

18. BSAI Sharks

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16.2.0 EXECUTIVE SUMMARY

Summary of Major Changes

The Shark SAFE chapter is now split into two chapters; one chapter for the Bering Sea/Aleutian Islands (BSAI), and a separate chapter for the Gulf of Alaska (GOA). This is the BSAI chapter.

Input Data

Incidental catch for sharks by species in the BSAI was updated for 2006 with estimates provided by the NMFS Alaska Regional Office (AKRO - as of October 22, 2006). Previous incidental catch estimates were provided by Sarah Gaichas from her pseudo-blend data for the years 1997 – 2002, and by the AKRO for the years 2003, 2004, and 2005. Bottom trawl survey biomass data was updated for the 2006 Eastern Bering Sea shelf and Aleutian Islands. Previous survey data were available from NMFS AFSC bottom trawl surveys in the eastern Bering Sea (EBS) shelf (1979 – 2005), EBS slope (historical 1979-1991, and new time series 2002, 2004), and Aleutian Islands (1980 – 2004).

Assessment Methodology

Tier 6 options for BSAI shark ABC and OFL are presented in the text both for individual species and for sharks as a complex. If Tier 6 is adopted, then Tier 6 for sharks as a complex is recommended. Pacific sleeper shark catch may serve as a reliable indicator species for the complex. Pacific sleeper sharks composed 69% of total shark catch, unidentified sharks 22%, salmon sharks 8%, and spiny dogfish 1% (Table 3). The time series of incidental catch for sharks during the years 1997 – 2005 is used here to provide an approximate Tier 6 option for BSAI shark ABC and OFL.

Tier 5 options for BSAI shark ABC and OFL are presented in the text both for individual species and for sharks as a complex. Tier 5 is not recommended for BSAI sharks. Pacific sleeper sharks account for most of the BSAI shark biomass. Reliable point estimates of Pacific sleeper shark biomass and natural mortality are not available. However, if Tier 5 is adopted, then the Tier 5 option for sharks as a complex is recommended with Pacific sleeper sharks as an indicator species and the natural mortality

estimate (0.097) from spiny dogfish in the Gulf of Alaska as a conservative estimate of natural mortality for the BSAI shark complex.

ABC and OFL Calculations

	Tier 6 BSAI – Shark Complex	Tier 5 BSAI – Shark Complex
ABC	0.75*Average catch (1997-2005)	0.75*M*Average biomass (1996 – 2006)
OFL	Average catch (1997-2005)	M*Average biomass (1996 – 2006)

Tier 6 ABC and OFL Options

	Tier 6 Options BSAI – Sharks (mt)	Tier 5 Options BSAI – Sharks (mt)
ABC	463	1,271
OFL	617	1,694

Responses to 2006 February SSC Comments, Section D-1(c).

“The SSC requests that the authors describe what is known about the distribution and the migratory behavior of these species. This will help evaluate the utility of various surveys to adequately index shark biomass. The SSC also encourages research on the spatial and temporal distribution of sharks, including depth distribution and segregation by sex.”

Response

See sections on Distribution, Evidence for Stock Structure, and Ecosystem Considerations. A more detailed analysis was not completed for this assessment cycle.

“The author noted that there has not yet been a significant market for sharks from the BSAI or GOA. The SSC requests that the authors include a description of the potential markets for these species. For example, world markets exist for dogfish.”

Response

Time constraints on the authors limited analysis to the biological assessment. The authors did make contact with the AKRO regarding potential markets for shark species. However, it quickly became apparent that a basic knowledge of economics was required to ask meaningful questions regarding “potential markets for these species,” and that a biological assessment might not be the best place for an economic analysis.

“Catch data exist from the “pseudo-blend” 1990-1998, “improved pseudo-blend” 1997 – 2002 and from NMFS Alaska Regional Office 2003-2005. The authors should develop a single set of best catch estimates for sharks in consultation with AFSC and Regional office staff. Catches are categorized as spiny dogfish, Pacific sleeper shark, salmon shark, and unidentified shark.”

Response

The 1979 – 2005 time series of shark bycatch established in the 2005 SAFE is considered the best available data for estimating exploitation rates for shark species in the BSAI and was used again here to recommend a Tier 6 option for ABC and OFL for sharks (as a complex).

“The author noted that none of the sleeper sharks sampled during the longline survey were mature in the GOA region. In addition, the author noted that several requests have been made to collect age and size composition data for sharks.”

“Although, the quality of the catch information for this species is quite good for observed fisheries, there are potentially substantial catches in the halibut and other unobserved fisheries; estimates of these catches should be included in the analysis. Observers identify the species composition of the catch. The SSC encourages the authors to include bycatch estimates from halibut and other fisheries.”

Response

Completed for IPHC halibut fisheries in the GOA only.

“The author recommends managing Pacific sleeper shark as an indicator species for the BSAI shark assemblage. In the BSAI, Pacific sleeper shark is the dominant species. In the GOA, spiny dogfish and Pacific sleeper shark dominate and salmon sharks are a minor component. The author noted that one option would be to manage spiny dogfish in the GOA as a separate species and manage Pacific sleeper shark as part of the other shark assemblage.”

“The SSC notes that the natural mortality rate used in the assessment comes from an Atlantic dogfish species that does not live as long as dogfish on the west coast. Thus, the use of this value of mortality may not be appropriate. The SSC inquired about the possibility of obtaining estimates of maximum age for Alaskan shark species. The author noted that he is conducting aging studies on sharks from Alaska to establish a maximum age and hopes that results from this effort will be available in the fall.”

Response

A natural mortality estimate (0.097) for spiny dogfish in the Gulf of Alaska is included in Appendix A.

“The author noted that the biomass estimates for sharks are uncertain and variable. Salmon sharks are highly migratory and potential seasonal residents in the GOA and BSAI. Current biomass estimates do not suggest evidence of a conservation concern for the GOA stocks. Biomass trends are stable. The SSC encourages using the longline survey data for biomass estimates. Also, the SSC requests that authors include the coefficient of variation in the survey.”

Response

Weng et al. (2005) show that while some salmon sharks embarked on migrations to subtropical waters in winter, others remained in GOA waters (over-wintering). Analysis is

ongoing of Pacific sleeper shark and Spiny dogfish bycatch in the domestic sablefish longline survey. Salmon shark are not encountered in large numbers in the domestic sablefish longline survey and are not included in the analysis.

“The SSC requests that the author provide information that would allow estimation of Tier 5 and Tier 6 management of sharks as a complex or as individual species. They note that the authors could consider development of tier 5 biomass estimates for the abundant species and a tier 6 alternative recommendation for the others.”

Response

Tier 5 and Tier 6 options for sharks as a complex or as individual species are included in the analytic approach and results.

16.2.1 INTRODUCTION

Alaska Fisheries Science Center (AFSC) survey and fishery observer catch records provide information on shark species known or suspected to occur in the Bering Sea and Aleutian Islands (BSAI) (Table 1). The three shark species most likely to be encountered in BSAI fisheries and surveys are the Pacific sleeper shark, *Somniosus pacificus*, the piked or spiny dogfish, *Squalus acanthias*, and the salmon shark, *Lamna ditropis*.

16.2.1.2 General Distribution

Spiny Dogfish

Spiny dogfish are demersal, occupying shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the North Pacific, and worldwide in non-tropical waters. They are considered more common off the U.S. west coast and British Columbia (BC) than in the Gulf of Alaska or Bering Sea and Aleutian Islands (Hart 1973, Ketchen 1986, Mecklenburg 2002). This species may once have been the most abundant living shark. However, it is commercially fished worldwide and has been heavily depleted in many locations. Directed fisheries for spiny dogfish are often selective on larger individuals (mature females), resulting in significant impacts on recruitment (Hart 1973, Sosebee 1998).

Spiny dogfish are captured periodically in National Marine Fisheries Service (NMFS) bottom trawl surveys of the Aleutian Islands, but biomass estimates are very low (0 - 62 mt, Table 15, Figure 6). Spiny dogfish are captured less frequently in NMFS bottom trawl surveys of the Bering Sea shelf and Bering Sea slope, and biomass estimates are also very low (0 - 389 mt, Tables 13 and 14, Figures 4 and 5).

Pacific Sleeper Shark

Little biological information is available for Pacific sleeper sharks, although they are considered common in boreal and temperate regions of shelf and slope waters of the

North Pacific. Sleeper sharks are found in relatively shallow waters at higher latitudes and in deeper habitats in temperate waters.

Pacific sleeper shark biomass from NMFS bottom trawl surveys appears to be distributed primarily on the eastern Bering Sea slope (estimates between 2,000 and 25,000 mt, Table 14, Figure 5). Pacific sleeper sharks are captured consistently in NMFS bottom trawl surveys of the eastern Bering Sea shelf and the Aleutian Islands, but biomass estimates are relatively low (<5,600 mt, Tables 13 and 15, Figures 4 and 6).

Salmon Shark

Salmon sharks range in the North Pacific from Japan through the Bering Sea and Gulf of Alaska to southern California and Baja, Mexico. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Salmon sharks have been considered a nuisance for both eating salmon and damaging fishing gear (Macy et al. 1978, Compagno 1984) and investigated as potential target species in the Gulf of Alaska (Paust and Smith 1989).

Salmon sharks are rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI (Tables 13 – 15, Figures 4 – 6).

16.2.1.3 Management Units

There are no directed fisheries for sharks in the Bering Sea or Aleutian Islands (BSAI), but some incidental catch of sharks results from directed fisheries for commercial species. Sharks are currently managed in aggregate as part of the “Other Species” complex in the BSAI Fishery Management Plan (FMP) (Gaichas et al. 1999, Gaichas 2003). The Other Species complex includes sharks, skates, sculpins, and octopus. Other Species are considered ecologically important and may have future economic potential. An aggregate annual quota limits Other Species catch under an interim management policy for the BSAI. Acceptable Biological Catch (ABC) and Overfishing Limits (OFL) are based upon Tier 5 and Tier 6 criteria for species groups within the Other Species complex. Total allowable catch (TAC) for the Other Species complex is constrained by the BSAI optimum yield (OY) cap of 2 million metric tons. Sharks have only been reported to species in the catch since 1997 and have made up from 1% to 5% of Other Species catch from 1997 – 2006.

In 1998 the SSC recommended Tier 5 procedures for specification of Other Species ABC involving multiplication of the natural mortality rate by estimated biomass. At the time, this shift in methodology would have indicated nearly a 4-fold increase in maximum allowable ABC. The SSC was uncomfortable with such a large increment and implemented a 10-year stair-step process to gradually change the ABC.

Last year (2005 recommendations for 2006), the SSC calculated the Other Species specifications as sums of Tier 5 calculations for skates and sculpins and Tier 6

calculations for sharks and octopus, and recommended a total of the ABCs and OFLs for the Other Species complex.

16.2.1.4 Evidence of Stock Structure

Spiny Dogfish

Complex structure characterizes spiny dogfish population in other areas. Tagging studies show separate migratory populations that mix seasonally on feeding grounds in the United Kingdom. British Columbia and Washington State have both local and migratory populations that don't mix (Compagno 1984, McFarlane and King 2003). In some areas, dogfish form large feeding aggregations, segregated by size, sex, and maturity stage. Male dogfish are generally found in shallower water than females, except for pregnant females that enter shallow bays to pup.

