Chapter 19 Octopus Complex

M. Elizabeth Conners and Elaina Jorgensen
Alaska Fisheries Science Center
November 2007

Executive Summary

Through 2007, octopuses have been 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 value of skates and octopus, retention of other species complex members is increasing. This appendix to the other species SAFE chapter was prepared in anticipation that the other species complex will be split into separate components for future management. All octopus species would continue to be grouped into a species assemblage. At least seven species of octopus are found in the BSAI, and the species composition both of the natural community and the commercial harvest is unknown at this time. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the BSAI; the highest catch rates are from Pacific cod fisheries in the three statistical areas around Unimak Pass.

The current data are not sufficient for a model-based assessment. The Bering Sea and Aleutian Island trawl surveys produce estimates of biomass for octopus, but these estimates are highly variable and may not reflect the same species and sizes of octopus caught by industry. As an example of how this species complex might be managed under catch quotas, we have estimated catch limits from available data under both Tier 5 and Tier 6. If the most recent 10-year average of bottom trawl survey biomass (BS shelf + BS slope + AI) of 7,251 tons and a conservative estimate of M=0.53 are used, Tier 5 OFL and ABC levels would be 3,843 and 2,882 tons, respectively. There are no historical catch records for octopus. Estimates of incidental catch rate (including discards) are available for 1997-2006; the average incidental catch rate over this period was 324 mt and the maximum incidental catch was 516 mt in 2004. We feel that a standard Tier 6 approach based on the average incidental catch would result 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**.** In 2006, we proposed an alternative approach under Tier 6 that treats the existing data as a “probable safe catch rate”, and uses the maximum incidental catch to set the ABC. This approach would result in an ABC of 516 mt and an OFL of 688 mt. In 2005 and 2006, the BSAI plan team elected to use the Tier 5 approach to contribute to overall catch limits for the other species assemblage.

	2006			**2007**	
Method	**ABC**	**OFL**		**ABC**	**OFL**
Tier 5	2882	3843		1540	2053
Tier 6 (avg)	242	323		243	324
Tier 6 (max)	516	688		516	688

Because of the lack of information at this time, we recommend that directed fishing for octopus be discouraged in federal waters of the BSAI and that incidental catch be limited by conservative catch limits. As better catch accounting and biological data for these species are collected, possible future assessment methods can be investigated.

Summary of Major Changes

There have been only minor changes from the 2006 octopus SAFE. The most important new information comes from a cooperative research project in which an AFSC scientist (Jorgensen) visited processing plants in Dutch Harbor and Kodiak in October 2006 and February-March 2007. Species identification of all octopus observed in plant deliveries was confirmed as giant Pacific octopus (*E. dofleini*). A section has been added under "data" describing results of this project. The observer program special project that records sex and individual weight of octopus continued through 2007 and has been extended through 2008. In 2007, the observed sex ratios were different between octopus observed on vessels and those in plant deliveries. As data accumulate for this project, changes in sex ratio by gear and season are beginning to be apparent. The section describing this data source has been revised.

The table of trawl survey biomass estimates and the Tier 5 calculations based on these estimates have been updated to include the summer 2007 Bering Sea Shelf Survey. The estimated biomass from the 2007 shelf survey was 2,192 tons; this estimate is slightly higher than 2006 but substantially lower than in 2003-2005. The Bering Sea Slope and Aleutian Island Surveys were not conducted in 2007.

The table of incidental catch rates has been updated to include estimated catch for the entirety of 2006 and the first part of 2007. The estimated total catch for 2006 was 334 tons, similar to the catch in 2005. The estimated catch through October 5, 2007 was only 139 tons. Revised Tier 6 catch numbers have been calculated based on catch data through 2006. Other data and report sections are largely unchanged from the 2006 SAFE.

Responses to SSC Comments

The SSC made comments on the original draft of this SAFE in Sept 2005. Responses to these comments are included below. There have been no further SSC comments for BSAI octopus. The option of using a maximum of incidental catch rates for Tier 6 management was introduced in 2006 based on SSC comments on the GOA octopus SAFE in February 2006; this option is presented under Projections and Harvest Alternatives.

<u>Spatial distribution of octopus species</u> – Unfortunately, there are not enough data available to make any definitive statements about spatial distributions or possible spatial separation of octopus species. *Graneledone boreopacifica* and the *Benthoctopus* species may be more common in the deeper waters of the slope than on the shelf, but *Benthoctopus* species and the new *Octopus* species have been collected near the "horseshoe" at Unimak Pass, where they may overlap with shelf species. We hope that continued improvement of species identification during surveys will help to resolve this issue. However, survey data only reflect summer spatial distributions, and directed sampling would be necessary to confirm any spatial segregation during other seasons.

<u>Tier 5 management approach for octopus</u> – Discussion of relevant literature has been added to this draft. In other countries, octopus and squid are managed by a variety of methods that include the equivalent of Tier 5 management, where mortality is estimated for the portion of the stock that is vulnerable to fishing, prior to spawning. Terminal spawners are also managed by preserving a minimum reproductive capacity, although this approach is not one of the options in the current Tier system. In Japan, fishing on the *E. dofleini* stock is restricted seasonally based on

a known seasonal spawning pattern. This document has been revised to discuss several different possibilities for management of octopus, including Tier 6, Tier 5, and MRAs. The authors feel that catch history data from the period where there was no market and no directed effort for octopus do not meet the intent of Tier 6 management. We concur that Tier 5 management based on estimates of biomass of the species and size groups most vulnerable to harvest would be more suitable. It is not feasible to estimate biomass of larger size groups based on trawl survey data because of gear selectivity and possible seasonal movements. The idea that trawl survey biomass represents a low estimate is based on an assumption that the true selectivity of trawl gear for octopus is significantly smaller than the value of one used in compiling biomass estimates. We concur that a great deal more information is needed in order to know how summer trawl survey biomass relates to fall and winter biomass available to the fishery.

<u>Survey methodology for octopus</u> – Fishery-independent methods for assessing biomass of vulnerable size groups 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. These methods would, however, require either extensive industry cooperation or funding for directed field research.

<u>Octopus as prey for Steller Sea Lions</u> – Discussion of octopus as prey of Steller sea lions and other pinnipeds has been added to the ecosystem considerations section of this report. Ecosystem models indicate that octopus are an important component of Steller sea lion diets in the Bering Sea, but are not significant components in the GOA and Aleutians. Octopus are not important in the diet of northern fur seals, but make up an important item in diets of resident seals (primarily harbor seal, *Phoca vitulina richardsi*) in both the Bering Sea and Aleutians.

Introduction

Description and General Distribution

Octopuses are marine molluscs 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 and are by far 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 (Table 19.1) found in the Bering Sea, including one potentially new species. Members of these seven species come from six genera and can be found 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 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 19.1). The highest diversity is along the shelf break region where three to four species of octopus can be collected in approximately the same area. The highest diversity is found 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. Octopuses have been observed throughout the western GOA and Aleutian Island chain.

There are not enough data available to make any definitive statements about spatial distributions or possible spatial separation of octopus species. *Graneledone boreopacifica* and the *Benthoctopus* species may be more common in the deeper waters of the slope than on the shelf, but *Benthoctopus* species and the new *Octopus* species have been collected near the "horseshoe" at Unimak Pass, where they may overlap with shelf species. Efforts are underway to improve octopus species identification during surveys to better assess species distributions. 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.

Life History and Stock Structure

In general, octopus life spans are either 1-2 years or 3-5 years. Specific life histories for six of the seven species in the Bering Sea are not known. *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 will be inferred from what is known about other members of the genus.

Enteroctopus dofleini is sexually mature after approximately three years. In Japan, females weigh between 10 – 15 kg at maturity while males are 7 – 17 kg (Kanamaru and Yamashita, 1967). *E. dofleini* in the Bering Sea may mature at larger sizes given the more productive waters in the Bering Sea. *Enteroctopus dofleini* in Japan move to deeper waters to mate during July –

October and move to shallower waters to spawn during October – January. There is a two-month lag time between mating and spawning. This time may be necessary for the females to consume extra food to last the seven months required for hatching of the eggs, during which time the female guards and cleans the eggs but does not feed. *Enteroctopus dofleini* is a terminal spawner, females die after the eggs hatch while males die shortly after mating. While females may have 60,000 - 100,000 eggs in their ovaries only an average of 50,000 eggs are laid (Kanamaru, 1964). 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 is also estimated to be high (Hartwick, 1983). Since the highest mortality occurs during the larval stage it stands to reason that ocean conditions would 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.

