 m (Jorgensen 2010). It was previous identified in surveys as *Benthoctopus sp.* or as *Octopus sp. n.* In recent groundfish surveys of the Bering Sea Slope this was the most abundant octopus collected, multiple specimens were collected in over 50% of the tows. *Sasakiopus salebrosus* is a small-sized species, maximum total length < 25 cm. Mature females collected in the Bering Sea carried

100 to 120 eggs (Laptikhovsky 1999). Hatchlings and paralarvae have not been collected or described (Jorgensen 2009).

Benthoctopus leioderma is a medium-sized species, maximum total length approximately 60 cm. Its life span is unknown. It occurs from 250 – 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.

Benthoctopus oregonensis is larger than *B. leioderma*, maximum total length approximately 1 m. This is the second largest octopus in the Bering Sea and based on size could be confused with *E. dofleini*. We know very little about this species of octopus. Other members of this genus brood their eggs and we would assume the same for this species. The hatchlings are demersal and likely much larger than those of *E. dofleini*. The samples of *B. oregonensis* all come from deeper than 500 m. This species is the least collected incirrate octopus in the Bering Sea and may live from the shelf break to the abyssal plain and therefore often out of our sampling range.

Graneledone boreopacifica is a deep-water octopus with only a single row of suckers on each arm (the other benthic incirrate octopuses have two rows of suckers). It is most commonly collected north of the Pribilof Islands but occasionally is found in the southern portion of the shelf break region. *Graneledone* species have also been shown to individually attach eggs to hard substrate and brood their eggs throughout development. Samples of *G. boreopacifica* all come from deeper than 650 m and therefore do not occur on the shelf.

Opisthoteuthis californiana is a cirrate octopus and has fins and cirri (on the arms). It is common in the Bering Sea but would not be confused with *E. dofleini*. It is found from 300 – 1100 m and 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. This is not a common octopus in the Bering Sea and would not be confused with *E. dofleini*.

In summary, there are at least seven species of octopus present in the BSAI, and the species composition both of natural communities and commercial harvest is unknown. It is likely that some species, particularly *G. boreapacifica*, are primarily distributed at greater depths than are commonly fished. At depths less than 200 meters *E. dofleini* appears to be the most abundant species, but could be found with *S. salebrosus*, or *B. leioderma.*

Fishery

Directed Fishery

There is no federally-managed directed fishery for octopus in the BSAI. The State of Alaska allows directed fishing for octopus in state waters under a 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 mt per year (Fritz 1997). Between 1995 and 2003, all reported state harvests of octopus in the BSAI were incidental to other fisheries, primarily Pacific cod (ADF&G 2004). In 2004, commissioner's permits were given for directed harvest of Bering Sea octopus on an experimental basis (Karla Bush, ADF&G, personal communication). Nineteen vessels registered for this fishery, and 13 vessels made landings of 4,977 octopus totaling 84.6 mt. The majority of this catch was from larger pot boats during the fall season cod fishery (Sept.-Nov.). Average weight of sampled octopus from this harvest was 14.1 kg. The sampled catch was 68% males. Only one vessel was registered for octopus in 2005. ADF&G is developing policy on implementation of new and developing fisheries, which include octopus (ADF&G 2004).

Incidental Catch

Octopus are caught incidentally throughout the BSAI in both state and federally-managed bottom trawl, longline, and pot fisheries. Until around 2003, retention of octopus when caught was minor, because of a lack of commercial market. Retained octopus were used and sold primarily for bait. In 2004-2008 a commercial market for human consumption of octopus developed in Dutch Harbor, with ex-vessel prices running as high as $0.90/lb. The main processor marketing food-grade octopus went out of business in 2009, decreasing demand; other processors continue to buy octopus for bait at ex-vessel prices in the $0.50 - $0.70/lb range. The worldwide demand for food-grade octopus remains high (www.fao.org), so the possibility of increased future marketing effort for octopus exists.

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 federal waters (including discards) has been estimated using the NMFS regional office catch accounting system. **Minor updates and changes to this system in 2010 have changed estimated catch numbers slightly from previous assessments.** Incidental catch rates are presented in the data section. The majority of both federal and state incidental catch of octopus continues to come from Pacific cod fisheries, primarily pot fisheries (Table 3, ADF&G 2004). Some catch is also taken in bottom trawl fisheries for cod, flatfish, and pollock. The overwhelming majority of catch in federal waters occurs around Unimak Pass in statistical reporting areas 519, 517, and 509. The species of octopus taken is not known, although size distributions suggest that the majority of the catch from pots is *E. dofleini* (see below).

Mortality of discarded octopus is expected to vary with gear type and octopus size. Octopuses have no swim bladder and are not affected by depth changes, and can survive out of water for brief periods. At present, catch accounting for octopus uses the conservative assumption of 100% mortality for all octopus caught, whether retained or discarded. As discussed in the data section, recent research suggests that actual mortality from pot gear is likely substantially lower than 100%, and past SAFEs have raised the possibility of including a discard mortality factor in future octopus management.

Catch History

Since there has been no market for octopus and no directed fishery in federal waters, there are no data available for documenting catch history. Historical rates of incidental catch (prior to 2003) do not necessarily reflect future fishing patterns where octopus are part of retained market catch. Estimates of incidental catch based on observer data (Table 3) 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*.

Fisheries in Other Countries

Worldwide, fisheries for *Octopus vulgaris* and other octopus species are widespread in waters off southeast Asia, Japan, India, Europe, West Africa, and along the Carribean coasts of South, Central, and North America (Rooper et al.1984). World catches of *O. vulgaris* peaked at more than 100,000 tons per year in the late 1960's and are currently in the range of 30,000 tons (www.fao.org). Octopus are harvested with commercial bottom trawl and trap gear; with hooks, lures and longlines; and with spears or by hand. Primary markets are Japan, Spain, and Italy, and prices in 2004-2005 were near record highs (www.globefish.org). Declines in octopus abundance due to overfishing have been suggested in waters off western Africa, off Thailand, and in Japan's inland sea. Morocco has recently set catch quotas for octopus as well as season and size limits (www.globefish.org). Caddy and Rodhouse (1998) suggest that cephalopod fisheries (both octopus and squid) are increasing in many areas of the world as a result of declining availability of groundfish.

Fisheries for *E. dofleini* occur in northern Japan, where specialized ceramic and wooden pots are used, and off the coast of British Columbia, where octopus are harvested by divers and as bycatch in trap and trawl fisheries (Osako and Murata 1983, Hartwick et al 1984). A small harvest occurs in Oregon as incidental catch in the Dungeness crab pot and groundfish trawl fisheries. In Japan, the primary management tool is restriction of octopus fishing seasons based on known seasonal migration and spawning patterns. In British Columbia, effort restriction (limited licenses) is used along with seasonal and area regulation.

Descriptions of octopus management in the scientific literature tend to be older (before 1995) and somewhat obscure; formal stock assessments of octopus are rare. Cephalopods in general (both octopus and squid) are difficult to assess using standard groundfish models because of their short life span and terminal spawning. Caddy (1979, 1983) discusses assessment methods for cephalopods by separating the life cycle into three stages: 1) immigration to the fishery, including recruitment; 2) a period of relatively constant availability to the fishery; and 3) emigration from the fishery, including spawning. Assuming that data permit separation of the population into these three stages, management based on estimation of natural mortality (equivalent to Tier 5) can be used for the middle stage. He also emphasizes the need for data on reproduction, seasonal migration, and spawner-recruit mechanisms. General production models have been used to estimate catch limits for *O. vulgaris* off the African coast and for several squid fisheries (Hatanaka 1979, Sato and Hatanaka 1983, Caddy 1983). These models are most appropriate for species with low natural mortality rates, high productivity, and low recruitment variability (Punt 1995). Another approach, if sufficient data are available, is to establish threshold limits based on protecting a minimum spawning biomass (Caddy 2004). Perry et al. (1999) suggest a framework for management of new and developing invertebrate fisheries. The BSAI octopus fishery is clearly in phase 0 of this scheme, where existing information is being collected and reviewed.

Data

Incidental Catch Data

Reported harvest of octopus from incidental catch in state fisheries in the BSAI ranged from 18-69 mt between 1996 and 2002, but more than doubled to 166 mt in 2003 (ADF&G 2004). From 1992-2002 total incidental catch of octopus in federal waters, estimated from observed hauls, was generally between 100 and 400 mt, although an unusually high catch of 1,017 mt was estimated for 1995 (Table 3). Since 2003 the total octopus catch in federal waters (including discards) has been estimated using the NMFS regional office catch accounting system. **Minor updates and changes to this system in 2010 have changed estimated catch numbers slightly from previous assessments.** Total incidental catch during this period has continued to be in the general range of 200-300 tons. The maximum incidental catch occurred in 2004, when the estimated catch of octopus was 528 tons. 2004 appears to have been a high abundance year for octopus, with reports of octopus so numerous they interfered with pot cod fishing (R. Morrison, NMFS, personal communication). Catch in 2005-2006 was lower, at 338 and 350 tons, respectively. Catch in 2007- 2009 was very low, with 181 mt caught in 2007 and only 72 mt in 2009. The low octopus catch during this period may be a result of a drop in cod pot-fishing effort due to a decline in the market price of cod and increased fuel prices. The estimated catch through October 2010 is up from 2009, at 126 tons. As in previous years, the majority of the 2009-2010 catch came from Pacific cod fisheries, primarily pot fisheries in statistical reporting areas 519, 517, and 509. The incidental catch of octopus in the Aleutian Islands (statistical areas 541, 542, and 543) was also relatively high in 2009-2010.

AFSC Survey Data

Catches of octopus are recorded during the annual NMFS bottom trawl survey of the Bering Sea shelf and biennial surveys of the Bering Sea slope and Aleutian Islands. In older survey data (prior to 2002), octopus were often not identified to species; other species may also have been sometimes misidentified as *E. dofleini*. Since 2002, increased effort has been put into cephalopod identification and species composition data are considered more reliable. Species composition data from the summer Bering Sea surveys in 2007-2010 and from the two most recent Bering Sea slope and Aleutian island surveys is shown in Tables 4 and 5. These catches are our only source of species-specific information within the species group. In general, the shelf survey rarely encounters octopus (less than 15% of the tows contain octopus), while the slope survey finds octopus in over half the tows. The dominant species on the shelf is *E. dofleini*, accounting for over 80% of the estimated octopus biomass. The slope survey, which covers deeper waters, encounters a much wider variety of octopus species. The species most abundant numerically in the slope survey is the newly identified *Sasakiopus salebrosus* (previously thought to be a *Benthoctopus* species). Numerous tows contained several individuals of this species. As this species is very small-bodied, however, the estimated biomass of the slope is still dominated by *E. dofleini* (Table 5). Recent slope surveys also included substantial catches of *Opisthoteuthis californicus, Benthoctopus leioderma, and Graneledone boreopacifica.* The Aleutian Islands survey encounters octopus in about a quarter of the tows, primarily *E. dofleini.*

Survey data are beginning to provide information on the spatial and depth distribution of octopus species. Survey catches of octopus in the Bering Sea shelf are most frequent on the outer shelf adjacent to the slope and in the northernmost portions of the survey. Octopus are rarely caught in Bristol Bay and the inner front. Biomass estimates from the slope surveys suggest that of *Opisthoteuthis californian,* and *Benthoctopus leioderma* are distributed primarily toward the southern portion of the slope, while *Granoledone boreopacifica* and *Benthoctopus oregonensis* are found primarily at the northern end. *E. dofleini* were found throughout the slope survey. The Aleutian Island survey in 2010 caught octopus throughout the Aleutian Island chain, primarily at depths of 75-200 m.

