Chapter 18b: Assessment of the sharks in the Gulf of Alaska

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EXECUTIVE SUMMARY

Summary of Major Changes

Changes to the input data

1. Total catch for GOA sharks from 2003-2010 has been updated (as of Oct 10, 2010).
2. NMFS longline and IPHC survey data has been updated.
3. An examination of spatial observed catch was added to the incidental catch section and a similar analysis of survey data was included in the survey biomass section.
4. Alternatives to the average catch history Tier 6 method are presented.

Changes in assessment methodology

At the September 2010 Plan Team meeting, the joint plan teams discussed alternative methods for estimating ABC and OFL for Tier 6 species. Based on that discussion and recommendations by the SSC, five alternatives to the current Tier 6 method (OFL = average catch 1997-2007 and ABC = 0.75*OFL) are presented in the ABC and OFL calculations sections. Alternatives include OFL = maximum catch, OFL = 70th, 80th, or 90th percentile of the catch history, and the last alternative places spiny dogfish in Tier 5 with all other shark species in Tier 6.

Summary of Results

There is no evidence to suggest that over fishing is occurring for any shark species in the GOA. Total shark catch in 2009 was 1,167 t and catch in 2010 was 478 as of October 10, 2010. We recommend that sharks be managed as Tier 6 species with the ABC and OFL based on the average catch between 1997-2007. This results in an ABC of 839 t and an OFL of 1,118 t for the shark complex combined. The slight decrease in ABC and OFL is due to an adjustment made in the Catch Accounting System which resulted in slightly altered catch estimates during the 1997-2007 time period. We recommend continuing with the current ABC and OFL calculation methods because catch in unobserved fisheries has not yet been added to the time series. The issue of which method to use to determine ABC and OFL should be re-evaluated after unobserved catch estimates are incorporated. There are currently no directed commercial fisheries for shark species in federally 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. Sharks have only been reported to species in the catch since 1997 and have made up from 11% to 64% of Other Species catch from 1997 – 2009. In 2009, spiny dogfish made up 93% of the shark catch, but on average are 53% of total shark catch. Pacific sleeper made up 4% of the total shark catch in 2009 and are on average 30% of the shark catch.

ABC and OFL Calculations and Tier 6 recommendations for 2010-2011.

Total Shark Complex Quantity/Status	**Last year** 2010	2011	**This year** **2011**	2012
M (natural mortality)	0.097	0.097	**0.097**	0.097
Specified/recommended Tier	6	6	**6**	6
Specified/recommended OFL (t)	1,276	1,276	**1,118**	1,118
Specified/recommended ABC (t)	957	957	**839**	839
Is the stock being subjected to overfishing?	No	No	**No**	No
(for Tier 6 stocks, data are not available to determine whether the stock is in an overfished condition)				

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unidentified shark	**Total shark Complex**
Tier	6	6	6	6	6
M	0.097	unknown	0.18	unknown	0.097
Recommended Method:					
Average catch (t)	544	316	71	188	1,118
ABC (t)	408	237	53	141	839
OFL (t)	544	316	71	188	1,118

Responses to SSC Comments

Responses to SSC comments specific to this assessment
From the December 2009 SSC minutes:

The SSC supports the four plan team recommendations on pg. 16 of the November 2009 Plan Team minutes:

1) *Need to clarify the amount of sportfish catch in state waters and whether or not it counts against ACLs*
2) *Evaluate how to better estimate bycatch by using both fishery and survey data from halibut (fishery or surveys)*
3) *Examination of raw observer data of catch (especially in 2004) be done prior to extrapolation given variability in catch records*
4) *Evaluate potential for Tier 5 assessment for spiny dogfish and sleeper sharks. Note that no M estimate for sleeper sharks is currently available.*

1) A table has been added based on data provided by S. Meyer (ADF&G) describing the retained and discarded catch of all shark species and retention of salmon shark (Table 3). The issue of whether or not the sport harvest counts against the ACL has not been discussed at this time.
2) This topic is being investigated in a separate report. See the report titled: "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet". The working group is recommending using a method which extrapolates commercial catch based on survey CPUE and commercial effort. Further the working group is recommending proportionally weighting the survey data by commercial effort to more accurately represent commercial fishing.
3) The spatial distribution of observed bycatch in the GOA has been examined to investigate areas of high bycatch (Figures 3 & 4) and to help delineate the "other/unidentified sharks" (in the incidental catch section).
4) A discussion of the possibility of moving spiny dogfish to Tier 5 is included in the ABC and OFL calculations section. We do not recommend moving spiny dogfish to Tier 5 because of the unreliable biomass estimates and because unobserved fisheries are not accounted for in the catch history yet. Data do not support Tier 5 for Pacific sleeper shark.

The SSC also recommends adding a research priority on the development of aging methods for Pacific sleeper sharks, so that M and other life history parameters can be estimated for future assessments.

This has been added as a research priority. A pilot study took place in October at the REFM age and growth lab examining a potential method for aging Pacific sleeper shark, as well as improving aging methods for spiny dogfish. Methods for aging Pacific sleeper sharks have also been investigated by one of the assessment authors at ADF&G. Aging of Pacific sleeper sharks is very difficult because their hard structures (vertebrae, jaws, etc.) do not calcify well and to date none of the attempted methods have been able to elucidate readable banding patterns.

The results of Rice's (2007) master's thesis on spiny dogfish, such as biomass estimates relative to virgin biomass, should be referenced in the chapter. His findings may be relevant to discussions about the difficulty using the NMFS biennial trawl survey to estimate dogfish biomass.

Rice's M.S. Thesis has been referenced in the discussion of the trawl survey spiny dogfish biomass estimates. The results presented in his thesis suggest that spiny dogfish biomass is nearly 2 million t, comparable to arrowtooth flounder biomass, which seems unreasonable for the species. Rice did not use NMFS biennial trawl survey biomass estimates in his models because longline and trawl CPUE are not comparable and he was unable to standardize it with the other survey and observer longline data. Efforts are underway by the authors to examine Rice's approach and to build biomass projection models for spiny dogfish for future assessments.

The SSC supports further development of both proposed methods to estimate shark bycatch in halibut fisheries reported in the Appendix. When completed, reconstructed historical estimates of shark catch should be added to the historical catch time series for sharks.

A working group was formed in early 2010 to further investigate methods to estimate bycatch of all non-target species in the unobserved portion of the halibut fleet. See the report titled: "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet".

The SAFE chapter authors should consider shark bycatch in state-managed fisheries, such as salmon gillnets and groundfish longline fisheries for cod and sablefish. The authors should explore ways to extend bycatch estimates to the state managed longline fisheries. For instance, the same approach used to extend halibut survey bycatches of sharks to the halibut fishery could perhaps be applied to ADF&G longline surveys for sablefish in Southeast Alaska. Regarding salmon fisheries, such an approach may be unlikely, but shark bycatch could at least be characterized by ADF&G area managers.

We concur. Shark bycatch in state-managed salmon gillnet and seine fisheries is an issue of concern and has been brought before the Board of Fish. Bycatch data does not exist for those fisheries, but the SAFE authors have been discussing options with area managers in Cook Inlet and Yakutat Bay. With regards to state-managed longline fisheries, after the method presented by the working group is approved by the SSC, the authors will investigate applying it to ADF&G survey data for Southeast Alaska.

Introduction

Squalus acanthias is the scientific name that has historically been used for the spiny dogfish of the North Pacific and many areas of the world, however, the *S. acanthias* "group" is not monospecific and has a history of being taxonomically challenging. The North Pacific spiny dogfish were reclassified by Girard (1854) as *S. suckleyi*, but the description was vague and no type specimens were preserved, thus it remained *S. acanthias*. In a study published this year, *S. suckleyi* was resurrected based on morphological, meristic and molecular data (Ebert et al. 2010). Beginning in 2010, spiny dogfish will be classified as *S. suckleyi* in the SAFE, but both names may be used to be consistent with data sources (e.g. RACEBASE survey data).

Alaska Fisheries Science Center (AFSC) surveys 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 suckleyi)*, and the salmon shark (*Lamna ditropis*).

General Distribution

Spiny Dogfish

Spiny dogfish occupy 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). Spiny dogfish inhabit both benthic and pelagic environments with a maximum recorded depth of 677 m (Tribuzio, unpublished data). Spiny dogfish are commonly found in the water column and at surface waters (Tribuzio, unpublished data). This species may once have been the most abundant living shark (Mecklenburg et al. 2002). It is commercially fished worldwide and has been heavily depleted in many locations (http://www.iucnredlist.org/apps/redlist/details/39326/0). 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 (S. Meyer, pers. comm.). Salmon sharks tend to be more pelagic and surface oriented than the other shark species in the GOA, with about 72% of their time spent in water shallower than 50 m (Weng et al. 2005). While some salmon sharks migrate south during the winter months, others remain in the GOA throughout the year (Weng et al. 2005, Hulbert et al. 2006).

Management Units

Sharks were formerly 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 included sculpins, sharks, squid, and octopus. Skates were separated from the GOA Other Species complex in 2003 (Gaichas et al. 2003). The total allowable catch (TAC) for the GOA Other Species complex has been set at 4,500 t since 2008 (Table 2). Acceptable Biological Catch (ABC) and Overfishing Limits (OFL) were set Gulf wide as an aggregate of the Other Species complex. In response to the requirements for annual catch limits contained within the reauthorization of the Magnuson Stevens Fishery Conservation and Management Act, the NPFMC reviewed the management of other species in the GOA. The NPFMC passed amendment 87 (http://www.fakr.noaa.gov/sustainablefisheries/amds/95-96-87/amd87.pdf) to the GOA FMP that requires sharks be managed as a separate complex and that Annual Catch Limits (ACLs) would be established annually by the SSC starting in 2011.

Evidence of Stock Structure

Spiny Dogfish

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 et al. 2010).

Pacific Sleeper Shark

Little is known about sleeper shark migratory behavior, or their life history. However, tagging studies in Alaska have shown that 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 (Orlav and Moiseev 1999, Hulbert et al. 2006), but do not migrate far from initial tagging locations in the GOA (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, sonically tagged sharks in Southeast Alaska were 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).

Salmon Shark

Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific (WNP) and the eastern North Pacific (ENP) separated by the longitude of 180°W (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° - 16°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). In 2009, staff at AFSC calculated vulnerability scores for 21 GOA species based on life history and fishery susceptibility characteristics (http://www.afsc.noaa.gov/refm/docs/2009/GOAvulnerability.pdf). Sharks were 3 of the 4 most vulnerable species, with salmon shark the least vulnerable shark at 1.96 (lower scores are less vulnerable), spiny dogfish at 2.10 and Pacific sleeper shark at 2.24, the most vulnerable of all GOA species calculated.