Octopus n. sp. is a small-sized species, maximum total length < 15 cm. Although little is known about this species, a start at estimating its life history could come from what we know of *O. rubescens*, another small species of *Octopus* found in the North Pacific. *Octopus rubescens* lives 1 – 2 years and is also a terminal spawner, likely maturing after 1 year. *Octopus rubescens* has a planktonic stage while the new species of *Octopus* does not. Females of the new species have approximately 80 – 120 eggs. The eggs of *Octopus* n. sp. are likely much larger as benthic larvae are often bigger; they could take up to six months or more to hatch. In the most recent groundfish survey of the East Bering Sea Slope this was the most abundant octopus collected, multiple specimens were collected in over 50% of the tows.

Benthoctopus leioderma is a medium-sized species, maximum total length ~ 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. They are thought to spawn under rock ledges and crevices (Voight and Grehan, 2000). The hatchlings are benthic.

Benthoctopus oregonensis is larger than *B. leioderma*, maximum total length ~ 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. It could have a life span similar to *E. dofleini*. 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. 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, it 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. 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 *Graneledone 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 mixed *with B. leioderma*, *O. n.* sp., and *O. reubescens.*

Management Units

Through 2007, octopuses have been managed as part of the BSAI "other species" complex, with catch reported only in the aggregate with sharks, skates, and sculpins (Table 19.2). In the BSAI, catch of other species has been limited by a Total Allowable Catch (TAC) which is based on an Allowable Biological Catch (ABC) estimated by summing estimates for several of the groups (Gaichas 2004, 2005). Historically, catches of other species were well below TAC 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 has remained on bycatch-only status with 20% retention through 2007 and 2006, since the expected incidental catch for this category is close to the TAC.

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. In anticipation of this change, we prepared this appendix to the other species chapter to provide insight to managers on the implications of this change. All octopuses would continue to be grouped into a species assemblage, as octopus are difficult to identify to species. Octopus are recorded by fisheries observers as either "octopus unidentified" or "pelagic octopus unidentified", and routine species identification of octopus by observers is not anticipated (although special projects may be pursued). *E. dofleini* is the key species in the assemblage and is the best known. It is important to note, however, that the seven species in the assemblage 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 species.

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 is registered for octopus in 2005.

ADF&G is currently 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 recently, retention of octopus when caught has been minor, because of a lack of commercial market. Retained octopus were used and sold primarily for bait. In recent years, however, a commercial market for human consumption of octopus has developed in Alaska, with ex-vessel prices in the range of $0.90/lb (J. Nordeen, Harbor Crown Seafoods, personal communication). Reported harvest from incidental catch in state fisheries in the BSAI ranged from 18-69 mt between 1996 and 2002, but more than doubled to166 mt in 2003 (ADF&G 2004). From 1997 through 2003, percent retention of octopus from observed hauls in federal waters averaged 22-31% across all gears, with highest retention (48-59%) in pot gear, presumably for bait. In 2005 and 2006, however, reported retention was 70% from pot gear and 36-41% from bottom trawls. Reported retention of octopus in longline fisheries is small, probably due to processing limitations.

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 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.

For 1992-2002, total incidental catch of octopus in federal waters, was estimated based on “blend” data (Gaichas, 2004) This catch was generally between 100 and 400 mt, although an unusually high catch of 1,017 mt is estimated for 1995 (Table 19.3). Since 2003, catch has been estimated more accurately by the NMFS Alaska Region catch accounting system. In 2004, the estimated catch of octopus was 516 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 334 tons, respectively. Catch through October 5, 2007 was 139 tons. The majority of both federal and state incidental catch of octopus comes from Pacific cod fisheries, primarily pot fisheries (Table 19.3, 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).

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 19.3) suggest substantial year-to-year variation in abundance, which would result in large annual fluctuations in harvest. This large interannaul variability is consistent with anecdotal reports (Paust 1989) 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. dofelini* 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

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 recorded as *Octopus* sp. and 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 from the 2004 surveys is shown in Table 19.4. These catches are our only source of species-specific information within the species group. In the most recent Bering Sea slope survey, the species most commonly encountered was a newly described species of *Octopus*. In recent shelf surveys, the dominant species is *E. dolfleni*. The size distribution by weight of individual octopus collected by the bottom trawl surveys from 1987 through 2004 is shown in Figure 19.2. Survey-caught octopus ranged in weight from less than 5 g up to 25 Kg; 50% of all individuals were <0.5 Kg. Larger octopus may be under-represented in trawl data because of increased ability to avoid the trawl.

Survey catches of octopus in the Bering Sea are concentrated on the outer shelf and slope, with frequent catches near the “horseshoe” at Unimak Pass. Survey catches occur throughout the Aleutian Island chain. The majority of survey-caught octopuses are caught at depths greater than 60 fathoms (110 meters), with roughly a third of all survey-caught octopus 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, *Octopus* n. sp. peaks at 450 m, *B. leioderma* peaks at 450 and 650 m, and *Graneledone boreopacifica* peaks at 1050 m. At depths less than 200 m, *E. dofelini* is the most common species.

Biomass estimates for the octopus species complex based on bottom trawl surveys are shown in Table 19.5. 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 t, approximately equal to the estimated BS commercial catch (Table 19.2). In general, survey biomass was low in 1993-1999; high in 1990-1992 and in 2003-2005, and low again in 2006 and 2007.

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 19.1 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 19.3); 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, especially the newly described species.

There are some areas of the BSAI which are consistently fished for Pacific cod every year. Incidental catch rates from observed hauls in these areas may be a more consistent time-series index of octopus abundance than trawl survey biomass. Figure 19.4 shows time series of octopus catch rates from pot gear in federal stat area 519 (Unimak Pass), longline gear in area 521 (outer shelf near the Pribilofs) and bottom trawl gear in areas 517 and 509 (north of Unimak Island). All of these series indicate high abundances in the early 1990s and in 2003-2004, with lower catch rates 1993-2002. The trawl series is the most variable, and may be affected by year-to-year variation in seasonal effort for different targets (pollock, cod, flatfish). As seen in these figures, overall incidental catch rates (averaged over stat area and year) were on the order of 100-400 lbs/100pots for pot gear, 0.1-3.0 lbs/1000 hooks for longline gear, and 1-8 lbs/hour towed for trawl gear. Time series for longline and trawl CPUE in the eastern AI (stat area 541) show similar time trends with increasing catch rates in recent years.

Observer Program Special Project Data

Beginning in January 2006, some fishery observers are also 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 from January 2006 through July 2007 have been entered and summarized, further data collection will continue through 2008.

The initial data reflect the size selectivity in gear as seen in Figure 19.3. 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 an average gutted weights of 13.3 and 13.4 kg. 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).

In 2006, approximately 35% of the observed octopus from vessels were discarded, 23% retained for market, and the remainder retained for bait or for consumption onboard the vessel. In 2007, approximately 35% of the vessel-observed octopus were retained for market, 61% were discarded, and the remainder retained for bait for onboard consumption. In both years, the majority of octopus retained for market were on pot boats, although trawlers also had some market retention.

Cooperative Research Program Project

The most important new information since the 2006 stock assessment comes from a cooperative research project in which an AFSC scientist (E. Jorgensen) visited processing plants 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 all octopus observed in plant deliveries was confirmed as giant Pacific octopus (*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. Data were collected for estimating gutted weight to round weight ratios and weight to mantle length relationships.

In October 8-12 006, 81% of the animals observed in Dutch Harbor were male and only 19% female. In February 17-20, 2007, 50% of the observed animals were male and 44% female, with two animals (6%) unsexed. During each period, males and females had similar minimum, maximum, and average weights (Figure 19.6). Animals observed in February, however, were substantially lower in both average weight (11.1 kg vs. 14.1 kg) and maximum weight than those observed in October.

Based on the results of this project and plant data form the observer special project, there appears to be a temporal trend in the abundance, size, and sex ratio of *E. dofleini* delivered to Harbor Crown Seafoods. In each of the sampled months, catches were dominated by male octopus. The highest numbers of animals were delivered in January, which also saw the least skewed sex ratio of all months. The largest animals were collected in October, tipping the scales at 102 lbs. These data may indicate that the largest animals are feeding more actively in the latter months of the year, that there is a differential mortality of the largest animals in early winter, or that the largest animals are being diminished in number by fishing. With the difference in sex ratio between pots and trawl gear in the observer data, it is difficult to tell if the relative absence of females in plant deliveries represents a true skewness in the underlying sex ratio of the population. The skewed sex ratio may represent a difference in mobility and feeding behavior of males and females or a physical separation of males and females. If the skewed sex ratio were a true reflection of the population, then it would be imperative to release female octopus. This would be especially important for the large females, which produce more eggs than smaller females.

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. A new procedure for determining catch limits under Tier 6 has also been suggested.

Parameters Estimated Independently – Biomass

Estimates of octopus biomass based on the annual Bering Sea trawl surveys (Table 19.5) 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, but the survey does not at this time provide species-specific information that could be used in a stock assessment model.