The majority of survey-caught octopuses are caught at depths greater than 60 fathoms (110 meters), with roughly a third of all survey-caught octopuses coming from depths greater than 250 fathoms (450 meters). Sizes are depth stratified with larger (and fewer) animals living deeper and smaller animals living shallower. Species are also somewhat depth stratified, *E. dofleini* have a peak frequency at 250 m, *Sasakiopus salebrosus* peaks at 450 m, *B. leioderma* peaks at 450 and 650 m, and *G. boreopacifica* peaks at 1,050 m. At depths less than 200 m, *E. dofelini* is the most common species. It is important to note that survey data only reflect summer spatial distributions and seasonal migrations may result in different spatial distribution in other seasons.

The size distribution by weight of individual octopus collected by the bottom trawl surveys from 1987 through 2004 is shown in Figure 2 (compared to size frequencies in commercial catch in Figure 3). Survey-caught octopus ranged in weight from less than 5 g up to 25 Kg; 50% of all individuals captured in the shelf survey were <0.5 Kg. This pattern continues into the most recent shelf survey data. The slope survey captures more *E. dofelini* in the 0.5-3 kg range than the shelf survey; both surveys collect the occasional animal over 10 kg. In the 2008 surveys, the largest octopus caught were 4.5 kg for the shelf survey and 16.6 kg for the slope survey, both of which were *E. dofleini*. Data from the 2008 and 2010 slope survey show the marked difference in size distributions between the three most common species: *E. dofleini*, *B. leioderma*, and *S. salebrosus* (Figure 4). In general, the large individuals of *E. dofleini* typically seen in pot gear may be under-represented in trawl survey data because of increased ability to avoid the trawl.

Biomass estimates for the octopus species complex based on bottom trawl surveys are shown in Table 6. These estimates show high year-to-year variability, ranging over two orders of magnitude. There is a large sampling variance associated with estimates from the shelf survey because of a large number of tows that have no octopus. It is impossible to determine how much of the year to year variability in estimated biomass reflects true variation in abundance and how much is due to sampling variation. In 1997, the biomass estimate from the shelf survey was only 211 mt, approximately equal to the estimated BS commercial catch (Table 3). In general, shelf survey biomass was low in 1993-1999; high in 1990-1992 and in 2003-2005, and low again in 2006 -2010. The shelf survey biomass for 2010 was the lowest since 1997, at 823 metric tons. The estimated total biomass from the 2008 slope survey was 621 tons, down from 2004 and 2008 estimates. The 2010 estimate of biomass in the Aleutian Islands was 3,075 tons, similar to the 2006 estimate.

Regression Analysis – Octopus Catch vs Other Time Series

An analysis was conducted to see if the high year-to-year variation in octopus catch could be explained by other time series. The annual incidental octopus catch rate from 1997-2009 (2010 catch data were not yet complete at time of the analysis) were examined. Octopus catch was compared to annual cod catch from federal pot fisheries and the ex-vessel price of cod to see if variations in octopus catch were related to effort in the cod pot fisheries. The total number of observed pot hauls in the BSAI was tabulated as an index of overall commercial effort by the pot sector. Data from the annual Bering Sea shelf survey was used in several forms, including the overall shelf biomass of octopus, the percentage of survey hauls containing octopus, the biomass of the survey stratum representing the southwestern-most portion of the shelf (where most pot fishing occurs), and the percentage of survey hauls from this stratum containing octopus. Survey data was also lagged one year to see if there was a correspondence between octopus catch in a given year and the survey results in the preceding year.

Octopus catch showed very little relationship with observed pot effort, cod catch, cod price, or either of the survey biomass estimates from the same year. There was some correlation (rho = 0.50) between octopus catch and the proportion of survey hauls in stratum 6 (southwest shelf) that contained octopus. The strongest correlation observed, however, was between octopus catch and the shelf survey biomass lagged by one year (rho = 0.58) (Figure 5).The correlations with lagged biomass for the entire shelf was stronger than those for lagged percentage of hauls containing octopus. This analysis suggests that there may be some linkage between the abundance of the smaller animals typically seen by the summer survey and the availability of larger animals to the pot fishery the following winter. The linkage is tentative, however. Future SAFE’s will continue to look at this relationship.

Federal Groundfish Observer Program Data

Groundfish observers record octopus in commercial catches as either “octopus unidentified” or “pelagic octopus unidentified”. Therefore, we do not know which species of octopus are in the catch. Observer records do, however, provide a substantial record of catch of the octopus species complex. Figure 1 shows the spatial distribution of observed octopus catch in the BSAI. The majority of octopus caught in the fishery come from depths of 40-80 fathoms (70-150 m). This is in direct contrast to the depth distribution of octopus caught by the survey. This difference is probably reflective of the fact that octopus are generally taken as incidental catch at preferred depths for Pacific cod. The size distribution of octopus caught by different gears is very different (Figure 3); commercial cod pot gear clearly selects for larger individuals. Over 86% of octopus with individual weights from observed pot hauls weighed more than 5 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, with a wide range in sizes and a large fraction of octopus weighing less than 2 kg. These smaller octopuses may be juvenile *E. dofleini* or may be any of several species, including the newly identified *Sasakiopus salebrosus*.

Observer Special Project Data

Since 2006, some fishery observers have also been collecting data for a special project on octopus. These observers record the individual weights of all octopus caught to improve size frequency distribution data. The observers also determine and record the sex of each octopus from external characters (male octopus have one arm especially adapted for mating). Octopus are also sampled in processing plants. Data collection for this project continues through 2010.

The special project data reflect the size selectivity in gear as seen in Figure 3. Octopus collected on cod pot boats were generally in the range of 5-20 kg, while octopus caught in trawl gear were often less than 2 kg. All of the octopus observed at the processing plants in both years of the study were over 3 kg gutted weight, with average gutted weights of 13.3 and 13.4 kg for males and females respectively. Male octopus predominated in pot catch and processing plant deliveries in both years by a factor of at least 2:1. Sex ratios from octopus observed on vessels differed between the two years, in part because the 2007 data includes both winter 2007 and fall 2006 data. In the first year of the study, males predominated in pot catch but females dominated in other gear types. In 2007, males were more common in bottom trawl catch; the sex ratio in pot catch was near even, and females predominated in pelagic trawl and longline observations. As more data are acquired for this project we hope to use it to look at seasonal patterns in sex ratios in order to gain insight into reproductive timing. The reason that pot catch seems to include more males than other gear types is not known, but probably reflects the fact that pots select for larger animals and draw catch by scent. It is possible that male octopus move around more than females in searching for mates, and so have a higher chance of encountering pots (Roland Anderson, Seattle Aquarium, personal communication Oct 2007).

Cooperative Research Program Project 2006

A NOAA Cooperative Research Program project was conducted in 2006 and 2007 by AFSC scientist Elaina Jorgensen. Processing plants that buy octopus were visited in Dutch Harbor and Kodiak in October 2006 and February-March 2007. A total of 282 animals were examined at Harbor Crown Seafoods in Dutch Harbor and 102 animals at Alaska Pacific Seafoods in Kodiak. Species identification of octopus observed in plant deliveries confirmed that all individuals were *E. dofleini*. All animals delivered to the plants came from the Pacific cod pot fishery. Octopus in Dutch Harbor ranged from 4.5 to 27.7 kg gutted weight with an average gutted weight of 13.6 kg (Figure 6). Data were collected for estimating gutted weight to round weight ratios and weight to mantle length relationships.

NPRB Projects 2009-2012

The North Pacific Research Board has funded field studies in support of stock assessment for octopus, beginning in fall 2009. The studies are being conducted by AFSC and UAF researchers in both the Gulf of Alaska near Kodiak and in the southeast Bering Sea near Dutch Harbor. The main focus of the 2009-2011 study is to increase our knowledge of reproductive biology of *E. dofleini*, in particular to document the seasonality of mating, denning, and egg incubation in Alaskan waters. Specimens are being collected from a variety of sources throughout the calendar year for dissection and examination of the gonads; a gonad maturity coding system has been developed and samples collected for laboratory analysis of fecundity and weight at sexual maturity. In addition to the reproductive work, this project also included a pilot tagging study near Dutch Harbor and testing of habitat pot gear for use in octopus studies.

Octopus specimens for reproductive study were obtained during the months of February, May, and October 2010. During the 2010 winter pot cod season, 25 octopus were donated by commercial cod pot fishermen. These octopus ranged in size from 4.1 to 17 kg and comprised a nearly equal number of male and female specimens. During the spring and fall charters in 2010 an additional 44 octopus were sampled. These octopus ranged in size from 1.2 to 22.3 kg and were comprised of 22 males and 22 females. Additional samples will be obtained during the fall habitat pot charter, the fall 2010 and winter 2011 cod-pot fisheries, and opportunistically throughout 2011.

The large size range of specimens collected should facilitate the determination and description of maturity stages for this species. All octopus sampled were weighed, sexed, the mantle length was measured and the reproductive tract was removed and weighed. The weight and diameter of the gonad was measured and the condition of the reproductive tract was noted. For male specimens the presence and number of fully or partially formed spermatophores was noted. For female specimens the presence of visible eggs within the ovary was noted. For all specimens, all or part of the gonad was preserved. Thin sections of these tissues will be embedded in paraffin, thin sectioned, and stained utilizing standard histological techniques. Histological results in combination with visual observations and gonadosomatic indices will be utilized to examine maturity status and seasonality of the reproductive cycle.

Preliminary reproductive study results from samples obtained during the months of February, May, and October 2010 do not indicate strong seasonality in the reproductive cycle. To date, mature males and females have been observed within each sampling period. Preliminary visual inspection and GSI results indicate both male and female E. dofleini mature around 10-12 kg and there is some evidence that female reproductive structures are largest in February.

The pilot tagging study conducted in fall 2009-winter 2010 near Dutch Harbor was highly successful. Tagging studies will look at the local dynamics and seasonal movement of octopus, and may eventually allow estimation of parameters for Tier 5 management of the octopus species group. The results from initial tagging efforts have shown that the tagging method using Visual Implant Elastomers (VIE tags) is feasible, and that the tags are readily visible in recaptured animals and have no associated tissue damage (Brewer, in prep). Based on these results, NPRB has funded continued tagging effort through 2012. The goal of the extended effort is to collect enough tag recapture data to fit a Jolly-Seber or similar quantitative model that will allow estimation of natural mortality rates and local abundance of octopus in the study area.

Tagged octopus are weighed at each recapture and release to assess in-situ growth rates. Of the *E. dofleini* recaptured thus far, change in weight for octopus appears to be variable; no apparent pattern in weight change can be observed. When a larger data set has been collected, we will attempt to fit growth information from tagged octopus to a Bertanlaffy growth curve. Parameter estimates from a fitted curve may be used to compare to literature values for other species and regions and in estimation of population growth for general production models.

