18c. Assessment of the Octopus Complex in the Gulf of Alaska

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Executive Summary

Through 2009, octopuses have been managed as part of the "other species" complex, with catch reported only in the aggregate with sharks, squids, and sculpins. Due to increasing interest in retention of other species complex members, the North Pacific Fisheries Management Council is considering separate management for subgroups within this category. This appendix to the other species SAFE chapter was prepared to review available information that would be needed if the other species complex were to 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 Gulf of Alaska (GOA). The species composition both of the natural community and the commercial harvest is not well documented, but recent research indicates that the Giant Pacific octopus *Enteroctopus dofleini* 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 GOA; the highest catch rates are from Pacific cod pot fisheries in the central and western GOA (statistical areas 610 and 630).

The current data are not sufficient for any model-based assessment. The GOA trawl surveys produce estimates of biomass for octopus, but these estimates are highly variable and may not reflect the same sizes of octopus caught by industry. As an example of how this species complex might be managed under catch quotas, we have estimated Tier 6 and Tier 5 catch limits from available data. If the most recent 10-year average of bottom trawl survey biomass of 2,395 tons and a conservative estimate of M=0.53 are used, Tier 5 OFL and ABC levels would be 1,269 and 952 tons, respectively. There are no historical catch records for octopus. Estimates of incidental catch rate (including discards) are available for 1997-2008; based on comments by the SSC, the plan teams have decided to fix the Tier 6 period fo those other species groups with no historical data at 1997-2007. The average incidental catch rate over this period was 193 mt; if this were used as the Tier 6 OFL, the ABC would be 145 tons. Under an alternative Tier 6 proposed in 2007, the maximum incidental catch rather than the average is used as OFL. Under this alternative, the OFL would be 298 tons and the ABC 224 tons, as in 2008. The incidental catch rate in 2008 was the highest recorded at 339 tons. We feel that the average Tier 6 approach results in a very conservative limit, because these data are from a period in which there was very little market or directed effort for octopus. However, because of difficulties with estimation of both biomass and mortality rates, Tier 6 should be used for octopus catch limit calculations.

	2008		**2009**		**2010**	
Method	**ABC**	**OFL**	**ABC**	**OFL**	**ABC**	**OFL**
Tier 6 (max)	224	298	224	298	224	298

Because of the lack of information at this time, we recommend that directed fishing for octopus be discouraged in federal waters of the GOA 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 will be investigated. The low Tier 6 OFL has some potential to affect cod fisheries that take octopus as bycatch. In order to address this potential conflict, we propose that investigations into possible use of a discard mortality factor for octopus be continued. New research to document the life history of *E. dofleini* in Alaska and to develop field methods for octopus studies has been funded for 2010-2011.

Summary of Major Changes

The primary change from the 2008 octopus SAFE is updated data from bottom trawl surveys, catch accounting, and observer special projects. The assessment methodologies and much of the text of the assessment are unchanged since this document was reviewed by the SSC in February 2006. New data includes results of the NMFS bottom trawl surveys in 2007 and 2009. Catch data for 2003-2009 from the Alaska region have been revised, and the resulting average catch rate is higher than previously reported. Catch data for the first half of 2009 (winter season fisheries) have been included, but these figures are expected to increase during the fall cod fisheries. Time trends in CPUE of octopus from pot fisheries have been updated through 2009. A small section of new text has been added summarizing new research underway on octopus, and the life history section has been updated.

Octopus remains difficult to place within the existing tier system for setting regulatory catch limits. In February 2006, the SSC concurred with the SAFE authors that the size difference between trawl and pot-caught octopus makes biomass data based on the trawl survey questionable for this species group. In 2007 and 2008, a modification of tier 6 was suggested based on maximum incidental catch rate, rather than average. This approach was accepted by the GOA plan team and SSC for 2007 and 2008, and has been included among the alternatives for 2009. **Based on discussion with the joint plan teams in September 2009, the 12-year period from 1997-2008 has been selected as the Tier 6 reference period for the other species subgroups that do not have historical catch records (octopus and sharks). This period will be used as the basis for Tier 6 estimation in this and future stock assessments.** Since there will be no need to set separate ABC and OFL for octopus in 2009, this report remains a discussion of possible future management approaches, without specific recommendations for setting catch levels.

Response to SSC comments

There have been no specific SSC comments or requests about octopus assessment in the last year. In December 2008, the SSC agreed with the plan team recommendation to use the alternative tier 6 approach (OFL = maximum catch) for GOA octopus. Responses to previous comments have been incorporated into the current stock assessment document and format.

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 (cilia-like strands on the suckers) and paddle-shaped fins suitable for swimming in their deep oceanic pelagic and epibenthic habitats (Boyle and Rodhouse 2005) and are much less common than the incirrate which contain the more traditional forms of octopus. Octopuses are found in every ocean in the world and range in size from less than 20 cm (total length) to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini* (Wülker, 1910). *Enteroctopus dofleini* is one of at least

seven species of octopus (Table 1) found in the GOA. Members of these seven species represent five 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 GOA, including the true species composition, is very limited.

In the GOA, octopuses are found from subtidal waters to deep areas near the outer slope (Figure 1). The highest diversity is along the shelf break region of the GOA, although, unlike the Bering Sea, there is a high abundance of octopuses on the shelf. While octopuses are observed throughout the GOA, they are more commonly observed in the Central and Western GOA (stat areas 610-630) than in the Eastern GOA. The greatest number of observations are clustered around the Shumagin Islands and Kodiak Island. These observations are influenced by the distribution of fishing effort and may not reflect true spatial patterns. AFSC survey data also demonstrate the presence of octopus throughout the GOA and also indicate highest biomass in areas 610 and 630. Octopuses were caught at all depths ranging from shallow inshore areas (mostly pot catches) to trawl and longline catches on the continental slope at depths to nearly 1000 meters. The majority of octopus caught with pots in the GOA came from 40-60 fathoms (70-110 meters); catches from longline vessels tended to be in deeper waters of 200-400 fathoms (360-730 meters). Octopuses are also common in the eastern Bering Sea and throughout the Aleutian Island chain.

Life History and Stock Structure

In general, octopuses are fast growing with a life span generally less than 5 years. Life histories of six of the seven species in the Gulf of Alaska are largely unknown. *Enteroctopus dofleini* has been studied extensively in Japanese and Canadian waters and its life history will be reviewed here; generalities on the life histories of the other six species will be inferred from what is known about other members of the genus.

Enteroctopus 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 larger sizes (Robinson 1983). *Enteroctopus dofleini* are problematic to age due to a documented lack of beak growth checks and soft chalky statoliths (Robinson and Hartwick 1986). Therefore the determination of age at maturity is difficult for this species. *Enteroctopus dofleini* move to deeper waters to mate during July – October; they move to shallower waters to spawn during October – January. There is a two-month lag time between mating and spawning (Kanamaru 1964). Due to the delay between mating and spawning it is assumed female *E. dofleini* store sperm (Kanamaru 1964) and this phenomenon has been documented in an aquarium study of octopus in British Columbia (Gabe 1975). *Enteroctopus 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 (1975) estimated a female in captivity in British Columbia laid 35,000 eggs and it appears likely fecundity is similar within 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 is also estimated to be high (Hartwick, 1983). Since the highest mortality occurs during the larval stage, it is probable that ocean conditions have a large impact on numbers of *E. dofleini* in the GOA and large fluctuations in numbers of *E. dofleini* should be expected.

