18 Assessment of the shark stocks in the Bering Sea

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EXECUTIVE SUMMARY

Summary of Major Changes

Changes to the input data

1. Total catch weight for BSAI sharks is updated for 2008 (as of Oct 3, 2008).
2. Biomass estimates from the 2008 EBS shelf and slope surveys are incorporated.
3. Life history and population demographic information has been updated with recent research results.

Changes in assessment methodology

There are no changes in the assessment methodology; however, an expanded timeline (1997-2007) is presented for consideration as the time series used to set the ABC & OFL for the shark complex. The expanded timeline does not change the Tier 6 ABC and OFL values significantly. The 1997-2005 timeline is short, only providing 9 years of data for Tier 6 calculations. The standard time series for the Tier 6 calculations is 1978-1995, providing up to 17 years of data. We recommend using the 1997-2007 timeline for estimating ABC and OFL, which includes 11 years of data for the Tier 6 calculations.

Summary of Results

ABC and OFL Calculations and Tier 6 recommendations for 2009-2010

BSAI Tier 6 Calculations (mt) ABC=0.75*Average Catch, OFL=Average Catch

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	**Total shark complex**
Average catch (1997-2005)	9	445	46	117	617
ABC (1997-2005)	7	334	35	88	463
OFL (1997-2005)	9	445	46	117	617
Average catch (1997-2007)	8	414	47	126	**596**
ABC (1997-2007)	6	311	35	94	**447**
OFL (1997-2007)	8	414	47	126	**596**

Tier 6 is the recommended method for ABC and OFL. The Plan Team and the SSC have suggested moving sharks to Tier 5, or moving spiny dogfish to Tier 5 and using Tier 6 for all the others. Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass, which do not exist for sharks in the BSAI as the efficiency of bottom trawl gear varies by species and is unknown. Therefore we do not recommend placing the sharks or any of the component species in Tier 5. 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. Survey biomass estimates for shark species in the BSAI are often zero, and should not be considered an accurate indicator of biomass. Tier 5 criteria also require reliable point estimates of natural mortality, which are now available for spiny dogfish and salmon sharks in the GOA, but which do not exist for the Pacific sleeper sharks in the GOA or for any shark species in the BSAI.

Responses to SSC Comments

Responses to SSC comments specific to this assessment
From the December 2007 SSC minutes:

1) *The SSC supports the Plan Team recommendation for using tier 5 criteria for sculpin and tier 6 criteria for sharks and octopus.*

Response: We concur.

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, Figure 1). The three shark species most likely to be encountered in BSAI fisheries and surveys are two members of the family Squalidae, the Pacific sleeper shark (*Somniosus pacificus*) and the piked or spiny dogfish (*Squalus acanthias*), and the salmon shark (*Lamna ditropis*). A history of the management measures taken for the other species group and shark complex is summarized in Table 2.

General Distribution

<u>Spiny Dogfish</u>
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 3, Figure 2). 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 4 and 5, Figures 3 and 4).

<u>Pacific Sleeper Shark</u>
Pacific sleeper sharks (*Somniosus spp*.) 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 (Orlov and Moiseev 1999), and south along the Alaskan and Pacific coast and possibly as far south as the coast of South America (de Astarloa 1999). 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 3, 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 4 and 5, Figures 2 and 3).

<u>Salmon Shark</u>
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 because they eat salmon and damage fishing gear (Macy et al. 1978, Compagno 1984). They have been investigated as potential target species in the Gulf of Alaska, however they are currently only targeted by sport fishermen in the state fishery (Paust and Smith 1989).

Salmon sharks are rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI (Tables 2 - 4, Figures 2 - 4).

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. 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. Because data for these species are sparse, acceptable biological catch (ABC) and overfishing levels (OFL) are usually based on Tier 5 and Tier 6 criteria (Table 2). 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 (Table 6).

In 1998 the SSC recommended Tier 5 procedures for specification of Other Species ABC (ABC = 0.75*M*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 increase the ABC from the Tier 6 values to the Tier 5 values.

Last year (2007 recommendations for 2008), 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

<u>Spiny Dogfish</u>
Previous studies have shown complex population structure for spiny dogfish populations 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 mix at a very small rate (Compagno 1984, McFarlane and King 2003). The migratory populations of spiny dogfish may undertake large scale migrations, ranging from British Columbia to Japan or Mexico (McFarlane and King 2003). Spiny dogfish tend to segregate by sex and by size, meaning that large males and large females are generally separate, and large sub-adults and small mature adults of both sexes tend to mix. The observed age structure in the GOA ranges from 8-50 years, and all areas of the GOA have generally the same age structure (Tribuzio and Kruse in review(a)).

<u>Pacific Sleeper Sharks</u>
Little is known about sleeper shark migratory behavior, or their life history. Tagging studies in Alaska have shown that at least some Pacific sleeper sharks reside in the Gulf of Alaska and

Prince William Sound throughout the year, where they exhibit relatively limited geographic movement (< 100 km; Hulbert et al. 2006). Sleeper sharks commonly migrate vertically throughout the water column (Hulbert et al. 2006; Orlov and Moiseev 1999), but did not migrate far from initial tagging locations in the Gulf of Alaska (Hulbert et al 2006). Median distance traveled for conventionally tagged sharks was 29.2 km, and median time at liberty was 1,729 days (Courtney and Hulbert 2007). Median vertical movement rate calculated from 4,781 hours of recorded depth data from one shark was 6 km/day (Hulbert et al. 2006). Similarly, sharks with acoustic tags in Southeast Alaska were tracked at depths greater than 500 m and made vertical migrations off the bottom (Courtney and Hulbert 2007). Another tracked shark also made horizontal movements of 6 km/day (Courtney and Hulbert 2007).

Salmon Sharks

Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific Ocean (WNP) and the eastern North Pacific Ocean (ENP) separated by longitude 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) for males and 170-180 cm PCL for females (Tanaka 1980). These lengths correspond to ages of approximately 5 years and 8-10 years, respectively. 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, Goldman and Musick 2006). Tanaka (1980, see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP salmon shark 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) and Goldman and Musick (2006) gave maximum ages for ENP salmon shark (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, 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, a band of high productivity at the southern boundary of the sub-arctic domain (~40-45˚N) of the North Pacific Ocean. According to Nakano and Nagasawa (1996), juveniles (70-110 cm PCL, slightly larger than term embryos) 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 in near coastal waters (Goldman and Musick 2008, Goldman and Musick 2006).

Life History Information

Sharks are long-lived species with slow growth to maturity, a large maximum size and low fecundity. Therefore, the productivity of shark populations 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 gestation periods (6 months - 2 years), with small numbers of large, well-developed offspring (Pratt and Casey 1990). Because of these life history characteristics, 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 AFSC's Fishery Monitoring and Analysis program, fishery observers measured spiny dogfish lengths 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, Figure 5). The average female length was larger than the male (average = 82.4, range 9-128, N = 601). Female modal lengths occured at a smaller size (74 cm) than males (82 cm), however, the length frequency extended to larger sizes than males. Although females peaked earlier, there were a greater proportion of females 94-128 cm long than males. In comparison, size frequencies for dogfish sampled during a UAF study in the GOA showed similar average sizes, but distributions were different. Male length averaging 80.3 cm TL_{ext} (measured from the tip of the snout to the tip of the upper caudal lobe with the tail depressed to align with the horizontal axis of the body) with a mode at 85 cm and ranged from 53-99 cm (N=623). The average female length was 87.6 cm, ranged from 50-123 cm, but was fairly uniformly distributed between 65-100 cm, with no apparent peak in length frequency (N=1351). While females had a larger size range than males, both sexes had similar frequencies for sizes <75 cm.

Historic estimates of spiny dogfish age-at-50%-maturity for the ENP range from 20 to 34 years. Ages-at-50%-maturity for BC spiny dogfish are reported at 35 years for females, and 19 years for males.(Saunders and McFarlane 1993). Ages from the spines of oxytetracycline-injected animals provided validation of an age-length relationship (Beamish and McFarlane 1985, McFarlane and Beamish 1987). The ages of ENP spiny dogfish have further been validated by bomb radiocarbon (Campana et al. 2006). The same study suggested that longevity in the ENP is between 80 and 100 years and that several earlier published ages-at-maturity (and therefore longevity) were low due to agers rejecting difficult to read spines and spine annuli that were grouped very close together. Age-at-maturity is similar in the GOA, 34 years for females and 19 years for males (Tribuzio, unpublished data). Growth rates for this species are among the slowest of all shark species, κ=0.03 for females and 0.06 for males (Tribuzio and Kruse, in review a).