Spiny Dogfish

Eastern North Pacific spiny dogfish grow to a relatively large maximum size of 160 cm (Compagno 1984). The average length for spiny dogfish caught in the GOA biennial trawl survey (spiny dogfish are rarely caught in the BSAI surveys) was 77.8 cm TL_{ext} for females (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 75.4 cm TL_{ext} for males (N = 1,770 females and N = 3,044 males, all survey years combined, Figure 2). The average length for females sampled in the 2010 annual longline survey (first year of length data for this survey) was 65 cm TL_{ext} for females and 63 cm TL_{ext} for males (N = 378 females and N = 243 males, Figure 2). Average size of females collected during a 2006 special project with the observer program was 81.9 cm TLext and 79.6 cm TLext for males (N = 604 females and N = 528 males Figure 2).

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 were 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 biased low due to agers rejecting difficult to read spines and spine annuli that were grouped very close together. Age-at-maturity is similar to BC 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 et al. 2010).

The mode of reproduction for spiny dogfish is aplacental viviparity. Embryos are nourished by their yolk sac while being retained in utero for 18-24 months. 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 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). 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).

Pacific Sleeper Shark

Sleeper sharks (*Somniosus* spp.) can attain large sizes, most likely possess a slow-growth rate and are likely long-lived (Fisk et al. 2002). A Greenland shark (*Somniosus microcephalus*), the North Atlantic cogener of the Pacific sleeper shark, was sampled in 1999 and 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 average 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 were 440 cm for females and 400 cm for males (Mecklenburg et al. 2002). Pacific sleeper sharks have been measured on AFSC longline surveys (2001 and 2002) and during biennial trawl surveys. Longline caught female Pacific sleeper sharks averaged 170 cm (N = 119) PCL (pre-caudal length, measured from the tip of the snout to the pre-caudal notch) and 166 cm (N = 79) PCL for males (Sigler et al. 2006). Sample size was low in bottom trawl survey samples so sexes were combined, average length was 270 cm (N = 74) PCL. 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, 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 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. One of these sharks had several thousand small eggs (< 10 mm) as well as 372 large vascularized eggs (24 - 50 mm) present in the ovaries (Ebert et al. 1987). Another mature Pacific sleeper shark 370 cm long was caught off Trinidad, California (Gotshall and Jow 1965). The ovaries contained 300 large ova 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 PCL female was caught during the annual sablefish survey near Yakutat Bay and in 2009 another 85 cm PCL female was caught by a commercial halibut fisherman inside Chatham Strait in Southeast Alaska (Tribuzio unpublished data). Because of a lack of observations of mature and newly born sharks, and the absence of dates in literature, the spawning and pupping season is unknown for sleeper sharks.

Salmon Shark

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 (Goldman 2002, Goldman and Musick 2006) in the eastern North Pacific 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). 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 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 shark (also from vertebral analysis) of 17 years for males and 30 years for females (Goldman, unpublished data), 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).

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

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. 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 (about 11,363 kg landed) and decreased in 2008 to 138 kg landed. There were no recorded landings of dogfish in Yakutat in 2009 or 2010.

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, and most of the harvest occurs in state waters. The shark fishery is managed under a statewide regulation (5 AAC 75.012), which was modified in 2010 to liberalize limits for spiny dogfish. Effective 2010, the bag and possession limit for spiny dogfish is five fish and there is no size or annual limit. For all other species of the orders Lamniformes, Carcharhiniformes, and Squaliformes, the daily bag limit is one shark of any size with an annual limit of two sharks per year. The season is open year-round.

There are three sources of information on sport harvest: (1) the ADF&G statewide harvest survey (SWHS) provides estimates of catch (harvest plus released fish) and harvest (fish kept) of all shark species combined, in numbers of fish, (2) the mandatory charter logbook provides estimates of statewide charter harvest of salmon sharks (numbers of fish) since 1998, and (3) dockside monitoring in the Southcentral Region obtains reported harvest and release and biological information for spiny dogfish, salmon shark, and Pacific sleeper shark. Biological information includes length, sex, and age structures. ADF&G also maintains a tagging database that includes only external numbered tags deployed by ADF&G, NMFS, and other permitted researchers in Southcentral Alaska, mostly in Prince William Sound.

Estimates of shark harvest from the SWHS are available for selected portions of the state since 1996. Shark harvest was explicitly requested in SWHS standard questionnaires in the Kodiak, Cook Inlet, and Prince William Sound areas since 1996, but statewide in the supplemental questionnaire since 1998. Therefore, estimates are presented only since 1998. Estimated annual harvest of sharks (all species combined) was in the range 0-17 fish in the Western GOA, 200-834 fish in the Central GOA, and 196-749 fish in the Eastern GOA (Table 3). The CV of shark harvest estimates ranged from 16-32% in the Central Gulf and 21-45% in the Eastern Gulf.

In addition to the harvest, numbers of fish released were obtained by subtracting estimated harvest from estimated catch. Standard errors are not available for the release numbers. Estimated numbers of sharks released annually ranged from about 0 to 400 in the Western GOA, about 5,000-43,000 in the Central GOA, and about 5,000-32,000 in the Eastern GOA. The contrasting harvest and release numbers indicate that most sharks are caught incidentally and are released.

There is a relatively small directed sport fishery for salmon sharks in Southcentral Alaska. The fishery is primarily a charter boat fishery, with charter harvest accounting for over 90% of reported harvest from dockside surveys. Most of the harvest has taken place in Prince William Sound. Logbook data for salmon sharks have not been rigorously edited, but indicate annual statewide charter harvests in the range 63-284 fish over the years 1998-2009 (except 1999). About 60-65% of the harvest in recent years has come from Prince William Sound. Charter harvest of salmon sharks appeared to increase in the late 1990s in response to media attention, but has declined since the peak harvest in 2006. Average length (TL_{nat}) of salmon sharks sampled from the Southcentral Alaska sport harvest from 1998 to 2009 ranged from about 216 to 236 cm. Average predicted round wt ranged from about 124 to 158 kg. Females have dominated the harvest each year (56-97%). Ages of fish sampled from the harvest from 1997-2000 ranged from 5 to 17 years. ADF&G is still planning to complete 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. Only 69 spiny dogfish were sampled from the Southcentral Alaska sport harvest from 1998 through 2009. The mean total length (TL_{nat}) of these fish was 93 cm and mean predicted round weight was 4.1 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 Sharks and 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 2).

DATA

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Non-target catch	2003 - 2010
(AFSC) Improved Pseudo Blend	Non-target catch	1997 - 2002
(AFSC) Pseudo Blend	Non-target catch	1990 - 1998
ADF&G	Target catch	2003 - 2008
NMFS Bottom Trawl Surveys – GOA	Biomass Index	1984 - 2009
NMFS Sablefish Longline Survey	Survey catch numbers	1989 - 2010
IPHC Longline Survey	Survey catch numbers	1998 - 2009

Incidental Catch

This report summarizes incidental commercial catches by species as three data time series: 1990 - 1998, 1997 - 2002, and 2003 - 2010 (Table 4). Discard rates for sharks are presented in Table 5. Generally, > 90% of sharks are discarded, however, “Other/unidentified sharks” are generally retained at a higher rate (69% discards on average) than identified shark species, and in 2009 only 5% of the “other/unidentified sharks” were discarded (amounting to approximately 21 t retained). Prior to 2003, shark catches, by species, were estimated by 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. 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. 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. Catch estimates from 2003-2010 were estimated by the AKRO using the same methods as Gaichas (2001, 2002) and are comparable to the 1997-2002 time series.

From 1997 – 2010, total shark catches composed from 11% to 64% of the estimated Other Species total catches (Table 4). On average spiny dogfish composed 53% of total shark catch, however in 2009, they were 93% of the total shark catch. Pacific sleeper sharks are 30% of the total shark catch on average, but in 2009 were only 4%. Other/unidentifed sharks and salmon sharks are generally a smaller portion of the total shark catch (10% and 6% on average). Blue sharks and brown cat sharks were rarely identified in catches and were included with unidentified sharks. These two species are not delineated in the CAS catch estimates, but examination of the observer data showed that blue sharks are between 0% (2008 & 2009) and 60% (2006) of the other/unidentified shark catch. Brown cat sharks were at most < 1% (2006) of the other/unidentified shark catch. The majority of caught sharks are discarded (Table 5) and those that are retained are nearly all used for fishmeal (T. Hiatt, pers. comm.).

Based on the 1997 – 2010 GOA catch estimates, spiny dogfish were caught primarily in the Pacific cod (28%) and halibut (22%) fisheries (Table 6). The halibut fishery catch estimates are based only on groundfish landings, where halibut was the target species (for a definition of target species determination, see Cahalan et al. 2010). This estimate does not reflect the total estimate of catch from the IFQ halibut fleet. Pacific sleeper sharks were caught primarily in the Pacific cod (37%) and pollock (37%) fisheries (Table 7), and salmon sharks were caught primarily in the pollock (80%) and halibut (11%) fisheries (Table 8). 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 9).

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 shark catch aboard observed vessels is representative of shark 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. This is an area of concern for sharks, and work is underway to estimate the catch in unobserved fisheries. See the halibut fishery incidental catch estimation document for discussion on methods for estimating catch in the halibut IFQ fishery.

Observer data was used to map the spatial distribution of catch for the years 2006 – 2009. Data is available through the Fisheries Monitoring and Analysis division website (http://www.afsc.noaa.gov/FMA/spatial_data.htm). One caveat with this data is that observers in the GOA account for approximately 40% of the groundfish tonnage and may not characterize the fishery completely. Further, this data does not represent catches in ADF&G managed fisheries or in the IFQ halibut fishery. Because observer coverage is limited due to vessel size and fishery type observer requirements, this catch data may be biased. Smaller unobserved groundfish vessels likely do not fish in the same areas and in the same manner as larger observed vessels. Data presented here represent only non-confidential data aggregated by 100km^2 grids of observed catch.

Bycatch of spiny dogfish within observed commercial fisheries (Figure 3) occur throughout the entire continental shelf of the GOA, but predominately off Kodiak Island. The year 2006 had an especially high catch of spiny dogfish throughout the entire coastal belt and along the Gulf side of Kodiak Island. The spatial distribution of Pacific sleeper sharks catch (Figure 4) is much more confined than spiny dogfish. Pacific sleeper shark catch primarily occurs within Shelikof Strait in the Central GOA, and along the arm of the Alaska Peninsula. Both 2006 and 2007 saw higher catches of Pacific sleeper sharks within observed commercial fisheries. The amount of salmon shark and unidentified shark bycatch within observed commercial fisheries is small and rarely available in non-confidential data. Therefore, we did not examine the spatial distribution of this catch.

Survey Biomass Estimates

NMFS AFSC bottom trawl survey biomass estimates are available for shark species in the GOA (1984 - 2009, Table 10). 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 5). The efficiency of bottom trawl gear is not known for sharks, 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 not while it is in contact with the bottom, but rather 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. Also, 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.