Pacific Sleeper Sharks

There has been no work done investigating the population structure in BSAI Pacific sleeper sharks.

Salmon Shark

Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific (WNP) and the eastern North Pacific (ENP) separated by the longitude of 180° (Goldman and Musick 2006). Length-at-maturity in the WNP has been estimated to occur at approximately 140 cm pre-caudal length PCL (age five) for males and 170-180 cm PCL (ages eight to ten) for females (Tanaka 1980). Length-at-maturity in the ENP has been estimated to occur between 125-145 cm PCL (age three to five) for males and between 160-180 cm PCL (age six to nine) for females (Goldman 2002-b, Goldman and Musick 2006). Tanaka (1980, see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP *Lamna ditropis* is at least 25 years for males and 17 years for females and that the von Bertalanffy growth coefficients (k) for males and females are 0.17 and 0.14, respectively. Goldman (2002-b) and Goldman and Musick (2006) gave maximum ages for ENP *L. ditropis* (also from vertebral analysis) of 17 years for males and 20 years for females, with growth coefficients of 0.23 and 0.17 for males and females, respectively. Longevity estimates are similar (20-30 years) for the ENP and WNP. Salmon sharks in the ENP and WNP attain the same maximum length (approximately 215 cm PCL for females and about 190 cm PCL for males). However, males past approximately 140 cm PCL and females past approximately 110 cm PCL in the ENP are of a greater weight-at-length than their same-sex counterparts in the WNP (Goldman 2002-b, Goldman and Musick 2006).

In the WNP, a salmon shark pupping and nursery ground may exist just north of the transitional domain in oceanic waters. According to Nakano and Nagasawa (1996), larger juveniles than term (70-110 cm PCL) were caught in waters with SST's of 14°-

16°C, with adults occurring in colder waters further north. Another pupping and nursery area may exist in the ENP and appears to range from southeast Alaska to northern Baja California, Mexico (Goldman and Musick in press, Goldman and Musick 2006).

16.2.1.5 Life History Information

Sharks are long-lived species with slow growth to maturity and large maximum size. The productivity of shark populations therefore, is very low relative to most commercially exploited teleosts (Holden 1974 and 1977, Compagno 1990, Hoenig and Gruber 1990). Shark reproductive strategies in general are characterized by long (6 months - 2 years) gestation periods, with small numbers of large, well-developed offspring (Pratt and Casey 1990). Many large-scale directed fisheries for sharks have collapsed, even where management was attempted (Anderson 1990, Hoff and Musick 1990, Castro et al. 1999).

Spiny Dogfish

Eastern North Pacific spiny dogfish grow to a relatively large maximum size of 1.6 m (Compagno 1984). British Columbia female spiny dogfish are reported to mature at 35 years, and males at 19 (Saunders and McFarlane 1993). Historic estimates of the age at 50% maturity for the eastern North Pacific range from 20 to 34 years. Ages from the spines of oxytetracycline-injected animals provided validation of an age-length relationship and indicated that 50% sexual maturity occurs at 35.3 years of age (Beamish and McFarlane 1985, McFarlane and Beamish 1987). The same study suggested that longevity in the eastern North Pacific is between 80 and 100 years and stated that several earlier published ages at maturity (and therefore longevity) were low due to the rejection of difficult to read spines and the grouping of annuli that were very close together.

The mode of reproduction in spiny dogfish is aplacental viviparity with gestation periods of 18-24 months. The majority of biological knowledge of spiny dogfish is based on field biology conducted in the North Atlantic and European stock assessments, and in controlled laboratory experiments (Tsang and Callard 1987, da Silva and Ross 1993, Polat and Guemes 1995, Rago et al. 1998, Koob and Callard 1999, Jones and Uglund 2001, Soldat 2002, Stenberg 2002). Little research has been conducted in the North Pacific outside of British Columbia. Ketchen (1972) reported timing of parturition in BC to be October through December, and in the Sea of Japan it was reported to occur between February and April (Yamamoto and Kibezaki 1950, Sato and Inukai 1934, Anon 1956, Kaganovskaia 1937). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio 2004). Pupping is believed to occur in estuaries and bays (Richards 2004) or mid-water over depths of about 90-200 fm (Ketchen 1986). Immature juveniles tend to inhabit the water column near the surface and are not available to the targeted fishery until they mature and descend to the benthos (Beamish et al. 1982). The average litter size is 6.9 pups for spiny dogfish in Puget Sound, WA (Tribuzio 2004) and 6.2 for BC (Ketchen 1972). The number of pups per female also increases with the size of the female, with estimates ranging from 0.20 – 0.25 more pups for every centimeter in female length from the onset of maturity (Ketchen 1972, Richards 2004, Tribuzio 2004).

Pacific Sleeper Sharks

Mature Pacific sleeper sharks have not been reported from the BSAI or GOA and the mode of reproduction is unknown, although aplacental viviparity is suspected. One pregnant female Pacific sleeper shark (12 feet, 3.7 m), was captured on May 12, 1964, off Trinidad California while trawling in 130 fathoms (238 m) at Lat. 41° 03 'N by Long. 124° 23' West (Gotshall and Jow, 1965). The ovary contained 300 large unfertilized eggs and many small undeveloped ova. Diameters of the large eggs ranged from 45 to 58 mm, averaging 52.4. The oviduct was 3 inches in diameter; it had many lateral folds and appeared capable of distension. The jaws and egg sample were donated to the California Academy of Sciences (CAS 27082).

Sleeper sharks grow to large sizes. Individuals have been measured to 4.3 m, and lengths to 7 m have been observed under water (Compagno 1984).

Salmon Sharks

Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2 °C above ambient water temperatures and appear to maintain a constant body core temperature regardless of ambient temperatures (Goldman 2002-b, Goldman et al. 2004). Adult salmon sharks typically range in size from 180-210 cm PCL (where $TL = 1.1529 \cdot PCL + 15.186$, from Goldman 2002-b, Goldman and Musick 2006) for eastern North Pacific (no conversions are given in the literature for salmon sharks in the western North Pacific) and can weigh upwards of 220 kg. Lengths of 260 cm PCL (300 cm TL) and greater and weights exceeding 450 kg are unsubstantiated (Goldman and Musick in press).

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage (Tanaka 1986 cited in Nagasawa 1998). Litter size in the western Pacific is four to five pups, and litters have been reported to be male dominated 2.2:1 (Nagasawa 1998), but this is from a very limited sample size. The number of pups and sex ratio of eastern North Pacific litters is currently unknown. Gestation times throughout the North Pacific appear to be nine months, with mating occurring during the late summer and early fall and parturition occurring in the spring (Tanaka 1980, Nagasawa 1998, Goldman 2002-b, Goldman and Human 2004, Goldman and Musick 2006). Size at parturition is between 60-65 cm PCL in both the ENP and WNP (Tanaka 1980, Goldman 2002-b, Goldman and Musick 2006).

16.2.2 FISHERY

16.2.2.1 Directed Fishery

There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI and most incidentally captured sharks are not retained. There is, however, a Commissioners Permit fishery for spiny dogfish in lower Cook Inlet, but only one application has been received to date. Spiny dogfish are also allowed as retained incidental catch in some ADF&G managed fisheries, and salmon sharks are targeted by some sport fishermen in Alaska state waters. Some deliveries of spiny dogfish captured in federal waters have also been made to Kodiak in 2004 and 2005.

16.2.2.2 Bycatch, Discards, and Historical Catches

There are no directed fisheries for sharks in the BSAI. Historical catches of sharks in the BSAI are composed entirely of incidental catch, and nearly all incidental shark catch is discarded. Mortality rates of discarded catch are unknown, but are conservatively estimated in this report as 100%. Aggregate incidental catches of the Other Species management category from federally prosecuted fisheries for Alaskan groundfish in the BSAI are tracked in-season by the NMFS AKRO (Table 2). Other Species reported catches have been relatively small each year since 1977 in the BSAI (e.g., in 2001 Other Species catches of 25,482 metric tons made up 1.5% of the 1,652,802 metric ton total BSAI catch).

16.2.3 DATA

Source	Data	Years
NMFS Observer Program – (AKRO)	Non-target catch	2003 – 2006
NMFS Observer Program – (AFSC) Pseudo Blend	Non-target catch	1997 – 2002
NMFS Bottom Trawl Surveys – Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2006
NMFS Bottom Trawl Surveys – Eastern Bering Sea Slope (Historical)	Biomass Index	1979 – 1991
NMFS Bottom Trawl Surveys – Eastern Bering Sea Slope (New)	Biomass Index	2002, 2004
NMFS Bottom Trawl Surveys – Aleutian Islands (Biannual)	Biomass Index	1980 – 2006

16.2.3.1 Incidental Catch

This report summarizes incidental shark catches by species as two data time series: 1997 – 2002 and 2003 - 2006. Sharks have been reported by species at the NMFS AKRO since 2003. Shark catches by species from 1997 – 2002 were estimated by staff at the

AFSC. These time series are not directly comparable because different methods were used to estimate incidental catch.

For the years 1997 – 2002, annual catches of sharks by species in the BSAI were estimated using a pseudo-blend method (Gaichas 2001, 2002). In the pseudo-blend method, target fisheries were assigned to each vessel / gear / management area / week combination based upon retained catch of allocated species, according to the same algorithm used by the NMFS AKRO. Observed catches of other species (as well as forage and non-specified species) were then summed for each year by target fishery, gear type, and management area. The ratio of observed Other Species group catch to observed target species catch was multiplied by the NMFS AKRO blend-estimated target species catch within that area, gear, and target fishery (Table 3). This method more closely matched the NMFS AKRO blend catch estimation system than the previous pseudo-blend estimation method (Gaichas et al. 1999) and is therefore considered more accurate. In making these catch estimates, we are assuming that Other Species catch aboard observed vessels is representative of Other Species catch aboard unobserved vessels throughout the BSAI. Observer coverage is fairly complete in the BSAI, but because observer assignment to vessels is not random, there is a possibility that this assumption is incorrect.

Based on the pseudo-blend estimates from 1997 – 2002 Gaichas (2001, 2002) and the NMFS AKRO estimates from 2003 – 2006, BSAI shark catch composed from 1% to 5% of Other Species total catch (Table 3). Pacific sleeper sharks composed 69% of total shark catch, unidentified sharks 22%, salmon sharks 8%, and spiny dogfish 1% (Table 3).

From 1997 – 2001 in the BSAI, Pacific sleeper sharks were caught primarily by the Pacific cod longline fishery (30%), pollock pelagic trawl fishery (26%), Greenland turbot longline fishery (17%), flatfish trawl fishery (12%), and sablefish longline fishery (10%) (Table 5). From 1997 – 2002 in the BSAI, Pacific sleeper sharks were caught primarily in areas 521 (57%) and 517 (20%) (Table 9, Figure 2). There appears to be an increasing trend in catch of Pacific sleeper sharks from BSAI areas 521 and 517 during the years 1997 – 2002 (Figure 2) which may reflect and change in fishing effort. Catches of spiny dogfish, salmon shark, and other shark were rare in the BSAI (Tables 4, 6, 7, 8, 10, and 11; Figures 1 and 3). Pseudo-blend shark catch by gear type was not available for 2002 (Tables 4 - 7). Shark catches by species from the NMFS AKRO for the years 2003 - 2006 were not broken down by gear type and region for this assessment.