The mode of reproduction in spiny dogfish is aplacental viviparity where embryos are retained within the uterus throughout gestation, but there is no physical attachment (such as a placenta) between the mother and offspring. In this case, spiny dogfish embryos are nourished solely by their yolk sac. Gestation is 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 parturition occured between February and April (Kaganovskaia 1937, Yamamoto and Kibezaki 1950, Anon 1956,). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio 2004). In the GOA, pupping may occur during winter months, based on the size of embryos observed during summer and fall sampling (Tribuzio, pers. obs.). Pupping is believed to occur in estuaries and bays (Richards 2004) or mid-water over depths of about 165-370 m (Ketchen 1986). Small juveniles and young of the year tend to inhabit the water column near the surface or areas not fished commercially. Therefore juveniles are not available to commercial fisheries until they grow or migrate to fished areas (Beamish et al. 1982, Tribuzio and Kruse,in review(b)). The average litter size is 6.9 pups for spiny dogfish in Puget Sound, WA (Tribuzio 2004), 6.2 in BC (Ketchen 1972) and 9.7 in the GOA (Tribuzio and Kruse , in review (b)). 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 after the onset of maturity (Ketchen 1972, Tribuzio 2004, Tribuzio and Kruse in review(b)).

Pacific Sleeper Sharks

Measurement techniques for determining the length of Pacific sleeper sharks are varied. In NMFS bottom trawl surveys, sleeper shark lengths have been recorded as pre-caudal length (PCL; tip of snout to the dorsal insertion of the caudal peduncle), fork length (FL; tip of snout to fork in tail), and total length (TL; tip of snout to tip of tail in a natural position). In NMFS longline research Pacific sleeper shark lengths have been reported in PCL (Sigler et al. 2006). In the GOA, Pacific sleeper shark length frequency distributions show peaks between 150 and 210 cm TL (Figure 2, bottom panel), with observations between 120-340 cm TL for the bottom trawl survey (1987-2007, n = 86, 76 hauls, 72% female) and 120-280 cm TL for longline research (n = 198, 24 hauls, 60% female, Courtney unpublished data, Sigler et al. 2006).

Sleeper sharks are most likely slow growing and long lived (Fisk et al. 2002). A Greenland shark (*Somniosus microcephalus*) sampled in 1999 was determined to be alive 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). The cartilage in sleeper sharks does not calcify to the degree of many other shark species, therefore aging is difficult and methods are under investigation. Sharks up to 7 m in length have been observed underwater (Compagno 1984). Sleeper sharks can attain large size. The maximum lengths of captured and measured Pacific sleeper sharks are 4.4 m for females and 4.0 m for males (Mecklenburg et al. 2002). Larger individuals have been reported to reach up to 7 m or more in length, estimated from photographs taken in deep water (Compagno 1984). The maximum lengths of Somniosus (sp.) are 3.9 m +- 1.07 (1.50 – 5.00) (n=36) captured and measured from mid-water trawls in the Southern Ocean off the outer shelf and upper continental slope of subantarctic islands (Cherel and Duhamel 2004).). In the Gulf of Alaska, Pacific sleeper sharks of 1.5-2.5 m have been measured (e.g. Sigler et al 2006) and Pacific sleeper sharks as large as 4.2 m have been measured in the Northwestern Pacific (Orlov 1999). This species exhibits an observed 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) (Orlov 1999).

Published observations suggest that mature female Pacific sleeper sharks are in excess of 3.65 m TL (total length), mature male Pacific sleeper sharks are in excess 397 cm TL, and that size at birth is approximately 40 cm TL (Gotshall and Jow 1965; Yano et al. 2007). However, 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 (Orlov 1999). Two recently-born 74 cm sharks have been caught off the coast of California at 1300 and 390 m depth; 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 sleeper sharks, 65-75 cm long, have been caught in the Northwest Pacific, but the date of sampling was not reported (Orlov and Moiseev 1999). In 2005, an 85 cm (pre-caudal length) female was caught during the annual sablefish survey near Yakutat Bay (Tribuzio, unpublished data). Because of a lack of mature and newly born sharks, and the absence of dates in the literature, the spawning and pupping season is unknown for sleeper sharks.

Salmon Sharks

Like other sharks of the family Lamnidae, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2 ^{o}C above ambient water temperatures and apparently maintaining a constant body core temperature regardless of ambient temperatures (Goldman 2002, 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, Goldman and Musick 2006) in the ENP (no conversions are given in the literature for salmon sharks in the WNP) and can weigh upwards of 220 kg. Lengths of 260 cm PCL (300 cm TL) and greater and weights exceeding 450 kg are rumored but unsubstantiated (Goldman and Musick 2008).

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage in which embryos feed on eggs produced by the ovary (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 in a 2.2:1 ratio (Nagasawa 1998), but this is from a very limited sample size. In the eastern Pacific, one record of a pregnant female salmon shark caught near Kodiak Island had four pups: two males and two females (Gallucci et al. 2008). 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 1986, Nagasawa 1998, Goldman 2002, 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, 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 sharks captured incidentally are not retained.
However, a small amount of spiny dogfish landings in Kodiak have been reported in 2004, 2005 and 2007 (~ 1 mt each year, J. Gasper, AKRO, pers. comm.). There is a Commissioners Permit fishery for spiny dogfish in lower Cook Inlet, but only one application has been received to date and the permit was not issued.

Some retention of incidentally caught spiny dogfish is allowed in ADF&G managed fisheries, with some landings reported in Yakutat during 2005 - 2008. The landings were highest in 2005, with about 11,363 kg landed, and decreased in 2008 (138 kg landed). Salmon sharks are targeted by sport fishermen in Alaska state waters.

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). Other Species reported catches have been relatively small each year since 1977 in the GOA (e.g., in 2001 Other Species catches of 25,482 tons made up 1.5% of the 1,652,802 ton total BSAI catch).

DATA

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Nontarget catch	2003 – 2008
Improved Pseudo Blend (AFSC)	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2008
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope (Historical)	Biomass Index	1979 – 1991
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope	Biomass Index	2002, 2004, 2008
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 – 2008 (Table 6). Sharks have been reported by species by the NMFS AKRO Catch Accounting System (CAS) 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 fishes and nonspecified 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 – 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 to 2008 in the BSAI, spiny dogfish were caught primarily in the Pacfic cod fishery (85%, Table 7), while Pacific sleeper sharks were caught primarily in the pollock fishery (53%, Table 8). Pacific sleeper sharks were also caught in the Pacific cod fishery (39%). Salmon sharks were rarely encountered, but 80% of the salmon shark catch occurred in the pollock fisheries (Table 9). Other sharks and unidentified sharks occurred primarily in the pollock fisheries (48%, Table 10). From 1997 – 2008 in the BSAI, spiny dogfish were caught primarily in areas 509 (36%) and 517 (24%; Table 11, Figure 1). Pacific sleeper sharks were caught primarily in areas 521 (53%) and 517 (25%; Table 12, Figure 1). There appears to be an increasing trend in catch of Pacific sleeper sharks from BSAI areas 521 and 517 during the years 1997 – 2002 (Table 12) which may reflect a change in fishing effort. During the years 2004-2008 catches in the same areas decreased. The catch of salmon sharks primarily occurred in areas 517 (41%) and 521 (27%; Table 13). Other sharks and unidentified sharks were caught mostly in areas 521 (33%), 519 (23%) and 524 (22%; Table 14).

Survey Biomass Estimates

Biomass estimates are available for shark species from NMFS AFSC bottom trawl surveys conducted in the Aleutian Islands (AI, 1979 – 2004,Tables 3 and 15), the eastern Bering Sea (EBS) shelf (1979 – 2008, Tables 4 and 15), and during two different time periods on the EBS slope (1979-1991 and 2002-2008; Tables 5 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 are very rare, and there does not appear to be any biomass trend for shark species (Tables 4 and 15, Figure 3). 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, 2004, and 2008 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 5 and 15, Figure 4). 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, 2004 and 2008) show a substantial biomass of Pacific sleeper sharks on the EBS slope in 2002 but not in 2004 (Tables 5 and 15, Figure 4). 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, and 2008 Table 5).

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 2). 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.

Other Data Sources

Weight-at-length and average length and weight values for all three species are presented in Table 14. Length-at-age models have been published for salmon sharks (Goldman and Musick, 2006) in the GOA, and are under review for spiny dogfish in the GOA (Tribuzio and Kruse, in review a). Growth models have been published for this species for many areas around the globe though. Because of the difficulty with aging Pacific sleeper sharks, growth models are not available for this species. Length at age models have been estimated for both spiny dogfish and salmon shark (Tribuzio and Kruse in review a; Goldman and Musick 2006). Growth model parameters for the von Bertalannffy growth models are presented in Table 14. While sharks are slow growing compared to teleosts fish, the spiny dogfish has the slowest growth rate of any modeled shark species.

ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Model Structure

Demographic models have been evaluated for spiny dogfish (Tribuzio and Kruse, in review b) and salmon sharks (Goldman 2002). Age- and stage-based Leslie matrix type models were used for spiny dogfish to compare the applicability of each type for a long lived species and life tables were used for salmon sharks to validate the compensation model of Au and Smith (1997). All models estimated intrinsic rebound potential (r), sustainable fishing mortality (F), and, for the spiny dogfish models, risk contours with different fishing scenarios.

Parameters Estimated Independently

Parameters estimated independently are identified for the major shark species in the Gulf of Alaska or North Pacific where data are lacking (Table 18, estimates are not available for BSAI stocks and thus GOA values are used as a proxy). Data gaps are identified where data are not available (NA). An estimate of the natural mortality rate (M = 0.097) is derived for spiny dogfish in the Gulf of Alaska (Tribuzio and Kruse, in review b). The value of M (0.097) for the Gulf of Alaska is comparable to the previously published estimate of M from British Columbia spiny dogfish of 0.094 (Wood et al. 1979). A range of natural mortality estimates is derived for salmon shark in the central Gulf of Alaska (Goldman, 2002). A natural mortality estimate is not available for Pacific sleeper sharks. Maximum reported age for central Gulf of Alaska salmon shark is 30 years (Goldman and Musick 2006). Maximum age of spiny dogfish in the eastern North Pacific is between 80 and 100 years (Beamish and McFarlane 1985, McFarlane and Beamish 1987). Age at first recruitment to a commercial fishery would be 5 years old for central Gulf of Alaska salmon sharks (Goldman, 2002). Maximum age and age of first recruitment are not available for spiny dogfish or Pacific sleeper shark, however, Tribuzio and Kruse (in review a) report the youngest encountered dogfish in fishery dependent sampling was 8 years old. Ages are not currently available for Pacific sleeper shark as this species appears to be very difficult to age.

Parameters Estimated Conditionally

Demographic analyses have been performed for both GOA spiny dogfish (Tribuzio and Kruse, in review) and ENP salmon sharks (Goldman, 2002) to estimate the rebound potential and sustainable fishing levels. Assuming an unfished population, the spiny dogfish population is increasing at a rate of 3.4% (1.2-6%, 95% confidence intervals) and salmon shark are increasing at a rate of 1.2% (-1.5-4.1%, 95% confidence intervals). Sustainable fishing levels for spiny dogfish were at F<0.03 and for salmon shark F<0.05. In both models, fishing mortality was uniform across all selected age classes. These models do not take into account bycatch mortality from unobserved fisheries. Because of the assumptions of the model (i.e. closed populations, uniform F across all ages), results should be considered as a "best case" scenario. Assuming a true unfished population is not realistic, because the actual fishing mortality is >0, however, the actual level of fishing mortality is unknown. Bycatch in unobserved halibut fisheries has been modeled, but not for state fisheries such as the salmon gill net fisheries, which may have at times very high spiny dogfish mortality. Salmon sharks are rare in commercial fisheries and the sport fishery is small, therefore the actual level of fishing mortality may be closer to zero.

ABC and OFL Calculations

The Tier 6 option is 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, however catch has been estimated from 1995-2008. For this reason, Courtney et al. (2006) provided a 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, fixing the final year at 2005. We recommend using the Tier 6 methodology to estimate ABC and OFL for sharks. We also present the ABC and OFL using 1997-2007 time series, which includes 2 additional years of data.

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, Tribuzio and Kruse, in review b), and is included 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 in the BSAI. Reliable point estimates of biomass do not exist for sharks in the BSAI due to their distribution and the questionable catchability of sharks by the survey gear. The biomass estimates are questionable for many reasons: 1) spiny dogfish and sleeper sharks are patchily distributed and an alternative method for estimating biomass may be necessary; 2) the current method for estimating biomass results in large coefficient of variations and unreasonable growth rates (i.e. the population tripling in two years); and 3) salmon sharks pelagic species, not easily encountered by bottom contact gear (Courtney et al. 2006, Booth and Quinn 2006, Hammond and Ellis 2005). 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 - 2007 were provided by the NMFS AKRO CAS(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 – 2007 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) and recommendations for 2009-2010.

BSAI Tier 6 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	**Total shark complex**
Average catch (1997-2005)	9	445	46	117	617
ABC (1997-2005)	7	334	35	88	463
OFL (1997-2006)	9	445	46	117	617
Average catch (1997-2007)	8	414	47	126	**596**
ABC (1997-2007)	6	311	35	94	**447**
OFL (1997-2007)	8	414	47	126	**596**

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.

<u>Spiny dogfish</u>
Previous studies have shown spiny dogfish 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). Spiny dogfish in the northwest Atlantic can eat twice as much in summer as in winter (Jones and Geen 1977). Spiny dogfish have also been shown to prey heavily on out-migrating salmon smolts (Beamish et al. 1992). In the GOA, preliminary diet studies further suggest that spiny dogfish are highly generalized, opportunistic feeders (Tribuzio, unpublished data).

<u>Pacific sleeper shark</u>
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*), indicating that they make depth oscillations in search of food (Orlov 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), suggesting that these sharks may not be as sluggish and benthic oriented as once thought. Although sleeper sharks share 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 at locations 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* sp.), 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). 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).

Ecosystem effects on *GOA Sharks*

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys, changes mean wt-at-age	Stable, data limited	Unknown
Non-pandalid shrimp and other benthic organism	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Composes the main portion of spiny dogfish diet	Unknown
Sandlance, capelin, other forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Salmon	Populations are stable or slightly decreasing in some areas	Small portion of spiny dogfish diet, maybe a large portion of salmon shark diet	No concern
Flatfish	Increasing to steady populations currently at high biomass levels	Adequate forage available	No concern
Pollock	High population levels in early 1980's, declined to stable low level at present	Primarily a component of salmon shark diets	No concern
Other Groundfish	Stable to low populations	Varied in diets of sharks	No concern

Ecosystem effects on *GOA Sharks* (cont'd)			
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	No likely a predator on sharks	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	No concern
Fish (Pollock, Pacific cod, halibut)	Stable to increasing	Possible increases to juvenile spiny dogfish mortality	
Sharks	Stable to increasing	Larger species may prey on spiny dogfish	Currently, no concern
Changes in habitat quality			
Temperature regime	Warm and cold regimes	May shift distribution, species tolerate wide range of temps	No concern
Benthic ranging from inshore waters to shelf break and down slope	Sharks can be highly mobile, and benthic habitats have not been monitored historically, species may be able to move to preferred habitat, no critical habitat defined for GOA	Habitat changes may shift distribution	No concern

***GOA Sharks* effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Not Targeted	None	No concern	No concern
Fishery concentration in space and time	None	No concern	No concern
Fishery effects on amount of large size target fish	If targeted, could reduce avg size of females, reduce recruitment, reduce fecundity, skewed sex ratio (observed in areas targeting species)	No concern at this time	No concern at this time
Fishery contribution to discards and offal production	None	No concern	No concern
Fishery effects on age-at-maturity and fecundity	Age at maturity and fecundity decrease in areas that have targeted species	No concern at this time	No concern at this time

Data Gaps and Research Priorities

Data are severely limited 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 - 2008 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 of 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 fishery observers in the BSAI do 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. Bycatch data from unobserved fisheries (i.e. halibut, salmon gill net) are necessary to adequately estimate the true fishing mortality on these species, especially given that sustainable F is estimated to be low.

SUMMARY

There is no evidence to suggest that overfishing 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 catches 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. 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 (Courtney et al. 2006). 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.

2009 and 2010 recommendations	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other/unid Shark
Tier	6	6	6	6
M	0.097	0.097	0.18	0.097
Avg catch (1997-2007)	8	414	47	126
ABC	6	311	35	94
OFL	8	414	47	126

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Table 1. Shark species in the eastern Bering Sea, and Aleutian Islands (BSAI) with life history and biological characteristics. Missing information is denoted by “?”.

