18d. Assessment of the shark stocks in the Gulf of Alaska

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EXECUTIVE SUMMARY

Summary of Major Changes

Changes to the input data

1. Total catch weight for GOA sharks is updated with 2007 and 2008 data (as of Oct 3, 2008).
2. Biomass estimates from the 2007 GOA bottom trawl survey 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 and OFL for the shark complex. The expanded timeline does not change the Tier 6 ABC and OFL values substantially. The 1997-2005 timeline is short, only providing 9 years of data for Tier 6 calculations. The standard time series for Tier 6 calculations for other stock assessments is 1978-1995, which provides 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.

GOA 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)	422	313	63	208	**1,005**
ABC (1997-2005)	316	235	47	156	**754**
OFL (1997-2005)	422	313	63	208	**1,005**
Average catch (1997-2007)	482	304	63	187	**1,036**
ABC (1997-2007)	362	228	47	140	**777**
OFL (1997-2007)	482	304	63	187	**1,036**

Alternative GOA Tier 6 Calculations (mt) ABC=0.75*Maximum Catch, OFL=Maximum Catch

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Unidentified shark	**Total shark complex**
Max catch (1997-2005)	865	608	132	1,380	**2,985**
ABC	649	456	99	1,035	**2,239**
OFL	865	608	132	1,380	**2,985**

*NOTE: there was no change to the observed maximum catch by including years 2006-2008.

The Tier 6 methodology is recommended for calculating ABC and OFL; however, the alternative Tier 6 is also presented for consideration. We recommend Tier 6 over the alternative Tier 6 because of the potentially large unobserved or unreported catches in the halibut IFQ and ADF&G managed salmon set net fisheries. For example, Courtney et al. (2006, Appendix D) estimated shark catch by species and for 2004, the estimated spiny dogfish catch in the halibut IFQ fishery was roughly equal to the estimated catch for all sharks in the observed fisheries in the GOA. The Plan Team, and the SSC, has 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 GOA as the efficiency of bottom trawl gear varies by species and is unknown, thus, 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. Tier 5 criteria also require reliable point estimates of natural mortality, which are now available for spiny dogfish and salmon sharks, but which do not exist for Pacific sleeper sharks or other/unidentified sharks.

Responses to SSC Comments

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

There were no comments specific to this assessment in the December 2007 SSC minutes.

Responses to SSC comments on assessments in general
1) *The SSC accepts Plan Team reasoning for setting a 4000t catch level to meet incidental catch needs (for other species).*
Response:
We concur.

Introduction

Alaska Fisheries Science Center (AFSC) survey and fishery observer catch records provide information on shark species known or suspected to occur in the Gulf of Alaska (GOA) (Table 1, Figure 1). The three shark species most likely to be encountered in GOA fisheries and surveys are the Pacific sleeper shark (*Somniosus pacificus)*, the piked or spiny dogfish (*Squalus acanthias)*, 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 GOA or Bering Sea and Aleutian Islands (Hart 1973, Ketchen 1986, Mecklenburg et al. 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).

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 (de Astarloa et al. 1999). However, Yano et al. (2004) reviewed the systematics of sleeper sharks and suggested that sleeper sharks in the southern hemisphere and the southern Atlantic were misidentified as Pacific sleeper sharks 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 1,750 m (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).

Salmon Shark

Salmon sharks range in the North Pacific from Japan through the Bering Sea and GOA 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 consume salmon and they damage fishing gear (Macy et al. 1978, Compagno 1984). Salmon sharks have been investigated as potential target species in the GOA; however, they are currently only targeted by sport fishermen in the state fishery (Paust and Smith 1989).

Management Units

There are no directed fisheries for sharks in the GOA, but some incidental catch of sharks results from directed fisheries for other commercial species. Sharks are currently managed in aggregate as part of the "Other Species" complex in the GOA Fishery Management Plan (FMP) (Gaichas et al. 1999, 2003). The Other Species complex includes sculpins, sharks, squid, and octopus. Skates were separated from the GOA Other Species complex in 2003 (Gaichas et al. 2003). Other Species are considered ecologically important and may have future economic potential. An aggregate Total Allowable Catch (TAC) for Other Species is set for the GOA. The TAC for the

GOA Other Species complex is set at less than or equal to 5% of the sum of the TAC's of managed GOA species (Table 2). 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 for the Other Species complex is constrained by the GOA Optimum Yield (OY) cap of 2 million metric tons. Sharks catches have only been identified to the species level since 1997 and have made up from 11% to 64% of Other Species catch from 1997–2008 (Table 3).

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; 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. However, tagging studies in Alaska have shown that at least some Pacific sleeper sharks reside in the GOA 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, Orlav and Moiseev 1999), but did not migrate far from initial tagging locations in the GOA (Hulbert et al 2006). Median distance traveled for numerically 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, sonically tagged sharks in Southeast Alaska were acoustically tracked at depths greater than 500 m and made vertical migrations off the bottom (Courtney and Hulbert 2007). In addition, one sonically tagged shark also made horizontal movements of 6 km/day (Courtney and Hulbert 2007).

<u>Salmon Sharks</u>

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}W (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, Goldman and Musick 2006). Tanaka (1980, see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP salmon sharks is at least 25 years for males and 17 years for females and that von Bertalanffy growth coefficients (κ) for males and females are 0.17 and 0.14, respectively. Goldman (2002) and Goldman and Musick (2006) gave maximum ages for ENP salmon sharks (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 longer than approximately 140 cm PCL and females longer than 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 in 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 sea surface temperatures of 14^{o}-16^{o}C; adults occurred 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 in near coastal waters (Goldman and Musick 2006, 2008).

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, 1977, Compagno 1990, Hoenig and Gruber 1990). Shark reproductive strategies in general are characterized by long gestational periods (6 months - 2 years), with small broods 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).

<u>Spiny Dogfish</u>

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 NMFS observer program, spiny dogfish lengths were measured throughout the eastern Bering Sea (EBS), Aleutian Islands (AI), and the GOA. Sample sizes were not sufficient for determining length frequencies by area, but for all areas combined, male lengths averaged 80.2 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) and ranged from 48-110 cm (N = 524, Figure 2). Females averaged 82.4 cm and ranged from 9-128 cm (N = 601). The highest proportion of females at a given length occurred at 74 cm; the highest proportion of males was observed at 82 cm. Although the distribution of female lengths peaked at a smaller size than the peak in males, there were a greater proportion of females 94-128 cm long. In comparison, average dogfish lengths observed during a University of Alaska (UAF) study in the GOA were similar to those reported by NMFS observers, but length distributions were different. Male lengths averaged 80.3 cm TL_{ext} and ranged from 53-99 cm (N=623) while the greatest proportion of individuals were 85 cm. 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 length frequencies among fish <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. Embryos are retained within the uterus throughout gestation, but there is no physical attachment (such as a placenta) between the mother and offspring. During gestation, which is 18-24 months, spiny dogfish embryos are nourished solely by their yolk sac. The majority of biological knowledge of spiny dogfish is based on field biology conducted in 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 BC. Ketchen (1972) reported timing of parturition in BC to be October through December, and in the Sea of Japan, parturition occurred 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 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 in areas not fished commercially and are therefore not available to commercial fisheries until they grow or migrate to fished areas (Beamish et al. 1982, Tribuzio and Kruse b in review). 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 b in review).

Pacific Sleeper Sharks

Sleeper sharks (*Somniosus* spp.) can attain large sizes and are most likely slow-growing and long-lived (Fisk et al. 2002). A Greenland shark (*Somniosus microcephalus*), a sleeper shark of the same genus as the Pacific sleeper shark, 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 maximum lengths of *Somniosus* sp. captured in mid-water trawls in the Southern Ocean off the outer shelf and upper continental slope of subantarctic islands are 390 cm TL (total length with the tail in the natural position) +- 107 cm (range 150-500 cm, n=36, Cherel and Duhamel 2004). Large *Somniosus* sharks observed in photographs from deep water have been estimated at lengths up to 700 cm (Compagno 1984). The maximum lengths of captured Pacific sleeper sharks are 440 cm for females and 400 cm for males (Mecklenburg et al. 2002). Pacific sleeper sharks 150-250 cm in length are most common in Alaska (Sigler et al. 2006). Pacific sleeper sharks as large as 430 cm have been caught in the northwestern Pacific Ocean, where the species exhibits sexual dimorphism, 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). The cartilage in sleeper sharks does not calcify to the degree of many other shark species, therefore aging is difficult and methods of age validation are under investigation.

Published observations suggest that mature female Pacific sleeper sharks are in excess of 365 cm 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 (<10 mm) were present as well as 372 large vascularized eggs (24-50 mm) (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 depths of 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). 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.

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).

<u>Salmon Sharks</u>

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, 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 greater than 260 cm PCL (300 cm TL) 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 when 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 2.2:1 (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

Commercial

There are currently no directed commercial fisheries for shark species in federal or state managed waters of the GOA and most incidentally caught sharks 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 an ADF&G Commissioner's Permit fishery for spiny dogfish in lower Cook Inlet; however only one application has been received to date and the permit was not issued.

Spiny dogfish are also allowed as retained incidental catch in some ADF&G managed fisheries with some landings reported in Yakutat for 2005-2008. The landings were highest in 2005, with about 11,363 kg landed, and decreased in 2008 to 138 kg landed. A limited sport fishery for salmon sharks also occurs in Alaska state waters.

Recreational (provided by Scott Meyer, ADF&G)

Spiny dogfish, salmon shark, and Pacific sleeper shark are caught in the recreational fisheries of Southeast and Southcentral Alaska. Sleeper sharks are uncommon in the recreational catch and rarely retained. The State of Alaska manages recreational shark fishing in state and federal waters, but most of the harvest occurs in state waters. The shark fishery is managed under a statewide plan with a daily bag limit of one shark of any species and an annual limit of two sharks (5 AAC 75.012).

There are three sources of information on sport harvest: (1) the ADF&G statewide harvest survey (SWHS) provides estimates of catch (including released fish) and harvest (fish kept) of all shark species combined, (2) the mandatory charter logbook provides estimates of statewide charter harvest of salmon sharks, and (3) onsite harvest monitoring provides estimates of species, age, length, and sex composition in Southcentral Alaska. ADF&G also maintains a tagging database that includes only external numbered tags deployed by ADF&G, NMFS, and other permitted researchers.

The SWHS estimates of shark harvest are available for portions of the state since the late 1990s, but estimates for more recent years include the entire state. Estimated annual harvest of all shark species combined averaged 308 fish in Southeast Alaska (range 149-576) and 795 fish in Southcentral Alaska (range 502-1,007) from 2003-2007. The precision of these estimates is quite low; CVs are on the order of 50% for Southeast Alaska and 20% for Southcentral Alaska in 2007. Estimated annual catch, including released fish, averaged about 18,000 sharks in Southeast and 36,000 sharks in Southcentral Alaska from 2003 to 2007. The discrepancy between catch and harvest illustrates that the vast majority of sharks are caught incidentally and released.

There is a modest directed sport fishery for salmon sharks involving a few charter boats, most of which operate in Prince William Sound. Onsite sampling indicates that a small fraction of the directed salmon shark harvest is taken by unguided anglers. Logbook data for salmon sharks have not been rigorously edited or summarized, but indicate annual statewide harvests ranging from about 140-280 fish per year. About 25-65% of the harvest in recent years has come from Prince William Sound. The directed salmon shark fishery appeared to increase in the late 1990s in response to media attention, but appeared to wane in 2007 and 2008. Female salmon sharks sampled from the Southcentral Alaska sport harvest from 1997 to 2007 averaged 227 cm total length (n=300), and 145 kg predicted round weight. Males averaged 220 cm in length (n=50) and 131 kg predicted round weight. The smaller sample size for males reflects their lower frequency in the catch. Ages of fish harvested from 1997 to 2000 ranged from 5-17 years. ADF&G is currently working on age estimation for a backlog of salmon shark vertebrae collected since 2001.

Spiny dogfish make up the vast majority of the recreational shark catch and harvest but are rarely targeted. Instead, most of the catch is incidental to the halibut fishery. Catch rates can be quite high at certain times of the year, particularly in Cook Inlet, southwestern Prince William Sound, and near Yakutat. Anecdotal reports indicate that many spiny dogfish are handled poorly when released. Discard mortality is unknown but probably substantial. The numbers of spiny dogfish observed seem low in relation to harvest estimates from the mail survey, suggesting that anglers are reporting some spiny dogfish that are not retained as harvest. These fish may be released dead or cut up for bait. Only 62 spiny dogfish were sampled from the Southcentral Alaska sport harvest from 1998 through 2007. The mean total length of these fish was 92 cm and mean round weight was 3.75 kg.

ADF&G has provided tissue samples from salmon sharks and spiny dogfish to the Alaska Department of Environmental Conservation for analysis of methylmercury. These species had substantially higher methylmercury levels than all other species tested (Verbrugge 2007). It is unknown to what degree these results are influencing angler demand.

