20. Assessment of the shark stock complex in the Bering Sea and Aleutian Islands

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EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Changes to the input data

1. Total catch for BSAI sharks is updated to include 2012 (as of Oct 1, 2012)
2. IPHC survey RPNs have been calculated for 1997 – 2011
3. Biomass estimates have been updated for the Aleutian Islands and EBS slope surveys for 2012

Changes in assessment methodology

The SSC requested alternative Tier 6 ABC and OFL methods to incorporate the Halibut Fishery Incidental Catch Estimates (HFICE). Based on this request we present two alternatives: OFL = maximum catch and OFL = average catch, both where catch is the sum of the Catch Accounting System (CAS) catch estimates and HFICE and ABC = 0.75*OFL. HFICE is only available 2001 - 2011, thus a ratio of HFICE to AKRO catch estimates during 2001 – 2011 was used to estimate HFICE catch for the years 1997 - 2000.

Summary of Results

For 2013 we recommend the maximum allowable ABC of 1,022 t and an OFL of 1,363 t for the shark complex. Catch in 2011 was 172 t and in 2012 was 74 t as of October 1, 2012. The stock complex was not subject to overfishing last year, and data do not exist to determine if the species in the complex are overfished.

We do not recommend any of the Tier 6 alternatives which incorporate HFICE catch estimates. CAS does not plan to include/support the HFICE estimates, thus they are not official NMFS catch estimates and should only be considered an exploratory analysis. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI, and most incidentally captured sharks are not retained.

ABC and OFL calculations and Tier 6 recommendations for 2012 - 2013. OFL = maximum shark catch from 1997 - 2007. ABC = OFL*0.75.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2012	2013	2013	2014
Tier	6	6	6	6
OFL (t)	1,360	1,360	**1,363***	1,363
maxABC (t)	1,020	1,020	1,022	1,022
ABC (t)	1,020	1,020	**1,022**	1,022
	As determined *last* year for:		As determined *this* year for:	
Status	2010	2011	2011	2012
Overfishing	No	n/a	No	n/a

*The small discrepancy between the author recommendations and the specifications is due to the Plan Teams recommending and the SSC accepting the use of a rounded value. These values have not changed since 2010.

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)
The HFICE working group has determined that it is not possible to delineate the degree of overlap between the CAS and HFICE with current data available. Details are described in Appendix 20A and in a final report from the working group that will be available as a tech memo.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)
The HFICE removals are included in Appendix 20A. The non-commercial removals were moved from the appendix to Table 12, replacing the old research catch table.

Responses to SSC and Plan Team Comments Specific to this Assessment

"Develop biomass indices for lowest tier species (Tier 5 for crab, Tier 6 for groundfish), such as sharks, and conduct net efficiency studies for spiny dogfish. Explore alternative methodologies for Tier 5 and 6 stocks, such as length-based methods or biomass dynamics models." (SSC, June 2012)
Alternative Tier 6 options were presented in this assessment. The shark species are caught infrequently in the BSAI surveys (i.e. a small number of fish are caught each year) and data do not exist to develop reliable biomass estimates, nor do data exist to manage at a Tier 5 level (e.g. natural mortality for Pacific sleeper sharks).

"*A priority need for improvement in the shark assessment is the development of improved estimates of shark catches. This is a difficult task, owing to the probable large amount of dogfish bycatch in un-observed fisheries. The SSC appreciates the formation of a working group to develop methods to estimate shark bycatch in the unobserved halibut IFQ fleet and looks forward to inclusion of this important information into catch estimates in next year's assessment."* (SSC, December 2010)
Appendix 20A contains estimates of catch from the halibut fishery for all shark species in the BSAI and a description of the issues associated with the HFICE estimates.

"As with the GOA shark assessment, the SSC also encourages approaches to attempt to estimate shark removals in other unobserved fisheries that may have substantial shark catches." (SSC, December 2010)
Efforts to apply the HFICE approach to state groundfish fisheries (such as Pacific cod) have been held up because the HFICE working group has been addressing the uncertainties in the HFICE method. The authors are working with ADF&G to collect survey and fishery data in a similar format to that used by HFICE so that the HFICE method can be applied in the future. The other unaccounted for source of shark bycatch is in salmon fisheries, but no observer data exist and there is not a survey to use as proxy data.

"Research priorities for BSAI shark research should also include priorities identified by the SSC for sharks in the GOA." (SSC, December 2010)
An extensive list of research priorities relevant to both the GOA and BSAI SAFEs is included in the Data Gaps and Research Priorities section.

"The assessment includes an appendix with estimates of non-commercial shark catches (e.g., research, subsistence, personal use, recreational, and exempted fishing permits) and halibut fishery incidental catch estimates (HFICE). As with GOA sharks, the goal is to incorporate best estimates of total shark

catch from all sources in the annual assessment, including OFL and ABC determinations. The main hurdle is to establish the degree to which these additional incidental catch estimates duplicate any shark bycatch records in the CIA database. The BSAI Groundfish Plan Team remarked that the overlap is likely to be minimal. In any case, once any such duplication has been estimated and addressed, the SSC recommends that total shark catches should be incorporated into the historical catch estimates and OFL/ABC determinations." (SSC, December 2012)
After extensive efforts at determining the degree of overlap between the CAS database and HFICE, the working group determined that the overlap between the two cannot be separated because data do not exist to appropriately separate the two. Details are available in Appendix 20A. With regards to the shark SAFE, options for incorporating the HFICE catch in the time series for Tier 6 calculations are presented in the "Harvest Recommendations" section. The authors do not recommend incorporating HFICE at this time and recommend continuing with the status quo Tier 6 approach.

INTRODUCTION

Alaska Fisheries Science Center (AFSC) surveys and fishery observer catch records provide biological information on shark species that occur in the Bering Sea and Aleutian Islands (BSAI) (Table 20.1 and Figure 20.1). The three shark species most likely to be encountered in BSAI fisheries and surveys are the Pacific sleeper shark (*Somniosus pacificus),* the spiny dogfish (*Squalus suckleyi),* and the salmon shark (*Lamna ditropis*).

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

General Distribution

Pacific Sleeper Shark

Pacific sleeper sharks range as far north as the Arctic Circle in the Chukchi Sea (Benz et al. 2004), west off the Asian coast and the western Bering Sea (Orlov and Moiseev 1999), and south along the Alaskan and Pacific coast and possibly as far south as the coast of South America (de Astarloa et al. 1999). They are the most commonly encountered shark in the BSAI. However, Yano et al. (2007) reviewed the systematics of sleeper sharks and suggested that sleeper sharks in the southern hemisphere and the southern Atlantic were misidentified as Pacific sleeper sharks and are actually *Somniosus antarcticus*, a species of the same subgenera. Pacific sleeper sharks have been documented at a wide range of depths, from surface waters (Hulbert et al. 2006) to 1,750 m (seen on a planted grey whale carcass off Santa Barbara, CA, www.nurp.noaa.gov/Spotlight/Whales.htm) but are found in relatively shallow waters at higher latitudes and in deeper habitats in temperate waters (Yano et al. 2007).

Salmon Shark

Salmon sharks range in the North Pacific from Japan through the Bering Sea and GOA to southern California and Baja, Mexico. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Salmon sharks tend to be more pelagic and surface oriented than the other shark species in the GOA, spending 72% of their time in water shallower than 50 m (Weng et al. 2005). While some salmon sharks migrate south during the winter months, others remain in Alaskan waters throughout the year (Weng et al. 2005, Hulbert et al. 2005).

Spiny Dogfish

Spiny dogfish occupy shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the North Pacific. They are considered more common off the U.S. west coast and British Columbia (BC) than in the Gulf of Alaska (GOA) or BSAI (Hart 1973, Ketchen 1986, Mecklenburg et al. 2002). In Alaska, they are more common in the GOA than in the BSAI. Spiny dogfish inhabit both benthic and pelagic environments with a maximum recorded depth of 677 m (Tribuzio, unpublished data). Spiny dogfish are commonly found in the water column and at surface waters (Tribuzio, unpublished data).