Octopus californicus is a medium-sized octopus with a maximum total length of approximately 40 cm. Very little is known about this species of octopus. It is collected between 100-1000 m. It is believed to spawn 100-500 eggs. Hatchlings are likely benthic; hatchling size is unknown. The female likely broods the eggs and dies after hatching.

Octopus rubescens has been reported from Prince William Sound in the central GOA, but has not been verified in survey collections. *Octopus rubescens* lives 1 – 2 years and is also a terminal spawner, likely maturing after 1 year. *Octopus rubescens* has a planktonic larval stage. *Octopus sp. A* is a small-sized species with a maximum total length < 10 cm. This species has only recently been identified in the GOA and its full taxonomy has not been determined. *Octopus sp. A* is likely a terminal spawner with a life-span of 12-18 months. The eggs of *Octopus sp. A* are likely much larger than those of *O. rubescens*, as benthic larvae are often bigger. Females of *Octopus sp. A lay between* 80-90 eggs that take up to six months or more to hatch.

Benthoctopus leioderma is a medium-sized species; its maximum total length is approximately 60 cm. Its life span is unknown. It occurs from 250 – 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. The hatchlings are benthic.

Opisthoteuthis californiana is a cirrate octopus, it has fins and cirri (on the arms). It is common in the GOA but is not likely to be confused with *E. dofleini*. It is found from 300 – 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 Gulf of Alaska and not likely to be confused with *E. dofleini*.

Vampyroteuthis infernalis is a cirrate octopus. It is not common in the Gulf of Alaska and is easily distinguishable from other species of octopus by its black coloration. Nothing is known of its reproduction or early life history.

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

Management Units

Through 2009, octopuses have been managed as part of the “other species” complex in the GOA (Table 2). Prior to 2003 catch of other species (squid, octopus, sharks, skates, and sculpins) was reported only in the aggregate. Separate catch reporting for different components of the other species complex has been initiated, but octopus are still reported as an aggregate catch for all species. Increasing market value and a small directed fishery for skates in 2003-2004 caused this group to be broken out of the GOA other species complex and managed under a separate TAC. Catch of other species through 2005 has been limited by a Total Allowable Catch (TAC) set at 5% of the total catch of all species. In 2009, the NPFMC is expected to set the other species TAC at or below the 5% level. The GOA Plan Team and NPFMC are reviewing procedures and options for future management of other species catch, including octopus.

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 fishers and observers is not anticipated (although special projects may be pursued). *Enteroctopus dofleini* is the key species in the assemblage; it is the best known and is most likely to be encountered at shallower depths. It is important to note, however, that the other octopus species in the assemblage do not necessarily share common patterns of distribution, growth, and life history.

Fishery

Directed Fishery

There is no federally-managed directed fishery for octopus in the GOA. One processor in Kodiak purchases incidentally-caught octopus, primarily for halibut bait. Ex-vessel prices for octopus in Kodiak are currently in the range of $0.50 -$0.75/lb (Sept 2009). Recent increases in global market value have increased retention of incidentally-caught octopus in the BSAI and GOA. Because of the relatively large number of small boats in the GOA commercial fleet and recent changes to crab fishing seasons, there may be some interest in directed fishing for octopus in the GOA.

The State of Alaska allows directed fishing for octopus in state waters under a commissioner's permit. A small directed fishery in state waters of the BSAI 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 octopuses 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 registered for octopus in 2005. Two vessels registered in 2006, but have not reported any octopus catch. ADF&G is currently developing policy on implementation of new and developing fisheries, which include octopus (ADF&G 2004).

Catch History

Since there has been only a limited market for octopus and no directed fishery in federal waters, there are no data available for documenting catch history. Historical rates of incidental catch do not necessarily reflect future fishing patterns where octopuses 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) and with life-history patterns for *E. dofleini*.

Incidental Catch

Octopus are caught incidentally throughout the GOA in both state and federally-managed bottom trawl, longline, and pot fisheries. From 1997-2001 total incidental catch of octopus in federal waters was generally between 100 and 200 t (Table 3). Catches in 2002-2009 have been somewhat higher, between 150 and 300 t. The estimated catch in 2008 was the highest on record at 338 t. Catch through Oct 7, 2009 was 238 t. High rates of incidental catch in 2002, 2004, and 2009 correspond to high survey catches in 2003 and 2009 (Table 5). The majority of incidental catch of octopus comes from Pacific cod fisheries, primarily pot fisheries (Table 3). Some catch is also taken in trawl fisheries for cod and other species. The overwhelming majority of catch in federal waters occurred in the central and western GOA in statistical reporting areas 610, 620 and 630. The species of octopus taken is not known, although size distributions suggest that the majority of the catch from pots is *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 Caribbean 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 t (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). Caddy (2004) also suggests the use of surplus production models to protect minimum spawning biomass, if sufficient data are available. Perry et al. (1999) describe a framework for management of new and developing invertebrate fisheries; GOA and BSAI octopus fisheries are 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 semi-annual NMFS bottom trawl survey of the GOA. In older survey data (prior to 2003), octopus were often recorded as Octopodidae or *Octopus* sp. and not identified further; other species may also have been sometimes misidentified as *E. dofleini*. Since 2003, increased effort has been put into cephalopod identification and species composition data are considered more reliable; species composition of octopus catch in recent GOA bottom trawl surveys is shown in Table 4. These catches are our only source of species-specific information within the species group. Based on available data, the species with the highest biomass in shelf waters is *E. dofleini*. The size distribution by weight of individual octopus collected by the bottom trawl surveys from 1999 through 2005 is shown in

Figure 2. Survey-caught octopus ranged in weight from less than 0.1 kg up to 18 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. The 2007 and 2009 GOA trawl surveys caught primarily *E dofleini*, *B. leioderma*, and *O. californiana*. The largest individual in these trawl surveys was a female *E. dofleini* at 17.9 kg.

Survey catches of octopus occur throughout the GOA but are more frequent in the central and western GOA, and estimated biomass of octopus is higher in these regions. The survey catches octopuses at all depths from 25 to over 900 meters; the most frequent depth of survey catch is in the 100-300 meter range.

Biomass estimates for the octopus species complex based on bottom trawl surveys are shown in Table 5. These estimates show moderately strong year-to-year variability, but less so than in the BSAI surveys. Survey biomass estimates range from 994 t in 1999 and 2001 to 3,767 t in 2003 and 3,807 t in 2009. The average biomass of surveys within the last ten years is 2,398 t. Because bottom trawls are not efficient for catching benthic octopus, the true biomass of octopus in the GOA is probably higher than the survey estimates (see discussion below under estimation of biomass). The estimate of octopus biomass from the Ecopath food-web model for the GOA is on the order of 200,000 t (Aydin et. al, *in review*).

Federal Groundfish Observer Program Data

Groundfish observers record octopus in commercial catches as either "octopus unidentified" or "pelagic octopus unidentified". Observer records do, however, provide a substantial record of catch of the octopus species complex. Figure 1 shows the spatial distribution of observed octopus catch in the GOA (aggregated over 400 km^2 blocks). The majority of GOA octopus caught by pot gear came from depths of 40-60 fathoms (70-110 meters); catches from longline vessels tended to be in deeper waters of 200-400 fathoms (360-730 meters). Unlike the BSAI, the depth range of octopus catches in the GOA is similar between industry and survey data. The size distribution of octopus caught by different gears is variable (Figure 3); commercial cod pot gear clearly selects for larger individuals. Over 88% 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 *B. leioderma* or *Octopus* sp. A.