Bycatch, Discards, and Historical Catches

Historical catches of sharks in the GOA are composed entirely of incidental catch, and nearly all 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 GOA are tracked in-season by the NMFS Alaska Regional Office (AKRO) (Table 3). Other Species reported catches have been relatively small each year since 1977 in the GOA (e.g., in 2001 the Other Species catch of 4,801 tons made up 2.6% of the 182,011 ton total GOA catch).

DATA

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Non-target catch	2003–2008
(AFSC) Improved Pseudo Blend	Non-target catch	1997–2002
(AFSC) Pseudo Blend	Non-target catch	1990–1998
NMFS Bottom Trawl Surveys – GOA	Biomass Index	1984–2007

Incidental Catch

This report summarizes incidental shark catches by species as three data time series: 1990–1998, 1997–2002, and 2003–2008 (Table 3). Prior to 2003, shark catches, by species, were estimated by staff at the AFSC by two different methods: one for the years 1997–2002 and the other for years 1990–1998.

For the years 1990–1998, the pseudo-blend method of Gaichas et al. (1999) was used to estimate catches of sharks by species. Using data reported by fishery observers, the method uses the following procedure: each year’s observed catch by species group was summed within statistical area, gear type, and target fishery. The ratio of observed Other Species group catch to observed target species catch was multiplied by the AKRO blend-estimated target species catch within that area, gear, and target fishery. Other Species annual total catches estimated in this manner were generally lower than AKRO reported catches of Other Species due to both targeting assignment discrepancies and gear strata with no observer coverage (i.e., jig gear fisheries, Gaichas et al. 1999). Direct application of this method to estimate Other Species catches using foreign and joint venture observer data is not possible due to differences in database structure. Consequently, incidental catches for sharks by species are not available prior to the beginning of the domestic observer program in 1990. Using the pseudo-blend estimates from 1990–1998 in the GOA, spiny dogfish composed 49% of total shark catch, Pacific sleeper sharks 19%, salmon sharks 12%, and unidentified sharks 18%, and Blue, sixgill, and brown cat sharks were rarely identified in catches (Table 3).

For the years 1997–2002, Gaichas (2001, 2002) used a new pseudo-blend method to estimate species group catches, and catches by species for sharks within the Other Species complex in the GOA. In the new pseudo-blend method, target fisheries were assigned to each vessel, gear, management area, and week combination based upon retained catch of allocated species according to the same algorithm used by the 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 AKRO blend-estimated target species catch within that area, gear, and target fishery (Table 4). This method more closely matched the AKRO blend catch estimation system and is therefore considered more accurate and an improvement over the previous pseudo-blend method.

There is a two year overlap (1997-1998) between the two catch estimation methodologies. For these two years, the catches estimated from the earlier method (Gaichas et al. 1999) were considerably lower than catches estimated by the later method (Gaichas 2001, 2002). Therefore, these two data series are not directly comparable; however, the earlier time series is still valuable as an indicator of trends. All stock assessment computations will use only the time series calculated with the new pseudo-blend method that began in 1997.

From 1997–2008, shark catches composed from 19% to 64% of the estimated Other Species total catches. Spiny dogfish composed 47% of total shark catch, Pacific sleeper sharks 29%, unidentified sharks 18%, and salmon sharks 6% (Table 3). Blue sharks, sixgill sharks, and brown cat sharks were rarely identified in catches and were included with unidentified sharks.

Based on the 1997–2008 GOA catch estimates, spiny dogfish were caught primarily in the flatfish (29%) and sablefish (26%) fisheries (Table 4). Pacific sleeper sharks were caught primarily in the Pacific cod (40%) and pelagic pollock (24%) fisheries (Table 5), and salmon sharks were caught primarily in the pelagic pollock (57%) and bottom pollock (16%) fisheries (Table 6). Incidental catches of other and unidentified shark species were rare in the GOA except for a large catch in 1998 taken in the sablefish fishery (Table 7). The highest incidences of catches for all shark species occur in area 630 (Figure 1). For the years 1997–2008, area 630 accounted for 49% of the spiny dogfish catch (Table 8), 43% of Pacific sleeper shark catch (Table 9), and 55% of salmon shark catch (Table 10). However, other sharks and unidentified sharks were caught primarily in area 659 during the years 1997-2008 (61%, Table 11).

The majority of vessels fishing in the GOA are smaller vessels subject to 30% observer coverage, although some target fisheries (i.e. rockfish) are conducted by larger vessels with 100% observer coverage. 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 GOA. These catch estimates do not include unobserved fisheries such as the halibut IFQ fishery or ADF&G managed fisheries such as the salmon setnet fisheries, both of which are thought to have high levels of shark bycatch. For example, Courtney et al. (2006, Appendix D) estimated shark catch by species and for 2004, the estimated spiny dogfish catch in the halibut IFQ fishery was roughly equal to the estimated catch for all sharks in the observed fisheries in the GOA.

Survey Biomass Estimates

NMFS AFSC bottom trawl survey biomass estimates are available for shark species in the GOA (1984-2007, Table 12). Where available, individual species biomass trends were evaluated for the three most commonly encountered shark species (spiny dogfish, Pacific sleeper shark, and salmon shark, Figure 3). 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 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.

Analyses of GOA biomass trends are subject to several caveats regarding the consistency of the survey time series. Survey efficiency in the GOA may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Gaichas et al. 1999). Surveys in 1984, 1987, and 1999 included deeper strata than the 1990-1996 surveys; therefore the biomass estimates for deeper-dwelling species are not comparable across years. The 2001 survey did not include all areas of the Eastern GOA and consequently, the 2001 survey may not be comparable with the other surveys for species such as spiny dogfish which appear to be relatively abundant in the Eastern GOA.

Data from the 1984-2007 GOA bottom trawl surveys indicate an increasing biomass trend for the shark species group as a result of increases in spiny dogfish and sleeper shark biomass between 1990 and 2007 (Table 12, Figure 3). An independent analysis of NMFS AFSC bottom trawl surveys in the GOA found that Pacific sleeper shark abundance had significantly increased in the central GOA during 1984-1996 (Mueter and Norcross 2002). Salmon shark biomass has been stable or decreasing according to this survey, but salmon sharks are pelagic and unlikely to be sampled efficiently by bottom trawls. Both salmon shark and Pacific sleeper shark biomass estimates are also based on a very small number of individual hauls in a given survey (Table 12). No salmon sharks were encountered in either the 1999 or 2001 survey. Spiny dogfish were captured in a relatively large number of hauls each year. However, spiny dogfish distributions in the GOA water column are not well known and may affect biomass estimation. In particular, if spiny dogfish are caught off the bottom, then biomass estimates may be unreliable. Regardless, since spiny dogfish are captured in a large number of hauls each year, the NMFS AFSC bottom trawl surveys in the Gulf of Alaska may be useful for determining the relative proportion of spiny dogfish biomass by area in the Gulf of Alaska. The total NMFS survey catch of all sharks (excluding the longline surveys) is listed in Table 13.

Other Data Sources

Relative population numbers (RPNs) have been estimated from the GOA longline survey for the years 1982-2003 (Figure 4, Courtney et al. 2006). This index shows the RPN for Pacific sleeper shark increasing from 1994-2001, then declining through the remainder of the time series. The spiny dogfish index is more variable and shows peaks in 1993 and 1998, otherwise the index was relatively low. Analysis of data from the years 2004-2008 is underway.

Catch from unobserved fisheries is a concern. Courtney et al. (2006, Appendix D) estimated catch for the three main shark species from IPHC survey and fish ticket data for the years 1997-2004. There is no apparent trend in the catches of spiny dogfish and salmon shark, but Pacific sleeper shark catches increased from 1997-2002 and then decreased (Figure 5). However, the confidence intervals around the catch estimate are overlapping, so no significant trend is apparent. Catches were also estimated by grouped IPHC statistical area (Figure 6). For spiny dogfish, catches were greatest in all years in areas 250-261 (Figure 7). Pacific sleeper sharks were primarily caught along the Alaska peninsula in areas 290-310 (Figure 8) and salmon shark were a rare occurrence, but generally were caught in areas 270, 280, and 290-310 (Figure 9).

The Alaska Department of Fish and Game has conducted annual longline surveys in and around Prince William Sound from 1997-2006. Not all stations were surveyed each year, and thus trends in catches are difficult to detect. However, spiny dogfish catch was low with sporadic large catches (up to 52 dogfish per 100 hooks, Figure 10 and 11), with the greatest dogfish catches in 1998 in the central and eastern part of Prince William Sound and in 2006 near the western entrance to Prince William Sound. Sleeper shark catch was low in all years, relative to spiny dogfish (maximum of 2 sleeper sharks per 100 hooks, Figure 12 and 13), and the greatest catches were in 1999 in western Prince William Sound.

Weight-at-length and average length and weight values for all three species are presented in Table 14. Length-at-age models for the GOA have been published for salmon sharks (Goldman and Musick 2006), and are under review for spiny dogfish (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, respectively). Parameters of the von Bertalanffy growth model are presented in Table 14. While sharks are slow-growing compared to teleost 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, equivalent to population growth $\lambda = e^r$), 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 b) and ENP salmon sharks (Goldman 2002) to estimate 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 a "best-case" scenario. The assumption that shark populations are unfished 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 gillnet fisheries, which may have very high spiny dogfish mortality in some years. 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

Both Tier 6 options are provided for consideration in the GOA. Tier 6 criteria require a reliable catch history from 1978-1995, which do not exist for sharks in the GOA prior to 1997. In 2006, 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. Also recommended was an alternative to using the average catch. Instead, Courtney et al. (2006) proposed using the maximum catch to calculate the Tier 6 limits because GOA shark catches are very low compared to the Other Species TAC (Figure 14, top panel). The SSC recommended placement of sharks in Tier 6 with the alternative base period, fixing the final year at 2005, and using the maximum catch. We do not recommend continuing to use the alternative Tier 6. Rather we recommend using the standard Tier 6 methodology to estimate ABC and OFL for sharks. We also present the ABC and OFL using 1997-2008 time series, which includes 3 additional years of data (Figure 14, bottom panel).

Available data do not support Tier 5 criteria for establishing ABC and OFL for sharks in the GOA. Typical Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass and natural mortality. Natural mortality estimates for spiny dogfish and salmon shark in the GOA are available but do not exist for Pacific sleeper sharks, which make up 28% of shark biomass in the GOA (Table 3). Reliable point estimates of biomass do not exist for sharks in the GOA as the efficiency of bottom trawl gear varies by species. 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 GOA shark ABC and OFL are presented both for individual species and for sharks as a complex. Incidental shark catches for the years 2003-2008 were provided by the NMFS AKRO (Table 3). The time series of incidental catch for sharks for the years 1997-2005 is considered the best available information on catch of shark species in the GOA and is used here to provide an approximate Tier 6 option for GOA shark ABC and OFL. Catches of other shark species in the GOA are rare and consequently catch estimation for other shark species is unreliable. We also present an expanded time series (1997-2007) for consideration for estimation of the average catch.

GOA Tier 6 Calculations (mt)

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark complex
Average catch (1997-2005)	422	313	63	208	1,005
ABC (1997-2005)	316	235	47	156	754
OFL (1997-2005)	422	313	63	208	1,005
Average catch (1997-2007)	482	304	63	187	1,036
ABC (1997-2007)	362	228	47	140	777
OFL (1997-2007)	482	304	63	187	1,036

Alternative Tier 6 Option

Courtney et al. (2006) proposed an alternative Tier 6 based on the premise that the estimated incidental catch data be considered a “known safe” level of fishing. This approach was adopted for 2007 and 2008. However, this premise assumes that because shark catches are low relative to the total Other Species catch, that shark catch levels are safe. There is no biological meaning regarding the sustainability of shark catch rates in that assumption. Moreover, without further data, we are unable to validate the premise that the maximum catch is a “known safe” level of fishing. While using the average catch is also assuming that it is a known safe level of fishing, the average catch is lower and thus more conservative.

We recommend Tier 6 over the alternative Tier 6 for two reasons: 1) using the average catch is more conservative; and 2) because of the potentially large unobserved or unreported catches in the halibut IFQ and ADF&G managed salmon set net fisheries. For example, Courtney et al. (2006, Appendix D) estimated the shark catch by species and for 2004, spiny dogfish catch in the halibut IFQ fishery was roughly equal to the estimated catch for all sharks in the observed fisheries in the GOA. Expanding the time series to include 1997-2007 catches as a baseline does not alter the maximum catch observed.

GOA Alternative Tier 6 Calculations (mt)

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Unidentified shark	Total sharks
Max catch (1997-2005)	865	608	132	1,380	2,985
ABC	649	456	99	1,035	2,239
OFL	865	608	132	1,380	2,985

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 GOA. 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 GOA.

Spiny dogfish

Previous studies have shown spiny dogfish to be opportunistic feeders, not wholly dependent on one food source (Alverson and Stansby 1963). Small dogfish are limited to consuming smaller fish and invertebrates, while larger dogfish 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, pers obs.).