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 1989). 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 19.5 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 likely 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 both the size range of octopus caught and the depth distribution of octopus catch. The average weight for individual octopus in survey catches is less than 2Kg; 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. Octopus 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). If the species composition of commercial harvest can be verified, then it may be appropriate to use species-specific and/or depth-based biomass estimates.

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) use 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 get an estimated M = 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 a 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, will be 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.

We do not recommend a directed fishery for octopus in federal waters at this time, because data are insufficient for adequate management. It is not clear that it is necessary, however, to explicitly prohibit directed fishing. The majority of octopus incidental catch in the BSAI comes from the cod pot fisheries (both state and federal). It is not certain that directed fishing for octopus using cod gear would be cost-effective. Commercial octopus fisheries in Japan are conducted as inshore, small-boat fisheries, using large numbers of smaller, unbaited "habitat" pots (Mottett 1974, Osako and Murata 1983). 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 cod pot fisheries.

If octopus are split from the "other species" category, it will be necessary to set annual catch limits for the octopus complex. In 2006 we suggested an approach for management of octopus under Tier 6. Examination of trends in both survey biomass data and selected fishery CPUE **data suggest that fishing patterns in 1997-2004 did not adversely affect octopus;** the trend in survey biomass during this period is strongly increasing (Figure 19.7). **We propose that the estimated incidental catch data over this period be considered a "probable safe" level of fishing and that the <u>maximum</u> incidental catch over this period be used to set the ABC for the octopus complex. The OFL would then be set so that this ABC would represent 75% of the OFL. This approach allows continued fishing under historical patterns where octopus was not a target species, but will restrict catch rates for the complex from substantially increasing, (thus achieving the management goal of preventing a rapidly expanding directed octopus fishery).** The higher OFL provides a margin of error so that fisheries that take octopus as bycatch would not be constrained unless catch rates increases well past current levels. **Using this approach, the ABC for octopus would be 516 mt and the OFL would be 688 mt.** This OFL is roughly double the average incidental catch rate.

Catch limits could also be set under Tier 6 using an average of the available estimates of incidental catch. There is no historical catch data for the period specified under the usual application of Tier 6 (1975-1995). The best available data are estimated incidental catch rates from 1997-2002 and catch accounting data from 2003-2007. The average estimated incidental catch rate for 1997-2006 is 324 mt. If this incidental catch rate was treated as the long-term average catch under standard Tier 6 procedure, the OFL would be 324 mt and the ABC would be 243 mt. **We do not recommend the standard application of Tier 6. It is the belief of the authors that this approach is overly conservative, and would unnecessarily constrain fishing, in particular cod pot fishing. An** ABC of 243 tons is almost an order of magnitude lower than the Tier 5 estimate, and would have been reached in all but three of the last 9 years. We feel that this approach is not appropriate 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. The low mortality of octopus caught in pots also suggest that the usual spread between ABC and OFL may be overly conservative for this group.

Finally 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 (1998 – 2007) of survey biomass of 7,449 tons and the conservative M estimate of 0.53 are used, the Tier 5 OFL and ABC would be 3,948 and 2,961 tons, respectively. **Because of serious concerns with both the biomass estimate and the mortality estimate, however, we do not recommend use of a Tier 5 approach for this group at present**. 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. If future management of the octopus complex under Tier 5 is envisioned, then dedicated field 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.

Because of the overall lack of biological data and the large uncertainty in both abundance and mortality estimates, we strongly recommend continued monitoring and catch limits for this complex.

Ecosystem Considerations

Ecosystem Effects on Stock

Little is known about the role of octopus in North Pacific ecosystems. In Japan, *Enteroctopus dofleini* prey upon crustaceans, fish, bivalves, and other octopuses (Mottet 1974). Food habits data and ecosystem modeling of the Bering Sea and AI (Livingston et al. 2003, Aydin et al, In Review) 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 19.8) 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 1990's 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. 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 Aleutians. 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 are not a dominant predator of octopus, however, octopus are important prey in the diet of Stellers in the Bering Sea. According to diet information from Perez (1990), (Figure 19.9) 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 (1989) 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 (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 and ice cover in the Bering Sea is having some effect on octopus, but data are not adequate to evaluate these effects.

Fishery-Specific Effects on the Ecosystem

There is no directed fishery for octopus in federal waters of the BSAI. If cod pot fishing effort were increased in order to target octopus, the primary effect would be on Pacific cod, which would continue to be caught in the gear. Since cod caught in this manner would continue to be regulated by cod TAC and gear apportionment, effects of this catch on the ecosystem would be regulated through the cod assessment process. Increased catch of octopus may locally benefit survival of epibenthos and juvenile snow crab, but decrease prey availability for Steller sea lions, halibut, and Pacific cod. Fishery effects on both octopus and the ecosystem are likely to be extremely local in nature, as fishing effort is likely to be concentrated in accessible nearshore areas. The areas north of Akun, Akutan, and Unimak Islands that are the source of most of the current bycatch of octopus are part of Steller sea lion critical habitat, but are not among areas currently identified as habitat of particular concern (HAPC) or essential fish habitat (EFH). The size and apparent sex selectivity of pot gear definitely has the potential to affect the structure of the octopus stock (especially *E. dofleini*) and its overall fecundity and reproductive capability. Until much more is known about the reproductive biology of octopus, however, this will be difficult to evaluate.

Data Gaps and Research Priorities

The first data gap for management of an octopus species assemblage in the BSAI is separate catch accounting, both of retained and discarded octopus catch. This accounting is currently being implemented by the Alaska Region. It may in the future be desirable to separate octopus into two size categories to separate *E. Dofleini* from the assemblage of smaller species. In this case, separate catch accounting would need to be performed for the different size categories. Dropoff of larger octopus from longlines before hooks are brought aboard is reportedly common, and needs to be treated consistently in catch reporting and accounting. Estimates of the percentage of catch retained, and of octopus retained as a percentage of target catch, are also important for future management of octopus as a bycatch complex. Communication with the State of Alaska regarding directed fisheries in state waters, gear development, and octopus biology are essential.

Identification of octopus to species is difficult even for trained biologists, and we do not expect that either fishing industry employees or observers will be able to accurately determine species on a routine basis. A volume on cephalopod taxonomy in Alaska is in development and is expected to be published within a few years (Jorgensen, in press). 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. One simple addition that could be made to observer data collection would be to collect individual weights of all octopus by sex; the sex of octopus is readily observed by external characters on the third right arm. This information may lead to better understanding of seasonal and sex-specific migration patterns in Alaska.

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. 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 add greatly to 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. Based on recent field studies by AFSC's FIT, an index survey using research pot gear is highly feasible. It may also be feasible to collect valuable data from a well-designed experimental fishery.

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-described species. The most abundant species in shelf surveys is the Giant Pacific octopus *Enteroctopus dofleini***,** but the species composition of octopus harvested by fisheries is unknown. 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. Recent trends in catch per unit effort data are generally increasing but show high year-to-year variation. 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.

Management statistics are summarized below for three management options under the existing tier system. The authors recommended option is Tier 6 (avg). Because of high uncertainty in estimates of both B and M, we do not recommend Tier 5 at this time. We strongly feel that appropriate management of octopus in the BSAI will require development of management and modeling methods different from those currently used for groundfish.

Tier	**B**	**M**	**F_{OFL}**	**Max F_{ABC}**	**Recc F_{ABC}**	**OFL**	**Max ABC**	**Recc ABC**
Tier 5	7449	0.53	N/A	N/A	N/A	2053	1540	1540
Tier 6 (avg)			N/A	N/A	N/A	324	243	243
Tier 6 (max)			N/A	N/A	N/A	688	516	516

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. In review. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.

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.

Conners, M. E., P. Munro, and S. Neidetcher (2004). Pacific cod pot studies 2002-2003. AFSC Processed Report 2004-04. June 2004

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.

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.

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.

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.

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.

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.

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.

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, 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.

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.

Walters, G. E. Report to the fishing industry on the results of the 2004 Eastern Bering Sea Groundfish Survey. AFSC Process Report 2005-03. Feb 2005.

Wilson, J.R. and A.H. Gorham (1982). Alaska underutilized species Volume II: Octopus. Alaska Sea Grant Report 82-3. May 1982. 64 p.

Table 19.1. 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	BS deeper than 250 m	unknown	< 500 g
	Benthoctopus oregonensis	none	BS shelf break	unknown	> 2 kg
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	*Octopus*				
	***Octopus* n. sp. (Jorgensen)**	stubby octopus	BS shelf break, 200 - 1200 m	unknown	75 - 150 g

Table 19.2 History of federally-managed other species complex (skates, sharks, octopus, and sculpins) and incidental catch of octopus (all species). Estimates of octopus catch from federal waters for 1991-2002 are extrapolated from observed hauls (Fritz 1996, Fritz 1997, Gaiches 2004). Incidental catch for 2003-2006 were provided by NMFS Alaska Region. Incidental catch from state fisheries are from ADF&G Shellfish Fisheries Annual Management Reports (Bowers et al 2004, Granath and Bon 2004).

