Appendix E

GOA Sharks

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EXECUTIVE SUMMARY

Summary of Major Changes

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

Input Data

Incidental catch for sharks by species in the GOA was updated for 2003 - 2006 with estimates provided by the NMFS Alaska Regional Office (AKRO - as of Oct 22, 2006). Previous incidental catch estimates were provided by NMFS AKRO for 2003 – 2005 and by Sarah Gaichas from her pseudo-blend estimates in two time series: one for the years 1990 – 1998, and the other for the years 1997-2001. Sarah's pseudo-blend estimates were updated here for 2002. GOA bottom trawl survey biomass data was updated for 2005. Previous trawl survey data were available from NMFS AFSC bottom trawl surveys conducted triennially and biannually in the GOA (1984 – 2003).

Assessment Methodology

An alternative Tier 6 option is provided based on the premise that the estimated incidental catch data from 1997 – 2005 can be considered a "known safe" level of fishing. Based on this premise, the maximum incidental catch over this period can be used to set the OFL for the shark complex. The ABC would represent 75% of the OFL. For long lived species such as Pacific sleeper sharks the premise that recent catch history is reflective of stock status may not be realistic. Nevertheless, this approach does allow continued fishing under historical patterns where sharks are not a target species, but will restrict catch rates for the complex from substantially increasing. The higher OFL provides a margin of error so that fisheries that take sharks as incidental catch would not be constrained unless catch rates increase well past current levels. Using this approach, the ABC for sharks would be 1,792 mt and the OFL would be 2,390 mt. The alternative

Tier 6 OFL is substantially higher than the average catch from 1997 – 2005 (1,005 mt) and higher than incidental catch in 2006 (1,615 mt). The alternative Tier 6 OFL is several times lower than the Tier 5 OFL estimates (8,575 mt).

Traditional Tier 6 and Tier 5 options are provided in the text and summarized below for consideration in the GOA with caveat that available data do not support either Tier 6 or Tier 5 criteria for establishing ABC and OFL for sharks in the GOA. Tier 6 criteria require a reliable catch history from 1978 – 1995, which do not exist for sharks in the GOA prior to 1997. The time series of incidental catch for sharks for the years 1997 – 2005 is considered the best available information on exploitation rates of shark species in the GOA and is used here to provide an approximate Tier 6 option for GOA shark ABC and OFL.

Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass which do not exist for sharks in the GOA as the efficiency of bottom trawl gear varies by species and is unknown. The biomass estimates presented here should be considered at best a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted. Average biomass from 1996 – 2006 is used here as the best available biomass estimate for sharks in the GOA. Tier 5 criteria also require reliable point estimates of natural mortality which do not exist for Pacific sleeper sharks or other/unidentified sharks. Natural mortality has recently been estimated for spiny dogfish in the Gulf of Alaska ($M = 0.097$, Appendix A), and this estimate is applied here to GOA spiny dogfish. This estimate ($M = 0.097$, Appendix A) is also applied to Pacific sleeper sharks for Tier 5. There is no biomass estimate for other/unidentified sharks and other/unidentified sharks are not included in Tier 5 calculations. Gulf of Alaska spiny dogfish natural mortality is considered a conservative estimate of natural mortality for Pacific sleeper sharks. However, Gulf of Alaska spiny dogfish natural mortality is likely not a reliable point estimate for natural mortality of these species.

A demographic analysis for eastern and western North Pacific salmon sharks is presented in Appendix B. The demographic analysis suggests that the salmon shark population in the eastern North Pacific (which includes the Gulf of Alaska) is stable at this time.

Alternative Tier 6 ABC and OFL Options

	Alternative Tier 6 Criteria GOA – Shark Complex	Alternative Tier 6 Options GOA – Sharks (mt)
ABC	0.75*Maximum catch (1997-2005)	1,792
OFL	Maximum catch (1997-2005)	2,390

Traditional Tier 6 ABC and OFL Options

	Traditional Tier 6 Criteria GOA – Shark Complex	Traditional Tier 6 Options GOA – Sharks (mt)
ABC	0.75*Average catch (1997-2005)	754
OFL	Average catch (1997-2005)	1,005

Traditional Tier 5 ABC and OFL Options

	Traditional Tier 5 Criteria GOA – Shark Complex	Tier 5 GOA – Shark Complex
ABC	0.75*M*Average biomass (1996 – 2005)	6,431
OFL	M*Average biomass (1996 – 2005)	8,575

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

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

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

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

Response
Time constraints on the authors limited analysis to the biological assessment. The authors did make contact with the AKRO regarding potential markets for shark species. However,

it quickly became apparent that a basic knowledge of economics was required to ask meaningful questions regarding "potential markets for these species," and that a biological assessment might not be the best place for an economic analysis.

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

Response

The 1979 – 2005 time series of shark bycatch established for the February 2006 SSC presentation is considered the best available data for estimating exploitation rates for shark species in the GOA and was used again here to recommend a Tier 6 option for ABC and OFL for sharks (as a complex and as individual species).

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

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

Response

Analysis is ongoing to estimate shark bycatch from IPHC halibut fisheries in the GOA and preliminary results are presented (Appendix-D).

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

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

Response

A natural mortality estimate (0.097) for spiny dogfish in the Gulf of Alaska is included in Appendix A and was used for spiny dogfish and Pacific sleeper shark.

"The author noted that the biomass estimates for sharks are uncertain and variable. Salmon sharks are highly migratory and potential seasonal residents in the GOA and BSAI. Current biomass estimates do not suggest evidence of a conservation concern for the GOA stocks.

Biomass trends are stable. The SSC encourages using the longline survey data for biomass estimates. Also, the SSC requests that authors include the coefficient of variation in the survey."

Response
Weng et al. (2005) show that while some salmon sharks embarked on migrations to subtropical waters in winter, others remained in GOA waters (over-wintering). Analysis is ongoing to estimate Pacific sleeper shark and Spiny dogfish bycatch in the domestic sablefish longline survey (Appendix E). Salmon shark are not encountered in large numbers in the domestic sablefish longline survey and are not included in the analysis.

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

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

1 INTRODUCTION

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

1.2 General Distribution

Spiny Dogfish

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

Pacific Sleeper Shark

Little information is available for Pacific sleeper shark distribution, although they are considered common in boreal and temperate regions of shelf and slope waters of the North Pacific. Sleeper sharks are also thought to be found in relatively shallow waters at higher latitudes and in deeper habitats in temperate waters.

Salmon Shark

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

1.3 Management Units

There are no directed fisheries for sharks in the GOA, but some incidental catch of sharks results from directed fisheries for commercial species. Sharks are currently managed in aggregate as part of the "Other Species" complex in the GOA Fishery Management Plan (FMP) (Gaichas et al. 1999, Gaichas 2003). The Other Species complex includes sculpins, **sharks**, squid, and octopus. Skates were separated from the GOA Other Species complex in 2003 (Gaichas et al. 2003). Other Species are considered ecologically important and may have future economic potential. An aggregate annual quota limits Other Species catch in the GOA. The TAC for the GOA Other Species complex is set in aggregate at less than or equal to 5% of the sum of the TAC's of managed GOA species.

1.4 Evidence of Stock Structure

Spiny Dogfish

During the years 2004 – 2006 scientists from the Auke Bay Laboratory have deployed 100 electronic archival tags, 617 numerical tags, and one satellite popup tag on spiny dogfish in Yakutat Bay, Alaska. Data from tag recoveries will provide insights into the seasonal residency and movement patterns of spiny dogfish in Yakutat Bay and the northeast Pacific Ocean.

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 don't mix (Compagno 1984, McFarlane and King 2003). In some areas, dogfish form large feeding aggregations, segregated by size, sex, and maturity stage. Male dogfish are generally found in shallower water than females, except for pregnant females that enter shallow bays to pup.

Pacific Sleeper Sharks

In August 2001 and May 2002, scientists from the Auke Bay Laboratory collected data on the vertical and geographic movement of sleeper sharks in the Gulf of Alaska with electronic and numerical tagging (Hulbert et al. 2006). Thirty-three sleeper sharks were tagged with archival satellite tags designed to transmit depth data and location to polar orbiting Argos satellites. Data from 25 satellite tags have been recovered. Based on tag endpoint locations, the sharks typically moved less than 100 kilometers from the release locations. Archived depth data showed some sleeper sharks regularly ascended and descended at rates over 200 meters per hour and sometimes came to the surface at night.

During the summers of 2003 – 2006, scientists from the Auke Bay Laboratory deployed 91 electronic archival tags, 24 acoustic tags, and 8 satellite popup tags on Pacific sleeper sharks in the upper Chatham Strait region of Southeast Alaska. The recovery of temperature, depth, and movement data from the electronic archival and acoustic tags will aid in the identification of Pacific sleeper shark habitat utilization and distribution in Southeast Alaska and identify the potential for interactions between Pacific sleeper sharks and other species in this region.

Salmon Shark

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

In the WNP, a salmon shark pupping and nursery ground may exist just north of the transitional domain in oceanic waters. According to Nakano and Nagasawa (1996), larger juveniles than term (70-110 cm PCL) were caught in waters with SST's of 14^{o}-16^{o}C, with adults occurring in colder waters further north. Another pupping and nursery area may exist in the ENP and appears to range from southeast Alaska to northern Baja California, Mexico (Goldman and Musick in press, Goldman and Musick 2006).

During the summers of 1998–2001, scientists from the Auke Bay Laboratory investigated the movements of salmon sharks aggregating in Prince William Sound (PWS), Alaska (Hulbert et al. 2005). During the study, 246 salmon sharks were tagged with conventional (spaghetti) tags and 16 salmon sharks with satellite transmitters. Movement data from satellite tag transmissions and conventional tag recoveries provided insights into the seasonal residency and movement patterns of salmon sharks in PWS and the northeast Pacific Ocean. Observations suggest salmon sharks were attracted by Pacific salmon (*Oncorhynchus spp*.) runs returning to the streams and hatcheries in PWS during summer months. In PWS, large salmon shark aggregations peaked with salmon spawning migrations during July and August. As the summer salmon runs declined in late summer, the sharks dispersed. Some continued to forage in PWS and the Gulf of Alaska into autumn and winter months, while others underwent rapid migrations hundreds to thousands of kilometers toward the west coasts of Canada and the United States. Fifty percent of the sharks tracked by this study traveled long distances. Weng et al (2005) show that while some salmon sharks embarked on migrations to subtropical waters in winter, others remained in GOA waters (over-wintering).

1.5 Life History Information

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

Spiny Dogfish

Eastern North Pacific spiny dogfish grow to a relatively large maximum size of 1.6 m (Compagno 1984). British Columbia female spiny dogfish are reported to mature at 35 years, and males at 19 (Beamish and McFarlane 1985, McFarlane and Beamish 1987). Historic estimates of the age at 50% maturity for the eastern North Pacific range from 20 to 34 years. Ages from the spines of oxytetracycline-injected animals provided validation of an age-length relationship and corroborated that 50% sexual maturity for females occurs at 35.3 years of age and 50% size at maturity is 93.9 (cm) (Saunders and McFarlane 1993). The same study suggested that longevity in the eastern North Pacific is between 80 and 100 years and stated that several earlier published ages at maturity (and therefore longevity) were low due to the rejection of difficult to read spines and the grouping of annuli that were very close together.

The mode of reproduction in spiny dogfish is aplacental viviparity with gestation periods of 18-24 months. The majority of biological knowledge of spiny dogfish is based on field studies conducted on North Atlantic and European stocks and controlled laboratory experiments (Tsang and Callard 1987, da Silva and Ross 1993, Polat and Guemes 1995, Rago et al. 1998, Koob and Callard 1999, Jones and Ugland 2001, Soldat 2002, Stenberg

2002). Little research has been conducted in the North Pacific outside of British Columbia. Ketchen (1972) reported timing of parturition in BC to be October through December, and in the Sea of Japan it was reported to occur between February and April (Yamamoto and Kibezaki 1950, Sato and Inukai 1934, Anon 1956, Kaganovskaia 1937). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio 2004). Pupping has been reported to occur in estuaries and bays (Richards 2004) and in mid-water over depths of about 90-200 fm (Ketchen 1986). The average litter size is 6.9 pups for spiny dogfish in Puget Sound, WA (Tribuzio 2004) and 6.2 for BC (Ketchen 1972). The number of pups per female also increases with the size of the female, with estimates ranging from 0.20 – 0.25 more pups for every centimeter in female length from the onset of maturity (Ketchen 1972, Richards 2004, Tribuzio 2004). Immature juveniles tend to inhabit the water column near the surface and are not available to the targeted fishery until they mature and descend to the benthos (Beamish et al. 1982).

Pacific Sleeper Sharks

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

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

Salmon Sharks

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

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage (Tanaka 1986 cited in Nagasawa 1998). Litter size in the western Pacific is four to five pups, and litters have been reported to be male dominated 2.2:1

(Nagasawa 1998), but this is from a very limited sample size. The number of pups and sex ratio of eastern North Pacific litters is currently unknown. Gestation times throughout the North Pacific appear to be nine months, with mating occurring during the late summer and early fall and parturition occurring in the spring (Tanaka 1986, Nagasawa 1998, Goldman 2002-b, Goldman and Human 2004, Goldman and Musick 2006). Size at parturition is between 60-65 cm PCL in both the ENP and WNP (Tanaka 1980, Goldman 2002-b, Goldman and Musick 2006).

2 FISHERY

2.1 Directed Fishery

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. However, some deliveries of spiny dogfish captured in federal waters have also been made to Kodiak in 2004 and 2005. There is, however, a Commissioners Permit fishery for spiny dogfish in lower Cook Inlet, but only one application have been received to date. Spiny dogfish are also allowed as retained incidental catch in some ADF&G managed fisheries with some landings reported in Yakutat for 2005 and 2006. Salmon sharks are targeted by sport fishermen in Alaska state waters (Appendix D).

2.2 Bycatch, Discards, and Historical Catches

Historical catches of sharks in the GOA are composed entirely of incidental catch, and nearly all shark catch is discarded. Mortality rates of discarded catch are unknown, but are conservatively estimated in this report as 100%. Aggregate incidental catches of the Other Species management category from federally prosecuted fisheries for Alaskan groundfish in the GOA are tracked in-season by the NMFS AKRO (Table 2). Other Species reported catches have been relatively small each year since 1977 in the GOA (e.g., in 2001 Other Species catches of 25,482 tons made up 1.5% of the 1,652,802 ton total BSAI catch).

Incidental catch of elasmobranch in Pacific halibut fisheries may be under reported (Gaichas et al. 2005). An estimate of incidental shark catch in the unobserved GOA Pacific halibut fisheries is ongoing and preliminary results for the years 1997 – 2004 are presented in Appendix D.

3 DATA

Source	Data	Years
NMFS Observer Program – (AKRO)	Non-target catch	2003 – 2006
NMFS Observer Program – (AFSC) Improved Pseudo Blend	Non-target catch	1997 – 2002
NMFS Observer Program – (AFSC) Pseudo Blend	Non-target catch	1990 – 1998
NMFS Bottom Trawl Surveys – GOA	Biomass Index	1984 – 2005

3.1 Incidental Catch

This report summarizes incidental shark catches by species as three data time series: 1990 – 1998, 1997 – 2002, and 2003 - 2006. Sharks have been reported by species at the NMFS AKRO since 2003. Prior to 2003, shark catches by species were estimated by staff at the AFSC. Two methods were used, one for the years 1997 – 2002 and the other for years 1990 – 1998. The 1990 – 1998 time series is not directly comparable with later years because different methods were used to estimate incidental catch.

For the years 1990 – 1998, annual Other Species catches of sharks by species were estimated by the AFSC using data reported by fishery observers (Gaichas et al. 1999) using the following method: each year's observed catch by species group was summed within statistical area, gear type, and target fishery. The ratio of observed Other Species group catch to observed target species catch was multiplied by the Regional Office blend-estimated target species catch within that area, gear, and target fishery (Table 3). Other Species annual total catches estimated in this manner were generally lower than Regional Office reported catches of Other Species due to both targeting assignment discrepancies and gear strata with no observer coverage (i.e., jig gear fisheries, Gaichas et al. 1999). Direct application of this method to estimate Other Species catches using foreign and joint venture observer data is not possible due to differences in database structure. Consequently, incidental catches for sharks by species are not available prior to the beginning of the domestic observer program in 1990.

Using the Gaichas et al. (1999) pseudo-blend estimates from 1990 – 1998 in the GOA, spiny dogfish composed 49% of total shark catch, Pacific sleeper sharks 19%, salmon sharks 12%, and unidentified sharks 18%, and Blue, sixgill, and brown cat sharks were rarely identified in catches (Table 3).

For the years 1997 – 2002, Gaichas (2001, 2002) used a new pseudo-blend method to estimate species group catches, and catches by species for sharks within the Other Species complex in the GOA for 1997-2002 (and updated here for 2002). In the new pseudo-blend method, target fisheries were assigned to each vessel / gear / management area / week combination based upon retained catch of allocated species, according to the same algorithm used by the NMFS Alaska Regional Office. Observed catches of other species (as well as forage and non-specified species) were then summed for each year by target fishery, gear type, and management area. The ratio of observed Other Species group catch to observed target species catch was multiplied by the Regional Office blend-estimated target species catch within that area, gear, and target fishery (Table 4). This method more closely matched the Regional Office blend catch estimation system and is therefore considered more accurate and an improvement over the previous pseudo-blend method. However, because the pseudo-blend catch estimates from Gaichas et al. (1999) and Gaichas (2001, 2002) were not identical (e.g., compare years 1997 and 1998 in Tables 3 and 4), the time series 1990 – 1996 and 1997 – 2002 are presented separately and are not comparable.

Incidental catch for sharks by species in the GOA was updated for 2003 through 2006 with estimates provided directly by the NMFS Alaska Regional Office using methods similar to Gaichas (2001, 2002) Table 4. The time series of incidental catch for sharks for the years 1997 – 2005 was presented in February, 2006 to the North Pacific Fishery Management Council, Scientific and Statistical Committee. The time series of catch for the years 1997 – 2005 is considered the best available information on exploitation rates of shark species in the GOA and is used again here to provide an approximate Tier 6 option for GOA shark ABC and OFL.

From 1997 – 2006, shark catches composed from 19% to 63% of the estimated Other Species total catches. Spiny dogfish composed 48% of total shark catch, Pacific sleeper sharks 28%, unidentified sharks 18%, and salmon sharks 6% (Table 4). Blue sharks, sixgill sharks, and brown cat sharks were rarely identified in catches and were included with unidentified sharks (Table 4).

The majority of vessels fishing in the GOA are smaller vessels subject to 30% observer coverage, although some target fisheries (i.e. rockfish) are prosecuted by larger vessels with 100% observer coverage. Therefore, in making these catch estimates, we are assuming that Other Species catch aboard observed vessels is representative of Other Species catch aboard unobserved vessels throughout the GOA.

From 1990 – 1996 in the GOA pseudo-blend estimates (Gaichas et al. 1999), spiny dogfish were caught primarily in the flatfish trawl (35%), sablefish longline (23%), and pollock trawl (18%) fisheries in NMFS statistical and reporting area 630 (83%, Tables 5 and 13, Figure 1). Pacific sleeper sharks were caught primarily in the pollock trawl (52%) and sablefish longline (21%) fisheries in areas 630 (43%), 620 (38%), and 610 (11%, Tables 7 and 15, Figure 2). Salmon sharks were caught primarily with pollock trawl (85%) in areas 630 (49%), 620 (41%), and 610 (9%, Tables 9 and 17, Figure 3). Incidental catches of other and unidentified shark species were rare in the GOA from 1990 –1996 (Tables 11 and 19).

Based on the 1997 – 2002 GOA improved pseudo-blend estimates (Gaichas 2001, 2002), spiny dogfish were caught primarily in the Pacific cod longline and trawl (42%), sablefish longline (20%), flatfish trawl (18%), and rockfish longline (17%) fisheries in areas 630 (45%), 640 (29%), and 650 (22%, Tables 6 and 14, Figure 1). Pacific sleeper sharks were caught primarily in the Pacific cod longline (61%) and pollock trawl (25%) fisheries in areas 630 (60%), 620 (23%), and 610 (14%, Tables 8 and 16, Figure 2). Salmon sharks were caught primarily in the pollock trawl (66%) fisheries in areas 630 (55%), 620 (25%), and 610 (16%, Tables 10 and 18, Figure 3). Incidental catches of other and unidentified shark species were rare in the GOA except for a large catch in 1998 taken with sablefish longline gear in area 659 (Tables 12 and 20).