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 GOA (Hulbert et al. 2006). Diet analyses support the depth oscillation theory, as prey from different depths such as, giant grenadier (*Albatrossia pectoralis*) and pink salmon (*Oncorhynchus gorbuscha*), have been documented in the stomach of a single shark (Orlav and Moiseev 1999). Other diet studies have found that Pacific sleeper sharks prey on fast moving fish and mammals that live near the surface such as, salmon (*O.* spp.), tuna (*Thunnus* spp.), and harbor seals (*Phoca vitulina*), (e.g., Bright 1959; Ebert et al. 1987; Crovetto et al. 1992; Sigler et al. 2006), proving 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 GOA, they were not found to prey on newborn sea lions, 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).

<u>Salmon Shark</u>

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* spp.), rockfish (*Sebastes* spp.), sablefish (*Anoplopoma fimbria*), lancetfish (*Alepisaurus* spp.), daggertooth (*Anotopterus* spp.), lumpfish (*Cyclopteridae*), sculpin (*Cottidae*), Atka mackerel (*Pleurogrammus monopterygius*), mackerel (*Scombridae*), pollock and tomcod (*Gadidae*), herring (*Clupeidae*), spiny dogfish, tanner crab (*Chionocetes* spp.), squid, and shrimp (Sano 1960, 1962, Farquhar 1963, Hart 1973, Urquhart 1981, Compagno 1984, 2001, Nagasawa 1998). Incidental catch of salmon sharks 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 et al. 1993, H. Nakano pers. comm.). Additionally, recent demographic analyses support the contention that salmon shark populations in the ENP and WNP 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 organisms	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

Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Not 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 habitat 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 limitations are severe for shark species in the GOA 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 data 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 for the Other Species management category, it is essential that we continue to improve shark data collection by species 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 (17 %) are not identified to species. Length measurements from the fishery are critical for determining the effect of commercial catch on shark populations in the GOA. Identification of sharks to species in the GOA 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) is necessary to adequately estimate the true fishing mortality of these species, especially given that sustainable F is estimated to be low.

SUMMARY

There is no evidence to suggest that over fishing is occurring for any shark species in the GOA. There are currently no directed commercial fisheries for shark species in federal or state managed waters of the GOA, 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 GOA fisheries have been very small compared to catch rates of target species. The TAC for the GOA Other Species complex is set in aggregate at less than or equal to 5% of the sum of the TAC's of managed GOA species. 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 spiny dogfish and Pacific sleeper sharks in the GOA. In the GOA, average catch of spiny dogfish from 1997-2005 (422 tons) represented less than 1% of the available spiny dogfish biomass from GOA bottom trawl surveys 1996-2005 (average of 47,733 tons, Table 12). The 2001 survey did not include all areas of the eastern GOA and consequently, the 2001 survey may not be comparable with the other surveys for species such as spiny dogfish which appear to be relatively abundant in the eastern GOA. Average catch of Pacific sleeper sharks from 1997-2005 (313 tons) represented less than 1% of the available Pacific sleeper shark biomass from GOA bottom trawl surveys 1996-2005 (average of 37,459 tons, Table 12). Average catch of salmon sharks from 1997-2005 (63 tons) was relatively small. GOA bottom trawl survey biomass estimates for salmon sharks are unreliable because trawl gear is an inefficient sampling technique for salmon sharks and salmon sharks were only caught in four hauls from 1996-2005 (Table 12).

2009 and 2010 recommendations	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other/Unid Sharks	Total Sharks
Tier	6	6	6	6	6
M	0.097	0.097	0.18	0.097	0.097
Biomass (2007)	161,965	39,635	12,340		213,940
Avg Catch (1997-2007)	482	304	63	187	1,036
ABC	362	228	47	140	777
OFL	482	304	63	187	1,036

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Table 1. Shark species in the Gulf of Alaska (GOA) including life history and biological characteristics. Missing information is denoted by "?". Lengths presented as total length (TL) except as precaudal length (PCL) when noted in table.

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]	?	? yrs, 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 et al. 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 unpublished data; [20]G. A. McFarlane pers. comm.

Table 2. Time series of Other Species TAC, Other Species and shark catch, and ABC for sharks. Other species TAC is set ≤5% of the total groundfish TAC for the GOA, prior to 2008, it was 5%, in 2008 it was set at a much lower value, 4,500 mt. Note that the decrease in TAC in 2008 was a regulatory change and not based on biological trends.

Year	TAC	Other Spp. Catch	Shark Catch	ABC	Management Method
1992	13,432	12,313	517	N/A	Other Species TAC (included Atka)
1993	14,602	6,867	1,027	N/A	Other Species TAC (included Atka)
1994	14,505	2,721	360	N/A	Other Species TAC
1995	13,308	3,421	308	N/A	Other Species TAC
1996	12,390	4,480	484	N/A	Other Species TAC
1997	13,470	5,439	1,041	N/A	Other Species TAC
1998	15,570	3,748	2,390	N/A	Other Species TAC
1999	14,600	3,858	1,036	N/A	Other Species TAC
2000	14,215	5,649	1,117	N/A	Other Species TAC
2001	13,619	4,801	853	N/A	Other Species TAC
2002	11,330	4,040	427	N/A	Other Species TAC
2003	11,260	6,335	759	N/A	Other Species TAC
2004	12,592	1,608	468	N/A	Other Species TAC*
2005	13,871	2,347	959	N/A	Other Species TAC
2006	13,856	3,467	1,615	N/A	Other Species TAC
2007	12,229	2,800	1,186	1,792	Other Species TAC
2008	4,500	2,208	246	1,792	Other Species TAC

*Skates were removed from the GOA Other Species category in 2004.
Sources: TAC and Other Species catch from AKRO. Estimated shark catches from 1992-1996 from Gaichas et al. 1999, catches from 1997-2002 from Gaichas et al. 2003 and catches from 2003-2008 from AKRO Catch Accounting System (CAS, Updated Oct 3, 2008).

Table 3. NMFS estimated catch (tons) of sharks (by species) and Other Species (in aggregate) in the Gulf of Alaska. 1990-1998 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2002 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas, 2002). Years 2003-2008 from NMFS AKRO as of October 3, 2008. Breaks in the table represent different catch estimation periods.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks	Total other species	% of Other Species Catch
1990	171	20	53	30	274	6289	4%
1991	141	49	42	108	340	5700	6%
1992	321	38	142	17	517	12313	4%
1993	383	215	89	340	1027	6867	15%
1994	160	120	25	56	360	2721	13%
1995	141	63	55	49	308	3421	9%
1996	337	66	28	53	484	4480	11%
1997	233	118	25	59	436	5,439	8%
1998	298	161	79	132	669	3,748	18%
-	-	-	-	-	-	-	-
1997	657	136	124	123	1,041	5,439	19%
1998	865	74	71	1,380	2,390	3,748	64%
1999	314	558	132	33	1,036	3,858	27%
2000	398	608	38	74	1,117	5,649	20%
2001	494	249	33	77	853	4,801	18%
2002	117	226	58	26	427	4,040	11%
-	-	-	-	-	-	-	-
2003	369	292	36	62	759	6,335	12%
2004	175	232	22	39	468	1,608	29%
2005	408	440	52	58	959	2,347	41%
2006	816	238	29	83	1,166	3,424	34%
2007	690	294	95	107	1,186	2,800	42%
2008	171	66	1	8	246	2,208	11%
Average 1997-2005*	421.8	312.8	62.7	208	1,005.40	4,192.30	
Maximum 1997-2005*	865	608	132	1,380	2,985	6,335	
Total 1997-2008	5,473	3,413	691	2,070	11,647	46,257	
% of Total Sharks	47%	29%	6%	18%	100%		
Avg. % of Other Spp.	12%	7%	1%	4%	25%		
Average 1997-2007	482	304	63	187	1,036	4,004	
Maximum 1997-2007	865	608	132	1,380	2,390	6,335	

* Average and maximum catch 1997-2005 used for Tier 6 calculations.

Table 4. Estimated catch (tons) of spiny dogfish in the Gulf of Alaska by fishery. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure. Catch by target fishery not estimated for 2002.

Fishery	Bottom Pollock	Pelagic Pollock	Pacific Cod	Flatfish	Rockfish	Other	Atka	Sablefish	Total	Year % Of Total 97-08
1990	57.1	0.5	36.0	13.5	1.8	3.1	0.0	59.0	170.9	
1991	26.7	2.6	52.6	16.2	16.4	0.5	0.0	26.2	141.2	
1992	73.4	11	50.5	116.0	22.4	6.7	0.0	40.7	320.6	
1993	114.5	22.5	10.1	138.5	2.4	0.0	0.0	95.3	383.4	
1994	20.8	1.2	16.9	83.4	2.5	0.0	0.0	35.4	160.2	
1995	2.8	0	28.1	24.1	18.4	16.4	0.0	50.7	140.6	
1996	0.5	2.4	15.3	182.6	19.8	36.8	0.0	79.5	336.9	
-	-	-	-	-	-	-	-	-	-	-
1997	1.2	1.6	57.6	137.2	326.2	0.0	0.0	133.7	657.5	12%
1998	0.4	4.5	727.2	69.0	3.1	1.1	0.0	59.6	864.9	16%
1999	0	8.6	160.2	56.6	4.8	0.0	0.0	83.4	313.6	6%
2000	4.1	14.6	29.4	66.3	146.6	0.0	0.0	136.6	397.6	7%
2001	4.4	7.2	172.8	162.5	25.1	0.0	0.0	122.1	494.0	9%
2002	-	-	-	-	-	-	-	-	-	
2003	3.1	3.5	43.6	139.2	35.5	82.5	0.0	27.4	334.7	6%
2004	5.5	2.3	18.4	45.5	2.1	0.2	0.0	128.0	202.1	4%
2005	5.9	7.8	27.1	62.6	2.8	0.5	0.0	305.8	412.5	8%
2006	45.2	4.1	110.4	520.5	2.0	9.4	0.0	137.6	829.2	15%
2007	41.8	4.9	228.0	276.2	5.1	0.0	0.0	153.4	709.5	13%
2008	2.7	0.2	25.3	45.9	4.2	0.0	0.0	92.6	171.0	3%
Total 97-08	114.3	59.3	1,600.1	1,581.5	557.4	93.7	0.0	1,380.3	5,386.5	
Fishery % Of Total 97-08	2%	1%	30%	29%	10%	2%	0%	26%		

Table 5. Estimated catch (tons) of Pacific sleeper sharks in the Gulf of Alaska by fishery. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure. Catch by target fishery not estimated for 2002.

Fishery	Bottom Pollock	Pelagic Pollock	Pacific Cod	Flatfish	Rockfish	Other	Atka	Sablefish	Grand	Year % Of Total 97-08
1990	0.7	2.2	9.9	0.4	4.3	0.1	0.0	2.2	19.7	
1991	11.8	15.4	2.8	3.1	0.0	0.0	0.0	16.2	49.4	
1992	0	1.1	27.4	2.7	0.0	0.0	0.0	6.4	37.6	
1993	125.3	31.2	21.8	1.0	0.0	0.0	0.0	35.5	214.8	
1994	58.5	21.1	16.6	0.8	1.3	0.0	0.0	21.2	119.5	
1995	7.1	9.8	13.7	20.7	0.1	0.0	0.0	11.6	63.0	
1996	3.3	11.2	11.9	12.1	0.0	0.7	0.2	26.4	65.9	
-	-	-	-	-	-	-	-	-	-	-
1997	0.0	22.3	59.3	46.0	0.9	0.0	0.0	7.5	135.9	4%
1998	4.6	27.8	19.6	10.1	0.2	0.5	0.0	11.3	74.0	2%
1999	0.9	33.2	505.8	6.0	3.0	0.0	0.0	8.7	557.7	17%
2000	1.3	177.1	376.8	35.9	0.3	0.0	0.0	16.7	608.2	19%
2001	11.1	134.8	65.8	6.3	0.7	0.0	0.0	30.3	249.0	8%
2002	-	-	-	-	-	-	-	-	-	
2003	2.6	65.5	56.3	153.1	0.3	1.6	0.0	13.0	292.4	9%
2004	36.3	83.2	25.0	80.0	0.6	0.5	0.0	6.7	232.3	7%
2005	62.0	104.1	133.3	120.0	0.2	0.9	0.0	19.8	440.3	14%
2006	90.8	54.5	10.0	61.0	0.4	0.0	0.0	21.7	238.3	7%
2007	31.8	26.7	9.1	224.0	0.0	0.0	0.0	2.7	294.3	9%
2008	0.7	46.2	13.2	2.2	1.1	0.0	0.0	2.2	65.6	2%
Total 97-08	242.2	775.4	1,274.1	744.6	7.7	3.5	0.0	140.6	3,188.1	
Fishery % Of Total 97-08	8%	24%	40%	23%	0%	0%	0%	4%		

Table 6. Estimated catch (tons) of salmon sharks in the Gulf of Alaska by fishery. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure. Catch by target fishery not estimated for 2002.