	Other Species Complex				Estimated Octopus Bycatch (mt)						Directed
					Federal Waters			State Fisheries			Harvest
Year	Catch	TAC	ABC	OFL	BS	AI	BSAI	BS	AI	BSAI	ADF&G
1988											< 8
1989											< 8
1990	20,808										< 8
1991	17,199	15,000	28,700								< 8
1992	33,075	20,000	27,200	27,200	495	183	678				< 8
1993	23,851	22,610			134	50	185				< 8
1994	24,555	26,390	27,500	141,000	121	18	139				< 8
1995	22,213	20,000	26,600	136,000	977	39	1,017	8		8	8
1996	21,440	20,125	25,600	137,000	178	145	323	12	28	41	
1997	25,176	25,800	25,800	133,900	210	39	248	6	33	39	
1998	25,531	25,800	25,800	134,000	145	44	190	4	13	18	
1999	20,562	32,860	32,860	129,000	125	202	326	3	52	55	
2000	26,108	31,360	31,360	71,500	356	63	418	18	10	28	
2001	27,178	26,500	33,600	69,000	186	41	227	23	6	29	
2002	28,619	30,825	39,100	78,900	351	24	374	25	44	69	
2003	28,703	32,309	43,300	78,900	249	19	268	56	110	166	
2004	27,266	27,205	46,810	81,150	496	20	516				85
2005	29,415	29,000	53,860	87,920	322	16	338				
2006	25,195	29,000	58,882	89,404	284	50	334				

Table 19.3 Estimated catch (mt) of all octopus species combined by target fishery, gear, and area. 1997-2002 estimated from blend data. 2003-2007 data from AK region catch accounting, as provided on October 5, 2007. *Note that 2007 data includes only part of the year, January - September.

Target Fishery	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007***
Atka mackerel	1	3	0	1	1	2	1	6	0	2	0
Pacific cod	160	168	310	359	211	334	216	266	311	315	126
Flatfish	86	13	14	57	9	21	31	43	17	5	6
Pollock	1	5	0	1	5	8	9	3	1	2	3
Rockfish	0	0	0	0	0	1	1	1	0	0	3
Sablefish	0	0	1	0	1	8	6	0	0	0	0
Grand Total	248	190	326	418	227	374	268	516	338	334	139

Table 19.4 Species Composition of octopus from AFSC Bering Sea and Aleutian Islands bottom trawl surveys in 2004.

Species	Number	Weight (Kg)	Pct by Number	Pct by Weight
Octopodidae (unidentified)	67	32.5	6.5%	2.9%
Octopus dofleini	409	892	39.7%	79.2%
Benthoctopus leioderma	222	89.9	21.5%	8.0%
Opisthoteuthis californiana	47	49.7	4.6%	4.4%
Graneledone boreopacifica	44	41.8	4.3%	3.7%
Octopus sp. 1 (Jorgensen)	232	20.0	22.5%	1.8%
Japatella diaphana	7	0.92	0.7%	0.1%
Grand Total	1028	1127		

Table 19.5 Biomass estimates for octopus (all species) from AFSC bottom trawl surveys.

Year	EBS Shelf Survey Biomass	EBS Slope Survey Biomass	AI Survey Biomass	Total BSAI
1975	6,129			
1976				
1977				
1978				
1979	30,815	729		
1980			757	
1981		234		
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			
Average All	5,456	554	1,539	7,549
Avg last 10	3,874	1,468	2,107	7,449
Most Recent	2,192	1,957	3,060	7,208
stdev	3,593	757	1,198	
cv	0.66	0.12	0.82	
OFL 10 yr	2,053			3,948
ABC 10 yr	1,540			2,961

Figure 19.1. Distribution of octopus (all species) in the BSAI, based on octopus occurring in observed hauls during the period 1990-1996.

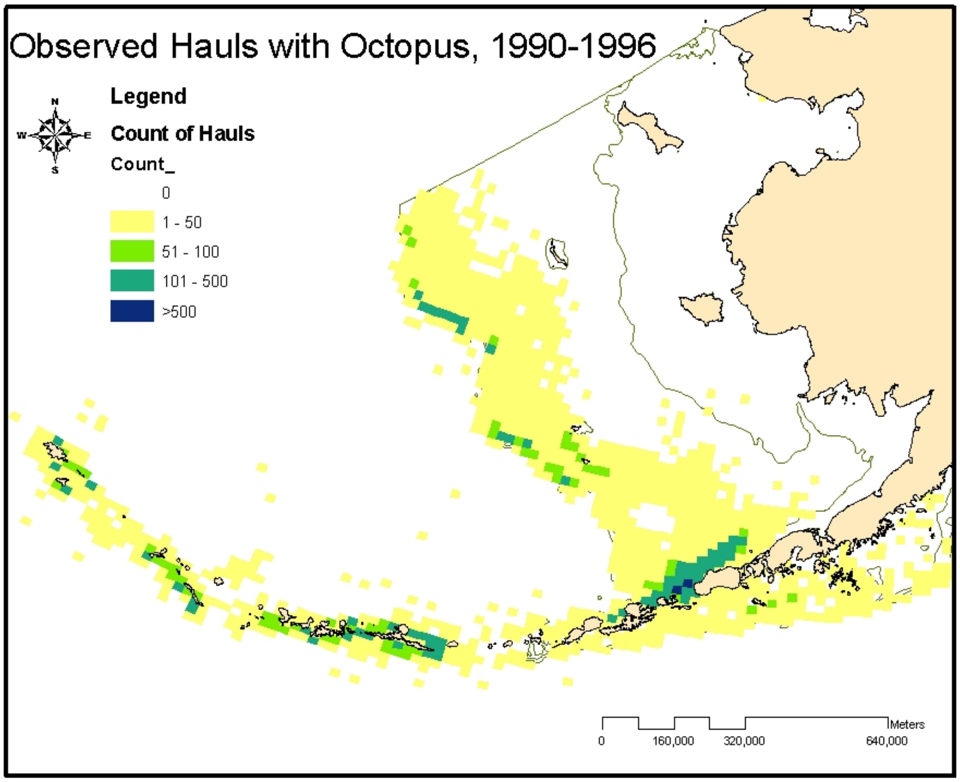


Figure 19.2 Size frequency of individual octopus (all species) from AFSC bottom trawl surveys in the Bering Sea and Aleutian Islands 1987 - 2004.

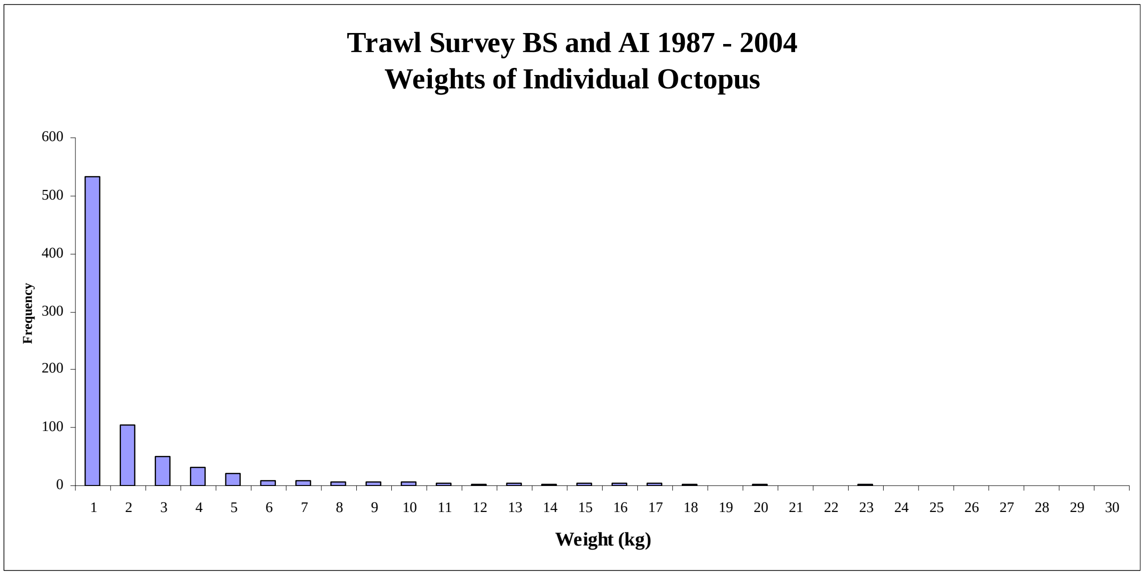


Figure 19.3 Size frequency of individual octopus (all species) from observed commercial hauls by gear type, 1987 – 2005: a)bottom trawl, b) longline, c) pots.

