18 BSAI Sharks

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EXECUTIVE SUMMARY

Summary of Major Changes

There are no major changes to the stock assessment.

Input Data

Incidental catch for sharks by species in the BSAI was updated for 2006 and 2007 with estimates provided by the NMFS Alaska Regional Office (AKRO - as of October 5, 2007). Bottom trawl survey biomass estimates were updated for the 2007 Eastern Bering Sea shelf.

Assessment Methodology

We recommend that sharks be placed in Tier 6 for ABC and OFL calculations. Last year both Tier 5 and Tier 6 computations were presented for BSAI sharks. The Tier 6 calculation was based on using 1997 – 2005 as the base period for incidental catches as an alternative to 1978 – 1995 period typically specified for Tier 6. The SSC recommended placement of sharks in Tier 6 with this alternative base period and fixing the final year at 2005. Thus the Tier 6 ABC and OFL remains identical to that presented last year.

ABC and OFL Calculations

	Tier 6 BSAI sharks 2008 methodology	Tier 6 BSAI sharks 2008 recommendation (mt)
ABC	0.75*Average catch (1997-2005)	463
OFL	Average catch (1997-2005)	617

Tier 5 options for BSAI shark ABC and OFL were presented last year for individual species and for sharks as a complex. We do not recommend Tier 5 be used for sharks because of the unreliability of biomass estimates. However we continue to provide Tier 5 calculations given that the Plan Team recommended that sharks be placed in Tier 5. Tier 5 computations are updated by including the biomass estimates from the 2007 Eastern Bering Sea Shelf survey. Tier 5 methodology for BSAI spiny dogfish, Pacific sleeper sharks, and other sharks is based on natural mortality of 0.097 for Gulf of Alaska spiny dogfish. For salmon sharks the Tier 5 calculation is based on a natural mortality estimate of 0.18. These individual ABC's are added together to compute an ABC for the complex. This results in Tier 5 ABC of 1,271 mt and OFL 1,693 mt.

Responses to December 2006 SSC comments

"The SSC does not agree with the Plan Team's recommended placement of octopus and sharks in Tier 5. The SSC understands the intent of the Plan Team to provide a conservative minimum estimate of biomass, but does not find any new information suggesting that biomass estimates are more reliable than they were last year for sharks and octopuses in the BSAI. For this reason, the SSC recommends the same method used last year of calculating the other species specifications as sums of tier 5 calculations for skates and sculpins, and tier 6 calculations for sharks and octopuses. The SSC notes that the assessment authors concluded that reliable estimates of M and biomass do not exist for sharks (p. 1083), and that the authors for the octopus assessment identified serious drawbacks in octopus biomass estimates (pages 1140-1141)."

Response:

We concur with the SSC and recommend that sharks be placed in Tier 6.

"For sharks in last year's assessment, the SAFE authors recommended a base period of 1997 to 2005 for incidental catches. The SSC accepted this as the scientifically best alternative to the 1978 to 1995 period typically specified for Tier 6 determinations and advised that the final year should be fixed at 2005, so that we do not create a continuously shifting baseline for a standard period of 1978-2005."

Response:

We concur.

"The SSC notes that the loss of the Bering Sea slope survey may have serious consequences for the estimation of biomass for sleeper sharks, and this may forestall the eventual consideration of a Tier 5 approach for sharks in the BSAI."

Response:

We agree with the SSC. Hopefully the slope survey will be restored so that estimates of biomass can be computed.

INTRODUCTION

Alaska Fisheries Science Center (AFSC) bottom trawl and longline surveys and fishery observer catch records provide information on sharks that 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*), which are both member of the family Squalidae, and the salmon shark (*Lamna ditropis*).

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 2, Figure 1). 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 3 and 4, Figures 2 and 3).

Pacific Sleeper Shark

Pacific sleeper sharks range as far north as the arctic circle in the Chukchi Sea (Benz et al. 2004), west off the Asian coast and the western Bering Sea (Orlav and Moiseev 1999), and south along the Alaskan and Pacific coast and possibly as far south as the coast of South America (Corvetto et al. 1992). However, Yano et al. (2004) reviewed the systematics of sleeper sharks and suggested that sleepers in the southern hemisphere and the southern Atlantic were misidentified as Pacific sleeper and are actually *Somniosus antarcticus*, a species of the same subgenera. Pacific sleeper sharks have been documented at a wide range of depths, from surface waters (Hulbert et al 2006;) to 5,700 ft (seen on a planted grey whale carcass off Santa Barbara, CA, www.nurp.noaa.gov/Spotlight/Whales.htm). Sleeper sharks are found in relatively shallow waters at higher latitudes and in deeper habitats in temperate waters (Yano et al. 2007).

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 4, Figure 3). 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 2 and 3, Figures 1 and 2).

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 2 - 4, Figures 1 - 3).

Management Units

There have been 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. Recently a plant in Kodiak has been retaining some spiny dogfish. 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 (2006 recommendations for 2007), 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.

Evidence of Stock Structure

Spiny Dogfish

Spiny dogfish populations generally have complex stock structure. 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

Sleeper sharks commonly migrate vertically throughout the water column (Hulbert et al. 2006; Orlav and Moiseev 1999), but did not migrate far from initial tagging locations in the Gulf of Alaska (Hulbert et al 2006). Little is known about sleeper shark migratory behavior or their home range size.

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^{o} (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 Bertalannfy 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).

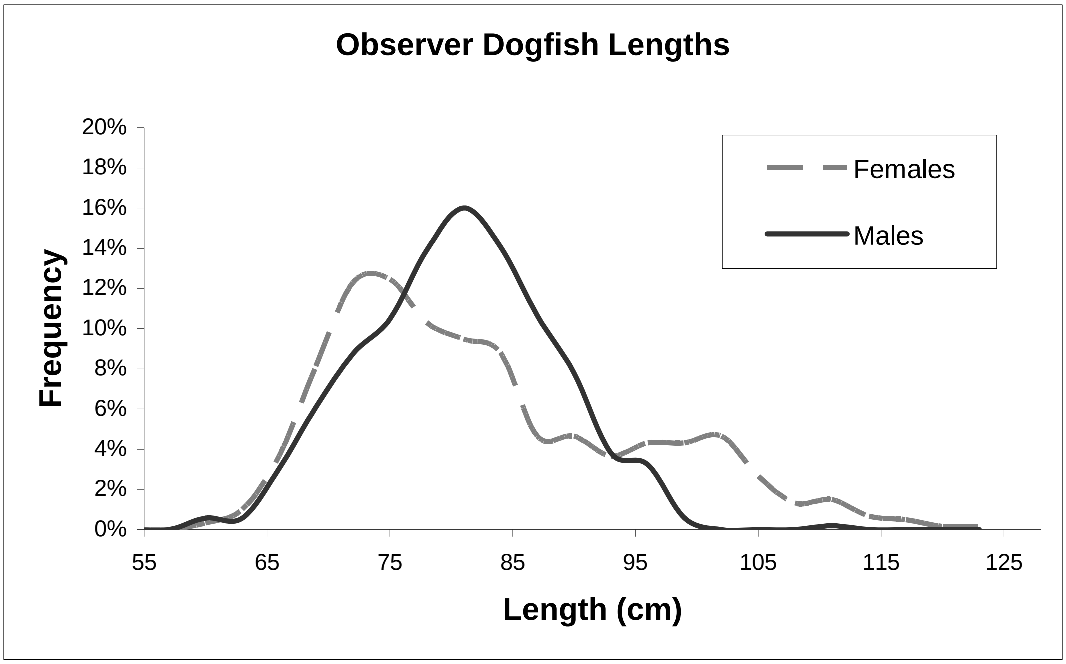
In the WNP, a salmon shark pupping and nursery ground may exist just north of the transitional domain in oceanic waters. According to Nakano and Nagasawa (1996), larger juveniles than term (70-110 cm PCL) were caught in waters with SST's of 14^{o}-16^{o}C, with adults occurring in colder waters further 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).

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 160 cm (Compagno 1984). In 2006, through a special project with the observer program, spiny dogfish lengths were measured throughout the EBS, AI, and the GOA. Sample sizes were not substantial enough to break length frequencies out by area, but for all areas combined male lengths averaged 80.2 cm and ranged from 48-110 cm (N = 524). The average female length was larger than the male (average = 82.4, range 9-128, N = 601). Female lengths peaked at a smaller size (74 cm) than males (82 cm), and then tapered off slowly. Although females peaked earlier, there were a greater proportion of females 94-128 cm long than males.