Fishery	Bottom Pollock	Pelagic Pollock	Pacific Cod	Flatfish	Rockfish	Other	Atka	Sablefish	Total	Year % Of Total 97-08
1990	20.7	24.6	3.2	0.2	0.7	1.2	0.0	2.1	52.7	
1991	5.4	30.8	0.0	0.0	0.0	0.0	0.0	5.3	41.6	
1992	83.3	39.8	16.5	0.2	0.0	0.0	0.0	2.1	141.9	
1993	38.1	48.6	0.0	2.5	0.0	0.0	0.0	0.0	89.2	
1994	3.3	20.9	0.0	0.0	0.0	0.3	0.0	0.0	24.5	
1995	3.3	22.6	21.6	3.2	0.2	0.9	0.0	3.1	54.9	
1996	5.8	21.1	0.0	0.0	0.0	0.6	0.1	0.2	27.8	
-	-	-	-	-	-	-	-	-	-	-
1997	4.4	15.4	0.1	0.0	0.0	103.9	0.0	0.0	123.8	20%
1998	2.4	67.3	0.0	0.8	0.4	0.0	0.0	0.0	71.0	11%
1999	0.0	111.8	0.7	0.7	0.0	0.0	0.0	18.4	131.6	21%
2000	7.3	25.4	0.0	3.7	0.8	0.0	0.0	0.6	37.8	6%
2001	0.2	29.3	0.0	1.5	1.8	0.0	0.0	0.0	32.8	5%
2002	-	-	-	-	-	-	-	-	-	
2003	0.0	35.0	0.0	0.3	0.0	0.3	0.0	0.1	35.7	6%
2004	3.8	10.2	1.7	5.4	0.1	0.0	0.0	0.4	21.6	3%
2005	11.5	23.7	0.8	15.7	0.5	0.0	0.0	0.0	52.2	8%
2006	18.9	6.7	0.6	1.6	0.6	0.0	0.0	0.0	28.5	5%
2007	53.8	31.5	0.0	9.1	0.5	0.0	0.0	0.0	95.0	15%
2008	0.2	0.8	0.0	0.1	0.3	0.0	0.0	0.0	1.4	0%
Total 97-08	102.4	357.2	4.0	39.0	5.1	104.2	0.0	19.5	631.3	
Fishery % Of Total 97-08	16%	57%	1%	6%	1%	16%	0%	3%		

Table 7. Estimated catch (tons) of unidentified/other sharks in the Gulf of Alaska by fishery. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure. Catch by target fishery not estimated for 2002.

Fishery	Bottom Pollock	Pelagic Pollock	Pacific Cod	Flatfish	Rockfish	Other	Atka	Sablefish	Total	Year % Of Total 97-08
1990	1.1	3.0	21.3	0.8	1.4	0.0	0.0	2.9	30.5	
1991	13.2	4.6	36.7	35.5	4.4	0.0	0.0	13.7	108.1	
1992	2.1	1.2	8.4	3.5	0.1	0.4	0.0	1.5	17.2	
1993	129.8	8.5	38.1	3.7	0.0	0.2	0.0	159.3	339.6	
1994	34.9	6.7	2.3	3.0	0.0	0.0	0.0	8.9	55.8	
1995	2.0	2.0	3.4	10.6	9.7	7.3	0.0	14.3	49.3	
1996	9.5	4.7	3.1	17.8	1.9	0.3	0.1	16.0	53.4	
-	-	-	-	-	-	-	-	-	-	-
1997	0.0	8.9	13.4	9.0	47.5	0.7	0.0	43.9	123.4	6%
1998	0.0	24.2	10.2	17.9	2.3	0.0	0.0	1325.2	1379.8	68%
1999	0.0	6.1	12.3	8.1	0.1	0.0	0.0	6.4	33.0	2%
2000	0.0	12.3	3.5	34.0	4.8	0.3	0.0	18.7	73.6	4%
2001	0.2	34.8	1.4	1.5	1.4	0.0	0.0	37.7	77.0	4%
2002	-	-	-	-	-	-	-	-	-	
2003	0.2	7.2	6.4	44.8	0.2	0.2	0.0	3.5	62.4	3%
2004	2.6	8.5	2.7	20.9	0.2	0.0	0.0	4.1	39.0	2%
2005	20.5	10.4	1.2	21.7	0.2	0.0	0.0	4.0	57.9	3%
2006	38.9	2.0	11.9	24.4	1.6	0.0	0.0	4.2	83.0	4%
2007	12.1	1.5	38.9	49.6	0.4	0.0	0.0	4.7	107.1	5%
2008	0.3	1.7	1.6	1.4	0.0	0.0	0.0	2.9	7.8	0%
Total 97-08	74.7	117.5	103.4	233.3	58.7	1.2	0.0	1,455.3	2,044.1	
Fishery % Of Total 97-08	4%	6%	5%	11%	3%	0%	0%	71%		

Table 8. Estimated catch (tons) of spiny dogfish in the Gulf of Alaska by statistical area. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure.

Year	610	620	630	640	649	650	659	Total	Year % Of Total 97-08
1990	0.2	3.6	147.8	2.3	0.0	17.0	0.0	170.9	
1991	2.2	3.5	113.1	3.1	0.0	18.2	0.0	141.2	
1992	2.7	8.1	283.6	1.8	0.0	24.4	0.0	320.6	
1993	0.6	3.0	322.3	11.0	0.0	5.4	41.2	383.4	
1994	1.4	4.8	115.5	5.0	0.0	33.6	0.0	160.2	
1995	0.4	8.7	103.7	13.8	0.0	14.0	0.0	140.6	
1996	1.3	3.4	279.2	23.0	0.5	29.5	0.0	336.9	
-	-	-	-	-	-	-	-	-	-
1997	0.5	11.7	265.7	45.0	0.0	334.7	0.0	657.5	12%
1998	3.6	3.1	255.0	574.8	2.2	26.1	0.0	864.9	16%
1999	11.0	42.8	175.6	38.9	3.2	42.2	0.0	313.6	6%
2000	5.3	1.0	148.6	82.9	0.0	159.9	0.0	397.6	7%
2001	3.3	1.8	396.3	40.5	0.0	52.1	0.0	494.0	9%
2002	5.2	5.8	47.1	51.9	0.0	7.0	0.0	117.0	2%
2003	9.4	61.1	237.5	38.8	0.8	18.6	2.4	368.6	7%
2004	17.2	10.8	80.0	26.6	0.7	23.1	16.5	174.9	3%
2005	8.0	22.7	244.7	72.8	1.1	37.0	21.8	408.1	7%
2006	55.2	125.4	367.7	94.3	8.6	134.4	30.8	816.5	15%
2007	45.9	91.0	356.8	25.3	2.1	157.8	11.1	689.9	13%
2008	4.0	6.5	84.7	26.7	0.0	48.5	0.4	170.7	3%
Total 97-08	168.6	383.6	2,659.7	1,118.4	18.6	1,041.5	83.0	5,473.3	
Area % Of Total 97-08	3%	7%	49%	20%	0%	19%	2%		

Table 9. Estimated catch (tons) of Pacific sleeper sharks in the Gulf of Alaska by statistical area. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure.

Year	610	620	630	640	649	650	659	Total	Year % Of Total 97-08
1990	2.4	1.2	12.8	3.0	0.0	0.3	0.0	19.7	
1991	4.0	3.0	40.9	1.4	0.0	0.0	0.0	49.4	
1992	4.0	23.2	6.3	2.2	1.9	0.0	0.0	37.6	
1993	10.5	127.9	68.2	8.3	0.0	0.0	0.0	214.8	
1994	11.9	23.0	75.9	8.7	0.0	0.0	0.0	119.5	
1995	6.5	23.3	27.0	2.4	0.1	3.7	0.0	63.0	
1996	21.3	12.0	14.5	5.5	0.0	12.5	0.0	65.9	
-	-	-	-	-	-	-	-	-	-
1997	16.0	45.0	69.5	1.3	0.9	3.2	0.0	135.9	4%
1998	11.0	11.4	42.5	0.7	0.0	8.5	0.0	74.0	2%
1999	63.9	33.8	454.7	0.3	0.0	4.9	0.0	557.7	16%
2000	18.6	162.7	415.4	1.0	0.0	10.5	0.0	608.2	18%
2001	90.7	67.3	74.6	6.0	0.0	10.3	0.0	249.0	7%
2002	65.2	110.8	46.6	2.3	0.7	0.0	0.0	225.6	7%
2003	62.2	92.7	104.0	3.3	23.4	2.1	4.7	292.4	9%
2004	31.1	147.9	41.7	3.6	1.6	3.6	2.8	232.3	7%
2005	44.6	208.4	172.6	9.3	3.3	1.0	1.2	440.3	13%
2006	15.4	162.1	46.4	7.8	0.1	5.6	0.9	238.3	7%
2007	55.6	220.4	14.9	0.4	0.0	0.9	2.1	294.3	9%
2008	11.5	51.2	0.9	0.0	0.0	0.4	1.7	65.6	2%
Total 97-08	485.8	1,313.7	1,483.8	36.0	30.0	50.9	13.4	3,413.6	
Area % Of Total 97-08	14%	38%	43%	1%	1%	1%	0%		

Table 10. Estimated catch (tons) of salmon sharks in the Gulf of Alaska by statistical area. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure.

Year	610	620	630	640	649	650	659	Total	Year % Of Total 97-08
1990	3.4	3.0	46.2	0.1	0.0	0.0	0.0	52.7	
1991	4.3	6.9	30.4	0.0	0.0	0.0	0.0	41.6	
1992	0.2	130.3	11.4	0.0	0.0	0.0	0.0	141.9	
1993	5.2	19.5	63.1	1.4	0.0	0.0	0.0	89.2	
1994	3.1	4.7	16.7	0.0	0.0	0.0	0.0	24.5	
1995	8.2	4.1	41.7	0.0	0.9	0.1	0.0	54.9	
1996	14.1	10.8	2.7	0.0	0.0	0.2	0.0	27.8	
-	-	-	-	-	-	-	-	-	-
1997	5.6	10.3	107.4	0.0	0.5	0.0	0.0	123.8	18%
1998	10.0	39.6	20.7	0.4	0.3	0.0	0.0	71.0	10%
1999	15.1	39.9	58.3	0.0	0.0	18.4	0.0	131.6	19%
2000	7.1	11.1	19.0	0.6	0.0	0.0	0.0	37.8	5%
2001	13.0	1.7	18.1	0.0	0.0	0.0	0.0	32.8	5%
2002	20.5	11.2	26.4	0.0	0.0	0.0	0.0	58.2	8%
2003	11.1	9.8	12.8	0.0	1.9	0.1	0.0	35.7	5%
2004	11.2	6.0	4.3	0.0	0.0	0.0	0.0	21.6	3%
2005	14.0	8.2	29.8	0.0	0.3	0.0	0.0	52.2	8%
2006	2.4	4.2	21.4	0.4	0.0	0.0	0.0	28.5	4%
2007	10.7	22.0	62.2	0.0	0.0	0.0	0.0	95.0	14%
2008	0.4	0.6	0.3	0.0	0.0	0.0	0.0	1.4	0%
Total 97-08	121.2	164.6	380.8	1.5	3.1	18.5	0.0	689.5	
Area % Of Total 97-08	18%	24%	55%	0%	0%	3%	0%		

Table 11. Estimated catch (tons) of other and unidentified sharks in the Gulf of Alaska by statistical area. 1990-1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997-2001 catch estimated with NMFS new pseudo-blend estimation procedure (Gaichas 2002). Years 2003-2008 from NMFS AKRO using the improved pseudo-blend estimation procedure.

Year	610	620	630	640	649	650	659	Total	Year % Of Total 97-08
1990	0.9	3.6	25.1	0.1	0	0.7	0	30.4	
1991	6.9	1.1	99.9	0.3	0	0	0	108.2	
1992	4.5	1.4	11.3	0	0	0	0	17.2	
1993	2.1	5.6	195	4	0	133	0	339.7	
1994	5.5	27.5	22.9	0	0	0	0	55.9	
1995	2	0.9	32	1.2	0	13.3	0	49.4	
1996	3	16.1	17.6	3.9	0	12.8	0	53.4	
-	-	-	-	-	-	-	-	-	-
1997	5.9	5.6	72.6	26.4	0	13	0	123.5	6%
1998	1.3	25.7	48.1	4.9	1.1	46.2	1,252.6	1,379.9	68%
1999	9.3	2.1	13.4	0.5	1.9	5.7	0	32.9	2%
2000	3.7	17.5	29.8	6.1	0	16.6	0	73.7	4%
2001	0.9	19.2	21.7	1.9	0	33.3	0	77.0	4%
2002	NA	NA	NA	NA	NA	NA	NA	0.0	0%
2003	5.0	27.4	26.7	0.1	0.0	2.7	0.4	62.4	3%
2004	12.2	8.0	13.8	2.1	0.1	1.8	1.1	39.0	2%
2005	5.9	12.8	33.2	2.2	0.5	3.1	0.3	57.9	3%
2006	11.6	10.8	57.4	0.0	0.0	3.1	0.1	83.0	4%
2007	11.3	11.5	79.2	0.0	0.0	4.4	0.6	107.1	5%
2008	1.9	0.1	3.0	0.1	0.0	2.8	0.0	7.8	0%
Total 97-08	69.0	140.7	398.8	44.3	3.6	132.7	1,255.1	2,044.3	
Area % Of Total 97-08	3%	7%	20%	2%	0%	6%	61%		

Table 12. Gulf of Alaska AFSC trawl survey estimates of individual shark species total biomass (tons) with Coefficient of Variation (CV), and number of hauls with catches of sharks. Data updated October, 2008 (RACEBASE).