Tagging data show that spiny dogfish spend a significant amount of time in near surface waters or shallow depths during the summer and while inhabiting the geographic areas where the trawl survey occurs (Tribuzio, unpublished data) and are thus likely poorly sampled. Trawl survey catch of spiny dogfish is highly variable from year to year. For example in 2007 there was one haul with a large number of dogfish, and consequently the biomass estimate was an order of magnitude larger than previous years. It is possible that the trawl survey biomass estimate for spiny dogfish is an underestimate and could be considered a minimum biomass. Rice (2007) estimated biomass of spiny dogfish to be almost 2 million t, which is similar to arrowtooth flounder and may be an over estimate of biomass. His estimate was based only on longline data (both observer and survey) because he was unable to standardize the trawl CPUE to be comparable with longline CPUE. Therefore, Rice's biomass estimate and the trawl survey biomass estimate are not directly comparable and neither should be considered reliable.

Analyses of GOA biomass trends are subject to several caveats regarding the consistency of the survey time series. 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.

If the biomass estimates from the trawl survey are considered a relative index of abundance, then the 1984 - 2009 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 10, Figure 5). Salmon shark biomass has been stable or decreasing according to this survey. Both salmon shark and Pacific sleeper shark biomass estimates are based on a very small number of individual hauls in a given survey (Table 10). No salmon sharks were encountered in either the 1999, 2001 or 2009 survey. The 2009 survey biomass estimate for spiny dogfish was the lowest since 1987 and had the lowest CV of any previous biomass estimate. Spiny dogfish were captured in a larger number of hauls each year than any other shark but were never captured at more than 25% of the stations surveyed in any year. The total NMFS survey catch of all sharks in trawl surveys is listed in Table 11.

Other Data Sources

Relative population numbers (RPNs) are now available for all species caught on the annual NMFS longline survey. The RPN is calculated by multiplying the CPUE of the species of interest by the geographic area of the strata (here strata are defined as an area/depth combination, for example area 610/200 - 400m) then summing over interested regions (Courtney and Sigler 2007). For future shark assessments we are investigating which stations and depth strata regularly catch Pacific sleeper sharks and spiny dogfish so that an index for 1990-present can be calculated. The LL survey samples depths from 0 - 1000 meters, but RPNs are currently not available for the 0 - 200 m depth range. This is unfortunate since spiny dogfish often inhabit shallow shelf waters. Over the next year we plan on evaluating whether there is any useful information from the LL survey for these shallower areas. Similar methods are being used to calculate RPNs from the IPHC survey data, which has a greater spatial and depth coverage for spiny dogfish. Results for the IPHC and NMFS longline surveys may be presented in next year's SAFE.

An examination of the spatial distribution of spiny dogfish and Pacific sleeper shark catch in the three main surveys (NMFS bottom trawl and longline and IPHC longline) has been included in this year's SAFE. Spiny dogfish are the most abundant catch of all shark species within GOA surveys. An examination of their spatial distribution during years 2006 - 2009 shows that spiny dogfish are heavily caught throughout the continental shelf along the entire coastal belt of the Gulf. Areas of particularly high catch within the NMFS trawl (Figure 6) and IPHC LL (Figure 7) surveys are in waters surrounding Yakutat Bay, and at gully stations sampled during the NMFS LL surveys (Figure 8). In 2007, catches of spiny dogfish were higher, particularly within the north central Gulf heading southeast along the coast beyond Yakutat Bay during the NMFS trawl survey (Figure 6). During the IPHC LL survey (Figure 7) in 2008, abnormally high catches of spiny dogfish were seen from Yakutat Bay southeast towards Dixon Entrance.

In contrast, Pacific sleeper shark catch within the GOA is more concentrated to shelf waters in the western half of the Gulf, from Prince William Sound southwest through Shelikof Strait to the end of the Alaska Peninsula, particularly in the NMFS trawl survey (Figure 9). The IPHC LL survey (Figure 10) consistently catches the greatest numbers of Pacific sleeper sharks within Shelikof Strait, but also samples nearshore waters and in 2008 there were especially high catches within Icy and Chatham Straits in Southeast Alaska. Pacific sleeper shark catches are also consistent from year to year in Prince William Sound in the IPHC survey. Both the NMFS trawl (Figure 9) and LL (Figure 11) surveys see smaller catch of Pacific sleeper sharks, and this catch is concentrated around the entrance to Yakutat Bay and within Shelikof Strait.

Survey catches from ADF&G surveys in Prince William Sound, Southeast Alaska and Kodiak Island are being compiled by the AKRO and will be available for the next assessment cycle.

Weight-at-length and average length and weight values for all three species are presented in Table 12. 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 press). 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. Parameters of the von Bertalanffy growth model are presented in Table 12. 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

Sharks in the GOA are managed under Tier 6 (harvest specifications based on average historical catch), so no stock assessment modeling is performed.

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 13). Tribuzio and Kruse, (in review) derived an estimate of the natural mortality rate (M = 0.097) for spiny dogfish in the Gulf of Alaska. The value of M (0.097) for the Gulf of Alaska is similar to the previously published estimate of M from British Columbia spiny dogfish of 0.094 (Wood et al. 1979). Goldman (2002) derived an M estimate for salmon shark in the central Gulf of Alaska of 0.18. 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) and for spiny dogfish in the eastern North Pacific 80 - 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 sharks, however, Tribuzio et al. (2010) 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 is 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 rebound potential and sustainable fishing levels. Assuming an unfished population, the spiny dogfish population has an estimated rate of increase of 3.4% (1.2 - 6%, 95% confidence intervals, Tribuzio and Kruse, in review) and salmon shark are increasing at a rate of 1.2% (-1.5 - 4.1%, 95% confidence intervals, Goldman 2006 Appendix B in Courtney et al. 2006). Sustainable fishing levels for spiny dogfish were at $F < 0.04$ and for salmon shark $F < 0.05$. In both models, fishing mortality was uniform across all recruited 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 is being investigated, but not for state fisheries such as the salmon gillnet fisheries, which may have very high spiny dogfish mortality in some years. Further salmon sharks, while rare in federal commercial fisheries, but may occur in salmon seine fisheries and there is a small sport fishery for the species, suggesting that F > 0 for that species as well.

ABC and OFL Calculations

Sharks have been considered a Tier 6 species because they are a non-target and only limited data are available. The current Tier 6 method adopted in 2008 for sharks uses the average catch during 1997 - 2007 where OFL is equal to this average and ABC is 75% of OFL. The NPFMC hosted a workshop on July 8, 2010 where a number of Tier 6 alternatives were discussed. Tier 6 assessment authors were requested to present alternatives to the average catch history at the September 2010 Groundfish Plan Team meeting and based on recommendations by the Plan Team and the ensuing SSC comments, a number of alternatives for sharks have been suggested. Below are ABC and OFL estimates for the suggested Tier 6 approaches: average catch, maximum catch, 70th, 80th, 90th percentile of catch history and a minimum biomass approach for spiny dogfish.

		Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks
OFL=avg catch	ABC	408	237	53	141	839
	OFL	544	316	71	188	1,118
OFL=max catch	ABC	924	456	113	1,035	2,528
	OFL	1,232	608	151	1,380	3,371
OFL=70th percentile	ABC	493	223	53	62	831
	OFL	657	297	71	83	1,109
OFL=80th percentile	ABC	638	365	93	81	1,176
	OFL	850	486	124	108	1,568
OFL=90th percentile	ABC	649	419	99	92	1,259
	OFL	865	558	132	123	1,678
Dogfish OFL=0.097*avg biomass	ABC	5,766	237	53	141	6,197
All others OFL=avg catch	OFL	7,688	316	71	188	8,262
Dogfish OFL=0.04*avg biomass	ABC	2,378	237	53	141	2,809
All others OFL=avg catch	OFL	3,170	316	71	188	3,745

It has been suggested to move spiny dogfish to Tier 5, however Tier 5 requires reliable biomass and M estimates and assumes that F = M is sustainable. Spiny dogfish data do not support placing them in Tier 5 because NMFS bottom trawl biomass estimates cannot be considered reliable for spiny dogfish for reasons described earlier, and estimates of sustainable F = 0.04, which is not comparable to estimates of M (Tribuzio and Kruse in review). An alternative is to assume that the trawl survey biomass estimate is a reliable *minimum* biomass and use the estimated sustainable F from Tribuzio and Kruse (in review) Further, to account for high variability in biomass estimates, an approach similar to that used for some GOA rockfish species would be to average the most recent three biomass estimates.

We do not recommend using the minimum biomass approach for spiny dogfish because bycatch in unobserved fisheries is still unaccounted for. Preliminary catch estimates of spiny dogfish bycatch in the IFQ halibut fishery could increase the estimated catch by about 50% on average (final catch estimates are not ready for this assessment and results may change), which is a substantial amount for a species with a low sustainable F. When the catch estimates from the IFQ halibut fleet are incorporated into the time series, actual catch could be a larger portion of the minimum survey biomass estimate and data do not currently exist to determine the sustainability of that catch. In that regard, we do not recommend taking any action that would increase the catch limits of spiny dogfish until unobserved removals are accounted for.

We recommend continuing with the current Tier 6 method for all sharks until more data is available, and we recommend that the method be reassessed again in one year. 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 - 2010 were provided by NMFS AKRO (Table 4). Examining the catch history from 1997 to the present shows that catches would have exceeded the recommended ABC eight out of 14 years (Figure 12).

Tier 6 calculations by species and recommendations for 2011-2012.

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark complex
Average Catch (t)	544	316	71	188	1,118
ABC (t)	408	237	53	141	839
OFL (t)	544	316	71	188	1,118

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 effect of fluctuations in shark populations on community structure in the GOA.

Spiny dogfish

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).

Pacific sleeper shark

Pacific sleeper sharks were once thought to be sluggish and benthic because their stomachs commonly contain offal, cephalopods, and bottom dwelling fish such as flounder (*Pleuronectidae*) (e.g., Yang and Page 1999). The more current hypothesis is that these sharks make vertical oscillations throughout the water column searching for prey as well as scavenging. Evidence for this behavior was documented in a tagging study in the Gulf of Alaska (Hulbert et al. 2006). Also, a diet analysis 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. 1992; Sigler et al. 2006), suggesting that these sharks may not be as sluggish and benthic oriented as once thought. Although Pacific 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 sea lions but did have tissues from other marine mammals in their stomachs (Sigler et al. 2006). Taggart et al. (2005) found that Pacific 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 Pacific 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 (*Theragra 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 smaller 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 (family Sebastes), sablefish (*Anoplopoma fimbria*), lancetfish (family Alepisaurus), daggertooth (family Anotopterus), lumpfishes (family Cyclopteridae), sculpins (family Cottidae), Atka mackerel (*Pleurogrammus*), mackerel (family Scomber), pollock and tomcod (family Gadidae), herring (family Clupeidae), spiny dogfish, tanner crab (family Chionoecetes), 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 et al. 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
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 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 for Pacific sleeper sharks. Regardless of future management decisions regarding the structure of the Other Species management category, it is essential to continue to improve shark fishery and survey sampling with the collection of biological data from sharks. Future shark research priorities will focus on the following areas:

1. Expand collection of length data and begin collecting age samples from NMFS and IPHC surveys in the GOA
    a. Actions: Began collecting lengths of spiny dogfish in the NMFS longline survey.
2. Collect length data from sharks caught in observed hauls/samples on observed commercial vessels
    a. Actions: Instituted observer special projects to record lengths on sharks for 2011
3. Estimate bycatch from unobserved fisheries
    a. Actions: Working group formed to estimate bycatch in unobserved halibut fleet for all non-target species. See "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet" document
4. Define the stock structure and migration patterns (i.e. tagging studies, genetics)
    a. Actions: Recovered tags from first year of pop-off archival study, data still being analyzed. Deployed more tags in 2010.
5. Determine or clarify existing estimates of life history parameters for use in models
    a. Actions: Pilot study underway to examine improved aging methods for spiny dogfish
6. Development of aging methods for Pacific sleeper sharks, estimate M and other life history parameters
    a. Actions: Investigations of aging methods have been underway as part of research conducted at ADF&G and as part of the above mentioned pilot study.