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 Ugland 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 targeted fisheries 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 in 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 length from the onset of maturity (Ketchen 1972, Richards 2004, Tribuzio 2004). Cindy Tribuzio is investigating the ages, natural mortality, and fecundity schedules of spiny dogfish in Alaska as part of her dissertation and will have more information in 2008.

Pacific Sleeper Sharks

Sleeper sharks are most likely slow growing and long lived (Fisk et al. 2002). Another sleeper shark of the same genus, the Greenland shark (*Somniosus microcephalus*), was determined to be living during the 1950's-1970's because it had high levels of DDT, which was used as an insecticide during this period (Fisk et al. 2002). Ageing of sleeper sharks is difficult because they have very few bony structures. Sharks up to 7 m in length have been observed under water (Compagno 1984). In Alaska, sharks of 1.5-2.5 m are most common (e.g. Sigler et al 2006) and sharks as large as 4.3 m have been caught (Orlav 1999). This species exhibits sexual dimorphism in the northwest Pacific Ocean, with females being shorter and heavier (avg. length = 138.9 cm, avg. weight = 28.4 kg) than males (avg. length = 140 cm, avg. weight = 23.7 kg) (Orlav 1999).

Sleeper sharks probably mature at a relatively large size and a late age, but only five mature female sleeper sharks have been documented in the literature. The reproductive mode of sleeper sharks is thought to be aplacental viviparity. Three mature females 370-430 cm long were opportunistically sampled off the coast of California. In one of these specimens several thousand small eggs (<10mm) were present as well as 372 large vascularized eggs (24-50mm) (Ebert et al 1987). Another mature shark 370 cm long was caught off Trinidad California (Gotshall and Jow 1965). The ovaries contained 300 large unfertilized eggs and many small undeveloped ova. Diameters of the large eggs ranged from 45 to 58 mm. Additionally, a single mature female was found off the Kuril Islands, northeast of Hokkaido, Japan, that measured 423 cm long (Orlav 1999). Two recently born 74 cm sharks have been caught off the coast of California at 1300 and 390 m; one still had an umbilical scar (Ebert et al. 1987). Unfortunately, the date of capture was not reported. A newly born shark of 41.8 cm was also caught at 35 m depth off Hiraiso, Ibaraki, Japan (Yano et al 2007). Additionally, three small sharks, 65-75 cm long, have been sampled in the Northwest Pacific, but the date of sampling was not reported (Orlov and Moiseev 1999). Because of a lack of mature sharks, newly born sharks, and due to the absence of dates in the literature, the spawning and pupping season in unknown for sleeper sharks.

Sleeper sharks have been caught at a wide range of depths throughout their geographical distribution; however, the movements of Pacific sleeper sharks have only been studied in the Gulf of Alaska. Tagged sharks in the Gulf spent 61% of their time between 150-450 m and ascended above 100 m on 58% of days (Hulbert et al. 2006). These sharks exhibited daily vertical oscillations, coming to the surface at night, as well as systematic oscillations that were independent of the diel clock (Hurlbert et al. 2006). Seasonal depth differences in shark catches were noted north of the Kuril Islands but not in the Bering Sea perhaps due to a lack of thermal gradient in the Bering Sea. However, these sharks were not part of a tagging study nor was the sampling designed to research shark depth preferences (Orlov and Moiseev 1999).

Salmon Sharks

Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2 ^{o}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•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).

FISHERY

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. Recently a plant in Kodiak has been retaining spiny dogfish. 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 recent years.

Bycatch, Discards, and Historical Catches

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 5).

DATA

Source	Data	Years
NMFS Observer Program – (AKRO)	Non-target catch	2003 – 2007
NMFS Observer Program – (AFSC) Pseudo Blend	Non-target catch	1997 – 2002
NMFS Bottom Trawl Surveys – Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2007
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

Incidental Catch

This report summarizes incidental shark catches by species as two data time series: 1997 – 2002 and 2003 - 2007. 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 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 6). 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 – 2007, BSAI shark catch composed from 1% to 5% of Other Species total catch (Table 6). Pacific sleeper sharks composed 69% of total shark catch, unidentified sharks 22%, salmon sharks 8%, and spiny dogfish 1% (Table 6).

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 7, Figure 4). 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 4) which may reflect and change in fishing effort. Catches of spiny dogfish, salmon shark, and other shark were rare in the BSAI (Tables 8 - 13; Figures 5 and 6). Pseudo-blend shark catch by gear type was not available for 2002 (Tables 8 – 10 and 14). 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.

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 – 2007, Tables 3 and 15), EBS slope historical (1979-1991, Tables 4 and 15), EBS slope new (2002, 2004, Tables 4 and 15), and Aleutian Islands (AI, 1979 – 2004,Tables 2 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 3 and 15, Figure 2). 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 4 and 15, Figure 3). 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 2 and 15, Figure 3). 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 4).

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 2 and 15, Figure 1). 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.

ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Both Tier 6 and Tier 5 options are provided for consideration 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. Last year Courtney et al. (2006) provided an alternative Tier 6 calculation using 1997 – 2005 as the base period for the catch history as an alternative to 1978 – 1995 period typically specified for Tier 6. The SSC recommended placement of sharks in Tier 6 with this alternative base period and fixing the final year at 2005. Thus the Tier 6 ABC and OFL remains identical to that presented last year.

Available data do not support Tier 5 criteria for establishing ABC and OFL for sharks in the BSAI. Typical 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 for BSAI shark ABC and OFL are presented both for individual species and for sharks as a complex. The Tier 6 option for sharks as a complex is recommended for ABC and OFL. Incidental shark catches for the years 1997 – 2002 were obtained from the pseudo-blend method (Gaichas 2001 and 2002,

Table 6). Incidental shark catches for the years 2003 - 2005 were provided by the NMFS AKRO (Table 6). 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 1997 – 2006 are probably reliable, but catch estimates for other shark species may not be reliable.

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 were presented last year for individual species and for sharks as a complex. We continue to provide Tier 5 calculations given that the BSAI Plan Team recommended that sharks be placed in Tier 5. Tier 5 methodology for BSAI spiny dogfish, Pacific sleeper sharks, and other sharks is based on natural mortality of 0.097 for Gulf of Alaska spiny dogfish (Appendix A). For salmon sharks, the Tier 5 calculation is based on a natural mortality estimate of 0.18. These individual ABC's are added together to compute an ABC for the complex.

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 complex[2]**
M[3,4]	0.097	0.097	0.18	0.097	**0.097**
Average biomass					
Eastern Bering Sea shelf (1996 – 2007) [5]	27	1,866	0	0	**1,893**
Eastern Bering Sea slope (2002 and 2004) [6]	0	13,853	0	0	**13,853**
Aleutian Islands (1997, 2000, 2002, 2004, & 2006)[7]	20	1,351	179	0	**1,550**
Total of average biomass	49	17,071	179	0	**17,296**
ABC (0.75M x biomass)	4	1,242	24	0	**1,271**
OFL (M x biomass)	5	1,656	32	0	**1,693**

ECOSYSTEM CONSIDERATIONS

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.

[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 morality for all ages.
[5] Table 3.
[6] Table 4.
[7] Table 2.

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

Pacific sleeper sharks were once thought to be sluggish and benthic because their stomachs commonly contain offal, cephalopods, and bottom dwelling fish such as flounder (*Pleuronectidae*) (e.g., Yang and Page 1999). The more current hypothesis is that these sharks make vertical oscillations throughout the water column searching for prey as well as scavenging. Evidence for this behavior was documented in a tagging study in the Gulf of Alaska (Hulbert et al 2006). Also, a diet analyses documented prey from different depths in the stomachs of a single shark, such as giant grenadier (*Albatrossia pectoralis*) and pink salmon (*Oncorhynchus gorbuscha*), demonstrating that they make depth oscillations in search of food (Orlav and Moiseev 1999). Other diet studies that have found that Pacific sleeper sharks prey on fast moving fish, such as salmon (*O. spp.)* and tuna (*Thunnus spp*.), and marine mammals, such as harbor seals (*Phoca vitulina*), that live near the surface (e.g., Bright 1959; Ebert et al 1987; Crovetto et al 1991; Sigler et al 2006), proving that these sharks may not be as sluggish and benthic oriented as once thought. Although sleeper sharks share use the same areas as pupping Stellar sea lions (*Eumetopias jubatus*) in the Gulf of Alaska, they were not found to prey on newborn sealions but did have tissues from other marine mammals in their stomachs (Sigler et al 2006). Taggart et al. (2005) found that sleeper sharks in Glacier Bay were only caught in traps where harbor seals were at their highest concentrations. However, they did not find any seal tissue in their stomachs and concluded that sleeper sharks may either be a predator of the seals or might be attracted to the same food sources as the seals, such as walleye pollock (*Thereagra chalcogramma*), cephalopods, flounder, or capelin (*Mallotus villosus*).