3.2 Survey Biomass Estimates

NMFS AFSC bottom trawl survey biomass estimates are available for shark species in the GOA (1984 – 2005). Where available, individual species biomass trends were evaluated for the three most commonly encountered shark species (spiny dogfish, Pacific sleeper shark, and salmon shark). Sharks may not be well sampled by bottom trawl surveys (as evidenced by the high uncertainty in many of the biomass estimates). The efficiency of bottom trawl gear also varies by species, and trends in these biomass estimates should be considered, at best, a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted. In particular, pelagic shark species such as salmon sharks are encountered by the trawl gear while it is not in contact with the bottom, either on the way down or on the way up. Biomass estimates are based, in part, on the amount of time the net spends in contact with the bottom. Consequently, bottom trawl survey biomass estimates for pelagic species are unreliable. Spiny dogfish are patchily distributed, and their distribution may vary seasonally, both geographically and within the water column. This can result in highly uncertain biomass estimates. Pacific sleeper sharks are large animals and may be able to avoid the bottom trawl gear. In addition, biomass estimates for Pacific sleeper sharks are often based on a very small number of individual hauls within a given survey and a very small number of individual sharks within a haul. Consequently, these biomass estimates can be highly uncertain.

Analysis of GOA biomass trends is 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.

Data from the 1984 – 2005 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 2005 (Table 21, Figure 4). An independent analysis of NMFS AFSC bottom trawl surveys in the Gulf of Alaska found that Pacific sleeper shark abundance had significantly increased in the central Gulf of Alaska during 1984 - 1996 (Mueter and Norcross 2002). Salmon shark biomass has been stable to decreasing according to this survey, but salmon sharks are pelagic and unlikely to be well sampled by a bottom trawl. Both salmon shark and Pacific sleeper shark biomass estimates are also based on a very small number of individual hauls in a given survey (Table 21). No salmon sharks were encountered in either the 1999 or 2000 survey. Spiny dogfish were captured in a relatively large number of hauls each year. However, spiny dogfish distributions in the GOA water column are not well known and may affect biomass estimation. In particular, if spiny dogfish are caught off the bottom, then biomass estimates may be unreliable and should be considered at best a relative index of abundance and distribution. However, because spiny dogfish are captured in a large number of hauls each year, the NMFS AFSC bottom trawl surveys in the Gulf of Alaska may be useful for determining the relative proportion of spiny dogfish biomass by area in the Gulf of Alaska.

3.3 Parameters Estimated Independently

Parameters estimated independently are identified for the major shark species in the Gulf of Alaska (or North Pacific when Gulf of Alaska data are lacking): spiny dogfish, Pacific sleeper sharks, and salmon sharks. Data gaps are identified where data are not available (NA). An estimate of the natural mortality rate ($M = 0.097$) is derived for spiny dogfish in the Gulf of Alaska in Appendix - A. The value of M (0.097) for the Gulf of Alaska from Appendix A is comparable to the previously published estimate of M from British Columbia spiny dogfish of 0.094 (Wood et al. 1979). A range of natural mortality estimates is derived for salmon shark in the central Gulf of Alaska in Appendix - B. A natural mortality estimate is not available for Pacific sleeper sharks. Maximum reported age for central Gulf of Alaska salmon shark is 30 years (Goldman and Musick 2006). Maximum age of spiny dogfish in the eastern North Pacific is between 80 and 100 years (Beamish and McFarlane 1985, McFarlane and Beamish 1987). Age at first recruitment to a commercial fishery would be 5 years old for central Gulf of Alaska salmon sharks (Appendix – B). Maximum age and age of first recruitment are not available for spiny dogfish or Pacific sleeper shark. Ages are not currently available for Pacific sleeper shark as this species appears to be very difficult to age.

Species	Area	Mortality rate (M)	Maximum age	Age of first recruitment
Spiny dogfish	Gulf of Alaska	0.097	NA	NA
Spiny dogfish	Eastern North Pacific	0.094	80 – 100	NA
Pacific sleeper shark	NA	NA	NA	NA
Salmon shark	Central Gulf of Alaska	0.2550 to 0.0908	30	5

For Pacific spiny dogfish off of British Columbia, 50% sexual maturity for females occurs at 35.3 years of age and 50% size at maturity is 93.9 (cm) (Saunders and McFarlane 1993). Only one mature Pacific sleeper shark (12 feet, 3.7 m) has been recorded in the North Pacific (Gotshall and Jow, 1965).

Species	Area	Size at 50% maturity (cm)	Age at 50% maturity	Sample Size
Spiny dogfish	Eastern North Pacific	93.9	35.3	NA
Pacific sleeper shark	NA	NA	NA	NA
Salmon shark	NA	NA	NA	NA

Sharks appear to segregate by sex. Observed sex ratios are provided. A spiny dogfish sex ratio of about 1.5:1 (F:M) was observed during special projects on board NMFS sablefish longline surveys in the central Gulf of Alaska in 2004 - 2006, and on board NMFS GOA bottom trawl surveys in 2005 (Pers. Comm. Cindy Tribuzio, UAF). A sex ratio 1.5:1 (F:M) was estimated based upon NMFS longline studies of Pacific sleeper shark diet in the central Gulf of Alaska (Sigler et. al 2006). A sex ratio of 10.4:1 (F:M) was observed from the central Gulf of Alaska (primarily Prince William Sound) and reported in Goldman and Musick (2006).

Species	Area	Gear type	Sex ratio (F:M)	Sample size
Spiny dogfish	Gulf of Alaska	NMFS bottom trawl surveys	1.5:1	232
Pacific sleeper shark	Gulf of Alaska	NMFS bottom trawl surveys	NA	NA
Salmon shark	Gulf of Alaska	NMFS bottom trawl surveys	NA	NA
Spiny dogfish	Gulf of Alaska	Longline surveys	1.4:1	396
Pacific sleeper shark	Central Gulf of Alaska	Longline surveys	1.5:1	NA
Salmon shark	Central Gulf of Alaska	NA	10.4:1	NA

Length-weight coefficients are provided for the formula $W=aL^b$, where W = weight in kilograms and L = PCL (precaudal length in cm), for spiny dogfish, Pacific sleeper shark, and salmon shark. Length-weight coefficients for spiny dogfish are available from special projects on board NMFS sablefish longline surveys in the central Gulf of Alaska in 2004 - 2006, and on board NMFS GOA bottom trawl surveys in 2005 (Pers. Comm. Cindy Tribuzio, UAF); for Pacific sleeper sharks in the central Gulf of Alaska longline studies from Sigler et al (2006); and for central Gulf of Alaska salmon sharks from Goldman and Musick (2006).

Species	Area	Gear type	Sex	a	b	Sample size
Spiny dogfish	Gulf of Alaska	NMFS bottom trawl surveys	M	1.40E-05	2.86	92
Spiny dogfish	Gulf of Alaska	NMFS bottom trawl surveys	F	8.03E-06	3.02	140
Spiny dogfish	Gulf of Alaska	Longline surveys	M	9.85E-06	2.93	156
Spiny dogfish	Gulf of Alaska	Longline surveys	F	3.52E-06	3.20	188
Pacific sleeper shark	Central Gulf of Alaska	Longline surveys	M	2.18E-05	2.93	NA
Pacific sleeper shark	Central Gulf of Alaska	Longline surveys	F	2.18E-05	2.93	NA
Salmon shark	Central Gulf of Alaska	NA	M	3.20E-06	3.383	NA
Salmon shark	Central Gulf of Alaska	NA	F	8.20E-05	2.759	NA

Average length PCL are provided for spiny dogfish, Pacific sleeper shark, and salmon shark. Average lengths for spiny dogfish are available from special projects on board NMFS sablefish longline surveys in the central Gulf of Alaska in 2004 - 2006, and on board NMFS GOA bottom trawl surveys in 2005 (Pers. Comm. Cindy Tribuzio, UAF); for Pacific sleeper sharks in the central Gulf of Alaska longline studies from Sigler et al (2005); and for central Gulf of Alaska salmon sharks from Goldman and Musick (2006). Average weight was computed at average length (PCL) from the weight-at-length relationships above by species, gear type and sex.

Species	Area	Gear type	Sex	Average size PCL (cm)	Average weight (kg)	Sample size
Spiny dogfish	Gulf of Alaska	NMFS bottom trawl surveys	M	63.4	2.00	92
Spiny dogfish	Gulf of Alaska	NMFS bottom trawl surveys	F	63.8	2.29	140
Spiny dogfish	Gulf of Alaska	Longline surveys	M	64.6	1.99	156
Spiny dogfish	Gulf of Alaska	Longline surveys	F	64.7	2.20	188
Pacific sleeper shark	Central Gulf of Alaska	Longline surveys	M	166	69.7	NA
Pacific sleeper shark	Central Gulf of Alaska	Longline surveys	F	170	74.8	NA
Salmon shark	Central Gulf of Alaska	NA	M	171.9	116.7	NA
Salmon shark	Central Gulf of Alaska	NA	F	184.7	146.9	NA

4 ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Demographic Approach for Salmon Sharks

A demographic analysis of salmon sharks in the North Pacific is presented in Appendix B for consideration by the Plan Teams and SSC. Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific (WNP) and the eastern North Pacific (ENP) separated by the longitude of 180^{o} (Goldman and Musick 2006) and were analyzed separately. Natural mortality was estimated from six methods and ranged from 0.2550 to 0.0908 for salmon sharks in the ENP (which includes the Gulf of Alaska) and from 0.2089 to 0.0968 for the WNP (Goldman 2002-b). The range of natural mortality estimates was incorporated into the demographic models as survivorship probability distributions. Results of the demographic analysis suggest that salmon shark populations in the ENP (including the Gulf of Alaska) and WNP are likely stable at this time (Appendix – B, Goldman 2002-b).

Alternative Tier 6 Option

An alternative Tier 6 option is provided based on the premise that the estimated incidental catch data be considered a “known safe” level of fishing. Based on this premise, the maximum incidental catch over this period can be used to set the OFL for the shark complex. The ABC would represent 75% of the OFL. For long lived species such as Pacific sleeper sharks the premise that recent catch history is reflective of stock status may not be realistic. Nevertheless, this approach does allow continued fishing under historical patterns where sharks are not a target species, but will restrict catch rates for the complex from substantially increasing. The higher OFL provides a margin of error so that fisheries that take sharks as incidental catch would not be constrained unless catch rates increase well past current levels. Using this approach, the ABC for sharks would be 1,792 mt and the OFL would be 2,390 mt. The alternative Tier 6 OFL is double higher than the average catch from 1997 – 2005 (1,005 mt) and higher than incidental catch in 2006 (1,615 mt). The alternative Tier 6 OFL is several times lower than the Tier 5 OFL estimates (8,575 mt).

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

Alternative GOA Tier 6 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Unidentified shark	**Total sharks**
Maximum catch (1997-2005)	1,324	608	132	1,380	2,390
ABC	993	456	99	1035	**1,792**
OFL	1324	608	132	1380	**2,390**

Traditional Tier 6 and Tier 5 Options

Traditional Tier 6 and Tier 5 options are also provided for consideration in the GOA with the caveats that available data do not support either Tier 6 or Tier 5 criteria for establishing ABC and OFL for sharks in the GOA. Tier 6 criteria require a reliable catch history from 1978 – 1995, which does not exist for sharks in the GOA prior to 1997. Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass which do not exist for sharks in the GOA as the efficiency of bottom trawl gear varies by species. The biomass estimates presented here should be considered at best a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted. Tier 5 criteria also require reliable point estimates of natural mortality which do not exist for Pacific sleeper sharks or other/unidentified sharks. Natural mortality has recently been estimated for spiny dogfish in the Gulf of Alaska (M = 0.097, Appendix A), and this estimate is applied here to GOA spiny dogfish and Pacific sleeper sharks. Gulf of Alaska spiny dogfish natural mortality is considered a conservative estimate of natural mortality for Pacific sleeper sharks, because Pacific sleeper sharks are assumed to be a long lived slow growing species similar to spiny dogfish. However, Gulf of Alaska spiny dogfish natural mortality may not be a reliable point estimate of natural mortality for Pacific sleeper shark. There is no biomass estimate for other/unidentified sharks and other/unidentified sharks are not included in Tier 5 calculations.

Tier 6

Tier 6 options for GOA shark ABC and OFL are presented both for the individual species and for sharks as a complex. The time series of incidental catch for sharks for the years 1997 – 2005 is considered the best available information on exploitation rates of shark species in the GOA and is used here to provide an approximate Tier 6 option for GOA shark ABC and OFL. If Tier 6 is adopted, then the Tier 6 option for sharks as a complex after the removal of spiny dogfish may be a practical alternative for establishing ABC and OFL. After removal of spiny dogfish, Pacific sleeper sharks dominate the remainder of the catch and may serve as an indicator species for the GOA shark complex. Catches of other shark species in the GOA are rare and consequently catch estimation for other shark species is unreliable.

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

Traditional GOA Tier 6 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Unidentified shark	**Total shark complex**
Average catch (1997-2005) [1]	422	313	63	208	**1,005**
ABC	316	235	47	156	**754**
OFL	422	313	63	208	**1,005**

Tier 5

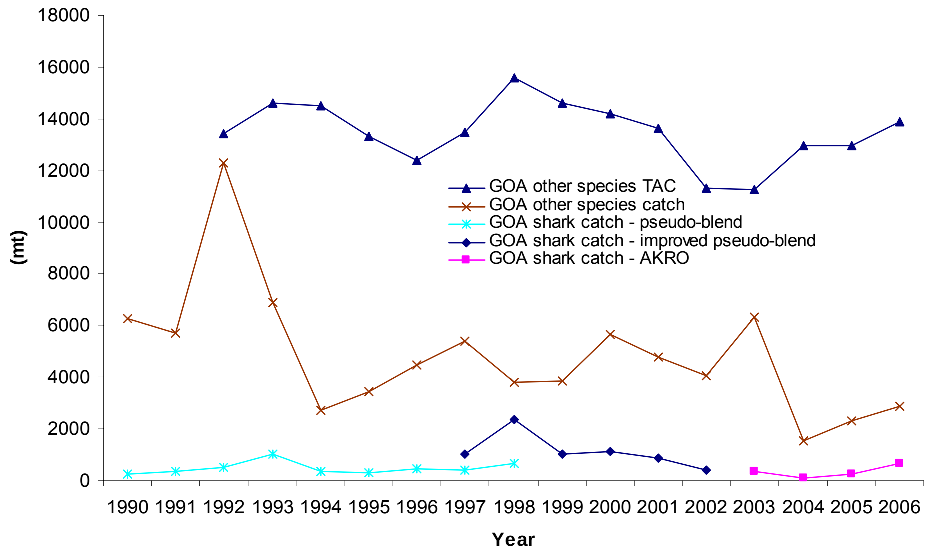
Tier 5 options for GOA shark ABC and OFL are presented both for the individual species and for sharks as a complex. If Tier 5 is adopted, then we suggest Tier 5 ABC for spiny dogfish alone. Tier 5 criteria for establishing ABC and OFL require reliable point estimates for biomass and natural mortality. A natural mortality estimate for Gulf of Alaska spiny dogfish (0.097) is presented in Appendix A. However, reliable point estimates of biomass do not exist for any shark species in the GOA as the efficiency of bottom trawl survey gear varies by species and is highly uncertain. The biomass estimates presented here should be considered at best a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted.

[1] Table 4. NMFS REFM estimated catches (tons) of sharks in the Gulf of Alaska by species, 1997-2001; from an improved pseudo-blend catch estimation procedure (Gaichas 2001, 2002). New data for this report includes non-target catch (bycatch) data for sharks by species in the GOA provided by the NMFS Alaska Regional Office (AKRO) for the years 2003 – 2006 and by the NMFS Alaska Fishery Science Center (AFSC) pseudo-blend estimates for the year 2002.

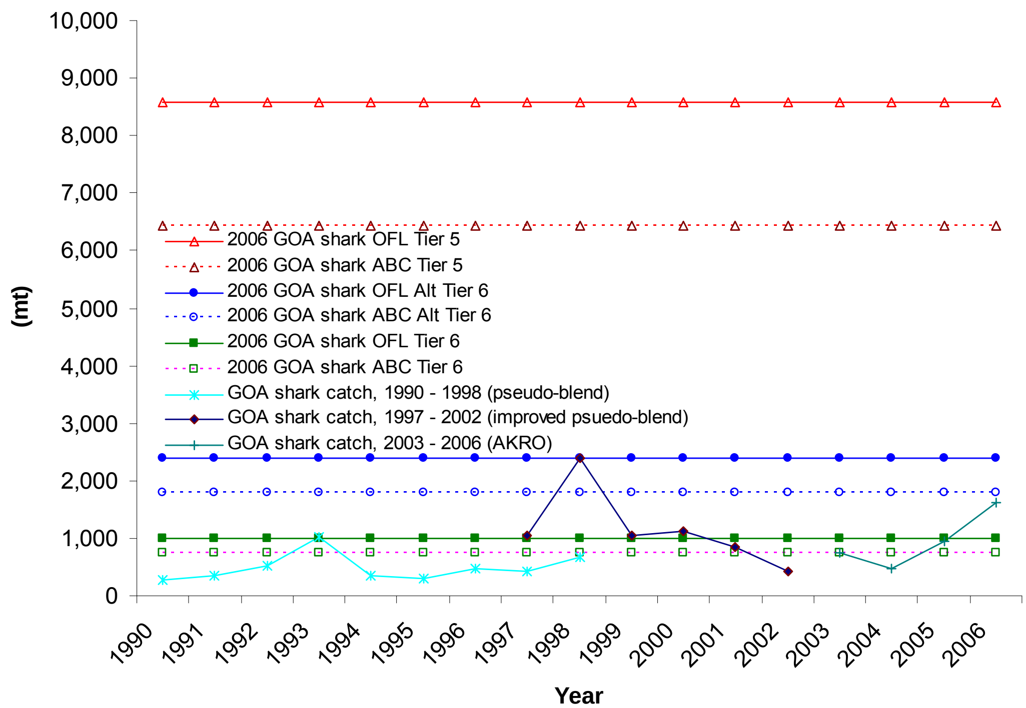
Traditional GOA Tier 5 calculations by species and total of all species (mt).

GOA Tier 5 Calculations (mt)					
Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other sharks	**Total shark complex**[2]
M[3,4]	0.097	0.097	0.18		
Average Gulf of Alaska biomass (1996 – 2005) [5]	47,733	37,459	1,729		**86,921**
ABC	3,473	2,725	233		**6,431**
OFL	4,630	3,634	311		**8,575**

[2] Biomass estimates for Other/unidentified sharks are not available. Total shark estimates are the sum of estimates for Spiny dogfish, Pacific sleeper shark and salmon shark.
[3] *Squalus acanthias* from Appendix A.
[4] Natural mortality for *Lamna ditropis* from Goldman (2002-B), average of minimum .091 and maximum 0.255 natural morality for all ages (Appendix – B).
[5] Table 21. Gulf of Alaska AFSC trawl survey estimates of individual shark species total biomass (tons).



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



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

5 ECOSYSTEM CONSIDERATIONS

5.1 Ecosystem Effects on Stock and Fishery Effects on Ecosystem

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

Spiny dogfish

The Auke Bay Laboratory has collaborated with the Juneau Center of the University of Alaska Fairbanks (UAF) School of Fisheries and Ocean Sciences during the years 2004 – 2006 to investigate the ecological role of spiny dogfish in the Gulf of Alaska. Analysis of spiny dogfish diet in the Gulf of Alaska is ongoing at UAF and results from graduate student research will be incorporated into annual stock assessments when completed.

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).

Pacific sleeper shark

In August 2001 and May 2002, scientists from the Auke Bay Laboratory investigated the diet of Pacific sleeper sharks in the Gulf of Alaska to test the hypothesis that sleeper sharks prey on Steller sea lions (*Eumetopia jubatus*), (Sigler et al, 2006). Scientists collected 198 stomach samples and found predominant prey items to be walleye pollock, octopus, unidentified teleost fish, Pacific salmon, and marine mammal tissue appearing to be from cetaceans. Stomach content analysis found no direct evidence of sea lion predation.

Salmon Shark

During the summers of 1998–2001, scientists from the Auke Bay Laboratory investigated the diet of salmon sharks in Prince William Sound (PWS), Alaska (Hulbert et al. 2005). Salmon shark diet included adult Pacific salmon—pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), and coho (*Oncorhynchus kisutch*)— which were the principal prey as measured by both percent number (35 percent) and percent weight (76 percent). Even when adult salmon were locally abundant, salmon sharks had a varied diet including squid (*Teuthoidea spp.*), sablefish (*Anoplopoma fimbria*), Pacific herring (*Clupea pallasii*), rockfish (*Sebastes spp.*), eulachon (*Thaleichthes pacificus*), capelin (*Mallotus villosus*), spiny dogfish (*Squalus acanthias*), arrowtooth flounder (*Atheresthes stomias*), and cods (*Gadidae*).