Management Units

The shark complex is managed as an aggregate species group in the BSAI Fishery Management Plan (FMP). Prior to the 2011 fishery, sharks were managed as part of the "Other Species" complex, with sculpins, skates and octopus. The breakout was in response to the requirements for annual catch limits contained within the reauthorization of the Magnuson Stevens Fishery Conservation and Management Act. The NPFMC passed amendment 87 (http://www.fakr.noaa.gov/sustainablefisheries/amds/95-96-87/amd87.pdf) to the BSAI FMP, requiring sharks to be managed as a separate complex and Annual Catch Limits (ACLs) be established annually by the SSC starting in the 2011 fishery. The total allowable catch (TAC), acceptable biological catch (ABC), and overfishing limits (OFL) for the shark complex (and previously the Other Species complex) are set in aggregate (Table 20.2).

Evidence of Stock Structure

The stock structure of the BSAI and GOA shark complexes was examined and presented to the joint Plan Teams in September 2012. The analysis is attached to this document in Appendix 20B. There is very little data available to evaluate whether different stocks exist among regions within the GOA or BSAI for any of the three species. Sharks are generally long-lived and slow growing. There is insufficient life history data for any of the species to compare between or within the GOA and BSAI. Additionally, no genetic information is available to infer any genetic stock structure between or within areas.

Life History Information

There is little data specific to the BSAI region for any of the three primary shark species, thus GOA information is used as proxy. Sharks are long-lived species with slow growth to maturity, a large maximum size, and low fecundity. Therefore, the productivity of shark populations is very low relative to most commercially exploited teleosts (Holden 1974, Compagno 1990, Hoenig and Gruber 1990). Shark reproductive strategies in general are characterized by long gestational periods (6 months - 2 years), with small broods of large, well-developed offspring (Pratt and Casey 1990). Because of these life history characteristics, many large-scale directed fisheries for sharks have collapsed, even where management was attempted (Castro et al. 1999). In 2009, staff at AFSC calculated vulnerability scores for 21 Alaskan species based on life history and fishery susceptibility characteristics (http://www.afsc.noaa.gov/refm/docs/2009/GOAvulnerability.pdf). Sharks were 3 of the 4 most vulnerable species, with salmon shark the least vulnerable shark at 1.96 (lower scores are less vulnerable), spiny dogfish at 2.10 and Pacific sleeper shark at 2.24, the most vulnerable of all species calculated.

Pacific Sleeper Shark

Sleeper sharks (*Somniosus* spp.) attain large sizes, most likely possess a slow-growth rate and are likely long-lived (Fisk et al. 2002). A Greenland shark (*Somniosus microcephalus*), the North Atlantic congener of the Pacific sleeper shark, was sampled in 1999 and was determined to have been alive during the 1950's - 1970's because it had high levels of DDT (Fisk et al. 2002). The average lengths of *Somniosus* sp. captured in mid-water trawls in the Southern Ocean are 390 cm *TL* (total length with the tail in the natural position) +/- 107 cm (range 150-500 cm, n=36, Cherel and Duhamel 2004). Large *Somniosus* sharks observed in photographs from deep water have been estimated at lengths up to 700 cm (Compagno 1984). The maximum lengths of captured Pacific sleeper sharks were 440 cm for females and 400 cm for males (Mecklenburg et al. 2002). Pacific sleeper sharks as large as 430 cm have been caught in the western North Pacific (WNP), where the species exhibits sexual dimorphism, with females being shorter and heavier (avg. length = 138.9 cm, avg. weight = 28.4 kg) than males (avg. length = 140 cm, avg. weight = 23.7 kg) (Orlov 1999). The cartilage in sleeper sharks does not calcify to the degree of many other shark species, therefore aging is difficult and methods of ageing are under investigation.

Published observations suggest that mature female Pacific sleeper sharks are in excess of 365 cm *TL*, mature male Pacific sleeper sharks are in excess 397 cm TL, and that size at birth is approximately 40 cm *TL* (Gotshall and Jow 1965, Yano et al. 2007). The reproductive mode of sleeper sharks is thought to be aplacental viviparity. Three mature females 370 - 430 cm long were opportunistically sampled off the coast of California. One of these sharks had 372 large vascularized eggs (24 - 50 mm) present in the ovaries (Ebert et al. 1987). Another mature Pacific sleeper shark 370 cm long was caught off Trinidad, California (Gotshall and Jow 1965) with ovaries containing 300 large ova. Two recently born 74 cm sharks have been caught off the coast of California at depths of 1300 and 390 m; one still had an umbilical scar (Ebert et al. 1987). Unfortunately, the date of capture was not reported. A newly born shark of 41.8 cm was also caught at 35 m depth off Hiraiso, Ibaraki, Japan (Yano et al. 2007). Additionally, three small sharks, 65 - 75 cm long, have been sampled in the Northwest Pacific, but the date of sampling was not reported (Orlov and Moiseev 1999). In summer 2005, an 85 cm *PCL* female was caught during the annual AFSC longline survey near Yakutat Bay and in spring 2009 another 85 cm *PCL* female was caught by a commercial halibut fisherman inside Chatham Strait in Southeast Alaska (Tribuzio unpublished data). Because of a lack of observations of mature and newly born sharks, and the absence of dates in literature, the spawning and pupping seasons are unknown for sleeper sharks.

Salmon Shark

Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2^{o}C above ambient water temperatures and appear to maintain a constant body core temperature regardless of ambient temperatures (Goldman et al. 2004). Adult salmon sharks typically range in size from 180 - 210 cm *PCL* (Goldman and Musick 2006) in the eastern North Pacific and can weigh upwards of 220 kg. Length-at-maturity in the WNP has been estimated to occur at approximately 140 cm *PCL* for males and 170 - 180 cm *PCL* for females (Tanaka 1980). These lengths correspond to ages of approximately five years and 8 - 10 years, respectively. Length-at-maturity in the ENP has been estimated to occur between 125 - 145 cm *PCL* (3 – 5 years) for males and between 160 - 180 cm *PCL* (6 – 9 years) for females (Goldman and Musick 2006). Tanaka (1980) (see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP salmon shark is at least 25 years for males and 17 years for females and growth coefficients are 0.17 and 0.14 for males and females, respectively. Goldman and Musick (2006) gave maximum ages for ENP salmon shark (also from vertebral analysis) of 17 years for males and 30 years for females, with growth coefficients of 0.23 and 0.17 for males and females, respectively. 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 and Musick 2006).

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage when embryos feed on eggs produced by the ovary (Tanaka 1986 cited in Nagasawa 1998). Litter size in the WNP is four to five pups, and litters have been reported to be male dominated 2.2:1 (Nagasawa 1998). In the ENP, one record of a pregnant female salmon shark caught near Kodiak Island had four pups, two males and two females (Gallucci et al. 2008). Gestation times throughout the North Pacific appear to be nine months, with mating occurring during the late summer and early fall and parturition occurring in the spring (Nagasawa 1998, Tribuzio 2004, Goldman and Musick 2006). Size at parturition is between 60 - 65 cm *PCL* in both the ENP and WNP (Tanaka 1980, Goldman and Musick 2006).

Spiny Dogfish

Eastern North Pacific spiny dogfish grow to a maximum size of 160 cm (Compagno 1984). Recent studies estimated ages-at-50% maturity to be 36 years for females and 21 years for males (Tribuzio and Kruse 2012), which is similar to estimates from BC of 35 years and 19 years respectively (Saunders and McFarlane 1993). Longevity in the ENP is between 80 and 100 years (Campana et al. 2006). Growth coefficients (κ) for this species are among the slowest of all shark species, $\kappa = 0.03$ for females and 0.06 for males (Tribuzio et al. 2010).