Analyses of mercury and other elemental concentrations in the tissues of Pacific sleeper sharks show that they are at a lower trophic level than ringed seals (*Pusa hispida*) and were at a similar level as flathead sole (*Hippoglossoides elassodon*) (McMeans et al. 2007). Another study used stable isotopes to determine the trophic level of Greenland sharks and found that larger sharks were at a higher trophic level than small sharks because larger sharks were more likely to feed on marine mammals (Fisk et al 2002).

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, 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).

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 - 2007 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.

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 sine 1997 and have made up from 1% to 5% of Other Species catch from 1997 – 2005. Courtney et al. (2006) 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 2 - 4). Spiny dogfish and salmon sharks were rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI.

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REFERENCES

Allen, M. James, and Gary B. Smith, 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Technical Report NMFS 66. 151 pp.

Alverson, D. L. and M. E. Stansby. 1963. The spiny dogfish (*Squalus acanthias*) in the northeastern Pacific. USFWS Spec Sci Rep-Fisheries. 447:25p.

Anderson, E.D., 1990. Fishery models as applied to elasmobranch fisheries. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 473-484. NOAA Technical Report NMFS 90.

Anon. 1956. Biological study of important fish resources. Bull Jap Sea Res Lab. 4:141-158.

Beamish, R. J., G. A. McFarlane, K. R. Weir, M. S. Smith, J. R. Scarsbrook, A. J. Cass and C. C. Wood. 1982. Observations on the biology of Pacific hake, Walleye pollock and spiny dogfish in the Strait of Georgia, Juan de Fuca Strait and off the west coast of Vancouver Island and United States, July 13-24, 1976. Can MS Rep Fish Aquat Sci. 1651:150p.

Beamish, R.J., and G.A. McFarlane. 1985. Annulus development on the second dorsal spine of the spiny dogfish (*Squalus acanthias*) and its validity for age determination. Can. J. Fish. Aquat. Sci. 42:1799-1805.

Beamish, R.J., B.L. Thomson, and G.A. McFarlane. 1992. Spiny dogfish predation on chinook and coho salmon and the potential effects on hatchery-produced salmon. Trans Amer Fish Soc. 121:444-455.

Boldt, J., K.J. Goldman, B. Bechtol, C. Dykstra, S. Gaichas, and T Kong. 2003. Shark bycatch in Alaska state and federal waters. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Bonham, K. 1954. Food of the dogfish *Squalus acanthias*. Fish Res Paper. 1:25-36.

Bright, D.B. 1959. The occurance and food of the sleeper shark, *Sominus pacificus*, in a central Alaskan Bay. Copeia 1959. 76-77.

Brodeur, R.D. 1988. Zoogeography and trophic ecology of the dominant epipelagic fishes in the northern Pacific. *In* The biology of the subarctic Pacific. Proceedings of the Japan-United States of America seminar on the biology of micronekton of the subarctic Pacific (eds., T. Nemoto and W.G. Percy). Bulletin of Ocean Research Institute, University of Tokyo, No. 26 (Part II), 1-27.

Castro, J.I., C.M. Woodley and R. L. Brudek. 1999. A preliminary evaluation of the status of shark species. FOA Fisheries Tech. Paper No. 380. FAO Rome, 72p.

Compagno, L.J.V., 1984. FAO species catalogue vol 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date. Part 1. *Hexaniformes* to *Lamniformes*. FAO Fish. Synop., (125) Vol 4, Pt. 1, 249 p.

Compagno, L.V.J., 1990. Shark exploitation and conservation. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 391-414. NOAA Technical Report NMFS 90.

Compagno, L.J.V. 2001. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO Species Catalogue for Fishery Purposes, No. 1, Vol. 2 Rome, FAO. 269 p.

Courtney, D. L., and M.F. Sigler. 2002. A new analysis of Pacific sleeper shark (*Somniosus pacificus*) abundance trends. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2003. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Courtney, D. L. and M. F. Sigler. 2003. Analysis of Pacific sleeper shark (*Somniosus pacificus*) abundance trends from sablefish longline surveys 1979 – 2003. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Courtney, D., C. Tribuzio, S. Gaichas, and K. J. Goldman. 2005. BSAI Sharks. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2006. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Courtney, D., C. Tribuzio, and K. J. Goldman. 2006. BSAI Sharks. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2006. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Crovetto, A., J. Lamilla, and G. Pequeno. 1992. *Lissodelphis peronii*, Lacepede 1804 (Delphinidae, cetacean) within the stomach contents of a sleeping shark, *Somniosus cf. pacificus*, Bigelow and Schroeder, 1944, in Chilean waters. Mar. Mammal Sci. 8: 312-314.

da Silva, H. M. and M. R. Ross. 1993. Reproductive strategies of spiny dogfish, *Squalus acanthias*, in the NW Atlantic. ICES-Demersal Fish Comm. 17p.

Ebert, D.A., L.J.V. Compagno, and L.J. Natanson. 1987. Biological notes on the Pacific sleeper shark, *Somniosus pacificus (*Chondrichthyes: Squalidae). Calif. Fish and Game 73(2); 117-123.

Eschmeyer, W.N., E.S. Herald, and H. Hammann, 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston: 336 pp.

Farquhar, G.B. 1963. Sharks of the family lamnidae. Technical Report of the US Naval Oceanographic Office (TR-157). 22 pp.

Fisk, A.T., S.A. Pranschke, and J.L. Norstrom. 2002. Using anthropogenic contaminants and stable isotopes to asses the feeding ecology of Greenland sharks. Ecology 83: 2162-2172.

Gaichas, S.K. 2001. Squid and other species in the Bering Sea and Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands for 2002. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Gaichas, S.K. 2002. Squid and other species in the Bering Sea and Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands for 2003. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Gaichas, S.K. 2003. Squid and other species in the Bering Sea and Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands for 2004. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Gaichas, S., L. Fritz, and J. N. Ianelli. 1999. Other species considerations for the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. Appendix D. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Gaichas, S., and J. N. Ianelli. 1999. An approach to analyzing multi-species complexes in data-limiting situations. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. Appendix E. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Gaichas, S., M. Ruccio, D. Stevensen, and R. Swanson. 2003. Stock assessment and fishery evaluation of skate species (Rajidae) in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Gilmore, R.G. 1993. Reproductive biology of lamnoid sharks. Env. Biol. Fish. 38:95-114.

Goldman, K. J. 2001. Sharks and shark bycatch in Alaska state and federal waters. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2002. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Goldman, K. J. 2002-a. Sharks and shark bycatch in Alaska state and federal waters. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2003. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Goldman, K.J. 2002-b. Aspects of age, growth, demographics and thermal biology of two Lamniform shark species. Ph.D. dissertation. College of William and Mary, School of Marine Science, Virginia Institute of Marine Science. 220 pp.

Goldman, K.J., S.D. Anderson, R.J. Latour and J.A. Musick. 2004. Homeothermy in adult salmon sharks, *Lamna ditropis*. Env. Biol. Fish. December 2004.

Goldman, K.J. and Human B. 2004. Salmon shark, *Lamna ditropis*. *In* Sharks, rays and chimaeras: the status of the chondrichthyan fishes. (eds. Fowler, S.L., M. Camhi, G. Burgess, S. Fordham and J. Musick). IUCN/SSG Shark Specialist Group. IUCN, Gland, Switzerland, and Cambridge, UK.

Goldman, K.J. and J.A. Musick. In press. Biology of the Salmon Shark, *Lamna ditropis*. *In* Sharks of the open ocean. E.K. Pikitch and M. Camhi, eds. Blackwell Scientific.