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

5.2 Data Gaps and Research Priorities

Data limitations are severe for shark species in the GOA, and effective management of sharks is extremely difficult with the current limited information. Gaps include inadequate catch estimation, unreliable biomass estimates, lack of size frequency collections, and a lack of life history information including age and maturity – especially in regard to Pacific sleeper sharks. Improvements have been made in life history collections for salmon shark and spiny dogfish. An improvement was made with the addition of incidental catch estimates provided for 2003 - 2006 by the NMFS AKRO. The NMFS AKRO should be congratulated on getting these data out in a timely manner and should be encouraged to continue to make this data available to NMFS stock assessment biologists in the future. Regardless of management decisions regarding the future structure for the Other Species management category, it is essential that we continue to improve shark species fishery and survey sampling with the collection of biological data from sharks captured in the commercial fishery and on NMFS bottom trawl surveys.

Currently, the NMFS Observer Program does not measure lengths or collect age specimens for sharks. A NMFS Observer Program policy group met to discuss the addition of shark lengths to the standard Observer Program sampling program for 2007 and came to the conclusion that issues with the way Observer Program data is recorded will prevent adding shark data as standard collections at this time. The data recorded on

Observer Program length forms must be randomly collected. Unfortunately, the size of sharks prevents them from being randomly sampled in most cases. On trawlers they are removed in too many locations due to their size and the common operating practices of the vessels. As a result most sharks encountered by observers are pre-sorted before the observer can collect their random sample. On longliners large sharks usually break off the line before they are landed, preventing access by the observer. Age structures are also troublesome, again because of the size of the organisms. Observers don't have the materials or space to collect, store and transport the large age structures associated with these organisms. We are investigating alternatives to collect length data for all sharks and to collect age structures for spiny dogfish as a NMFS Observer Program special project for 2008. The data would be recorded on paper forms and won't be included in the data base. Age determination would be completed independently.

Several NMFS special projects to collect life history information for sharks in the GOA are already underway or nearing completion. A special project to collect spiny dogfish lengths and maturity in the GOA is underway for 2006 with the NMFS Observer Program. A special project to collect Pacific sleeper shark lengths and fatty acid biopsies in the GOA has been accepted for 2007 with the NMFS Observer Program. A NMFS bottom trawl survey special project to collect length, maturity, and age structures for spiny dogfish in the GOA was completed in 2005 in cooperation with UAF JC/SFOS. Spiny dogfish age determination is being coordinated independently by a UAF graduate student and ages should be available for the 2007 assessment cycle. A NMFS bottom trawl survey special project to collect diet for all sharks and to collect age structures for spiny dogfish in the GOA may be considered for 2007.

6 SUMMARY

There is no evidence to suggest that over fishing is occurring for any shark species in the GOA. There are currently no directed commercial fisheries for shark species in 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 (Appendix - C). Incidental catches of shark species in the GOA fisheries have been very small compared to catch rates of target species. The TAC for the GOA Other Species complex is set in aggregate at less than or equal to 5% of the sum of the TAC's of managed GOA species. Preliminary comparisons of incidental catch rates with available biomass by species suggest that current levels of incidental catches are low relative to available biomass for spiny dogfish and Pacific sleeper sharks in the GOA. In the GOA, average catch of spiny dogfish from 1997 – 2005 (422 tons) represented less than 1% of the available spiny dogfish biomass from GOA bottom trawl surveys 1996 – 2005 (average of 47,733 tons, Table 21). The 2001 survey did not include all areas of the eastern GOA and consequently, the 2001 survey may not be comparable with the other surveys for species such as spiny dogfish which appear to be relatively abundant in the eastern GOA. Average catch of Pacific sleeper sharks from 1997 – 2005 (313 tons) represented less than 1% of the available Pacific sleeper shark biomass from GOA bottom trawl surveys 1996 – 2005 (average of 37,459 tons, Table 21). Average catch of salmon sharks from 1997 – 2005 (63 tons) was relatively small, and GOA bottom trawl survey biomass estimates for salmon sharks were unreliable because salmon sharks were only caught in four hauls from 1996 – 2005 (Table 21).

7 ACKNOWLEDGMENTS

We gratefully acknowledge the following individuals: Michael Martin provided bottom trawl survey biomass estimates for the Gulf of Alaska (1984 – 2005). Claude Dykstra and Tom Kong provided IPHC longline survey data and updated the data to include ineffective stations from 1997-2003. Bill Bechtol provided ADF&G sablefish longline survey data from Prince William Sound. Dave Ackley (NMFS AKRO in Juneau, Alaska) provided catch estimates for shark species for the years 2003, 2004 and 2005. Mary Furuness (NMFS AKRO in Juneau, Alaska) updated catch estimates for shark species for 2003 - 2006.

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Table 1. Shark species in the Gulf of Alaska (GOA) by scientific and common name.

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

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

Table 2. Summary of NMFS AKRO blend-estimated annual catches (tons) for the Gulf of Alaska (GOA) Other Species management category, which includes sculpins, **sharks**, squid, and octopus.

Year	Foreign	Joint Venture	Domestic	Total
1977	4,725			4,725
1978	6,299			6,299
1979	4,507	38		4,545
1980	6,395	49		6,445
1981	8,247	33		8,280
1982	2,326	317		2,643
1983	2,523	395		2,918
1984	696	1,273		1,969
1985	103	2,253		2,356
1986	146	262		408
1987		182		182
1988		129		129
1989			1,560	1,560
1990			6,289	6,289
1991			5,700	5,700
1992			12,313	12,313
1993			6,867	6,867
1994			2,721	2,721
1995			3,421	3,421
1996			4,480	4,480
1997			5,409	5,409
1998			3,781	3,781
1999			3,859	3,859
2000			5,649	5,649
2001			4,801	4,801
2002			4,040	4,040
2003			6,339	6,339
2004			1,559	1,559
2005			2,294	2,294
2006			3,467	3,467

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

Table 3. NMFS REFM estimated catches (tons) of sharks in the Gulf of Alaska by species, 1990-1998; from a pseudo-blend catch estimation procedure (Gaichas et al. 1999).

Year	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Brown Cat Shark	Blue Shark	Sixgill Shark	Unidentified Shark	Total Sharks
1990	170.89	19.69	52.65	0.21		3.27	26.96	274
1991	141.23	49.36	41.58			4.21	103.93	340
1992	320.62	37.57	141.92	0.01			17.23	517
1993	383.36	214.78	89.16				339.62	1,027
1994	160.23	119.50	24.52			0.40	55.45	360
1995	140.63	62.97	54.93		7.54		41.81	308
1996	336.91	65.86	27.76		2.85		50.58	484
1997	233.48	118.12	24.63		3.25		56.28	436
1998	298.03	161.40	78.52	1.29	5.33		124.78	669
Total	2,185.37	849.25	535.68	1.52	18.98	7.89	816.64	4,415
% of Total	49%	19%	12%	0%	0%	0%	18%	100%

Source: Gaichas et al. (1999, Table 14).

Table 4. Estimated catch (mt) of sharks in the Gulf of Alaska (GOA) by species. Years 1997 – 2002 from the NMFS REFM pseudo-blend catch estimation procedure (Gaichas, 2002). Years 2003 - 2006 from NMFS AKRO.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks	Total other species	% of Total
1997	657	136	124	123	1,041	5,409	19%
1998	865	74	71	1,380	2,390	3,781	63%
1999	314	558	132	33	1,036	3,859	27%
2000	398	608	38	74	1,117	5,649	20%
2001	494	249	33	77	853	4,801	18%
2002	117	226	58	26	427	4,040	11%
2003	369	292	36	62	759	6,339	12%
2004	175	232	22	39	468	1,559	30%
2005	408	440	52	58	959	2,294	42%
2006	1,324	209	29	53	1,615	3,467	47%
Average 1997-2005*	421.8	312.8	62.7	208.0	1,005.4	4,192.3	
Maximum 1997-2005*	1,324	608	132	1,380	2,390	6,339	
Total All years	5,120	3,025	593	1,925	10,663	41,198	
% of Total All years	48%	28%	6%	18%	100%	26%	

* Average and maximum catch 1997-2005 used for Tier 6 calculations. Source: 1997 – 2002, Gaichas (2002, Table 15-5); 2003 – 2006, NMFS AKRO as of Oct 22, 2006.

Table 5. Estimated catches (tons) of spiny dogfish in the Gulf of Alaska by fishery and gear type, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Fishery	Gear	1990	1991	1992	1993	1994	1995	1996	Total	% of Total
Bottom Pollock	TWL	57.1	26.7	73.4	114.5	20.8	2.8	0.5	295.8	18%
Pelagic Pollock	TWL	0.5	2.6	11.0	22.5	1.2	0.0	2.4	40.2	2%
Pollock Total		57.6	29.2	84.4	137.0	22.0	2.9	2.9	336.0	20%
Pacific Cod	LGL	6.3	34.7	35.0	5.6	13.1	20.6	11.1	126.4	8%
	POT	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0%
	TWL	29.6	18.0	15.5	4.5	3.8	7.5	4.1	83.0	5%
Pacific Cod Total		36.0	52.6	50.5	10.1	16.9	28.1	15.3	209.5	13%
Flatfish	LGL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0%
	TWL	13.3	16.2	116.0	138.5	83.4	24.1	182.5	574.1	35%
Flatfish Total		13.5	16.2	116.0	138.5	83.4	24.1	182.6	574.3	35%
Rockfish	JIG			0.0						
	LGL	0.0	13.9	18.3	0.0	1.2	11.9	18.2	63.6	4%
	TWL	1.8	2.6	4.0	2.4	1.2	6.5	1.6	20.1	1%
Rockfish Total		1.8	16.4	22.4	2.4	2.5	18.4	19.8	83.7	5%
Other	LGL	3.1	0.0	0.1	0.0	0.0	15.3	23.0	41.5	3%
	POT			0.0	0.0		0.0	0.0	0.0	0%
	TWL	0.0	0.5	6.6	0.0	0.0	1.0	13.8	22.0	1%
Other Total		3.1	0.5	6.7	0.0	0.0	16.4	36.8	63.5	4%
Atka Mackerel	TWL					0.0	0.0	0.0	0.0	0%
Sablefish	LGL	59.0	26.2	40.7	95.3	35.4	50.7	79.5	386.8	23%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		59.0	26.2	40.7	95.3	35.4	50.7	79.5	386.9	23%
Grand Total		170.9	141.2	320.6	383.4	160.2	140.6	336.9	1,653.9	100%

Table 6. Estimated catches (tons) of spiny dogfish in the Gulf of Alaska by fishery and gear type, 1997-2001 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by fishery and gear type were not computed for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Bottom Pollock	TWL	1.2	0.4	0.0	4.1	4.4	10.1	0%
Pelagic Pollock	TWL	1.6	4.5	8.6	14.6	7.2	36.4	1%
Pollock Total		2.8	4.9	8.6	18.7	11.6	46.5	2%
Pacific Cod	LGL	27.6	103.6	146.2	8.0	111.3	396.8	15%
	POT	0.0	0.0	0.3	0.4	0.6	1.3	0%
	TWL	29.9	623.6	13.8	21.0	60.9	749.2	27%
Pacific Cod Total		57.6	727.2	160.2	29.4	172.8	1,147.2	42%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	137.2	69.0	56.6	66.3	162.5	491.5	18%
Flatfish Total		137.2	69.0	56.6	66.3	162.5	491.5	18%
Rockfish	JIG							
	LGL	314.3	0.0	2.4	139.2	19.1	475.0	17%
	TWL	11.9	3.1	2.4	7.4	5.9	30.7	1%
Rockfish Total		326.2	3.1	4.8	146.6	25.1	505.7	19%
Other/Unknown	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.0	1.1	0.0	0.0	0.0	1.1	0%
Other Total		0.0	1.1	0.0	0.0	0.0	1.1	0%
Atka Mackerel	TWL							
Sablefish	LGL	133.7	59.6	83.4	136.6	122.1	535.4	20%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		133.7	59.6	83.4	136.6	122.1	535.4	20%
Grand Total		657.5	864.9	313.6	397.6	494.0	2,727.5	100%

Table 7. Estimated catches (tons) of Pacific sleeper sharks in the Gulf of Alaska by fishery and gear type, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Fishery	Gear	1990	1991	1992	1993	1994	1995	1996	Total	% of Total
Bottom Pollock	TWL	0.7	11.8	0.0	125.3	58.5	7.1	3.3	206.7	36%
Pelagic Pollock	TWL	2.2	15.4	1.1	31.2	21.1	9.8	11.2	92.0	16%
Pollock Total		2.9	27.2	1.1	156.5	79.6	16.9	14.5	298.8	52%
Pacific Cod	LGL	8.4	0.0	24.6	6.3	15.0	12.5	3.9	70.8	12%
	POT	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0%
	TWL	1.4	2.8	2.7	15.5	1.6	1.2	7.9	33.2	6%
Pacific Cod Total		9.9	2.8	27.4	21.8	16.6	13.7	11.9	104.1	18%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0%
	TWL	0.4	3.1	2.7	1.0	0.8	20.5	12.1	40.5	7%
Flatfish Total		0.4	3.1	2.7	1.0	0.8	20.7	12.1	40.7	7%
Rockfish	JIG			0.0						
	LGL	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.9	0%
	TWL	4.3	0.0	0.0	0.0	0.4	0.1	0.0	4.8	1%
Rockfish Total		4.3	0.0	0.0	0.0	1.3	0.1	0.0	5.7	1%
Other	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0%
	POT			0.0	0.0		0.0	0.0	0.0	0%
	TWL	0.1	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0%
Other Total		0.1	0.0	0.0	0.0	0.0	0.0	0.7	0.8	0%
Atka Mackerel	TWL					0.0	0.0	0.2	0.2	0%
Sablefish	LGL	2.0	16.2	6.4	35.5	21.0	11.6	26.4	119.1	21%
	TWL	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0%
Sablefish Total		2.2	16.2	6.4	35.5	21.2	11.6	26.4	119.5	21%
Grand Total		19.7	49.4	37.6	214.8	119.5	63.0	65.9	569.7	100%

Table 8. Estimated catches (tons) of Pacific sleeper sharks in the Gulf of Alaska by fishery and gear type, 1997-2001 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by fishery and gear type were not computed for the years 2002 - 2006.

Fishery	**Gear**	**1997**	**1998**	**1999**	**2000**	**2001**	**Total**	**% of Total**
Bottom Pollock	TWL	0.0	4.6	0.9	1.3	11.1	17.9	1%
Pelagic Pollock	TWL	22.3	27.8	33.2	177.1	134.8	395.2	24%
Pollock Total		22.3	32.4	34.2	178.4	145.9	413.1	25%
Pacific Cod	LGL	42.3	14.0	501.0	365.8	65.8	989.0	61%
	POT	0.0	0.0	0.0	0.4	0.0	0.4	0%
	TWL	16.9	5.5	4.8	10.6	0.0	37.8	2%
Pacific Cod Total		59.3	19.6	505.8	376.8	65.8	1,027.2	63%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	46.0	10.1	6.0	35.9	6.3	104.2	6%
Flatfish Total		46.0	10.1	6.0	35.9	6.3	104.2	6%
Rockfish	JIG							
	LGL	0.9	0.0	0.0	0.2	0.0	1.0	0%
	TWL	0.0	0.2	3.0	0.2	0.7	4.1	0%
Rockfish Total		0.9	0.2	3.0	0.3	0.7	5.1	0%
Other/Unknown	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.0	0.5	0.0	0.0	0.0	0.5	0%
Other Total		0.0	0.5	0.0	0.0	0.0	0.5	0%
Atka Mackerel	TWL							
Sablefish	LGL	7.5	11.3	8.7	16.7	30.3	74.6	5%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		7.5	11.3	8.7	16.7	30.3	74.6	5%
Grand Total		135.9	74.0	557.7	608.2	249.0	1,624.7	100%

Table 9. Estimated catches (tons) of salmon sharks in the Gulf of Alaska by fishery and gear type, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Fishery	Gear	1990	1991	1992	1993	1994	1995	1996	Total	% of Total
Bottom Pollock	TWL	20.7	5.4	83.3	38.1	3.3	3.3	5.8	160.0	37%
Pelagic Pollock	TWL	24.6	30.8	39.8	48.6	20.9	22.6	21.1	208.3	48%
Pollock Total		45.3	36.3	123.1	86.7	24.2	25.9	26.8	368.3	85%
Pacific Cod	LGL	0.0	0.0	15.3	0.0	0.0	17.3	0.0	32.6	8%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	3.2	0.0	1.2	0.0	0.0	4.3	0.0	8.7	2%
Pacific Cod Total		3.2	0.0	16.5	0.0	0.0	21.6	0.0	41.2	10%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.2	0.0	0.2	2.5	0.0	3.2	0.0	6.0	1%
Flatfish Total		0.2	0.0	0.2	2.5	0.0	3.2	0.0	6.0	1%
Rockfish	JIG			0.0						
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.7	0.0	0.0	0.0	0.0	0.2	0.0	1.0	0%
Rockfish Total		0.7	0.0	0.0	0.0	0.0	0.2	0.0	1.0	0%
Other	LGL	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0%
	POT			0.0	0.0		0.0	0.0	0.0	0%
	TWL	1.2	0.0	0.0	0.0	0.3	0.0	0.6	2.1	0%
Other Total		1.2	0.0	0.0	0.0	0.3	0.9	0.6	3.0	1%
Atka Mackerel	TWL					0.0	0.0	0.1	0.1	0%
Sablefish	LGL	1.9	5.3	2.1	0.0	0.0	3.1	0.2	12.7	3%
	TWL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0%
Sablefish Total		2.1	5.3	2.1	0.0	0.0	3.1	0.2	12.8	3%
Grand Total		52.7	41.6	141.9	89.2	24.5	54.9	27.8	432.5	100%

Table 10. Estimated catches (tons) of salmon sharks in the Gulf of Alaska by fishery and gear type, 1997-2001 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by fishery and gear type were not computed for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Bottom Pollock	TWL	4.4	2.4	0.0	7.3	0.2	14.2	4%
Pelagic Pollock	TWL	15.4	67.3	111.8	25.4	29.3	249.3	63%
Pollock Total		19.8	69.7	111.8	32.7	29.5	263.5	66%
Pacific Cod	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.7	0.0	0.0	0.7	0%
	TWL	0.1	0.0	0.0	0.0	0.0	0.1	0%
Pacific Cod Total		0.1	0.0	0.7	0.0	0.0	0.8	0%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.0	0.8	0.7	3.7	1.5	6.7	2%
Flatfish Total		0.0	0.8	0.7	3.7	1.5	6.7	2%
Rockfish	JIG							
	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.0	0.4	0.0	0.8	1.8	3.0	1%
Rockfish Total		0.0	0.4	0.0	0.8	1.8	3.0	1%
Other/Unknown	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	103.9	0.0	0.0	0.0	0.0	103.9	26%
Other Total		103.9	0.0	0.0	0.0	0.0	103.9	26%
Atka Mackerel	TWL							
Sablefish	LGL	0.0	0.0	18.4	0.6	0.0	19.0	5%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		0.0	0.0	18.4	0.6	0.0	19.0	5%
Grand Total		123.8	71.0	131.6	37.8	32.8	396.9	100%

Table 11. Estimated catches (tons) of other and unidentified sharks in the Gulf of Alaska by fishery and gear type, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Fishery	Gear	1990	1991	1992	1993	1994	1995	1996	Total	% of Total
Bottom Pollock	TWL	1.1	13.2	2.1	129.8	34.9	2.0	9.5	192.7	29%
Pelagic Pollock	TWL	3.0	4.6	1.2	8.5	6.7	2.0	4.7	30.8	5%
Pollock Total		4.1	17.8	3.3	138.3	41.5	4.1	14.3	223.4	34%
Pacific Cod	LGL	0.3	24.1	8.1	36.8	2.2	2.5	0.1	73.9	11%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	21.0	12.6	0.4	1.3	0.2	0.8	3.0	39.4	6%
Pacific Cod Total		21.3	36.7	8.4	38.1	2.3	3.4	3.1	113.4	17%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.8	35.5	3.5	3.7	3.0	10.6	17.8	75.0	11%
Flatfish Total		0.8	35.5	3.5	3.7	3.0	10.6	17.8	75.0	11%
Rockfish	JIG			0.0						
	LGL	0.0	0.0	0.0	0.0	0.0	1.0	1.9	3.0	0%
	TWL	1.4	4.4	0.1	0.0	0.0	8.6	0.0	14.6	2%
Rockfish Total		1.4	4.4	0.1	0.0	0.0	9.7	1.9	17.6	3%
Other	LGL	0.0	0.0	0.0	0.2	0.0	5.5	0.0	5.7	1%
	POT			0.0	0.0		0.0	0.0	0.0	0%
	TWL	0.0	0.0	0.4	0.0	0.0	1.8	0.2	2.4	0%
Other Total		0.0	0.0	0.4	0.2	0.0	7.3	0.3	8.1	1%
Atka Mackerel	TWL					0.0	0.0	0.0	0.0	0%
Sablefish	LGL	2.9	13.7	1.5	159.3	8.9	14.3	16.0	216.6	33%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		2.9	13.7	1.5	159.3	8.9	14.3	16.0	216.6	33%
Grand Total		30.4	108.1	17.2	339.6	55.9	49.4	53.4	654.1	100%

Table 12. Estimated catches (tons) of other and unidentified sharks in the Gulf of Alaska by fishery and gear type, 1997-2001 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by fishery and gear type were not computed for the years 2002 - 2006.