As of October 2010, three seasons of tag and recapture efforts have occurred 20km north of Unalaska Island in depths ranging from 50 to 200m. Additional tagging efforts are planned for spring 2011 and fall 2011. Since October 2009, 749 *E. dofleini* have been tagged and 94 have been recaptured. While most of the recaptures have occurred within a few weeks after tagging, field efforts in fall 2010 included recapture of 5 tags from previous seasons.

The initial study also included a vessel charter for testing and developing a specialized gear for octopus fishing that may eventually be useful for scientific studies and index surveys of octopus abundance. The unbaited gear consists of small “habitat pots” that act as artificial den space for octopus. Similar gear is used in octopus fisheries in other parts of the world. A variety of pot designs and materials are being tested for use in Alaska. An initial trial of habitat pot gear was conducted in spring 2010, and more work is underway during fall 2010. The initial data indicate that longlined plywood box pots are an economical and feasible method for capturing octopus. In the spring trials, plywood box pots and scrap ATV tires had a capture rate of about 30%, but pots made from a variety of plastic materials had a much lower catch rate. Captured octopus ranged in size from than 2 kg to over 20 kg. A total of 91 octopus were captured in 479 pot lifts during the spring study, and 33 octopus have been captured so far in the fall study.

Discard Mortality for Octopus

Mortality of discarded octopus is expected to vary with gear type and octopus size. Mortality of small individuals and deep-water animals in trawl catch is probably high. Larger individuals may also have high trawl mortality if either towing or deck sorting times are long. Octopus caught with longline and pot gear are more likely to be handled and returned to the water quickly, thus improving the probability of survival. Octopuses have no swim bladder and are not affected by depth changes, and can survive out of water for brief periods. Large octopus caught in pots were observed to be very active during AFSC field studies and are expected to have a high survival rate. Octopus survival from longlines is probably high unless the individual is hooked through the mantle or head. Observers report that octopus in longline hauls are often simply holding on to hooked bait or fish catch and are not hooked directly. At present, catch accounting for octopus uses the conservative assumption of 100% mortality for all octopus caught, whether retained or discarded.

Data collected by the observer special project in 2006 and 2007 included a visual evaluation of the condition of the octopus when it was processed by the observer. In 2010, the special project was modified so that observers recorded the condition of octopus at the point of discard from the vessel. The 2010 project included a three-stage viability coding (Excellent, Poor, or Dead) based on the color and mobility of octopus and the presence of visible wounds. Data from both projects are presented in Table 7. The table shows the number of observations and the proportion of observed octopus alive or dead for each gear type.

These results provide partial data on the nature of discard mortality for octopus. In particular, the observed mortality rate for octopus caught in pot gear in 2006-2007 was less than one percent (two octopus out of 433, one coded as dead and the other as injured). In 2010, only 4 percent (six out of 159) of the octopus caught in pot gear were in poor condition or dead at the point of discard. Mortality rates in both time periods were roughly 25% for longline gear and 58% for bottom trawl gear. Mortality rates were highest for pelagic trawl gear, for which 85% of the observed octopus in 2006-2007 and all 10 observed octopus in 2010 were dead. Further research is needed to estimate the total mortality of discarded octopus in various conditions; laboratory or tagging studies are needed to document mortality in relation to condition coding. The data in Table 7, however, suggest that mortality from longline and pot gear may be substantially less than the assumed 100%

These data suggest that a gear-specific discard mortality factor could be estimated for octopus, similar to approach currently used for Pacific halibut. If a discard mortality factor were included in catch accounting for octopus, only a fraction of discarded octopus would be counted as "taken". The estimated catch for octopus would include all retained animals, but only a percentage of those discarded. While the mortality rates above for trawl gear were fairly high, the incidental catch of octopus in these gears is relatively small. The majority of the incidental catch of octopus occurs in pot gear, which had a very low mortality. Once the TAC for octopus was reached and all octopus were discarded, there would be very little further accumulation of catch toward OFL. Using this approach, retention of octopus for market or bait would be limited by the TAC, but a low TAC for octopus would be less likely to affect Pacific cod fisheries. It would also insure that estimated catch of octopus reflected only the animals retained or killed, which is more appropriate for management methods based on fishery mortality rate.

If this approach is used, data collection to document discard mortality rates will need to be continued and laboratory mortality studies conducted. Due to the low incidental catch rate of octopus, it may take several years to accumulate enough data for reliable mortality estimates. If this approach is adopted, mortality estimates should be re-evaluated periodically (e.g. every 5 years) to assess changes in mortality rates due to differences in fishing gear or sampling methodology.

Analytic Approach, Model Evaluation, and Results

The available data do not support population modeling for either individual species of octopus in the BSAI 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 methods such as general production models, estimation of reproductive potential, seasonal or area regulation, or size limits. Parameters for Tier 5 catch limits can be estimated (poorly) from available data and are discussed below. Catch limits under Tier 6 have also been calculated.

Parameters Estimated Independently – Biomass

Estimates of octopus biomass based on the annual Bering Sea trawl surveys (Table 6, Figure 7) represent total weight for all species of octopus, and are formed 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 serious drawbacks to use of the trawl survey biomass estimates for octopus.

Older trawl survey data, as with fishery or observer data, are commonly reported as octopus sp., without full species identification. In surveys from 1997 – 2001, from 50 to 90% of the total biomass of octopus collected was not identified to species. In more recent years up to 90% of collected octopus are identified to species, but some misidentification may still occur. Efforts to improve species identification and collect biological data from octopus are being made, and biomass estimates by species are available from the most recent surveys, but the variability associated with these estimates is very high. In most survey strata, over 90% of the hauls do not contain any octopus at all, so the estimation of biomass is based on only a few tows where octopus are present. This leads to high uncertainty in the biomass estimate, especially in years when the estimate is large (Figure 6).

Secondly, there is strong reason to question whether a trawl is an appropriate gear for sampling octopus. The bottom trawl net used for the Bering Sea shelf survey has no roller gear and tends the bottom fairly well, especially on the smooth sand and silt bottoms that are common to the shelf. The nets used in the Bering Sea slope, Aleutian Island, and GOA surveys, however, have roller gear on the footrope to reduce snagging on rocks and obstacles. Given the tendency of octopus to spend daylight hours near dens in rocks and crevices, it is entirely likely that both types of net have poor efficiency at capturing benthic octopus (D. Somerton, personal communication, 7/22/05). Trawl sampling is not feasible 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 1997). The survey also does not sample in inshore areas and waters shallower than 30m, which may contain sizable octopus populations (Scheel 2002). The estimates of biomass in Table 6 are based on a gear selectivity coefficient of one, which is probably not realistic for octopus. For this reason, these are probably conservative underestimates of octopus biomass in the regions covered by the survey. The sampling variability of survey biomass estimates is very high, which may mask year-to-year variability in octopus abundance.

Finally, there is considerable lack of overlap between the trawl survey and fishery data in the size range of octopus caught, the depth distribution of octopus catch, and the timing of catch. The average weight for individual octopus in survey catches is less than 2 kg; over 50% of survey-collected individuals weigh less than 0.5 kg. Larger individuals are strong swimmers and may disproportionately escape trawl capture. In contrast, the average weight of individuals from experimental pot gear was 18 kg. 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. The trawl survey also tends to catch octopus in deeper waters associated with the shelf break and slope; in 2002-2004 less than 30% of the survey-caught octopus came from depths less than 100 fathoms, where nearly all of the observed commercial catch is taken. Both rapid growth of individual octopus and possible seasonal movements make it difficult to compare the summer trawl survey with octopus vulnerable to fall and winter cod fisheries. Given the large differences in size and depth frequency, it is difficult to presume that the survey accurately represents the part of the octopus population that is subject to commercial harvest.

If future management of the octopus complex is to be based on biomass estimates, then species-specific methods of biomass estimation should be explored. Octopuses are readily caught with commercial or research pots. Given the strong spatial focus of the harvest, an index survey of regional biomass in the Unimak Pass area is appropriate and 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).

Parameters Estimated Independently – Mortality

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 within a given season were 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, Richter 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 (1996) discuss their use for invertebrate fisheries.

We attempted to estimate mortality for Bering Sea octopus from survey-based estimates of biomass and population numbers, however the values were too variable to allow accurate estimation. If we apply Hoenig's (1983) equation to *E. dofleini*, which have a maximum age of five years, we obtain an estimated M of 0.86. Rikhter and Efanov's (1976) equation gives a mortality value of 0.53 based on an age of maturity of 3 years for *E. dofleini*. The utility of maturity/ mortality relationship 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 mortality, based on information currently available. If future management of octopus is to be based on Tier 5 methods, a direct estimate of octopus mortality in the Bering Sea, based on either experimental fishing or tagging studies, is desirable.

Projections and Harvest Alternatives

We recommend that the BSAI octopus complex be separated from the other species complex to better monitor and control catches, especially given their rising market value. Separate catch accounting, both of retained catch and discards, is necessary to achieve this strategy. We recommend that octopus be managed very conservatively due to the poor state of knowledge of the species, life history, distribution, and abundance of octopus in the BSAI, and due to their important role in the diet of Steller sea lions. Further research is needed in several areas before octopus could even begin to be managed by the methods used for commercial groundfish species.

If separate catch quotas for octopus were desired, it would be possible to manage the complex under Tier 5 using trawl survey biomass estimates and estimates of mortality for *E. dofleini*. **If the most recent 10-year average (1999 – 2008) of survey biomass of 7,765 tons and the conservative M estimate of 0.53 are used, the Tier 5 OFL and ABC would be 4,115 and 3,086 tons, respectively.** This ABC is almost an order of magnitude higher than the current rate of incidental catch. Trawl survey estimates of biomass for the species complex represent the best available data at this time. There are serious concerns, however, about both the suitability of trawl gear for accurately sampling octopus biomass and the extent to which the survey catch represents the population subject to commercial harvest. **Because of serious concerns with both the biomass estimate and mortality estimates, we do not recommend use of a Tier 5 approach for this group at present**. **If future management of the octopus complex under Tier 5 is envisioned, then dedicated experiments are needed to obtain both a more realistic estimate of octopus biomass available to the fishery and a more accurate estimate of natural mortality.**

The remaining option is to set catch limits for the octopus assemblage under Tier 6. There is no historical catch data for the period specified under the usual application of Tier 6 (1975-1995). Available data are incidental catch rates from 1997-2009. Based on discussion at the September 2009 Plan team meetings, we used the 11-year period of incidental catch data from 1997 through 2007 as the basis for Tier 6 catch estimates. The teams recommended that this period be fixed as the standard for use in all future assessments. Using this period, the average estimated incidental catch rate is 305 mt. Another method discussed was to select a percentile of the incidental catch at the OFL; percentiles from the incidental catch data for 1997-2008 are shown in Table 8. The percentile method has as an advantage that the frequency with which an OFL would impact other fisheries is approximately known; for example, if the 90^{th} percentile is selected, it could be expected that octopus OFL would be reached approximately once in every ten years. The maximum catch from the selected period is 528 t caught in 2004.