Scientific Name	Common Name	Max. Obs. Length (TL, cm)	Max. Obs. Age	Age, Length, 50% Maturity	Feeding Mode	Fecundity	Depth Range (m)
Apristurus brunneus	brown cat shark	68[1]	?	?	Benthic[3]	?	1,306[2]
Carcharodon carcharias	White shark	792[4]	36[7]	15 yrs, 5 m[7]	Predator[6]	7-14[5]	1,280[3]
Cetorhinus maximus	basking shark	1,520[1]	?	5 yrs, 5m[8]	Plankton[6]	?	?
Hexanchus griseus	sixgill shark	482[9]	?	4m[1]	Predator[6]	22-108[1]	2,500[10]
Lamna ditropis	salmon shark	305[1]	20[11]	6-9 yrs, 165 cm PCL[11]	Predator[6]	3-5[7]	668[12]
Prionace glauca	blue shark	400[16]	15[13]	5 yrs[5], 221 cm[14]	Predator[6]	15-30 (up to 130)[15]	150[16]
Somniosus pacificus	Pacific sleeper shark	700[1]	?	?	Benth/Scav[17]	Up to 300[1]	2,700[18]
Squalus acanthias	Spiny dogfish	125[19]	107[20]	34 yrs, 80 cm[19]	Pred/Scav/Bent[19]	7-14[19]	300[3]

[1]Compagno, 1984; [2]Eschmeyer and Herald, 1983; [3]Mecklenburg et al. 2002; [4]Scott and Scott, 1988; [5]Smith et al. 1998; [6]Cortes, 1999; [7]Gilmore, 1993; [8]Mooney-Seus and Stone, 1997; [9]Castro, 1983; [10]Last and Stevens, 1994; [11]Goldman and Musick 2006, [12]Hulbert et al. 2005; [13]Stevens, 1975; [14] ICES 1997; [15] White et al. 2006; [16]Smith, 1997; [17]Yang and Page, 1999; [18]www.nurp.noaa.gov; [19]Tribuzio ongoing studies; [20]G. A. McFarlane, pers. comm.

Table 2. Time series of Other Species TAC, Other Species and shark catch, ABC for sharks and the management method for 1997-2008.

Year	Other spp. TAC	Est. other spp. catch	Est. shark catch	ABC	Management method
1997	25,800	25,176	368	N/A	Other Species TAC
1998	28,800	25,531	497	N/A	Other Species TAC
1999	32,860	20,562	530	N/A	Other Species TAC
2000	31,360	26,108	590	N/A	Other Species TAC
2001	26,500	27,178	764	N/A	Other Species TAC
2002	30,825	26,296	1,362	N/A	Other Species TAC
2003	32,309	25,373	515	N/A	Other Species TAC
2004	27,205	29,637	514	N/A	Other Species TAC
2005	29,000	29,505	414	N/A	Other Species TAC
2006	29,000	26,797	672	N/A	Other Species TAC
2007	37,355	26,667	330	463	Other Species TAC
2008	50,000	21,340	176	463	Other Species TAC

Data Sources: TAC and Other Species catch came from AKRO catch statistics website. 1977-2001 Gaichas (2002); 2002 - 2008 NMFS AKRO BLEND database, Juneau, AK 99801, as of Oct. 3, 2008.

Table 3. Aleutian Islands AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls. Source: Personal communication, Mark Wilkins, Oct. 2008.

		Spiny Dogfish			Sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1980	129	0			0			0		
1983	372	3	2.3	0.61	3	253.50	0.65	0		
1986	443	6	13.8	0.51	12	1994.90	0.36	0		
1991	331	0			3	2926.50	0.69	0		
1994	381	9	47.00	0.37	3	373.50	0.64	0		
1997	397	2	11.4	0.71	10	2485.70	0.29	0		
2000	419	3	25.00	0.62	3	2638.30	0.57	0		
2002	417	0			4	536.20	0.55	1	893.00	1.00
2004	420	0			2	1016.90	0.96	0		
2006	358	6	61.8	0.49	1	76.40	1.00	0		

Table 4. Eastern Bering Sea shelf AFSC trawl survey estimates of individual shark species total biomass (metric tons) with cv and number of hauls (Bob Lauth, pers. comm., October, 2008).

		Spiny Dogfish			Sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	452	4	389	0.56	0			0		
1980	342	0			0			0		
1981	290	0			0			0		
1982	329	0			0			0		
1983	354	2	379	0.83	0			0		
1984	355	0			0			0		
1985	353	1	47	0.99	0			0		
1986	354	0			0			0		
1987	342	3	223	0.60	0			0		
1988	353	1	249	1.0	0			1	3,808	1.0
1989	353	0			0			0		
1990	352	0			0			0		
1991	351	0			0			0		
1992	336	0			2	2,564	0.72	0		
1993	355	0			0			0		
1994	355	0			2	5,012	0.82	0		
1995	356	0			1	1,005	1.00	0		
1996	355	0			2	2,804	0.82	0		
1997	356	1	37	1	0			0		
1998	355	1	254	1	1	2,124	1.00	0		
1999	353	0			2	2,079	0.71	0		
2000	352	0			1	1,487	1.00	0		
2001	355	0			0			0		
2002	355	0			3	5,602	0.65	0		
2003	356	0			1	734	1.00	0		
2004	355	1	28	1.00	2	3,093	0.71	0		
2005	353	0			2	1,532	0.75	0		
2006	356	0			2	2,944	0.78	0		
2007	356	0			0			0		
2008	375	0			0			0		

Table 5. Eastern Bering Sea slope AFSC trawl survey estimates of individual shark species total biomass (metric tons) with cv, and number of hauls (Jerry Hoff, pers. comm., October, 2008).

		Spiny Dogfish			Sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	105	0			0			0		
1981	205	1	1	0.83	0			0		
1982	299	3	8	0.73	1	12	1.02	0		
1985	325	3	2	0.66	19	543	0.1	0		
1988	131	0			10	1,993	0.39	0		
1991	85	0			6	1,235	0.44	0		
New Slope Survey										
2002	141	0			15	25,445	0.87	0		
2004	231	0			24	2,260	0.34	0		
2008	207	1	14	1	28	2,037	0.27	0		

Table 6. Estimated incidental catch (mt) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 5, 2008. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2008 from NMFS AKRO blend-estimated annual catches.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks	Total other species	Shark % of other species
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	29,637	2%
2005	11	328	48	26	414	29,505	1%
2006	7	299	61	305	672	26,798	3%
2007	3	257	44	25	330	26,668	1%
2008	9	119	41	7	176	21,340	1%
Total est. catch	99	4,678	560	1,392	6,732	310,172	
species % of total sharks	1%	69%	8%	21%			
Avg. 1997 – 2005	9	445	46	117	617	26,131	
Avg. 1997-2008	8	414	47	126	596	25,848	

Sources:

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

2003 – 2008; NMFS AKRO as of October 5, 2008.

Table 7. Estimated catches (mt) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO blend-estimated annual catches.

Year	Atka Mackerel	Flatfish	Other	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Total	Avg. % total
1997	0	0		4.1	0	0	0	0	4.1	5%
1998	0.2	0.4	0	5.6	0.1	0	0	0	6.3	8%
1999	0	0	0	4.9	0	0	0	0	4.9	6%
2000	0	0.2	0	8.6	0	0	0	0	8.8	11%
2001	2.8	1.6	0	12.7	0.1	0	0.1	0	17.3	22%
2002										
2003										
2004	0	0.2	0	8.3	0	0	0.1	0	8.6	11%
2005	0	0.1	0	11.1	0	0	0	0	11.3	14%
2006	0	0.1	0	6.5	0.2	0	0.1	0	6.9	9%
2007	0	0.3	0	2.5	0.1	0	0	0	2.9	4%
2008	0	5.4	0	3.1	0	0.1	0	0	8.6	11%
Total	3.1	8.2	0	67.5	0.6	0.1	0.3	0	79.8	
Avg. % total	4%	10%	0%	85%	1%	0%	0%	0%		

Table 8. Estimated catches (mt) of Pacific sleeper sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish Total	Other Total	Pacific Cod Total	Pollock Total	Rockfish Total	Sablefish Total	Turbot Total	Total	Avg. % of Total
1997	0.1	0	0	0	6.7	0	0	0	6.8	0%
1998	0	0.1	0	0.8	16.2	0	0	0.8	17.9	1%
1999	0.2	2.5	0	1.2	24.7	0	0	1.5	30.1	2%
2000	0	0	0	3.8	19.5	0	0	0	23.3	2%
2001	0.4	0.4	0	1.2	22.5	0	0	0	24.5	2%
2002										
2003										
2004	2.0	38.5	0.3	229.9	143.7	0.7	2.3	2.5	419.9	28%
2005	0	7.8	0	190.2	123.8	0.1	3.4	2.7	328.1	22%
2006	0	9.6	0.1	121.9	164.8	0.1	0.9	1.3	298.9	20%
2007	1.1	9.1	3.7	44.6	181.6	14.5	2.2	0.5	257.3	17%
2008	0	6.0	0	5.8	105.0	1.2	0.6	0.3	118.8	8%
Total	3.8	74.0	4.2	599.4	808.6	16.6	9.5	9.5	1525.7	
Avg. % of Total	0%	5%	0%	39%	53%	1%	1%	1%		