The mode of reproduction for spiny dogfish is aplacental viviparity. Embryos are nourished by their yolk sac while being retained in utero for 18 - 24 months. In the GOA, pupping may occur during winter months, based on the size of embryos observed during summer and fall sampling (Tribuzio and Kruse 2012). Ketchen (1972) reported timing of parturition in BC to be October through December, and in the Sea of Japan, parturition occurred between February and April (Kaganovskaia 1937, Yamamoto and Kibezaki 1950). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio et al. 2009). Pupping is believed to occur in estuaries and bays or mid-water over depths of about 165 - 370 m (Ketchen 1986). Small juveniles and young-of-the-year tend to inhabit the water column near the surface or in areas not fished commercially and are therefore not available to commercial fisheries until they grow or migrate to fished areas (Beamish et al. 1982, Tribuzio and Kruse 2012). The average litter size is 8.5 pups for spiny dogfish in the GOA (Tribuzio and Kruse 2012), 6.9 in Puget Sound, WA (Tribuzio et al. 2009), and 6.2 in BC (Ketchen 1972). The number of pups per female also increases with the size of the female, with estimates ranging from 0.20 - 0.25 more pups for every centimeter in length after the onset of maturity (Ketchen 1972, Tribuzio et al. 2009, Tribuzio and Kruse 2012).

FISHERY

Directed Fishery, Effort and CPUE

There are currently no directed commercial fisheries for shark species in federally- or state- managed waters of the BSAI.

Discards

Nearly all incidental shark catch is discarded. Mortality rates of discarded catch are unknown, but are conservatively estimated in this report as 100%. Discard rates for sharks are presented in Table 20.3. Generally, > 90% of sharks are discarded, however, other/unidentified sharks are discarded at a lower rate (79% discarded on average, which is ~4 t on average) than identified shark species. The reasons for this lower discard rate of other/unidentified sharks is unclear. We surmise that much of the catch in the other/unidentified shark category is Pacific sleeper shark (see discussion in following section), but that does not explain why the discard rate is lower for this category than other categories. About 16 t of sharks are retained on average annually (~11 t is Pacific sleeper shark), and nearly all is used for fishmeal (T. Hiatt, pers. comm.). We are working with staff at the Fisheries Monitoring and Analysis Program (FMA, also known as the Observer Program) to determine why other/unidentified sharks are discarded at a lower rate than the other species in the complex.

Historical Catch

Historical catches of sharks in the BSAI are composed entirely of incidental catch. This report summarizes incidental shark catches by species as two data time series: 1997 – 2002 and 2003 – 2012 (Table 20.4). Sharks have been reported by species by the NMFS AKRO Catch Accounting System (CAS) since 2003. Prior to that, shark catches by species were estimated by staff at the AFSC using a pseudo-blend method (Gaichas 2001, 2002). Aggregate incidental catches of the shark management category from federally prosecuted fisheries for Alaskan groundfish in the BSAI are tracked in-season by NMFS AKRO (Table 20.2 and Table 20.4).

Unidentified sharks: We investigated the high proportion of other/unidentified sharks in the catch estimates (44% in 2006, average 16% of total shark catch, Table 20.4). Unidentified shark catch in observer data should be extremely rare, only occurring if there is an inexperienced observer who cannot identify the shark or if a shark falls off longline gear before it can be identified. There have not been any reports of sharks being so mangled that they couldn't be identified (K. Hallgren, pers. comm., FMA).

Unidentified sharks are most common on longline gear. Between 2005 and 2011, there were 220 hauls (a total of 197 sampled sharks) with unidentified shark catch in observed fisheries in the BSAI. Of these 220 hauls, 187 were on longline vessels, 28 on pelagic trawl vessels, and five on non-pelagic trawl vessels. It can be assumed, based on conversations with representatives from the FMA program, that most of the unidentified sharks observed on the longline gear were sharks that fell off the line before a positive identification could be made. It is likely that the majority of the sharks that were not identified on longline gear were either Pacific sleeper sharks or spiny dogfish sharks, due to their relatively high number of observed catches in the BSAI on these gear types. Pacific sleeper sharks are much more likely to fall off the line due to their large size. It is a reasonable assumption that most of the unidentified sharks from longline fishing operations are Pacific sleeper sharks.

There were 33 observed trips in the trawl fisheries which documented unidentified sharks. Of these, 23 observed trips reported unidentified sharks along with Pacific sleeper sharks, spiny dogfish, and/or salmon sharks. This suggests that the onboard observers were experienced enough to identify those three species. It is possible that other sharks were reported as unidentified sharks, however, there is no way to investigate this. The observer program reports no occurrences of other sharks (which could be blue sharks, brown cat sharks, or others), thus these species, if/when they occur, could be labeled as unidentified. At this time we are unable to determine the nature of the unidentified sharks in the trawl fisheries.

After this analysis of catch of unidentified shark, we are still unclear on the composition of the other/unidentified shark category. Further, it is unclear why they are retained at a higher rate than other species or why they are not identified to species even when they are retained.

Incidental catch of sharks: Pacific sleeper shark are the primary shark species caught in the BSAI (Table 20.4). On average (from 1997 – 2012) Pacific sleeper shark compose 68% (~ 307 t) of the total shark catch in the BSAI, however catches have been declining and well below average since 2005. Other/unidentified sharks are 19% of the total shark catch on average (~ 88 t) but have also been well below average since 2007, much of these are likely Pacific sleeper sharks and trends in this category mirror those in the Pacific sleeper sharks. Spiny dogfish are 2% (~ 9 t) of the total shark catch on average.

Salmon sharks are primarily caught in the walleye pollock trawl fishery and represent, on average, 11% (~49 t) of the total shark catch. In the last two years the proportion of the total shark catch that was salmon shark has been above average: 66%, 114 t, in 2011 (in which there was one recorded haul with an extrapolated weight of 60 t) and 37%, 27 t, in 2012. Also, in 2011 observer coverage for catcher vessels between 60 and 124 feet in length participating in the American Fisheries Act (i.e. vessels targeting walleye Pollock) increased from 30% coverage to 100% coverage, (B. Mason, pers. comm., FMA) and vessels in this size range represent approximately 68% of the vessels and 30% of the landings in this fleet.

The declining trend in Pacific sleeper shark catch was investigated with respect to environmental conditions. Various Bering climate indices (e.g. Aleutian Low, Pacific Decadal Oscillation, etc. http://www.beringclimate.noaa.gov/data/index.php) were compared to the catch of Pacific sleeper sharks and correlation coefficients calculated. None of the indices were significantly related to Pacific sleeper shark catches, however, the Pacific/North American Index was the most closely related ($p = 0.07$, corr = 0.49). A more detailed time series analysis will be conducted for the next full assessment cycle.

From 1997 to 2012, Pacific sleeper sharks were caught primarily in the walleye pollock fishery (36%, 97 t on average, Table 20.5) and the Pacific cod fishery (37%, 101 t on average). Much of the salmon shark catch occurred in the walleye pollock fishery (91%, 47 t on average, Table 20.6). Spiny dogfish catch in the BSAI was rare and primarily in the Pacific cod fishery (88%, 9 t on average, Table 20.7). Other/unidentified sharks occurred primarily in the walleye pollock fishery (48%, 38 t on average, Table 20.8). The walleye pollock fishery had an unusually high catch of unidentified sharks in 2006 (298 t), which is likely the result of one observed haul with an extrapolated weight of unidentified sharks >17 t. If 2006 is removed, the walleye pollock fishery contained only 17% of the unidentified sharks catch, and the Pacific cod fishery caught 25% of the unidentified sharks (likely Pacific sleeper sharks that fell off the line prior to positive identification).

Catch distribution: Observer catch data from the FMA website (http://www.afsc.noaa.gov/FMA/spatial_data.htm) was mapped to analyze spatial distribution of catch. Observers cover 90% of the groundfish tonnage in the BSAI. Data presented here represent non-confidential data aggregated by 400 km^2 grids from fisheries that occurred during 2008 - 2011.