If the **long-term average** of the incidental catch rate was used under standard **Tier 6 procedure, the OFL would be 305 mt and the ABC would be 229 mt. If the maximum incidental catch is used, the OFL would be 528 mt and the ABC would be 396 tons.** Use of an upper percentile of the catch data would yield annual catch limits between these two values. Given the order of magnitude of the survey and food web model biomass estimates, the authors and plan teams feel that all of the Tier 6 catch limits are artificially low, and that there is no conservation concern for octopus at the level of the incidental catch rates. It is the belief of the authors that Tier 6 is overly conservative, because the incidental catch estimates do not provide an actual "catch history". For most of this period there was very little market or directed effort for octopus. Although processors in Dutch Harbor began buying octopus in 2004-2006, the entire other species complex was on bycatch-only status for these years, so that the incidental catch rate still does not represent directed fishing. After review of the 2005 octopus SAFE, the Council's SSC concurred that neither Tier 5 nor the standard Tier 6 approach was satisfactory for this group, but supported use of Tier 6 until better methods could be found. **There is no strong scientific basis for choosing one catch limit over another out of the incidental catch data. The choice of average,**

percentile, or maximum catch for setting regulatory limits may be made based on overall management concerns.

One approach that could help avoid impacts of octopus catch limits on other fisheries would be to incorporate gear-specific mortality rate estimates into catch accounting for octopus. Based on data from the observer program special project, catch mortality rates of octopus are substantially lower than 100%, especially for longline and pot gears. Including a gear-specific mortality factor would make the estimate of octopus "taken" more consistent with actual fishing mortality. Since the majority of octopus incidental catch is with gears that have low mortality rates, this could also avoid closure of groundfish fisheries due to octopus bycatch. While the numbers of octopus retained would still be controlled by the TAC, the low mortality rate of discarded octopus is unlikely to drive total catch to OFL. We recommend that studies to develop and document octopus discard mortality rate estimates be continued.

We do not recommend a directed fishery for octopus in federal waters at this time, because data are insufficient for adequate management. We anticipate that octopus harvest in federal waters of the BSAI will continue to be largely an issue of incidental catch in existing groundfish fisheries. We do expect the high market value of octopus to increase percent retention of octopus for market, especially in Pacific cod pot fisheries.

Ecosystem Considerations

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 habits data and ecosystem modeling of the Bering Sea and AI (Livingston et al 2003, Aydin et al 2008) indicate that octopus diets in the BSAI are dominated by epifauna such as mollusks, hermit crabs (particularly in the AI), starfish, and snow crabs (*Chinoecetes sp.*). The Ecopath model (Figure 8) uses diet information on all predators in the ecosystem to estimate what proportion octopus mortality is caused by which predators and fisheries. Results from the early 1990s indicate that octopus mortality in the Bering Sea comes primarily from Pacific cod, resident seals (primarily harbor seal, *Phoca vitulina richardsi*), walrus and bearded seals, and sculpins; in the AI principal predators are Pacific cod, Pacific Halibut, and Atka mackerel. Adult and juvenile Steller sea lions account for approximately 7% of the total mortality of octopus in the Bering Sea, but cause insignificant octopus mortality in the GOA and Aleutian Islands. Modeling suggests that fluctuations in octopus abundance could affect resident seals, Pacific Halibut, Pacific cod, and snow crab populations. Modeling suggests that primary and secondary productivity and abundance of hermit crabs, snow crabs, resident seals, Pacific cod, and Pacific halibut affect octopus production.

While Steller sea lions (*Eumetopias jubatus*) are not a dominant predator of octopus, however, octopus are important prey item in the diet of Stellers in the Bering Sea. According to diet information from Perez (1990; Figure 9) octopus are the second most important species by weight in the sea lion diet, contributing 18% of adult and juvenile diets in the Bering Sea. Diet information from Merrick et al (1997) for the AI, however, do not show octopus as a significant item in sea lion diets. 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 Aleutians, although this analysis does not distinguish between octopus 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. Based on ecosystem models, octopus are not significant components of the diet of northern fur seals (*Callorhinus ursinus*). 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 that the octopus was among the lowest (1%).

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 (1997) reported increased trap catch rates in offshore areas during winter months. Octopus require secure dens in rocky bottom or boulders to brood its 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 (1997) 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 and ice cover in the Bering Sea is having some effect on octopus, but data are not adequate to evaluate these effects.

Data Gaps and Research Priorities

Recent efforts have improved collection of basic data on octopus, including catch accounting of retained and discarded octopus and species identification of octopus during research surveys. Both survey and observer efforts provide a growing amount of data on octopus size distributions by species and sex and spatial separation of species. Studies currently underway are expected to yield new information on the life-history cycle of *E. dofleini* in Alaskan waters, and may lead to development of octopus-specific field methods for capture, tagging, and index surveys. The AFSC has kept in communication with the state of Alaska regarding directed fisheries in state waters, gear development, octopus biology, and management concerns.

Identification of octopus to species is difficult, and we do not expect that either fishing industry employees or observers will be able to accurately determine species on a routine basis. A publication on cephalopod taxonomy and identification in Alaska has recently 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. Octopus species could be identified from tissue samples by genetic analysis, if funding for sample collection and lab analysis were available. Special projects and collections in octopus identification and biology will be pursued as funding permits.

Because octopuses are semelparous, a better understanding of reproductive seasons and habits is needed to determine the best strategies for protecting reproductive output. *E. dofleini* in Japan and off the US west coast reportedly undergo seasonal movements, but the timing and extent of migrations in Alaska is unknown. While many octopus move into shallower coastal waters for egg-laying, it is probable that at least some BSAI octopus reproduction occurs within federal waters. 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. Tagging studies to determine seasonal and reproductive movements of octopus in Alaska would enhance our ability to appropriately manage commercial harvest. If feasible, it would be desirable to avoid harvest of adult females following mating and during egg development. Larger females, in particular, may have the highest reproductive output (Hartwick 1983).

Factors determining year-to year patterns in octopus abundance are poorly understood. Octopus abundance is probably controlled primarily by survival at the larval stage; substantial year-to-year variations in abundance due to climate and oceanographic factors are expected. The high variability in trawl survey estimates of octopus biomass make it difficult to depend on these estimates for time-series trends; trends in CPUE from observed cod fisheries may be more useful.

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 would require either extensive industry cooperation or funding for directed field research.

Summary

Octopus are found throughout the Aleutian Islands and in the middle and outer front regions of the Bering Sea shelf, particularly along the shelf break and in the “horseshoe” region north of Unimak Pass. At least seven species of octopus are found in the BSAI, including a newly-identified species. The most abundant species in shelf surveys is the Giant Pacific octopus *Enteroctopus dofleini*; based on size data and plant observations, this species also makes up the majority of the retained commercial catch. Octopus are taken as incidental catch in bottom trawl, longline, and pot fisheries throughout the Bering Sea and AI, with the largest catches from pot gear. Recent development of markets and a high ex-vessel price has spurred increased interest in fishing for and retention of octopus in BSAI fisheries.

Octopus are short-lived and fast-growing, and their potential productivity is high. It is probable that the BSAI can support increased commercial harvest of octopus, since the historical catch rate is only a fraction of the estimated mortality. The difficulty with octopus as a commercial species is that data for determining appropriate management levels and strategies are almost nonexistent. Trawl surveys produce estimates of biomass for the octopus complex, but these estimates are highly variable and may not reflect the same species and sizes of octopus caught by industry. Information on life history patterns and mortality is limited for *E. dofleini* and not available at all for other species. Because of the lack of information at this time, we strongly recommend that directed fishing for octopus be discouraged in federal waters of the BSAI and that incidental catch be controlled either by catch limits or MRAs. Improved catch accounting, species identification of harvested octopus, and better understanding of seasonal movement and reproductive patterns are all needed to provide responsible management strategies.

Literature Cited

Alaska Department of Fish and Game (2004). Annual management report of the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea, and the westward region’s shellfish observer program, 2003. Regional Information Report No. 4K04-43

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2008. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.

Boyle, P. and P. Rodhouse. 2005. Cephalopods: Ecology and Fisheries. Blackwell Publishing, Oxford, UK.

Caddy, J.F. 1979. Preliminary analysis of mortality, immigration, and emigration on *Illex* population on the Scotian Shelf. ICNAF Res. Doc. 79/VI/120, Ser. No. 5488.

Caddy, J.F. 1983. The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. Pages 416-452 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Caddy, J.F. 2004. Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. Can. J Fish. Aquat. Sci. 61:1307-1324.

Caddy, J.F. and P.G. Rodhouse. 1998. Cephalopod and groundfish landings: evidence for ecological change in global fisheries? Rev. Fish Biology and Fisheries 8:431-444.

Charnov e.L. and D. Berrigan. 1991. Evolution of life history parameters in animals with indeterminate growth, particularly fish. Evol. Ecol. 5:63-68.

Fritz, L (1997). Summary of changes in the Bering Sea Aleutian Islands squid and other species assessment. (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.

Gabe, S.H. 1975. Reproduction in the Giant Octopus of the North Pacific, *Octopus dofleini martini*. Veliger 18 (2): 146-150.

Gaichas, S. 2004. Other Species (in) Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea / Aleutian Islands regions. N. Pacific Fish. Management Council, Anchorage, AK.

Hatanaka, H. 1979. Studies on the fisheries biology of common octopus off the northwest coast of Africa. Bull Far Seas Reserarch Lab 17:13-94.

Hartwick, B. 1983. Octopus dofleini. In Cephalopod Life Cycles Vol. I. P.R. Boyle eds. 277-291.

Hartwick, E.B., R.F. Ambrose, and S.M.C. Robinson. 1984. Dynamics of shallow-water populations of *Octopus dofleini*. Mar. Biol. 82:65-72.

Hartwick, E.B, and I. Barriga (1997) Octopus dofleini: biology and fisheries in Canada (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.

Hoenig, J.N. 1983. Empirical Use of Longevity Data to Estimate Mortality Rates. Fishery Bulletin V. 82 No. 1, pp. 898-903.

Iverson, S.J., K.J. Frost, and S.L.C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: factors contributing to among and within species variability. Marine Ecol. Prog. Ser. 241:161-181.

Jorgensen, E.M. 2009. Field guide to squids and octopods of the eastern North Pacific and Bering Sea. Alaska Sea Grant Pub. No. SG-ED-65, 100pp.

Jorgensen, E.M. 2010. Description and phylogenetic relationships of a new genus of octopus, Sasakiopus (Cephalopoda: Octopodidae), from the Bering Sea, with a redescription of Sasakiopus saleborsus (Sasaki, 1920). Journal of Molluscan Studies 76: 57-66.

Kanamaru, S. 1964. The octopods off the coast of Rumoi and the biology of mizudako. Hokkaido Marine Research Centre Monthly Report 21(4&5):189-210.

Kanamaru, S. and Y. Yamashita. 1967. The octopus mizudako. Part 1, Ch. 12. Investigations of the marine resources of Hokkaido and developments of the fishing industry, 1961 – 1965.

Kubodera, T. 1991. Distribution and abundance of the early life stages of octopus, *Octopus dofleini* Wulker, 1910 in the North Pacific. 49(1-2) 235-243.

Laptikhovsky, V.V. 1999. Fecundity and reproductive strategy of three species of octopods from the Northwest Bering Sea. Russian Journal of Marine Biology 25: 342-346.

Laptikhovsky, V. 2001. Fecundity, egg masses and hatchlings of *Benthoctopus* spp. (Octopodidae) in Falkland waters. J. Mar. Biol. Ass. U.K. 81: 267-270.