SUMMARY

There is no evidence to suggest that over fishing is occurring for any shark species in the GOA, because catch limits of the Other Species complex were not exceeded and overfishing limits had not previously been set for sharks. 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. 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 - 2010 (557 tons, 2010 catch as of Oct. 10, 2010) represented about 1% of the estimated spiny dogfish biomass from GOA bottom trawl surveys 1996-2009 (average of 61,216 tons, Table 10). 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 - 2010 (268 tons, 2010 catch as of Oct. 10, 2010) represented less than 1% of the available Pacific sleeper shark biomass from GOA bottom trawl surveys 1996 - 2009 (average of 38,088 tons, Table 10). Average catch of salmon sharks from 1997 - 2010 (64 tons) was relatively small compared to the other two shark species. 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 6 hauls from 1996 - 2009 (Table 10).

2011 and 2012 recommendations	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other/Unid Sharks	Total Sharks
Tier	6	6	6	6	6
M	0.097	Unk	0.18	unk	unk
Biomass 3 YR AVG	79,257	45,448	4,932	NA	129,637
Average Catch	544	316	71	188	1,118
ABC	408	237	53	141	839
OFL	544	316	71	188	1,118

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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 suckleyi	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. Note that the decrease in TAC in 2008 was a regulatory change and not based on biological trends.

Year	TAC	Other Sp. Catch	Est. 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	6,262	750	N/A	Other Species TAC
2004	12,592	3,580	573	N/A	Other Species TAC*
2005	13,871	2,512	1,102	N/A	Other Species TAC
2006	13,856	3,882	1,602	N/A	Other Species TAC
2007	12,229	3,026	1,406	1,792	Other Species TAC
2008	4,500	2,984	619	1,792	Other Species TAC
2009	4,500	2,085	1,167	777	Other Species TAC
2010	4,500	1,724	478	957	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 2003-2009 from AKRO Catch Accounting System (CAS, Updated Oct 10, 2010).

Table 3. Estimated numbers harvested and discards of sharks taken in the Alaska Department of Fish and Game managed recreational fishery. Estimates of total numbers of retained (with coefficient of variation) and discarded sharks are derived from the Statewide Harvest Survey. Estimates of retained salmon shark are derived from charter logbook and only reflect catch in the charter fleet.

All Sharks Combined

	Western			Central			Eastern			Total Est
Year	Retained	CV	Discarded	Retained	CV	Discarded	Retained	CV	Discarded	Catch
1998	0	--	0	494	0.16	9,575	269	0.23	5,226	15,564
1999	0	--	0	426	0.24	4,981	247	0.34	13,316	18,970
2000	0	--	0	351	0.24	8,283	402	0.39	16,561	25,597
2001	17	0.94	20	392	0.20	15,943	550	0.30	16,799	33,721
2002	0	--	0	347	0.27	6,833	239	0.41	4,643	12,062
2003	0	--	30	702	0.22	23,521	497	0.26	12,205	36,955
2004	0	--	37	342	0.22	16,015	403	0.30	9,529	26,326
2005	0	--	108	834	0.18	43,459	749	0.27	24,791	69,941
2006	0	--	0	441	0.25	37,816	426	0.21	20,287	58,970
2007	0	--	0	534	0.21	42,592	588	0.31	32,027	75,741
2008	0	--	410	546	0.22	21,846	371	0.38	29,827	53,000
2009	0	--	0	200	0.32	19,422	196	0.45	13,279	33,097

Salmon Shark Retained Estimates

Year	Western	Central	Eastern	Total
1998	0	122	84	206
1999	no data	no data	no data	
2000	0	76	99	175
2001	1	98	85	184
2002	0	110	90	200
2003	0	86	97	183
2004	1	103	56	160
2005	3	202	38	243
2006	1	246	37	284
2007	0	207	37	244
2008	0	81	13	94
2009	0	50	13	63

Table 4. 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 2003-2010 from NMFS AKRO as of October 10, 2010. Breaks in the table represent different catch estimation periods.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unident shark	Total sharks	Total other species	% of Other Species Catch
1990	171	20	53	30	274	6,289	4%
1991	141	49	42	108	340	5,700	6%
1992	321	38	142	17	517	12,313	4%
1993	383	215	89	340	1027	6,867	15%
1994	160	120	25	56	360	2,721	13%
1995	141	63	55	49	308	3,421	9%
1996	337	66	28	53	484	4,480	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	362	297	37	54	750	6,266	12%
2004	205	286	41	40	573	1,705	34%
2005	485	486	60	70	1,102	2,513	44%
2006	1,232	253	34	83	1,602	3,881	41%
2007	850	297	151	108	1,406	3,035	46%
2008	534	66	7	12	619	2,967	21%
2009	1,085	50	9	24	1,167	3,188	37%
2010	209	160	103	5	478	1,724	28%
1997-2007 Average	544	316	71	188	1,118	4,085	
1997-2010 Total	7,807	3,746	900	2,109	14,561	52,814	
Avg % of Total Sharks	53%	30%	6%	10%			
% of Other Species	15%	7%	2%	4%	28%		

Table 5. Estimated discard rates of sharks (by species) caught in the Gulf of Alaska. Source: AKRO CAS (queried Oct. 21, 2010). Years with no data are left blank and years with zero catches are listed as NA.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark
1999	83%	100%	NA	
2000	75%	100%	NA	
2001	78%	77%	NA	
2002	20%	98%	NA	81%
2003	98%	100%	100%	96%
2004	97%	100%	100%	89%
2005	98%	99%	98%	69%
2006	96%	100%	94%	77%
2007	96%	99%	99%	90%
2008	94%	100%	100%	64%
2009	97%	98%	100%	5%
2010	92%	94%	98%	50%
Average	85%	97%	99%	69%

Table 6. Estimated catch (tons) of spiny dogfish in 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 2003-2010 from NMFS AKRO using the improved pseudo-blend estimation procedure (as of Oct. 10, 2010). Catch by target fishery not estimated for 2002. Spiny dogfish do not occur in the Atka Mackerel fishery. Bycatch in the halibut fisheries has been estimated by NMFS AKRO since 2003, but it is based only on landed sharks and does not include discarded catch.

Fishery	Pollock	Pacific Cod	Flatfish	Rockfish	Halibut	Sablefish	Grand Total	Year % of Total 97-10
1990	57.6	36.0	13.5	1.8		59.0	170.9	
1991	29.3	52.6	16.2	16.4		26.2	141.2	
1992	84.4	50.5	116.0	22.4		40.7	320.6	
1993	137	10.1	138.5	2.4		95.3	383.4	
1994	22	16.9	83.4	2.5		35.4	160.2	
1995	2.8	28.1	24.1	18.4		50.7	140.6	
1996	2.9	15.3	182.6	19.8		79.5	336.9	
1997	2.8	57.6	137.2	326.2		133.7	657.5	8%
1998	4.9	727.2	69.0	3.1		59.6	864.9	10%
1999	8.6	160.2	56.6	4.8		83.4	313.6	4%
2000	18.7	29.4	66.3	146.6		136.6	397.6	5%
2001	11.6	172.8	162.5	25.1		122.1	494.0	6%
2002	-	-	-	-	-	-	-	
2003	6.7	43.6	166.0	35.5	7.3	20.0	279.1	4%
2004	9.2	19.6	15.5	2.3	15.0	142.6	204.1	3%
2005	15.8	27.9	50.1	2.8	18.0	369.9	484.6	6%
2006	50.0	113.2	122.9	2.0	770.1	153.0	1,211.2	16%
2007	47.6	251.6	151.4	6.2	226.7	166.8	850.1	11%
2008	59.6	290.2	87.3	4.8	0.5	91.2	533.7	7%
2009	17.6	115.2	204.9	7.0	659.4	80.8	1,084.9	14%
2010	14.1	80.4	37.8	2.2	3.8	70.8	209.2	3%
Total 97-10	267.2	2,088.9	1,327.5	568.6	1,700.8	1,630.5	7,584.5	
Fishery % of Total	4%	28%	18%	7%	22%	21%		

Table 7. 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 2003-2010 from NMFS AKRO using the improved pseudo-blend estimation procedure (as of Oct. 10, 2010). Catch by target fishery not estimated for 2002. Bycatch in the halibut fisheries has been estimated by NMFS AKRO since 2003, but it is based only on landed sharks and does not include discarded catch.

Fishery	Pollock	Pacific Cod	Flatfish	Rockfish	Atka Mackerel	Halibut	Sablefish	Grand Total	Year % of Total 97-10
1990	2.9	9.9	0.4	4.3	0		2.2	19.7	
1991	27.2	2.8	3.1	0	0		16.2	49.4	
1992	1.1	27.4	2.7	0	0		6.4	37.6	
1993	156.5	21.8	1	0	0		35.5	214.8	
1994	79.6	16.6	0.8	1.3	0		21.2	119.5	
1995	16.9	13.7	20.7	0.1	0		11.6	63	
1996	14.5	11.9	12.1	0	0.2		26.4	65.9	
1997	22.3	59.3	46	0.9	0		7.5	135.9	4%
1998	32.4	19.6	10.1	0.2	0		11.3	74	2%
1999	34.1	505.8	6	3	0		8.7	557.7	17%
2000	178.4	376.8	35.9	0.3	0		16.7	608.2	18%
2001	145.9	65.8	6.3	0.7	0		30.3	249	7%
2002	-	-	-	-	-		-	-	
2003	72.7	56.3	93.0	0.3	0.0	60.2	13.1	295.5	8%
2004	170.3	25.6	73.7	0.8	0.0	8.9	6.7	285.9	8%
2005	199.3	133.8	129.6	0.2	0.0	2.2	20.2	485.2	14%
2006	153.5	13.5	60.4	0.4	0.0	0.8	24.1	252.8	7%
2007	58.9	9.1	222.7	0.0	0.0	3.9	2.7	297.4	8%
2008	47.2	13.2	2.0	1.1	0.0	0.0	2.4	66.0	2%
2009	30.2	4.3	14.5	0.3	0.0	0.0	0.2	49.5	1%
2010	148.7	2.7	7.9	0.0	1.0	0.0	0.4	160.7	5%
Total 97-10	1,294.0	1,285.8	708.1	8.1	1.0	76.0	144.3	3,517.8	
Fishery % of Total	37%	37%	20%	0%	0%	2%	4%		

Table 8. 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 2003-2010 from NMFS AKRO using the improved pseudo-blend estimation procedure (as of Oct. 10, 2010). Catch by target fishery not estimated for 2002. Salmon shark do not occur in the Atka Mackerel fishery. Bycatch in the halibut fisheries has been estimated by NMFS AKRO since 2003, but it is based only on landed sharks and does not include discarded catch.