16.2.3.2 Survey Biomass Estimates

Biomass estimates are available for shark species from NMFS AFSC bottom trawl surveys conducted in the eastern Bering Sea (EBS) shelf (1979 – 2006, Tables 12 and 13), EBS slope historical (1979-1991, Tables 12 and 14), EBS slope new (2002, 2004, Tables 12 and 14), and Aleutian Islands (AI, 1979 – 2004, Tables 12 and 15). Where available, individual species biomass trends were evaluated for the three most commonly encountered shark species (spiny dogfish, Pacific sleeper shark, and salmon shark). Sharks may not be well sampled by bottom trawl surveys (as evidenced by the high

uncertainty in many of the biomass estimates). The efficiency of bottom trawl gear also varies by species, and trends in these biomass estimates should be considered, at best, a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted. In particular, pelagic shark species such as salmon sharks are encountered by the trawl gear while it is not in contact with the bottom, either on the way down or on the way up. Biomass estimates are based, in part, on the amount of time the net spends in contact with the bottom. Consequently, bottom trawl survey biomass estimates for pelagic species are unreliable. Spiny dogfish are patchily distributed, and their distribution may vary seasonally, both geographically and within the water column. This can result in highly uncertain biomass estimates. Pacific sleeper sharks are large animals and may be able to avoid the bottom trawl gear. In addition, biomass estimates for Pacific sleeper sharks are often based on a very small number of individual hauls within a given survey and a very small number of individual sharks within a haul. Consequently, these biomass estimates can be highly uncertain.

Analysis of the EBS shelf biomass time series is subject to the following caveats. The EBS shelf survey started as a crab survey in the 1960's. The survey was standardized in 1982 to its current gear type, fixed stations, and survey time period (June 1 – August 4). Prior to 1982, the set of survey stations varied greatly, and prior to 1979, the set of survey stations was very small. Consequently, surveys from 1982 to the present may be useful for identifying trends in relative abundance of commonly encountered species, while surveys between 1979 and 1982 should only be used for identifying the relative distribution of species (Gary Walters, pers. comm.).

Shark catches from the EBS shelf bottom trawl surveys were very rare, and there does not appear to be any biomass trend for shark species (Tables 12 and 13, Figure 4). Survey catches of Pacific sleeper sharks and spiny dogfish are so rare in the EBS shelf survey that relative abundance trends are probably unreliable (as evidenced by the high uncertainty in the biomass estimates). Salmon sharks were only captured in one haul during the entire time series of the EBS shelf survey.

Analysis of the EBS slope survey biomass time series is subject the following caveats. The slope survey was standardized in 2002 to its current gear type, survey strata, and survey design. Because the survey stratification changed in 2002, biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey biomass (2002 and 2004). In addition, prior to 2002, the survey utilized a mix of commercial and research vessels with various gear configurations. Consequently, surveys from 2002 and 2004 may be useful for estimating relative abundance of commonly encountered species, while surveys between 1979 and 1991 should only be used for identifying the relative distribution of species (Gary Walters, pers. Comm.).

Shark catches from the historical EBS slope bottom trawl surveys (1979 – 1991) show an increasing biomass trend for sleeper sharks but come from very few survey years (Tables 12 and 14, Figure 5). However, historical survey catches of Pacific sleeper sharks and spiny dogfish are rare and abundance trends are unreliable for these species (as evidenced

by the high uncertainty in the biomass estimates). Salmon sharks were not captured in the historical EBS slope survey (1979 – 1991).

Shark catches from the new EBS slope bottom trawl surveys (2002 and 2004) show a substantial biomass of Pacific sleeper sharks on the EBS slope in 2002 but not in 2004 (Tables 12 and 14, Figure 5). Until the 2000 EBS slope pilot survey, it was thought that bottom trawl surveys did not adequately sample large shark species such as Pacific sleeper sharks. However, Pacific sleeper sharks accounted for the third highest CPUE of the 2000 EBS pilot slope survey (Gaichas 2002). This recent information suggests that Pacific sleeper sharks can be sampled by bottom trawls and that a difference in the location and timing of EBS trawl surveys may result in differing biomass estimates for sharks in the EBS. Changes in distribution of particular species may also account for biomass fluctuations. Spiny dogfish and salmon sharks were not captured in the new EBS slope survey (2002, 2004, Table 14).

Shark catches in the AI bottom trawl surveys have been relatively rare, and there do not appear to be any biomass trends for shark species (Tables 12 and 15, Figure 6). As with the EBS shelf survey, spiny dogfish and Pacific sleeper shark catches are so rare in the AI survey that relative abundance trends are probably unreliable (as evidenced by the high uncertainty in the biomass estimates). Salmon sharks were only captured in one haul during the entire time series of the AI survey.

NMFS bottom trawl research survey catches of sharks from the EBS and AI are listed in Table 16.

16.2.4 ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Tier 6 and Tier 5 options are provided for consideration in the BSAI. However, available data do not support either Tier 6 or Tier 5 criteria for establishing ABC and OFL for sharks in the BSAI. Tier 6 criteria require a reliable catch history from 1978 – 1995, which do not exist for sharks in the BSAI prior to 1997. Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass and natural mortality. Natural mortality estimates do not exist for Pacific sleeper sharks which make up the 69% of shark biomass in the BSAI (Table 3). Natural mortality has recently been estimated for spiny dogfish in the Gulf of Alaska ($M = 0.097$, Appendix A), and is applied here as a conservative estimate of natural mortality for sharks in the BSAI. However, natural mortality estimates from spiny dogfish in the Gulf of Alaska may not be a reliable point estimate for the shark complex in the BSAI, which is dominated by Pacific sleeper sharks. Reliable point estimates of biomass do not exist for sharks in the BSAI as the efficiency of bottom trawl gear varies by species. The biomass estimates presented here should be considered at best a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted.

Tier 6

Tier 6 options for BSAI shark ABC and OFL are presented both for individual species and for sharks as a complex. If Tier 6 is adopted, then the Tier 6 option for sharks as a complex is recommended for ABC and OFL. Pacific sleeper sharks dominate the catch (69%) and may serve as an indicator species for the complex. Catches of other shark species in the BSAI are rare and consequently catch estimation for other shark species is unreliable. The time series of incidental catch for sharks for the years 1997 – 2005 is considered the best available information on exploitation rates of shark species in the BSAI and is used here to provide an approximate Tier 6 option for BSAI shark ABC and OFL.

Incidental shark catches for the years 1997 – 2002 were obtained from the pseudo-blend method (Gaichas 2001 and 2002, Table 3). Incidental shark catches for the years 2003 - 2006 were provided by the NMFS AKRO (Table 3). Because of the large size of most commercial fishing vessels in the BSAI, NMFS Observer coverage of incidental shark catch in BSAI commercial fisheries is fairly complete. However, Pacific sleeper sharks dominate the catch (69%) and other shark species are rare. Consequently, catch estimates of Pacific sleeper shark in the BSAI during the years 1979 – 2006 are probably reliable, but catch estimates for other shark species may not be reliable.

BSAI Tier 6 calculations by species and total of all species (mt).

BSAI Tier 6 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark complex
Average catch (1997-2005) ¹	9	445	46	117	617
ABC	7	334	35	88	463
OFL	9	445	46	117	617

Tier 5

Tier 5 options for BSAI shark ABC and OFL are presented both for individual species and for sharks as a complex. If Tier 5 is adopted, then the Tier 5 option for sharks as a complex is recommended with Pacific sleeper sharks as an indicator species subject to

¹ Table 3. Estimated incidental catch (mt) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species and for the total shark complex. Years 1997 – 2002 from the NMFS REFM pseudo-blend catch estimation procedure (Gaichas 2001, 2002). Years 2003 – 2005 from NMFS AKRO.

the following caveats. Tier 5 methodology for BSAI sharks as a complex is presented as natural mortality of Gulf of Alaska spiny dogfish (0.097, Appendix A) multiplied by total BSAI shark biomass. The authors are uncomfortable applying the natural mortality of spiny dogfish to the shark complex in the BSAI which is dominated by Pacific sleeper sharks. However, natural mortality of spiny dogfish is considered a conservative estimate of natural mortality for sharks in the BSAI. In addition, BSAI shark biomass estimates in the BSAI are highly variable and may be unreliable.

BSAI Tier 5 calculations by species and total of all species (mt).

BSAI Tier 5 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other sharks	Total shark complex²
M ^{3,4}	0.097	0.097	0.18	0.097	0.097
Average biomass					
Eastern Bering Sea shelf (1996 – 2006) ⁵	29	2,036	0	0	2,064
Eastern Bering Sea slope (2002 and 2004) ⁶	0	13,853	0	0	13,853
Aleutian Islands (1997, 2000, 2002, 2004, and 2006) ⁷	20	1,351	179	0	1,549
Total of average biomass	49	17,239	179	0	17,467
ABC	4	1,254	24	0	1,271
OFL	5	1,672	32	0	1,694

² Table 12. Total shark complex biomass estimates (mt) from AFSC bottom trawl surveys in the eastern Bering Sea (EBS), and Aleutian Islands (AI); Natural mortality (0.097) from *Squalus acanthias* in the Gulf of Alaska is considered a conservative estimate of natural mortality for the BSAI shark complex.

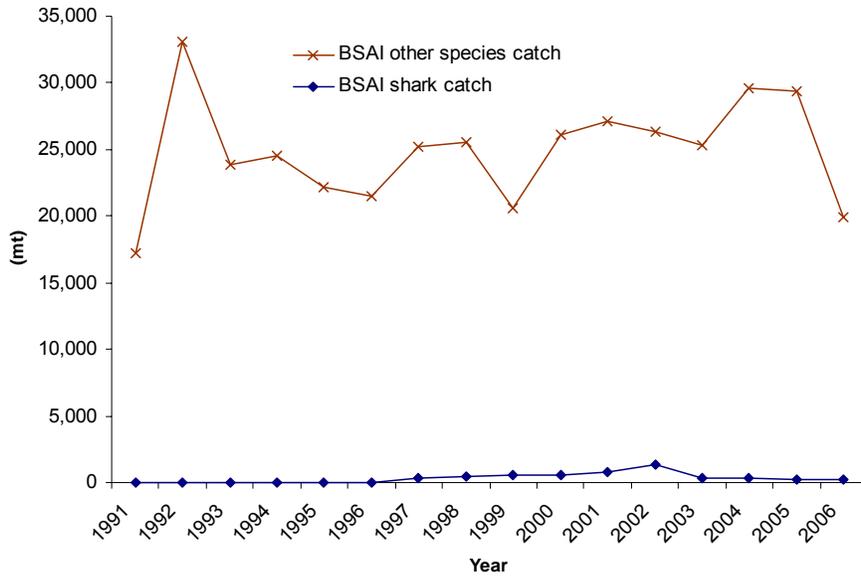
³ Natural mortality (0.097) from *Squalus acanthias* in the Gulf of Alaska – Appendix A.

⁴ Natural mortality for *Lamna ditropis* from Goldman (2002-B), average of minimum .091 and maximum 0.255 natural mortality for all ages.