Goldman, K.J. and J.A. Musick. 2006. Growth and maturity of salmon sharks in the eastern and western North Pacific, with comments on back-calculation methods. Fish. Bull 104:278-292.

Gotshall, D. W., and T. Jow. 1965. Sleeper sharks (*Somniosus pacificus*) off Trinidad, California, with life history notes. California Fish and Game 51:294 –298.

Gruber, and T. Taniuchi, eds., p. 1-16. NOAA Technical Report NMFS 90.

Gruber and T. Taniuchi, eds. Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of fisheries. NOAA Tech. Rep. NMFS 90.

Hart, JL. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada (Bull. 180), Ottawa, Canada. 749 pp.

Holden M.J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In* Sea fisheries research (Harden Jones, FR ed.). pp. 117-137.

Holden M.J. 1977. Elasmobranchs. *In* Fish population dynamics (Gulland, J.A., ed.).

Hoenig, J. M. and S. H. Gruber. 1990. Life history patterns in the elasmobranchs: implications for fishery management. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H.

Hoff, T. B., and J. A. Musick. 1990. Western North Atlantic shark-fishery management problems and informational requirements. Pages 455–472. *In* H. L. Pratt, Jr., S. H.

Hulbert, L. 2000. Alaska shark assessment program. *In* Stock assessment and fishery evaluation report ecosystem considerations for 2001. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Hulbert, L., A. M. Aires-Da-Silva, V. F. Gallucci, and J. S. Rice. 2005. Seasonal foraging behavior and migratory patterns of female *lamna ditropis* tagged in Prince William Sound, Alaska. J. Fish Biol. 67:490-509.

Hulbert, L., M. Sigler, and C. R. Lunsford. 2006. Depth and movement behaviour of the Pacific sleeper shark in the north-east Pacific Ocean. J. of Fish Biol. 69:406-425.

Jones, B. C. and G. H. Geen. 1977. Food and feeding of spiny dogfish (*Squalus acanthias*) in British Columbia Waters. J Fish Res Bd Canada. 34:2067-2078.

Jones, T. S. and K. L. Ugland. 2001. Reproduction of female spiny dogfish, *Squalus acanthias*, in the Oslo fjord. Fish Bull. 99:685-690.

Kaganovskaia, S. M. 1937. On the commercial biology of *Squalus acanthias*. Izv. Tikhookean. Nauch. Issled. Inst. Ryb. Khoz. Okeanogr. 10:105-115.

Ketchen, K. S. 1972. Size at maturity, fecundity, and embryonic growth of the spiny dogfish (*Squalus acanthias*) in British Columbia waters. J Fish Res Bd Canada. 29:1717-1723.

Ketchen, K. S. 1986. The spiny dogfish (*Squalus acanthias*) in the northeast Pacific and a history of its utilization. Can Spec Publ Fish Aquat Sci. 88:78p.

Koob, T. J. and I. P. Callard. 1999. Reproductive endocrinology of female elasmobranchs: lessons from the little skate (*Raja erinacea*) and spiny dogfish (*Squalus acanthias*). J Exp Zool. 284:557-574.

Laptikhovsky, V.V., A.I. Arkhipkin, A.C. Henderson. 2001. Feeding habits and dietary overlap in spiny dogfish *Squalus acanthias* (Squalidae) and narrowmouth catshark *Schroederichthys bivius* (Scyliorhinidae). J Mar Bio Assoc UK. 81:1015-1018.

Nagasawa, K. 1998. Predation by salmon sharks (*Lamna ditropis*) on Pacific salmon (*Oncorhynchus spp.*) in the North Pacific Ocean. Bulletin of the North Pacific Anadromous Fish Commission, No. 1:419-433.

Nakano, H. and Nagasawa K. 1996. Distribution of pelagic elasmobranchs caught by salmon research gillnets in the North Pacific. Fisheries Science 62(5):860-865.

Macy, P. T., J. M. Wall, N. D. Lampsakis, and J. E. Mason, 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea. Part 1: Introduction. General fish resources and fisheries. In Reviews of literature on non-salmonid pelagic fish resources. DOC/NOAA/NMFS Northwest and Alaska Fishery Science Center, unpublished manuscript.

McFarlane, G. A. and J. R. King. 2003. Migration patterns of spiny dogfish (*Squalus acanthias*) in the North Pacific Ocean. Fish Bull. 101:358-367.

McFarlane, G.A., and R. J. Beamish. 1987. Validation of the dorsal spine method of age determination for spiny dogfish. *In* Age and growth of fish. pp. 287-300.

McMeans, B.C., K. Borga, W.R. Bechtol, D. Higginbotham, and A.T. Fisk. 2007. Essential and non-essential element concentrations in two sleeper shark species collected in arctic waters. Environmental Pollution 148: 281-290.

Mecklenburg, C.W., T.A. Anthony, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda Maryland 1037 pp.

Mueter, F. J. and B. L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf on upper slope regions of the Gulf of Alaska. Fisheries Bulletin. 100(3):559-581.

Orlav, A.M. 1999. Capture of especially large sleeper shark *Somniosus pacificus* (Squalidae) with some notes on its ecology in Northwestern Pacific. Jornal of Ichthyology. 39: 548-553.

Orlav, A.M., and S.I. Moiseev. 1999. Some biological features of Pacific sleeper shark, *Somniosus pacificus* (Bigelow et Schroeder 1944) (Squalidae) in the Northwestern Pacific Ocean. Oceanological Studies. 28: 3-16.

Paust, B. and R. Smith, 1989. Salmon shark manual. The development of a commercial salmon shark, Lamna ditropis, fishery in the North Pacific. Alaska Sea Grant Report 86-01, Revised 1989.

Phillips, J.B. 1953. Sleeper shark, *Somniosus pacificus*, caught off Fort Bragg, California. Calif. Fish and Game 39: 147-149.

Pratt, H., L., Jr. and J. G. Casey. 1990. Shark reproductive strategies as a limiting factor in directed fisheries, with a review of Holden's method of estimating growth parameters. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 97-109. NOAA Technical Report NMFS 90.

Polat, N. and A. K. Gumus. 1995. Age determination of spiny dogfish (*Squalus acanthias* L. 1758) in Black Sea Waters. ISR J Aquacult Bamidgeh. 47:17-24.

Rago, P. J., K. A. Sosebee. J. K. T. Brodziak, S. A. Murawski and E. D. Anderson. 1998. Implications of recent increases in catches on the dynamics of northwest Atlantic spiny dogfish (*Squalus acanthias*). Fish Res. 39:165-181.

Richards, J. 2004. M. Sc Thesis. Oregon State University

Sano, O. 1960.The investigation of salmon sharks as a predator on salmon in the North Pacific, 1959. Bulletin of the Hokkaido Regional Fisheries Research Laboratory, Fisheries Agency 22:68–82 (in Japanese).

Sano, O. 1962. The investigation of salmon sharks as a predator on salmon in the North Pacific, 1960. Bulletin of the Hokkaido Regional Fisheries Research Laboratory, Fisheries Agency 24:148–162 (in Japanese).

Saunders, M.W. and G.A. McFarlane. 1993. Age and length at maturity of the female spiny dogfish (*Squalus acanthias*) in the Straight of Georgia, British Columbia, Canada. Environ Biol Fish 38:49-57.

Sigler M.F., L. Hulbert, C. R. Lunsford, N. Thompson, K. Burek, G. Corry-Crowe, and A. Hirons. 2006. Diet of Pacific sleeper shark, a potential Steller sea lion predator, in the north-east Pacific Ocean. J. Fish Biol. 69:392-405.

Soldat, V. T. 2002. Spiny dogfish (*Squalus acanthias L.*) of the northwest Atlantic ocean (NWA). NAFO SCR Doc. 02/84. 33p.

Sosebee, K., 1998. Spiny dogfish and skates. *In* Status of fishery resources off the northeastern United States for 1998 (S.H. Clark, ed.), p. 112-115. NOAA Technical Memorandum NMFS-NE-115.

Stenberg, C. 2002. Life history of the piked dogfish (*Squalus acanthias L.*) in Swedish waters. NAFO SCR Doc. 02/91. 13p.