		Spiny Dogfish			Sleeper Shark			Salmon Shark			
Year	Survey Hauls	Haul w/ catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Total Shark Biomass
1984	929	125	10,143.0	0.206	1	163.2	1	5	7,848.8	0.522	18,155.0
1987	783	122	10,106.8	0.269	8	1,319.2	0.434	15	12,622.5	0.562	24,048.5
1990	708	114	18,947.6	0.378	3	1,651.4	0.66	13	12,462.0	0.297	33,061.0
1993	775	166	33,645.1	0.204	13	8,656.8	0.5	9	7,728.6	0.356	50,030.5
1996	807	99	28,477.9	0.736	11	21,100.9	0.358	1	3,302.0	1	52,880.8
1999	764	168	31,742.9	0.138	13	19,362.0	0.399	0	NA	NA	51,104.9
2001	489	75	31,774.3	0.45	15	37,694.7	0.362	0	NA	NA	69,469.0
2003	809	204	98,743.8	0.219	28	52,115.6	0.247	2	3,612.8	0.707	154,472.2
2005	839	156	47,926.1	0.17	26	57,022.0	0.263	1	2,455.3	1	107,403.4
2007	820	164	161,965.1	0.35	15	39,634.8	0.39	2	12,339.7	0.75	213,939.6

Table 13. Research survey catch (tons) of sharks between 1977 and 2007 in the Gulf of Alaska (GOA). Catch does not include longline surveys.

Year	**GOA**
1977	0.14
1978	1.44
1979	1
1980	0.86
1981	2.23
1982	0.36
1983	1.03
1984	3.12
1985	0.96
1986	1.38
1987	3.55
1988	0.27
1989	0.87
1990	3.52
1991	0.15
1992	0.12
1993	5.03
1994	0.43
1995	0.57
1996	3.48
1997	0.52
1998	0.58
1999	NA
2000	NA
2001	2.98
2002	NA
2003	7.98
2004	NA
2005	4.76
2006	NA
2007	6.77

Sources: Gaichas et al. (1999, Table 3) and Mark Wilkins (AFSC) (pers. comm., Oct 2008) for 2001–2007 data.

Table 14. 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 in cm 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). 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 b).

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 15. Natural mortality (*M*) parameter estimates for shark species in the Gulf of Alaska (GOA). Source: GOA spiny dogfish (Tribuzio and Kruse in review b); eastern North Pacific (ENP) spiny dogfish (Wood et al. 1979); salmon shark (Goldman 2002).

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

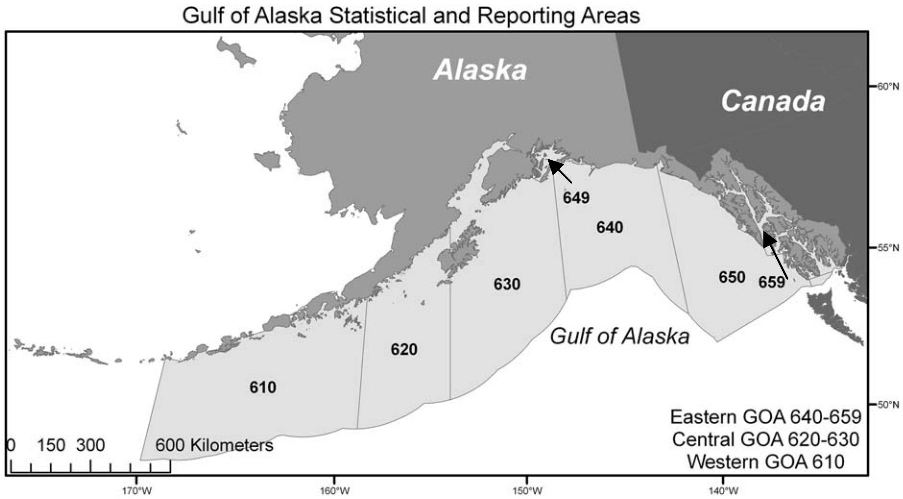

Figure 1. The statistical areas for NMFS observer data in the Gulf of Alaska.

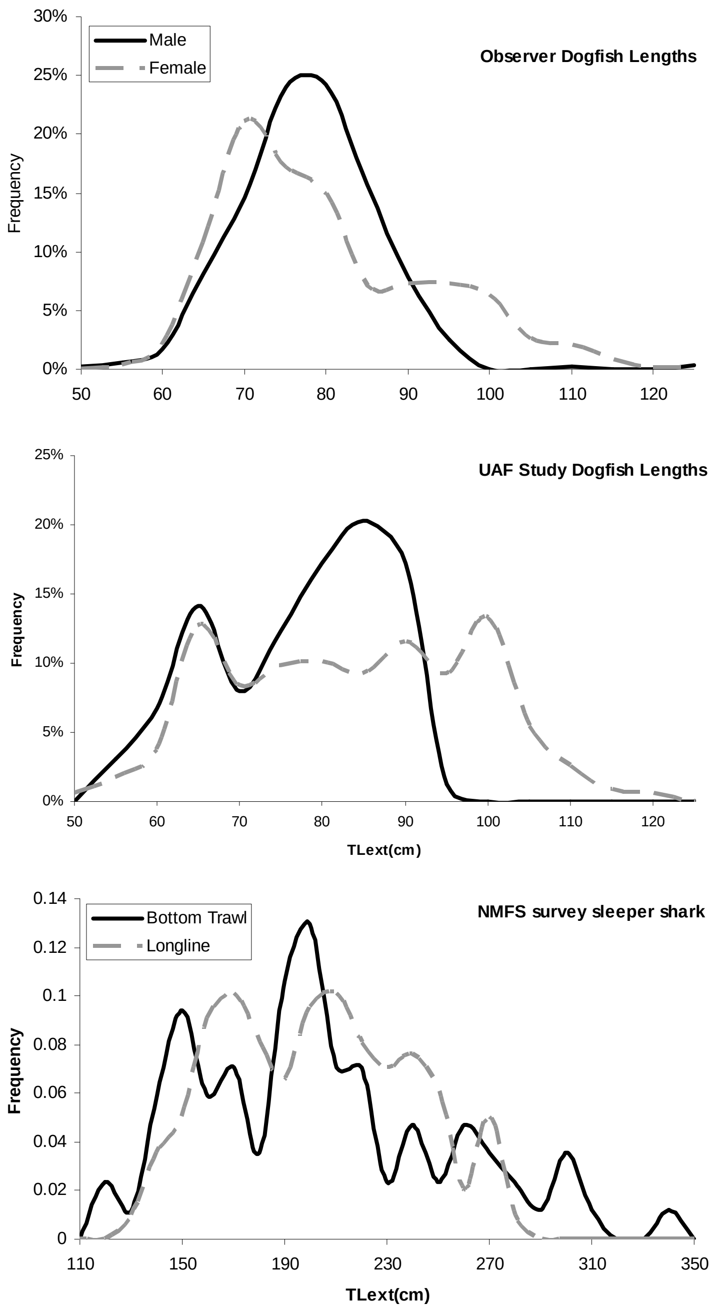

Figure 2. Observed length frequencies for: (top) spiny dogfish from a special project with the NMFS observer program; (center) spiny dogfish from University of Alaska Fairbanks study; (bottom) Pacific sleeper shark from NMFS bottom trawl and longline surveys.

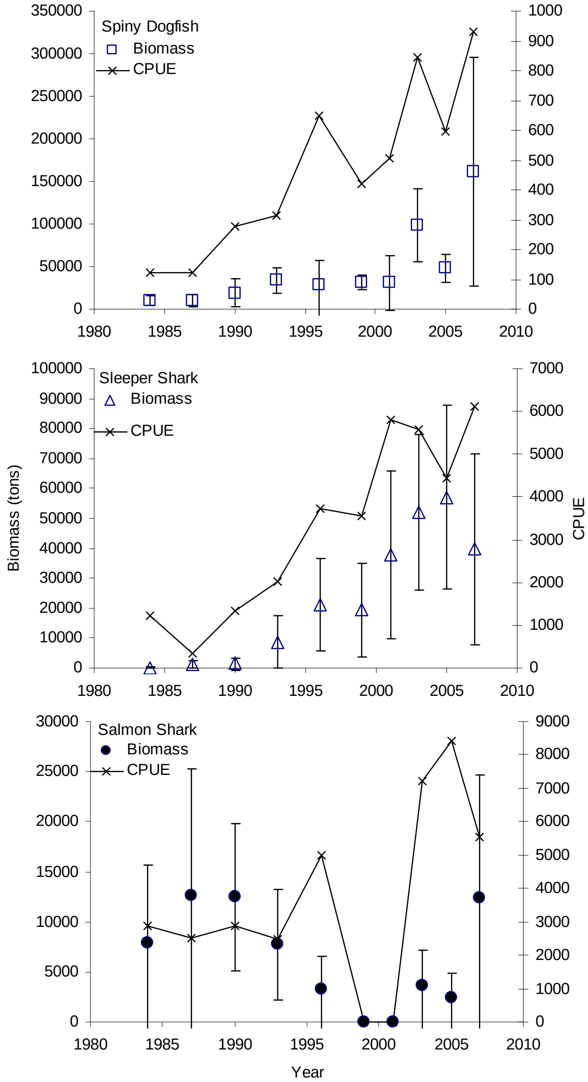

Figure 3. Trends in Gulf of Alaska (GOA) AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of GOA biomass trends are subject to the following caveats regarding the consistency of the survey time series. Survey efficiency in the GOA may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Gaichas et al. 1999). Surveys in 1984, 1987, and 1999 included deeper strata than the 1990-1996 surveys; therefore the biomass estimates for deeper-dwelling species are not comparable across years. The 2001 survey did not include all areas of the Eastern GOA and consequently, the 2001 survey may not be comparable with the other surveys for species such as spiny dogfish which appear to be relatively abundant in the Eastern GOA. Source: Gaichas et al. (1999), RACEBASE.

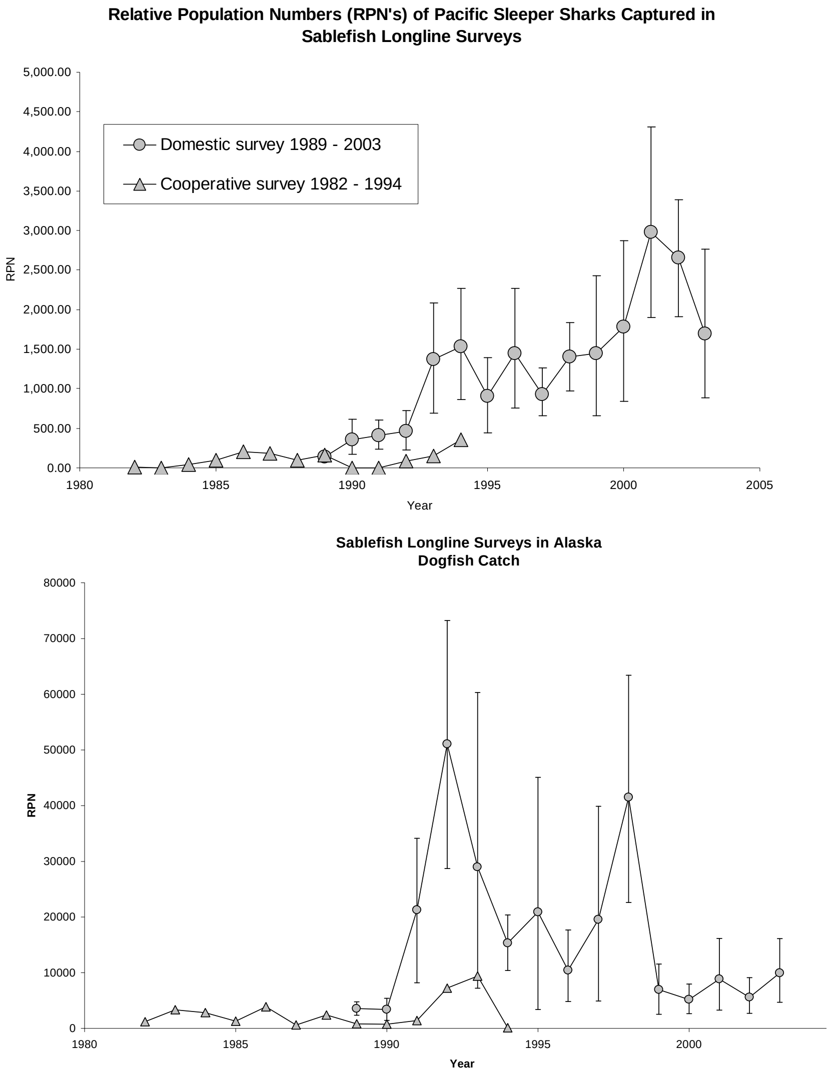

Figure 4. Relative population numbers (RPN's) of Pacific sleeper sharks (top) and spiny dogfish (bottom) captured in the northeast Pacific (Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska) during the years 1982-1994 by the Japan-U.S. cooperative sablefish longline survey, and during the years 1989-2003 by the domestic sablefish longline survey (with 95% bootstrap confidence intervals). From Courtney et al. 2006, Appendix E.