Incidental catch rates from observed hauls in frequently-fished areas may provide a time-series index of octopus abundance that includes years not covered by the trawl survey. Figure 4 shows time series of octopus catch rates from pot gear in federal stat areas 610 (Shumagin), 602 (Chirikof), and 630 (Kodiak). These series indicate occasional years of very high abundance; the peak abundance years are not consistent between the three areas. For example, the CPUE data indicate that 2002-2004 were all high abundance years in the Shumagin and Kodiak regions, but that abundance declined after a 2001 peak in the Chirikof region. Isolated years of high catch rates appear in 1990 in the Kodiak region and in 1996 in the Chirikof region. Incidental catch rates in most years (averaged over stat area and year) were on the order of 50-150 lbs/100pots. The earlier data in these series may be less reliable than more recent data due to limited observer coverage. Catch rates for 2008 were high in the Kodiak region, but lower in Shumagin and Chirikof regions.

Observer Program Special Project Data

A special project has been initiated with the North Pacific Observer Program to collect individual weight and sex data on octopuses in the GOA and the Bering Sea. So far, data from the fisheries in 2006-2009

have been collected. These data include sampling at the one plant in Kodiak that purchases octopus, Alaska Pacific Seafoods. All of the octopus data collected at this plant in January – March 2006 came from pot boats targeting Pacific cod. The size frequency of octopus in these deliveries is shown in Figure 5. All of the delivered octopus were over 3.5 kg gutted weight, with an average weight of 11.6 kg.

The majority of octopus sampled at sea during this period were also from cod pot boats. In the pot fishery, the ratio of males to females was skewed towards males; males were, on average, four times more abundant than females. This was not the case for the other three gear types included in the sample (longline, bottom and pelagic trawls). Without further spatial and temporal information it would be difficult to explain the discrepancy in sex ratio in the different fisheries. A few observations from sablefish pot fisheries in May and June included noticeable smaller specimens; these octopus were not retained for market.

ADF&G Survey Time Series

The Alaska Department of Fish and Game provided a time series of octopus catch data from their bottom trawl survey of state waters from 1990-2004. As with the NMFS trawl survey, octopus are not frequently caught by the ADF&G trawl, but octopus biomass for the surveyed areas was estimated (Figure 6, Table 6). The ADF&G survey does not record weights of individual octopus or identify octopus to species, so there is no size or species composition data associated with these catch estimates. The areas with the greatest average estimated biomass of octopus were the northeast and north mainland sections of Kodiak Island, each with an average estimated biomass over 60 t. Octopus were present in nearly all survey years in these areas. Within the surveyed areas along the south side of the Alaskan peninsula, catches of octopus were present every year at Pavlof Bay, with an average estimated biomass of 39 t for the time series. Both Pavlof Bay and west Nagai had estimated biomass over 250 t in 2003, consistent with the high biomass estimate seen in NMFS trawl data and commercial CPUE data for that year. Catches of octopus in the Chignik region were generally slight. A combined biomass for all ADF&G trawl areas is plotted in Figure 6, along with NMFS trawl survey biomass estimates. In general, these data support the characterization of octopus as a “breakout” species, with occasional years of high abundance. The time series does not show any evidence of declining biomass for this species group. In fact, the high biomass estimates in 2003 and 2004 suggest an overall increasing trend from 1990-2004.

Cooperative Research Program Project 2006

A cooperative research 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 5). Data were collected for estimating gutted weight to round weight ratios and weight to mantle length relationships.

NPRB Project 2009-2011

The North Pacific Research Board has funded a field study in support of stock assessment for octopus, beginning in fall 2009. The study will be conducted by AFSC and UAF researchers in both the GOA near Kodiak and in the southeast BS near Dutch Harbor. The main focus of the 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 will be collected from a variety of sources throughout the calendar year for dissection and examination of the gonads; a gonad maturity coding system will be developed and data collected on fecundity and weight at sexual maturity. An outreach

effort with local and research divers will be used to find and monitor nearshore dens with octopus guarding egg clusters.

In addition to the reproductive work, this project will also include a pilot tagging study near Dutch Harbor that will look at the local dynamics and seasonal movement of octopus. This pilot study will provide initial estimates of tagging rates, tag recoveries, and tag mortality that can be used in design of larger future studies. Tagging methods have the potential to address both questions of seasonal movement and estimation of assessment parameters such as natural mortality rates. The NPRB project will also include development and testing of longlined habitat pot gear as a potential research and survey gear for octopus.

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. Octopuses have no swim bladder and can survive out of water for brief periods. Large octopus caught in pots are typically very active 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.

Data collected by the observer special project in 2006 and 2007 included a visual evaluation of the condition of the octopus by the observer. These data have been reviewed to see if using a discard mortality factor would be appropriate in catch accounting and regulation for octopus. Table 7 summarizes this data. Observers were asked to classify each octopus as either: A) alive and healthy, M) missing an arm but otherwise healthy, I) injured, or D) dead. In Table 7, octopus coded as A or M have been grouped as “Alive”. Octopus coded as injured are included under “Dead”. The table shows the number of observations and the proportion of observed octopus alive or dead for each gear type.

These results cover only a portion of the octopus caught and are based on a subjective visual coding of condition. However, they provide preliminary data on the nature of discard mortality for octopus. In particular, the observed mortality rate for octopus caught in pot gear was less than one percent (two octopus out of 433 -- one coded as dead and the other as injured). These preliminary data suggest that a gear-specific discard mortality factor could be estimated for octopus, similar to the 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 for trawl gear are 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, more data need to be collected to document discard mortality rates. Federal fisheries observers could collect data on octopus vitality as they currently do for halibut, but a more detailed and objective procedure needs to be developed for coding injuries and condition. Laboratory or tagging studies would be needed to document mortality in relation to condition. Due to the low incidental catch rate of octopus, it may take several years to accumulate enough data for reliable mortality estimates. 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 GOA or for the multi-species complex. As better catch and life-history data become available, it may become feasible to manage the key species *E. dofleini* through 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.

Parameters Estimated Independently – Biomass

Estimates of octopus biomass based on the semi-annual GOA trawl surveys (Table 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 industry or observer data, are commonly reported as octopus sp., without full species identification. In surveys prior to 2003, most octopus collected were not identified to species. In more recent years, a greater fraction of collected octopus is 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 is only beginning to provide species-specific information that could be used in a stock assessment model.

There is strong reason to question whether a trawl is the most suitable gear for sampling octopus. The bottom trawl net used for the GOA survey has roller gear on the footrope to reduce snagging on rocks and obstacles and may allow benthic organisms, including octopus, to escape under the net. Given the tendency of octopus to spend daylight hours near dens in rocks and crevices, it is entirely likely that the actual capture efficiency for benthic octopus is poor (D. Somerton, personal communication, 7/22/05). Trawl sampling is not conducted in areas with extremely rough bottom and/or large vertical relief, exactly the type of habitat where den spaces for octopus would be most abundant (Hartwick and Barringa 1989). The survey also does not sample in inshore areas and waters shallower than 30m, which may contain sizable octopus populations (Scheel 2002). The estimates of biomass in Table 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 large numbers of survey tows with no octopus also tend to increase the sampling variability of the survey estimates; in many years, octopus were present in only 5% of the survey tows.