Taggart, S. J., A.G. Andrews, J. Mondragon, and E.A. Mathews. 2005. Co-occurance of Pacific sleeper sharks *Somniosus pacificus* and harbor seals *Phoca vitulina* in Glacier Bay. Alaska Fish. Res. Bull. 11(2): 113-117.

Tanaka, S. 1980. Biological investigation of *Lamna ditropis* in the north-western waters of the North Pacific. *In* Report of investigation on sharks as a new marine resource (1979). Published by: Japan Marine Fishery Resource Research Center, Tokyo [English abstract, translation by Nakaya].

Tribuzio, C.A. 2004. An investigation of the reproductive physiology of two North Pacific shark species: spiny dogfish (*Squalus acanthias*) and salmon shark (*Lamna ditropis*). MS Thesis, University of Washington. 137pgs.

Tsang, P and I. P. Callard. 1987. Morphological and endocrine correlates of the reproductive cycle of the aplacental viviparous dogfish, *Squalus acanthias*. Gen Comp Endocrinol. 66:182-189.

Urquhart, D.L. 1981. The North Pacific salmon shark. Sea Frontiers 27(6):361-363.

Yamamoto, T. and O. Kibezaki. 1950. Studies on the spiny dogfish *Squalus acanthias*. (L.) on the development and maturity of the genital glands and growth. Hokkaido Reg Fish Resour Res Rep. 3:531-538.

Yang, M., and B.N. Page. 1998. Diet of Pacific sleeper shark, *Sominus pacificus*, in the Gulf of Alaska. Fish. Bull. 97: 406-4-9.

Yano, K., J.D. Stevens, and L.J.V. Compagno. 2007. Distribution, reproduction and feeding of the Greenland shark *Somniosus (Somniosus) microcephalus*, with notes on two other sleeper sharks, *Somniosus (Somniosus) pacificus* and *Somniosus (Somniosus) antarticus.* J. Fish. Biol. 70: 374-390.

Yatsu, A., K. Hiramatsu and S. Hayase. 1993. Outline of the Japanese squid driftnet fishery with notes on the bycatch. *In* Symposium on biology, distribution and stock assessment of species caught in the high seas driftnet fisheries in the North Pacific Ocean (held by the standing committee on biology and research at Tokyo Japan Nov. 4-6, 1991), J. Ito, W. Shaw, and R.L. Burgener (eds.). International North Pacific Fisheries Commission, Bull. Vol. 53., pp. 5. Vancouver, Canada 1993.

Weng, K.C., A. Landiera, P.C. Castilho, D.B. Holts, R.J. Schallert, J.M. Morrissette, K.J. Goldman, and B.A. Block. 2005. Warm sharks in polar seas: satellite tracking from the dorsal fins of salmon sharks. Science 310:104-106.

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

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

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

Table 2. 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 3. 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 3. 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 3. 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	355	Hauls with catch	1	2	0
		Biomass	28	3,093	
		CV of biomass	0.999	0.711	
2005	353	Hauls with catch	0	2	0
		Biomass		1,532	
		CV of biomass		0.748	
2006	356	Hauls with catch	0	2	0
		Biomass		2,944	
		CV of biomass		0.780	
2007	356	Hauls with catch	0	0	0
		Biomass			
		CV of biomass			

Table 4. 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	Sleeper Shark	Salmon Shark
		Historical Slope Survey			
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 5. 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.

	Eastern Bering Sea				Aleutian Islands				
Year	**Foreign**	**JV**	**Domestic**	**Total**	**Foreign**	**JV**	**Domestic**	**Total**	**Grand 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									26,537
2007									26,185

Data Sources: 1977- 2001 Gaichas (2002); 2002 - 2007 NMFS AKRO BLEND database, Juneau, AK 99801, as of Oct. 20, 2007.

Table 6. Estimated incidental catch (mt) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 5, 2007. Years 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002). Years 2003 – 2007 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	26,537	2%
2007	3	190	13	20	226	22,786	1%
Avg 1997 - 2005 used for Tier 6 Calculation	9	445	46	117	617	26,131	
Total - all years	89	4,448	487	1,374	6,399	288,518	
% of total	1%	70%	8%	21%	100%	2%	

Sources:
1997 – 2002; Gaichas (2002, Table 15-5).
2003 – 2007; NMFS AKRO as of October 5, 2007.

Table 7. Estimated incidental catch (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 has not been summarized for the years 2003 – 2007.

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 8. 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 has not been summarized for the years 2002 - 2007.

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 Total		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 9. 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 has not been summarized for the years 2002 - 2007.

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 Total		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 10. 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 has not been summarized for the years 2002 - 2007.

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 11. 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 – 2007.

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 12. 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 – 2007.

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 13. 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 – 2007.

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 14. 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 has not been summarized for the years 2002 - 2007.

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 Total		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 15. 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	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
2007	0		

Source: Gaichas et al. (1999, Table 15), Gaichas (2003, Table 16-8). EBS Shelf and Slope updated Oct, 2007 (Pers. Comm., Bob Lauth). 2005 EBS shelf 1,523 mt shark (reported as sleeper sharks).

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).

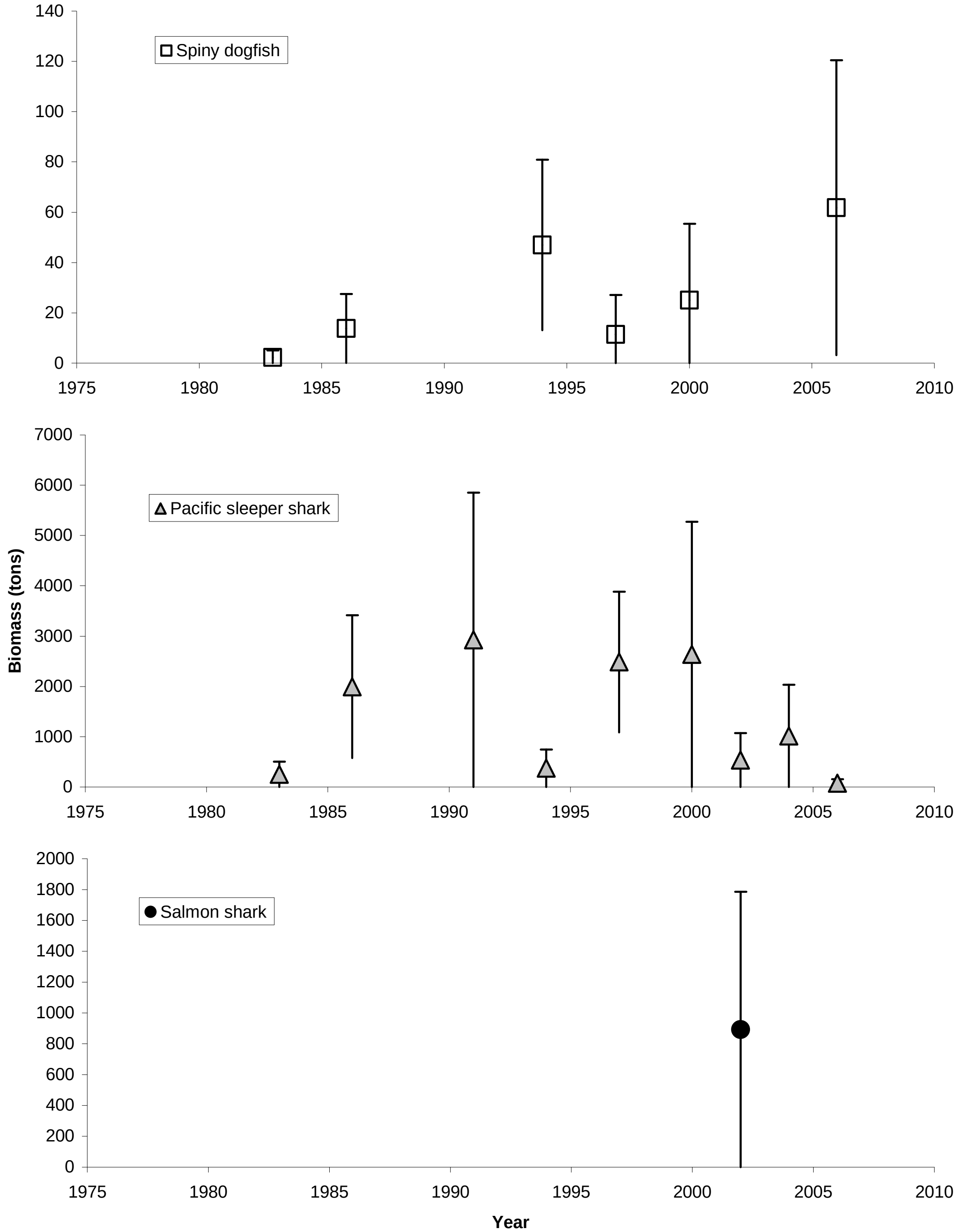


Figure 1. Trends in Aleutian Islands AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of AI survey biomass trends is subject the following time series caveats. Catchability of sharks in the survey is unknown.