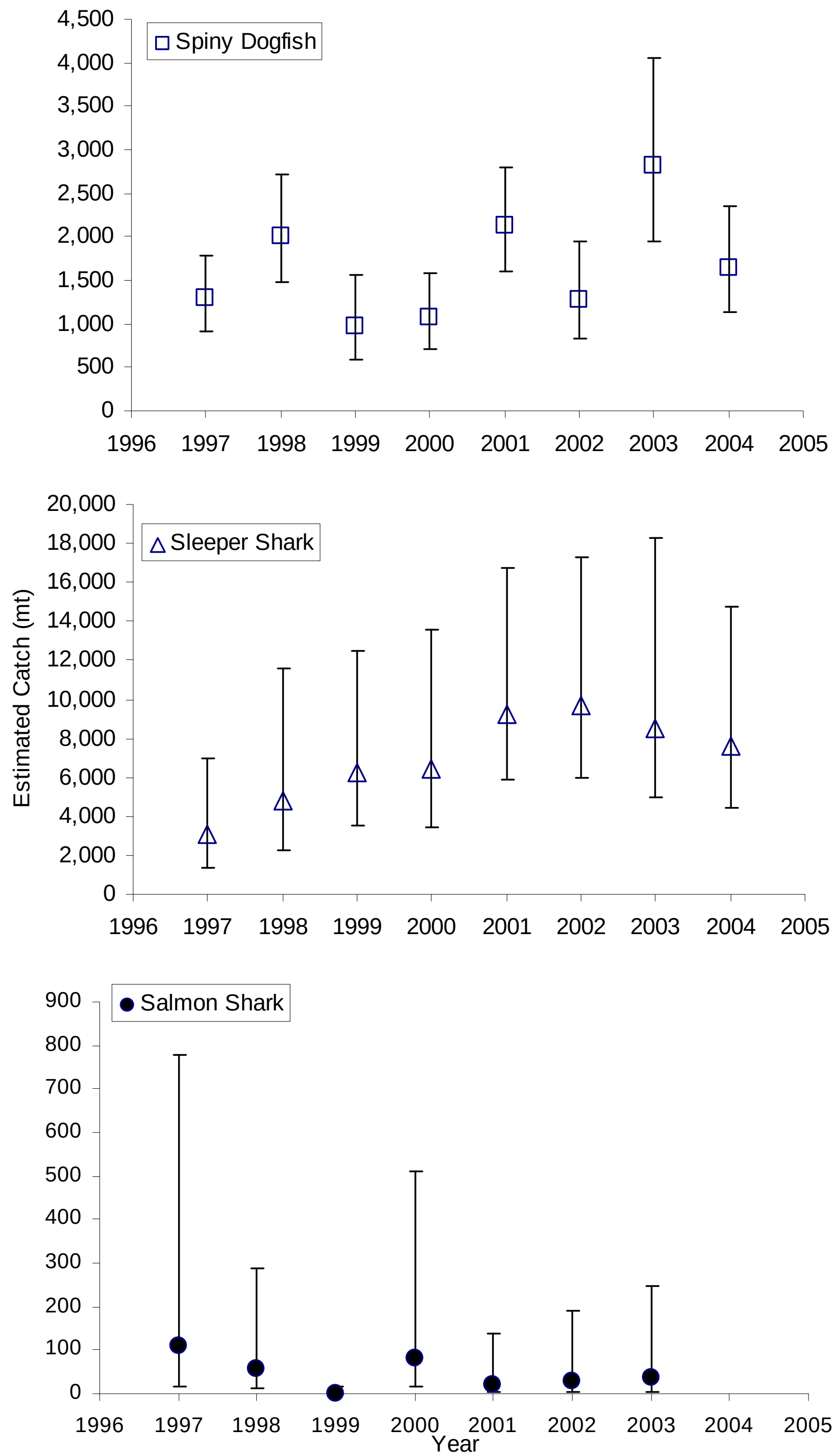

Figure 5. Estimated bycatch from unobserved fisheries, based on IPHC survey catch rates and commercial fishery effort from the halibut fishery in the GOA. Source: Courtney et al. 2006, Appendix D. Catches have not been estimated for years 2005-2008.

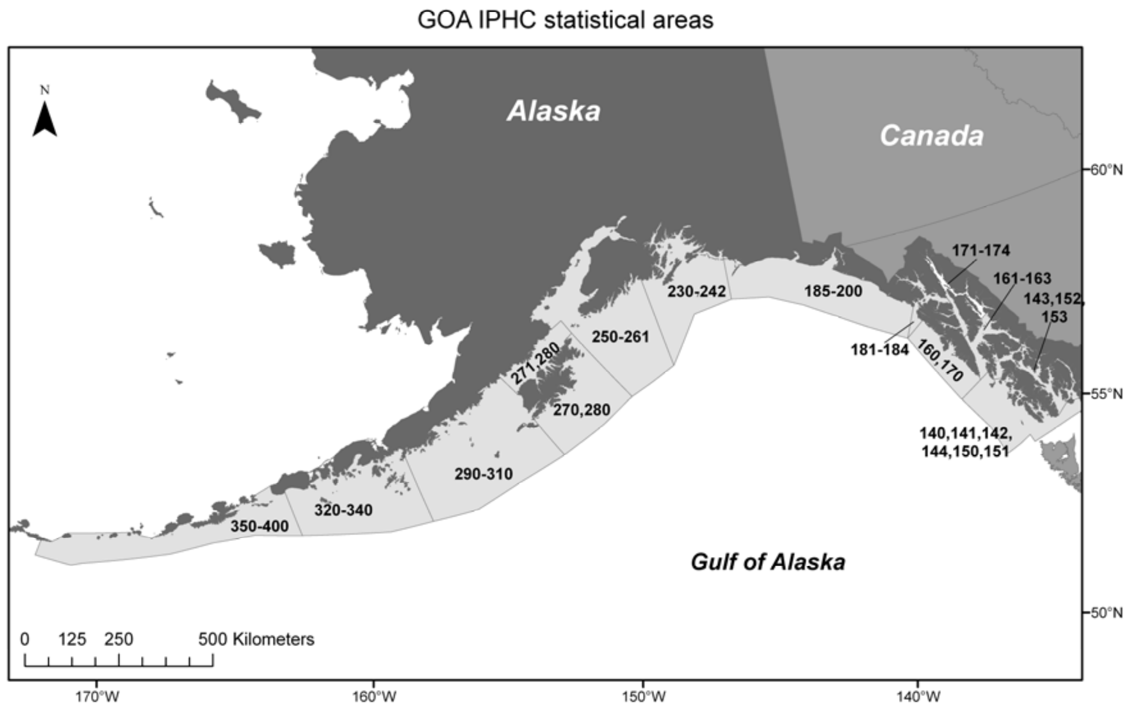

Figure 6. International Pacific Halibut Commission (IPHC) statistical areas grouped for detailing unobserved fisheries catch records in the Gulf of Alaska. Groupings were based on confidentiality requirements. Source: Courtney et al. 2006, Appendix D.

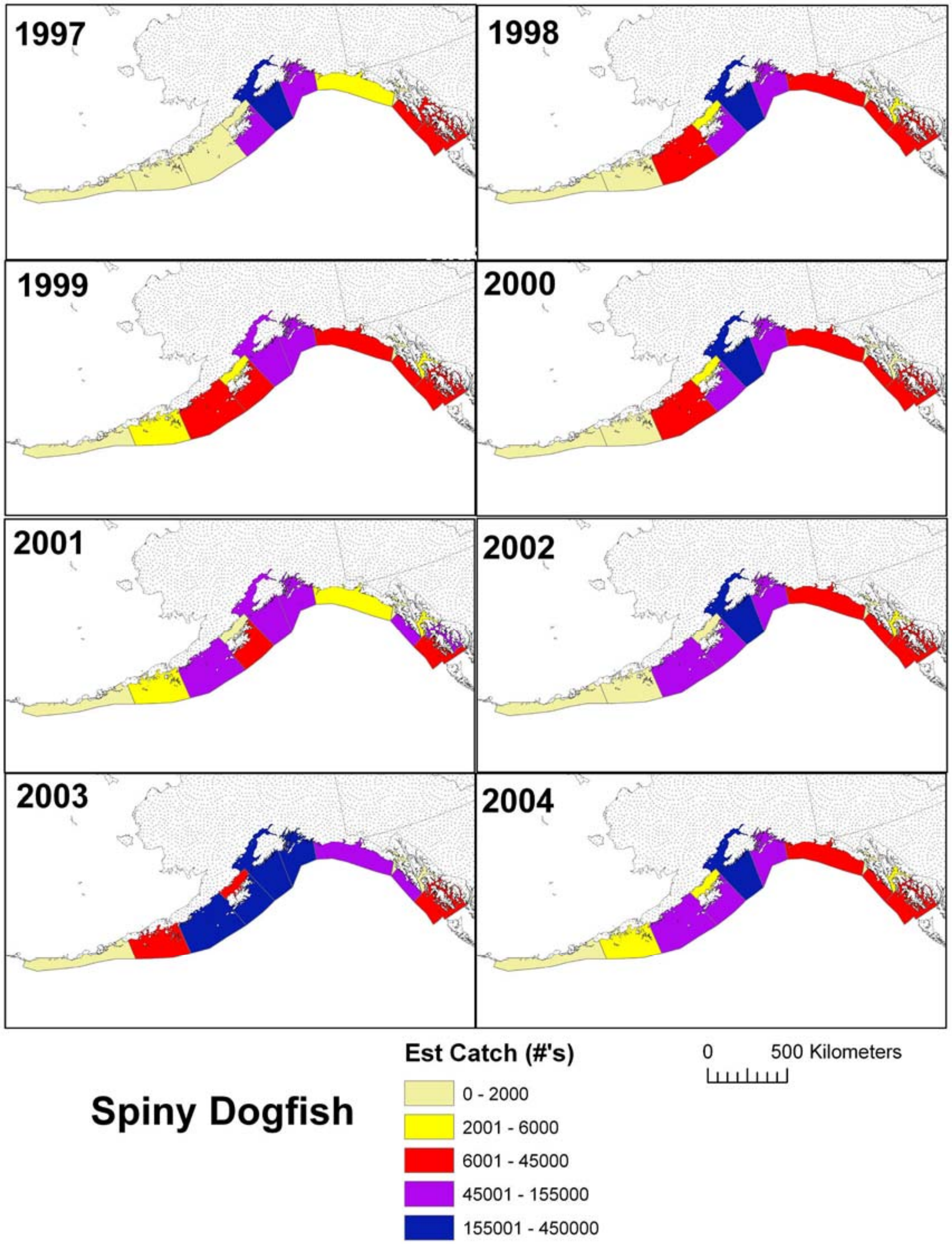

Figure 7. Estimated catch, in numbers, of spiny dogfish in the grouped IPHC statistical areas (see Fig. 5). Catches were estimated for 1997-2004 based on survey bycatch rates and commercial logbooks. Source: Courtney et al. 2006, Appendix D. Catches have not been estimated for 2005-2008.