Bycatch of Pacific sleeper sharks (Figure 20.2) within observed commercial fisheries was relatively high on the EBS shelf to approximately longitude 178°50'W, northwest of St. Matthews Island and from Unimak Pass northeast along the Alaska Peninsula. Observed Pacific sleeper shark bycatch was particularly high in 2008, specifically around Unimak Pass and heading northeast along the Alaska Peninsula.

Observed bycatch of salmon shark in commercial fisheries in the Bering Sea is generally low, but occasional large catches occur (Figure 20.3). Most of the catch occurs in the southern Bering Sea near the Pribilof and Bering Canyons.

Observed bycatch of spiny dogfish in commercial fisheries in the Bering Sea (Figure 20.4) is less than Pacific sleeper shark bycatch, but the spatial distribution is similar. Spiny dogfish bycatch occurs throughout the EBS shelf, generally along the shelf break heading northwest from Unimak Pass. In addition, spiny dogfish are observed within the Aleutian Islands. Observed spiny dogfish bycatch was particularly high in 2009.

Observed bycatch of other/unidentified sharks within commercial fisheries in the Bering Sea (Figure 20.5) is generally patchy in comparison to Pacific sleeper shark and spiny dogfish with only a small number of hauls reporting other/unidentified sharks.

DATA

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Nontarget catch	2003 – 2012
Improved Pseudo Blend (AFSC)	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2012
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope (Historical)	Biomass Index	1979 – 1991
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope	Biomass Index	2002 - 2012
NMFS Bottom Trawl Surveys –Aleutian Islands	Biomass Index	1980 – 2012
NMFS Longline Surveys	Catch Numbers	1989 - 2012
IPHC Longline Surveys	Catch Numbers	1997 - 2011

Catch at length (Fishery and Survey)

While a formal stock assessment model does not exist for the shark complex or any of the component species in the BSAI, length frequency data on surveys has been collected. The data presented below is from the AFSC GOA biennial survey, AFSC and IPHC longline surveys as well as special projects conducted by the Observer Program. There is very little data from the BSAI trawl surveys (i.e. a small number of sharks are caught each year), thus length frequencies have not been calculated for those surveys. Similarly, catch of salmon shark in either trawl or longline surveys is extremely rare and length frequencies are not calculated.

Length data have been collected on the GOA biennial trawl survey since 1984, the AFSC longline survey since 2010, and the IPHC longline survey since 2011. The average length for spiny dogfish caught in the GOA biennial trawl survey is 78.8 cm TL_{ext} for females (measured from the tip of the snout to the tip of the upper caudal lobe with the tail depressed to align with the horizontal axis of the body), and 77.1 cm TL_{ext} for males (n = 3,321 females and n = 2,011 males, all survey years combined, Figure 20.6). Similarly, the average length for spiny dogfish sampled in the AFSC longline survey was 77.6 cm TL_{ext} for females and 75.8 cm TL_{ext} for males (n = 1,689 females and n = 1,130 males, Figure 20.6). Spiny dogfish caught on the IPHC annual longline survey and the observed fishery were larger. The length of females from the IPHC survey was 89.5 cm TL_{ext} and 81.7 cm TL_{ext} for males (n = 2,405 females and n = 1,469 males, Figure 20.6). Average size of spiny dogfish collected during a 2006/2011 special project with the observer program was 83.9 cm TL_{ext} for females and 82.2 cm TL_{ext} for males (n = 604 females and n = 528 males, Figure 20.6).

Pacific sleeper sharks have been measured during biennial trawl surveys and as part of an AFSC research project targeting Pacific sleeper sharks with longline gear near Kodiak Island (Sigler et al. 2006). Longline caught female Pacific sleeper sharks averaged 170 cm (n = 119) *PCL* (pre-caudal length, measured from the tip of the snout to the pre-caudal notch), and males averaged 166 cm (n = 79) *PCL* for males. Sample size was low in bottom trawl survey samples so sexes were combined, average length was 270 cm (n = 74) *PCL*.

AFSC Trawl Survey Biomass Estimates

Biomass estimates are available for shark species from NMFS AFSC bottom trawl surveys conducted on the EBS slope (1979 - 1991 and 2002 - 2012; Table 20.9 and Figure 20.7), Aleutian Islands (AI, 1980 – 2012, Table 20.10 and Figure 20.8), the eastern Bering Sea (EBS) shelf (1979 – 2012, Table 20.11 and Figure 20.9). The shelf survey is annual, but the other surveys take place as funding allows. Sharks in the BSAI may not be sampled well by bottom trawl surveys. In many years, surveys fail to capture a single specimen of some shark species. As a result, the estimation procedure often indicates a biomass of zero or biomass estimates with high levels of uncertainty. Spiny dogfish, for example, occur in < 1% of survey hauls for all three of the BSAI surveys. The efficiency of bottom trawl gear 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 not while it is in contact with the bottom, but rather during gear deployment or retrieval, resulting in unreliable biomass estimates since the estimates are based, in part, on the amount of time the net spends in contact with the bottom. Although Pacific sleeper sharks are demersal, they are large animals that may be able to avoid bottom trawl gear. As a result biomass estimates may be uncertain since the gear may not efficiently capture this species. These surveys may not be informative for spiny dogfish because they are rarely caught in the surveys. However, catches are reported in the observer data and in other surveys sampling the same area; differences in catch rates are likely due to gear differences, as spiny dogfish may be more susceptible to longline gear.

Analysis of the EBS slope survey biomass time series is subject to the following caveats: the slope survey was standardized in 2002 to its current gear type, survey strata, and survey design. Because the survey stratification changed in 2002, biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey (2002 – 2012). Consequently, surveys from 2002 – 2012 may be useful for estimating relative abundance of commonly encountered species, while surveys between 1979 and 1991 should only be used for identifying the relative distribution of species (Gary Walters, pers. comm.).

Pacific sleeper sharks are the most abundant catch of all shark species within BSAI surveys. They are most consistently caught on the annual EBS slope survey in a relatively high number of hauls (at least 15 hauls each year, 8 - 14% of hauls, compared to < 5 hauls, <3% of hauls in the other surveys during the same time frame), with biomass estimates ranging from 833 t (2010) to 25,445 t (2002) (Table 20.9 and Figure 20.7). These large fluctuations are suspect for such a large and late to mature species. Pacific sleeper sharks are also captured consistently in NMFS bottom trawl surveys of the Aleutian Islands, but biomass estimates are based on a fewer number of hauls (at most 10 in 1997) and biomass estimates are generally lower than in the EBS slope area (22 t in 2012, Table 20.10 and Figure 20.8). Pacific sleeper sharks are not often caught in the annual EBS shelf survey and biomass estimates range from zero to 5,602 t (2002) (Table 20.11 and Figure 20.9). It is likely that most surveys and fisheries are not sampling much of the adult population because no mature Pacific sleeper sharks have been documented in Alaska.

Spiny dogfish and salmon shark are rarely captured in any of the NMFS bottom trawl surveys in the EBS or Aleutian Islands. Often, catches are zero, with a resultant zero biomass estimate. However, spiny dogfish were caught in one haul in 2008 in the EBS slope survey (Table 20.9 and Figure 20.7), were last caught in 2006 in the Aleutian Islands survey (Table 20.10 and Figure 20.8), and in one haul each in 2009 and 2010 in the EBS shelf survey (Table 20.11 and Figure 20.9). Salmon shark have never been caught in the EBS slope survey (Table 20.9). One salmon shark was caught in 2002 in the Aleutian Island survey (Table 20.10 and Figure 20.8) and one in 1988 in the EBS shelf survey (Table 20.11 and Figure 20.9).