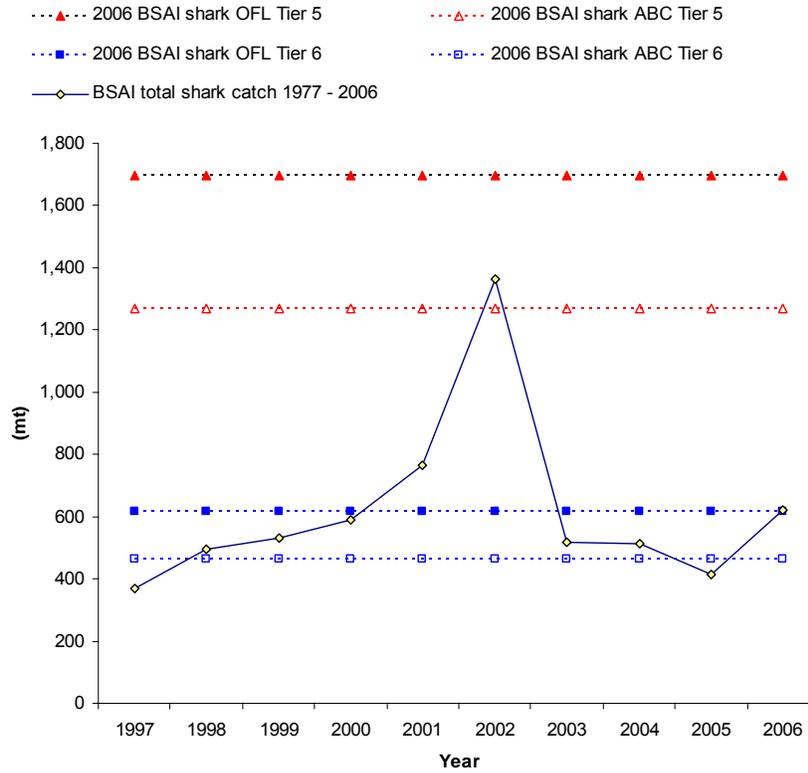
⁵ Table 13.

⁶ Table 14.

⁷ Table 15.



BSAI total shark catch has been low relative to BSAI other species catch.



BSAI total shark catch per year plotted relative to 2006 ABC and OFL options for the BSAI shark complex under Tier 5 and Tier 6.

16.2.5 ECOSYSTEM CONSIDERATIONS

16.2.5.1 Ecosystem Effects on Stock and Fishery Effects on Ecosystem

Understanding shark species population dynamics is fundamental to describing ecosystem structure and function in the Bering Sea. Shark species are top level predators as well as scavengers and likely play an important ecological role. Studies designed to determine the ecological roles of spiny dogfish, Pacific sleeper sharks, and salmon sharks are ongoing and will be critical to determine the affect of fluctuations in shark populations on community structure in the BSAI.

Spiny dogfish

Spiny dogfish have been shown to be opportunistic feeders (Alverson and Stansby 1963), not wholly dependent on one food source. Small dogfish are limited to consuming smaller fish and invertebrates, while the larger animals will eat a wide variety of foods (Bonham 1954). Diet changes are consistent with the changes of the species assemblages in the area by season (Laptikhovsky et al. 2001). Atlantic spiny dogfish can eat twice as much in summer as in winter (Jones and Geen 1977). Spiny dogfish have also been shown to prey heavily on outmigrating salmon smolts (Beamish et al. 1992).

Pacific sleeper shark

New information on diet, depth and movement behavior of pacific sleeper sharks is described in Sigler et al. (2006), and Hulbert et al. (2006).

Salmon Shark

Salmon sharks are opportunistic feeders, sharing the highest trophic level of the food web in subarctic Pacific waters with marine mammals and seabirds (Brodeur 1988, Nagasawa 1998, Goldman and Human 2004). They feed on a wide variety of prey, including salmon (*Oncorhynchus*), rockfishes (*Sebastes*), sablefish (*Anoplopoma fimbria*), lancetfish (*Alepisaurus*), daggerteeth (*Anotopterus*), lumpfishes (*Cyclopteridae*), sculpins (*Cottidae*), Atka mackerel (*Pleurogrammus*), mackerel (*Scomber*), pollock and tomcod (*Gadidae*), herring (*Clupeidae*), spiny dogfish (*Squalus acanthias*), tanner crab (*Chionocetes*), squid, and shrimp (Sano 1960 and 1962, Farquhar 1963, Hart 1973, Urquhart 1981, Compagno 1984 and 2001, Nagasawa 1998). Incidental catch in the central Pacific has been significantly reduced since the elimination of the drift gillnet fishery, and the population appears to have rebounded to its former levels (Yatsu 1993, H. Nakano pers. comm.). Additionally, recent demographic analyses support the contention that salmon shark populations in the eastern and western North Pacific are stable at this time (Goldman 2002-b). Seasonal foraging movements and migratory patterns of salmon sharks in the northeast Pacific Ocean have been described in Hulbert et al. (2005) and Weng et al. (2005).

16.2.5.2 Data Gaps and Research Priorities

Data limitations are severe for shark species in the BSAI, and effective management of sharks is extremely difficult with the current limited information. Gaps include inadequate catch estimation, unreliable biomass estimates, lack of size frequency collections, and a lack of life history information including age and maturity – especially in regard to Pacific sleeper sharks. Improvements have been made in life history collections for salmon shark and spiny dogfish. An improvement was made with the addition of incidental catch estimates provided for 2003, 2004, 2005, and 2006 by the NMFS AKRO. The NMFS AKRO should be congratulated on getting these data out in a timely manner and should be encouraged to continue to make this data available to NMFS stock assessment biologists in the future. Regardless of management decisions regarding the future structure for the Other Species management category, it is essential that we continue to improve shark species fishery and survey sampling with the collection of biological data from sharks captured in the commercial fishery and on NMFS bottom trawl surveys. Currently, the NMFS Observer program does not measure the lengths of sharks, and many sharks (22 %) are not identified to species. Length measurements from the fishery are critical for determining the effect of commercial catch on shark populations in the BSAI. Identification of sharks to species in the BSAI is necessary in order to accurately determine whether any individual species within the complex are at risk of over fishing. A special project is underway with the NMFS Observer Program to take length measurements of sharks and identify sharks to species in the future.

16.2.6 SUMMARY

There is no evidence to suggest that over fishing is occurring for any shark species in the BSAI. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI, and most incidentally captured sharks are not retained. Spiny dogfish are allowed as retained incidental catch in some ADF&G managed fisheries, and salmon sharks are targeted by some sport fishermen in Alaska state waters. Incidental catches of shark species in the BSAI fisheries have been very small compared to catch rates of target species. Sharks have only been reported to species in the catch since 1997 and have made up from 1% to 5% of Other Species catch from 1997 – 2005. Preliminary comparisons of incidental catch rates with available biomass by species suggest that current levels of incidental catches are low relative to available biomass for Pacific sleeper sharks in the BSAI. In the BSAI, average catch of Pacific sleeper sharks from 1997 – 2005 (445 metric tons) represented 2.5% of the available Pacific sleeper shark biomass from BSAI bottom trawl surveys 1996 – 2005 (Total of average Pacific sleeper shark biomass from EBS shelf, EBS slope and AI surveys for the years 1996 – 2005 is 17,647 metric tons; Tables 13, 14, and 15). Spiny dogfish and salmon sharks were rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI.

16.2.7 ACKNOWLEDGMENTS

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Table 1. Shark species in the eastern Bering Sea, and Aleutian Islands (BSAI) by scientific and common name.

Scientific name	Common name	Source of information	
		AFSC Survey	AFSC Observed Fishery
<i>Apristurus brunneus</i>	brown cat shark		X
<i>Cetorhinus maximus</i>	basking shark	X	
<i>Hexanus griseus</i>	sixgill shark	X	X
<i>Lamna ditropis</i>	salmon shark	X	X
<i>Prionace glauca</i>	blue shark		X
<i>Somniosus pacificus</i>	Pacific sleeper shark	X	X
<i>Squalus acanthias</i>	Spiny dogfish	X	X

Source: Gaichas et al. (1999, Table 1).

Table 2. Summary of NMFS AKRO blend-estimated annual catches (metric tons) for the eastern Bering Sea and Aleutian Islands (BSAI) Other Species management category, which includes sculpins, **sharks**, skates, and octopus.

Year	Eastern Bering Sea				Aleutian Islands				Grand Total
	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	
1977	35,902			35,902	16,170			16,170	52,072
1978	61,537			61,537	12,436			12,436	73,973
1979	38,767			38,767	12,934			12,934	51,701
1980	33,955	678		34,633	13,028			13,028	47,661
1981	32,363	3,138	100	35,651	7,028	246		7,274	42,925
1982	17,480	720		18,200	4,781	386		5,167	23,367
1983	11,062	1,139	3,264	15,465	3,193	439	43	3,675	19,140
1984	7,349	1,159		8,508	184	1,486		1,670	10,178
1985	6,243	4,365	895	11,503	40	1,978	32	2,050	13,553
1986	4,043	6,115	313	10,471	1	1,442	66	1,509	11,980
1987	2,673	4,977	919	8,569		1,144	11	1,155	9,724
1988		11,559	647	12,206		281	156	437	12,643
1989		4,695	298	4,993		1	107	108	5,101
1990			16,115	16,115			4,693	4,693	20,808
1991			16,261	16,261			938	938	17,199
1992			29,994	29,994			3,081	3,081	33,075
1993			20,574	20,574			3,277	3,277	23,851
1994			23,456	23,456			1,099	1,099	24,555
1995			20,923	20,923			1,290	1,290	22,213
1996			19,733	19,733			1,706	1,706	21,440
1997			23,656	23,656			1,520	1,520	25,176
1998			23,077	23,077			2,455	2,455	25,531
1999			18,884	18,884			1,678	1,678	20,562
2000			23,098	23,098			3,010	3,010	26,108
2001			23,148	23,148			4,029	4,029	27,178
2002									26,296
2003									25,373
2004									29,544
2005									29,415
2006									26,036

Data Sources: 1977- 2001 Gaichas (2002); 2002 - 2006 NMFS AKRO BLEND database, Juneau, AK 99801, as of Oct. 21, 2006.

Table 3. Estimated incidental catch (mt) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species. Years 1997 – 2002 from the NMFS REFM pseudo-blend catch estimation procedure (Gaichas 2001, 2002). Years 2003 – 2006 from NMFS AKRO.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks	Total other species	% of total
1997	4	304	7	53	368	25,176	1%
1998	6	336	18	136	497	25,531	2%
1999	5	319	30	176	530	20,562	3%
2000	9	490	23	68	590	26,108	2%
2001	17	687	24	35	764	27,178	3%
2002	9	839	47	468	1,362	26,296	5%
2003	11	280	192	33	515	25,373	2%
2004	9	420	25	60	514	29,544	2%
2005	11	328	48	26	414	29,415	1%
2006	5	255	60	299	619	26,036	2%
Average 1997 - 2005 used for Tier 6 Calculations	9.1	444.7	46.0	117.2	617.1	26,131.4	
Total - all years	87	4,258	474	1,354	6,173	261,219	
% of total	1%	69%	8%	22%	100%	2%	

Sources:

1997 – 2002; Gaichas (2002, Table 15-5).

2003 – 2006; NMFS AKRO as of October, 22, 2006.