Livingston, P.L., Aydin, K.Y., J. Boldt., S. Gaichas, J. Ianelli, J. Jurado-Molina, and I. Ortiz. 2003. Ecosystem Assessment of the Bering Sea/Aleutian Islands and Gulf of Alaska Management Regions. *In:* Stock assessment and fishery evaluation report for the groundfish resources or the Bering Sea/Aleutian Islands regions. North. Pac. Fish. Mgmt. Council, Anchorage, AK.

Merrick, R.L., M.K. Chumbley, and G.V. Byrd, 1997. Diet diversity of Steller sea lions (Eumetpias jubatus) and their population decline in Alaska: a potential relationship. Can J. Fish. Aquat. Sci. 54: 1342-1348.

Mottet, M. G. 1975. The fishery biology of *Octopus dofleini*. Washington Department of Fisheries Technical Report No. 16, 39 pp.

National Research Council. 1998. Improving fish stock assessments. National Academy Press, Washington, D.C.

Osako, M. and . Murata. 1983. Stock assessment of cephalopod resources in the northwestern Pacific. Pages55-144 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Paust, B.C. 1988. Fishing for octopus, a guide for commercial fishermen. Alaska Sea Grant Report No. 88-3, 48 pp.

Paust, B.C. (1997) Octopus dofleini: Commercial fishery in Alaska (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.

Perez, M. A. 1990. Review of marine mammal population and prey information for Bering Sea ecosystem studies. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-186, 81 p.

Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish Biology and Fisheries 9:125-150.

Punt, A.E. 1995. The performance of a production-model management procedure. Fish. Res. 21:349-374.

Rikhter, V.A. and V.N. Efanov, 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res.Doc., 79/VI/8, 12p.

Robinson, S.M.C. 1983.Growth of the Giant Pacific octopus, *Octopus dofleini martini* on the west coast of British Columbia. MSc thesis, Simon Fraser University.

Robinson, S.M.C. and E.B. Hartwick. 1986. Analysis of growth based on tag-recapture of the Giant Pacific octopus *Octopus dofleini martini*. Journal of Zoology 209: 559-572.

Rooper, C.F.E., M.J. Sweeny, and C.E. Nauen. 1984. FAO Species catalogue vol. 3 cephalopods of the world. FAO Fisheries Synopsis No. 125, Vol. 3.

Sato, K. 1996. Survey of sexual maturation in *Octopus dofleini* in the coastal waters off Cape Shiriya, Shimokita Peninsula, Aomori Prefecture. Nippon Suisan Gakkaishi 62(3): 355-360.

Sato, R. and H. Hatanaka. 1983. A review of assessment of Japanese distant-water fisheries for cephalopods. Pages 145-203 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Scheel, D. (2002) Characteristics of habitats used by Enteroctopus dofleini in Prince William Sound and Cook Inlet, Alaska. Marine Ecology 23(3):185-206.

Sinclair, E.H. and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (eumetopias jubatus). J Mammology 83:973-990.

Villanueva, R. 1992. Continuous spawning in the cirrate octopods *Opisthoteuthis agassizii* and *O. vossi*: features of sexual maturation defining a reproductive strategy in cephalopods. Marine Biology 114: 265-275.

Voight, J.R. and A.J. Grehan. 2000. Egg brooding by deep-sea octopuses in the North Pacific Ocean. Biological Bulletin 198(1): 94-100.

Wakabayashi, K, R.G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys (in) R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S. - Japan groundfish investigations in the Bering Sea during May - August 1979. International North Pacific Fisheries Commission Bulletin 44.

Table 1. Species of Octopodae found in the BSAI.

Rank	Scientific Name	Common Name	General Distribution	Age at Maturity	Size at Maturity
Class	Cephalopoda				
Order	Octopoda				
Group	Cirrata				
Family	Opisthoteuthidae				
Genus	*Opisthoteuthis*				
Species	***Opisthoteuthis*** cf ***californiana***	flapjack devilfish	BS deeper than 200 m	unknown	unknown
Group	Incirrata				
	Bolitaenidae				
	Japetella				
	Japetella diaphana	pelagic octopus	Pelagic	unknown	< 300 g
Family	Octopodidae				
Genus	*Benthoctopus*				
Species	***Benthoctopus leioderma***	smooth octopus	Southern BS deeper than 250 m	unknown	< 500 g
	Benthoctopus oregonensis	none	BS shelf break	unknown	> 2 kg
	Benthoctopus salebrosus	none	Northern BS	unknown	unknown
Genus	*Enteroctopus*				
Species	***Enteroctopus dofleini***	giant octopus	all BSAI, from 50 - 1400 m	3 - 5 yr	>10 kg
Genus	*Graneledone*				
Species	***Graneledone boreopacifica***	none	BS shelf break 650 - 1550 m	unknown	unknown
Genus	*Sasakiopus*				
	Sasakiopus salebrosus	stubby octopus	BS shelf break, 200 - 1200 m	unknown	75 - 150 g

Table 2 History of federally-managed other species complex (skates, sharks, octopus, and sculpins). Catches, pre-season catch specifications and estimated biomass (mt) of "Other species" in the BSAI, 1964-2010. Specifications included smelt through 1998.

Year	Catch[1]	TAC[2]	ABC	OFL	Biomass[3]
1980	47,661	-	-	-	-
1981	42,925	-	-	-	-
1982	23,367	-	-	-	517,403
1983	19,140	-	-	-	456,725
1984	10,178	-	-	-	441,727
1985	13,553	-	-	-	334,677
1986	11,980	-	-	-	555,462
1987	9,724	-	-	-	550,249
1988	12,643	-	-	-	656,149
1989	5,101	-	-	-	630,764
1990	6,325	-	-	-	765,140
1991	16,376	15,000	28,700	27,200	729,101
1992	33,074	20,000	27,200	-	638,303
1993	23,953	26,600	26,600	-	592387
1994	24,532	26,390	27,500	141,000	682,424
1995	22,201	20,000	27,600	136,000	614,245
1996	21,437	20,125	27,600	137,000	631,950
1997	22,552	25,800	25,800	138,000	609,730
1998	25,604	25,800	25,800	134,000	555,466
1999	18,678	32,860	32,860	129,000	519,639
2000	26,108	31,360	31,360	71,500	490,473
2001	27,177	26,500	33,600	69,000	568,233
2002	28,619	30,825	39,100	78,900	588,119
2003	28,312	32,309	43,300	81,100	604,796
2004	29,347	27,205	46,810	81,150	-
2005	29,467	29,000	53,860	87,920	-
2006	26,800	29,000	58,882	89,404	-
2007	26,829	37,355	68,800	91,700	-
2008	29,376	50,000	78,100	80,800	-
2009	26,675	50,000	63,700	80,800	-
2010	-	50,000	61,100	88,200	-

*Other Species category modified over time.

[1]Catch data current through November 2009.
[2]TAC, ABC and OFL data from annual Federal Registrar Harvest Specifications.
[3]Biomass data from 2003 BSAI SAFE EBS shelf survey estimates.

Table 3 Estimated catch (mt) of all octopus species in federal waters by target fishery. 1997-2002 estimated from blend data. 2003-2010 data from AK region catch accounting, as provided in October 2010. Note that slight revisions to the catch accounting database in 2010 have slightly changed the 2003-2008 number from preceding assessments. *2010 data includes only part of the year, January - September.

Target Fishery	1997	1998	1999	2000	2001	2002	2003
Atka mackerel	1	3	0	1	1	2	1
Pacific cod	160	168	310	359	211	334	216
Flatfish	86	13	14	57	9	21	32
Pollock	1	5	0	1	5	8	9
Rockfish	0	0	0	0	0	1	1
Sablefish	0	0	1	0	1	8	7
Other							3
Grand Total	248	190	326	418	227	374	269

Target Fishery	2004	2005	2006	2007	2008	2009	2010*
Atka mackerel	6	0	2	1	0	0	1
Pacific cod	279	311	331	166	194	56	111
Flatfish	44	17	5	7	11	10	10
Pollock	3	1	2	4	4	5	3
Rockfish	1	0	0	3	2	0	0
Sablefish	0	0	0	1	1	0	0
Other	196	8	10	0	0	0	0
Grand Total	528	338	350	181	213	72	126

Table 4 Species composition of octopus from recent AFSC Bering Sea and Aleutian Islands bottom trawl surveys: numbers of hauls containing octopus and numbers of octopus caught by species. b) biomass estimates by species.

	Bering Sea Shelf Survey				**Slope Survey**		**A.I. Survey**	
	2007	**2008**	**2009**	**2010**	**2008**	**2010**	**2006**	**2010**
Number of Hauls	376	375	376	376	200	200	358	418
No. Hauls w/ Octopus	32	26	37	47	113	110	86	99
Species	**Number of Octopus Caught**							
Enteroctopus dofleini	61	51	47	124	57	63	124	162
Sasakiopus salebrosus				17	73	94		
Benthoctopus leioderma	5	7	35	4	89	62	1	
Graneledone boreopacifica					41	33		
Opisthoteuthis californiana					39	39	3	
Benthoctopus oregonensis					8	3		
Japetella diaphana					16	1		
Octopus sp.	8	1	2		1		6	
Benthoctopus sp.		2	2		1	18		1
octopus unident.	6					1	6	6
All species	80	61	86	145	325	315	140	169

Table 5. Species composition of octopus from recent AFSC Bering Sea and Aleutian Islands bottom trawl surveys: biomass estimates by species.

Species	**2008 Slope Survey Biomass (mt)**	**2008 Shelf Survey Biomass (mt)**	**2010 Slope Survey Biomass (mt)**	**2010 Shelf Survey Biomass (mt)**
Enteroctopus dofleini	356.8	1,017	216.3	653
Graneledone boreopacifica	84.0		96.1	
Benthoctopus leioderma	155.8		86.6	
Benthoctopus sp.	0.44		76.9	
Opisthoteuthis californiana	156.1		70.4	
Sasakiopus salebrosus	23.6		32.2	
Benthoctopus oregonensis	28.1		27.8	
Opisthoteuthis sp.			14.6	
Japetella diaphana	10.0		0.5	
Vampyroteuthis infernalis			0.1	
octopus unident.	0.01		0.0	
All species	814.9	1,179	621.4	823

Table 6. Biomass estimates in tons for octopus (all species) from AFSC bottom trawl surveys.

Year	EBS Shelf Survey Biomass	EBS Slope Survey Biomass	AI Survey Biomass	Total BSAI
1982	12,442	180		
1983	3,280		440	
1984	2,488			
1985	2,582	152		
1986	480		781	
1987	7,834			
1988	9,846	138		
1989	4,979			
1990	11,564			
1991	7,990	61	1,148	
1992	5,326			
1993	1,355			
1994	2,183		1,728	
1995	2,779			
1996	1,746			
1997	211		1,219	
1998	1,225			
1999	832			
2000	2,041		775	
2001	5,407			
2002	2,435	979	1,384	
2003	8,264			
2004	4,902	1,957	4,099	
2005	9,562			
2006	1,877		3,060	
2007	2,192			
2008	1,179	815		
2009	1,031			
2010	823	621	3,075	
Average All	4,098	613	1,771	6,482
Avg last 10	3,767	1,093	2,904	7,765
Most Recent	823	621	3,075	4,713
OFL 10 yr				4,115
ABC 10 yr				3,086

Table 7. Results of observer program special project data on condition of octopus when observed (2006-2007) and at point of discard (2010).