Longline Surveys

The International Pacific Halibut Commission (IPHC) conducts a longline survey each year to assess Pacific halibut. This is a fixed station survey that samples down to 500 m in the Aleutian Islands, Eastern Bering Sea, and the Gulf of Alaska, as well as areas south of Alaska. More information on this survey can be found in Soderlund et al. (2009). Total catch of sharks in the IPHC survey is presented in Table 20.12.

Relative population numbers (RPN) for spiny dogfish and Pacific sleeper shark were calculated using the same methods that are used for the AFSC longline survey, the only difference being the depth stratum increments. First an average CPUE was calculated by depth stratum for each FMP sub-area (e.g., east Yakutat, west Yakutat, central GOA, etc.). The CPUE was then multiplied by the area size of that stratum. A FMP-wide RPN was calculated by summing the RPNs for all strata in the area. Area sizes used to calculate biomass in the RACE trawl surveys were utilized for IPHC RPN calculations.

For Pacific sleeper sharks, which are the primary shark species caught in the BSAI, RPNs have declined steeply since the late 1990s and have remained at low levels since 2005 (Figure 20.10). Spiny dogfish are not commonly caught, however, RPNs appear to be trending up slightly since 2005. Salmon shark are extremely rare in the IPHC survey, thus the RPNs do not provide useful information. Almost all of the IPHC survey catch of sharks occurs in the Bering Sea and only limited catch occurs in the Aleutian Islands.

The AFSC longline survey samples stations in the Bering Sea in even years and the Aleutian Islands in odd years. Shark catch is generally greater in the odd years associated with the Aleutian Islands, but overall shark catch is low. RPNs from the AFSC longline survey are not used because catches of sharks are very low (Table 20.12). The AFSC longline survey samples fewer stations along the slope, where the IPHC survey samples many stations at shallower depths across the shelf. It is possible that the AFSC longline survey does not sample shark habitat as well as the IPHC longline survey.

Distribution of catch in surveys

An examination of the spatial distribution of survey catches shows that Pacific sleeper shark are consistently caught throughout the EBS shelf in the IPHC LL (during years 2008 – 2011, Figure 20.11) and NMFS trawl surveys (Figure 20.12) with rare scattered catches in the Aleutian Islands. The distribution of Pacific sleeper sharks spreads from Unimak Pass and follows the shelf northwest beyond the Pribilof Islands, until approximately longitude 178°40’W. The IPHC LL survey caught relatively higher numbers of sleeper sharks near Unimak Pass in 2006 and 2009. Catch of sleeper sharks in the NMFS 2010 trawl survey is highest near Unimak Pass as well.

In contrast, spiny dogfish catch is mostly distributed throughout the Aleutian chain in the IPHC longline survey with highest concentrations of catch occurring near the western end of the Aleutian chain (Figure 20.13). Both 2006 and 2008 saw relatively high catches (compared to 2007 and 2009) of spiny dogfish in the IPHC LL surveys. Spiny dogfish occurrences in the NMFS trawl surveys are rare. Only one spiny dogfish was caught on the Bering shelf during the 2010 trawl survey.

ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Model Structure

Sharks in the BSAI are managed under Tier 6 (harvest specifications based on the historical catch or alternatives accepted by the Science and Statistical Committee), so no stock assessment modeling is performed.

Parameter Estimates

Although a model is not used to provide stock assessment advice for BSAI sharks we provide estimates of life history parameters, where available (Table 20.13). Estimates are not available for BSAI stocks and thus GOA or North Pacific values are used as a proxy. Parameters include weight at length, length at age, natural mortality (*M*), maximum age and age at first recruitment, when available. Weight at length and average length parameters were derived from both directed research projects (all three species) and standard survey collections (spiny dogfish only).

A method for aging Pacific sleeper shark has not yet been developed. However, samples of a similar species, the Greenland shark, were determined to have been between 20 - 40 years old because of DDT levels (Fisk et al. 2002). If we assume that this age range is a minimum estimate of maximum age and apply Hoenig’s (1983) natural mortality estimate, M = 0.223 – 0.113. The size range of the animals in that study suggests that they were immature, thus the estimate of maximum age is an underestimate and the range of natural mortalities is likely an over estimate. There is not sufficient resources or ages to investigate *M* by tagging studies or catch curve analysis with Pacific sleeper shark, and the lack of life history data (e.g. no mature animals caught or sampled in Alaska) precludes using life history invariant methods.

Numerous age and growth studies have been conducted on spiny dogfish in the GOA and North Pacific Ocean. An estimate of the natural mortality rate (*M* = 0.097) is derived for spiny dogfish in the GOA (Tribuzio and Kruse, 2012). The value of *M* (0.097) for the GOA is similar to an estimate for British Columbia spiny dogfish (0.094) (Wood et al. 1979). Maximum age of spiny dogfish in the ENP is between 80 and 100 years (Beamish and McFarlane 1985, Campana et al. 2006). Age of first recruitment is not available for spiny dogfish, however, Tribuzio et al. (2010) report the youngest dogfish encountered in fishery dependent sampling was 8 years old.

A range of natural mortality estimates is derived for salmon shark in the central GOA (Goldman 2002). Maximum reported age for central GOA salmon shark is 30 years (Goldman and Musick 2006). Age at first recruitment to a commercial fishery is 5 years old for central GOA salmon sharks (Goldman 2002).

Results

Harvest Recommendations

Sharks have been considered a Tier 6 species because they are not targeted and only limited data are available. The current Tier 6 method adopted in 2010 for sharks uses the catch time series during 1997 - 2007 where OFL is equal to the maximum catch and ABC is 75% of OFL. The status quo approach is unlikely to constrain the fishery, as current shark catches are substantially lower than the maximum historical catch. Examining the catch history from 1997 to the present shows that catches are not likely to have exceeded the recommended ABC (Figure 20.14) as CAS catches for the last 5 years have been < 20% of the ABC. We recommend continuing with the current Tier 6 method for all sharks until more data is available, and we will continue to monitor catches. Tier 6 ABC and OFL calculations for the BSAI shark complex are presented below for both individual species and the shark complex as a whole. The individual species ABC/OFLs are presented for information purposes, the recommendations are made for the total shark complex.

Tier 6 calculations by species and total of all species (t) and recommendations for 2012-2013.

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark Complex*
Maximum Catch	17	839	199	468	1,363
ABC	13	629	149	351	1,022
OFL	17	839	199	468	1,363

*The complex total is based on the maximum catch of the whole complex, not the sum of the individual species maximums.

In the 2011 assessment, estimates of catch in the unobserved halibut IFQ fleet (hereafter referred to as the HFICE estimates, from the halibut fishery incidental catch estimation working group) were presented (see Appendix 20A, this document). The SSC recommended that authors present options for Tier 6 calculations that consider the HFICE estimates in addition to those accounted for in the CAS catch estimates.

The HFICE estimates are available from 2001 - 2011, but the ABC/OFL calculations presented in this assessment use the maximum of the catch time series during 1997 - 2007. To fill in the missing years in the HFICE time series (1997 - 2000), the ratio of total weight of HFICE shark catch divided by total CAS weight of shark catch from 2001 - 2011 was estimated (0.599). The HFICE total shark catch from 1997 - 2000 was then estimated as the ratio of HFICE to CAS multiplied by the CAS total shark catch in these years. Alternative ABC and OFL calculations incorporating the combination of CAS catch and HFICE catch (CAS + HFICE) were computed using the combined time series from 1997 - 2007. Below is a table of Tier 6 alternatives (Figure 20.14):

		OFL=Maximum Catch			OFL=Average Catch		
		Status Quo[#]	Alternative 1		Alternative 2	Alternative 3	
		CAS Only	CAS + HFICE	% Change[1]	CAS Only	CAS + HFICE	% Change
Spiny Dogfish	ABC	13	13	0%	6	7	6%
	OFL	17	18	6%	8	9	6%
Pacific Sleeper Shark	ABC	629	868	38%	316	554	75%
	OFL	839	1,158	38%	422	739	75%
Salmon Shark	ABC	149	149	0%	36	36	0%
	OFL	199	199	0%	48	48	0%
Other/ Unidentified Sharks	ABC	351	351	0%	95	95	0%
	OFL	468	468	0%	126	127	0%
Total Sharks*	**ABC**	**1,022**	**1,091**	**7%**	**453**	**692**	**53%**
	OFL	**1,363**	**1,455**	**7%**	**605**	**922**	**53%**

[#]Authors recommendations
[1]The % change is the proportion that the ABC/OFL increases over that with CAS only.
[*]For the Total Sharks, the whole complex is used, not the sum of the individual species.