Table 4. Estimated catches (mt) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by fishery and gear type. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by fishery and gear type is unavailable for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Atka Mackerel	TWL	0.0	0.2	0.0	0.0	2.8	3.1	7%
Flatfish	TWL	0.0	0.4	0.0	0.2	1.6	2.2	5%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Flatfish Total		0.0	0.4	0.0	0.2	1.6	2.2	5%
Other/Unknown	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Other Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Pacific Cod	TWL	0.0	0.0	0.0	0.0	0.5	0.5	1%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	JIG	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	4.1	5.6	4.9	8.6	12.2	35.4	85%
Pacific Cod		4.1	5.6	4.9	8.6	12.7	35.9	86%
Bottom Pollock	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Pelagic Pollock	TWL	0.0	0.1	0.0	0.0	0.1	0.3	1%
Pollock	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Pollock Total		0.0	0.1	0.0	0.0	0.1	0.3	1%
Rockfish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Rockfish Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.1	0.1	0%
Sablefish Total		0.0	0.0	0.0	0.0	0.1	0.1	0%
Turbot	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Turbot Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Grand Total		4.1	6.4	5.0	8.9	17.3	41.6	100%

Table 5. Estimated catches (metric tons) of Pacific sleeper sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by fishery and gear type. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by fishery and gear type is unavailable for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Atka Mackerel	TWL	0.0	0.0	2.4	0.3	27.8	30.5	1%
Flatfish	TWL	0.9	0.6	39.4	42.0	179.6	262.6	12%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.3	0.0	0.0	0.0	0.3	0%
Flatfish Total		0.9	0.9	39.4	42.0	179.6	262.9	12%
Other/Unknown	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.5	0.4	0.0	0.3	1.2	0%
Other Total		0.0	0.5	0.4	0.0	0.3	1.2	0%
Pacific Cod	TWL	7.9	32.6	3.6	0.4	12.2	56.8	3%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	JIG	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	66.9	114.1	99.7	114.3	240.5	635.4	30%
Pacific Cod		74.8	146.7	103.3	114.7	252.7	692.2	32%
Bottom Pollock	TWL	15.1	0.6	0.1	0.0	0.0	15.9	1%
Pelagic Pollock	TWL	90.0	73.8	76.7	103.8	205.7	550.0	26%
Pollock	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Pollock Total		105.2	74.4	76.8	103.8	205.7	565.9	26%
Rockfish	TWL	0.0	0.0	1.4	2.7	0.0	4.1	0%
	LGL	0.9	0.0	1.7	0.0	0.0	2.5	0%
Rockfish Total		0.9	0.0	3.0	2.7	0.0	6.7	0%
Sablefish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.4	0.2	0.6	0%
	LGL	45.3	0.0	15.1	143.3	1.7	205.4	10%
Sablefish Total		45.3	0.0	15.1	143.7	1.8	206.0	10%
Turbot	TWL	6.5	0.3	0.2	0.0	0.0	7.0	0%
	POT	0.0	0.0	0.0	0.1	0.0	0.1	0%
	LGL	70.5	113.1	78.1	83.1	19.3	364.1	17%
Turbot Total		77.0	113.5	78.2	83.2	19.3	371.2	17%
Grand Total		304.1	336.0	318.7	490.4	687.3	2,136.5	100%

Table 6. Estimated catches (mt) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by fishery and gear type. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by fishery and gear type is unavailable for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Atka Mackerel	TWL	0.1	0.0	0.2	0.0	0.4	0.7	1%
Flatfish	TWL	0.0	0.1	2.5	0.0	0.4	3.0	3%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Flatfish Total		0.0	0.1	2.5	0.0	0.4	3.0	3%
Other/Unknown	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Other Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Pacific Cod	TWL	0.0	0.0	0.1	3.6	0.0	3.7	4%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	JIG	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.8	1.1	0.2	1.2	3.3	3%
Pacific Cod		0.0	0.8	1.2	3.8	1.2	7.0	7%
Bottom Pollock	TWL	1.4	0.0	0.0	0.0	0.0	1.4	1%
Pelagic Pollock	TWL	5.3	16.2	24.7	19.5	22.5	88.2	86%
Pollock	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Pollock Total		6.7	16.2	24.7	19.5	22.5	89.6	87%
Rockfish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Rockfish Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		0.0	0.0	0.0	0.0	0.0	0.0	0%
Turbot	TWL	0.0	0.3	0.0	0.0	0.0	0.3	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.5	1.5	0.0	0.0	2.0	2%
Turbot Total		0.0	0.8	1.5	0.0	0.0	2.3	2%
Grand Total		6.8	18.0	30.0	23.3	24.4	102.6	100%

Table 7. Estimated catches (mt) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by fishery and gear type. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by fishery and gear type is unavailable for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Atka Mackerel	TWL	0.0	13.1	0.0	0.0	0.0	13.1	3%
Flatfish	TWL	0.4	0.0	0.2	1.2	0.0	1.8	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Flatfish Total		0.4	0.0	0.2	1.2	0.0	1.8	0%
Other/Unknown	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	0.0	0.0	0.3	0.0	0.0	0.3	0%
Other Total		0.0	0.0	0.3	0.0	0.0	0.3	0%
Pacific Cod	TWL	0.2	0.0	0.3	9.1	2.3	11.9	3%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	JIG	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	26.6	48.4	18.5	47.0	17.3	157.9	34%
Pacific Cod Total		26.8	48.4	18.8	56.1	19.6	169.8	36%
Bottom Pollock	TWL	0.0	0.3	0.0	0.0	0.0	0.3	0%
Pelagic Pollock	TWL	15.6	45.2	10.3	0.1	2.3	73.5	16%
Pollock	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Pollock Total		15.6	45.4	10.3	0.1	2.3	73.8	16%
Rockfish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	2.5	0.0	0.0	0.0	0.0	2.5	1%
Rockfish Total		2.5	0.0	0.0	0.0	0.0	2.5	1%
Sablefish	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	1.2	2.1	1.8	7.2	10.4	22.7	5%
Sablefish Total		1.2	2.1	1.8	7.2	10.4	22.7	5%
Turbot	TWL	0.0	1.1	1.0	0.5	0.0	2.6	1%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	LGL	6.3	25.9	143.9	2.5	2.7	181.2	39%
Turbot Total		6.3	26.9	144.9	3.0	2.7	183.8	39%
Grand Total		52.8	136.1	176.4	67.6	35.0	467.8	100%

Table 8. Estimated catches (mt) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2002 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by area is unavailable for the years 2003 – 2006.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0.0	1.7	0.0	0.0	0.0	0.0	1.5	0.0	0.1	0.6	0.1	0.0	0.0	0.1	0.0	0.0	0.0	4.1
1998	0.0	3.1	0.0	0.1	0.0	0.0	1.3	0.2	0.1	0.8	0.1	0.0	0.0	0.4	0.1	0.0	0.0	6.4
1999	0.0	2.4	0.0	0.1	0.0	0.0	1.0	0.4	0.1	0.8	0.1	0.0	0.0	0.1	0.0	0.0	0.0	5.0
2000	0.0	5.8	0.0	0.2	0.0	0.0	1.9	0.1	0.2	0.4	0.0	0.0	0.0	0.2	0.1	0.0	0.0	8.9
2001	0.0	5.7	0.1	1.2	0.0	0.2	3.8	0.6	0.2	1.3	0.1	0.0	0.0	1.0	2.4	0.8	0.0	17.3
2002	0.0	3.9	0.0	0.2	0.0	0.3	1.9	0.0	0.0	2.8	0.1	0.0	0.0	0.1	0.0	0.0	0.0	9.4
Total	0.0	22.6	0.1	1.8	0.0	0.5	11.4	1.3	0.7	6.7	0.4	0.0	0.0	2.0	2.6	0.8	0.0	51.0
% of Total	0%	44%	0%	4%	0%	1%	22%	3%	1%	13%	1%	0%	0%	4%	5%	2%	0%	100%

Table 9. Estimated catches (mt) of Pacific sleeper sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2002 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by area is unavailable for the years 2003 – 2006.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0.0	1.0	0.0	4.7	0.0	0.0	76.2	35.4	32.5	108.5	8.1	9.7	0.0	26.9	0.9	0.0	0.0	304.1
1998	0.0	0.4	0.0	1.9	0.5	0.0	44.0	36.7	36.0	193.8	4.1	15.5	0.0	3.2	0.0	0.0	0.0	336.0
1999	0.0	0.5	0.0	1.5	0.0	0.0	76.4	18.9	2.8	163.8	7.7	15.6	0.0	6.8	24.7	0.0	0.0	318.7
2000	0.0	2.3	0.0	3.6	0.0	0.1	93.8	2.1	26.9	199.4	5.6	12.5	0.0	1.4	48.7	93.9	0.0	490.4
2001	0.0	11.7	0.0	6.4	0.0	0.0	142.5	9.3	48.6	420.5	3.2	9.6	0.0	26.7	8.7	0.0	0.0	687.3
2002	0.0	36.8	0.0	5.7	0.0	0.0	172.0	0.2	9.3	601.8	5.7	2.5	0.0	1.9	0.1	2.4	0.0	838.5
Total	0.0	52.7	0.0	23.9	0.5	0.2	605.0	102.5	156.1	1,687.8	34.5	65.5	0.0	66.9	83.1	96.3	0.0	2,975.0
% of Total	0%	2%	0%	1%	0%	0%	20%	3%	5%	57%	1%	2%	0%	2%	3%	3%	0%	100%

Table 10. Estimated catches (mt) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2002 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by area is unavailable for the years 2003 – 2006.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0.0	1.3	0.0	0.2	0.0	0.0	4.0	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.2	0.0	0.0	6.8
1998	0.0	2.0	0.0	0.5	0.0	0.0	10.3	0.2	1.4	2.5	0.0	0.1	0.0	0.0	0.0	1.0	0.0	18.0
1999	0.0	2.0	0.0	1.5	0.0	0.0	18.9	0.0	0.0	7.1	0.0	0.0	0.0	0.2	0.1	0.1	0.0	30.0
2000	0.0	4.5	0.0	0.8	0.0	0.0	6.0	0.0	0.4	7.8	0.0	0.3	0.0	0.1	3.4	0.0	0.0	23.3
2001	0.0	2.3	0.0	3.3	0.0	0.1	8.2	0.0	2.0	7.5	0.5	0.3	0.0	0.0	0.4	0.0	0.0	24.4
2002	0.0	2.9	0.0	4.3	0.0	0.0	11.3	0.0	1.2	26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.6
Total	0.0	15.0	0.0	10.7	0.0	0.1	58.6	0.2	5.3	52.6	0.5	0.7	0.0	0.4	4.0	1.1	0.0	149.2
% of Total	0%	10%	0%	7%	0%	0%	39%	0%	4%	35%	0%	0%	0%	0%	3%	1%	0%	100%

Table 11. Estimated catches (mt) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2002 from the pseudo-blend catch estimation procedure (Gaichas 2002). Catch by area is unavailable for the years 2003 – 2006.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0.0	6.8	0.0	0.6	0.0	0.0	9.3	6.3	1.7	23.0	1.9	3.0	0.0	0.1	0.1	0.0	0.0	52.8
1998	0.0	6.6	0.0	0.7	0.0	0.1	10.9	2.0	6.4	90.4	1.4	2.1	0.0	13.9	1.6	0.0	0.0	136.1
1999	0.0	0.3	0.0	0.2	0.0	0.0	3.7	3.0	2.6	21.6	3.9	140.7	0.0	0.4	0.0	0.0	0.0	176.4
2000	0.0	0.5	0.0	0.0	0.0	0.1	8.2	3.2	0.1	46.1	1.7	0.0	0.0	0.5	7.2	0.0	0.0	67.6
2001	0.0	0.7	0.0	0.2	0.0	0.0	7.5	0.0	0.3	15.2	0.7	0.0	0.0	0.0	10.4	0.0	0.0	35.0
2002	0.0	14.9	0.0	1.7	0.0	0.2	39.5	14.5	11.1	196.3	9.7	145.8	0.0	14.8	19.3	0.0	0.0	467.8
Total	0.0	29.7	0.0	3.4	0.0	0.4	79.0	29.0	22.3	392.6	19.4	291.6	0.0	29.6	38.6	0.0	0.0	935.7
% of Total	0%	3%	0%	0%	0%	0%	8%	3%	2%	42%	2%	31%	0%	3%	4%	0%	0%	100%

Table 12. Total shark biomass estimates (mt) from AFSC bottom trawl surveys in the eastern Bering Sea (EBS), and Aleutian Islands (AI).