2006-2007	Observer Special Project Data **Condition Reported for Observed Octopus**				
Gear		**Alive**	**Dead**	**Total**	**%Alive**
Bottom Trawl		32	43	75	42.7%
Pelagic Trawl		28	161	189	14.8%
Pots		431	2	433	99.5%
Longline		132	36	168	78.6%
2010					
Gear	**Excellent**	**Poor**	**Dead**	**Total**	**%Excellent**
Bottom Trawl	12	7	10	29	41.4%
Pelagic Trawl			10	10	0.0%
Pots	153	2	4	159	96.2%
Longline	32	6	5	43	74.4%

Table 8. Summary statistics and percentiles of BSAI incidental catch data from 1997-2002, and the catch limits that would result if each catch were set = OFL, with ABC = 0.75*OFL.

	Catch (t)	
Statistic	**OFL**	**ABC**
Minimum	181	136
Average	314	235
Median	326	245
70th percentile	350	263
80th percentile	374	281
90th percentile	418	314
Max	516	387

Figure 1. Distribution of octopus (all species) in the BSAI, based on octopus occurring in observed hauls during the period 1990-1996.

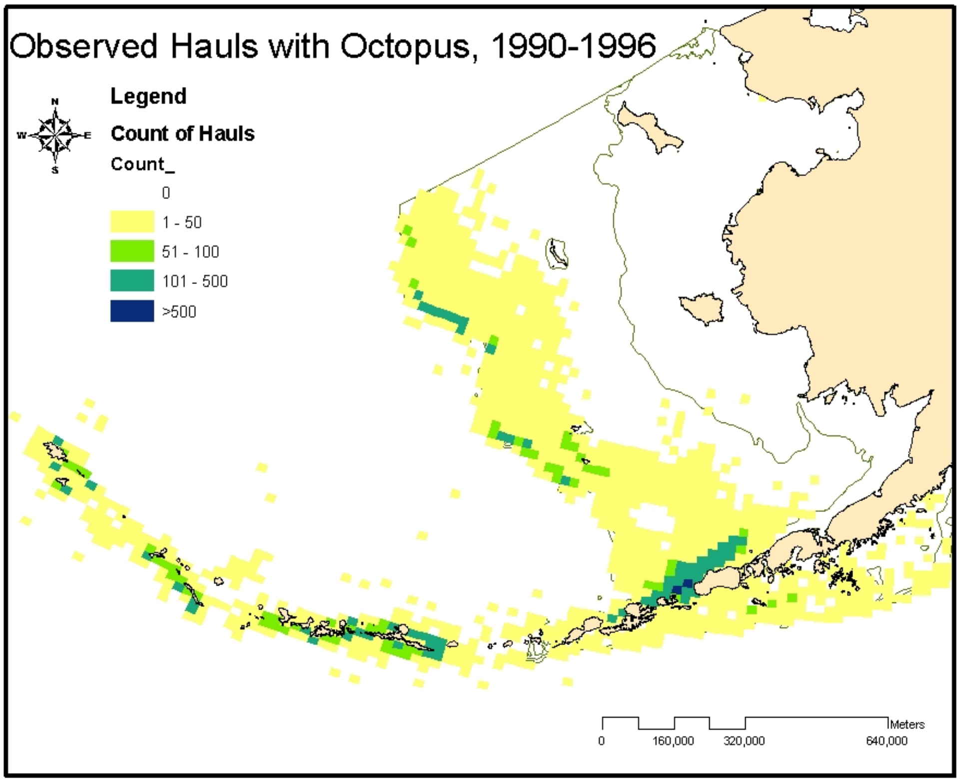


Figure 2 Size frequency of individual octopus (all species) from AFSC bottom trawl surveys in the Bering Sea and Aleutian Islands 1987 - 2004.

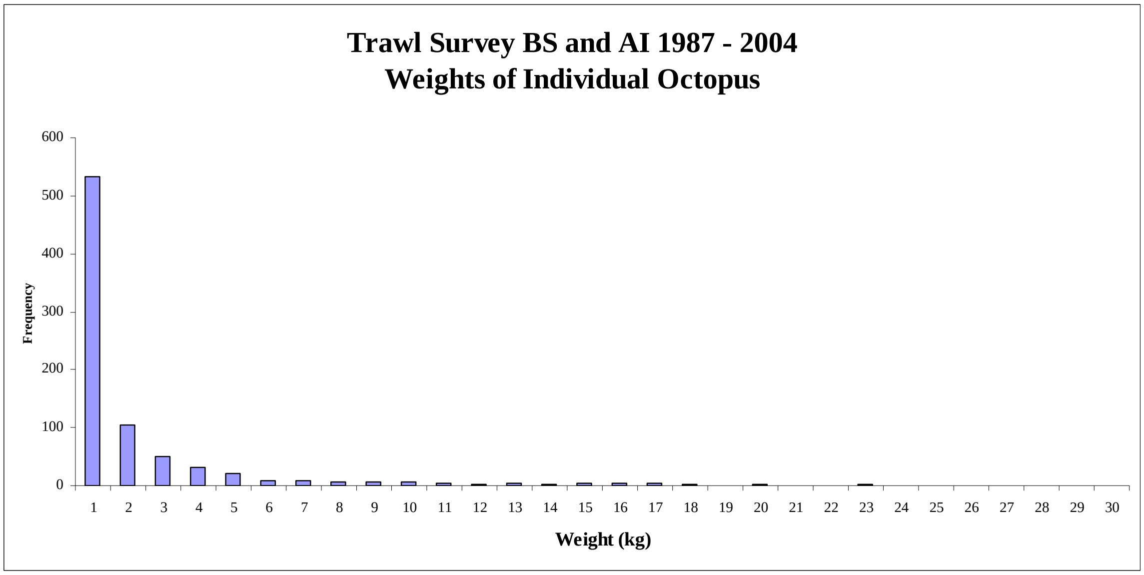


Figure 3 Size frequency of individual octopus (all species) from observed commercial hauls by gear type, 1987 – 2005: a)bottom trawl, b) longline, c) pots.

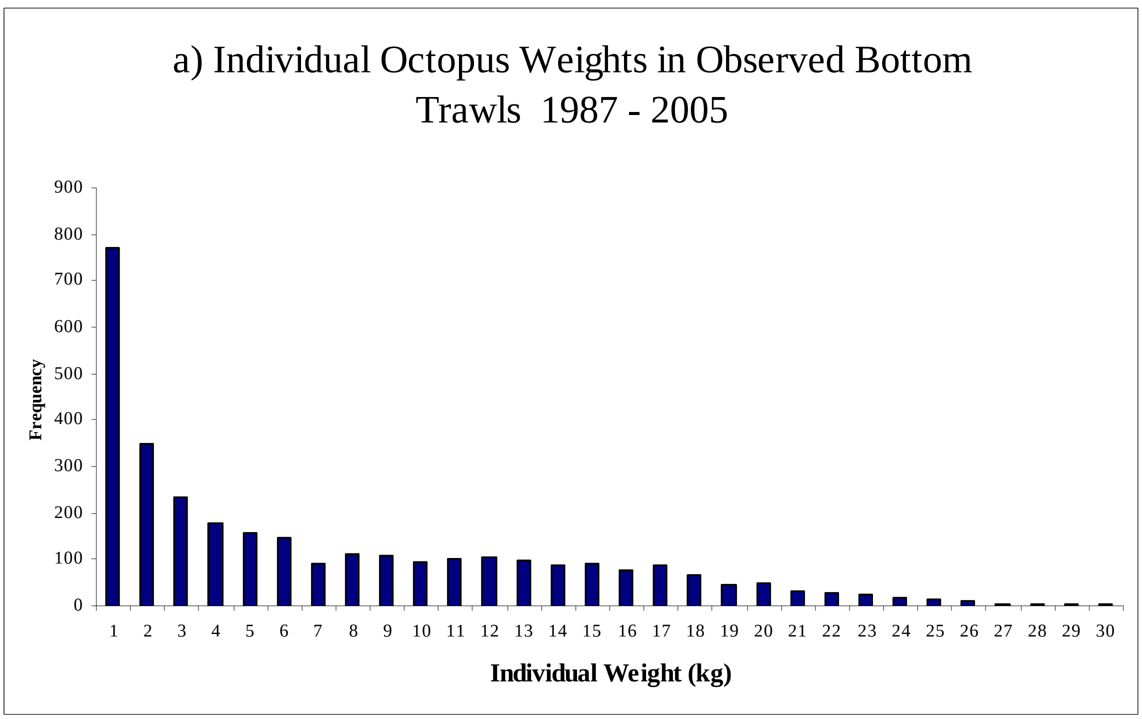
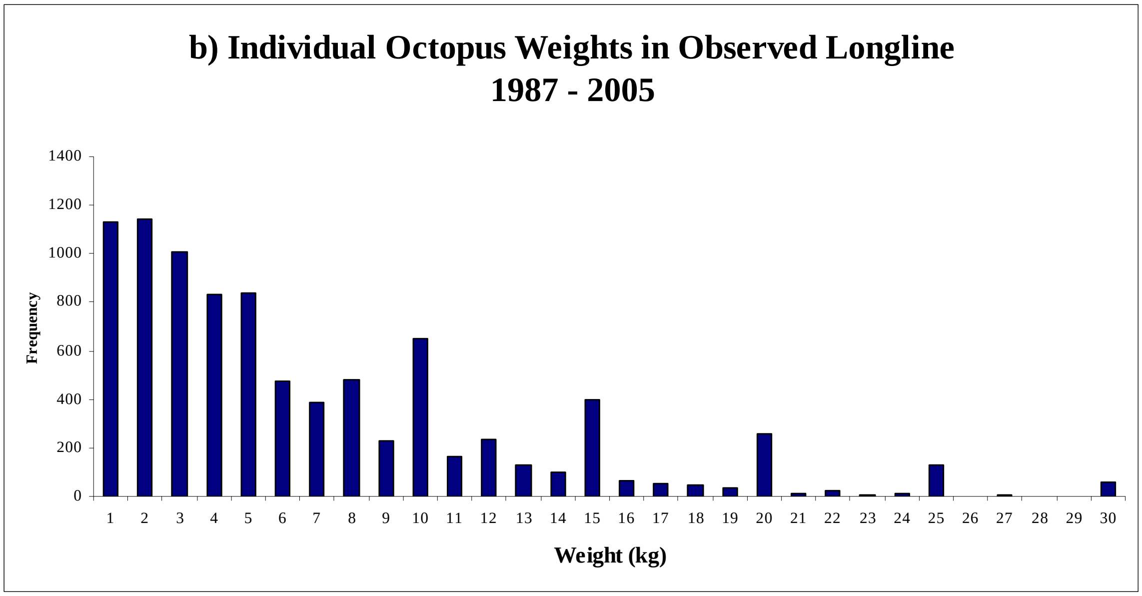


Figure 3 Continued.