Fishery	Gear	1997	1998	1999	2000	2001	Total	% of Total
Bottom Pollock	TWL	0.0	0.0	0.0	0.0	0.2	0.2	0%
Pelagic Pollock	TWL	8.9	24.2	6.1	12.3	34.8	86.2	5%
Pollock Total		8.9	24.2	6.1	12.3	35.0	86.4	5%
Pacific Cod	LGL	2.4	3.6	8.1	2.1	0.6	16.8	1%
	POT	0.0	0.0	0.1	0.0	0.0	0.1	0%
	TWL	11.0	6.7	4.0	1.4	0.8	23.9	1%
Pacific Cod Total		13.4	10.2	12.3	3.5	1.4	40.9	2%
Flatfish	LGL	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	9.0	17.9	8.1	34.0	1.5	70.6	4%
Flatfish Total		9.0	17.9	8.1	34.0	1.5	70.6	4%
Rockfish	JIG							
	LGL	45.2	0.0	0.0	3.7	0.0	48.9	3%
	TWL	2.3	2.3	0.1	1.1	1.4	7.2	0%
Rockfish Total		47.5	2.3	0.1	4.8	1.4	56.0	3%
Other/Unknown	LGL	0.0	0.0	0.0	0.3	0.0	0.3	0%
	POT	0.0	0.0	0.0	0.0	0.0	0.0	0%
	TWL	0.7	0.0	0.0	0.0	0.0	0.7	0%
Other Total		0.7	0.0	0.0	0.3	0.0	1.1	0%
Atka Mackerel	TWL							
Sablefish	LGL	43.9	1,325.2	6.4	18.7	37.7	1,432.0	85%
	TWL	0.0	0.0	0.0	0.0	0.0	0.0	0%
Sablefish Total		43.9	1,325.2	6.4	18.7	37.7	1,432.0	85%
Grand Total		123.5	1,379.9	33.0	73.6	77.0	1,687.0	100%

Table 13. Estimated catches (tons) of spiny dogfish in the Gulf of Alaska by statistical area, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Year	610	620	630	640	649	650	659	Total
1990	0.2	3.6	147.8	2.3	0.0	17.0	0.0	170.9
1991	2.2	3.5	113.1	3.1	0.0	18.2	0.0	141.2
1992	2.7	8.1	283.6	1.8	0.0	24.4	0.0	320.6
1993	0.6	3.0	322.3	11.0	0.0	5.4	41.2	383.4
1994	1.4	4.8	115.5	5.0	0.0	33.6	0.0	160.2
1995	0.4	8.7	103.7	13.8	0.0	14.0	0.0	140.6
1996	1.3	3.4	279.2	23.0	0.5	29.5	0.0	336.9
Total	8.8	35.0	1,365.2	59.9	0.5	142.1	41.2	1,653.9
% of Total	0.5%	2.1%	82.5%	3.6%	0.0%	8.6%	2.5%	100.0%

Table 14. Estimated catches (tons) of spiny dogfish in the Gulf of Alaska by statistical area, 1997-2002 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by area was not computed for the years 2003 – 2006.

Year	610	620	630	640	649	650	659	Total
1997	0.5	11.7	265.7	45.0	0.0	334.7	0.0	657.5
1998	3.6	3.1	255.0	574.8	2.2	26.1	0.0	864.9
1999	11.0	42.8	175.6	38.9	3.2	42.2	0.0	313.6
2000	5.3	1.0	148.6	82.9	0.0	159.9	0.0	397.6
2001	3.3	1.8	396.3	40.5	0.0	52.1	0.0	494.0
2002	5.2	5.8	47.1	51.9	0.0	7.0	0.0	117.0
Total	28.8	66.1	1,288.2	833.9	5.4	622.0	0.0	2,844.5
% of Total	1%	2%	45%	29%	0%	22%	0%	100%

Table 15. Estimated catches (tons) of Pacific sleeper sharks in the Gulf of Alaska by statistical area, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Year	610	620	630	640	649	650	659	Total
1990	2.4	1.2	12.8	3.0	0.0	0.3	0.0	19.7
1991	4.0	3.0	40.9	1.4	0.0	0.0	0.0	49.4
1992	4.0	23.2	6.3	2.2	1.9	0.0	0.0	37.6
1993	10.5	127.9	68.2	8.3	0.0	0.0	0.0	214.8
1994	11.9	23.0	75.9	8.7	0.0	0.0	0.0	119.5
1995	6.5	23.3	27.0	2.4	0.1	3.7	0.0	63.0
1996	21.3	12.0	14.5	5.5	0.0	12.5	0.0	65.9
Total	60.6	213.6	245.6	31.5	2.0	16.5	0.0	569.7
% of Total	10.6%	37.5%	43.1%	5.5%	0.4%	2.9%	0.0%	100.0%

Table 16. Estimated catches (tons) of Pacific sleeper sharks in the Gulf of Alaska by statistical area, 1997-2002 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by area was not computed for the years 2003 – 2006.

Year	610	620	630	640	649	650	659	Total
1997	16.0	45.0	69.5	1.3	0.9	3.2	0.0	135.9
1998	11.0	11.4	42.5	0.7	0.0	8.5	0.0	74.0
1999	63.9	33.8	454.7	0.3	0.0	4.9	0.0	557.7
2000	18.6	162.7	415.4	1.0	0.0	10.5	0.0	608.2
2001	90.7	67.3	74.6	6.0	0.0	10.3	0.0	249.0
2002	65.2	110.8	46.6	2.3	0.7	0.0	0.0	225.6
Total	265.5	430.9	1,103.4	11.6	1.6	37.3	0.0	1,850.3
% of Total	14%	23%	60%	1%	0%	2%	0%	100%

Table 17. Estimated catches (tons) of salmon sharks in the Gulf of Alaska by statistical area, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Year	610	620	630	640	649	650	659	Total
1990	3.4	3.0	46.2	0.1	0.0	0.0	0.0	52.7
1991	4.3	6.9	30.4	0.0	0.0	0.0	0.0	41.6
1992	0.2	130.3	11.4	0.0	0.0	0.0	0.0	141.9
1993	5.2	19.5	63.1	1.4	0.0	0.0	0.0	89.2
1994	3.1	4.7	16.7	0.0	0.0	0.0	0.0	24.5
1995	8.2	4.1	41.7	0.0	0.9	0.1	0.0	54.9
1996	14.1	10.8	2.7	0.0	0.0	0.2	0.0	27.8
Total	38.6	179.1	212.0	1.6	0.9	0.3	0.0	432.5
% of Total	8.9%	41.4%	49.0%	0.4%	0.2%	0.1%	0.0%	100.0%

Table 18. Estimated catches (tons) of salmon sharks in the Gulf of Alaska by statistical area, 1997-2002 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by area was not computed for the years 2003 – 2006.

Year	610	620	630	640	649	650	659	Total
1997	5.6	10.3	107.4	0.0	0.5	0.0	0.0	123.8
1998	10.0	39.6	20.7	0.4	0.3	0.0	0.0	71.0
1999	15.1	39.9	58.3	0.0	0.0	18.4	0.0	131.6
2000	7.1	11.1	19.0	0.6	0.0	0.0	0.0	37.8
2001	13.0	1.7	18.1	0.0	0.0	0.0	0.0	32.8
2002	20.5	11.2	26.4	0.0	0.0	0.0	0.0	58.2
Total	71.3	113.8	249.8	1.0	0.8	18.4	0.0	455.1
% of Total	16%	25%	55%	0%	0%	4%	0%	100%

Table 19. Estimated catches (tons) of other and unidentified sharks in the Gulf of Alaska by statistical area, 1990-1996 using a pseudo-blend catch procedure (Gaichas et al. 1999).

Year	610	620	630	640	649	650	659	Total
1990	0.9	3.6	25.1	0.1	0.0	0.7	0.0	30.4
1991	6.9	1.1	99.9	0.3	0.0	0.0	0.0	108.1
1992	4.5	1.4	11.3	0.0	0.0	0.0	0.0	17.2
1993	2.1	5.6	195.0	4.0	0.0	133.0	0.0	339.6
1994	5.5	27.5	22.9	0.0	0.0	0.0	0.0	55.9
1995	2.0	0.9	32.0	1.2	0.0	13.3	0.0	49.4
1996	3.0	16.1	17.6	3.9	0.0	12.8	0.0	53.4
Total	25.0	56.1	403.7	9.4	0.0	159.8	0.0	654.1
% of Total	3.8%	8.6%	61.7%	1.4%	0.0%	24.4%	0.0%	100.0%

Table 20. Estimated catches (tons) of other and unidentified sharks in the Gulf of Alaska by statistical area, 1997-2002 using the improved pseudo-blend estimation procedure (Gaichas 2002). Catch by area was not computed for the years 2003 – 2006.

Year	610	620	630	640	649	650	659	Total
1997	5.9	5.6	72.6	26.4	0.0	13.0	0.0	123.5
1998	1.3	25.7	48.1	4.9	1.1	46.2	1,252.6	1,379.9
1999	9.3	2.1	13.4	0.5	1.9	5.7	0.0	33.0
2000	3.7	17.5	29.8	6.1	0.0	16.6	0.0	73.6
2001	0.9	19.2	21.7	1.9	0.0	33.3	0.0	77.0
2002	NA	NA	NA	NA	NA	NA	NA	NA
Total	21.2	70.1	185.4	39.9	3.0	114.7	1,252.6	1,687.0
% of Total	1%	4%	11%	2%	0%	7%	74%	100%

Table 21. Gulf of Alaska AFSC trawl survey estimates of individual shark species total biomass (tons) with CV, and number of hauls.

Year	Total Hauls		Spiny	Sleeper Shark	Salmon shark
1984	929	Hauls with catch	125	1	5
		Biomass	10,143.0	163.2	7,848.8
		CV of Biomass	0.206	1.000	0.522
1987	783	Hauls with catch	122	8	15
		Biomass	10,106.8	1,319.2	12,622.5
		CV of Biomass	0.269	0.434	0.562
1990	708	Hauls with catch	114	3	13
		Biomass	18,947.6	1,651.4	12,462.0
		CV of Biomass	0.378	0.660	0.297
1993	775	Hauls with catch	166	13	9
		Biomass	33,645.1	8,656.8	7,728.6
		CV of Biomass	0.204	0.500	0.356
1996	807	Hauls with catch	99	11	1
		Biomass	28,477.9	21,100.9	3,302.0
		CV of Biomass	0.736	0.358	1.000
1999	764	Hauls with catch	168	13	0
		Biomass	31,742.9	19,362.0	
		CV of Biomass	0.138	0.399	
2001	489	Hauls with catch	75	15	0
		Biomass	31,774.3	37,694.7	
		CV of Biomass	0.450	0.362	
2003	809	Hauls with catch	204	28	2
		Biomass	98,743.8	52,115.6	3,612.8
		CV of Biomass	0.219	0.247	0.707
2005	839	Hauls with catch	156	26	1
		Biomass	47,926.1	57,022.0	NA
		CV of Biomass	0.170	0.263	NA
Average 1996-2005*		Biomass	47,433	37,459	1,729

* Average biomass 1996-2005 used for Tier 5 calculations. Source: Gaichas et al. (1999, Table 16) updated Oct, 2006 (RACEBASE).

Table 22. Research catches (tons) of sharks between 1977 and 2005 in the Gulf of Alaska (GOA). Catches do not include longline surveys.

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

Sources: Gaichas et al. (1999, Table 3).

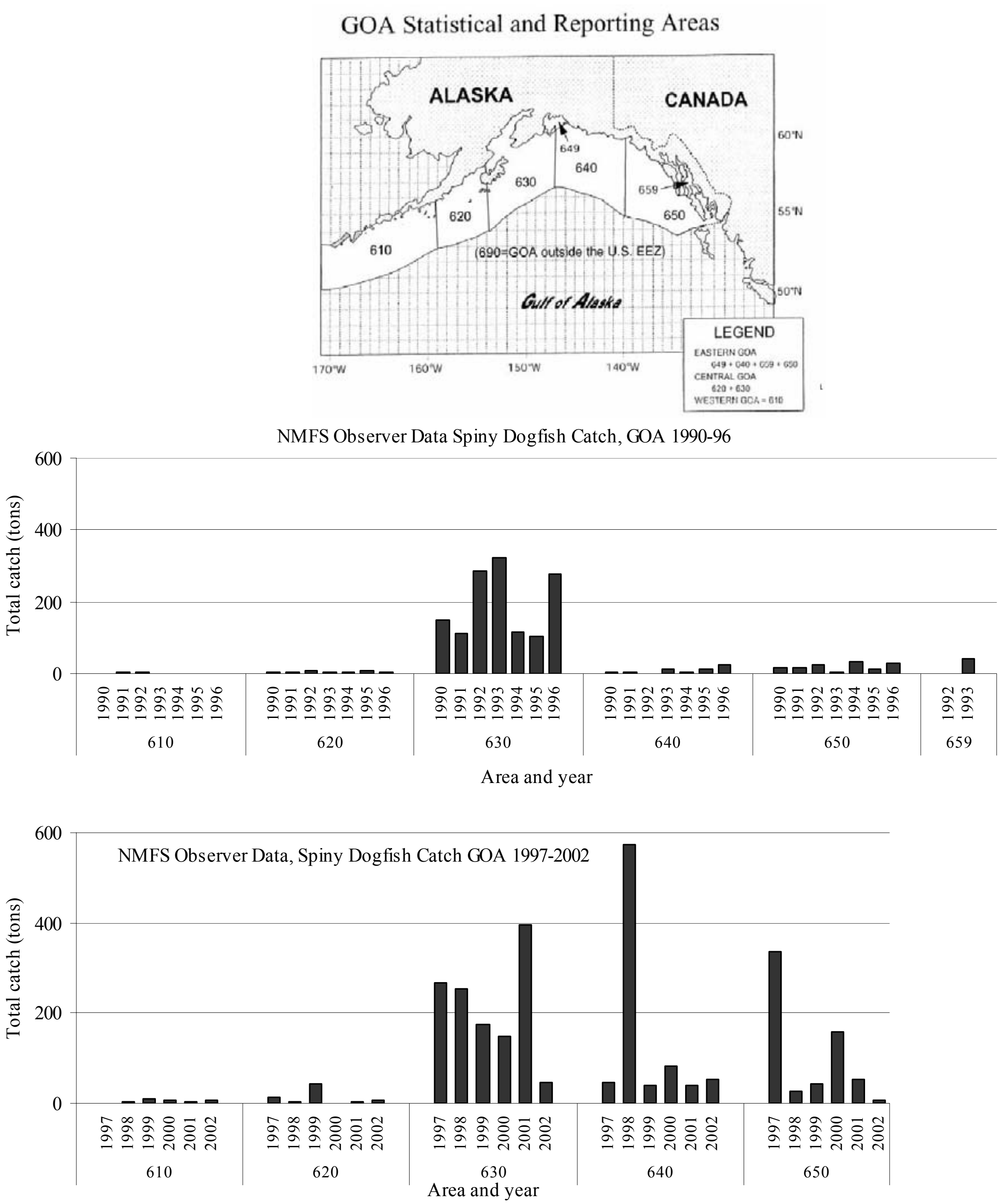


Figure 1. The statistical areas for NMFS observer data in the Gulf of Alaska and spiny dogfish incidental catch in the GOA from 1990-1996 using a pseudo-blend catch estimation procedure (Gaichas et al. 1999) and from 1997-2002 using the improved pseudo-blend catch estimation procedure (Gaichas 2002).

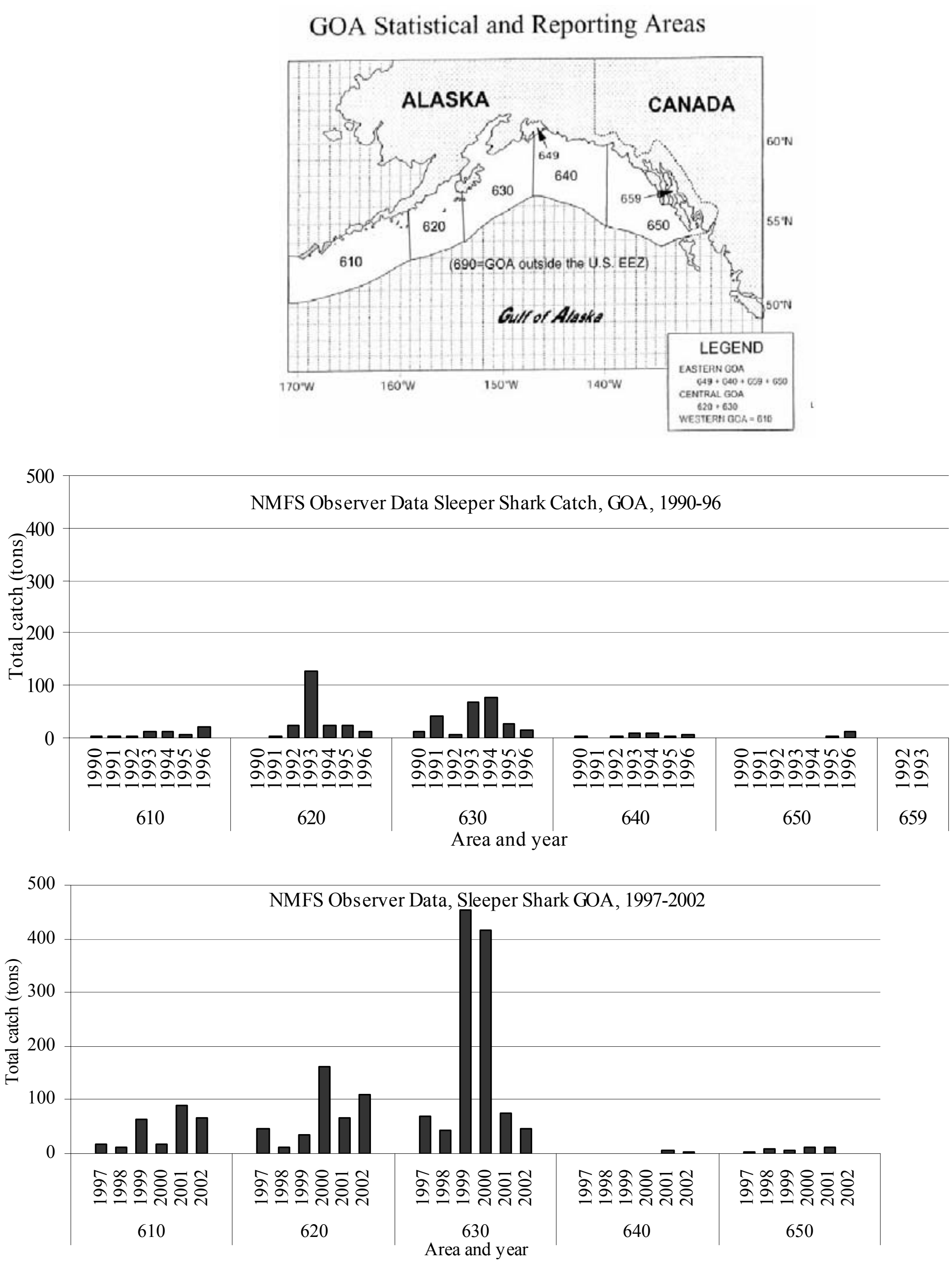


Figure 2. The statistical areas for NMFS observer data in the Gulf of Alaska and sleeper shark incidental in the GOA from 1990-1996 using a pseudo-blend catch estimation procedure (Gaichas et al. 1999) and from 1997-2002 using the improved pseudo-blend catch estimation procedure (Gaichas 2002).