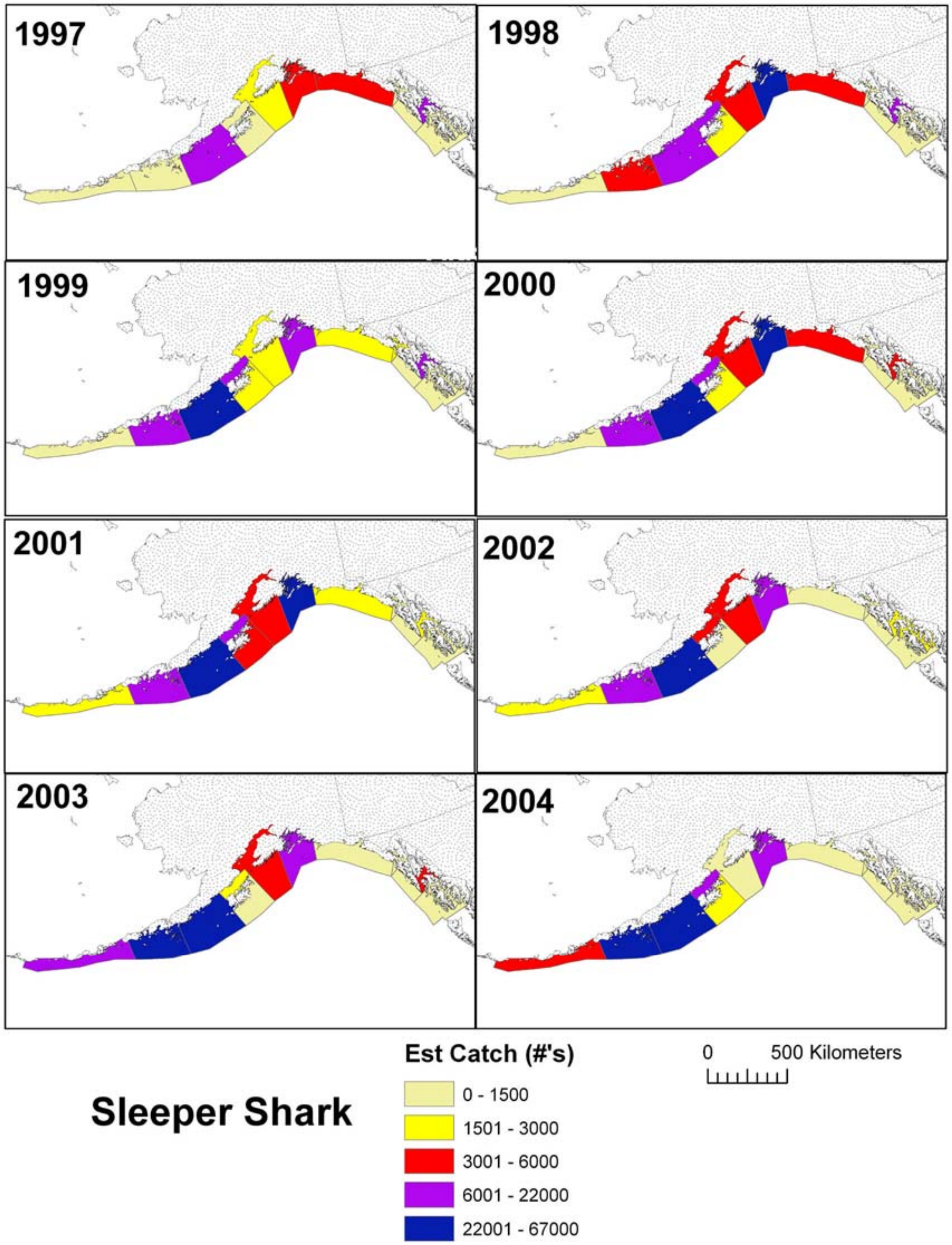

Figure 8. Estimated catch, in numbers, of Pacific sleeper sharks in the grouped IPHC statistical areas (see Fig. 5). Catches were estimated for 1997-2004 based on survey bycatch rates and commercial logbooks. Source: Courtney et al. 2006, Appendix D. Catches have not been estimated for 2005-2008.

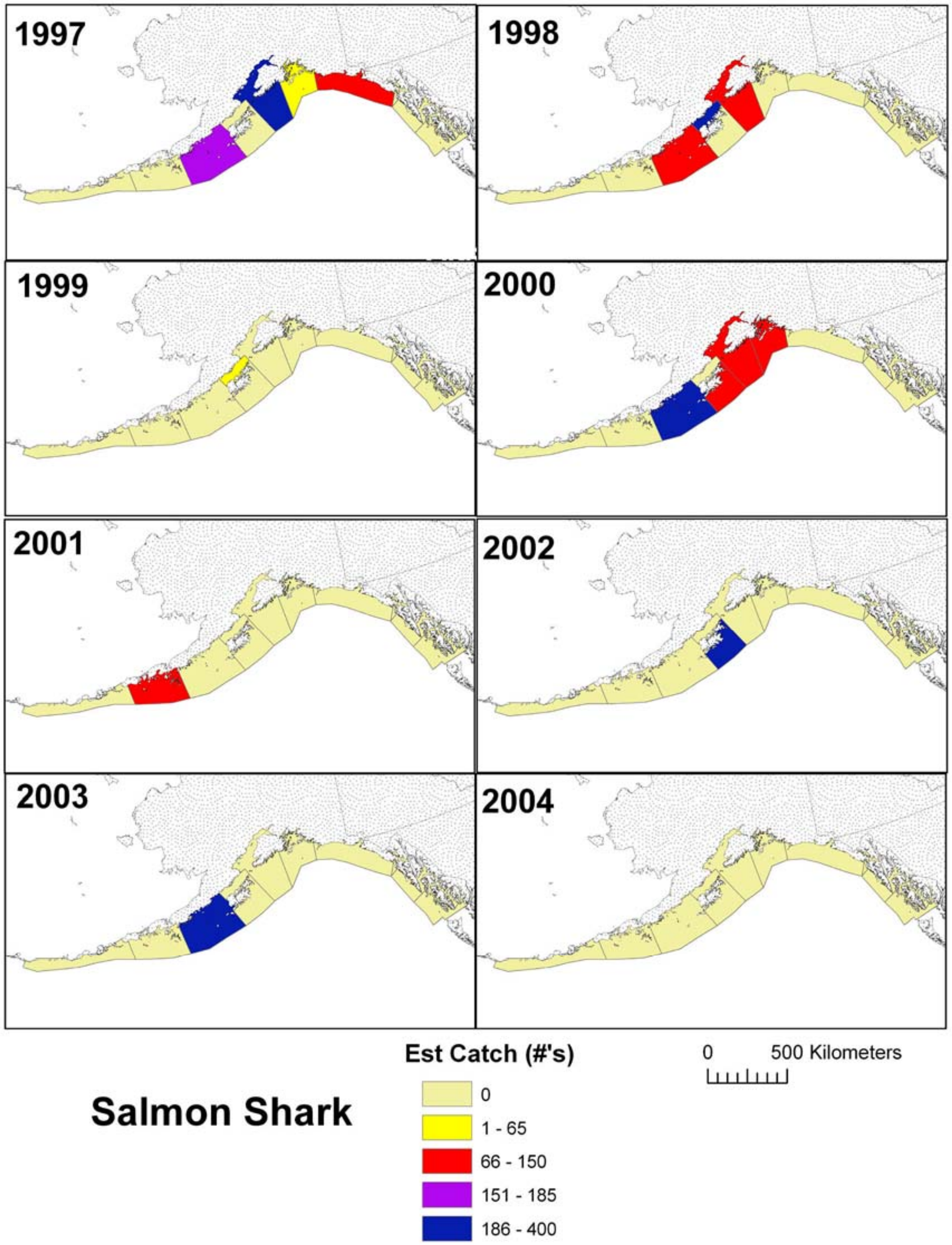

Figure 9. Estimated catch, in numbers, of salmon sharks in the grouped IPHC statistical areas (see Fig. 5). Catches were estimated for 1997-2004 based on survey bycatch rates and commercial logbooks. Source: Courtney et al. 2006, Appendix D. Catches have not been estimated for 2005-2008.

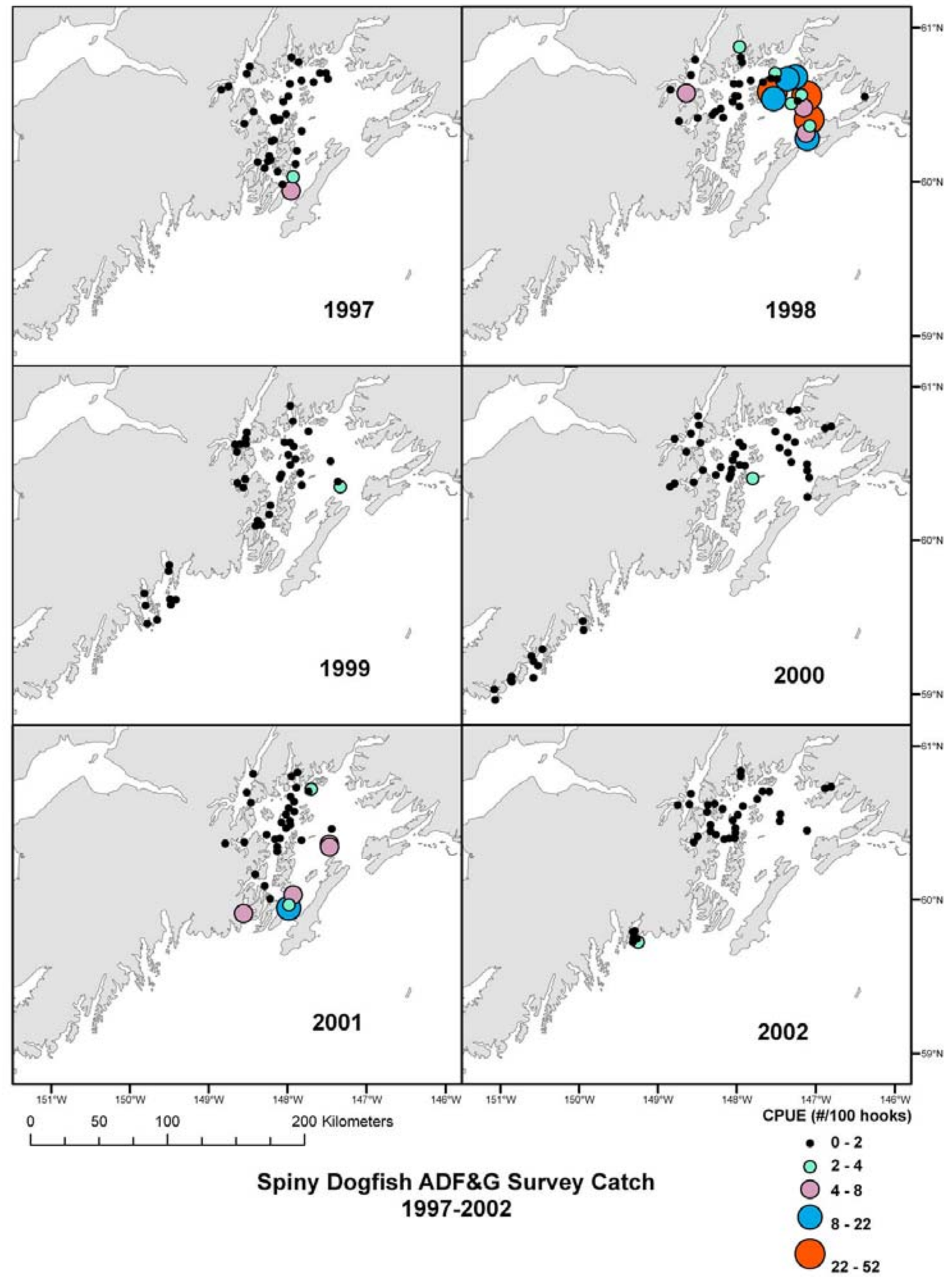

Figure 10. Spiny dogfish catch in the ADF&G longline surveys from 1997-2002.

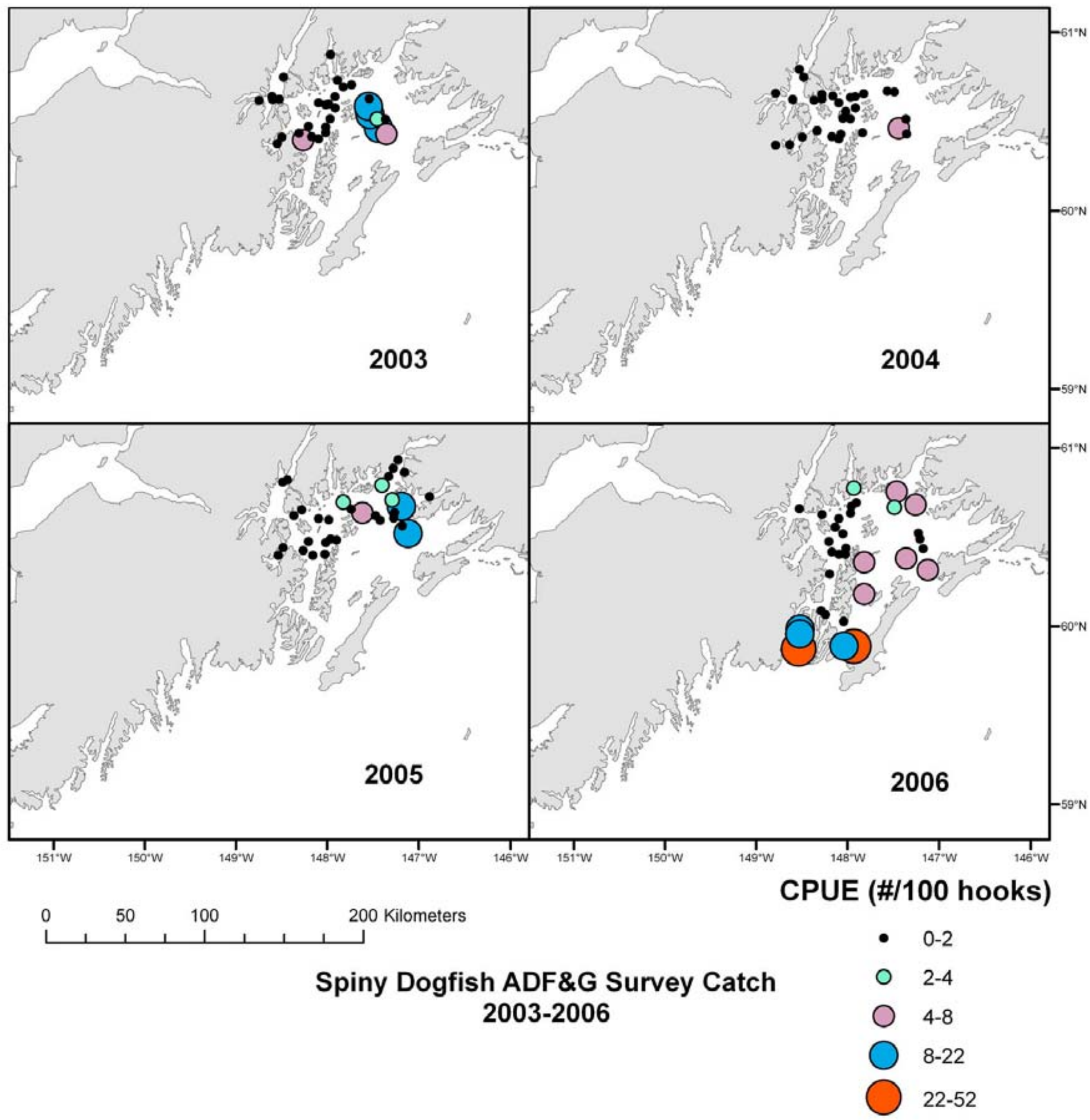

Figure 11. Spiny dogfish catch in the ADF&G longline surveys from 1997-2002.