Table 9. Estimated catches (mt) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish	Other	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Total	Avg. % of Total
1997	0.1	0	0	0	6.7	0	0	0	6.8	2%
1998	0	0.1	0	0.8	16.2	0	0	0.8	17.9	6%
1999	0.2	2.5	0	1.2	24.7	0	0	1.5	30.1	9%
2000	0	0	0	3.8	19.5	0	0	0	23.3	7%
2001	0.4	0.4	0	1.2	22.5	0	0	0	24.5	8%
2002									0	0%
2003									0	0%
2004	0	0.1	0	0.1	24.9	0	0	0	25.0	8%
2005	18.2	0.7	0	4.1	25.3	0	0	0	48.4	15%
2006	0.2	25.9	0	1.2	33.6	0	0	0	60.8	19%
2007	0.1	0	0	0	44.3	0	0	0	44.4	14%
2008	0	0.6	0	0	40.7	0	0	0	41.3	13%
Total	19.2	30.3	0	12.3	258.4	0	0	2.3	322.5	
Avg. % of Total	6%	9%	0%	4%	80%	0%	0%	1%		

Table 10. Estimated catches (mt) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish	Other	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Total	Avg. % of Total
1997	0	0.4	0	26.8	15.6	2.5	1.2	6.3	52.8	6%
1998	13.1	0	0	48.4	45.4	0	2.1	26.9	135.9	15%
1999	0	0.2	0.3	18.8	10.3	0	1.8	144.9	176.3	20%
2000	0	1.2	0	56.1	0.1	0	7.2	3	67.6	8%
2001	0	0	0	19.6	2.3	0	10.4	2.7	35.0	4%
2002										
2003										
2004	0	22.2	0	20.2	17.6	0	0	0	60.1	7%
2005	0	0.0	0	10.1	16.0	0	0	0	26.1	3%
2006	0	2.1	0	3.6	298.0	0	0.1	1.6	305.4	34%
2007	0	2.9	0	2.1	19.8	0	0	0	24.8	3%
2008	0	0.3	0	0.9	5.7	0	0	0	6.9	1%
Total	13.1	29.3	0.3	206.7	430.8	2.5	22.8	185.4	891.0	
Avg. % of Total	1%	3%	0%	23%	48%	0%	3%	21%		

Table 11. Estimated catches (mt) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0	1.7	0	0	0	0	1.5	0	0.1	0.6	0.1	0	0	0.1	0	0	0	4.1
1998	0	3.1	0	0.1	0	0	1.3	0.2	0.1	0.8	0.1	0	0	0.4	0.1	0	0	6.4
1999	0	2.4	0	0.1	0	0	1	0.4	0.1	0.8	0.1	0	0	0.1	0	0	0	5.0
2000	0	5.8	0	0.2	0	0	1.9	0.1	0.2	0.4	0	0	0	0.2	0.1	0	0	8.9
2001	0	5.7	0.1	1.2	0	0.2	3.8	0.6	0.2	1.3	0.1	0	0	1	2.4	0.8	0	17.3
2002	0	3.9	0	0.2	0	0.3	1.9	0	0	2.8	0.1	0	0	0.1	0	0	0	9.4
2003																		
2004	0	2.6	0.0	0.4	0	0.0	3.0	0.1	0.1	1.9	0.1	0.1	0	0.1	0.1	0.1	0	8.6
2005	0	3.7	0.0	0.8	0	0.0	3.6	0.0	0.4	2.0	0.2	0.1	0	0.4	0.0	0.0	0	11.3
2006	0	1.3	0.0	0.3	0	0.0	2.5	0.0	0.1	1.6	0.2	0.0	0	0.6	0.3	0.0	0	6.9
2007	0	1.0	0.0	0.1	0	0.0	0.5	0.0	0.1	0.6	0.1	0.0	0	0.3	0.1	0.1	0	2.9
2008	0	1.2	0.0	0.1	0	0.0	0.2	1.6	0.1	1.7	0.1	0.0	0	1.1	1.9	0.5	0	8.6
Total	0	32.5	0.1	3.5	0	0.6	21.2	3.0	1.5	14.5	1.3	0.3	0	4.4	4.9	1.5	0	89.4
Area % of Total	0%	36%	0%	4%	0%	1%	24%	3%	2%	16%	1%	0%	0%	5%	6%	2%	0%	

Table 12. 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), 2004-2008 are from NMFS AKRO CAS.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0	1	0	4.7	0	0	76.2	35.4	32.5	108.5	8.1	9.7	0	26.9	0.9	0	0	303.9
1998	0	0.4	0	1.9	0.5	0	44	36.7	36	193.8	4.1	15.5	0	3.2	0	0	0	336.1
1999	0	0.5	0	1.5	0	0	76.4	18.9	2.8	163.8	7.7	15.6	0	6.8	24.7	0	0	318.7
2000	0	2.3	0	3.6	0	0.1	93.8	2.1	26.9	199.4	5.6	12.5	0	1.4	48.7	93.9	0	490.3
2001	0	11.7	0	6.4	0	0	142.5	9.3	48.6	420.5	3.2	9.6	0	26.7	8.7	0	0	687.2
2002	0	36.8	0	5.7	0	0	172	0.2	9.3	601.8	5.7	2.5	0	1.9	0.1	2.4	0	838.4
2003																		
2004	0	13.3	0	6.7	0.0	0.0	134.8	0.2	13.8	230.3	3.1	12.2	0	2.2	3.4	0	0	419.9
2005	0	14.4	0	6.3	0.0	0.0	102.8	0.8	3.7	172.2	6.5	17.8	0	0.1	3.5	0	0	328.1
2006	0	41.2	0	9.3	0.0	0.0	102.7	0.2	7.7	124.9	2.1	10.5	0	0.2	0.0	0.1	0	298.9
2007	0	49.1	0	12.1	0.0	0.0	98.9	0.7	9.7	64.8	1.2	5.1	0	1.4	14.3	0	0	257.3
2008	0	36.9	0	1.3	0.0	0.0	36.7	0.1	3.4	36.2	0.4	2.5	0	0.6	0.6	0	0	118.8
Total	0	207.6	0	59.5	0.5	0.1	1080.6	104.6	194.4	2316.1	47.7	113.6	0	71.5	105.0	96.4	0	4397.7
Area % of total	0%	5%	0%	1%	0%	0%	25%	2%	4%	53%	1%	3%	0%	2%	2%	2%	0%	

Table 13. Estimated catches (mt) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0	1.3	0	0.2	0	0	4	0	0.3	0.8	0	0	0	0	0.2	0	0	4.1
1998	0	2	0	0.5	0	0	10.3	0.2	1.4	2.5	0	0.1	0	0	0	1	0	6.4
1999	0	2	0	1.5	0	0	18.9	0	0	7.1	0	0	0	0.2	0.1	0.1	0	5.0
2000	0	4.5	0	0.8	0	0	6	0	0.4	7.8	0	0.3	0	0.1	3.4	0	0	8.9
2001	0	2.3	0	3.3	0	0.1	8.2	0	2	7.5	0.5	0.3	0	0	0.4	0	0	17.3
2002	0	2.9	0	4.3	0	0	11.3	0	1.2	26.9	0	0	0	0	0	0	0	9.4
2003																		
2004	0	1.6	0	1.6	0	0.3	11.1	0	3.2	7.2	0	0	0	0	0	0	0	25.0
2005	0	3.9	0	0.3	0	1.6	9.4	0	1.1	13.7	0	0.1	0	0.1	0	18.2	0	48.4
2006	0	8.5	0	27.0	0	0.0	12.7	0	0.5	10.6	0	1.3	0	0	0.2	0	0	60.8
2007	0	1.3	0	1.6	0	0.0	31.2	0	0.5	6.1	0	3.5	0	0.1	0.1	0	0	44.4
2008	0	1.7	0	0.0	0	0.0	29.6	0	0.6	8.2	0	1.1	0	0	0	0	0	41.3
Total	0	32.0	0.0	41.1	0	2.0	152.6	0.2	11.3	98.4	0.6	6.7	0	0.5	4.4	19.3	0	369.1
Area % of Total	0%	9%	0%	11%	0%	1%	41%	0%	3%	27%	0%	2%	0%	0%	1%	5%	0%	

Table 14. Estimated catches (mt) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by statistical area. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2008 are from NMFS AKRO CAS.