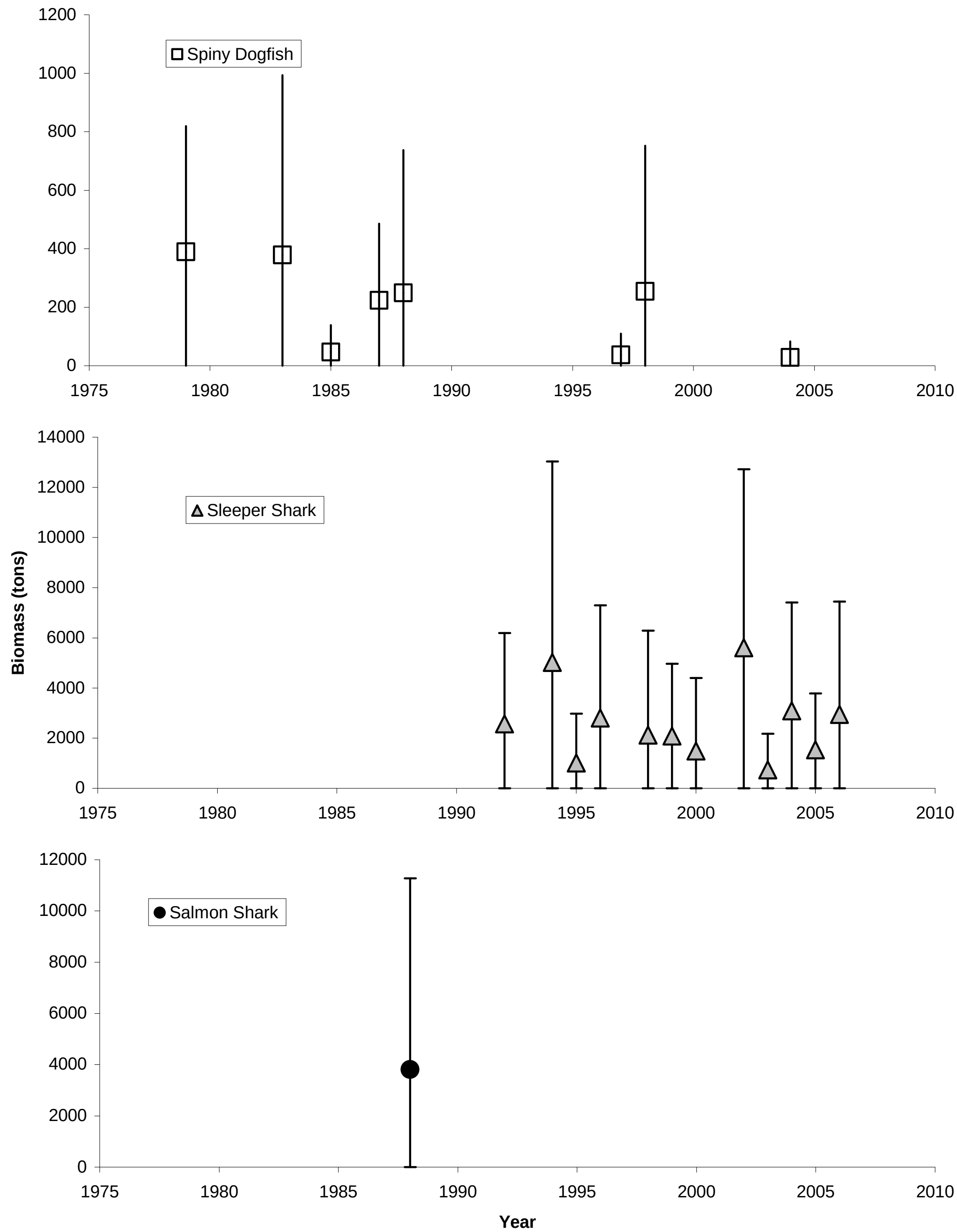


Figure 2. Trends in eastern Bering Sea shelf AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS shelf biomass trends is subject to following time series caveats. The 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.

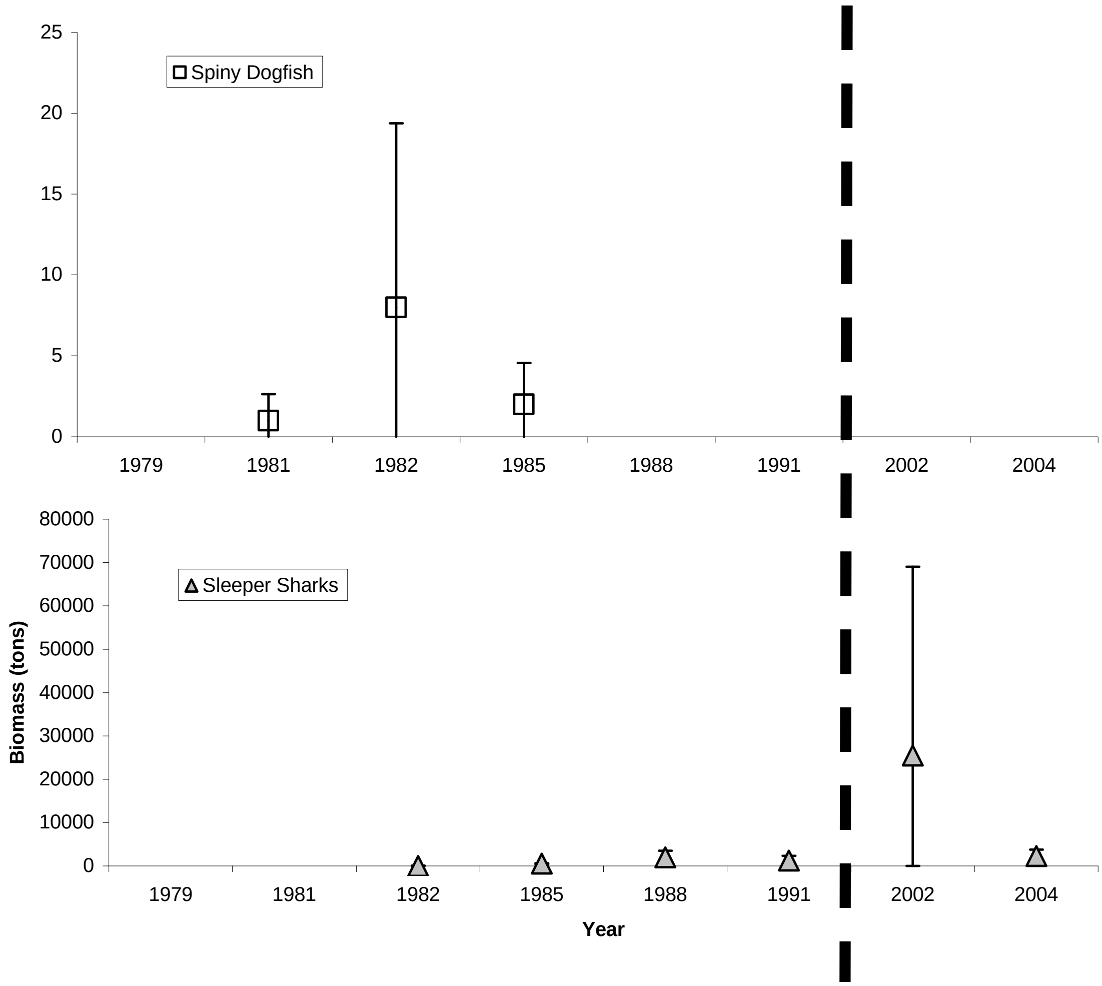
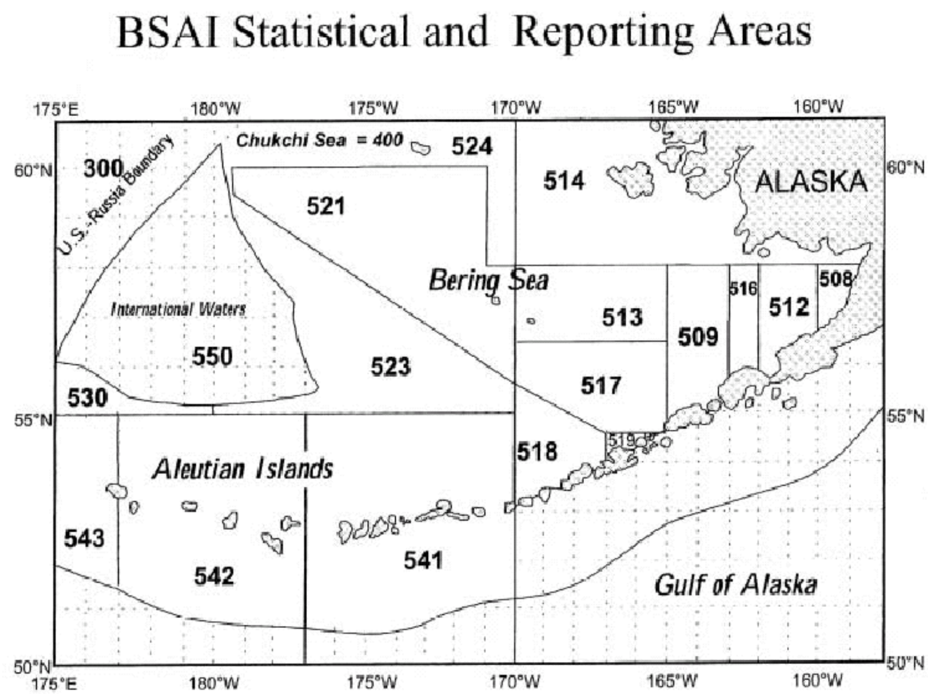