More importantly, there is a considerable difference in size selectivity between survey trawl gear and industry pot gear that catches most of the octopus harvested. The average weight for individual octopus in survey catches is 2.0 kg; over 50% of survey-collected individuals weigh less than 0.5 kg. Larger individuals are strong swimmers and may preferentially escape trawl capture. In contrast, the average weight of individuals from commercial pot gear was over 20 kg (Figure 3c). Pot gear is probably selective for larger, more aggressive individuals that respond to bait, and smaller octopus can easily escape commercial pots while they are being retrieved. Unlike the BSAI, the depth range of octopus catches in the GOA is similar between industry and survey data, although pot fisheries tend to be concentrated in shallower shelf waters**.** There is also a seasonal difference between summer trawl surveys

and the fall and winter cod seasons, when most octopus are harvested. In general, it may be possible to use trawl survey data as an index of interannual variation in abundance, but the relationship between the summer biomass of individuals vulnerable to trawls and the fall or winter biomass available to pot fisheries will be difficult to establish.

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. An index survey of regional biomass in selected areas of the Kodiak and Shumagin regions would be appropriate and is highly feasible. It may also be feasible to estimate regional octopus biomass using mark-recapture studies or depletion methods (Caddy 1983, Perry et al 1999). 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

It is important to note than not all species of octopus in the GOA have similar fecundity and life history characteristics. This analysis is based on *E. dofleini*, which probably make up the majority of the harvest. Since *E. dofleini* are terminal spawners, care must be taken to estimate mortality for the intermediate stage of the population that is available to the fishery but not yet spawning (Caddy 1979, 1983). If detailed, regular catch data 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, Rikhter and Efanov 1976) or von Bertalanffy growth coefficient (Charnov and Berrigan 1991) have also been used. While these equations have been widely used for finfish, their use for cephalopods is less well established. Perry et al. (1999) and Caddy (1983) discuss their use for invertebrate fisheries.

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

Projections and Harvest Alternatives

If GOA octopus were separated from the other species complex, it would be feasible 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. None of the existing groundfish Tier strategies is well suited to available information for octopus. Regulatory limits under two different strategies are presented below, but both are problematic.

Groundfish Tier 5 management is based on estimated overall biomass and natural mortality of the stock. It would be possible to manage GOA octopus 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 2,395 tons and the conservative M estimate of 0.53 are used, the Tier 5 OFL and ABC for GOA octopus would be 1,269 and 952 tons, respectively.** 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 the mortality estimate, 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 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 rates.**

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 1997-2008. **Based on discussion at the September 2009 Plan team meetings, we used the full 12-year period of incidental catch data from 1997 through 2008 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 208 t. If this incidental catch rate was treated as the long-term average catch under **standard Tier 6 procedure, the OFL would be 208 t and the ABC would be 156 t.** Under an alternative Tier 6 proposed in 2007, the maximum incidental catch rather than the average is used as OFL. Under this alternative, the OFL would be 339 tons and the ABC 254 tons. **Given the order of magnitude of the survey and food web model biomass estimates, we feel that the Tier 6 catch limits are artificially low.** It is the belief of the authors that Tier 6, especially using the average incidental cath as OFL, 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. 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.

The primary management difficulty in setting separate catch limits for octopus at this time is its potential to adversely affect Pacific cod fisheries. Since there is at present no directed federal fishery for octopus, a separate catch limit for this complex would have minimal effect on existing harvest. Under existing regulations, when the TAC for an incidentally caught species is reached, that species is put on discard-only status. If octopus catch reaches OFL, however, octopus would be placed on prohibited status and fisheries with significant octopus bycatch (i.e. Pacific cod pot fishing) would be restricted. If the very conservative average Tier 6 OFL is used, there is a strong likelihood that incidental octopus catch would hit OFL in some years.

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 partial 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**. Studies to document octopus discard mortality rate have been initiated. We recommend consideration of this approach if future management is based on Tier 6 estimates.**

Other options being discussed by the plan teams include removing octopus from the fishery management plan entirely or placing the complex in an "Ecosystem Component" (EC) classification that does not require annual catch limits. It is not clear at this time how much marketing of incidental catch would be permissible under the EC classification. Both of these alternatives will need to be considered further as procedures under the new Magnuson-Stevens Act become better defined. **In**

the case of octopus, industry opinions on the value of marketing incidental catch will need to be sought and included in these considerations.

Because of the overall lack of biological data and the large uncertainty in abundance estimates, we do not recommend a directed fishery for octopus in federal waters at this time. We anticipate that octopus harvest in federal waters of the GOA will continue to be largely an issue of incidental catch in existing groundfish fisheries. 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

Very little is known about the role of octopus in North Pacific ecosystems. In Japan, *E. dofleini* prey upon crustaceans, fish, bivalves, and other octopuses (Mottet 1975). Food habit data and ecosystem modeling of the GOA (Livingston et al. 2003, Aydin et al, in review) indicate that octopus diets in the GOA are dominated by epifauna such as snails and crabs and infauna such as mollusks. The Ecopath model (Figure 7) indicates that octopus in the GOA are preyed upon primarily by grenadiers, Pacific cod, halibut, and sablefish. **Unlike in the Bering Sea, Steller sea lions and other marine mammals are not significant predators of octopus in the GOA. Model estimates show octopus is less than 0.5% of the diet of both juvenile and adult Steller sea lions (Figure 8).** At least 20% of the estimated overall mortality of octopus in the GOA cannot be explained by the model.

Analysis of scat data (Sinclair and Zeppelin 2002) shows unidentified cephalopods are a frequent item in Steller sea lion diets in both the Bering Sea and Aleutian Islands, but much less so in the western GOA. This analysis does not distinguish between 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. 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 their young until hatching, which may be disrupted by fishing effort. Activity is believed to be primarily at night, with octopus staying close to their dens during daylight hours. Hartwick and Barriga (1989) suggest that natural den sites may be more abundant in shallow waters but may become limiting in offshore areas. In inshore areas of Prince William Sound, Scheel (2002), noted highest abundance of octopus in areas of sandy bottom with scattered boulders or in areas adjacent to kelp beds. Distributions of octopus along the shelf break are related to water temperature, so it is probable that changing climate is having some effect on octopus, but data are not adequate to evaluate these effects. Survey data are not yet adequate to determine depth and spatial distributions of the different octopus species in the GOA, but the patterns may become more clear as data accumulate over future surveys.

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 industry 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 prep). 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 analyses were available. Special projects and collections of octopus for 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. *Enteroctopus dofleini* in Japan and off the US west coast reportedly undergo seasonal movements, but the timing and extent of migrations in Alaska is unknown. The distribution of octopus biomass and extent of movement between federal and state waters is unknown and could become important if a directed state fishery develops. Tagging studies to determine seasonal and reproductive movements of octopus in Alaska would add greatly to our ability to appropriately manage a 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 GOA, but are more commonly observed in the central and western GOA (statistical areas 610-630) than in the eastern GOA. At least seven species of octopus are found in the GOA. The most abundant species in shelf surveys is the Giant Pacific octopus *E. dofleini;* size composition of octopus delivered to processing plants in January - March 2006 suggests that this species made up the majority of retained catch from cod pot fisheries. Other species of octopus may be included in other fisheries. Octopus are taken as incidental catch in bottom trawl, longline, and pot fisheries

throughout the GOA, with the largest catches from pot gear in areas 610 and 630. Recent development of markets and a high ex-vessel price has spurred increased interest in fishing for and retention of octopus in BSAI fisheries, and may lead to increased interest in the GOA.