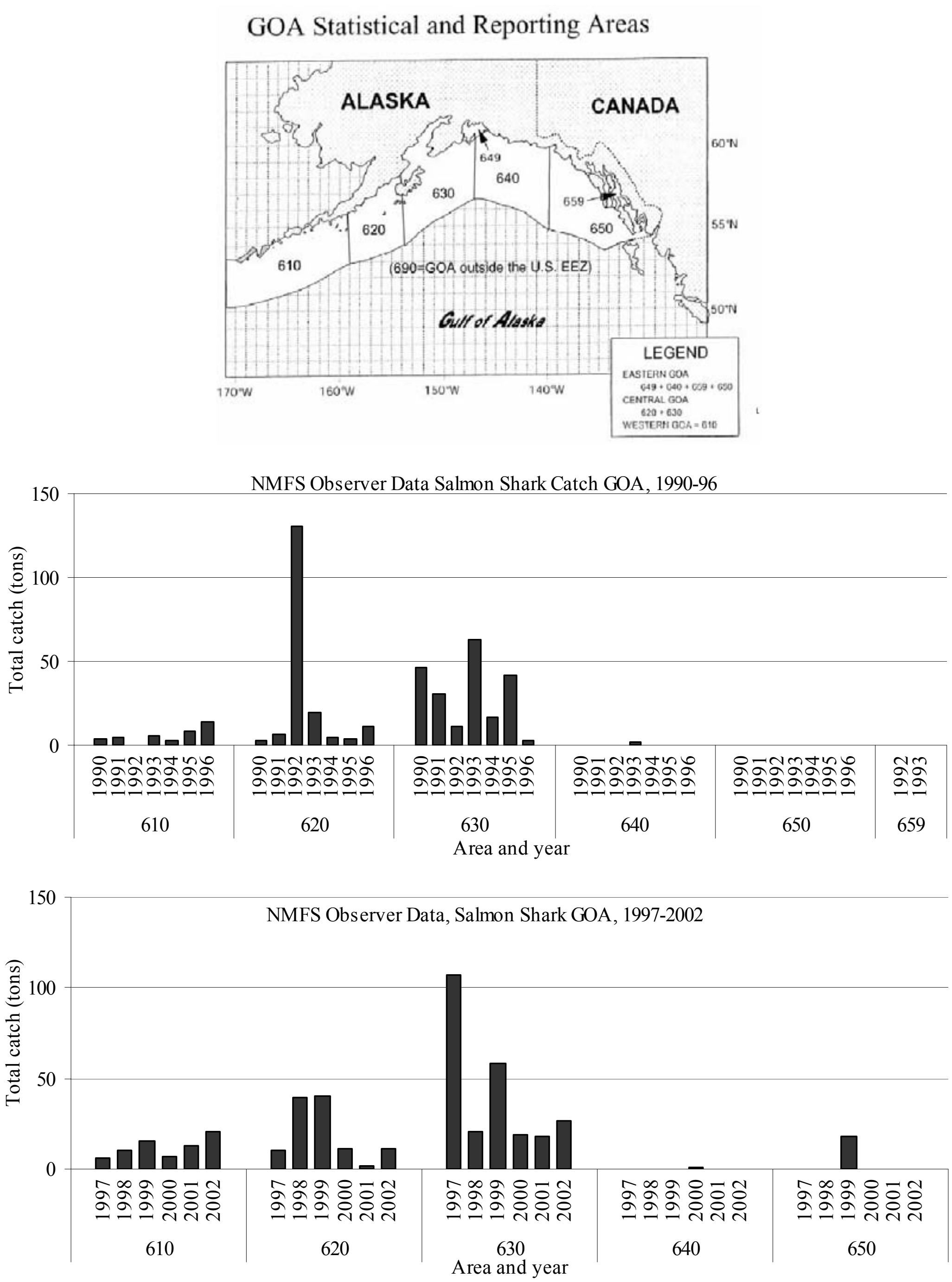
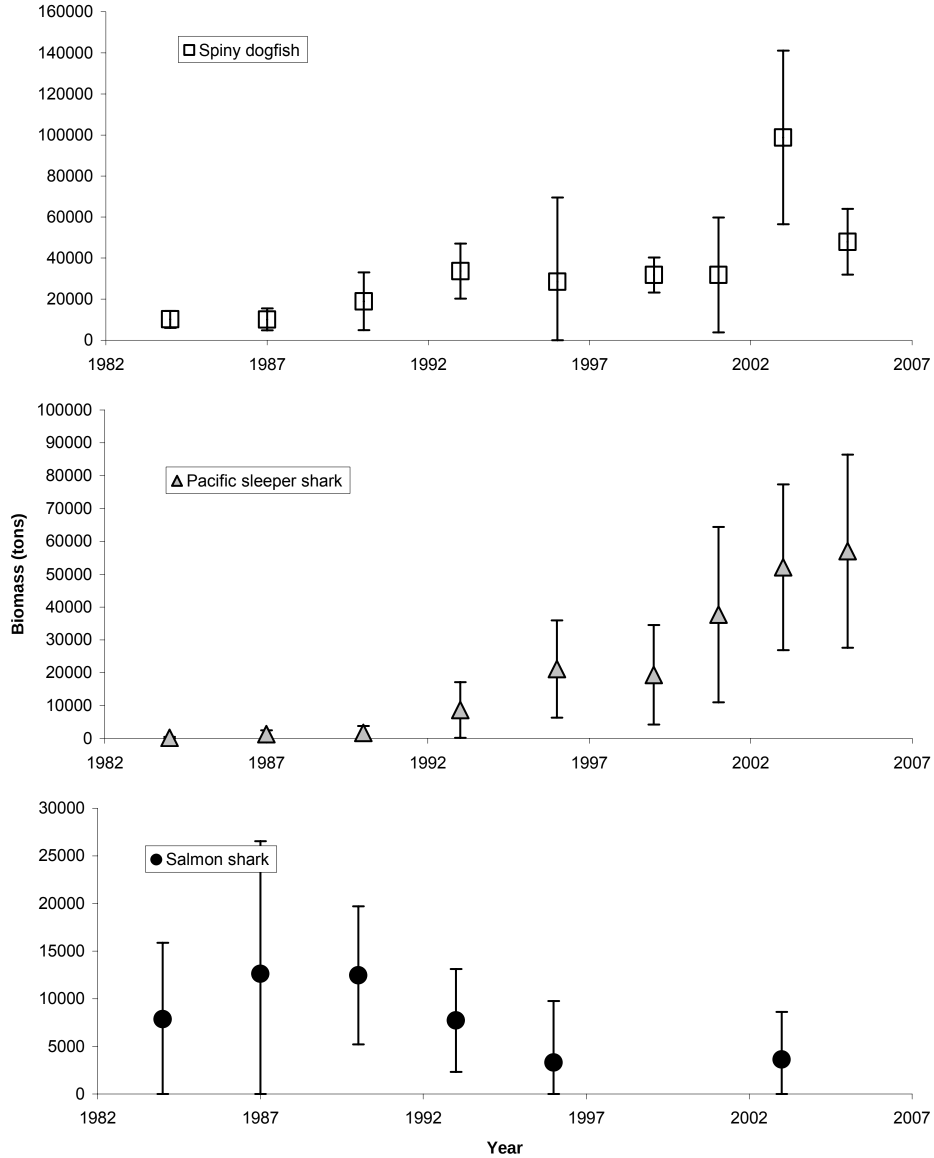
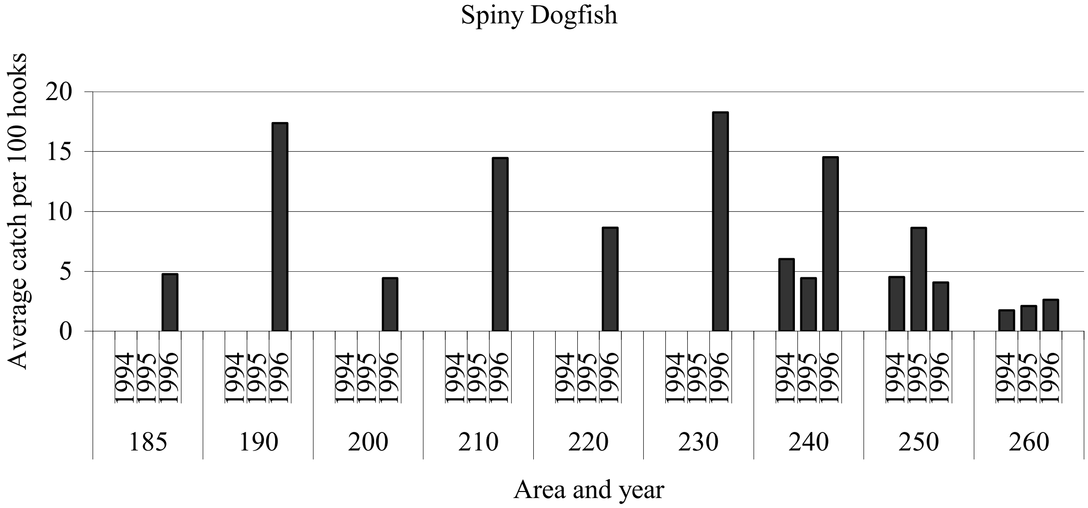


Figure 3. The statistical areas for NMFS observer data in the Gulf of Alaska and salmon shark incidental in the GOA from 1990-1996 using a pseudo-blend catch estimation procedure (Gaichas et al. 1999) and from 1997-2002 using the improved pseudo-blend catch estimation procedure (Gaichas 2002).



Source: Gaichas et al. (1999, Figure 3) updated May 14, 2004. (Pers. Comm. Michael Martins).

Figure 4. Trends in Gulf of Alaska AFSC bottom trawl survey estimates of individual shark species total biomass (mt) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of GOA biomass trends are subject to the following caveats regarding the consistency of the survey time series. Survey efficiency in the GOA may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Gaichas et al. 1999). Surveys in 1984, 1987, and 1999 included deeper strata than the 1990 - 1996 surveys; therefore the biomass estimates for deeper-dwelling species are not comparable across years. The 2001 survey did not include all areas of the Eastern GOA and consequently, the 2001 survey may not be comparable with the other surveys for species such as spiny dogfish which appear to be relatively abundant in the Eastern GOA.



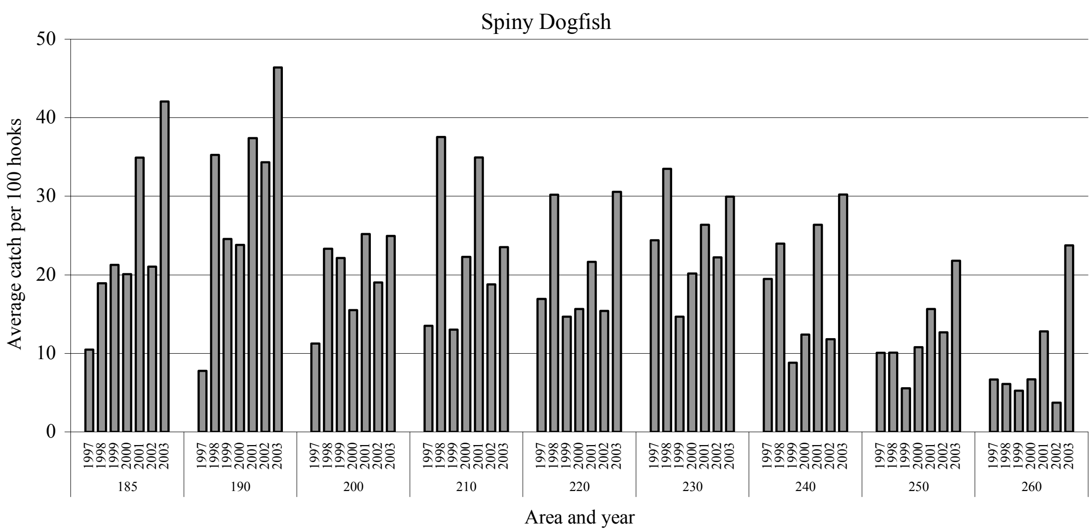
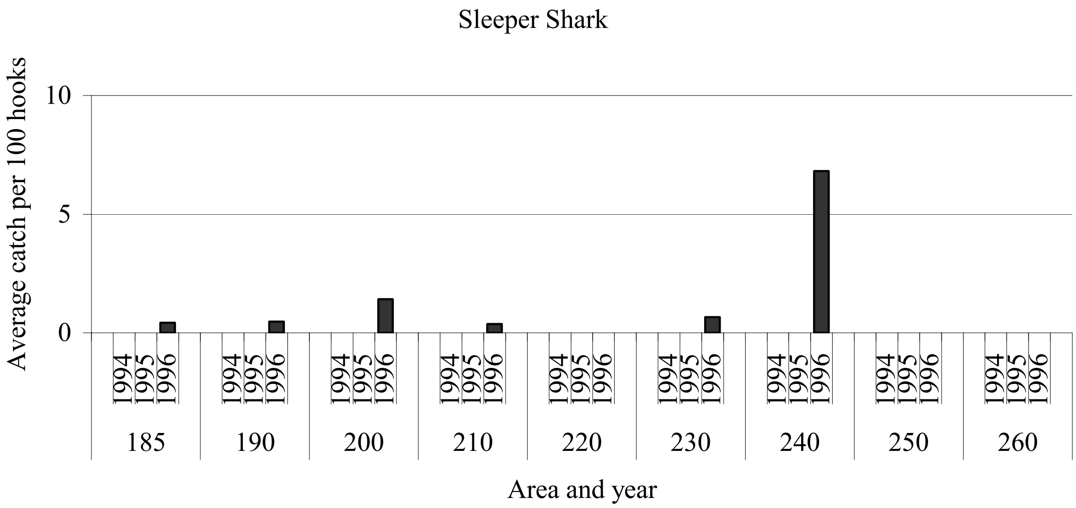


Figure 5. The statistical areas for IPHC survey data in the Gulf of Alaska and spiny dogfish incidental in the GOA as recorded in the IPHC survey data from two time series; the first from 1990 to 1996 and the second from 1997-2003. Areas 185-230 not sampled in 1994 or 1995.



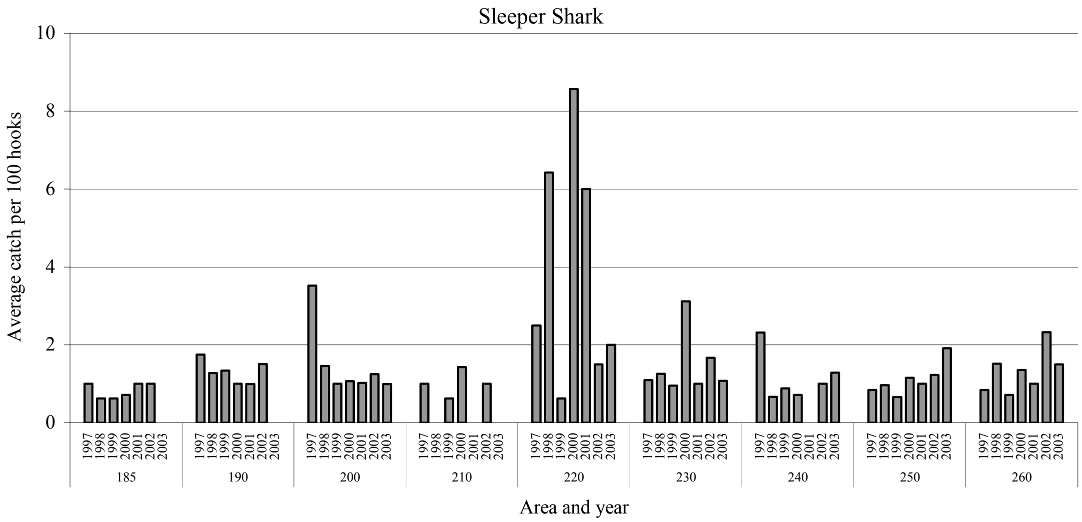


Figure 6. The statistical areas for IPHC survey data in the Gulf of Alaska and Pacific sleeper shark incidental catch in the GOA as recorded in the IPHC survey data from two time series; the first from 1990 to 1996 and the second from 1997-2003. Areas 185-230 not sampled in 1994 or 1995.

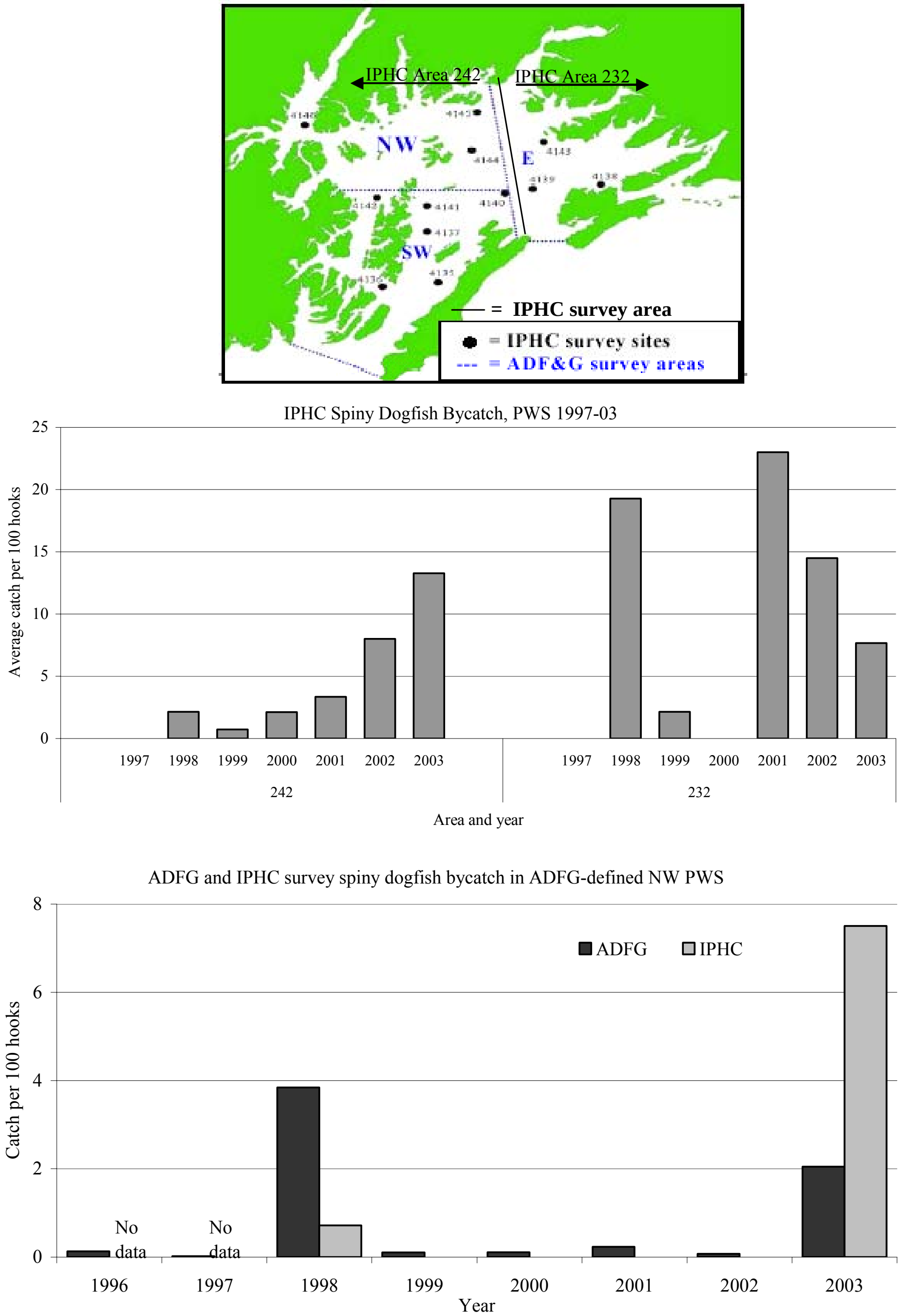
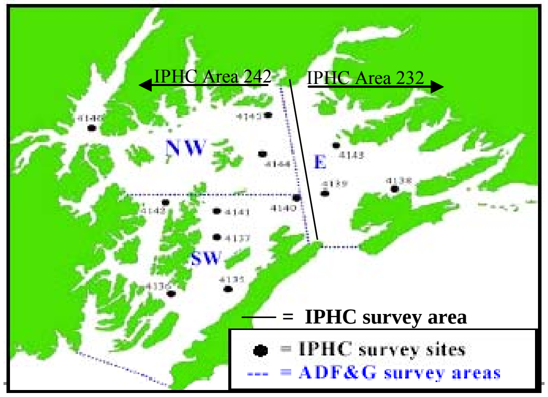
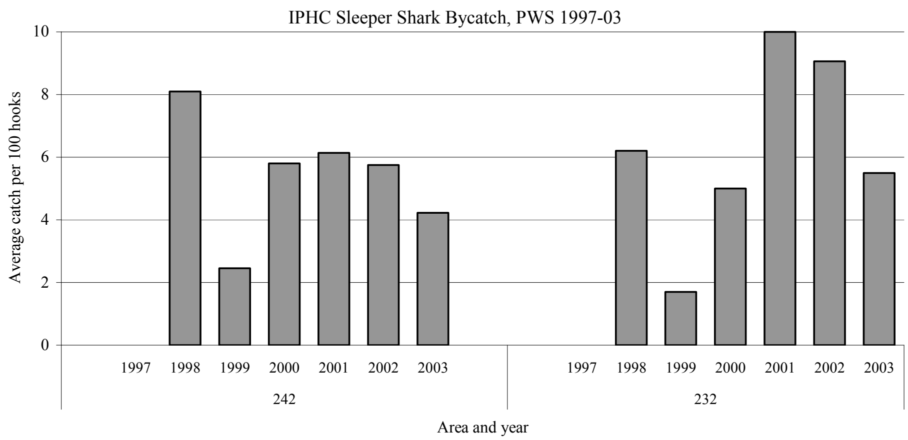


Figure 7. The statistical areas for IPHC survey data and ADFG survey data in Prince William Sound and spiny dogfish incidental catch in PWS as recorded in the IPHC and ADFG surveys from 1996 to 2003.