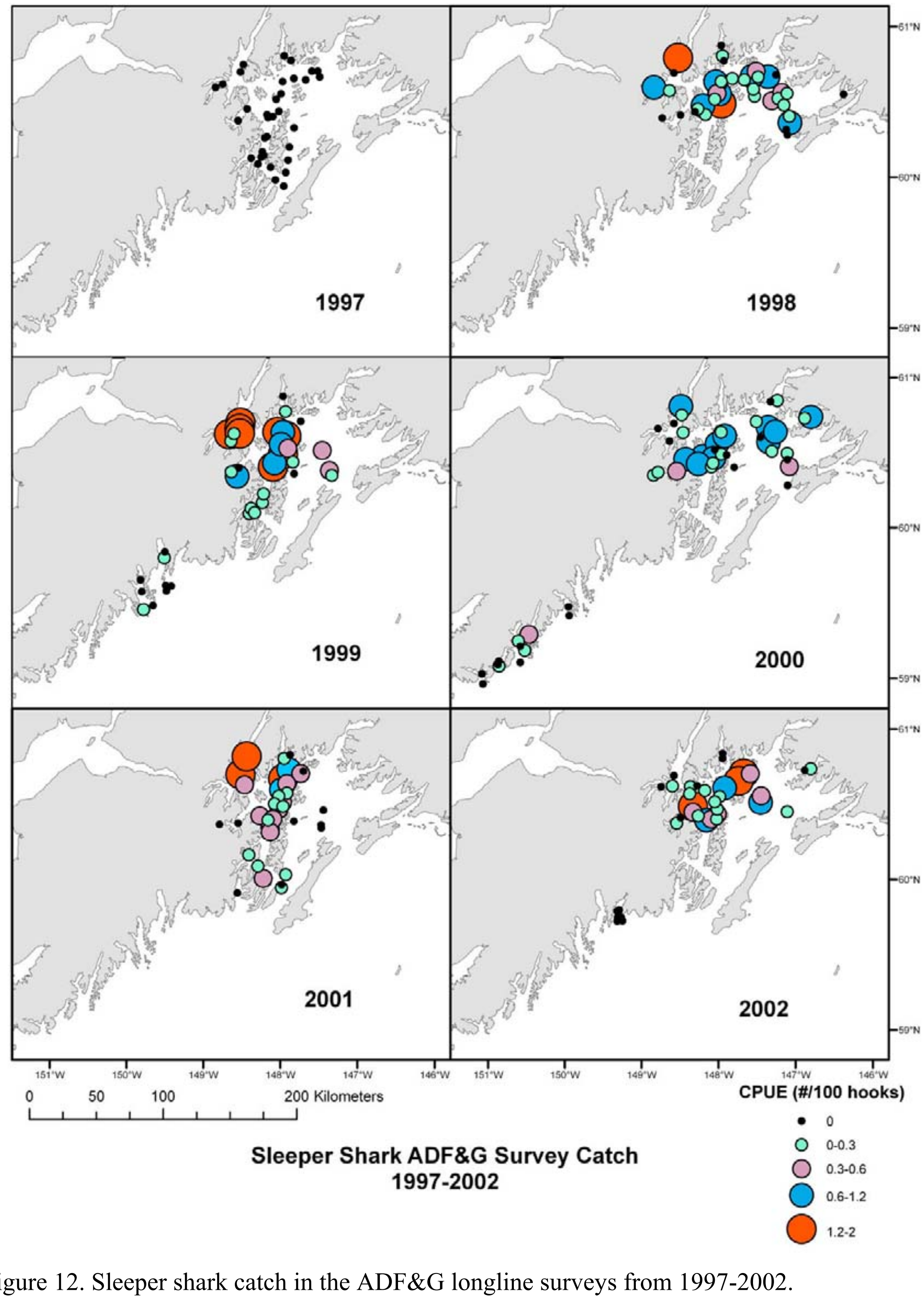

Figure 12. Sleeper shark catch in the ADF&G longline surveys from 1997-2002.

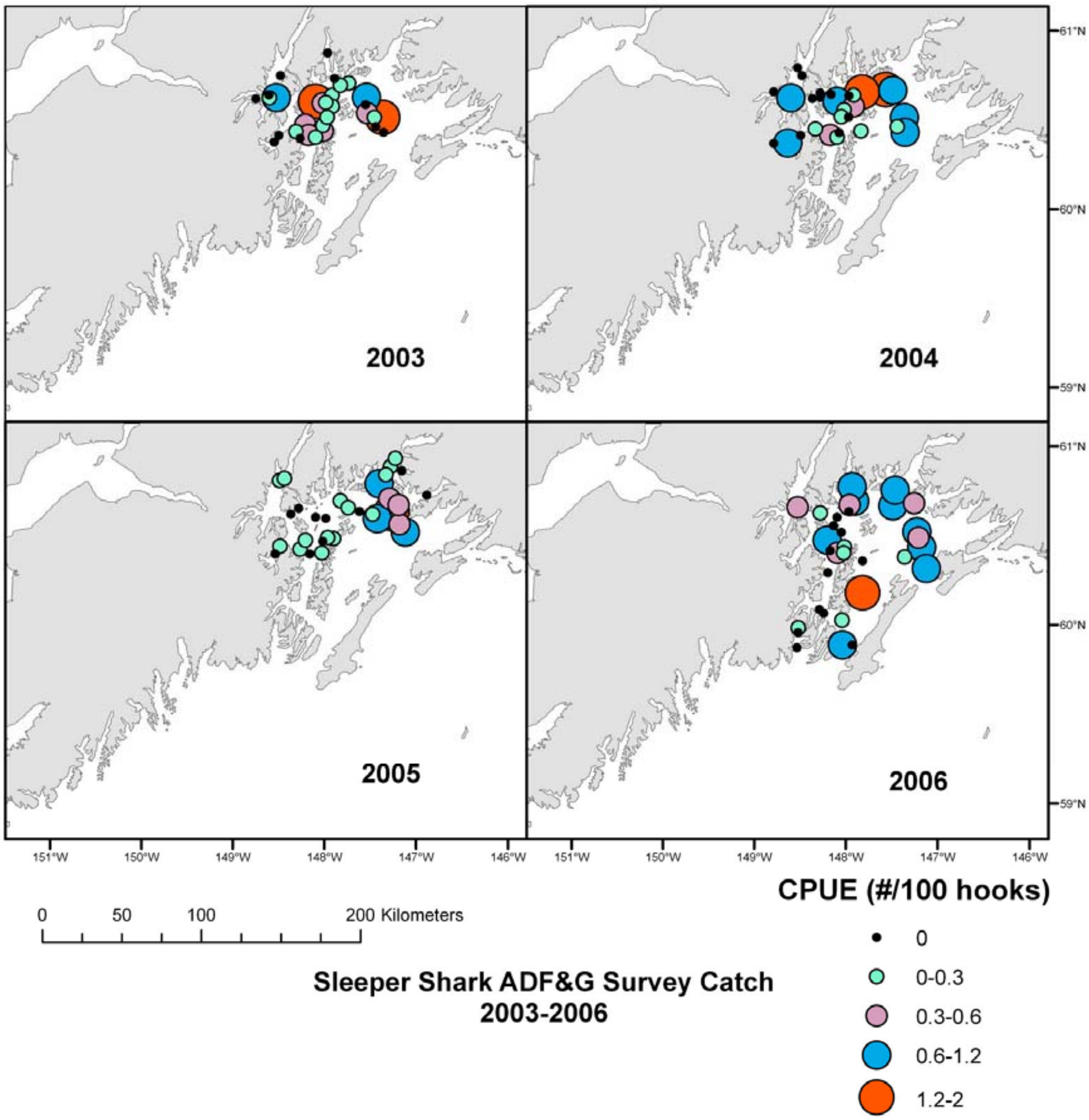

Figure 13. Sleeper shark catch in the ADF&G longline surveys from 1997-2002.

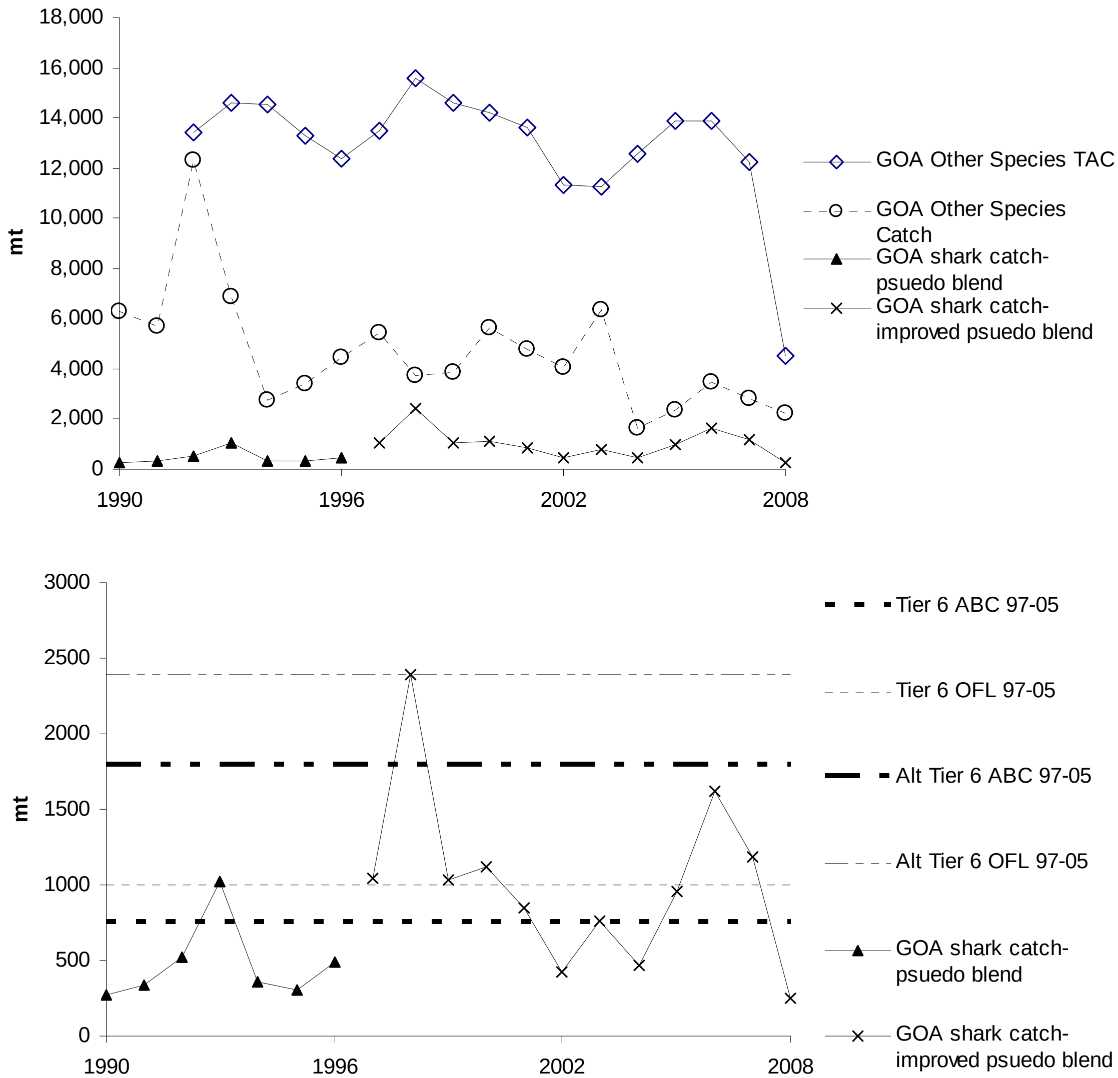

Figure 14. Top: comparison of total GOA shark catch relative to total Other Species catch and Other Species TAC. Bottom: total GOA shark catch per year plotted relative to 2006 ABC and OFL options for the GOA shark complex under Tier 6 and the alternative Tier 6 methodology (Courtney et al. 2006).

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