Year	EBS Shelf	EBS Slope	AI
1979	389	0	
1980	0		0
1981	0	1	
1982	0	20	
1983	379		255
1984	0		
1985	47	545	
1986	0		2,009
1987	223		
1988	4,057	1,993	
1989	0		
1990	0		
1991	0	1,235	2,926
1992	2,564		
1993	0		
1994	5,012		420
1995	1,005		
1996	2,804		
1997	37		2,497
1998	2,378		
1999	2,079		
2000	1,487	(Pilot survey)	2,663
2001	0		
2002	5,602	25,445	1,429
2003	734		
2004	3,121	2,260	1,017
2005	1,523		
2006	2,944		138

Source: Gaichas et al. (1999, Table 15), Gaichas (2003, Table 16-8). EBS Shelf and Slope updated Oct, 2004 (Pers. Comm., Gary Walters). 2005 EBS shelf 1,523 mt shark (reported as sleeper sharks).

Table 13. Eastern Bering Sea shelf AFSC trawl survey estimates of individual shark species total biomass (metric tons) with cv and number of hauls (Gary Walters Pers. Comm. October, 2004). 2005 EBS shelf 1,523 mt shark (reported as sleeper sharks).

Year	Total hauls		Spiny Dogfish	Sleeper Shark	Salmon Shark
1979	452	Hauls with catch	4	0	0
		Biomass	389		
		CV of biomass	0.564		
1980	342	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1981	290	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1982	329	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1983	354	Hauls with catch	2	0	0
		Biomass	379		
		CV of biomass	0.827		
1984	355	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1985	353	Hauls with catch	1	0	0
		Biomass	47		
		CV of biomass	0.991		
1986	354	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1987	342	Hauls with catch	3	0	0
		Biomass	223		
		CV of biomass	0.602		
1988	353	Hauls with catch	1	0	1
		Biomass	249		3,808
		CV of biomass	1.001		1.000

Table 13. Continued.

Year	Total hauls		Spiny Dogfish	Sleeper Shark	Salmon Shark
1989	353	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1990	352	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1991	351	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1992	336	Hauls with catch	0	2	0
		Biomass		2,564	
		CV of biomass		0.722	
1993	355	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1994	355	Hauls with catch	0	2	0
		Biomass		5,012	
		CV of biomass		0.816	
1995	356	Hauls with catch	0	1	0
		Biomass		1,005	
		CV of biomass		1.000	
1996	355	Hauls with catch	0	2	0
		Biomass		2,804	
		CV of biomass		0.817	
1997	356	Hauls with catch	1	0	0
		Biomass	37		
		CV of biomass	1.000		
1998	355	Hauls with catch	1	1	0
		Biomass	254	2,124	
		CV of biomass	1.000	1.000	

Table 13. Continued.

Year	Total hauls		Spiny Dogfish	Sleeper Shark	Salmon Shark
1999	353	Hauls with catch	0	2	0
		Biomass		2,079	
		CV of biomass		0.708	
2000	352	Hauls with catch	0	1	0
		Biomass		1,487	
		CV of biomass		1.000	
2001	355	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
2002	355	Hauls with catch	0	3	0
		Biomass		5,602	
		CV of biomass		0.648	
2003	356	Hauls with catch	0	1	0
		Biomass		734	
		CV of biomass		1.000	
2004	356	Hauls with catch	1	2	0
		Biomass	28	3,093	
		CV of biomass	0.999	0.711	
2005	39	Hauls with catch	0	2	0
		Biomass		1,532	
		CV of biomass		0.748	
2006	53	Hauls with catch	0	2	0
		Biomass		2,944	
		CV of biomass		0.780	

Table 14. Eastern Bering Sea slope AFSC trawl survey estimates of individual shark species total biomass (metric tons) with cv, and number of hauls (Gary Walters Pers. Comm. October, 2004).

Year	Total hauls		Spiny Dogfish Historical Slope Survey	Sleeper Shark	Salmon Shark
1979	105	Hauls with catch	0	0	0
		Biomass			
		cv of Biomass			
1981	205	Hauls with catch	1	0	0
		Biomass	1		
		cv of Biomass	0.832		
1982	299	Hauls with catch	3	1	0
		Biomass	8	12	
		cv of Biomass	0.726	1.022	
1985	325	Hauls with catch	3	19	0
		Biomass	2	543	
		cv of Biomass	0.655	0.101	
1988	131	Hauls with catch	0	10	0
		Biomass		1,993	
		cv of Biomass		0.389	
1991	85	Hauls with catch	0	6	0
		Biomass		1,235	
		cv of Biomass		0.441	
New Slope Survey					
2002	141	Hauls with catch	0	15	0
		Biomass		25,445	
		cv of Biomass		0.874	
2004	231	Hauls with catch	0	24	0
		Biomass		2,260	
		cv of Biomass		0.342	

Table 15. Aleutian Islands AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls.

Year	Total hauls		Spiny Dogfish	Sleeper Shark	Salmon shark
1980	129	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			
1983	372	Hauls with catch	3	3	0
		Biomass	2.3	253.5	
		CV of biomass	0.61	0.65	
1986	443	Hauls with catch	6	12	0
		Biomass	13.8	1,994.9	
		CV of biomass	0.51	0.36	
1991	331	Hauls with catch	0	3	0
		Biomass		2,926.5	
		CV of biomass		0.69	
1994	381	Hauls with catch	9	3	0
		Biomass	47.0	373.5	
		CV of biomass	0.37	0.64	
1997	397	Hauls with catch	2	10	0
		Biomass	11.4	2,485.7	
		CV of biomass	0.71	0.29	
2000	419	Hauls with catch	3	3	0
		Biomass	25.0	2,638.3	
		cv of Biomass	0.62	0.57	
2002	417	Hauls with catch	0	4	1
		Biomass		536.2	893.0
		CV of biomass		0.55	1.00
2004	420	Hauls with catch	0	2	0
		Biomass		1,016.9	
		CV of biomass		0.96	
2006	358	Hauls with catch	6	1	0
		Biomass	61.8	76.4	
		CV of biomass	0.49	1.00	

Table 16. Research catches (metric tons) of sharks between 1977 and 2004 in the eastern Bering Sea (EBS), and Aleutian Islands (AI). Catches do not include longline surveys.

Year	EBS	AI	Total
1977	0	-	0.14
1978	-	-	1.44
1979	0.03	-	1.03
1980	0	0.3	1.16
1981	0.07	-	2.3
1982	0.16	0.02	0.54
1983	0.01	0.26	1.3
1984	-	-	3.12
1985	0.59	-	1.55
1986	-	2.21	3.59
1987	0.01	-	3.56
1988	1.06	-	1.33
1989	0.07	-	0.94
1990	0	-	3.52
1991	0.56	0.52	1.23
1992	0.09	-	0.21
1993	-	-	5.03
1994	0.17	0.13	0.73
1995	0.04	-	0.61
1996	0.1	-	3.58
1997	0.11	0.42	1.05
1998	0.09	-	0.67
1999	0.08		
2000	8.50		
2001	-		
2002	5.74		
2003	0.03		
2004	0.76		

Sources: Gaichas et al. (1999, Table 3), Gaichas (2002, Table 15-9), Gary Walters (Pers. Comm. Oct 2004).

BSAI Statistical and Reporting Areas

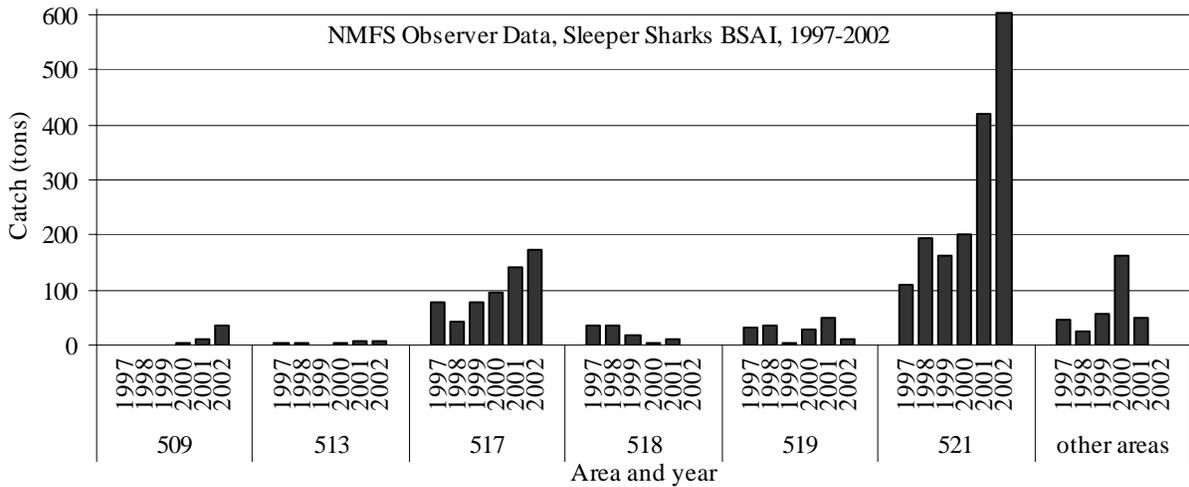
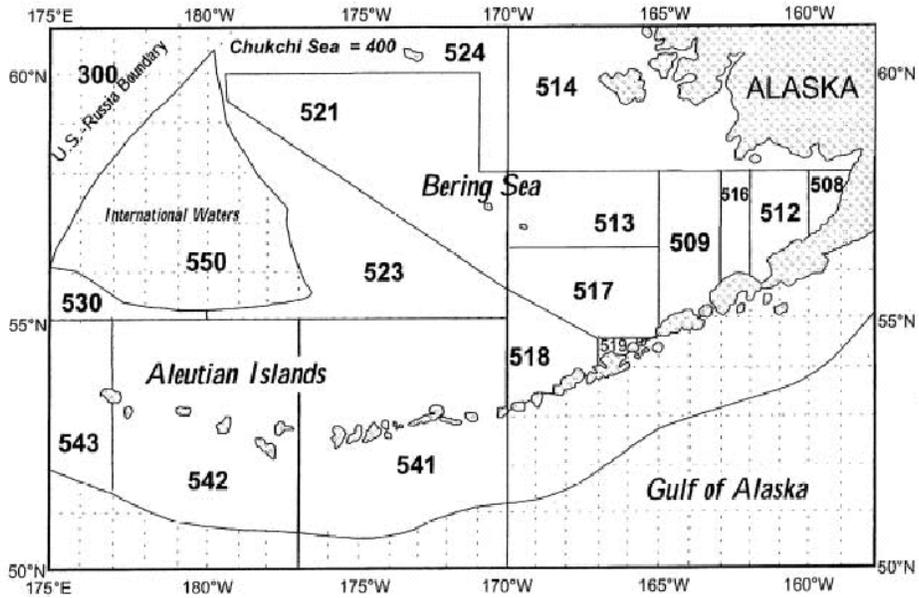


Figure 2. Pacific sleeper shark incidental catch from 1997-2002 using the pseudo-blend catch estimation procedure (Gaichas 2002) by statistical areas in the Bering Sea and Aleutian Islands.