Figure 3. Trends in eastern Bering Sea slope AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Dashed line indicates beginning of new EBS slope survey (2002, 2004), which is not comparable 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.



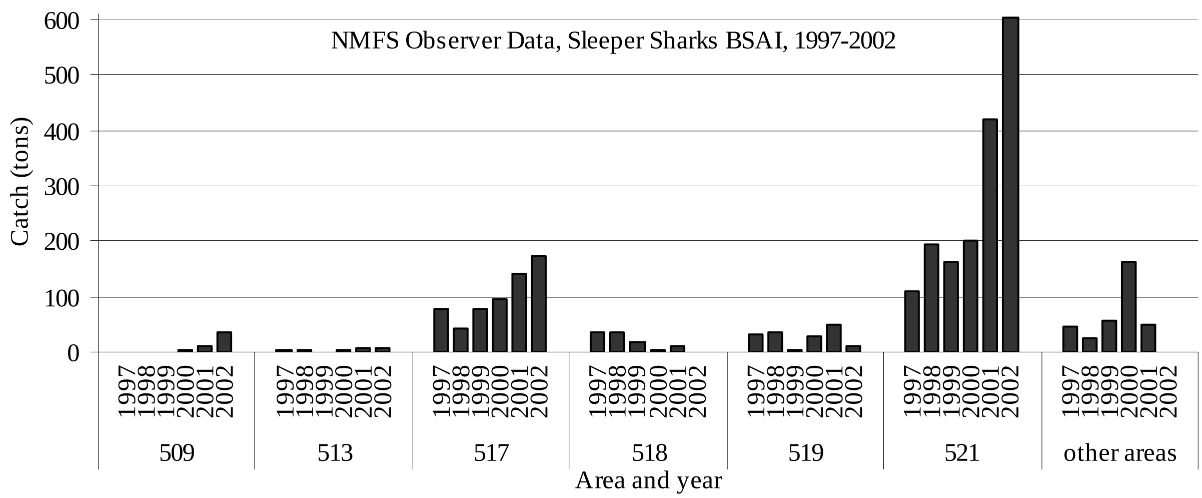
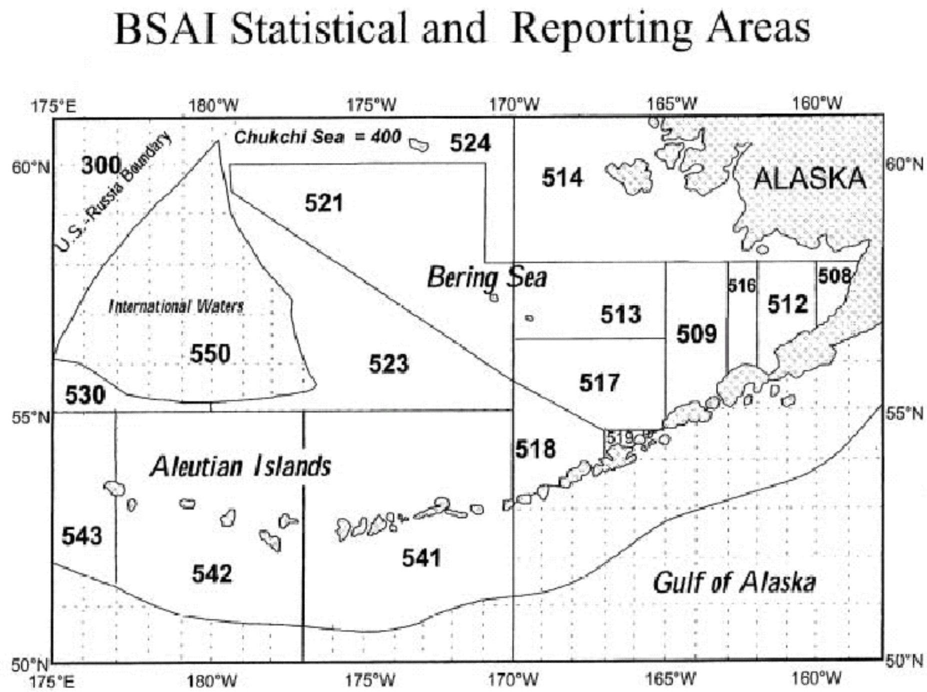


Figure 4. Pacific sleeper shark incidental catch from 1997-2002 using the pseudo-blend catch estimation procedure (Gaichas 2002) by statistical areas in the Bering Sea and Aleutian Islands.