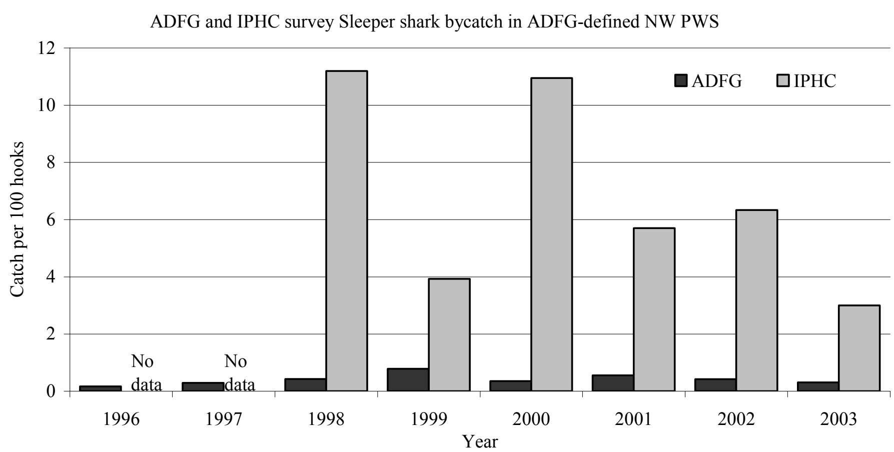


Figure 8. The statistical areas for IPHC survey data and ADFG survey data in Prince William Sound and sleeper shark incidental catch in PWS as recorded in the IPHC and ADFG surveys from 1996 to 2003.

Appendix A – Gulf of Alaska Spiny Dogfish Natural Mortality

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

Appendix A - Table 1

	Source	Equation	Variables and Inputs	M est (range)
1	Petersen & Wroblewski 1984	$M=1.92W_\infty^{-0.25}$	W_∞=4.798 (1.807, 11.093 95% CI)	1.318(1.078-1.666)
2	Pauly 1980 (1), length	$lnM=-0.0152-0.279ln(TL_{ext\infty})+0.6543ln\kappa+0.4634lnT$	$TL_{ext\infty}$=101.48 (98.694, 104.129 95% CI), κ=0.060 (0.056, 0.066 95% CI), T=6.65°C	0.104(0.103-0.104)
3	Pauly 1980 (2) weight	$lnM=-0.4852-0.0824ln(W_\infty)+0.6757ln\kappa+0.4627lnT$	W_∞=4.798 (1.807, 11.093 95% CI), κ=0.060 (0.056, 0.066 95% CI), T=6.65°C	0.194(0.181-0.211)
4	Hoenig 1983	$M=e^{1.44-0.982ln(tmax)}$	t_{max}=107 years	0.043
5	Alverson & Carney 1975	$M=3\kappa/(e^{0.38\kappa tmax}-1)$	κ=0.060 (0.056, 0.066 95% CI), t_{max}=107 years	0.017(0.015-0.019)
6	Jensen 1996 (1)	$M=1.65/t_{50\%mature}$	$t_{50\%mature}$=35.5 (35, 35.9 95% CI)	0.046(0.046-0.047)
7	Jensen 1996 (2)	$M=1.5\kappa$	κ=0.060 (0.056, 0.066 95% CI)	0.090(0.084-0.099)
8	Jensen 1996 (3)	$M=1.6\kappa$	κ=0.060 (0.056, 0.066 95% CI)	0.096(0.090-0.105)
9	Gunderson & Dygert 1988 (1)	*M=0.03+1.68GSI, GSI=ovary weight/eviscerated weight*	*GSI*=0.010-0.096	0.097(0.047-0.191)
10	Gunderson & Dygert 1988 (2)	*M=0.03+1.68GSI, GSI=ovary weight/whole weight*	*GSI*=0.007-0.073	0.081(0.042-0.153)
11	Gunderson & Dygert 1988 (3)	*M=0.03+1.68GSI, GSI=standardized ovary weight/eviscerated weight*	*GSI*=0.000857-0.00957	0.037(0.031-0.046)
12	Gunderson & Dygert 1988 (4)	*M=0.03+1.68GSI, GSI=standardized ovary weight/whole weight*	*GSI*=0.000581-0.00833	0.035(0.031-0.044)
13	Chen & Watanabe 1989	$M(t,t<t_m)=\kappa/(1-e^{-\kappa(t-t0)})$, $M(t,t\geq t_m)=\kappa/(a_0+a_1(t-t_m)+a_2(t-t_m)^2)$	κ=0.060 (0.056, 0.066 95% CI), t_{max}=107 years, a_0=0.881 (0.859, 0.906 95% CI), a_1=0.00713 (0.00788, 0.00617 95% CI), a_2=-0.00021 (-0.00022, -0.00020 95% CI)	0.108(0.064-1.033)

footnotes:

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

t_{max} actual observed maximum age from McFarlane, King and Bargmann AAAS 2004
$t_{50\%mature}$ from Saunders and McFarlane, 1993

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Appendix B – Salmon Shark Demographics

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Introduction

A demographic analysis of salmon sharks in the North Pacific is presented for consideration by the Plan Teams and SSC. Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific (WNP) and the eastern North Pacific (ENP) separated by the longitude of 180^o (Goldman and Musick 2006). Natural mortality was estimated independently from six methods and ranged from 0.2550 to 0.0908 for salmon sharks in the ENP (which includes the Gulf of Alaska) and from 0.2089 to 0.0968 for the WNP. The range of natural mortality estimates was incorporated into the demographic models as survivorship probability distributions. A relatively conservative approach was taken by setting the lowest and highest values from the six methods as lower and upper bounds for survivorship probability distributions.

Results of the demographic analysis presented here suggest that salmon shark populations in the ENP (including the Gulf of Alaska) and WNP are stable at this time. Estimates of salmon shark survivorship (natural mortality) by age class are presented in Table 1.

The effect of imposing additional fishing mortality (F) on salmon sharks in the ENP and WNP was considered by incorporating fishing mortality at F = 0.025 and increased F in steps of 0.025, stopping when the population could no longer remain at a stable or near-stable equilibrium. Estimates of salmon shark demographic parameters at values F of 0.0, 0.025, and 0. 05 are presented in Table 2. An examination of the stable age distributions when F was imposed showed minimal changes in the predicted stable age distributions (for both populations). If a fishery were to occur in the ANP, F should be kept below 0.025, as even that level of fishing mortality could push population parameter estimates below levels of stability. An F of 0.05 is clearly not sustainable based on these models. What follows is a portion of a manuscript submitted for peer review.

Methods

The Life-table Model

I used age-structured life-tables based on a yearly time step and a 2-year reproductive cycle (applied to only females) to model the demography of salmon sharks in the ENP and WNP. Monte Carlo simulation (n = 5,000) was used to incorporate uncertainty in demographic parameters and generate population growth rates (λ and r), generation time ($\overline{A}$), net reproductive rate (R_O), fertility, juvenile and adult elasticity, mean life expectancy, and population doubling or halving time. Due to differences in salmon shark life history parameter estimates and weight-at-length relationships between the ENP and WNP, separate demographic models were run for each area. I use the term "population" throughout this paper when referring to each area. This is not meant to infer that they are distinct populations or sub-populations (as this has not been demonstrated), but rather to distinguish between areas and models. Salmon shark life history parameters used for the ENP models are from Goldman and Musick (2006), and those used for the WNP models are from Tanaka (1980) and Nagasawa (1998).

To include uncertainty in parameter estimates, probability distributions were established for maximum age (ω), age at first reproduction (α), fecundity (m_x = # of female pups per female per year) and survivorship at age (S_x). The maximum age of salmon sharks appears to be very similar in the ENP and WNP, so 20 to 30 years of age was used for both areas and was represented by a linearly decreasing distribution scaled to a total relative probability of 1. Female salmon shark age at first maturity has been estimated at 6 to 9 in the ENP (Goldman and Musick 2006) and 8 to 10 in the WNP (Tanaka 1980, Nagasawa 1998). Age at first reproduction is required for the model, hence 7 to 10 years of age was used for the ENP and 9 to 11 years was used for the WNP. With no available information to specify any given age at first maturity as the "most likely", uniform probability distributions were used for this parameter.

Salmon sharks are thought to mate in late summer and early fall and have roughly a 9-month gestation period (Tanaka 1980, Goldman and Human 2004). The functional ovary in all mature females I examined (n = 55) in late summer and early fall in Prince William Sound, Alaska, appeared to be in a resting stage with small ovarian follicles (or in a postpartum condition). This indicates that salmon sharks (like several of the other lamniforms) possess a 2-year reproductive cycle.

Litter size of WNP salmon sharks has been reported to be between three and five, with a sex ratio of 2.2 males per female (Tanaka 1980). (Males are also the dominant sex in the WNP, while females are the dominant sex in the ENP – see Goldman and Musick 2006). There are no data on the litter size of ENP salmon sharks or the sex ratio of litters. However, females on both sides of the Pacific reach similar maximum lengths, therefore I assumed total fecundity (number of sharks per litter) to be the same. I did not, however, assume the same sex ratio for ENP salmon sharks. With no data available on the sex ratio of ENP salmon shark litters, I chose to use a 1:1 ratio. A 1:1 ratio tends to be more common in vertebrates, and ENP salmon sharks pup in a different location than those in the WNP (Goldman and Musick 2006) giving less reason to assume the same sex ratio amongst litters. I represented total fecundity for the ENP and WNP as normal distributions ranging between three and five with a standard error of 30% of the mean and used the minimum and maximum litter size to bound the distribution. This decision was in accordance with Cortés' (2002) observations that the standard deviation of the mean litter size in elasmobranch fishes ranged between 20 and 40% and, as such, he used a standard error of 30% when the value was not reported in the literature. Female-specific fecundity (m_x; # of females per female per year) was obtained by dividing the total number of offspring in a litter by the reproductive cycle in years accounting for the sex ratio of litters. For the ENP, this meant simply dividing by 4 to obtain the number of females per female per year, while for WNP it meant dividing by 6.4 to account for the 2.2:1 sex ratio of pups in a litter.

There are several methods available for estimating natural mortality (M), and hence survivorship ($S = e^{-M}$). I estimated the probability of annual survival at the beginning of each age using the following six life-history methods following Cortés (2002): 1) Hoenig (1983), 2) Pauly (1980), 3) Chen and Watanabee (1989), Peterson and Wrobleski (1984), and 5 and 6) Jensen (1996). Although method 4 uses dry weight, wet weight has been shown to yield more realistic estimates of survival for sharks (Cortés 2002 and pers. comm.).

I used a relatively conservative approach when setting probability distributions for survivorship. I used the lowest and highest values from the six methods as lower and upper bounds for setting survivorship probability distributions. The first five age classes (ages 0 to 4; < 1.5 m PCL) were represented by uniform distributions, as there are no data that would give reason to suspect that one estimate is more realistic than another. For ages five to 30 (> 1.5 m PCL), I assumed that survivorship would tend to be at the higher end of the distribution than the lower end because of their larger size, so I used a linearly ascending distribution scaled to a total relative probability of 1. This made the higher estimate of survivorship twice as likely to occur in model simulations.

Annual population growth rates ($\lambda = e^r$) were obtained by iteratively solving the discrete form of the Lotka-Euler equation (Goodman, 1982, Roff 1982):

$$1 = \sum_{x=1}^{\omega} e^{-rx} l_x m_x$$

where l_x is the probability of an individual being alive at the beginning of age x , m_x is the number of female offspring produced annually by a female at age x, and ω is maximum age. Generation time ($\overline{A}$) was calculated as

$$\overline{A} = \sum_{x=1}^{\omega} e^{-rx} x l_x m_x$$

which is the mean age of the parents of the offspring produced by a population at the stable age distribution (Caswell 2001).

The reproductive value distribution (v_x) was obtained through

$$\frac{v_x}{v_o} = \frac{e^{r(x-1)}}{l_x} \sum_{j=x}^{\omega} e^{-rx} l_x m_x$$

where v_o is the reproductive value at birth (which is equal to one), and j denotes all the ages a female will pass through from x to ω (Goodman 1982, Ebert 1999, Cortés 2002).

The stable age distribution (c_x) was obtained through

$$c_x = \frac{e^{-rx} l_x}{\sum_{x=1}^{\omega} e^{-rx} l_x}$$

The reproductive value and stable age distribution columns were used to calculate elasticities following Caswell (2001) and Cortés (2002) as

$$e_{ij} = \frac{a_{ij}}{\lambda} \frac{v_i \; w_j}{\langle w, v \rangle}$$

where a_{ij} is the element corresponding to row i of column j (survivorship), v_i is the value of row i in the reproductive value column (v_x), w_j is the value of row j in the stable age distribution column (c_x), and $\langle w, v \rangle$ is the scalar product of row elements in the w (c_x) and v (v_x) distributions. I calculated elasticities for age zero survival (fertility), juvenile survival and adult survival by summation of elasticity elements across relevant age classes, which may present viable management options.

The mean life expectancy was obtained by

$$\overline{X}_{Life\ Expectancy} = \frac{1}{-\ln\left(\sum_{x=0}^{\omega} P_x\right)}$$

where P_x is the mean survivorship of the probability distribution for age x (Lawless 1982).

The net reproductive rate (R_o) was obtained by

$$R_o = \sum_{x=0}^{\omega} l_x m_x$$

Population halving ($t_{\frac{1}{2}} = \frac{\ln 0.5}{r}$) and doubling ($t_2 = \frac{\ln 2}{r}$) times were calculated from the mean instantaneous rate of population growth (r) from model simulations.

The uncertainty in demographic traits (age specific survival and fecundity, age at first reproduction and maximum age) was randomly selected from each trait's probability distribution during Monte Carlo simulation. Ninety-five percent confidence intervals for each parameter were obtained from the 2.5th and 97.5th percentiles.

Density-Dependent Compensation

As with all life-tables, the above model is a density-independent model. To allow for density-dependent compensation (for a given level of F) due to the changes in mortality of fished ages, I used the predicted net increase in sub-adult survivorship from Au and Smith's (1997 – also see Smith et al. 1998) 'intrinsic rebound potential' model. This model provides, as output, a prediction of the net increase in pre-adult survivorship needed for a population to 'rebound' back to stationary equilibrium (r = 0) when a given level of F is imposed (and assumes r = 0 before F begins and that Z [= M+F] is sustainable).

The Au and Smith (1997) model solves for 'r' using a variant of the Lotka-Euler equation (See Au and Smith 1997 or Smith et al. 1998 for details of converting the Lotka-Euler equation given above to):

$$e^{-(M+r)} + l_{\alpha}\, b\, e^{-(r\alpha)}[1 - e^{-(M+r)(\omega-\alpha+1)}] = 1$$

where l_α = the net increase in sub-adult survivorship (from age 0 to age at first reproduction, α), and b = fecundity (females per female per year). Setting r = 0, changing M to the total level of mortality Z with $l_\alpha = l_{\alpha,Z}$ and solving for l_α, the solution to the above equation is:

$$l_{\alpha,z} = \frac{1-e^{-z}}{b[1-e^{-(z)(\omega - \alpha + 1)}]}$$

where $l_{\alpha,z}$ = the predicted net increase in sub-adult survivorship at a given level of Z.

I used Monte Carlo simulation (n = 5,000) to incorporate uncertainty in demographic parameters and generate estimates of l_α. I then evenly distributed the net increase in l_α, between when F = 0 and when a given level of F was present, amongst the sub-adult age classes in the life-table model and ran Monte Carlo simulations with F and the l_α 'factor' included. Survivorship was accordingly increased (compensation included) for ages zero through six in the ENP life-table model and for ages zero through eight in the WNP life-table model.

All simulations (life-table and intrinsic rebound potential) were implemented with Microsoft Excel spreadsheet software equipped with proprietary add-in risk assessment (Crystal Ball, Decisioneering Inc., Denver, CO) and Microsoft Visual Basic for Applications.

Fishing Mortality Scenarios

I examined the effect of fishing mortality (F) on salmon sharks in the ENP and WNP considering only scenarios that would be the most likely to occur if a sizeable commercial fishery began in either area. I started models that incorporated fishing mortality at F = 0.025 and increased F in steps of 0.025, stopping when the population could no longer remain at a stable or near-stable equilibrium (i.e. when compensation predicted by the Au and Smith (1997) model would no longer keep vital rates stable).

Eastern North Pacific

Salmon sharks are taken in U.S. waters (particularly Alaska) as incidental catch in trawl, gillnet, and seine fisheries, but this catch has been poorly documented (Camhi, 1999). There is currently no directed commercial fishery for salmon sharks in the ENP, but a small recreational fishery exists along Alaska's central coastline (the Gulf of Alaska, GOA, and in Prince William Sound, PWS). If commercial fishing began for salmon sharks in the ENP it would be in the central GOA and in PWS where large aggregations are commonly found, particularly during the summer months. Salmon sharks younger than five years of age have not been taken from GOA or PWS waters (Goldman and Musick 2006), as small salmon sharks (< 5 years of age) range between northern Baja, Mexico, and southeast Alaska. Additionally, small salmon sharks are not commonly taken as incidental catch in other fisheries, so it is unlikely that a fishery could be developed for them. The large overlap in length-at-age along with the fact that the purse seines and surface long-lines would probably be the primary gear of a fishery, makes it highly unlikely that a size-selective fishery could be developed in Alaska waters. Therefore, the fishing scenarios I used for the ENP included ages 5 to 30.

Results

Natural mortality estimates from the six methods used ranged from 0.2550 to 0.0908 for salmon sharks in the ENP and from 0.2089 to 0.0968 for the WNP. Minimum and maximum age-specific survivorships (P_x) for the ENP are given in Table 1. The Hoeing (1983) method predicts the average natural mortality for the whole population (relative to ω), and as such, consistently provided the highest survivorship values for ages zero through two in all models. The Peterson and Wrobleski (1984) method, which is weight-length based, consistently produced the highest survivorship values for ages three through 30 in all models. For ENP salmon sharks, the Jensen 'K' (1996) method produced the lowest estimates of survivorship, while the Hoeing (1983) method produced the lowest survivorship estimates for the WNP population.

The results of initial life-table model simulations (with F = 0) indicate that the salmon shark population in the ENP is slowly increasing at a rate of almost 1.2 % per year with a doubling time of 59.2 years (Table 2). In contrast, the results for the WNP population indicate it is decreasing at a rate of just over 2 % per year with a halving time of 29.6 years. While the mean results of the models indicate the ENP population is growing, the 95 % confidence bands show the variability (from uncertainty) of parameter inputs and indicate that under the conditions used in the model, that this range might be as high as 4.1 % per year or that the population could be slightly decreasing as a rate of 1.5 % per year (Table 2). Confidence bands for '*r*' in the WNP indicate that this population may be decreasing between 0.65 % and 3.8 % per year (Table 2). Deterministic estimates of '*r*' conducted with the Solver function in Microsoft Excel show that age at first reproduction accounted for a greater amount of variation in '*r*' than maximum age. Mean generation time and life expectancy were slightly higher for the WNP population (Table 2). Summed elasticites were largest for juveniles (followed by adult age groups and then young of the year) indicating that an increase in their mortality would have the largest effect on population growth rates in both populations (Table 2).

The predicted stable age distributions in the ENP and WNP were dominated by the first six age classes. The young-of-the-year comprised approximately 21 % of the ENP population and 15 % of the WNP population with the next five age classes comprising another 58 % of the ENP population and 52 % of the WNP population. The older age classes appear to contribute slightly more to the stable age distribution in the WNP than in the ENP. An examination of the stable age distributions when F was imposed showed minimal changes in the predicted stable age distributions (for both populations).