BSAI Statistical and Reporting Areas

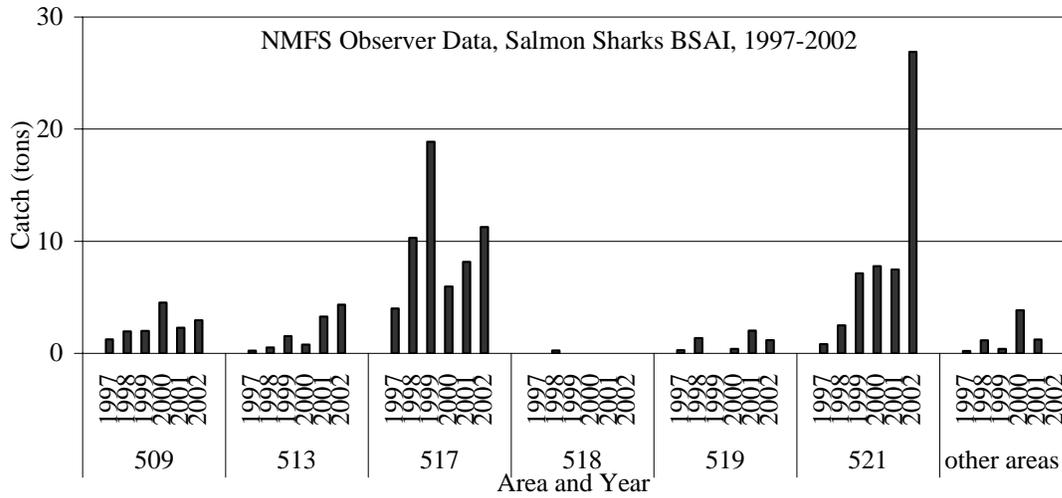
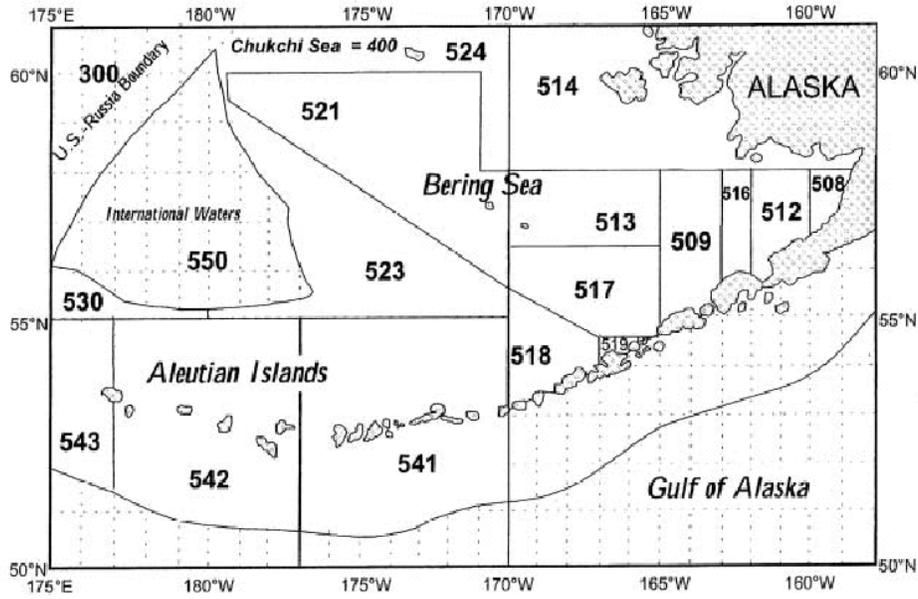


Figure 3. Salmon shark incidental catch from 1997-2002 using the pseudo-blend catch estimation procedure (Gaichas 2002) by statistical areas in the Bering Sea and Aleutian Islands.

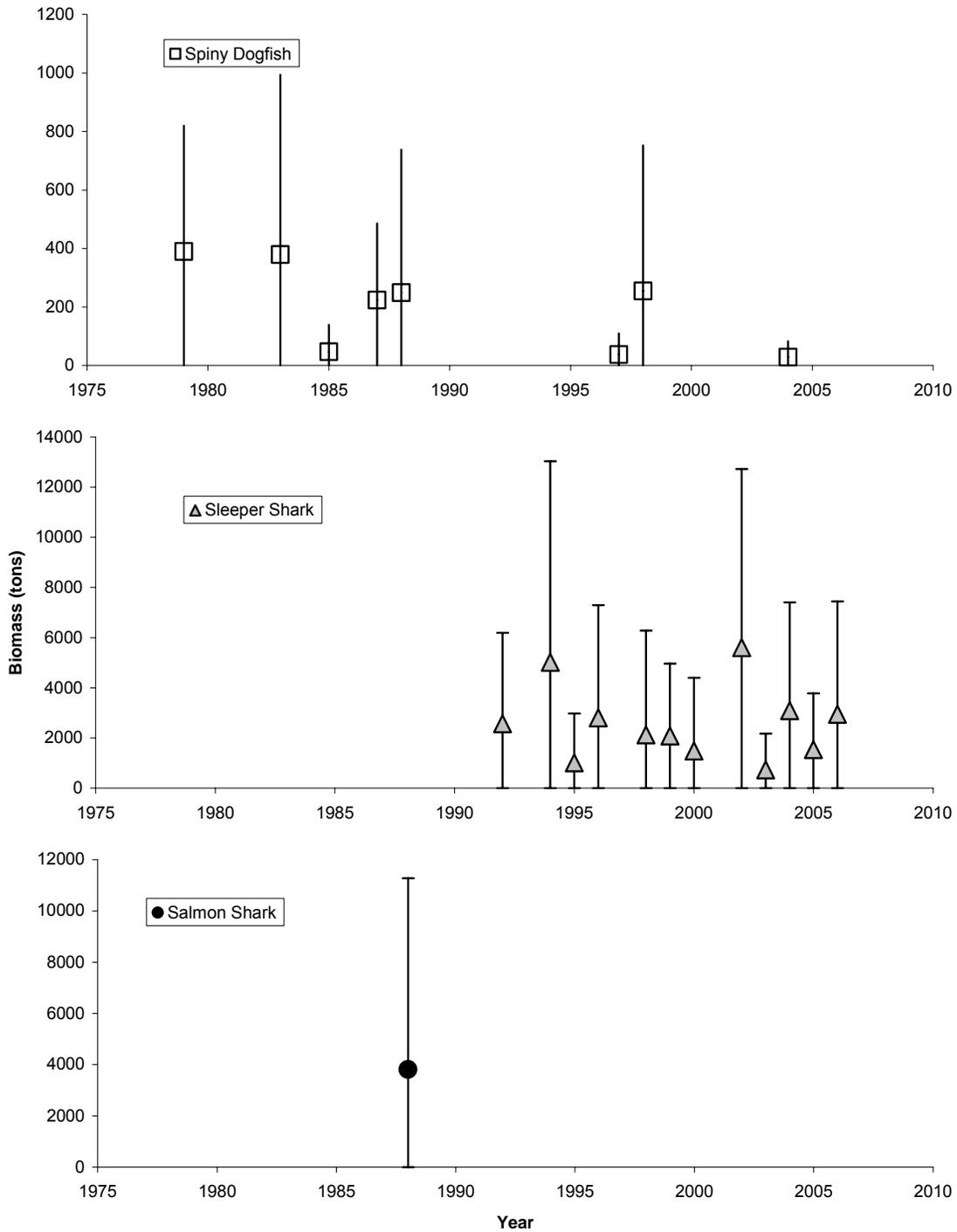


Figure 4. Trends in eastern Bering Sea shelf AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS shelf biomass trends is subject to following time series caveats. The EBS shelf survey started as a crab survey in the 1960's. The survey was standardized in 1982 to its current gear type, fixed stations, and survey time period (June 1 – August 4). Prior to 1982, the set of survey stations varied greatly, and prior to 1979 the set of survey stations was very small.

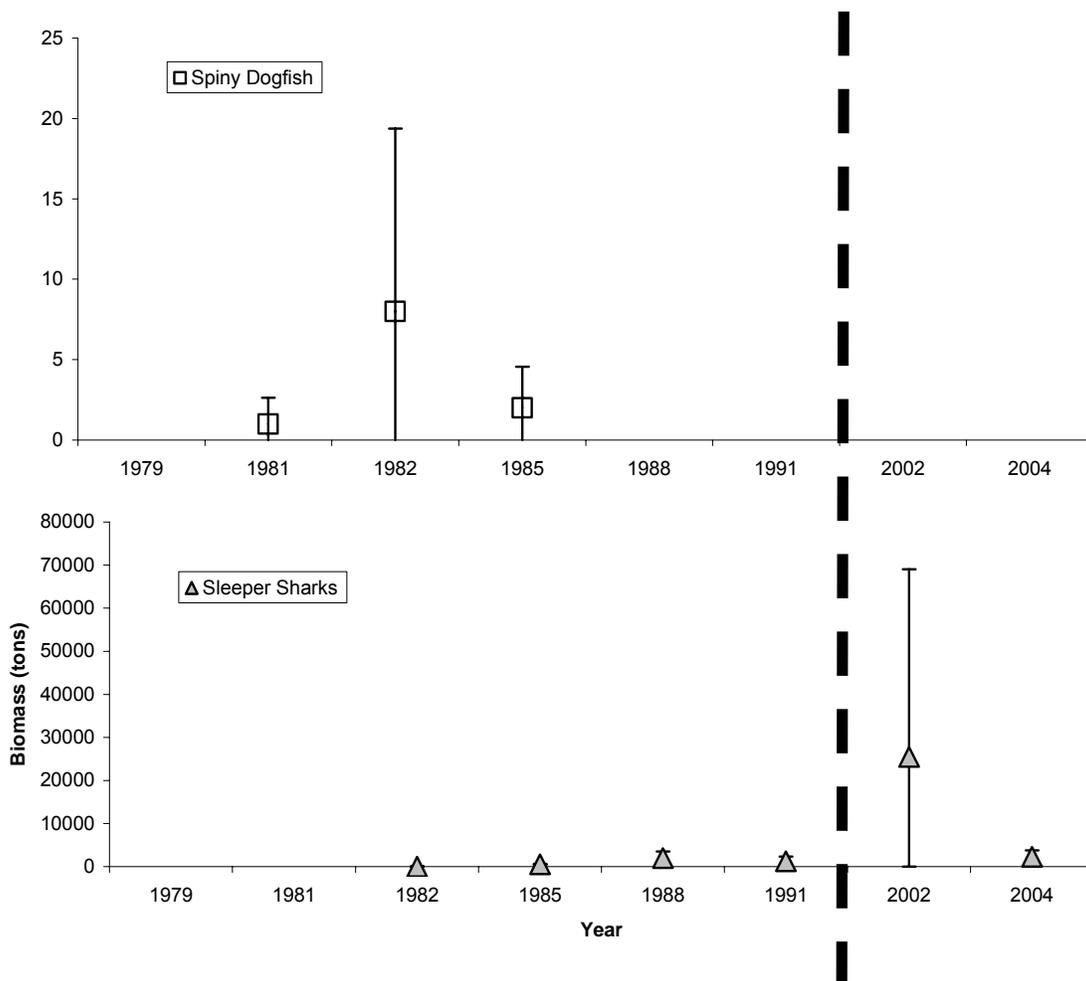


Figure 5. Trends in eastern Bering Sea slope AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Dashed line indicates beginning of new EBS slope survey (2002, 2004), which is not comparable to the historical survey (1979 – 1991). Analysis of EBS slope survey biomass trends is subject the following time series caveats. The slope survey was standardized in 2002 to its current gear type, survey strata, and survey design. Because the survey stratification changed in 2002, biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey biomass (2002 and 2004). In addition, prior to 2002, the survey utilized a mix of commercial and research vessels with various gear configurations.