Fishery	Pollock	Pacific Cod	Flatfish	Rockfish	Halibut	Sablefish	Grand Total	Year % of Total 97-10
1990	45.3	3.2	0.2	0.7		2.1	51.5	
1991	36.2	0.0	0.0	0.0		5.3	41.5	
1992	123.1	16.5	0.2	0.0		2.1	141.9	
1993	86.7	0.0	2.5	0.0		0.0	89.2	
1994	24.2	0.0	0.0	0.0		0.0	24.2	
1995	25.9	21.6	3.2	0.2		3.1	54.0	
1996	26.9	0.0	0.0	0.0		0.2	27.1	
1997	19.8	0.1	0.0	0.0		0.0	19.9	2%
1998	69.7	0.0	0.8	0.4		0.0	70.9	9%
1999	111.8	0.7	0.7	0.0		18.4	131.6	16%
2000	32.7	0.0	3.7	0.8		0.6	37.8	5%
2001	29.5	0.0	1.5	1.8		0.0	32.8	4%
2002	-	-	-		-	-		
2003	36.5	0.0	0.3	0.0	0	0.1	36.9	4%
2004	33.1	1.7	5.4	0.1	0	0.4	40.8	5%
2005	43.3	0.8	15.7	0.5	0	0.0	60.4	7%
2006	31.4	0.6	1.6	0.6	0	0.0	34.3	4%
2007	141.6	0.0	9.0	0.5	88	0.0	239.1	29%
2008	6.4	0.0	0.1	0.7	0	0.0	7.2	1%
2009	6.9	0.0	2.0	0.4	0	0.0	9.3	1%
2010	100.6	0.0	0.6	2.1	0	0.0	103.3	13%
Total 97-10	663.3	4.0	41.5	8.0	88.0	19.5	824.2	
Fishery % of Total	80%	0%	5%	1%	11%	2%		

Table 9. Estimated catch (tons) of other/unidentified 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 2003-2010 from NMFS AKRO using the improved pseudo-blend estimation procedure (as of Oct. 10, 2010). Catch by target fishery not estimated for 2002. Other/unidentified sharks do not occur in the Atka Mackerel fishery. Bycatch in the halibut fisheries has been estimated by NMFS AKRO since 2003, but it is based only on landed sharks and does not include discarded catch

Fishery	Pollock	Pacific Cod	Flatfish	Rockfish	Halibut	Sablefish	Grand Total	Year % of Total 97-10
1990	4.1	21.3	0.8	1.4		2.9	30.5	
1991	17.8	36.7	35.5	4.4		13.7	108.1	
1992	3.3	8.4	3.5	0.1		1.5	17.2	
1993	138.3	38.1	3.7	0.0		159.3	339.6	
1994	41.6	2.3	3.0	0.0		8.9	55.8	
1995	4.0	3.4	10.6	9.7		14.3	49.3	
1996	14.2	3.1	17.8	1.9		16.0	53.4	
1997	8.9	13.4	9.0	47.5		43.9	123.4	6%
1998	24.2	10.2	17.9	2.3		1325.2	1379.8	66%
1999	6.1	12.3	8.1	0.1		6.4	33.0	2%
2000	12.3	3.5	34.0	4.8		18.7	73.6	4%
2001	35.0	1.4	1.5	1.4		37.7	77.0	4%
2002		-	-	-		-	-	
2003	7.6	6.4	18.2	0.2	17.5	4.2	54.1	3%
2004	11.1	2.7	18.8	0.2	2.8	4.5	40.1	2%
2005	35.2	1.2	21.5	0.2	0.2	11.6	69.8	3%
2006	40.9	11.9	24.4	1.6	0.0	4.5	83.3	4%
2007	13.9	38.9	49.6	0.4	0.0	4.7	107.7	5%
2008	4.3	2.4	2.4	0.0	0.0	2.9	12.1	1%
2009	10.4	2.7	10.6	0.0	0.0	0.0	23.8	1%
2010	1.2	0.2	3.3	0.5	0.2	0.0	5.4	0%
Total 97-10	211.2	107.2	219.4	59.2	20.7	1,464.5	2,083.1	
Fishery % of Total	10%	5%	11%	3%	1%	70%		

Table 10. Gulf of Alaska AFSC trawl survey estimates of individual shark species total biomass (metric tons) with Coefficient of Variation (CV), and number of hauls with catches of sharks. Data updated October, 2009 (RACEBASE). 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.

		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
2009	884	182	27,879.9	0.120	8	39,687.7	0.446	0	NA	NA	67,567.6

Table 11. Research survey catch of sharks between 1977 and 2010 in the Gulf of Alaska (GOA). The GOA trawl survey did not occur in 2010 and no other trawl surveys caught sharks. The GOA LL and IPHC LL survey catches are provided in numbers. IPHC Survey data is delayed by one year, thus 2010 survey data will not be included until the 2011 SAFE. Also, the total catch numbers from the IPHC survey are estimated based on the subsample of observed hooks.

Year	GOA Trawl surveys (t)	GOA LL Survey (#s)	IPHC LL Survey (#s)
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	751	
1990	3.52	583	
1991	0.15	2,039	
1992	0.12	3,881	
1993	5.03	2,557	
1994	0.43	2,323	
1995	0.57	3,882	
1996	3.48	2,206	
1997	0.52	2,822	
1998	0.58	7,701	42,361
1999	NA	1,185	21,705
2000	NA	1,212	29,257
2001	0.45	1,726	34,227
2002	NA	1,576	22,028
2003	7.36	2,372	68,940
2004	NA	1,964	48,850
2005	7.13	3,775	44,082
2006	0	6,593	41,355
2007	14.06	3,552	34,023
2008	0.73	3,606	24,655
2009	4.03	4,709	29,299
2010	0	2,622	

Sources: Gaichas et al. (1999, Table 3) Sandra Lowe and Darin Jones (pers comm., Oct 2009) for 2001–2009 trawl surveys and C. Rodgveller (pers comm., Oct 2010) for 1989-2010 GOA longline survey. IPHC data provided by Claude Dykstra.

Table 12. 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 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).

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

		von Bertalanffy Parameters		
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 13. Natural mortality (*M*) parameter estimates for shark species in the Gulf of Alaska (GOA). Source: GOA spiny dogfish (Tribuzio and Kruse in review); 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

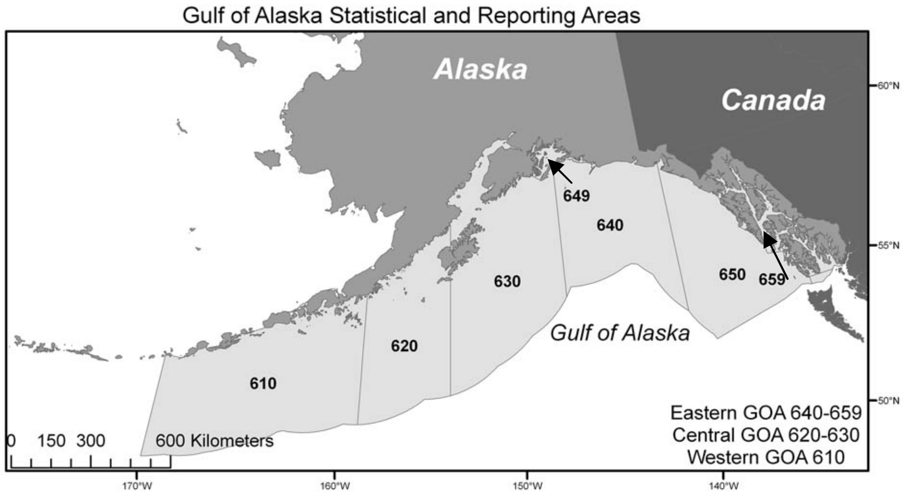

Figure 1. The statistical areas for NMFS observer data in the Gulf of Alaska.

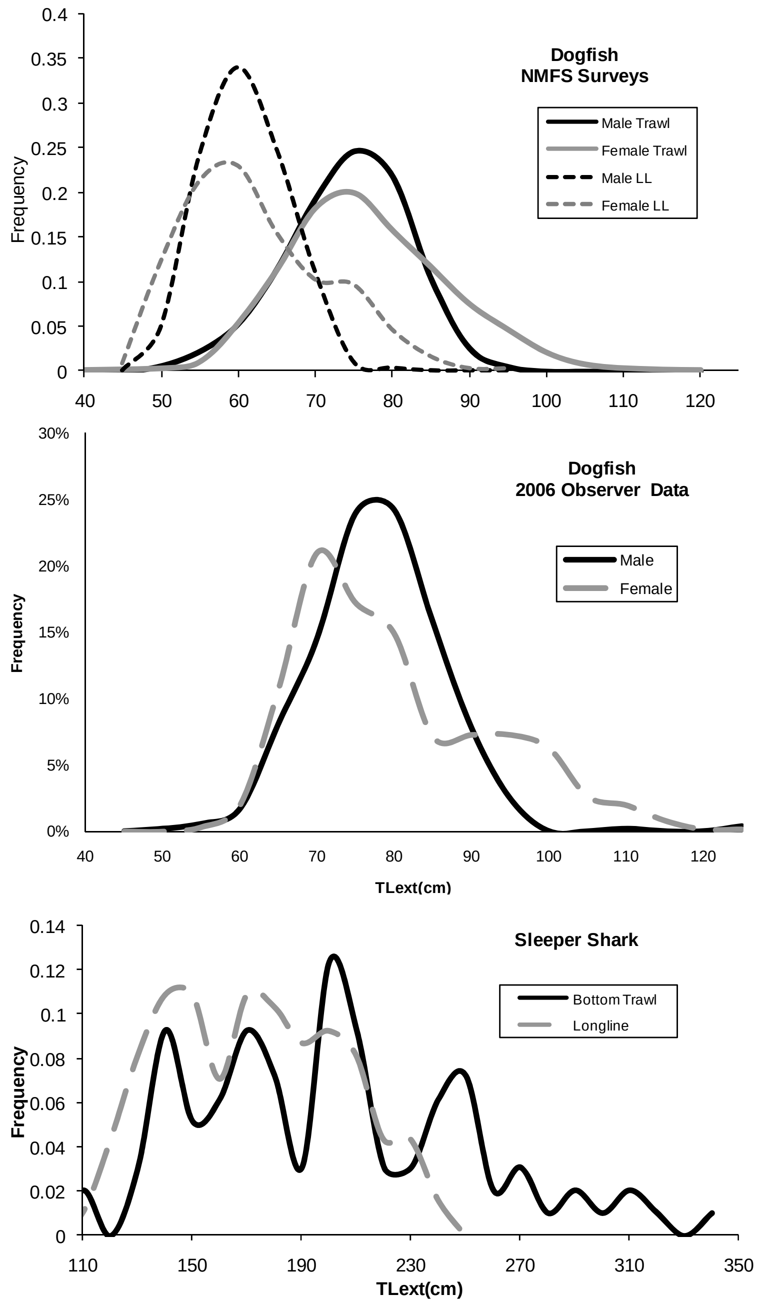

Figure 2. Observed length frequencies for spiny dogfish from (top) the most recent NMFS trawl and longline surveys, and (center) for a special project with the observer program in 2006 and for Pacific sleeper shark (bottom) from all years of the NMFS trawl survey and a targeted longline survey in 2001 near Kodiak Island.