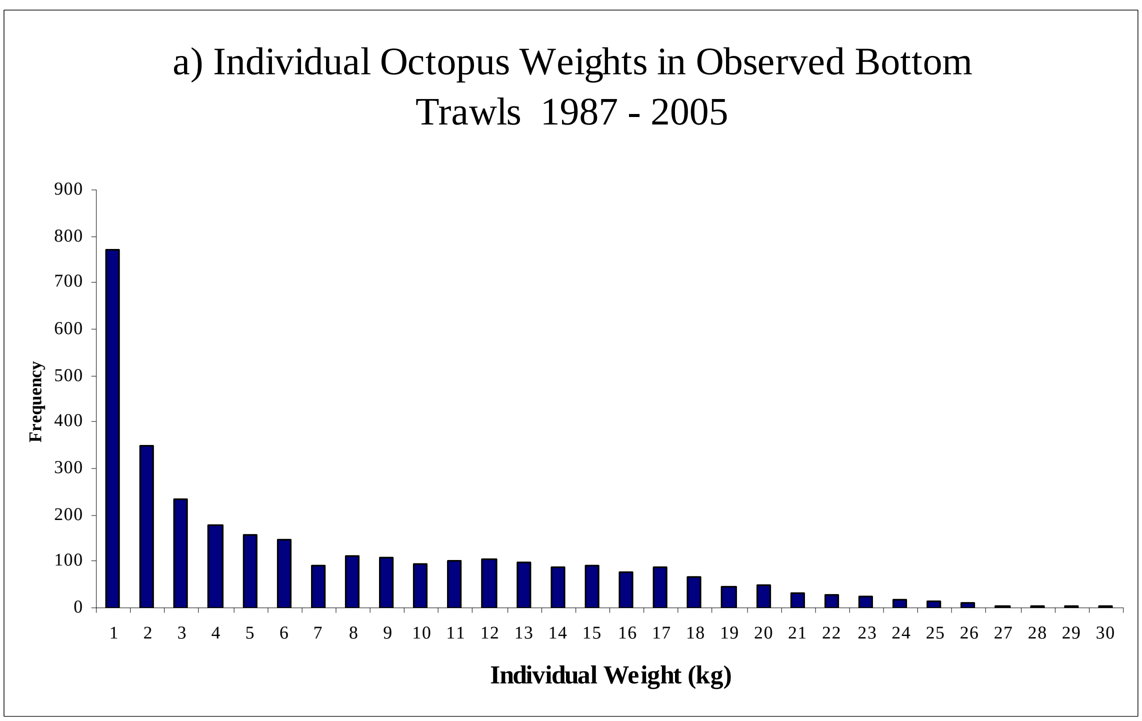
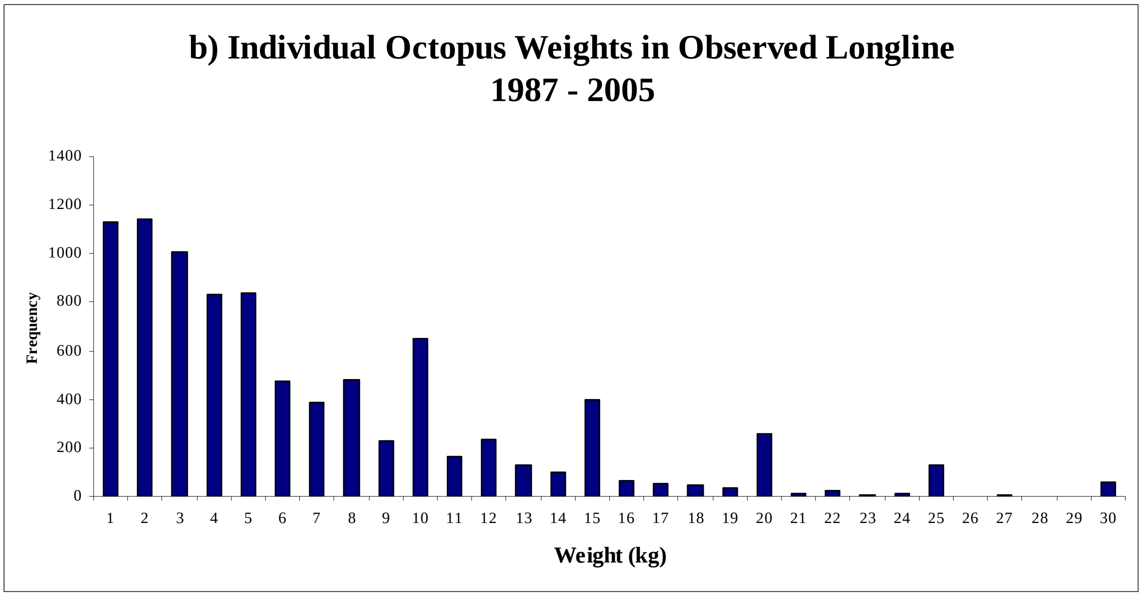


Figure 19.3 Continued.