Octopus are short-lived and fast-growing, and their potential productivity is high. It is probable that the GOA can support increased commercial harvest of octopus, since the historical catch rate is only a fraction of the estimated mortality. Both survey biomass estimates and industry catch per unit effort data show stable long-term catch levels with occasional years of markedly increased abundance. The difficulty with octopus as a commercial species is that data for determining appropriate management levels and strategies are almost nonexistent. The GOA trawl survey provides an estimate of biomass for the octopus complex, but these estimates 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 GOA and that incidental catch be controlled either by catch limits or maximum retainable amount (MRA) limits. 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.

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Table 1. Species of octopus found in the Gulf of Alaska.

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

Table 2 History of federally-managed other species complex (skates, sharks, squid, octopuses, and sculpins) in the GOA. Skates were removed from the complex in 2004.

Year	ABC	TAC	Other species catch*
1977	N/A		4,725
1978	N/A		6,299
1979	N/A		4,545
1980	N/A		6,445
1981	N/A		8,280
1982	N/A		2,643
1983	N/A		2,918
1984	N/A		1,969
1985	N/A		2,356
1986	N/A		408
1987	N/A		182
1988	N/A		129
1989	N/A		1,560
1990	N/A		6,289
1991	N/A		5,700
1992	N/A	13,432	12,313
1993	N/A	14,602	6,867
1994	N/A	14,505	2,721
1995	N/A	13,308	3,421
1996	N/A	12,390	4,480
1997	N/A	13,470	5,439
1998	N/A	15,570	3,748
1999	N/A	14,600	3,858
2000	N/A	14,215	5,649
2001	N/A	13,619	4,801
2002	N/A	11,330	3,748
2003	N/A	11,260	6,371
2004	N/A	12,942	1,704
2005	N/A	13,971	2,472
2006	N/A	13,856	3,898
2007	N/A	4,500	2,925
2008	N/A	4,500	2,238

Sources: TAC from AKRO website
*Other species catch from AKRO annual catch reports

Table 3 Estimated catch (t) of all octopus species combined by target fishery. Catch for 1997-2002 estimated from blend data. Catch for 2003-2009 data from AK region catch accounting. *Data for 2009 are as of October 7, 2009.

	Target Fishery						
Year	**Pacific cod**	**Pollock**	**Flatfish**	**Rockfish**	**Sablefish**	**Other**	**Total**
1997	193.85	0.74	1.35	2.26	22.41		232.19
1998	99.66	3.51	4.34	0.76	0.27		112.00
1999	163.21	0.03	2.43	0.47	0.18		166.33
2000	153.54	-	0.69	0.18	0.52		156.12
2001	72.10	0.18	0.84	0.04	2.01		87.59
2002	265.44	0.04	17.16	0.66	0.99		298.14
2003	188.90	-	17.22	0.65	2.82	0.06	209.65
2004	266.54	0.00	2.52	0.43	0.09	16.44	286.01
2005	140.68	0.06	8.42	0.19	0.22	1.65	151.22
2006	146.22	3.41	8.85	0.47	0.32	0.16	159.43
2007	248.09	1.46	11.45	0.05	1.79	-	262.85
2008	325.97	9.55	0.03	2.89	0.21	0.08	338.73
2009*	229.66	6.26	0.05	1.14	0.25	0.94	238.31

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Table 4, Species composition of octopus (number or animals) from AFSC Gulf of Alaska bottom trawl survey.

	Year					
Species	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**
Octopodidae	33	22	36	38	10	2
Octopus sp.					13	1
Benthoctopus sp.						3
Enteroctopus dofleini	5	7	32	9	144	80
Benthoctopus leioderma	6	4	7	8	8	10
Opisthoteuthis californiana	18		1	14	10	11
Japatella diaphana			2	2	8	1
Octopus californicus				4		
Vampyroteuthis infernalis	6		3			

Table 5 Biomass estimates for octopus (all species) from GOA bottom trawl surveys.

Survey Year	Survey Hauls	Hauls with Octopus Num	%	Estimated Biomass (t)
1984	929	89	9.6%	1,498
1987	783	35	4.5%	2,221
1990	708	34	4.8%	1,029
1993	775	43	5.5%	1,335
1996	807	34	4.2%	1,960
1999	764	47	6.2%	994
2001	489	29	5.9%	994
2003	809	70	8.7%	3,767
2005	839	56	6.7%	1,125
2007	820	71	8.7%	2,296
2009	824	172	20.9%	3,791

Table 6. Estimated biomass of octopus (all species), in metric tons, from 1990 – 2004 ADF&G bottom trawl survey of inshore areas.

	YEAR															
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	AVERAGE
KODIAK AREA																
NORTHEAST	44	79	87	95	15	16	122	15	58	89	42	69	119	82	104	69.07
EASTSIDE	0	22	0	7	4	13	0	30	54	73	2	10	51	0	0	17.73
SOUTHEAST	0	0	0	51	0	5	54	0	45	10	0	14	2	12	0	12.87
SOUTHWEST	0	0	2	0	0	65	3	1	0	0	3	5	6	31	0	7.73
WESTSIDE	20	0	39	101	13	2	23	29	49	42	13	37	43	34	36	32.07
NORTH MAINLAND	2	0	0	293	64	0	1	36	1	180	3	0	195	98	66	62.60
CHIGNIK AREA																
IVANOF BAY	0	0	0	0	0	14	0	0	0	0	0	31	0	0	11	3.73
MITROFANIA	0	0	0	0	0	0	0	8	0	0	0	0	60	0	0	4.53
CHIGNIK BAY	2	0	0	9	0	0	0	1	10	8	12	0	24	40	8	7.60
KUJULIK BAY	0	0	0	0	0	0	7	10	3	0	0	0	0	0	0	1.33
SOUTH AK PENINSULA																
SANAK ISLAND	0	0	0	0	0		0	0	0	0	0	75	0	0	0	5.36
MORZHOVOI BAY	21	0	11	10	16		0	15	6	0	31	0	0	12	37	11.36
COLD BAY/BELKOFSKI	57	0	92	88	16		18	26	18	20	21	7	1	69	58	35.07
PAVLOF BAY/VOLCANO	20	0	40	51	74		4	14	0	13	11	0	23	247	46	38.79
BEAVER/BALBOA/UNGA	0	0	0	0	0		0	0	0	42	0	1	74	129	143	27.79
STEPOVAK BAY	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0.00
WEST NAGAI	0	0	52	0	0		0	0	0	0	0	5	123	309	207	49.71
KODIAK TOTAL	66	100	127	548	97	101	204	111	207	394	63	136	416	257	206	202.20
CHIGNIK TOTAL	2	0	0	9	0	14	7	20	14	8	12	31	84	40	19	17.33
SOUTH PENINSULA TOTAL	97	0	193	149	106		22	55	24	75	63	87	222	766	490	167.79
TOTAL	165	100	320	706	203	115	233	186	245	477	138	254	722	1063	715	376.13

Table 7. Results of observer program special project (both BSAI and GOA) in 2003-2007.