Year	508	509	512	513	514	516	517	518	519	521	523	524	530	541	542	543	550	Total
1997	0	6.8	0	0.6	0	0	9.3	6.3	1.7	23	1.9	3	0	0.1	0.1	0	0	4.1
1998	0	6.6	0	0.7	0	0.1	10.9	2	6.4	90.4	1.4	2.1	0	13.9	1.6	0	0	6.4
1999	0	0.3	0	0.2	0	0	3.7	3	2.6	21.6	3.9	140.7	0	0.4	0	0	0	5.0
2000	0	0.5	0	0	0	0.1	8.2	3.2	0.1	46.1	1.7	0	0	0.5	7.2	0	0	8.9
2001	0	0.7	0	0.2	0	0	7.5	0	0.3	15.2	0.7	0	0	0	10.4	0	0	17.3
2002	0	14.9	0	1.7	0	0.2	39.5	14.5	11.1	196.3	9.7	145.8	0	14.8	19.3	0	0	9.4
2003																		
2004	0	5.0	0.1	0.0	0	0.1	16.8	0	1.0	36.5	0	0.3	0	0	0	0	0	60.0
2005	0	1.8	0	1.3	0	0	11.2	0	2.0	9.5	0.1	0.2	0	0	0	0	0	26.1
2006	0	3.5	0	0.2	0	0	14.2	0	279.3	8.0	0.2	0.1	0	0	0	0	0	305.4
2007	0	3.1	0	1.2	0	0	12.8	0	2.5	4.8	0	0.4	0	0	0	0	0	24.8
2008	0	0.7	0	0.0	0	0	3.0	0.3	0.7	2.1	0	0.1	0	0	0	0	0	6.9
Total	0	43.8	0.1	6.2	0	0.5	137.2	29.3	307.7	453.5	19.6	292.7	0	29.7	38.6	0.0	0	1359.0
Area % of Total	0%	3%	0%	0%	0%	0%	10%	2%	23%	33%	1%	22%	0%	2%	3%	0%	0%	

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 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
2007	0		
2008	0	2,051	

Source: Gaichas et al. (1999, Table 15), Gaichas (2003, Table 16-8). EBS Shelf and Slope updated Oct, 2008 (Pers. Comm., Bob Lauth, Jerry Hoff). AI updated Oct 2008 (Pers. Comm., Mark Wilkins).

Table 16. Research catches (metric tons) of sharks between 1977 and 2008 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	-	0.08
2000	8.50	0.62	9.12
2001	-	-	-
2002	5.74	0.23	5.97
2003	0.03	-	0.03
2004	0.76	0.10	0.86
2005	0	-	0
2006	0	0.07	0.07
2007	0	-	0
2008	0.47	-	0.47

Sources: Gaichas et al. (1999, Table 3), Gaichas (2002, Table 15-9), Bob Lauth, Mark Wilkins and Jerry Hoff (Pers. Comm.)

Table 17. Life history parameters. Top: Length-weight coefficients and average lengths and weights are provided for the formula $W=aL^b$, where W = weight in kilograms and L = PCL (precaudal length in cm). Bottom: Length at age coefficients are from the von Bertalanffy growth model, with L_∞ either being the PCL or the TL_{ext} (total length with the upper lobe of the caudal fin depressed to align with the horizontal axis of the body). Sources: NMFS sablefish longline surveys 2004 - 2006, NMFS GOA bottom trawl surveys in 2005; Sigler et al (2006); Goldman and Musick (2006) and Tribuzio and Kruse (in review).

Species	Area	Gear type	Sex	Average size PCL (cm)	Average weight (kg)	a	b	Sample size
Spiny dogfish	GOA	NMFS bottom trawl surveys	M	63.4	2	1.40E-05	2.86	92
Spiny dogfish	GOA	NMFS bottom trawl surveys	F	63.8	2.29	8.03E-06	3.02	140
Spiny dogfish	GOA	Longline surveys	M	64.6	1.99	9.85E-06	2.93	156
Spiny dogfish	GOA	Longline surveys	F	64.7	2.2	3.52E-06	3.2	188
Pacific sleeper shark	Central GOA	Longline surveys	M	166	69.7	2.18E-05	2.93	NA
Pacific sleeper shark	Central GOA	Longline surveys	F	170	74.8	2.18E-05	2.93	NA
Salmon shark	Central GOA	NA	M	171.9	116.7	3.20E-06	3.383	NA
Salmon shark	Central GOA	NA	F	184.7	146.9	8.20E-05	2.759	NA

Species	Sex	L_∞ (cm)	κ	t_0 (years)
Spiny Dogfish	M	93.7 (TL_{ext})	0.06	-5.1
Spiny Dogfish	F	132.0 (TL_{ext})	0.03	-6.4
Pacific Sleeper Shark	M	NA	NA	NA
Pacific Sleeper Shark	F	NA	NA	NA
Salmon Shark	M	182.8 (PCL)	0.23	-2.3
Salmon Shark	F	207.4 (PCL)	0.17	-1.9

Table 18. Natural mortality parameter estimates for each species in the GOA. Sources for GOA spiny dogfish are Tribuzio and Kruse (in review), ENP spiny dogfish (Wood et al. 1979) and Goldman (2002) for salmon shark.

Species	Area	M for Tier calc	Max age	Age of first recruit
Spiny dogfish	GOA	0.097	NA	NA
Spiny dogfish	ENP	0.094	80 – 100	NA
Pacific sleeper shark	NA	NA	NA	NA
Salmon shark	GOA	0.18	30	5

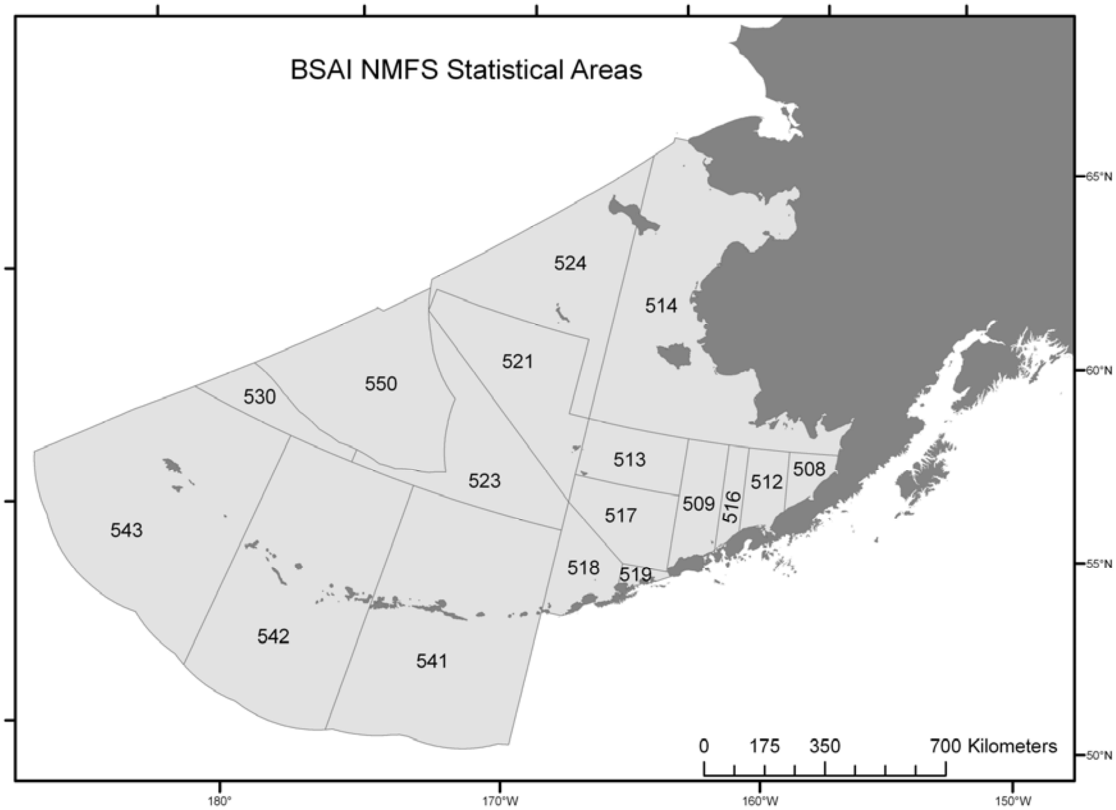

Figure 1. NMFS statistical areas in the Bering Sea and Aleutian Islands.