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Table 1. Salmon shark survivorship (S) and natural mortality (M; $S = e^{-M}$) estimates in the absence of fishing mortality (F = 0.0) by age class.

	F = 0			
	Survivorship (S)		Natural mortality (M)	
Age x	Minimum	Maximum	Maximum	Minimum
0	0.775	0.87	0.255	0.139
1	0.775	0.87	0.255	0.139
2	0.775	0.87	0.255	0.139
3	0.775	0.878	0.255	0.130
4	0.775	0.886	0.255	0.121
5	0.775	0.892	0.255	0.114
6	0.775	0.896	0.255	0.110
7	0.775	0.899	0.255	0.106
8	0.775	0.902	0.255	0.103
9	0.775	0.904	0.255	0.101
10	0.775	0.906	0.255	0.099
11	0.775	0.907	0.255	0.098
12	0.775	0.908	0.255	0.097
13	0.775	0.909	0.255	0.095
14	0.775	0.91	0.255	0.094
15	0.775	0.91	0.255	0.094
16	0.775	0.911	0.255	0.093
17	0.775	0.911	0.255	0.093
18	0.775	0.912	0.255	0.092
19	0.775	0.912	0.255	0.092
20	0.775	0.912	0.255	0.092
21	0.775	0.913	0.255	0.091
22	0.775	0.913	0.255	0.091
23	0.775	0.913	0.255	0.091
24	0.775	0.913	0.255	0.091
25	0.775	0.913	0.255	0.091
26	0.775	0.913	0.255	0.091
27	0.775	0.913	0.255	0.091
28	0.775	0.913	0.255	0.091
29	0.775	0.913	0.255	0.091
30	0.775	0.913	0.255	0.091

Table 2. Salmon shark demographic parameters under fishing mortality (F) of 0, 0.025, and 0.05 starting age 0 or 5 for the western North Pacific (WNP) and eastern north Pacific (ENP, which includes the Gulf of Alaska).

F (starts at age) ENP	λ	r	$\bar{A}$	Ro	Mean Life Expectancy
0	1.012 (0.985-1.042)	0.0117 ([-0.0151]-0.0412)	13.1 (11.4-15.0)	1.2 (0.8-1.6)	5.9 (5.4-6.5)
0.025 (5)	1.003 (0.975-1.035)	0.0033 ([-0.0251]-0.0342)	12.9 (11.2-14.7)	1.0 (0.7-1.5)	5.4 (4.9-5.8)
0.05 (5)	0.995 (0.966-1.029)	-0.0047 ([-0.0052]-0.0282)	12.6 (10.9-14.4)	0.9 (0.6-1.4)	4.9 (4.6-5.3)
WNP					
0	0.977 (0.962-0.994)	-0.0234 ([-0.0385]-[-0.0065])	14.9 (13.0-16.7)	0.7 (0.6-0.9)	6.6 (6.1-7.0)
0.025 (0)	0.959 (0.945-0.975)	-0.0416 ([-0.0568]-[-0.0255])	14.8 (12.9-16.5)	0.5 (0.4-0.7)	5.7 (5.4-6.1)
0.025 (5)	0.967 (0.952-0.984)	-0.0331 ([-0.488]-[0.0161])	14.7 (12.8-16.3)	0.6 (0.4-0.8)	5.9 (5.5-6.2)
WNP if m_x=1:1					
0	1.009 (0.992-1.027)	0.0088 ([-0.0084]-0.0271)	14.5 (12.5-16.0)	1.1 (0.9-1.5)	6.6 (6.1-7.0)
0.025 (0)	0.991 (0.975-1.009)	-0.0093 ([-0.0258]-0.0091)	14.4 (12.5-15.9)	0.9 (0.7-1.1)	5.7 (5.4-6.1)
0.025 (5)	1.000** (0.982-1.020)	-0.0005 ([-0.179]-0.195)	14.3 (12.4-15.7)	1.0* (0.8-1.3)	5.9 (5.5-6.2)
	** = 0.9995			* = 0.997	

	Elasticities			Population
ENP	Fertility	Juvenile	Adult	doubling time
0	7.1 (6.2-8.1)	56.8 (53.4-60.2)	36.1 (33.1-39.1)	59.2
0.025 (5)	7.3 (6.4-8.2)	57.7 (54.4-61.0)	35.0 (32.0-38.0)	210.0
0.05 (5)	7.4 (6.5-8.3)	58.6 (55.3-61.8)	34.0 (31.1-36.9)	-147.5
WNP				
0	6.3 (5.6-7.1)	59.3 (56.3-62.3)	34.4 (31.3-37.7)	-29.6
0.025 (0)	6.3 (5.7-7.2)	59.6 (56.7-62.5)	34.1 (31.0-37.3)	-16.7
0.025 (5)	6.4 (5.8-7.3)	60.0 (57.1-62.8)	33.6 (30.7-36.7)	-20.9
WNP if m_x=1:1				
0	6.5 (5.9-7.4)	60.9 (58.2-63.5)	32.6 (29.9-35.6)	78.8
0.025 (0)	6.5 (5.9-7.4)	61.2 (58.5-63.9)	32.3 (29.5-35.1)	-74.5
0.025 (5)	6.6 (5.9-7.4)	61.6 (59.0-64.1)	31.8 (29.2-34.5)	-1,386.6

Appendix C – Salmon Shark Sport Harvest

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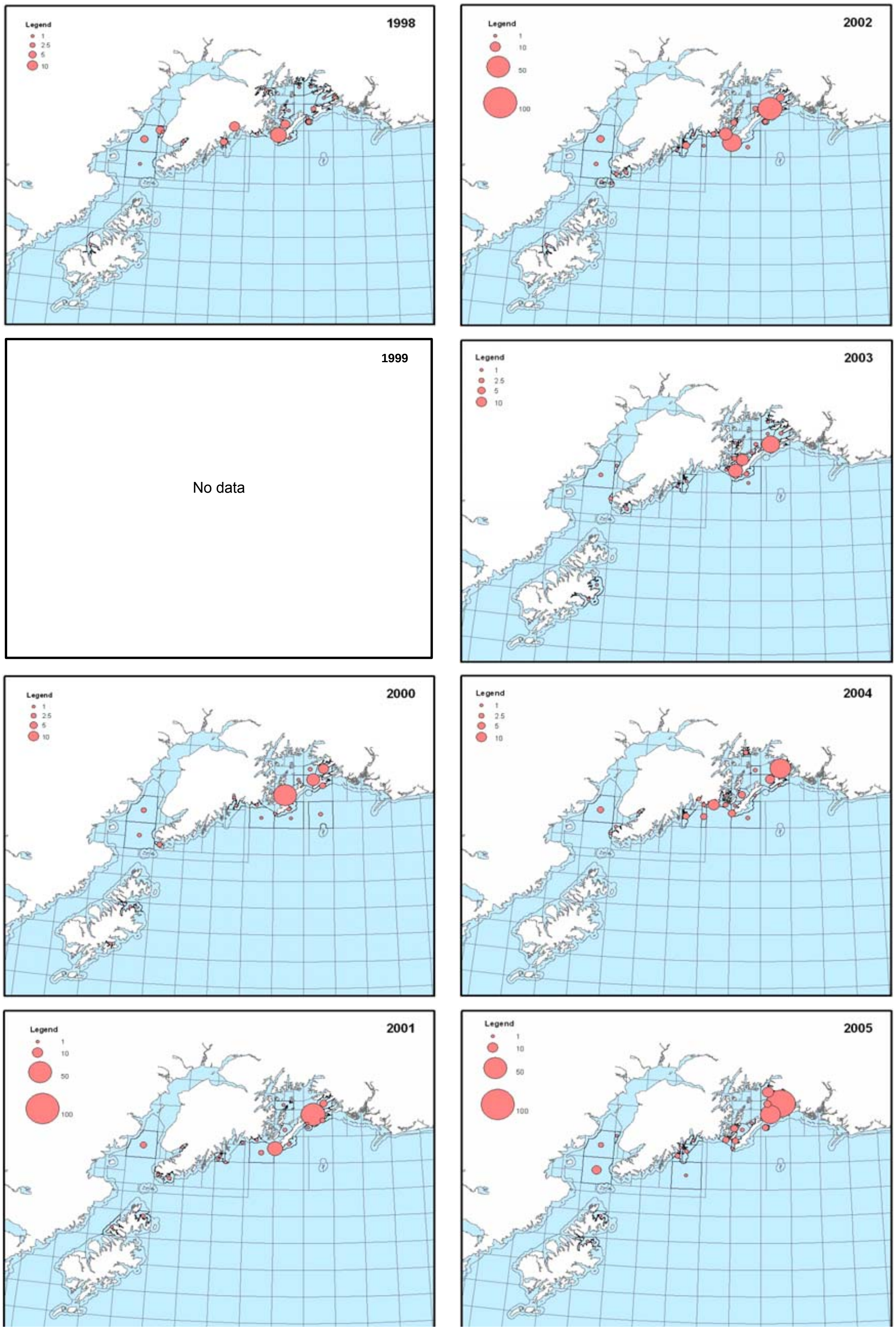
Updated numbers for 1998-2005 from program
SalmonSharkHarvDistrib_9805.sas. 9/12/06

Table 1. Number of salmon sharks harvested in the charter recreational fishery
by ADF&G Sport Fish management area, 1998-2005 (charter logbook data).

Year	Ak Pen.	Kodiak	Cook Inlet	North Gulf	PWS
1998	0	1	16	48	16
1999	nd	nd	nd	nd	nd
2000	0	2	8	58	37
2001	0	3	8	35	65
2002	0	1	13	50	86
2003	0	2	7	40	44
2004	0	0	7	36	63
2005	3	0	20	16	141

Distribution of Salmon Shark Charter Boat Harvest 1998-2005 (ADF&G charter logbook data)



Appendix D Calculating Incidental Catch of Sharks in the GOA from Unobserved Halibut Fisheries

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Incidental catches of sharks in the GOA (bycatch) originating from the unobserved Pacific halibut fishery is examined in this section. Methods for estimation of historical shark bycatch from the unobserved longline Pacific halibut fishery are outlined and bycatch estimates in numbers are provided for the years 1997 – 2004 for spiny dogfish, Pacific sleeper shark, salmon shark, and other/unidentified sharks. Catch in mt is estimated for spiny dogfish, Pacific sleeper shark, and salmon shark by multiplying catch in numbers by our best estimate of average weight in kg for these species.

International Pacific Halibut Commission (IPHC) survey data was used to estimate shark bycatch. For each survey haul from 1997 to 2004 catch per unit of effort (CPUE) was calculated for each shark species or species group. The overall CPUE by statistical area aggregation/depth stratum was calculated as a mean of all CPUE's in a statistical area aggregation/depth stratum. A coefficient of variation (CV) was calculated for each overall CPUE. It is assumed that the CPUE and CV from the observed survey are representative of unobserved commercial Pacific halibut fisheries. This assumption likely results in biased bycatch estimates for the commercial fishery as it assumes commercial fishing would continue at the same rate as the survey in areas with high bycatch. However, in practice, commercial fishing would likely not continue in the presence of high bycatch, but rather would move to a new location with lower bycatch. As a consequence these bycatch estimates should be considered a conservatively high estimate of shark bycatch in the commercial fishery. A 95% confidence interval (for CPUE) was calculated by calculating the 2.5th and 97.5th quantile of a lognormal distribution based on the CPUE and CV.

Gaichas et al. (2005) applied the overall catch rates for the skate complex (longnose, big, and *Bathyraja* skates) to the number of hooks retrieved to estimate the skate bycatch in the GOA halibut fishery. The same methodology is followed in this analysis.

The IPHC provided logbook information and total fish ticket landings information for combinations of IPHC stat areas/depth stratum in the GOA (statistical areas and depth strata are in Table 1). Due to confidentiality restrictions logbook data was unavailable for individual statistical areas in which less than three vessels operated; in such cases logbook and landing information was grouped. Groupings provided by the IPHC are based on geography/proximity (Fig 1).

Total effective hooks were calculated for each IPHC stat area/depth stratum aggregation based on scaling the number of effective hooks fished per pounds of halibut landed from logbook entries to the amount of total landed halibut in each stat area/depth stratum aggregation. Estimated total shark bycatch was calculated by multiplying the CPUE by area combination/ depth stratum by the total effective hooks in each area combination/ depth stratum. Confidence intervals (95%) were calculated by multiplying the confidence interval (from the CPUE calculation) by the total effective hooks in each area combination/ depth stratum.

Spiny Dogfish

Estimated bycatch of Pacific sleeper sharks (in numbers) from Pacific halibut fishery are shown in Table 1. Total dogfish bycatch in kilograms was calculated by assuming a sex ratio of 1:1 (F:M) multiplying with the average weight for males and females combined (2.3 kg) from NMFS spiny dogfish longline tagging cruises during 2005.

Pacific sleeper sharks

Estimated bycatch of Pacific sleeper sharks (in numbers) from Pacific halibut fishery are shown in Table 2. Total Pacific sleeper shark bycatch in kilograms was calculated by multiplying catch in numbers with the observed sex ratio 1.5:1 (F:M) and average weight of males (69.7 kg) and females (74.8 kg) from NMFS longline studies of Pacific sleeper shark diet in the Gulf of Alaska (Sigler et. al 2006).

Salmon Sharks

Estimated bycatch of salmon sharks (in numbers) from Pacific halibut fishery are shown in Table 3. Total salmon shark bycatch in kilograms was calculated by multiplying catch in numbers with the observed sex ratio 10.4:1 (F:M) and average weight of males (116.7 kg) and females (146.9 kg) from Goldman and Musick (2006).

Other / Unidentified Sharks

Estimated bycatch of other/ unidentified sharks (in numbers) from Pacific halibut fishery are shown in Table 4. Total other/ unidentified shark bycatch in kilograms was not calculated because the sex ratio and average weight of other/ unidentified sharks is unknown. Breakdowns by statistical areas are shown in Tables 5 – 8.

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Table 1. Spiny dogfish bycatch in Pacific halibut fisheries.

Year	(1,000's)	95% LCI	95% UCI	(t)	95% LCI	95% UCI
1997	565	398	776	1,299	916	1,784
1998	873	646	1,177	2,008	1,487	2,707
1999	419	252	678	963	579	1,560
2000	468	310	691	1,076	714	1,590
2001	927	696	1,220	2,131	1,602	2,805
2002	552	359	842	1,270	826	1,936
2003	1,227	849	1,763	2,823	1,954	4,054
2004	710	490	1,024	1,633	1,129	2,356

Table 2. Pacific sleeper shark bycatch in Pacific halibut fisheries.

Year	(1,000's)	95% LCI	95% UCI	(t)	95% LCI	95% UCI
1997	42	18	96	3,063	1,317	6,962
1998	66	31	159	4,823	2,291	11,574
1999	86	48	172	6,249	3,499	12,498
2000	88	48	186	6,394	3,477	13,567
2001	127	81	230	9,210	5,907	16,717
2002	133	82	237	9,661	5,994	17,248
2003	116	68	252	8,468	4,961	18,310
2004	104	61	202	7,558	4,445	14,731

Table 3. Salmon shark bycatch in Pacific halibut fisheries.

Year	(#'s)	95% LCI	95% UCI	(t)	95% LCI	95% UCI
1997	760	107	5,394	110	15	778
1998	387	82	1,997	56	12	288
1999	16	2	112	2	0	16
2000	578	101	3,535	83	15	510
2001	135	19	959	19	3	138
2002	186	26	1,318	27	4	190
2003	243	34	1,727	35	5	249
2004						

Table 4, Other/unidentified shark bycatch in Pacific halibut fisheries.

Year	(#'s)	95% LCI	95% UCI	(t)	95% LCI	95% UCI
1997	3,116	632	17,947	NA		
1998	599	84	4,250	NA		
1999	757	107	5,371	NA		
2000	0					
2001	757	166	3,695	NA		
2002	5,272	1,413	23,147	NA		
2003	0					
2004	391	55	2,776	NA		

Table5. Spiny dogfish bycatch in Pacific halibut fisheries by region.

Estimated Numbers of individual dogfish caught in Pacific Halibut fisheries

Year		Statistical Area Combination 140/141/142/144/150/151	143/152/153	160/170	161/162/163	171/174	181/182/184	185-220
1997	**Bycatch (numbers)**	**15,322**	**10,108**	**33,479**	**9,634**	**0**	**0**	**4,056**
	Lower (5%) quantile	9,263	4,217	18,621	550	0	0	475
	Upper (95%) quantile	23,655	19,546	54,273	14,756	0	0	12,743
1998	**Bycatch (numbers)**	**25,623**	**24,039**	**31,009**	**3,859**	**0**	**822**	**44,238**
	Lower (5%) quantile	18,496	12,526	17,243	924	0	96	13,891
	Upper (95%) quantile	34,414	40,609	50,236	9,696	0	2,583	98,756
1999	**Bycatch (numbers)**	**23,560**	**43,373**	**28,829**	**3,636**	**0**	**1,324**	**27,537**
	Lower (5%) quantile	15,083	15,216	11,861	1,382	0	354	5,161
	Upper (95%) quantile	34,756	91,746	56,521	7,467	0	3,175	75,553
2000	**Bycatch (numbers)**	**34,961**	**37,132**	**29,690**	**1,692**	**0**	**408**	**12,538**
	Lower (5%) quantile	21,260	15,479	17,700	198	0	48	2,663
	Upper (95%) quantile	53,807	71,907	45,918	5,315	0	1,281	32,763
2001	**Bycatch (numbers)**	**37,619**	**57,873**	**55,851**	**5,015**	**0**	**0**	**2,079**
	Lower (5%) quantile	27,740	38,597	31,291	964	0	0	145
	Upper (95%) quantile	49,939	82,308	90,892	13,699	0	0	3,887
2002	**Bycatch (numbers)**	**19,778**	**6,244**	**35,702**	**3,490**	**0**	**0**	**27,832**
	Lower (5%) quantile	12,894	3,022	18,683	779	0	0	3,782
	Upper (95%) quantile	28,689	11,211	60,291	9,134	0	0	83,402
2003	**Bycatch (numbers)**	**21,963**	**11,452**	**57,419**	**0**	**0**	**614**	**105,012**
	Lower (5%) quantile	13,109	4,694	36,592	0	0	72	28,725
	Upper (95%) quantile	34,202	22,444	84,470	0	0	1,930	250,288
2004	**Bycatch (numbers)**	**21,612**	**8,437**	**6,712**	**2,731**	**0**	**0**	**32,285**
	Lower (5%) quantile	11,513	3,718	3,399	684	0	0	6,004
	Upper (95%) quantile	35,981	15,831	11,807	6,873	0	0	89,314

Table 5. Continued.

Estimated Numbers of individual dogfish caught in Pacific Halibut fisheries

Year		Statistical Area Combination 230/232/240/242	250-261	270/280	271/281	290-310	320-340	350-400	Total GOA
1997	**Bycatch (numbers)**	**51,481**	**346,304**	**92,870**	**545**	**0**	**704**	**169**	**564,672**
	Lower (5%) quantile	36,207	270,594	57,567	318	0	310	67	398,191
	Upper (95%) quantile	70,856	437,972	139,443	854	0	1,318	334	775,752
1998	**Bycatch (numbers)**	**153,604**	**449,590**	**106,821**	**5,791**	**24,905**	**1,924**	**635**	**872,860**
	Lower (5%) quantile	121,960	364,138	83,156	3,840	8,470	1,347	325	646,412
	Upper (95%) quantile	192,363	548,164	134,570	8,368	53,562	2,636	1,185	1,177,142
1999	**Bycatch (numbers)**	**90,648**	**146,696**	**41,292**	**2,670**	**6,866**	**2,286**	**92**	**418,810**
	Lower (5%) quantile	61,496	109,224	27,076	1,850	1,860	1,015	23	251,600
	Upper (95%) quantile	131,293	193,666	59,597	3,689	16,410	4,260	229	678,363
2000	**Bycatch (numbers)**	**83,582**	**171,123**	**69,591**	**2,134**	**23,273**	**1,742**	**116**	**467,982**
	Lower (5%) quantile	62,099	127,234	52,057	981	9,934	777	28	310,458
	Upper (95%) quantile	112,421	225,124	90,722	3,894	44,462	3,236	287	691,137
2001	**Bycatch (numbers)**	**180,855**	**398,439**	**116,490**	**9,074**	**59,691**	**2,793**	**852**	**926,631**
	Lower (5%) quantile	148,012	317,132	92,410	5,780	31,890	1,963	463	696,387
	Upper (95%) quantile	221,377	495,016	144,453	13,561	99,282	3,814	1,402	1,219,630
2002	**Bycatch (numbers)**	**113,123**	**244,671**	**47,374**	**1,960**	**50,377**	**1,510**	**113**	**552,174**
	Lower (5%) quantile	83,627	187,765	30,245	1,378	16,226	846	13	359,259
	Upper (95%) quantile	149,869	312,487	70,099	2,709	111,104	2,430	355	841,780
2003	**Bycatch (numbers)**	**176,344**	**349,189**	**171,609**	**9,160**	**305,630**	**17,827**	**1,269**	**1,227,488**
	Lower (5%) quantile	140,071	292,730	138,790	6,212	180,804	7,035	662	849,495
	Upper (95%) quantile	221,465	413,690	209,358	12,862	474,491	35,471	2,143	1,762,816
2004	**Bycatch (numbers)**	**140,121**	**331,947**	**85,656**	**3,835**	**71,745**	**4,464**	**287**	**709,833**
	Lower (5%) quantile	105,861	260,303	64,999	1,982	29,663	2,402	128	490,655
	Upper (95%) quantile	182,545	417,743	110,270	6,802	139,182	7,385	534	1,024,268

Table 6. Pacific sleeper shark bycatch in Pacific halibut fisheries by region.