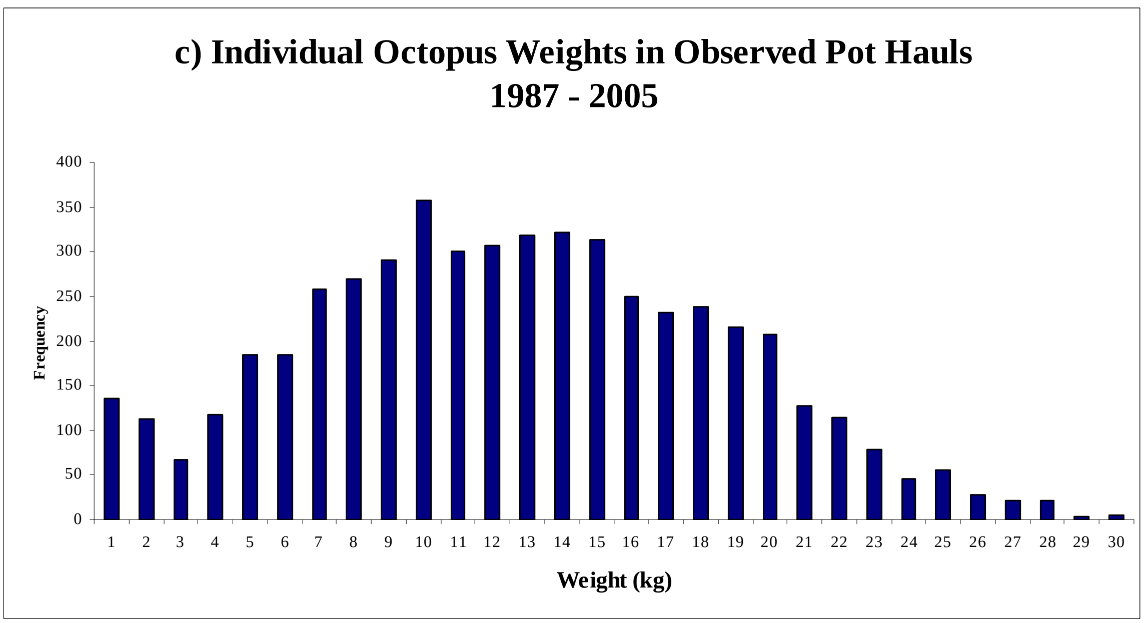
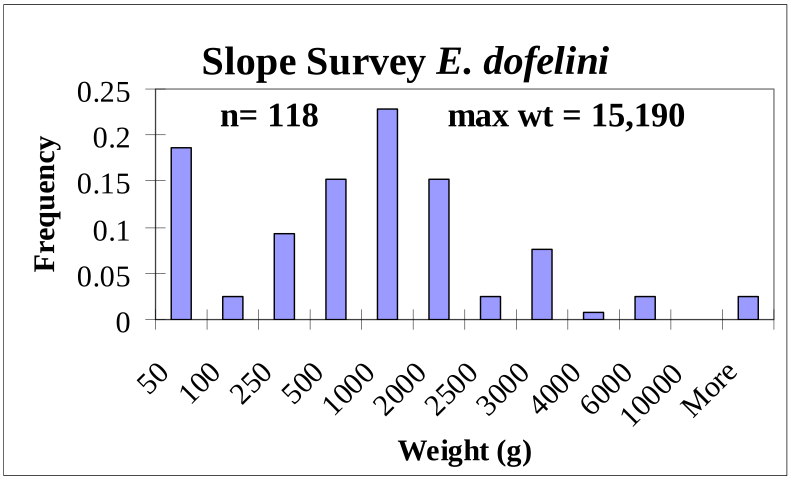
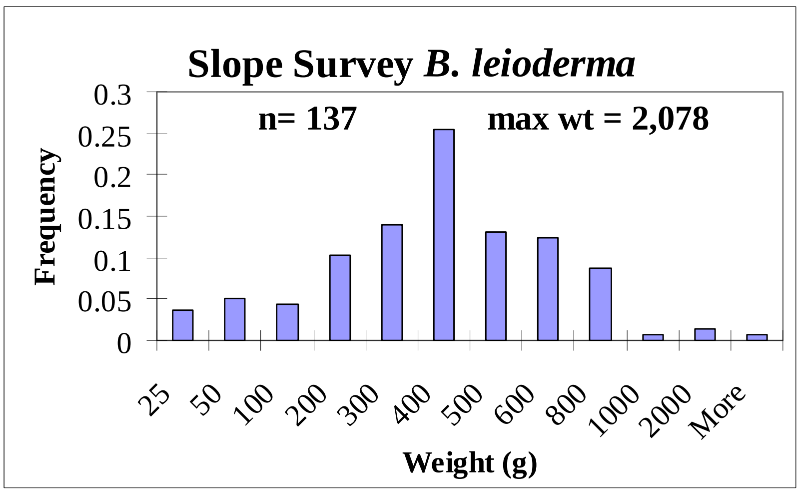


Figure 4 Size frequency octopus by species from the 2008 and 2010 slope surveys.





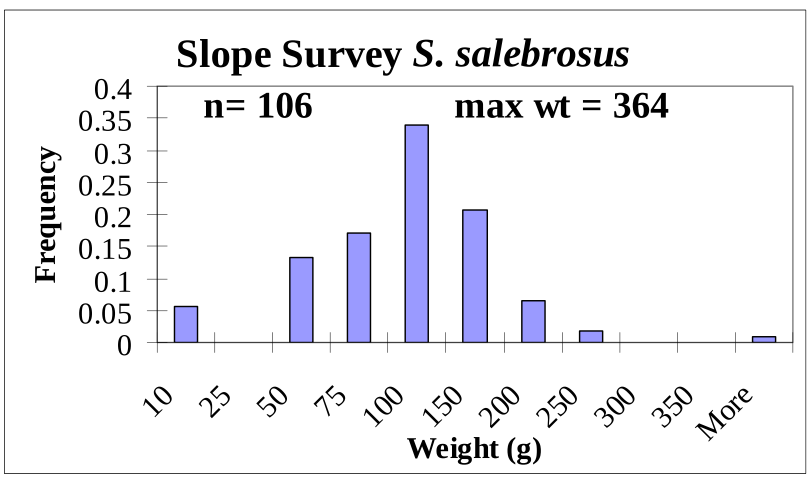


Figure 5. Regression of annual incidental octopus catch on Bering Sea shelf biomass estimates from the preceding year.

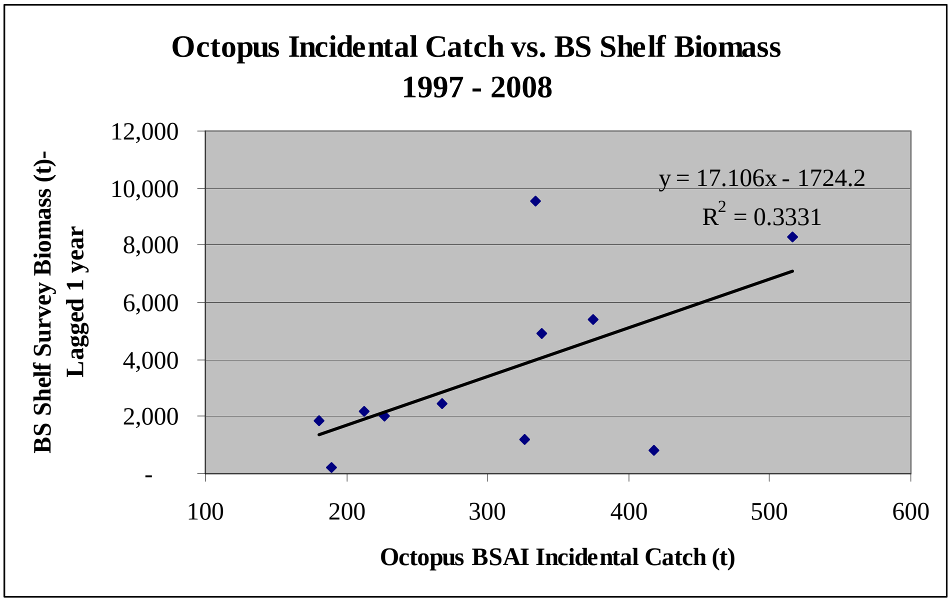


Figure 6. Size distribution (kg) of octopus sampled by observers at BSAI processing plant in winter 2006.

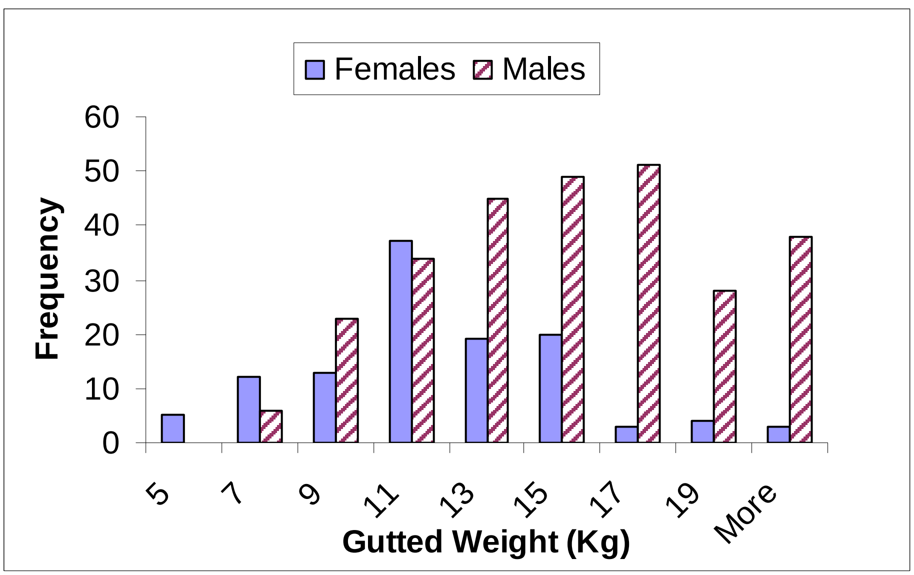


Figure 7. Biomass estimates of octopus (all species) from the Bering Sea Shelf Survey, with 95% confidence intervals shown.