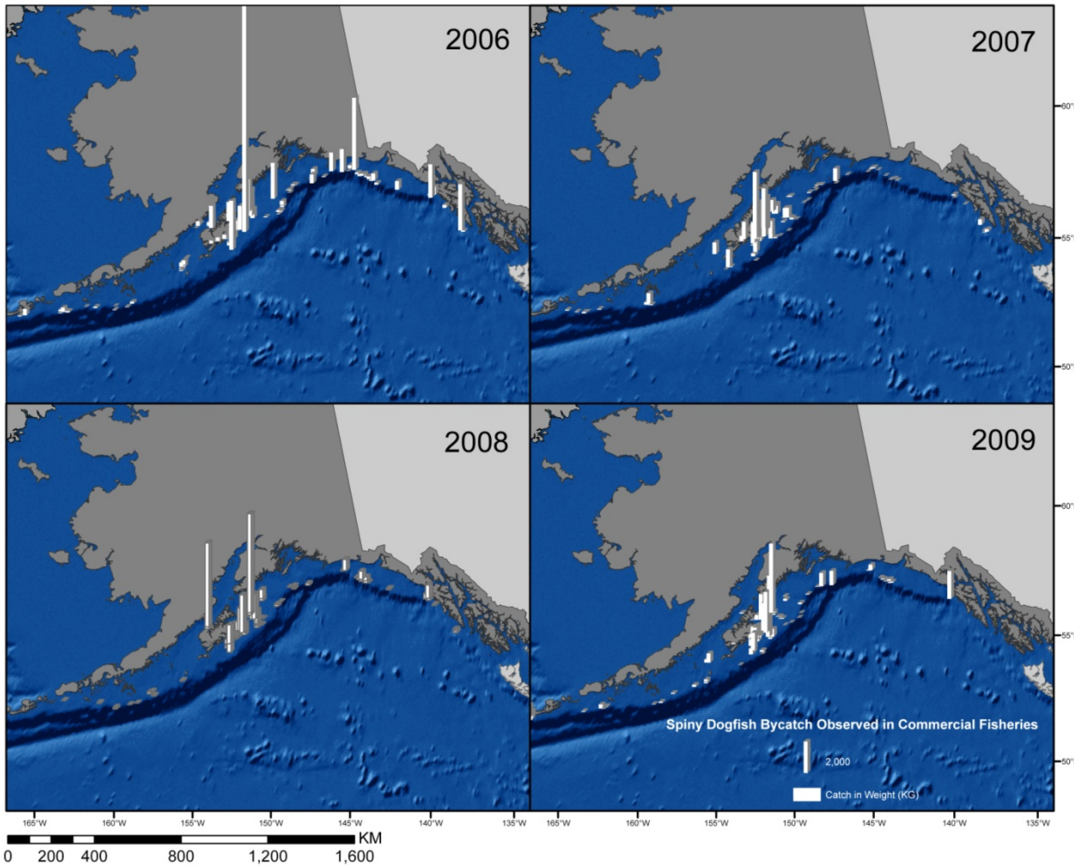

Figure 3. Spatial distribution of observed spiny dogfish catch in the GOA from 2006 – 2009 (all gear types). Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 100km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 15, 2010 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

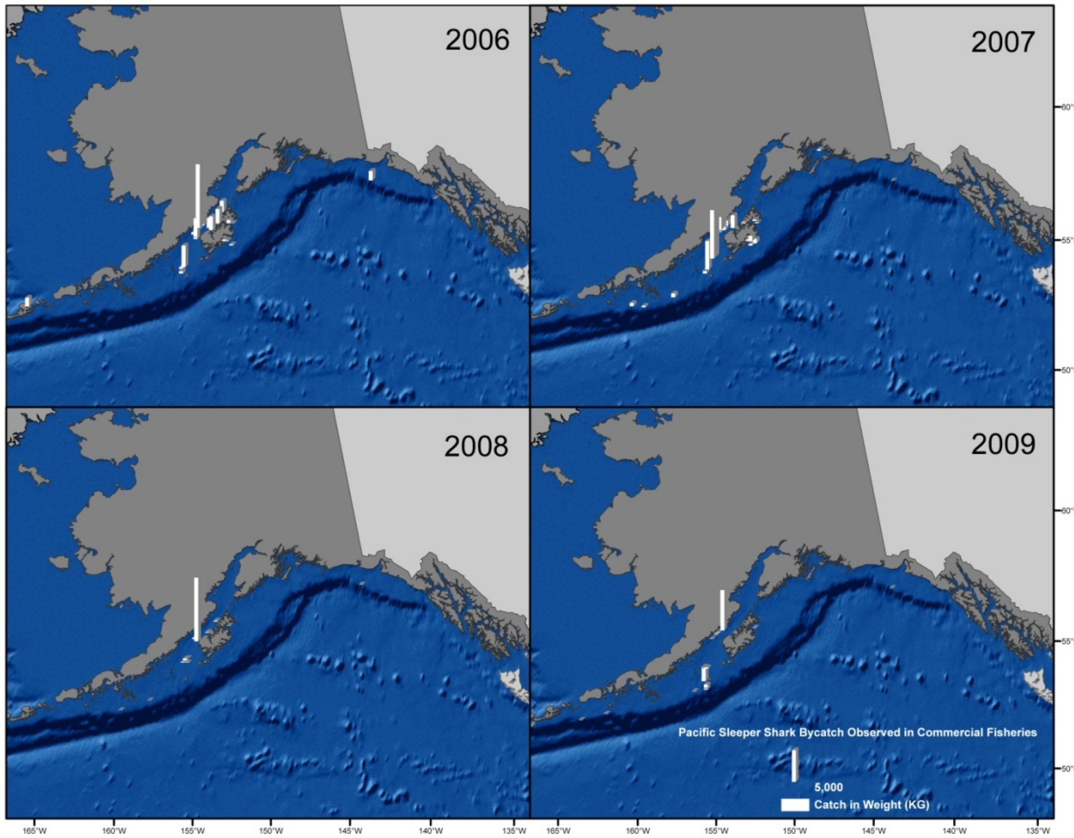

Figure 4. Spatial distribution of observed Pacific sleeper shark catch in the GOA from 2006 - 2009. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 100km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 15, 2010 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

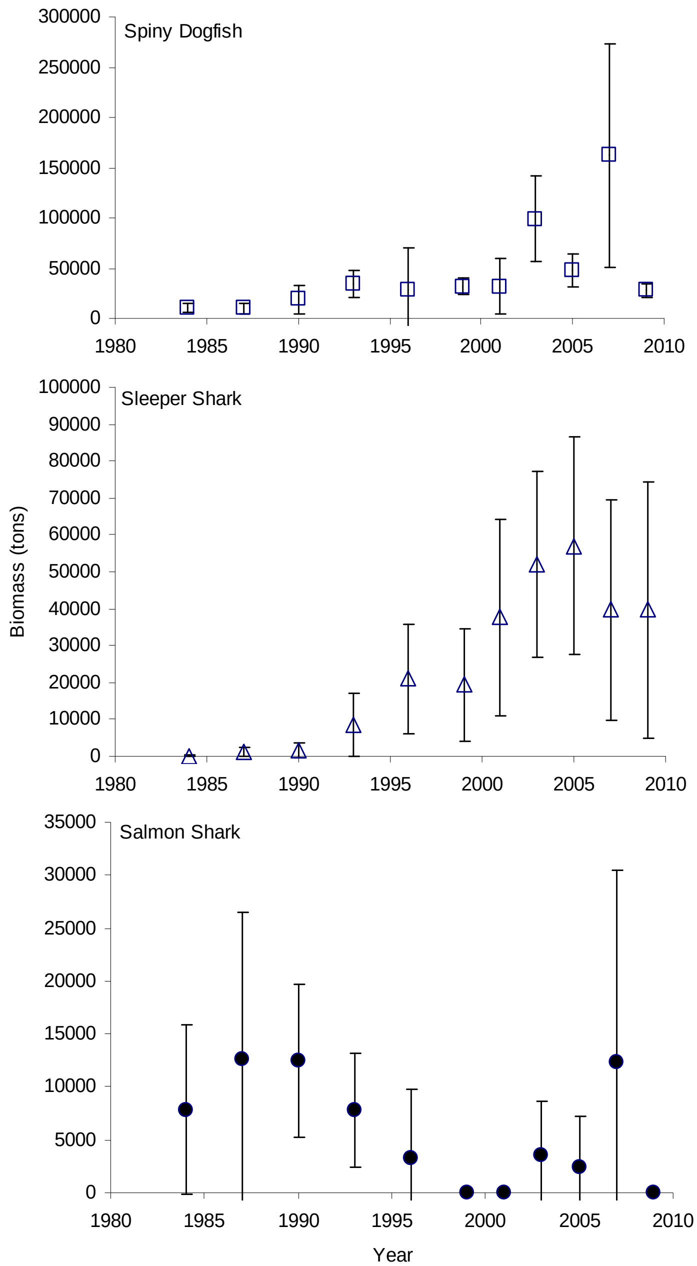

Figure 5. Trends in Gulf of Alaska (GOA) AFSC bottom trawl survey estimates of individual shark species total biomass (t) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of GOA biomass trends are subject to the following caveats regarding the consistency 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.