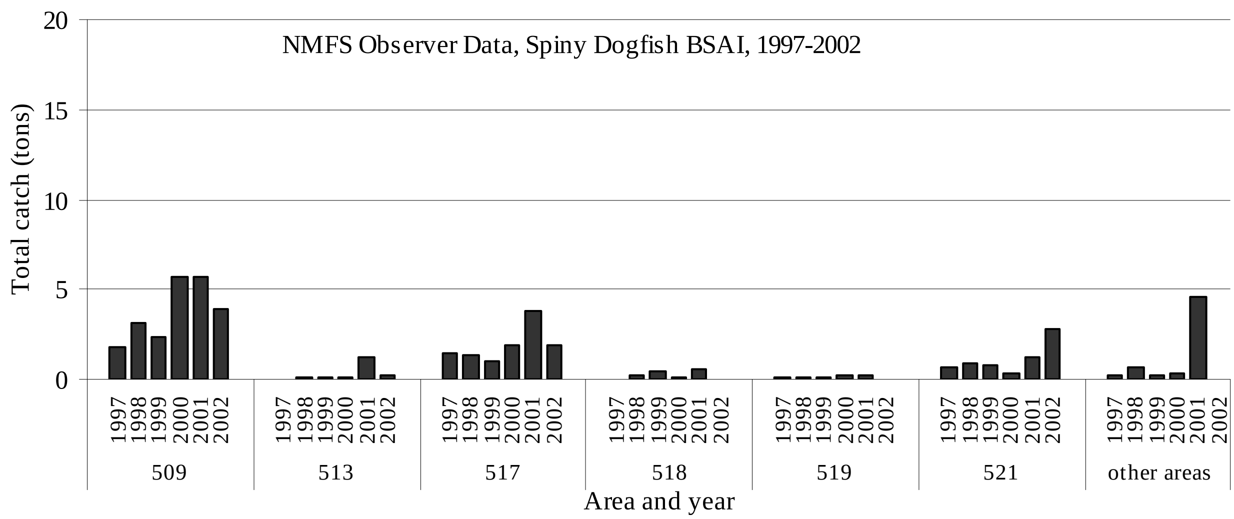
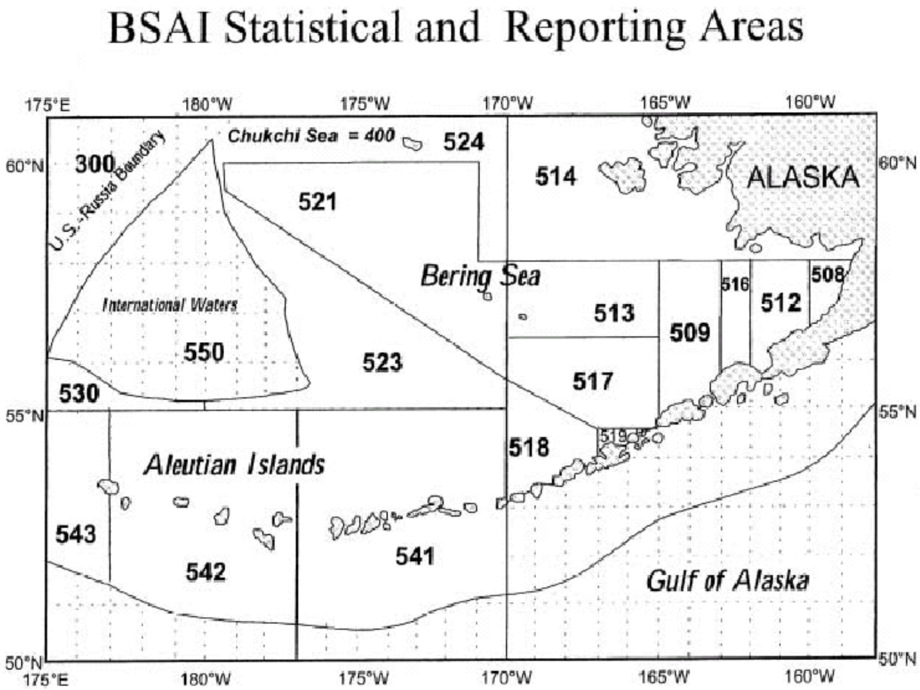


Figure 5. Spiny dogfish incidental catch from 1997-2002 using the pseudo-blend catch estimation procedure (Gaichas 2002) by statistical areas in the Bering Sea and Aleutian Islands.



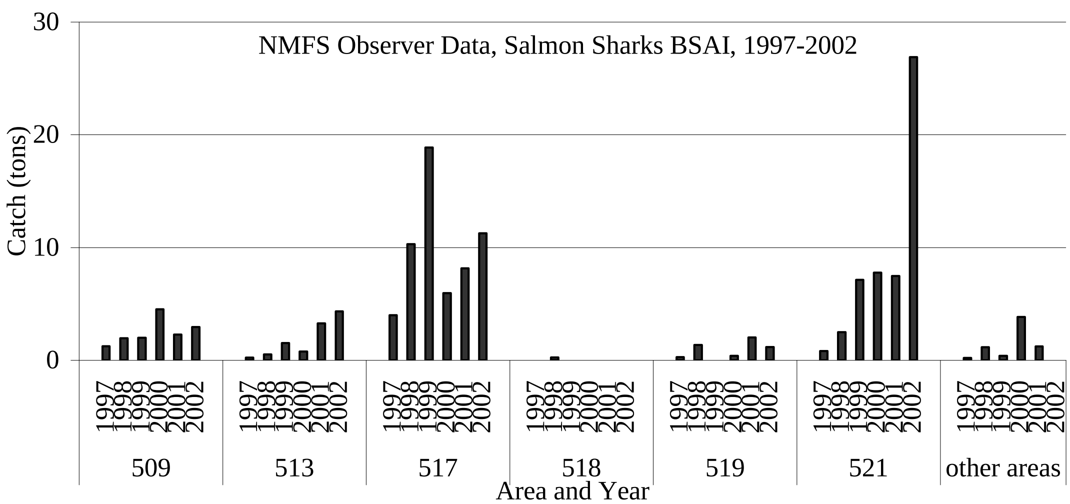


Figure 6. Salmon shark incidental catch from 1997-2002 using the pseudo-blend catch estimation procedure (Gaichas 2002) by statistical areas in the Bering Sea and Aleutian Islands.

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_∞=4.798 (1.807, 11.093 95% CI)	1.318(1.078-1.666)
2	Pauly 1980 (1), length	$lnM=-0.0152-0.279ln(TL_{ext\infty})+0.6543ln\kappa+0.4634lnT$	$TL_{ext\infty}$=101.48 (98.694, 104.129 95% CI), κ=0.060 (0.056, 0.066 95% CI), T=6.65°C	0.104(0.103-0.104)
3	Pauly 1980 (2) weight	$lnM=-0.4852-0.0824ln(W_\infty)+0.6757ln\kappa+0.4627lnT$	W_∞=4.798 (1.807, 11.093 95% CI), κ=0.060 (0.056, 0.066 95% CI), T=6.65°C	0.194(0.181-0.211)
4	Hoenig 1983	$M=e^{1.44-0.982ln(tmax)}$	t_{max}=107 years	0.043
5	Alverson & Carney 1975	$M=3\kappa/(e^{0.38\kappa tmax}-1)$	κ=0.060 (0.056, 0.066 95% CI), t_{max}=107 years	0.017(0.015-0.019)
6	Jensen 1996 (1)	$M=1.65/t_{50\%mature}$	$t_{50\%mature}$=35.5 (35, 35.9 95% CI)	0.046(0.046-0.047)
7	Jensen 1996 (2)	$M=1.5\kappa$	κ=0.060 (0.056, 0.066 95% CI)	0.090(0.084-0.099)
8	Jensen 1996 (3)	$M=1.6\kappa$	κ=0.060 (0.056, 0.066 95% CI)	0.096(0.090-0.105)
9	Gunderson & Dygert 1988 (1)	*M=0.03+1.68GSI, GSI=ovary weight/eviscerated weight*	*GSI*=0.010-0.096	0.097(0.047-0.191)
10	Gunderson & Dygert 1988 (2)	*M=0.03+1.68GSI, GSI=ovary weight/whole weight*	*GSI*=0.007-0.073	0.081(0.042-0.153)
11	Gunderson & Dygert 1988 (3)	*M=0.03+1.68GSI, GSI=standardized ovary weight/eviscerated weight*	*GSI*=0.000857-0.00957	0.037(0.031-0.046)
12	Gunderson & Dygert 1988 (4)	*M=0.03+1.68GSI, GSI=standardized ovary weight/whole weight*	*GSI*=0.000581-0.00833	0.035(0.031-0.044)
13	Chen & Watanabe 1989	$M(t,t<t_m)=\kappa/(1-e^{-\kappa(t-t0)})$, $M(t,t\geq t_m)=\kappa/(a_0+a_1(t-t_m)+a_2(t-t_m)^2)$	κ=0.060 (0.056, 0.066 95% CI), t_{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, $TL_{ext\infty}$, 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
$t_{50\%mature}$ from Saunders and McFarlane, 1993

Literature Cited

Alverson, D.L., and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer. 36:133-143.

Chen, S.B. and S. Watanabe. 1989. Age dependence of natural mortality coefficient in fish population dynamics. Nippon Suisan Gakkaishi/Bull. Jap. Soc. Sci. Fish. 55(2):205-208.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898-903.

Gunderson, D.R. and P.H. Dygert. 1988. Reproductive effort as a predictor of natural mortality rate. ICES J. Mar. Sci. 44:200-209.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal tradeoff of reproduction and survival. Can. J. Fish. Aquat. Sci. 53:820-822.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM. 39:175-192.

Peterson, I. and J.S. Wroblewski. 1984. Mortality rates of fishes in the pelagic ecosystem. Can. J. Fish. Aquat. Sci. 41:1117-1120.

Wood, C.C. , K.S. Ketchen, and R.J. Beamish. 1979. Population dynamics of spiny dogfish (Squalus acanthias) in British Columbia. J. Fish. Res. Board. Can. 36:647-656.