		Estimated Numbers of individual Pacific Sleeper Sharks Caught in Pacific Halibut fisheries														
		Statistical Area Combination														
Year		140/141/142/144/150/151	143/152/153	160/170	161/162/163	171/174	181/182/184	185-220	230/232/240/242	250-261	270/280	271/281	290-310	320-340	350-400	Total GOA
1997	**Bycatch (numbers)**	**329**	**986**	**29**	**15,179**	**2,193**	**503**	**5,673**	**5,195**	**2,299**	**1,218**	**0**	**7,177**	**906**	**389**	**42,077**
	Lower (5%) quantile	90	250	4	7,502	0	71	2,695	1,591	1,107	237	0	4,108	311	166	18,132
	Upper (95%) quantile	1,230	4,374	206	27,937	0	3,569	11,945	18,592	4,808	6,813	0	12,580	2,635	971	95,660
1998	**Bycatch (numbers)**	**68**	**1,041**	**0**	**6,011**	**2,301**	**822**	**4,080**	**22,590**	**3,362**	**2,542**	**6,915**	**11,619**	**4,048**	**920**	**66,319**
	Lower (5%) quantile	10	401	0	1,479	952	116	1,998	9,417	1,787	1,034	3,648	7,410	2,807	450	31,507
	Upper (95%) quantile	483	2,704	0	25,731	6,726	5,836	8,362	54,203	6,351	8,969	13,174	18,686	5,838	2,049	159,112
1999	**Bycatch (numbers)**	**0**	**1,297**	**331**	**6,352**	**8,104**	**2,186**	**2,752**	**11,770**	**2,355**	**2,625**	**16,777**	**22,084**	**7,954**	**1,342**	**85,930**
	Lower (5%) quantile	0	401	47	3,178	2,377	478	1,372	6,372	727	690	10,940	15,222	5,788	469	48,060
	Upper (95%) quantile	0	4,570	2,346	12,698	22,079	10,002	5,521	21,884	7,734	11,997	25,789	32,069	10,931	4,180	171,800
2000	**Bycatch (numbers)**	**330**	**983**	**910**	**3,463**	**5,406**	**1,019**	**3,312**	**22,287**	**5,905**	**2,929**	**7,822**	**25,993**	**6,533**	**1,042**	**87,935**
	Lower (5%) quantile	87	315	207	974	2,945	144	870	10,297	3,002	960	4,684	18,353	4,505	450	47,793
	Upper (95%) quantile	1,412	3,124	4,419	12,325	9,925	7,237	13,710	48,520	12,121	10,815	13,249	36,831	9,474	3,338	186,501
2001	**Bycatch (numbers)**	**230**	**0**	**873**	**2,618**	**2,596**	**0**	**1,804**	**29,438**	**5,180**	**4,882**	**8,649**	**50,500**	**17,271**	**2,520**	**126,561**
	Lower (5%) quantile	32	0	123	672	799	0	348	20,091	2,369	1,867	5,415	36,614	11,579	1,297	81,207
	Upper (95%) quantile	1,631	0	6,201	10,198	8,433	0	11,240	48,379	11,674	15,507	13,815	70,280	25,761	6,671	229,789
2002	**Bycatch (numbers)**	**460**	**1,908**	**1,074**	**2,713**	**2,869**	**0**	**1,420**	**20,422**	**4,932**	**1,156**	**5,863**	**66,385**	**21,143**	**2,454**	**132,799**
	Lower (5%) quantile	65	482	242	1,208	130	0	628	9,154	2,805	322	3,342	48,645	14,707	710	82,439
	Upper (95%) quantile	3,268	9,612	4,767	6,092	6,554	0	3,218	45,795	10,446	4,601	10,615	90,594	30,396	11,111	237,070
2003	**Bycatch (numbers)**	**184**	**587**	**0**	**5,771**	**1,403**	**461**	**869**	**9,999**	**3,339**	**1,437**	**2,838**	**54,160**	**24,441**	**10,880**	**116,369**
	Lower (5%) quantile	26	160	0	1,186	198	65	310	3,929	1,749	402	1,578	38,561	16,235	3,826	68,227
	Upper (95%) quantile	1,310	2,145	0	31,569	9,961	3,270	2,442	25,801	6,710	5,893	5,146	76,085	36,796	44,590	251,717
2004	**Bycatch (numbers)**	**0**	**750**	**429**	**781**	**3,446**	**0**	**490**	**14,497**	**1,171**	**1,948**	**6,748**	**47,462**	**22,786**	**3,360**	**103,868**
	Lower (5%) quantile	0	189	60	110	1,286	0	152	5,925	456	702	4,037	32,675	14,744	759	61,097
	Upper (95%) quantile	0	2,970	3,044	5,545	9,232	0	1,576	35,606	3,008	5,722	11,403	69,215	36,014	19,162	202,496

Table 7. Salmon shark bycatch in Pacific halibut fisheries by region.

		Estimated Numbers of individual Salmon Sharks Caught in Pacific Halibut fisheries														
		Statistical Area Combination														
Year		140/141/142/144/150/151	143/152/153	160/170	161/162/163	171/174	181/182/184	185-220	230/232/240/242	250-261	270/280	271/281	290-310	320-340	350-400	Total GOA
1997	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**149**	**62**	**366**	**0**	**0**	**183**	**0**	**0**	**760**
	Lower (5%) quantile	0	0	0	0	0	0	21	9	52	0	0	26	0	0	107
	Upper (95%) quantile	0	0	0	0	0	0	1,059	439	2,596	0	0	1,301	0	0	5,394
1998	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**69**	**0**	**233**	**85**	**0**	**0**	**387**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	10	0	60	12	0	0	82
	Upper (95%) quantile	0	0	0	0	0	0	0	0	493	0	899	605	0	0	1,997
1999	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**0**	**0**	**0**	**16**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	112	0	0	0	112
2000	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**91**	**148**	**146**	**0**	**193**	**0**	**0**	**578**
	Lower (5%) quantile	0	0	0	0	0	0	0	13	21	21	0	46	0	0	101
	Upper (95%) quantile	0	0	0	0	0	0	0	648	1,048	1,037	0	803	0	0	3,535
2001	**Bycatch (numbers)**	0	0	0	0	0	0	0	0	0	0	0	0	135	0	135
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	19	0	19
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	959	0	959
2002	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**186**	**0**	**0**	**0**	**0**	**186**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	26	0	0	0	0	26
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	1,318	0	0	0	0	1,318
2003	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**243**	**0**	**0**	**243**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	0	34	0	0	34
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	0	1,727	0	0	1,727
2004	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8. Other/Unidentified shark bycatch in Pacific halibut fisheries by region.

		Estimated Numbers of Sharks from the Other Shark Complex Caught in Pacific Halibut fisheries														
		Statistical Area Combination														
Year		140/141/142/144/150/151	143/152/153	160/170	161/162/163	171/174	181/182/184	185-220	230/232/240/242	250-261	270/280	271/281	290-310	320-340	350-400	Total GOA
1997	**Bycatch (numbers)**	**0**	**695**	**0**	**0**	**0**	**0**	**1,305**	**725**	**0**	**289**	**0**	**0**	**101**	**0**	**3,116**
	Lower (5%) quantile	0	98	0	0	0	0	377	102	0	41	0	0	14	0	632
	Upper (95%) quantile	0	4,936	0	0	0	0	5,090	5,149	0	2,054	0	0	718	0	17,947
1998	**Bycatch (numbers)**	**0**	**0**	**599**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**599**
	Lower (5%) quantile	0	0	84	0	0	0	0	0	0	0	0	0	0	0	84
	Upper (95%) quantile	0	0	4,250	0	0	0	0	0	0	0	0	0	0	0	4,250
1999	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**55**	**0**	**194**	**0**	**0**	**438**	**70**	**0**	**757**
	Lower (5%) quantile	0	0	0	0	0	0	8	0	27	0	0	62	10	0	107
	Upper (95%) quantile	0	0	0	0	0	0	389	0	1,374	0	0	3,110	498	0	5,371
2000	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**486**	**0**	**0**	**0**	**272**	**0**	**757**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	98	0	0	0	69	0	166
	Upper (95%) quantile	0	0	0	0	0	0	0	0	2,619	0	0	0	1,076	0	3,695
2002	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2,217**	**476**	**1,075**	**1,503**	**0**	**5,272**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	831	67	151	363	0	1,413
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	5,916	3,382	7,634	6,216	0	23,147
2003	**Bycatch (numbers)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Lower (5%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upper (95%) quantile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	**Bycatch (numbers)**	**0**	**0**	**391**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**391**
	Lower (5%) quantile	0	0	55	0	0	0	0	0	0	0	0	0	0	0	55
	Upper (95%) quantile	0	0	2,776	0	0	0	0	0	0	0	0	0	0	0	2,776

<u>Figures</u>

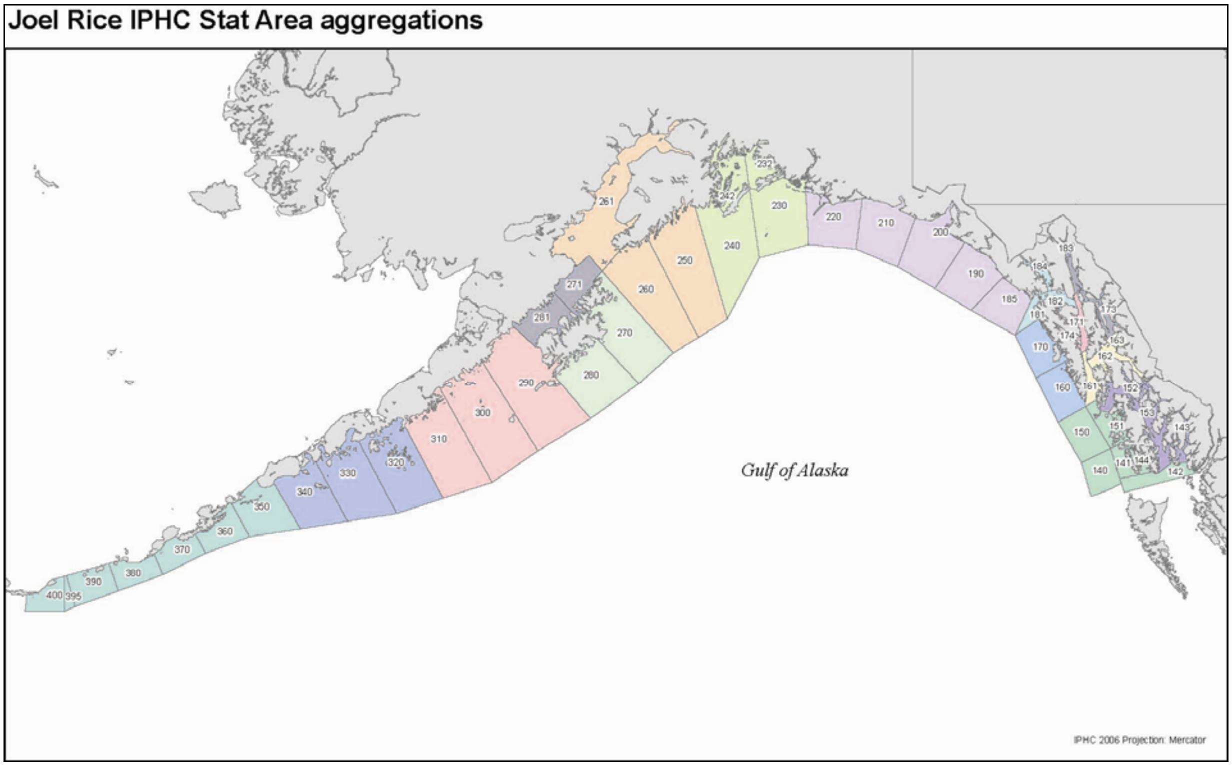

Figure 1. IPHC Stat Area aggregations.

Appendix E - Shark Bycatch in NMFS Domestic Sablefish Longline Surveys

Dean Courtney and Joel Rice

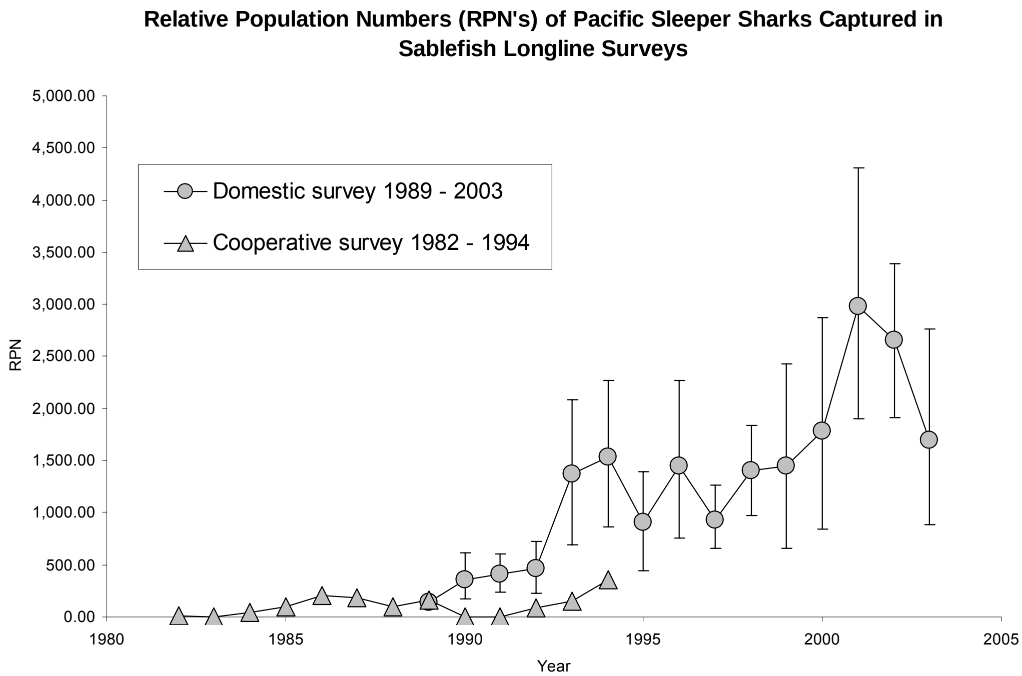

Figure 1. Relative population numbers (RPN's) of Pacific sleeper shark captured in the north east Pacific (Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska) during the years 1982-1994 by the Japan-U.S. cooperative sablefish longline survey, and during the years 1989-2003 by the domestic sablefish longline survey (with 95% bootstrap confidence intervals).

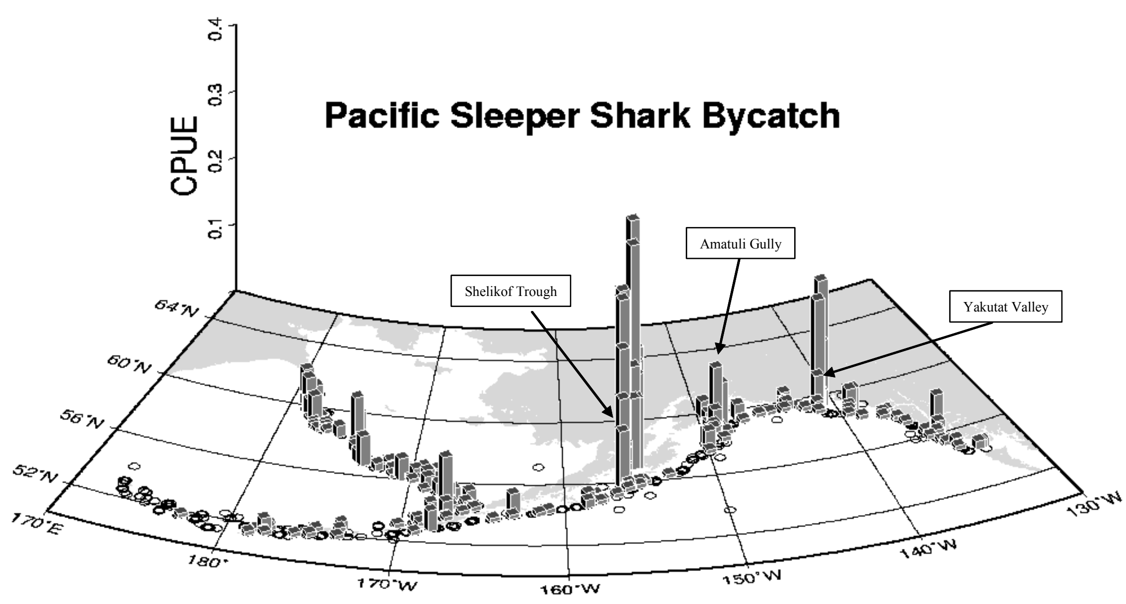

Figure 2. Distribution of Pacific sleeper shark bycatch per unit effort (CPUE) during the years 1982-1994 by the Japan-U.S. cooperative sablefish longline survey, and during the years 1989-2003 by the domestic sablefish longline survey.

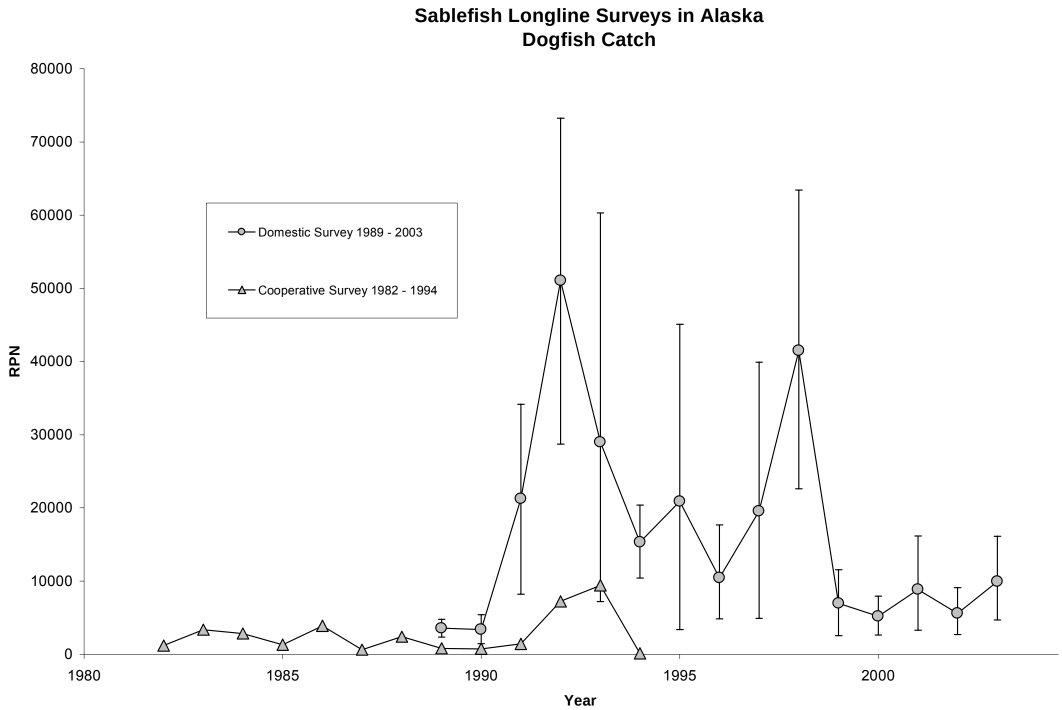

Figure 3. Relative population numbers (RPN's) of spiny dogfish captured in the north east Pacific (Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska) during the years 1982-1994 by the Japan-U.S. cooperative sablefish longline survey, and during the years 1989-2003 by the domestic sablefish longline survey (with 95% bootstrap confidence intervals).

References

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

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