The inclusion of the HFICE estimates increases the historical maximum catch by 7% (from 1,363 t to 1,455 t) and the average historical catch by 53% (from 605 t to 922 t). We do not recommend including the HFICE catch estimates in the ABC/OFL calculations for these reasons:

1) CAS does not plan to include/support the HFICE estimates because the estimation procedure is not compatible with CAS and HFICE estimates do not provide information useful for in-season management. The estimates are not available until after the IHPC releases the commercial data (usually August of the following year, e.g. 2011 HFICE estimates are available for this year's SAFE). These estimates cannot be considered official NMFS catch estimates and should only be considered an exploratory analysis. .
2) Prior to incorporating the HFICE estimates in assessments, it would be preferable to compare HFICE estimates to fishery dependent estimates (such as observer data after the observer program restructure).
3) HFICE estimates are in numbers, which is converted to weight using average weight data from FMA. However, observers may not be able to bring large animals, such as Pacific sleeper shark, on-board for weighing, or to accurately weigh them due to the large size, thus average weights are likely biased low. Further, length estimates used to convert to weight for animals not brought on board (as in longline fishing) are likely inaccurate.
4) The HFICE working group has determined that it is not possible to delineate the potential double counting between CAS and HFICE. An explanation of the reasons for this is in Appendix 20A, but in summary the available data do not support separating the double counting.

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on Stock

Pacific sleeper shark

Pacific sleeper sharks were once thought to be sluggish and benthic because their stomachs commonly contain offal, cephalopods, and bottom dwelling fish such as flounder (*Pleuronectidae*) (e.g., Yang and Page 1999). In contrast, another diet analysis documented prey from different depths in the stomachs of a single shark, such as giant grenadier (*Albatrossia pectoralis*) and pink salmon (*Oncorhynchus gorbuscha*), indicating that they make depth oscillations in search of food (Orlov and Moiseev 1999).

Other diet studies have found that Pacific sleeper sharks prey on fast moving fish such as salmon (*O. spp.)* and tuna (*Thunnus spp*.), and marine mammals such as harbor seals (*Phoca vitulina*), that live near the surface (e.g., Bright 1959; Ebert et al. 1987; Crovetto et al. 1992; Sigler et al. 2006), suggesting that these sharks may not be as sluggish and benthic oriented as once thought. Recent research using stable isotope concentrations in both liver and muscle tissue determined that Pacific sleeper sharks likely get a significant portion of their energy from lower trophic prey (i.e. Pacific herring, walleye pollock; Schauffler et al. 2005) and that they also feed on prey from a wide variety of trophic levels (Courtney and Foy, 2012). Similar to spiny dogfish, fluctuations in environmental conditions and prey availability may not significantly affect this species because of its wide dietary niche. There are no known predators of Pacific sleeper sharks. Data suggests that most of the Pacific sleeper sharks caught in the BSAI and GOA are immature and there is no information on spawning or mating or gestation, so it is unknown how the fishery affects their recruitment.

Salmon Shark

Salmon sharks are opportunistic feeders, sharing the highest trophic level of the food web in subarctic Pacific waters with marine mammals and seabirds (Brodeur 1988, Nagasawa 1998, Goldman and Human 2004). They feed on a wide variety of prey, from squid and shrimp to salmon (*Oncorhynchus* sp.) and rockfishes (family Sebastes) and even other sharks (Sano 1962, Hart 1973, Compagno 1984, Nagasawa 1998). The species is a significant seasonal predator of returning salmon in some areas (e.g. Prince William Sound), but the species is broadly dispersed across the North Pacific Ocean and likely does not have an overall significant impact on prey species. Salmon shark are endothermic, which enables them to have a broad thermal tolerance range and inhabit highly varying environments. Because of this ability, they can adapt to changing climate conditions and prey availability. Salmon shark generally mate in the fall and give birth the following spring. Much of the salmon shark catch in the BSAI occurs in the summer months after spawning.

Spiny dogfish

Previous studies have shown spiny dogfish to be opportunistic feeders that are not wholly dependent on one food source (Alverson and Stansby 1963). Small dogfish are limited to consuming smaller fish and invertebrates, while the larger animals will eat a wide variety of foods (Bonham 1954). In the GOA, preliminary diet studies further suggest that spiny dogfish are highly generalized, opportunistic feeders (Tribuzio, unpublished data). Thus, fluctuations in the environmental conditions and prey availability likely have little effect on the species because of its ability to switch prey, although this also depends on the overall abundance of the prey species. The primary predator on spiny dogfish are other sharks, but data suggest other potential predators could be orcas, lingcod and halibut (Tribuzio, unpublished data). It is not well known if fishing activity occurs when and where sharks spawn. Spiny dogfish have an 18 – 24 month gestation, therefore, fishing activity overlaps with reproduction, regardless of when it occurs.

Fishery Effects on Ecosystem

Because there has been virtually no directed fishing for sharks in Alaska, the reader is referred to the discussion on Fishery Effects in the SAFE reports for the species that generally have the greatest shark catches, Pacific cod and walleye pollock. It is assumed that all sharks presently caught in commercial fishing operations that are discarded do not survive. This could constitute a source of dead organic material to the ecosystem that would not otherwise be there, but also the removal of a top predator. Removing sharks can have the effect of releasing competitive pressure or predatory pressures on prey species. Studies have shown that removal of top predators may alter community structure in complex and non-intuitive ways, and that indirect demographic effects on lower trophic levels may occur (Ruttenberg et al. 2011).

Data Gaps and Research Priorities

Data limitations are severe for shark species in the BSAI, making effective management of sharks extremely difficult. Gaps include inadequate catch estimation, unreliable biomass estimates, lack of size frequency collections, and a lack of life history information including age and maturity, especially for Pacific sleeper sharks. It is essential to continue to improve the collection of biological data from sharks in the fisheries and surveys. Future shark research priorities will focus on the following areas:

1. Expand collection of shark data on surveys in the BSAI
    a. Actions: Began collecting lengths of spiny dogfish in the NMFS (2010) and IPHC (2011) longline surveys, began collection of genetics samples for Pacific sleeper sharks.
2. Examine catchability for sharks on trawl surveys.
    a. Actions: Investigating methods of using tagging data to estimate *q* for spiny dogfish.
3. Define the stock structure and migration patterns (i.e. tagging studies, genetics)
    a. Actions: Continued tagging of spiny dogfish with pop-off satellite archival tags; began pilot study investigating genetics of Pacific sleeper shark.
4. Determine or clarify existing estimates of life history parameters for use in models
    a. Actions: NPRB funded study underway to examine improved aging methods for spiny dogfish and to examine methods to age Pacific sleeper sharks.

SUMMARY

There is no evidence to suggest that overfishing is occurring for any shark species in the BSAI, because OFL catch limits of the shark complex were not exceeded. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI, and most incidentally captured sharks are not retained. Incidental catches of shark species in the BSAI fisheries have been very small compared to catches of target species. The recommendations are for the whole complex, but the ABC/OFL by species are shown for informational purposes as well.