	Observer Special Project Data from 2006 - 2007				
	Condition Reported for Observed Octopus				
Gear	No. Alive	No. Dead	Total	Alive	Dead
Bottom Trawl	32	43	75	42.7%	57.3%
Pelagic Trawl	28	161	189	14.8%	85.2%
Pots	431	2	433	99.5%	0.5%
Longline	132	36	168	78.6%	21.4%

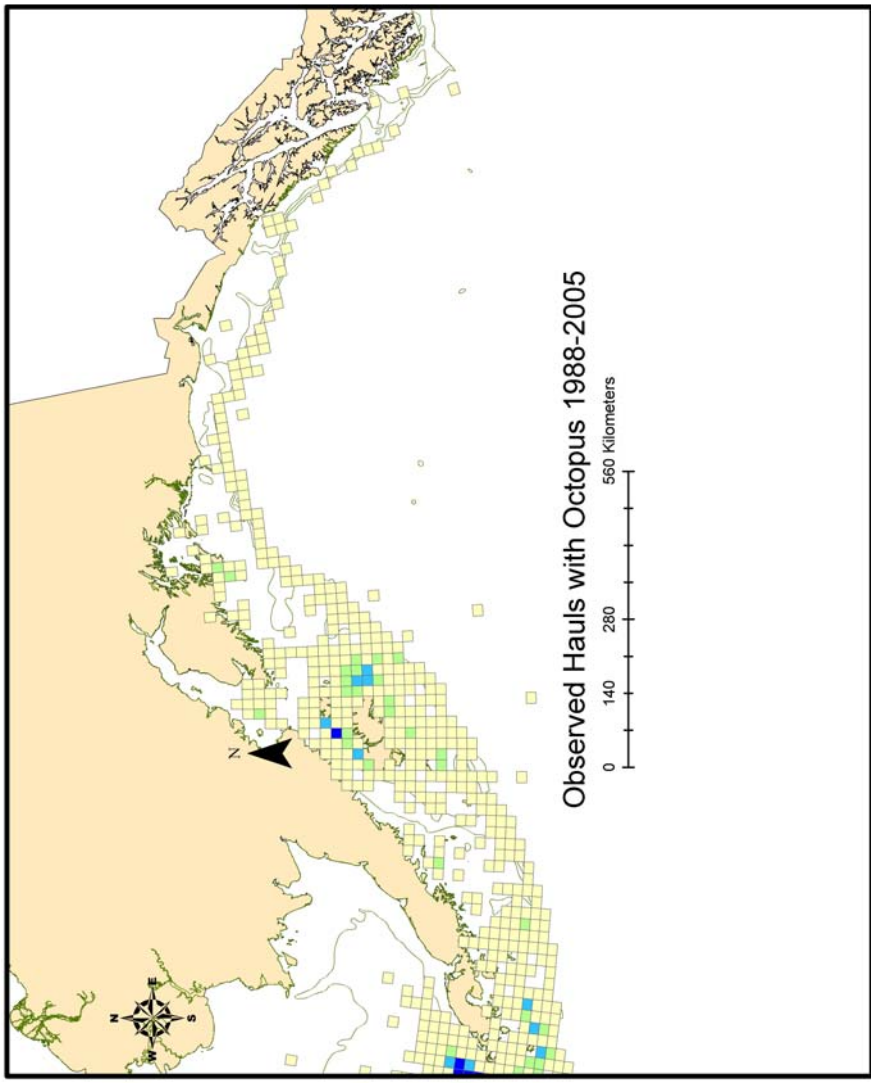


Figure 1. Distribution of octopus (all species) in the Gulf of Alaska based on octopus recorded in observed hauls. Shading shows the numbers of octopus observed in 400 km2 blocks over the period 1988-2005; darker colors (blue) are bocks with multiple observations.

Figure 2. Size frequency of individual octopus (all species) from AFSC bottom trawl surveys in the GOA 1999-2005.

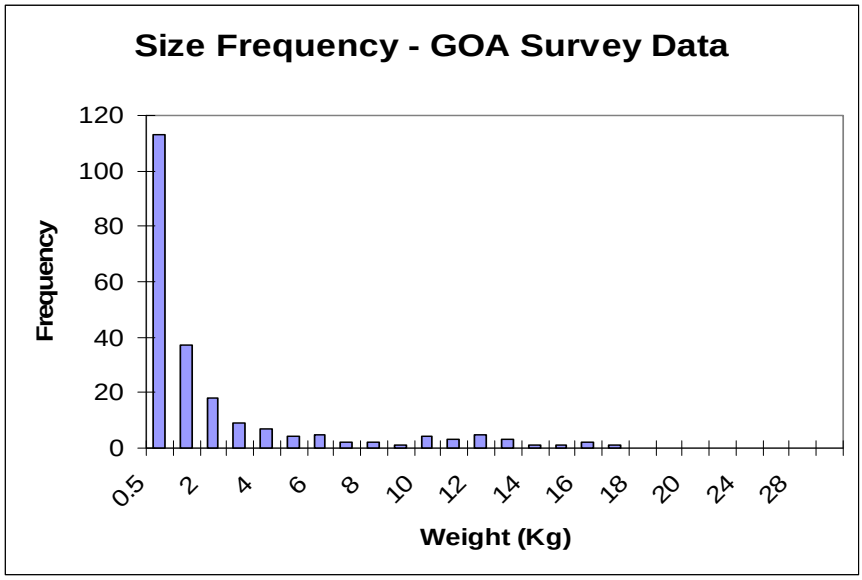


Figure 3. Size frequency of individual octopus (all species) from observed commercial hauls in the GOA 1987-2005, by gear type: a) bottom and pelagic trawls, b) longline, and c) pots.

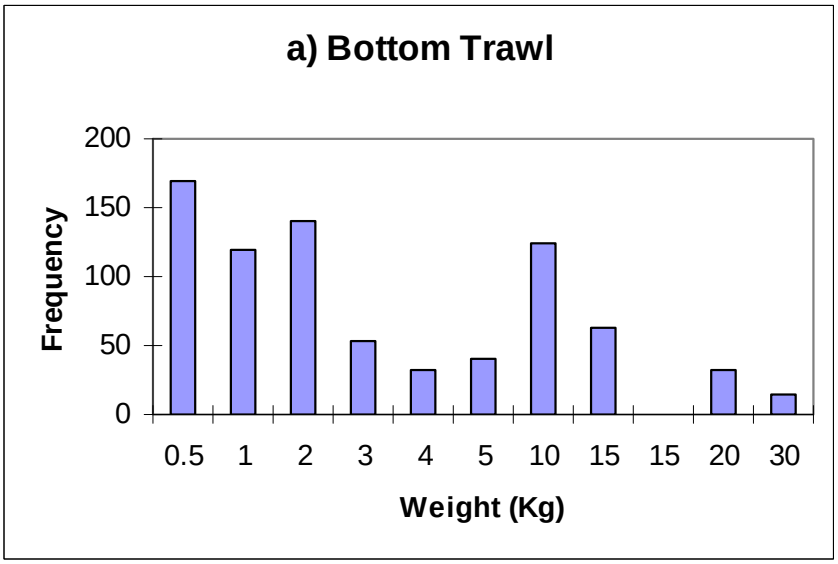
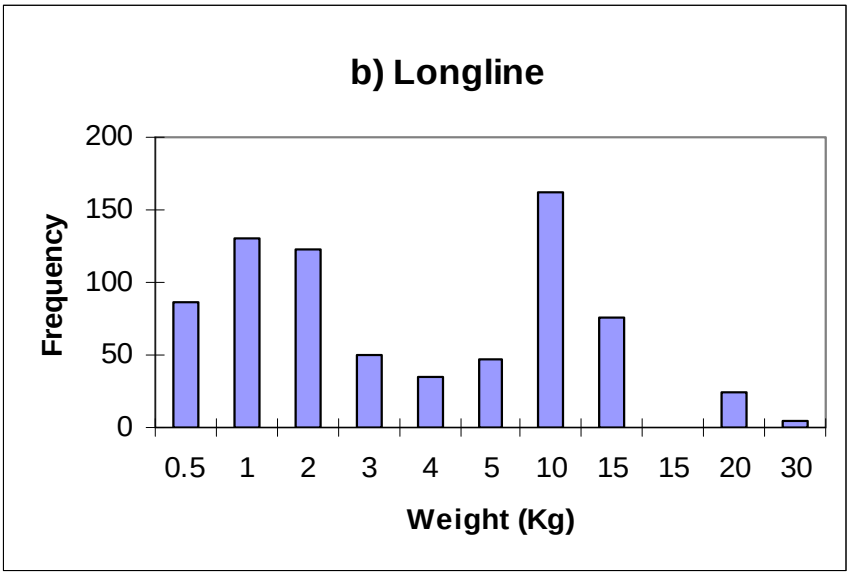


Figure 3. Continued.