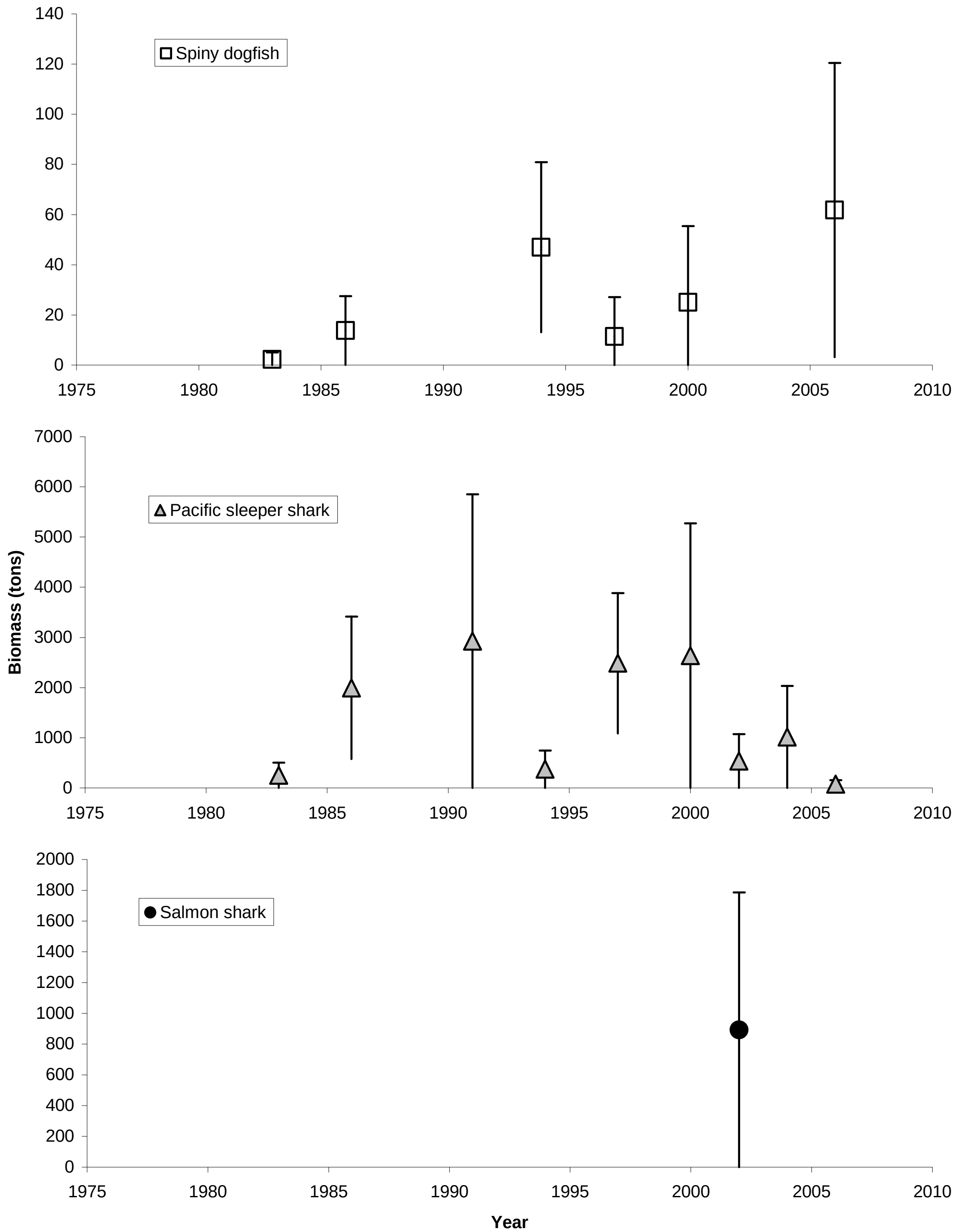

Figure 2. Trends in Aleutian Islands AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of AI survey biomass trends is subject the following time series caveats. Catchability of sharks in the survey is unknown.

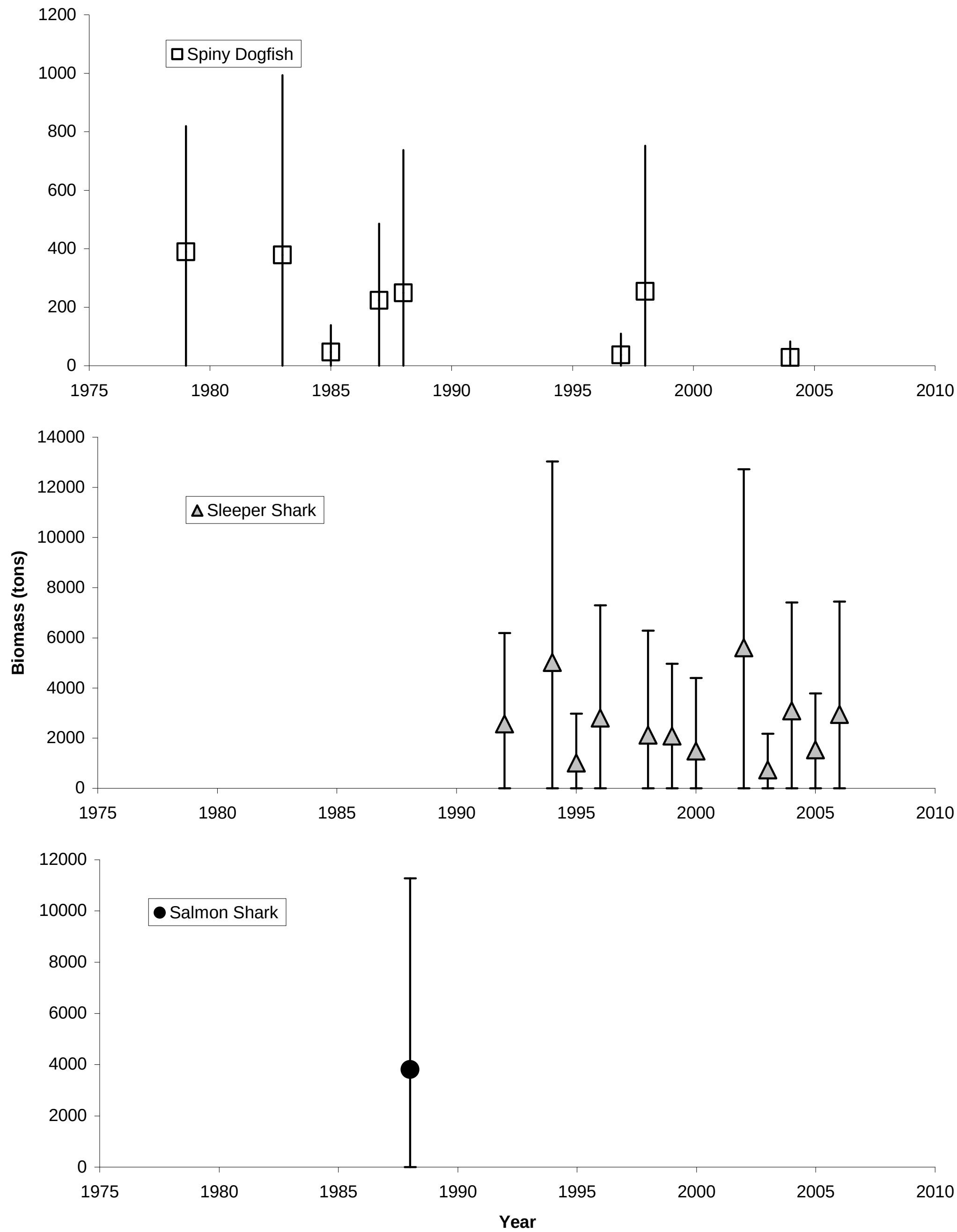

Figure 3. Trends in eastern Bering Sea shelf AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS shelf biomass trends is subject to following time series caveats. The 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.

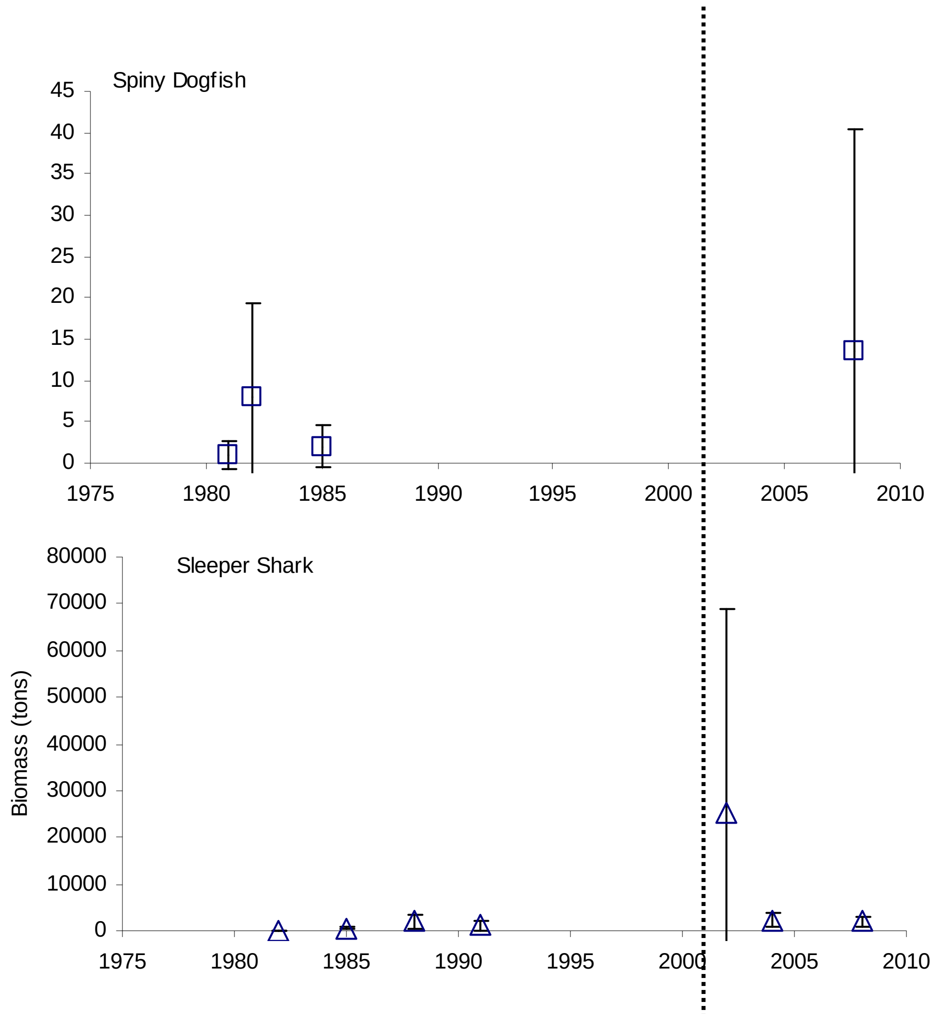

Figure 4. Trends in eastern Bering Sea slope AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Dashed line indicates beginning of new EBS slope survey (2002, 2004), which is not comparable 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 2008). In addition, prior to 2002, the survey utilized a mix of commercial and research vessels with various gear configurations.