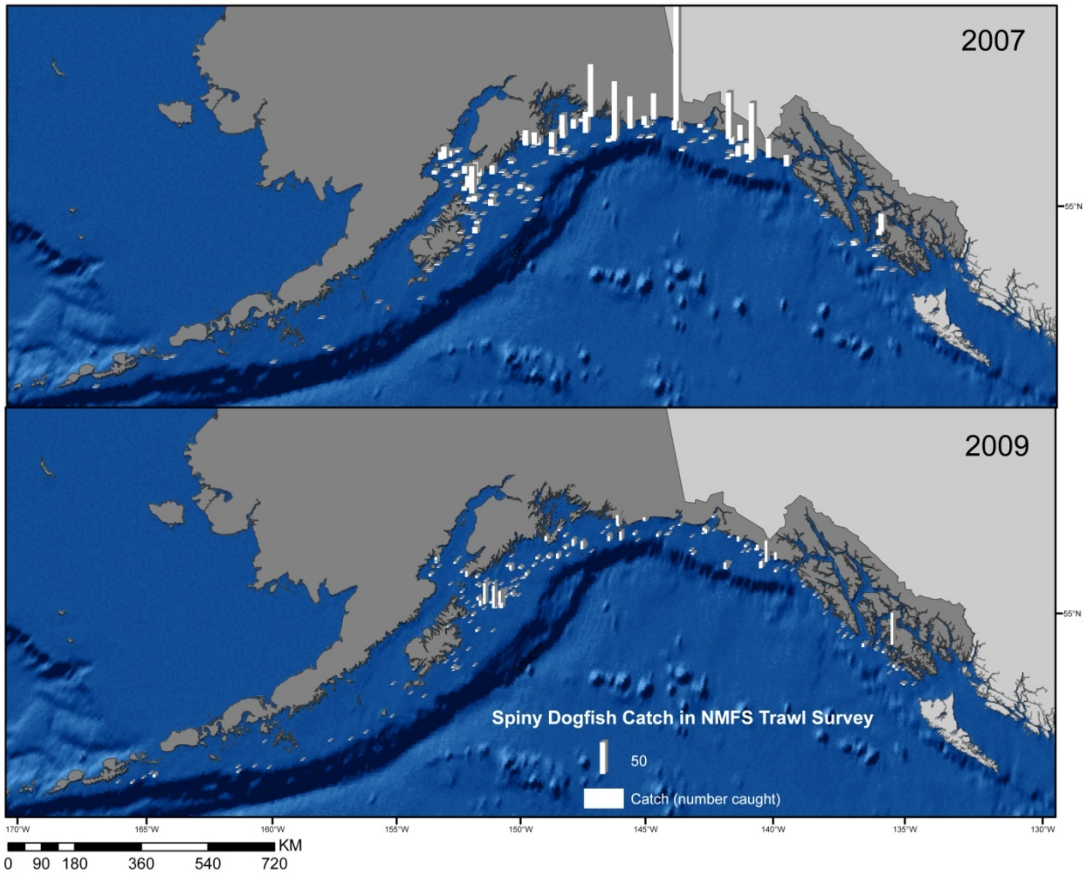

Figure 6. Spatial distribution of the catch of spiny dogfish during the 2007 and 2009 NMFS biennial trawl survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

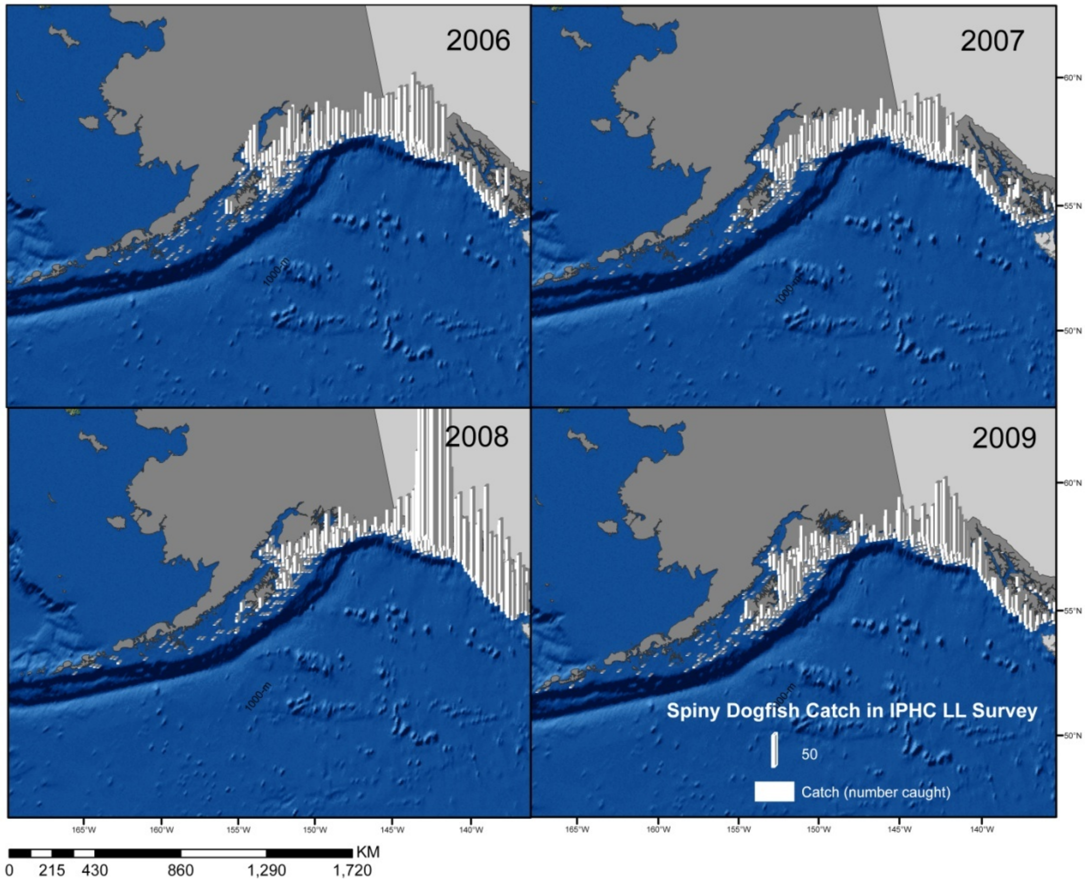

Figure 7. Spatial distribution of the catch of spiny dogfish during the 2006 - 2009 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

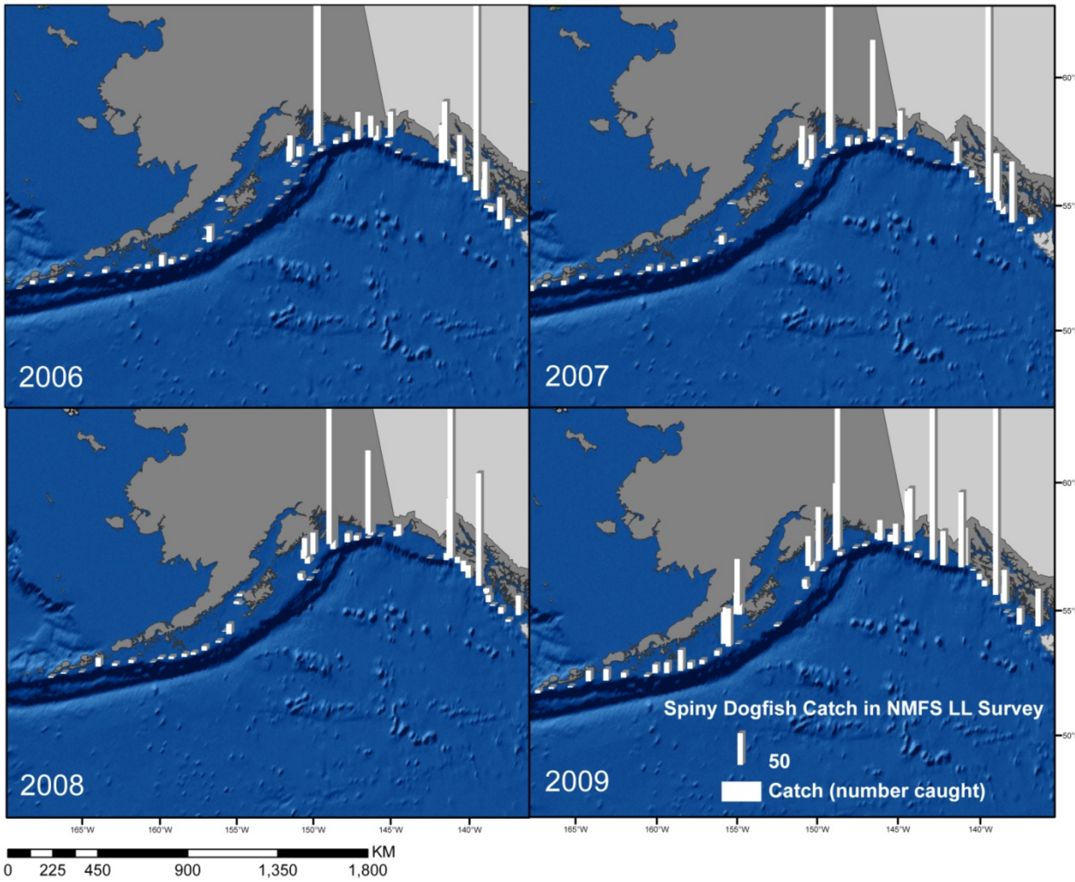

Figure 8. Spatial distribution of the catch of spiny dogfish during the 2006 - 2009 NMFS longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

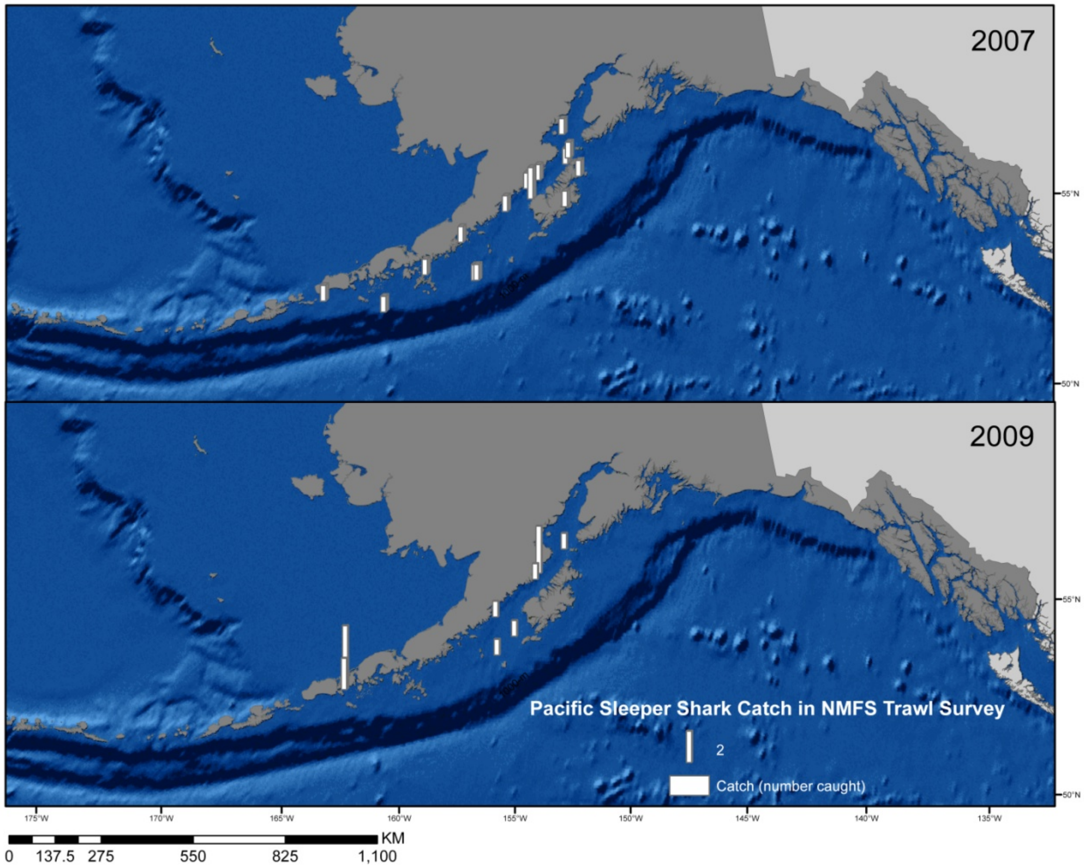

Figure 9. Spatial distribution of the catch of Pacific sleeper shark during the 2007 and 2009 NMFS biennial trawl survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