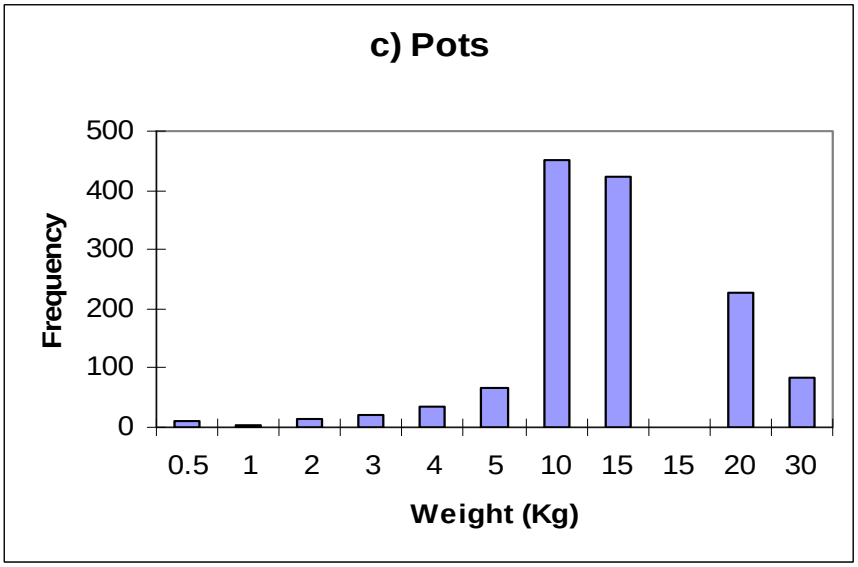


Figure 4. Time series of average octopus catch rates for observed hauls in selected statistical reporting areas of the GOA: annual averages for pot gear only.

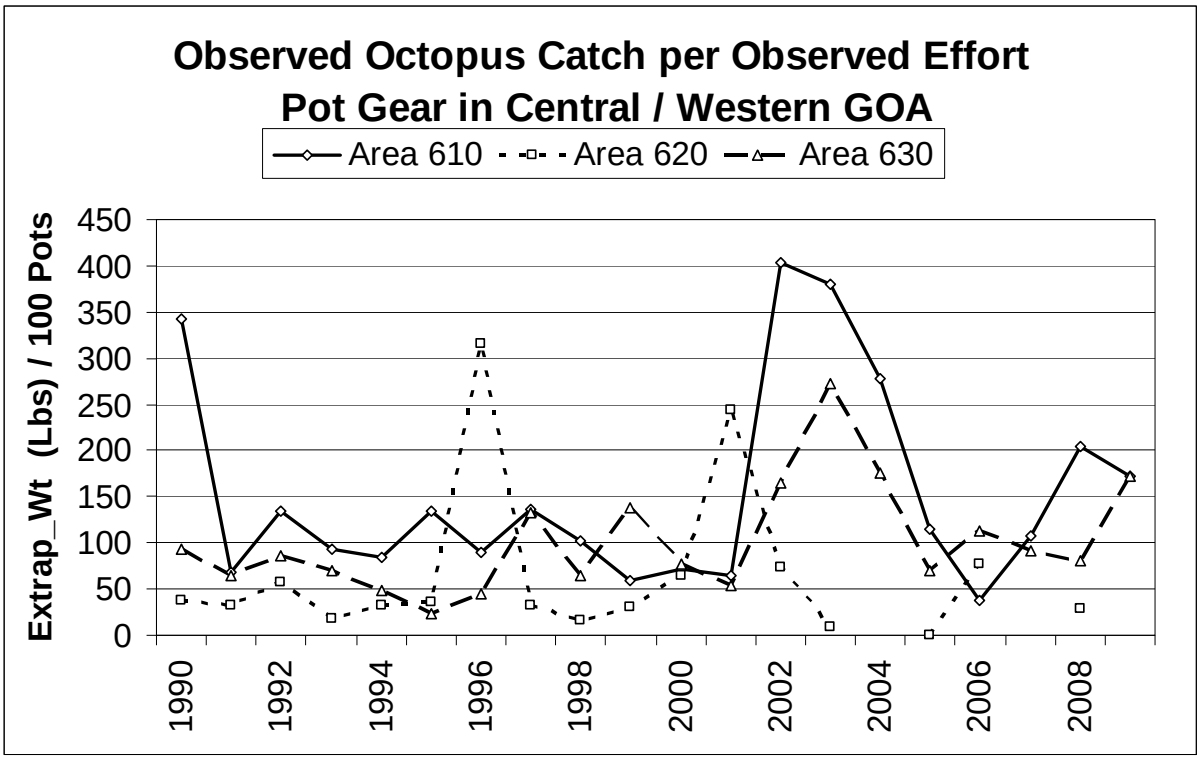


Figure 5. Size frequency (gutted weight in Kg) by sex for plant-delivered octopus from the observer program special project, January - March 2006.

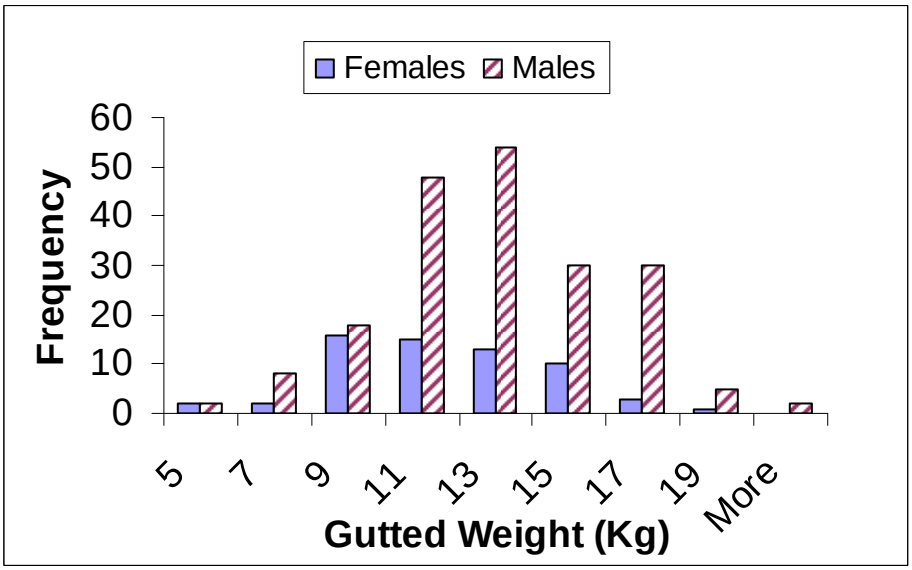


Figure 6. Time series of estimated octopus biomass (all areas combined) from the ADF&G trawl survey compared to biomass estimates from NMFS trawl surveys.