Quantity	As estimated or *specified last* year for: 2012	2013	As estimated or *recommended this* year for: 2013	2014
Tier	6	6	6	6
OFL (t)	1,360	1,360	**1,363**	1,363
maxABC (t)	1,020	1,020	1,022	1,022
ABC (t)	1,020	1,020	**1,022**	1,022
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
Overfishing	No	n/a	No	n/a

	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other/unid Shark	Total Shark Complex
Tier	6	6	6	6	6
M	0.097	unk	0.18	unk	NA
Max catch (t) (1997-2007)	13	629	149	351	1,363*
ABC (t)	17	839	199	468	1,022
OFL (t)	13	629	149	351	1,363*

* The complex total is based on the maximum catch of the whole complex, not the sum of the individual species maximums.

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Table 20.1. Biological characteristics and depth ranges for shark species in the eastern Bering Sea and Aleutian Islands (BSAI). Missing information is denoted by "?".

Scientific Name	Common Name	Max. Obs. Length (TL, cm)	Max. Obs. Age	Age, Length, 50% Maturity	Feeding Mode	Fecundity	Depth Range (m)
Apristurus brunneus	brown cat shark	68[1]	?	?	Benthic[3]	?	1,306[2]
Carcharodon carcharias	White shark	792[4]	36[7]	15 yrs, 5 m[7]	Predator[6]	7-14[5]	1,280[3]
Cetorhinus maximus	basking shark	1,520[1]	?	5 yrs, 5m[8]	Plankton[6]	?	?
Hexanchus griseus	sixgill shark	482[9]	?	4m[1]	Predator[6]	22-108[1]	2,500[10]
Lamna ditropis	salmon shark	305[1]	20[11]	6-9 yrs, 165 cm PCL[11]	Predator[6]	3-5[7]	668[12]
Prionace glauca	blue shark	400[16]	15[13]	5 yrs[5], 221 cm[14]	Predator[6]	15-30 (up to 130)[15]	150[16]
Somniosus pacificus	Pacific sleeper shark	700[1]	?	?	Benth/Scav[17]	Up to 300[1]	2,700[18]
Squalus suckleyi	Spiny dogfish	125[19]	80-100[19]	34 yrs, 80 cm[19]	Pred/Scav/Bent[19]	7-14[19]	300[3]

[1]Compagno, 1984; [2]Eschmeyer et al., 1983; [3]Mecklenburg et al. 2002; [4]Scott and Scott, 1988; [5]Smith et al. 1998; [6]Cortes, 1999; [7]Gilmore, 1993; [8]Mooney-Seus and Stone, 1997; [9]Castro, 1983; [10]Last and Stevens, 1994; [11]Goldman and Musick 2006, [12]Hulbert et al. 2005; [13]Stevens, 1975; [14] ICES 1997; [15] White et al. 2006; [16]Smith, 1997; [17]Yang and Page, 1999; [18]www.nurp.noaa.gov; [19]Tribuzio and Kruse 2012.

Table 20.2. Time series of Other Species TAC, Other Species and shark catch, ABC for sharks and the species complex (management method) for 1997 - 2012.

Year	TAC	Est. other spp. catch	Est. shark catch	ABC	Management Method
1997	25,800	25,176	368	N/A	Other Species TAC
1998	28,800	25,531	497	N/A	Other Species TAC
1999	32,860	20,562	530	N/A	Other Species TAC
2000	31,360	26,108	590	N/A	Other Species TAC
2001	26,500	27,178	764	N/A	Other Species TAC
2002	30,825	26,296	1,362	N/A	Other Species TAC
2003	32,309	27,010	520	N/A	Other Species TAC
2004	27,205	30,492	515	N/A	Other Species TAC
2005	29,000	30,761	417	N/A	Other Species TAC
2006	29,000	28,525	689	N/A	Other Species TAC
2007	37,355	27,837	331	463	Other Species TAC
2008	50,000	31,172	185	463	Other Species TAC
2009	50,000	28,352	144	447	Other Species TAC
2010	50,000	23,362	53	449	Other Species TAC
2011	50		172	1,020	Shark Complex TAC
2012	50		74	1,020	Shark Complex TAC

Data Sources: TAC, ABC and management category came from AKRO catch statistics website. Catch data was queried from AKFIN on Oct, 1 2012.

Table 20.3. Estimated discard rates of sharks (by species) in the BSAI. Source: AKFIN database, Oct 1, 2012. Years and species without available data are blank and years and species with zero catches are marked “NA”.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark
	Aleutian Islands			
1999				
2000		100%	100%	
2001				
2002	100%	100%		
2003	100%	99%	40%	NA
2004	100%	100%		100%
2005	100%	100%	100%	
2006	100%	100%	100%	
2007	99%	100%	100%	
2008	100%	100%		
2009	100%	100%	100%	100%
2010	100%	100%	100%	
2011	100%	100%	100%	
2012	100%	100%	100%	
Average	100%	100%	93%	100%
	Bering Sea			
1999	60%	98%	99%	100%
2000	96%	95%	97%	100%
2001	100%	96%	84%	100%
2002	96%	86%	91%	97%
2003	83%	78%	98%	87%
2004	98%	98%	94%	97%
2005	99%	96%	97%	74%
2006	98%	95%	98%	97%
2007	98%	93%	99%	47%
2008	100%	94%	97%	37%
2009	99%	96%	100%	57%
2010	100%	93%	99%	53%
2011	100%	92%	98%	67%
2012	98%	94%	97%	86%
Average	95%	93%	96%	79%

Table 20.4. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 1, 2012. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2012 from NMFS AKRO blend-estimated annual catches.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unidentified shark	Total sharks	Total other species	Shark % of other species
1997	4	304	7	53	368	25,176	1%
1998	6	336	18	136	497	25,531	2%
1999	5	319	30	176	530	20,562	3%
2000	9	490	23	68	590	26,108	2%
2001	17	687	24	35	764	27,178	3%
2002	9	839	47	468	1,363	26,296	5%
2003	13	342	199	34	589	25,559	2%
2004	9	420	26	60	515	29,363	2%
2005	11	333	47	26	417	29,482	1%
2006	7	313	63	305	689	27,021	3%
2007	3	256	44	28	331	26,829	1%
2008	17	120	43	7	186	29,439	1%
2009	20	47	71	9	146	27,852	1%
2010	15	21	12	5	53	23,362	0%
2011	8	47	114	3	172		
2012	2	43	27	2	74		
Total est. catch	154	4,918	794	1,415	7,282		
species % of total sharks	2%	68%	11%	19%			
Avg. 1997 – 2007	8	422	48	126	605		

Table 20.5. Estimated catches (t) of Pacific sleeper sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997 - 2002 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004 - 2012 are from NMFS AKRO blend-estimated annual catches, as of Oct 1, 2012. Estimated catch of Pacific sleeper shark by target fishery are not available for 2002 because the Gaichas (2002) catch estimates ended in 2001 and CAS did not begin until 2003.

Year	Atka Mackerel	Flatfish	Pacific Cod	Walleye Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0.1	0.9	74.8	105.2	0.9	45.3	77	0	304.2
1998	0	0.9	146.7	74.4	0	0	113.5	0	335.5
1999	2.4	39.4	103.3	76.8	3	15.1	78.2	0	318.2
2000	0.3	42	114.7	103.8	2.7	143.7	83.2	0	490.4
2001	27.8	179.6	252.7	205.7	0	1.8	19.3	0	686.9
2002									
2003	0.7	35.7	172.6	85.0	0.5	19.4	9.7	18.6	342.1
2004	2.0	37.3	229.8	144.0	0.7	2.3	2.7	1.1	420.0
2005	0.0	7.7	191.2	127.6	0.1	3.8	2.7	0.1	333.2
2006	0.0	9.5	123.1	178.0	0.1	1.0	1.3	0.1	313.1
2007	1.1	9.1	44.3	180.2	14.5	2.4	0.5	0.0	252.1
2008	0.1	6.3	12.7	98.3	1.2	1.2	0.4	0.0	120.1
2009	0.6	8.2	11.2	24.5	0.6	1.9	0.1	0.0	47.1
2010	0.0	1.2	8.6	10.4	0.1	0.9	0.1	0.0	21.3
2011	0.0	2.4	19.2	18.1	4.8	1.6	0.0	0.5	46.6
2012	0.9	8.2	7.6	25.8	0.6	0.1	0.1	0.0	43.3
Total	35.9	388.5	1,512.4	1,457.8	29.8	240.5	388.6	20.4	4,074.0
Avg. % of Total	1%	10%	37%	36%	1%	6%	10%	1%	

Table 20.6. Estimated catches (t) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997 - 2002 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2003 - 2012 are from NMFS AKRO blend-estimated annual catches, as of Oct 1, 2012. Estimated catch of salmon sharks by target fishery are not available for 2002 because the Gaichas (2002) catch estimates ended in 2001 and CAS did not begin until 2003.