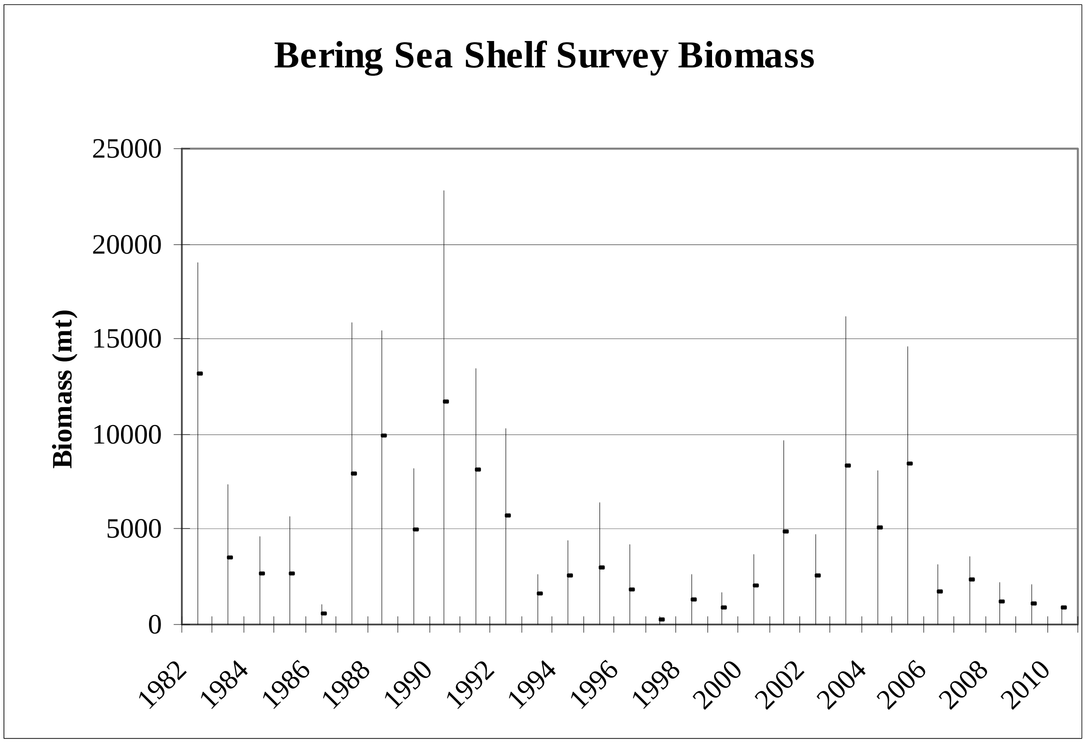
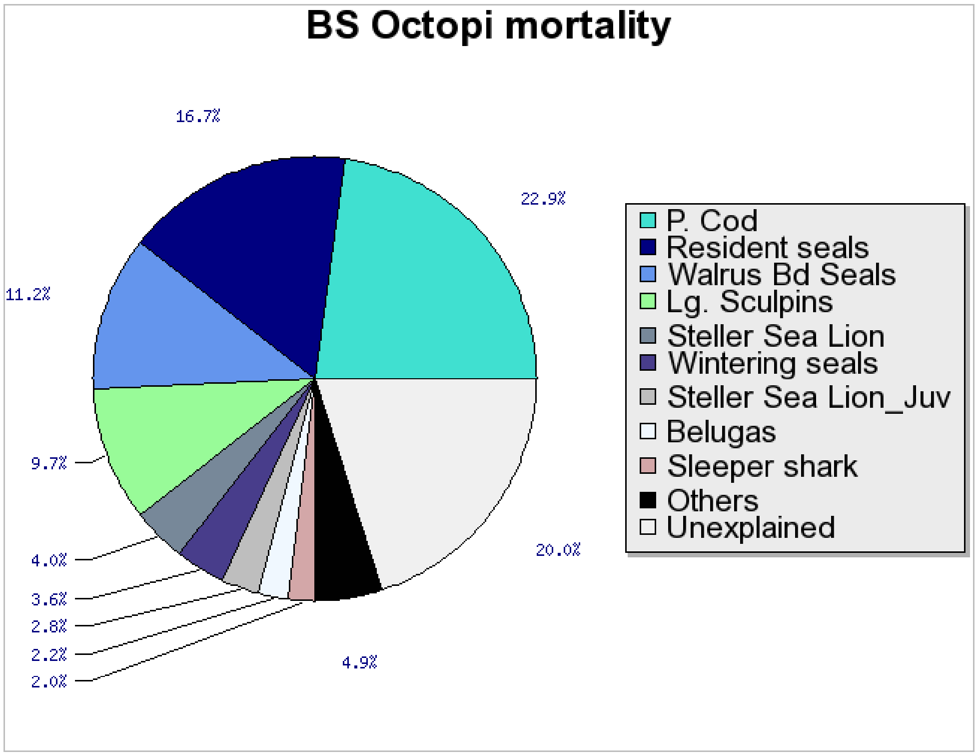


Figure 8 Ecopath model estimates of mortality sources of octopus in the BSAI.



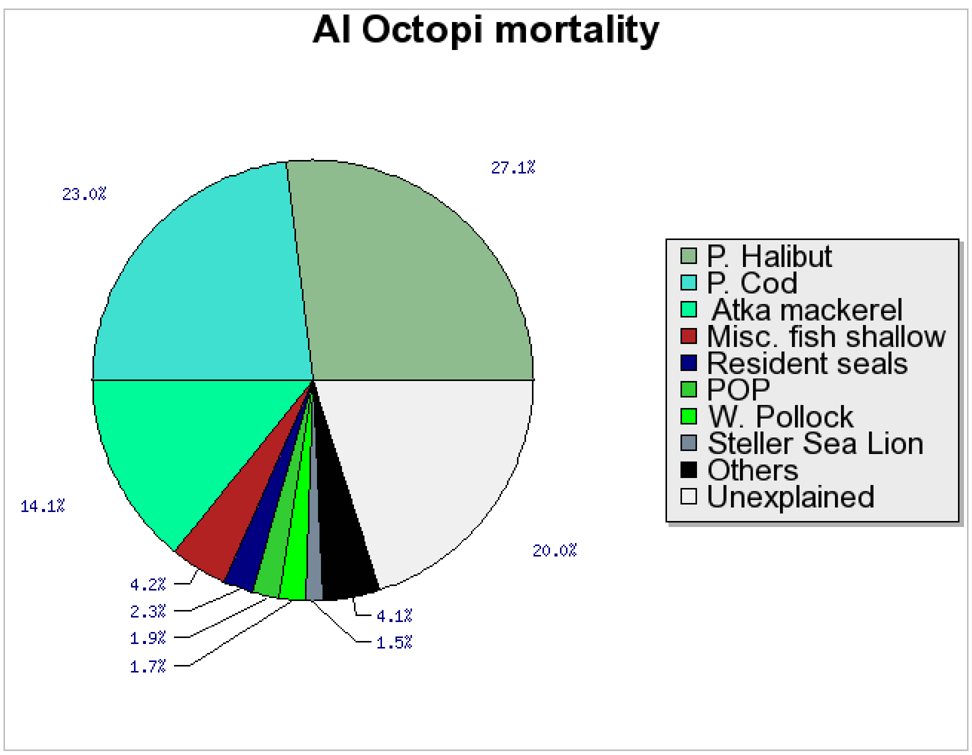
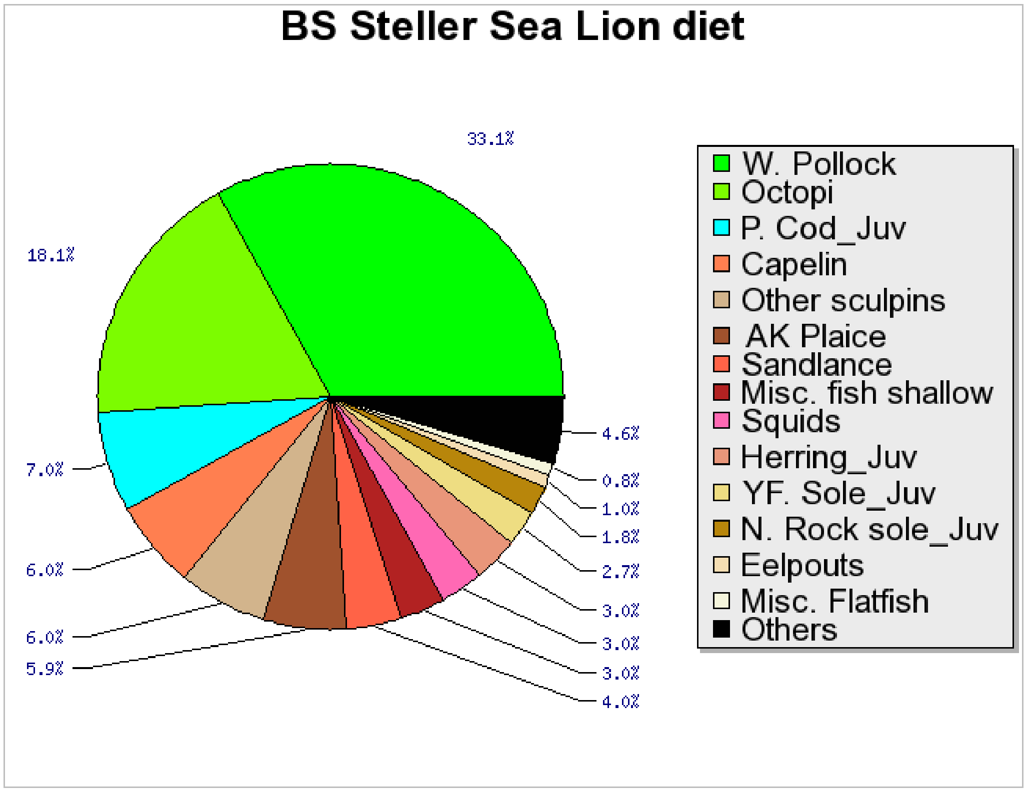
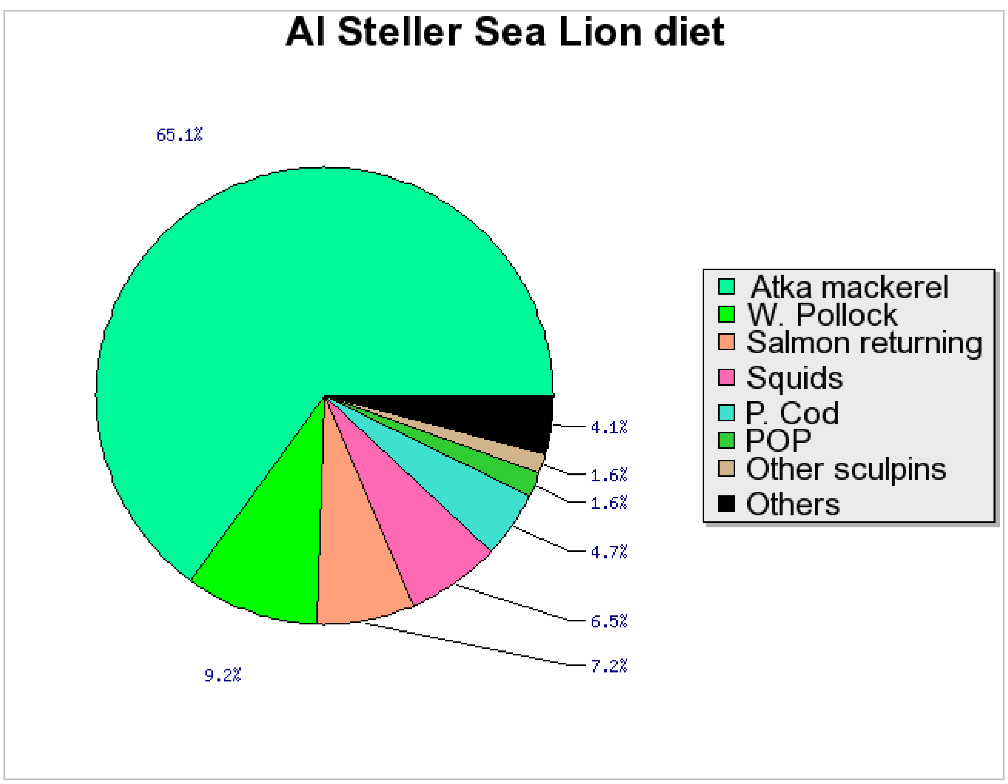


Figure 9 Literature-derived diets of Steller sea lions in the BS and AI.





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