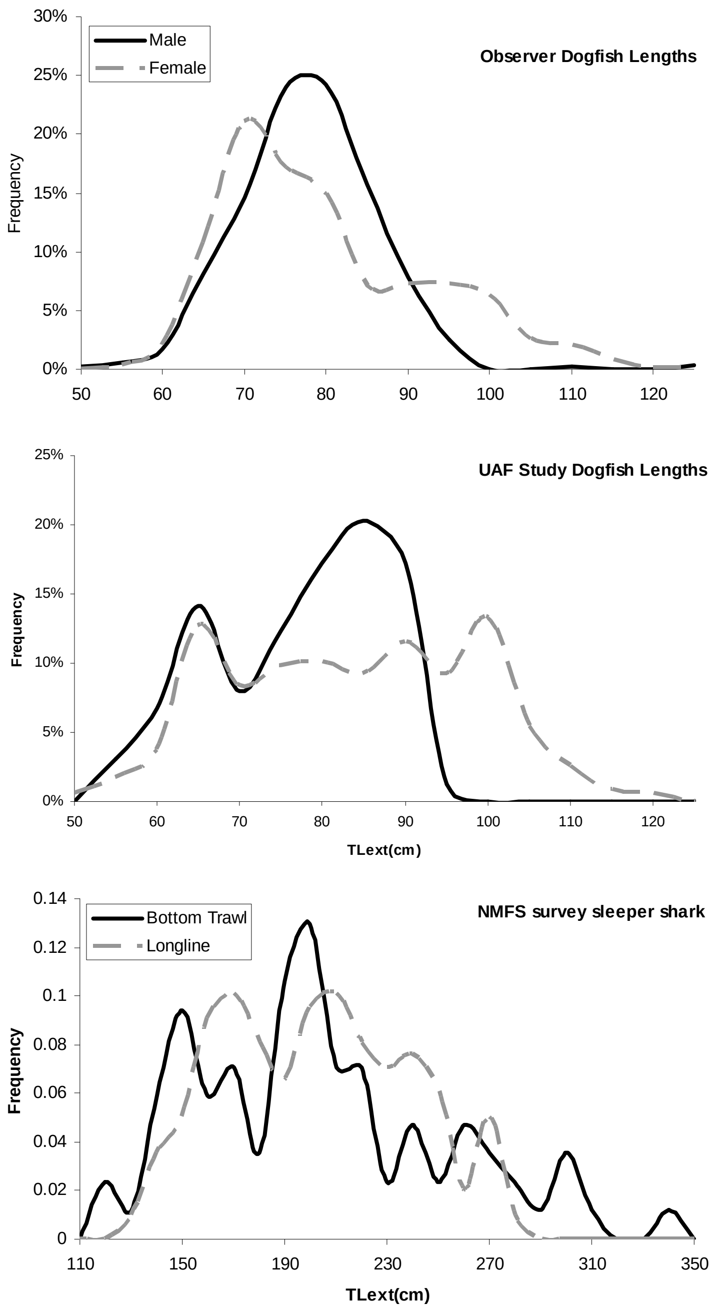

Figure 5. Observed length frequencies for: (top) spiny dogfish taken from a special project with the observer program; (center) spiny dogfish taken from a separate study conducted by the University of Alaska Fairbanks; (bottom) Pacific sleeper shark taken during both the bottom trawl and longline surveys.

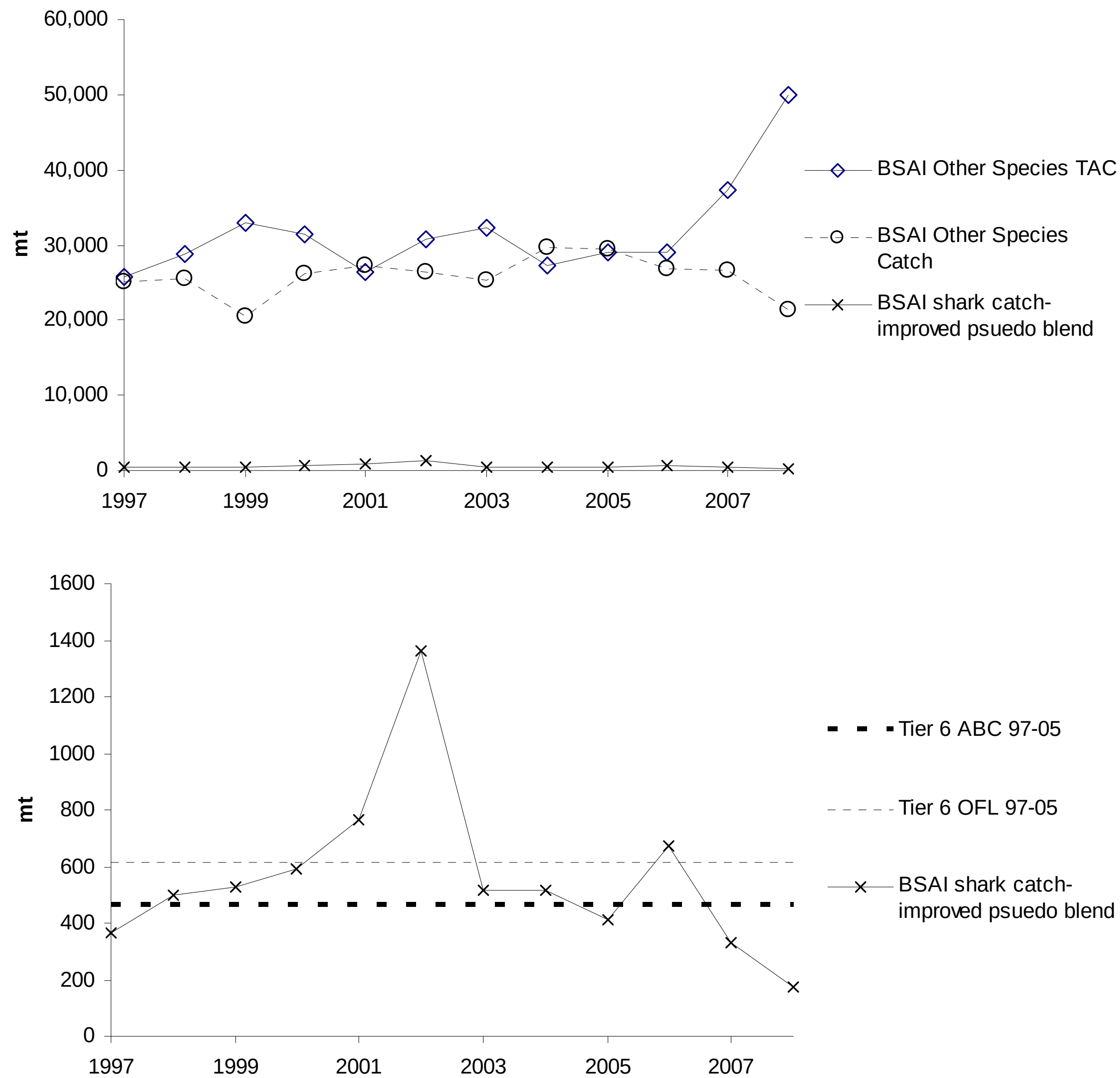

Figure 6. Top: comparison of total BSAI shark catch relative to the total Other Species catch and the Other Species TAC. BSAI total shark catch has been low relative to BSAI other species catch. Bottom: BSAI total shark catch per year plotted relative to 2006 ABC and OFL options for the BSAI shark complex under Tier 6. BSAI shark catch surpasses the Tier 6 ABC in many years.
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