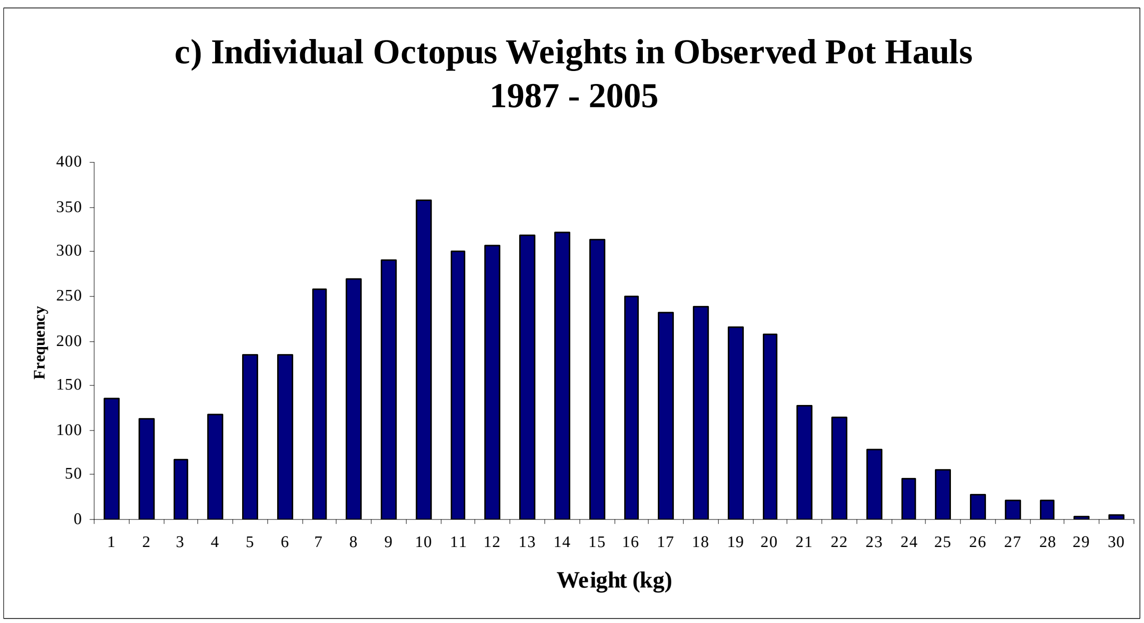
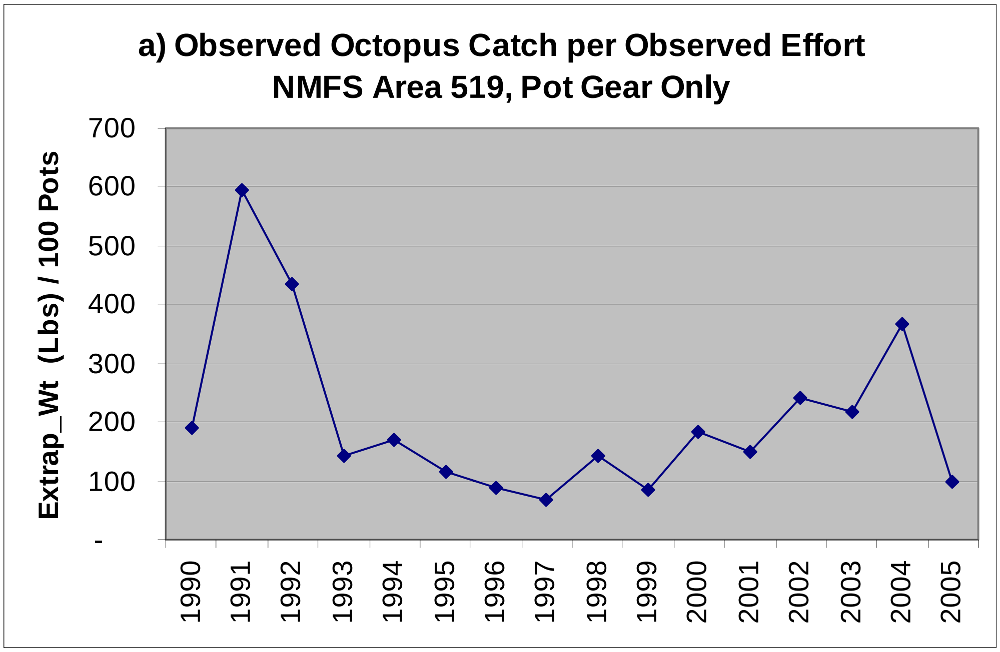
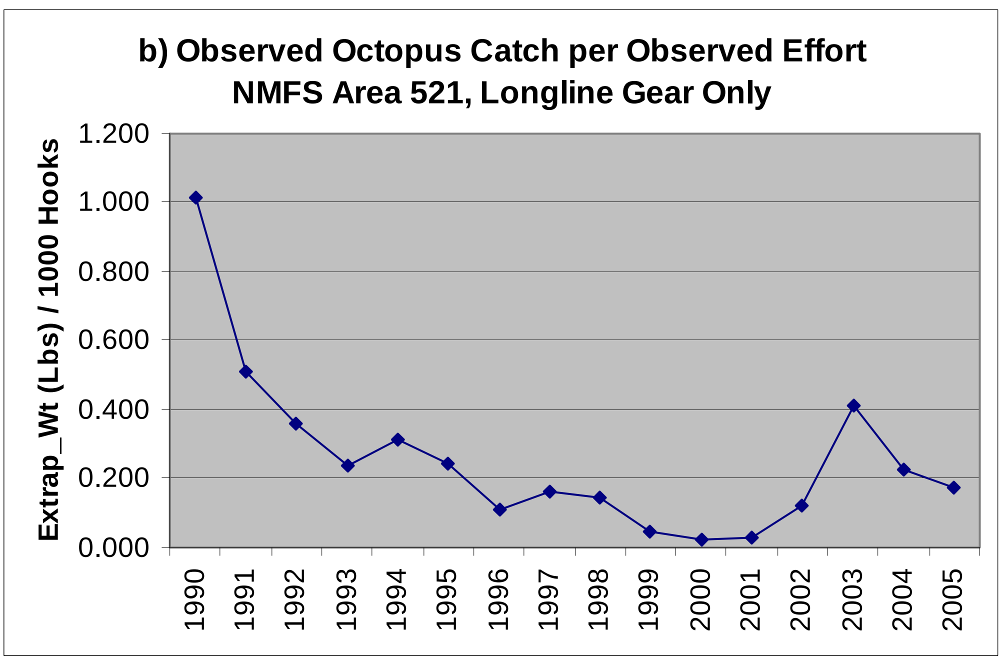
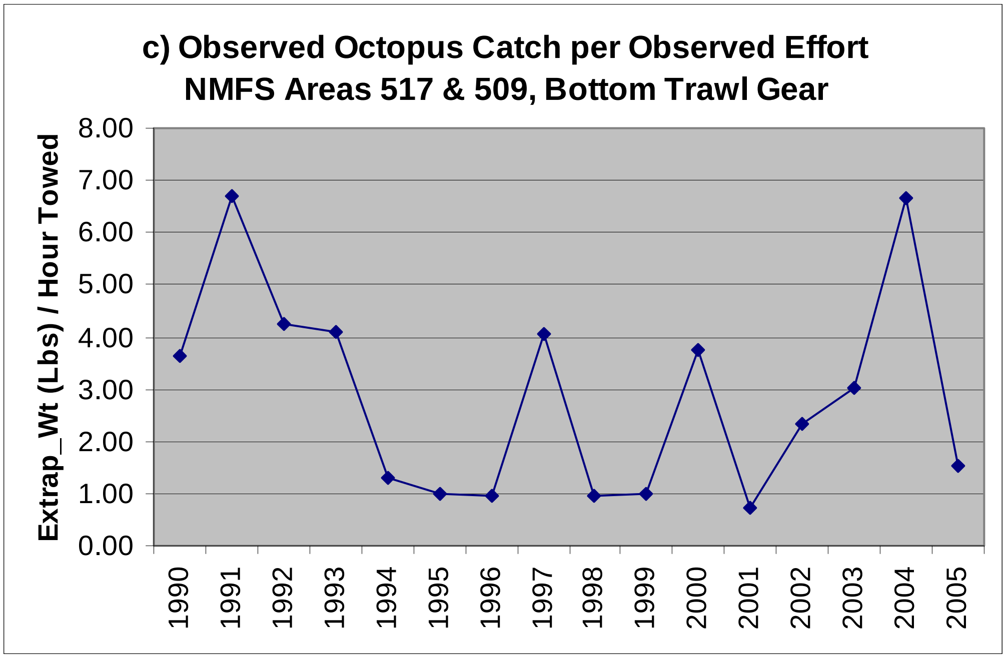


Figure 19.4. Time series of average octopus catch rates for observed hauls in selected federal statistical areas: a) pot gear in area 519, b) longline gear in area 521, c) bottom trawl gear in areas 517 and 509. CPUE units are specific to gear type and represent annual averages over all observed hauls in the statistical reporting area.






c) Observed Octopus Catch per Observed Effort
NMFS Areas 517 & 509, Bottom Trawl Gear
Extrap_Wt (Lbs) / Hour Towed
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

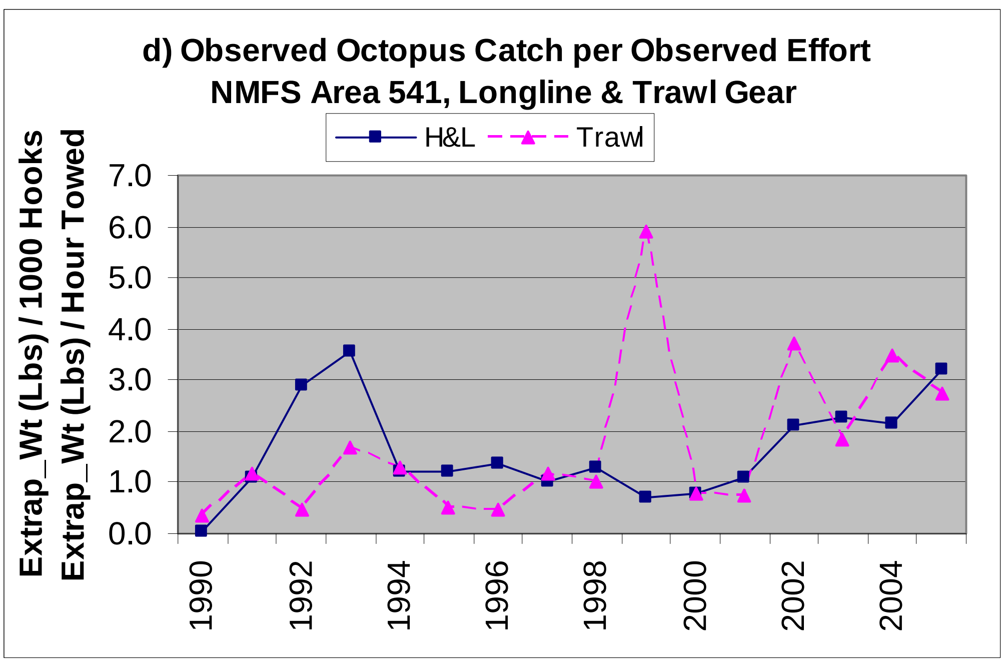

d) Observed Octopus Catch per Observed Effort
NMFS Area 541, Longline & Trawl Gear
H&L
Trawl
Extrap_Wt (Lbs) / 1000 Hooks
Extrap_Wt (Lbs) / Hour Towed
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990
1992
1994
1996
1998
2000
2002
2004

Figure 19.5. Size distribution (Kg) of octopus sampled by observers at BSAI processing plant in winter 2006.