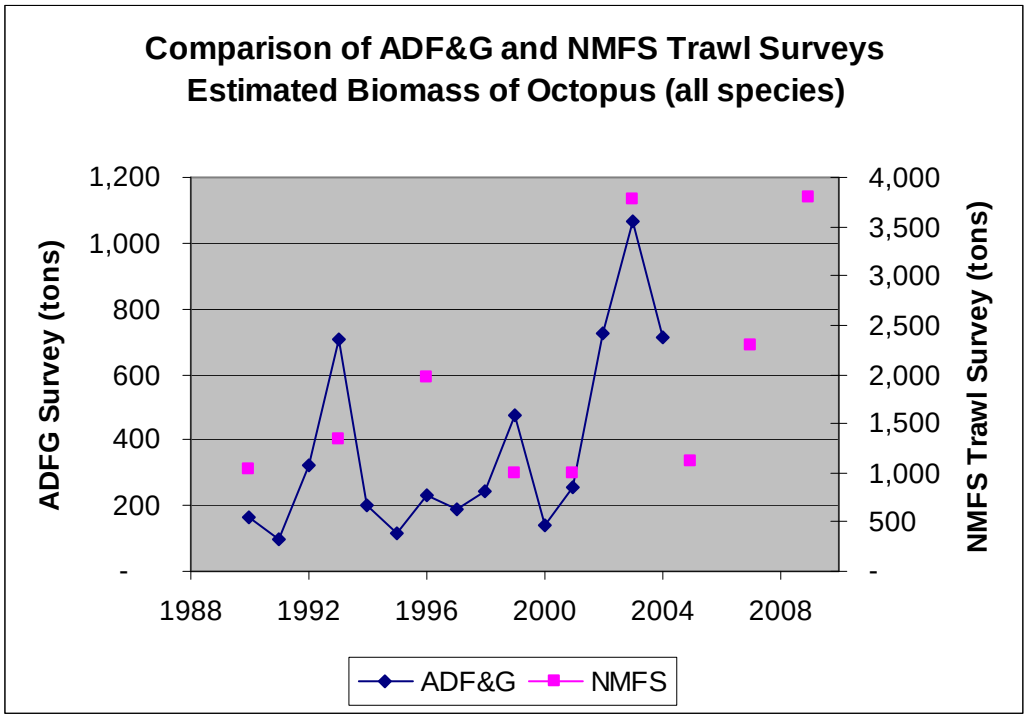


Figure 7. Ecopath model estimates of total consumption of octopus in the GOA.

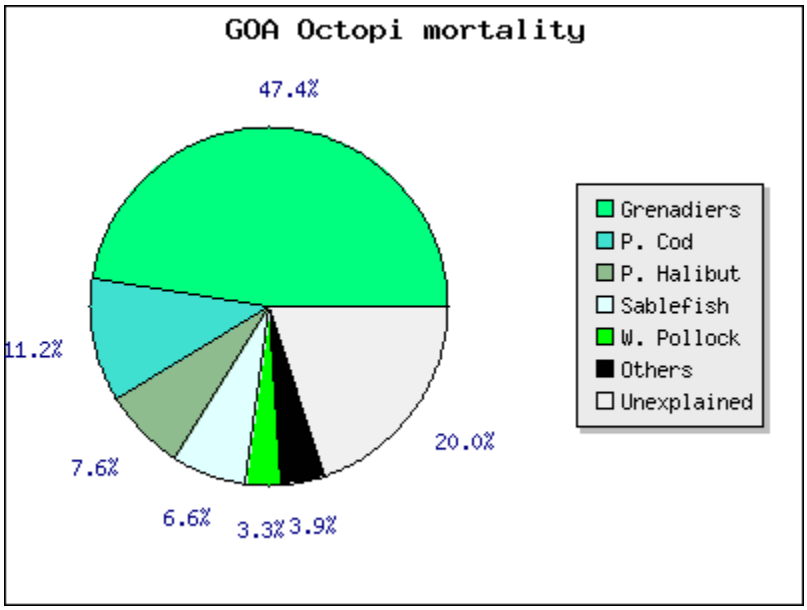
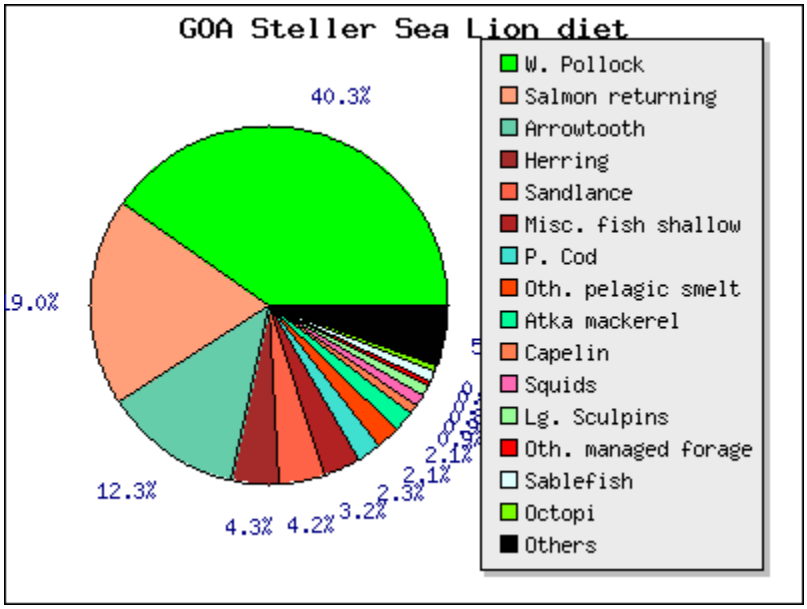
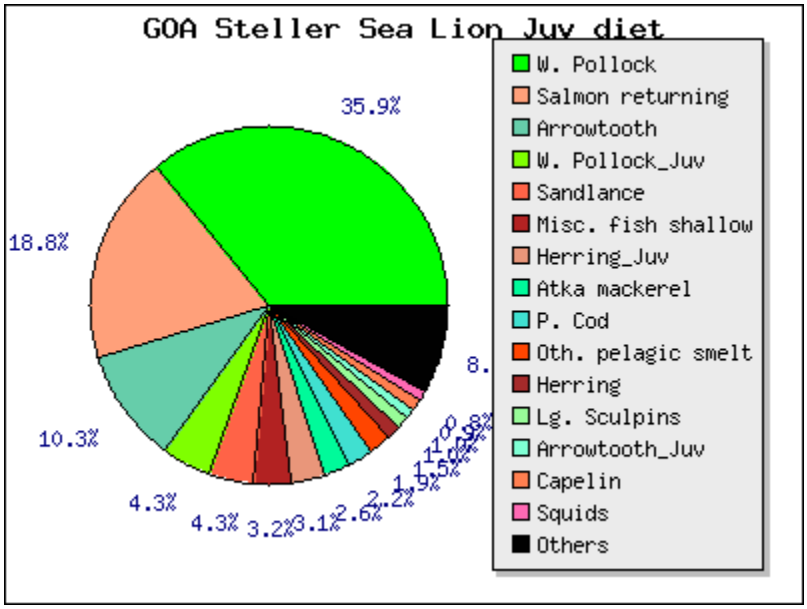



Figure 8. Ecopath model estimates of prey of Steller Sea Lions in the GOA.