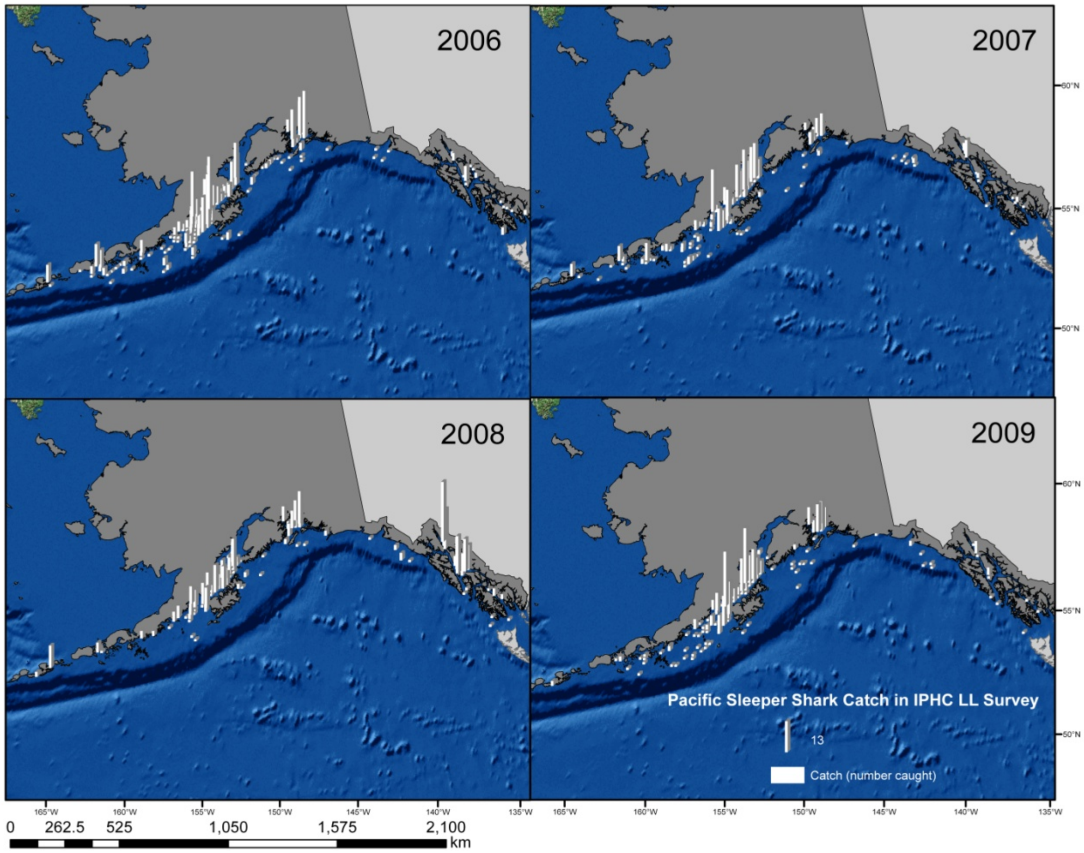

Figure 10. Spatial distribution of the catch of Pacific sleeper shark during the 2006 - 2009 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

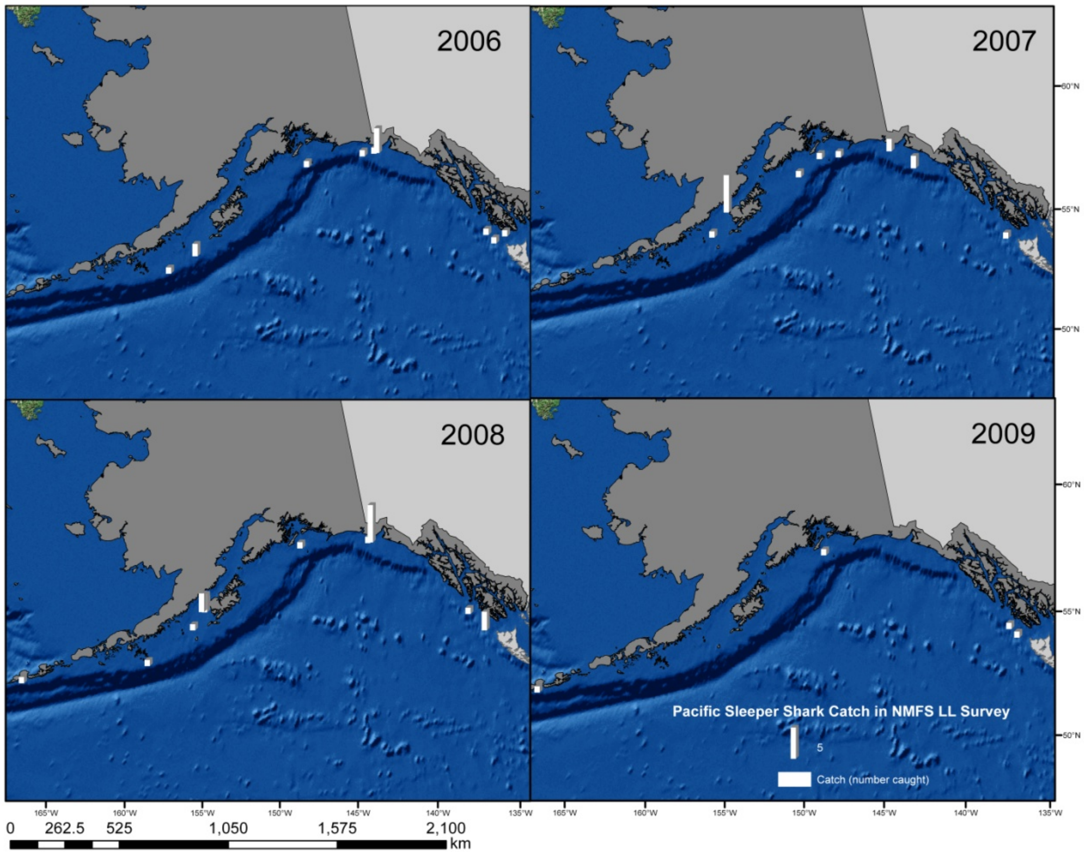

Figure 11. Spatial distribution of the catch of Pacific sleeper shark during the 2006 - 2009 NMFS longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

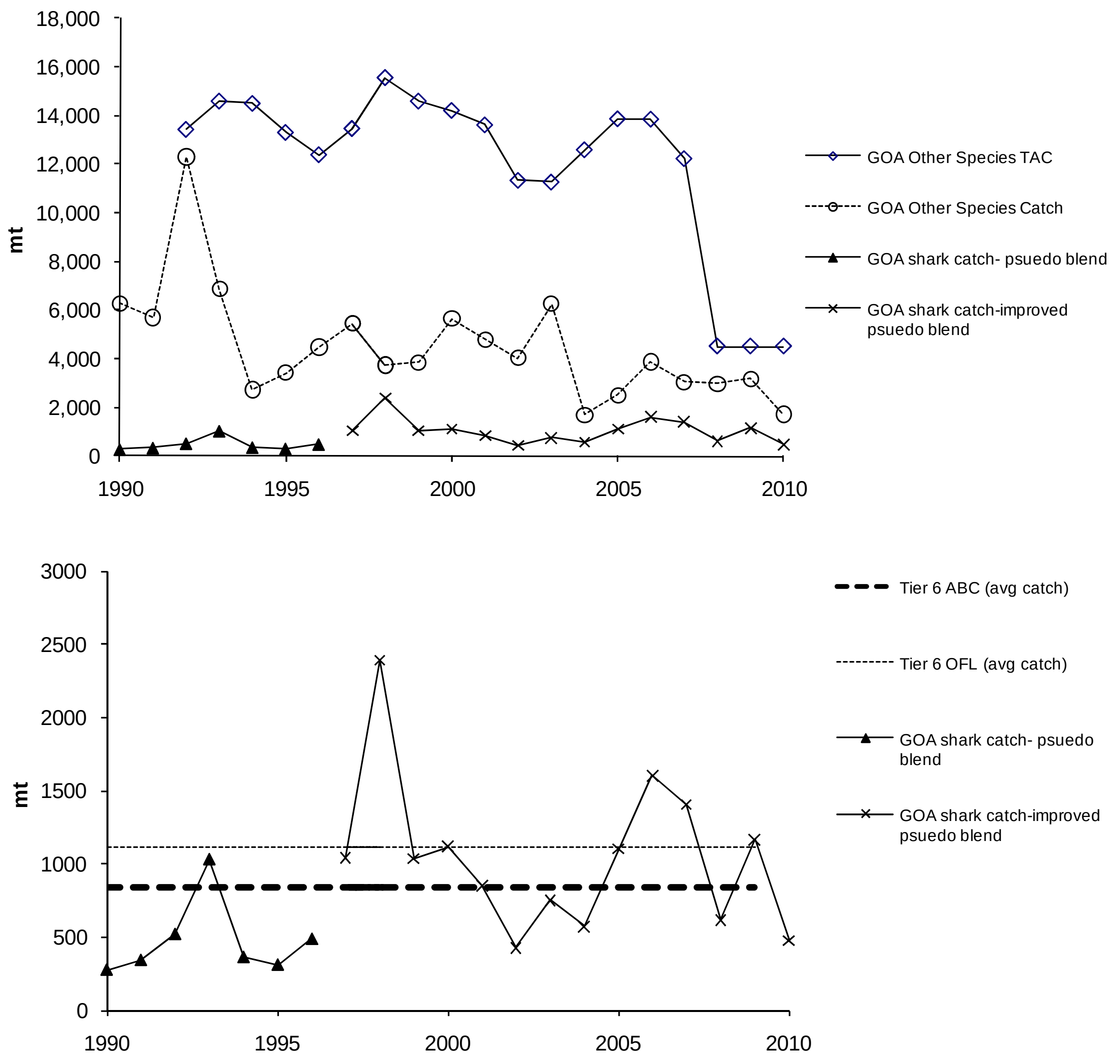

Figure 12 Top: comparison of total GOA shark catch relative to total Other Species catch and Other Species TAC. Bottom: total GOA shark catch per year plotted relative to 2010 ABC and OFL options for the GOA shark complex under Tier 6. Catch data updated as of October 10, 2010.