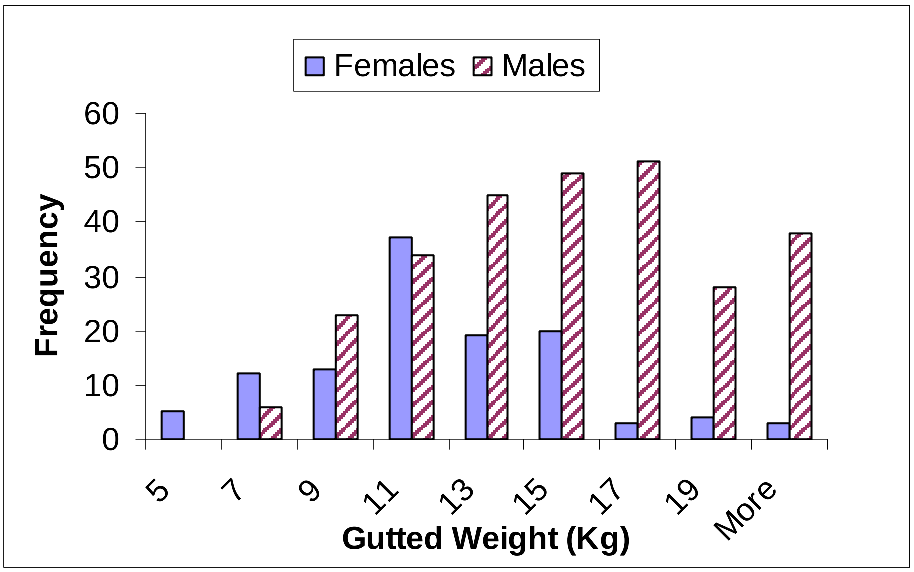
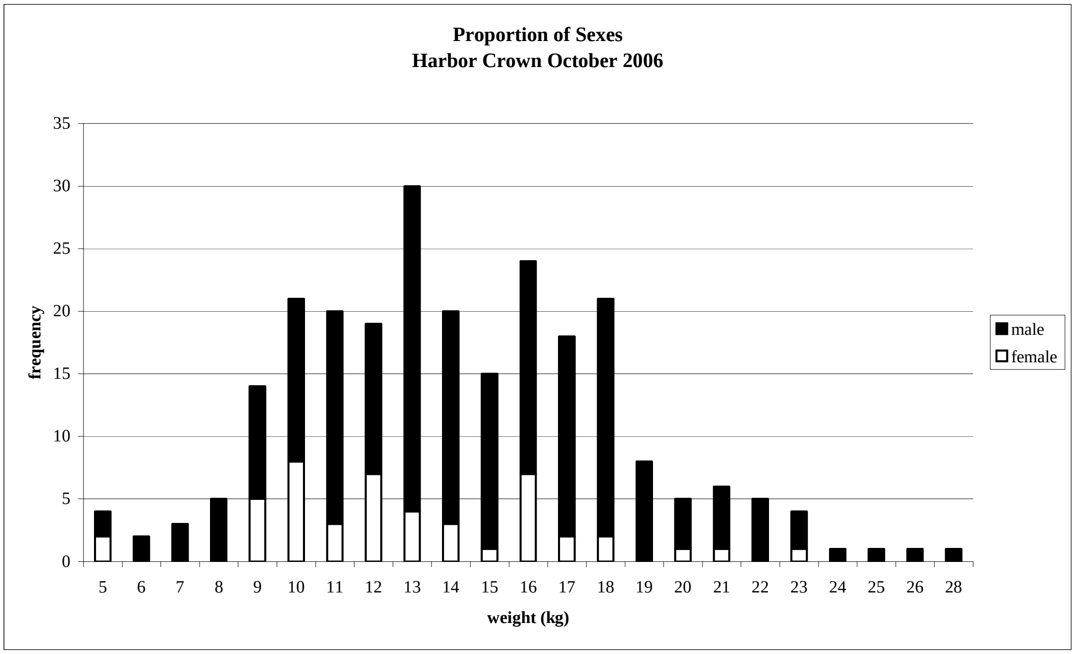


Figure 19.6. Size distribution (gutted weight) by sex of octopus examined at Harbor Crown Seafoods during the Cooperative Research Program project: a) October 8-12 2006; b) February 17-20, 2007.



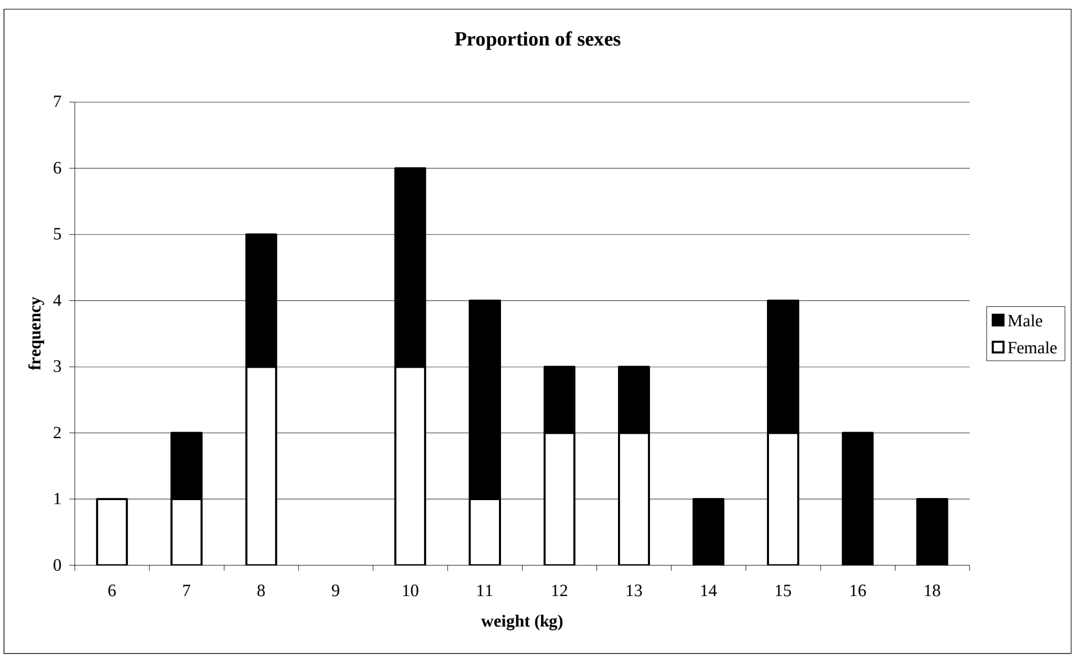


Figure 19.7. Recent trend in biomass estimates of octopus from the Bering Sea Shelf Survey.

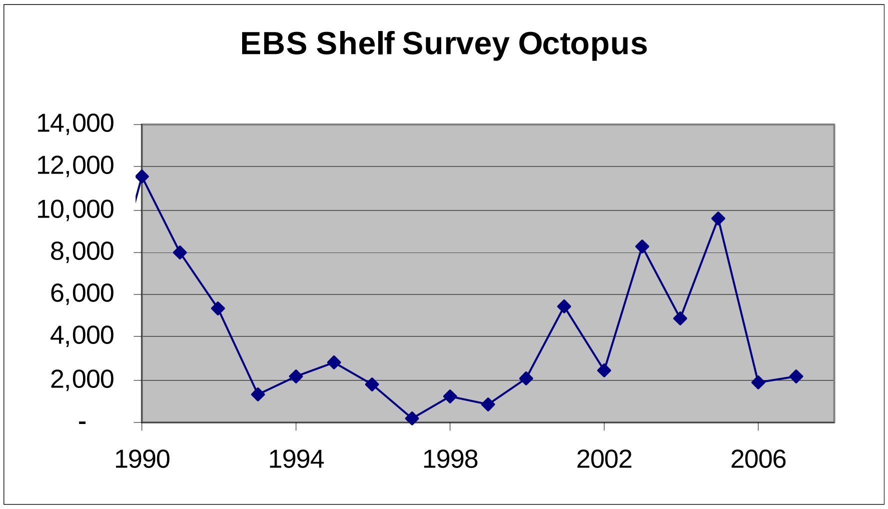
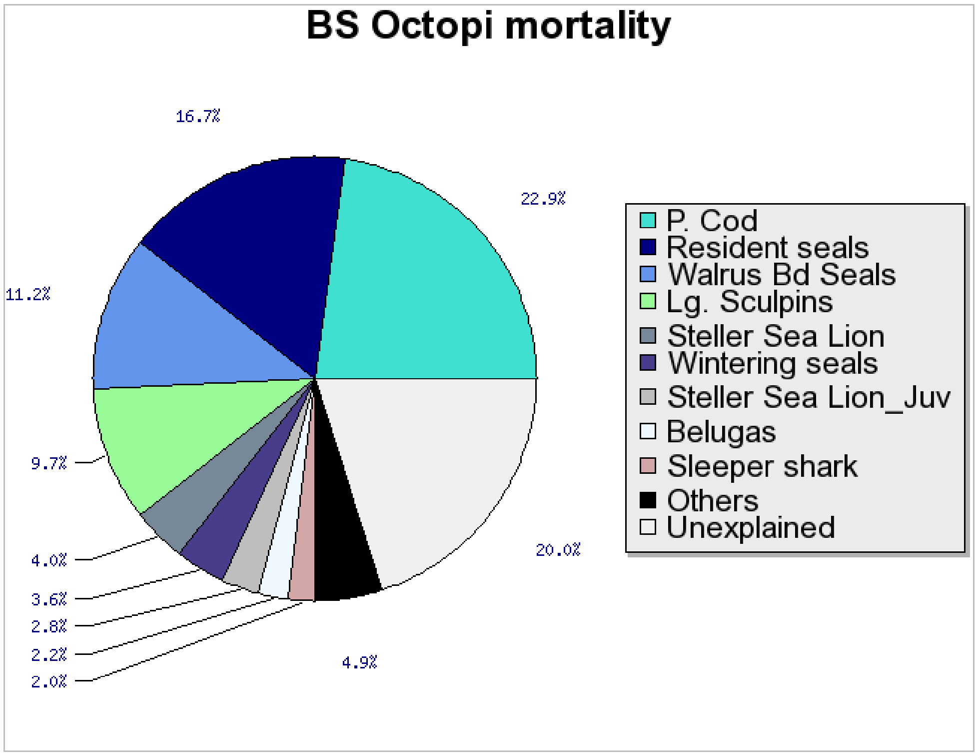


Figure 19.8 Ecopath model estimates of mortality sources of octopus in the BSAI.