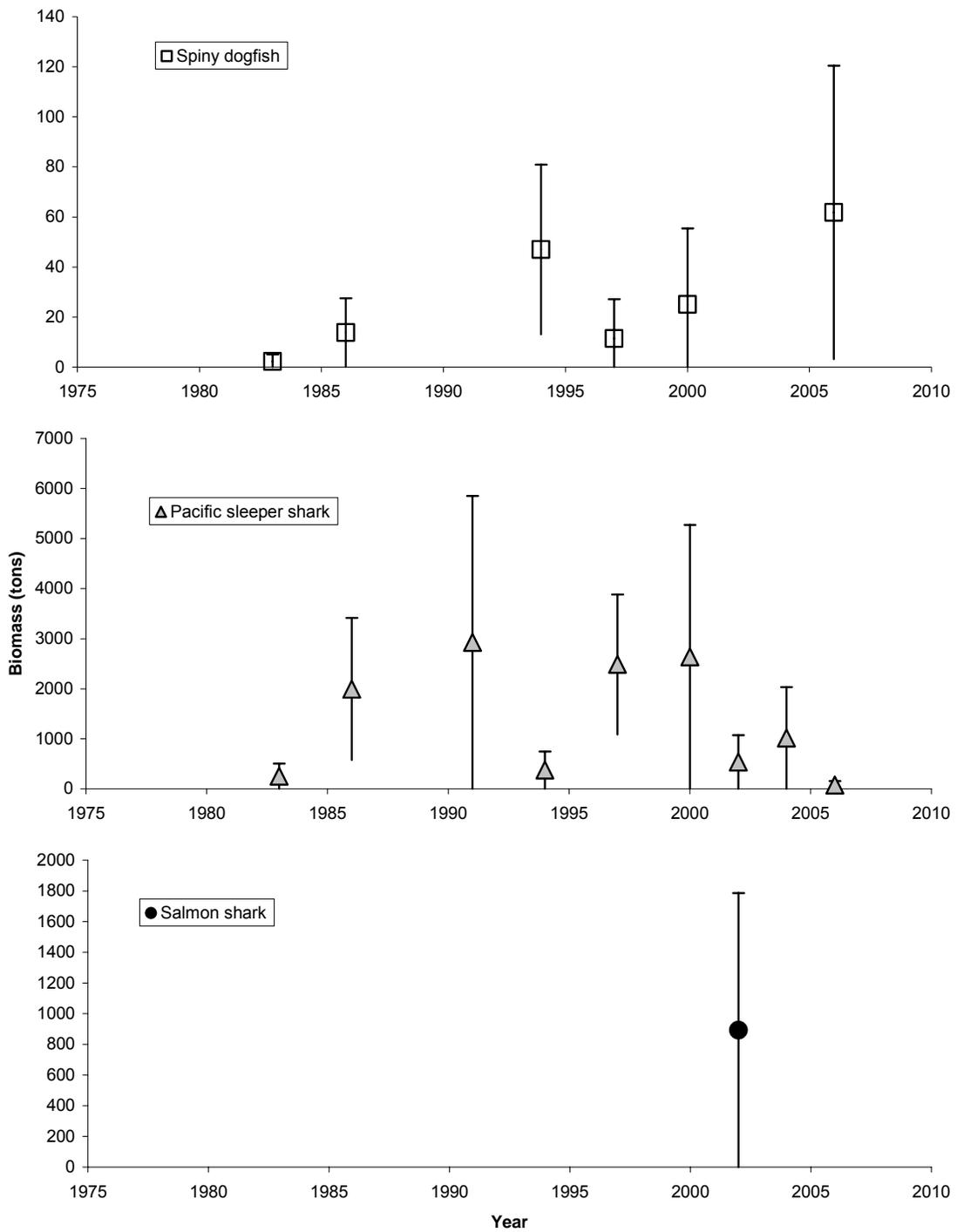


Figure 6. Trends in Aleutian Islands AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of AI survey biomass trends is subject the following time series caveats. Catchability of sharks in the survey is unknown.

Appendix A – Gulf of Alaska Spiny Dogfish Natural Mortality

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A preliminary estimate of natural mortality (M) was calculated for Gulf of Alaska spiny dogfish as 0.097 using a variety of published methods that incorporated life history traits of spiny dogfish collected from the Gulf of Alaska during the years 2004, 2005 and 2006. This preliminary estimate is part of an ongoing PhD project by Cindy Tribuzio, and final estimates are expected for the 2007 SAFE report. Ten methods of estimating M were examined: Alverson & Carney 1975; Pauly 1980 (length and weight versions), Hoenig 1983, Petersen & Wroblewski 1984, Gunderson & Dygert 1988 (using four methods of estimating gonad somatic index, GSI), Chen & Watanabe 1989 and Jensen 1996 (see table 1 for equations and inputs to each model). All but two methods were rejected either due to the design of the equation not including species of sharks or the equations returning unreasonable results. Pauly's (1980) length based model was designed with 184 species of fish, two of which were sharks. This model also incorporates two life history traits, as opposed to one, and an environmental variable. The Gunderson & Dygert (1988) model was designed based on 20 stocks of North Pacific fish, including spiny dogfish and includes a measure of reproductive effort. The two models returned estimates of M of 0.104 and 0.097, respectively (0.103-0.104 and 0.050-0.167 95% confidence interval, respectively). The value of M for spiny dogfish in the Gulf of Alaska (0.097) from the Gunderson & Dygert (1988) model is preferred because the model development included spiny dogfish and model design included a measure of reproductive success. The recommended value of M (0.097) from the Gunderson & Dygert (1988) model results was also more conservative relative to Pauly's (1980) length based model. Both Pauly's (1980) length based model and Gunderson & Dygert (1988) model are comparable to the previously published estimate of M from British Columbia spiny dogfish of 0.094 (Wood et al. 1979).

Appendix A - Table 1

Source	Equation	Variables and Inputs	M est (range)
1 Petersen & Wroblewski 1984	$M=1.92W_{\infty}^{-0.25}$	$W_{\infty}=4.798$ (1.807, 11.093 95% CI)	1.318(1.078-1.666)
2 Pauly 1980 (1), length	$\ln M = -0.0152 - 0.279 \ln(TL_{\text{ext}^{\infty}}) + 0.6543 \ln \kappa + 0.4634 \ln T$	$TL_{\text{ext}^{\infty}} = 101.48$ (98.694, 104.129 95% CI), $\kappa = 0.060$ (0.056, 0.066 95% CI), $T = 6.65^{\circ}\text{C}$	0.104(0.103-0.104)
3 Pauly 1980 (2) weight	$\ln M = -0.4852 - 0.0824 \ln(W_{\infty}) + 0.6757 \ln \kappa + 0.4627 \ln T$	$W_{\infty} = 4.798$ (1.807, 11.093 95% CI), $\kappa = 0.060$ (0.056, 0.066 95% CI), $T = 6.65^{\circ}\text{C}$	0.194(0.181-0.211)
4 Hoenig 1983	$M = e^{1.44 - 0.982 \ln(t_{\text{max}})}$	$t_{\text{max}} = 107$ years	0.043
5 Aliverson & Carney 1975	$M = 3\kappa / (e^{0.38\kappa t_{\text{max}}} - 1)$	$\kappa = 0.060$ (0.056, 0.066 95% CI), $t_{\text{max}} = 107$ years	0.017(0.015-0.019)
6 Jensen 1996 (1)	$M = 1.65 / t_{50\% \text{mature}}$	$t_{50\% \text{mature}} = 35.5$ (35, 35.9 95% CI)	0.046(0.046-0.047)
7 Jensen 1996 (2)	$M = 1.5\kappa$	$\kappa = 0.060$ (0.056, 0.066 95% CI)	0.090(0.084-0.099)
8 Jensen 1996 (3)	$M = 1.6\kappa$	$\kappa = 0.060$ (0.056, 0.066 95% CI)	0.096(0.090-0.105)
9 Gunderson & Dygert 1988 (1)	$M = 0.03 + 1.68 \text{GSI}$, GSI=ovary weight/viscerated weight	GSI=0.010-0.096	0.097(0.047-0.191)
1 0 Gunderson & Dygert 1988 (2)	$M = 0.03 + 1.68 \text{GSI}$, GSI=ovary weight/whole weight	GSI=0.007-0.073	0.081(0.042-0.153)
1 1 Gunderson & Dygert 1988 (3)	$M = 0.03 + 1.68 \text{GSI}$, GSI=standardized ovary weight/viscerated weight	GSI=0.000857-0.00957	0.037(0.031-0.046)
1 2 Gunderson & Dygert 1988 (4)	$M = 0.03 + 1.68 \text{GSI}$, GSI=standardized ovary weight/whole weight	GSI=0.000581-0.00833	0.035(0.031-0.044)
1 3 Chen & Watanabe 1989	$M(t, t < t_m) = \kappa / (1 - e^{-\kappa(t-t_0)})$, $M(t, t \geq t_m) = \kappa / (a_0 + a_1(t-t_m) + a_2(t-t_m)^2)$	$\kappa = 0.060$ (0.056, 0.066 95% CI), $t_{\text{max}} = 107$ years, $a_0 = 0.881$ (0.859, 0.906 95% CI), $a_1 = 0.00713$ (0.00788, 0.00617 95% CI), $a_2 = -0.00021$ (-0.00022, -0.00020 95% CI)	0.108(0.064-1.033)

footnotes:

κ , $TL_{\text{ext}^{\infty}}$, W_{∞} estimated from von Bertalanffy growth model, confidence intervals estimated via 5000 rep bootstrap
T, overall average temp of GOA, from GAK1 time series

t_{max} actual observed maximum age from McFarlane, King and Bargmann AAAS 2004

$t_{50\% \text{mature}}$ from Saunders and McFarlane, 1993

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