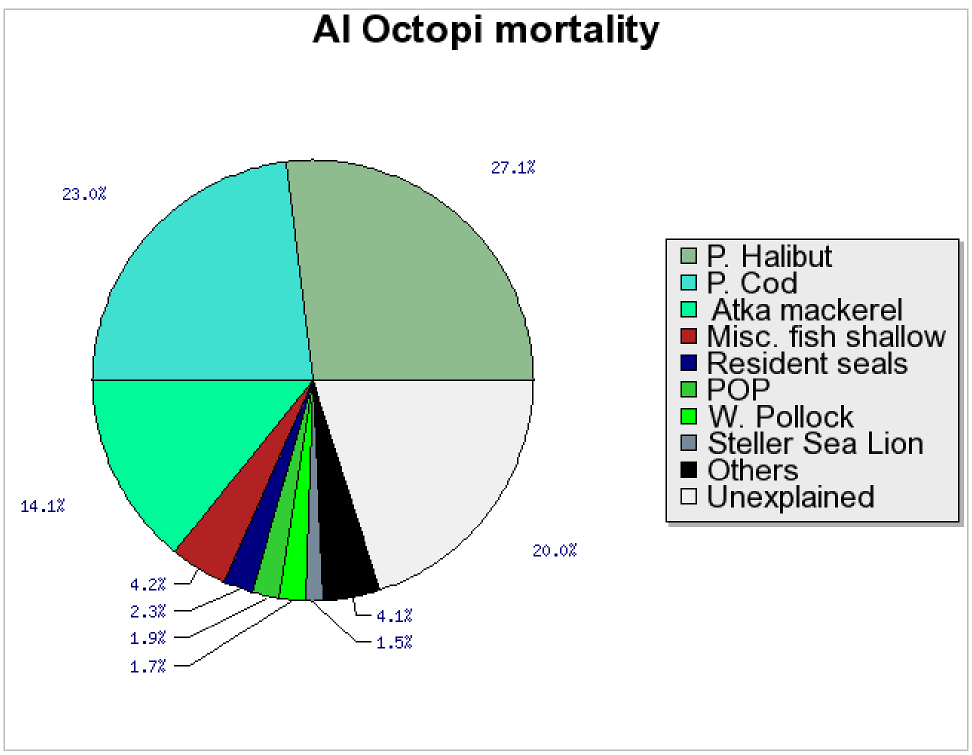
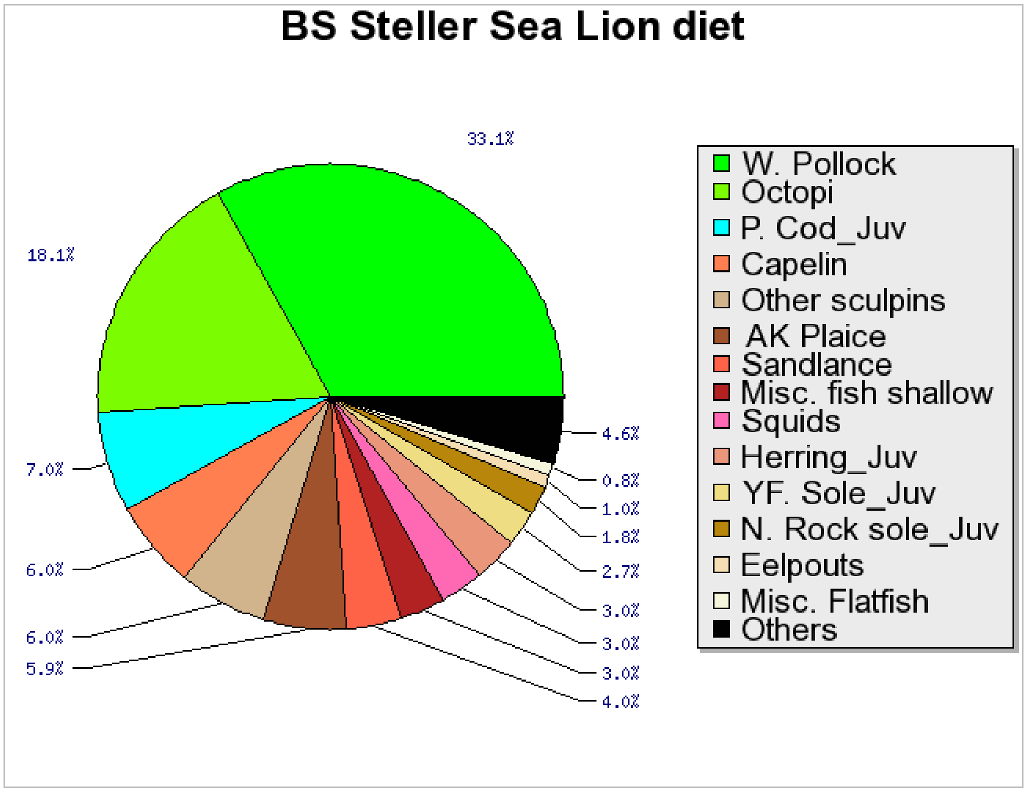
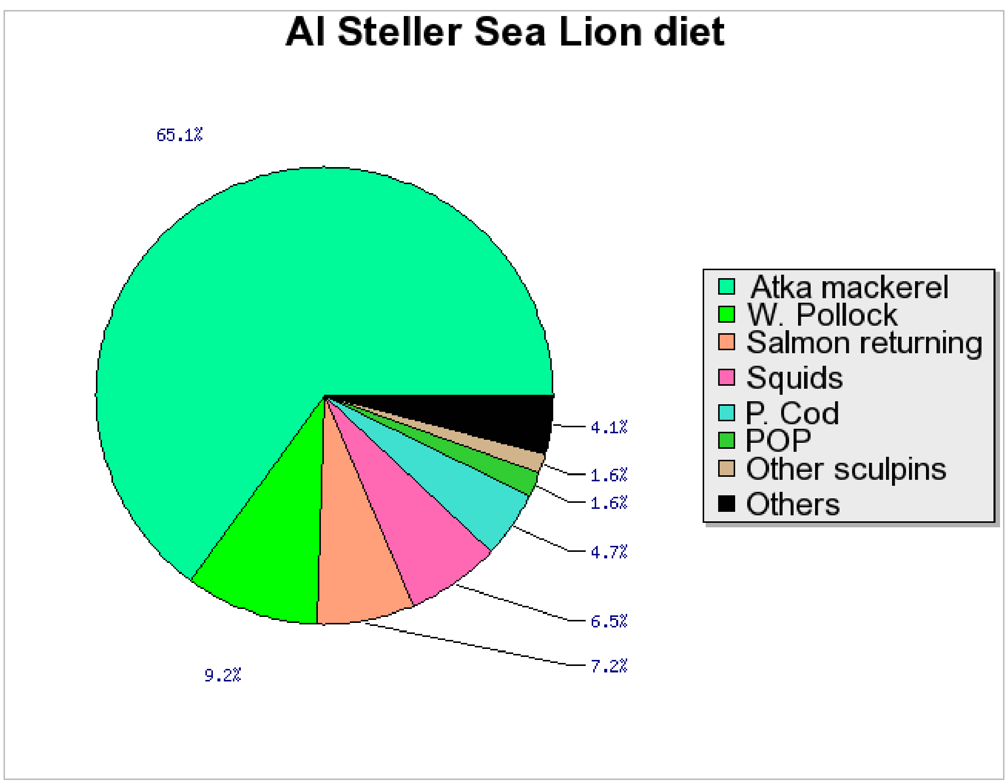


Figure 19.9. Literature-derived diets of Steller Sea Lions in the BS and AI.





(This page intentionally left blank)