Year	Atka Mackerel	Flatfish	Pacific Cod	Walleye Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0.1	0	0	6.7	0	0	0		6.8
1998	0	0.1	0.8	16.2	0	0	0.8		17.9
1999	0.2	2.5	1.2	24.7	0	0	1.5		30.1
2000	0	0	3.8	19.5	0	0	0		23.3
2001	0.4	0.4	1.2	22.5	0	0	0		24.5
2002									
2003	0.2	0.5	1.2	197.4	0	0	0	0	199.3
2004	0.0	0.1	0.1	25.5	0	0	0	0	25.6
2005	18.2	0.7	2.0	25.7	0	0	0	0	46.7
2006	0.2	25.9	1.2	36.2	0	0	0	0	63.4
2007	0.1	0.0	0.0	44.4	0	0	0	0	44.5
2008	0.0	0.8	0.0	41.8	0	0	0	0	42.5
2009	0.3	0.4	0.1	69.8	0	0	0	0	70.7
2010	0.1	0.4	0.0	11.1	0	0	0	0	11.6
2011	0.2	1.5	0.1	112.1	0	0	0	0	113.9
2012	0.3	0.0	0.0	27.0	0	0	0	0	27.3
Total	20.3	33.1	11.6	680.6	0.0	0.0	2.3	0.0	748.0
Avg. % of Total	3%	4%	2%	91%	0%	0%	0%	0%	

Table 20.7. Estimated catches (t) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997 - 2002 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2003 - 2012 are from NMFS AKRO blend-estimated annual catches, as of Oct 1, 2012. Estimated catch of spiny dogfish by target fishery are not available for 2002 because the Gaichas (2002) catch estimates ended in 2001 and CAS did not begin until 2003.

Year	Atka Mackerel	Flatfish	Pacific Cod	Walleye Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0	0	4.1	0	0	0	0		4.1
1998	0.2	0.4	5.6	0.1	0	0	0		6.3
1999	0	0	4.9	0	0	0	0		4.9
2000	0	0.2	8.6	0	0	0	0		8.8
2001	2.8	1.6	12.7	0.1	0	0.1	0		17.3
2002									
2003	0.1	0.0	13.0	0.0	0.0	0.0	0.0	0.0	13.3
2004	0.0	0.2	8.3	0.0	0.0	0.1	0.0	0.0	8.6
2005	0.0	0.1	11.2	0.0	0.0	0.0	0.0	0.0	11.4
2006	0.0	0.1	6.6	0.2	0.0	0.1	0.0	0.0	7.1
2007	0.0	0.3	2.5	0.2	0.0	0.1	0.0	0.0	3.0
2008	0.1	0.2	10.2	0.2	0.1	0.0	0.0	6.0	16.8
2009	0.0	0.6	18.3	0.4	0.0	0.2	0.0	0.0	19.5
2010	0.0	0.7	13.9	0.3	0.0	0.0	0.0	0.0	14.9
2011	0.0	0.4	7.3	0.2	0.0	0.0	0.0	0.0	7.8
2012	0.1	0.0	1.8	0.0	0.0	0.0	0.0	0.0	2.0
Total	3.5	4.8	129.1	1.7	0.1	0.6	0.1	6.0	145.8
Avg. % of Total	2%	3%	88%	1%	0%	0%	0%	4%	

Table 20.8. Estimated catches (t) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997 - 2002 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2003 - 2012 are from NMFS AKRO blend-estimated annual catches, as of Oct 1, 2012. Estimated catch of other and unidentified sharks by target fishery are not available for 2002 because the Gaichas (2002) catch estimates ended in 2001 and CAS did not begin until 2003.

Year	Atka Mackerel	Flatfish	Pacific Cod	Walleye Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0	0.4	26.8	15.6	2.5	1.2	6.3		52.8
1998	13.1	0	48.4	45.4	0	2.1	26.9		135.9
1999	0	0.2	18.8	10.3	0	1.8	144.9		176
2000	0	1.2	56.1	0.1	0	7.2	3		67.6
2001	0	0	19.6	2.3	0	10.4	2.7		35
2002									
2003	0	1.3	20.8	11.9	0	0.1	1.3	0	35.4
2004	0	22.2	20.2	17.6	0	0.0	0.0	0	60.1
2005	0	0.0	10.1	16.0	0	0.0	0.0	0	26.2
2006	0	3.7	3.6	298.0	0	0.1	1.6	0	307.0
2007	0	5.9	2.1	19.8	0	0	0.0	0	27.8
2008	0	0.3	0.6	5.9	0	0	0.0	0	6.8
2009	0	0.0	3.1	5.5	0.2	0.0	0.0	0	8.8
2010	0	0.0	0.8	4.1	0	0	0.0	0	4.9
2011	0	0.0	1.4	2.0	0	0	0.0	0	3.3
2012	0	0.0	0.3	1.7	0	0	0.0	0	2.0
Total	13.1	35.2	232.7	158.2	2.7	22.9	186.7	0.0	949.5
Avg. % of Total	1%	4%	25%	48%	0%	2%	20%	0%	

Table 20.9. Eastern Bering Sea slope AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls (Jerry Hoff, pers. comm., October, 2012).

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Total Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	105	0			0			0		
1981	205	1	1	0.83	0			0		
1982	299	3	8	0.73	1	12	1.02	0		
1985	325	3	2	0.66	19	543	0.1	0		
1988	131	0			10	1,993	0.39	0		
1991	85	0			6	1,235	0.44	0		
Change in slope survey design										
2002	141	0			15	25,445	0.87	0		
2004	231	0			24	2,260	0.34	0		
2008	207	1	14	1	28	2,037	0.27	0		
2010	200	0			19	833	0.27	0		
2012	210	0			16	1,337	0.28	0		

Table 20.10. Aleutian Islands AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls (Wayne Palsson, pers. comm., October 2012).

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Total Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1980	129	0			0			0		
1983	372	3	2	0.61	3	254	0.65	0		
1986	443	6	14	0.51	12	1,995	0.36	0		
1991	331	0			3	2,927	0.69	0		
1994	381	9	47	0.37	3	374	0.64	0		
1997	397	2	11	0.71	10	2,486	0.29	0		
2000	419	3	25	0.62	3	2,638	0.57	0		
2002	417	0			4	536	0.55	1	893	1.00
2004	420	0			2	1,017	0.96	0		
2006	358	6	62	0.49	1	76	1.00	0		
2010	418	0			1	74	1.00	0		
2012	420	0			1	22	1.00	0		

Table 20.11. Eastern Bering Sea shelf AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV and number of hauls (Bob Lauth, pers. comm., October, 2012). Biomass estimates were not calculated for 2011 and 2012 because only one shark was caught each year.

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Total Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	452	4	389	0.56	0			0		
1980	342	0			0			0		
1981	290	0			0			0		
1982	329	0			0			0		
1983	354	2	379	0.83	0			0		
1984	355	0			0			0		
1985	353	1	47	0.99	0			0		
1986	354	0			0			0		
1987	342	3	223	0.60	0			0		
1988	353	1	249	1.0	0			1	3,808	1.0
1989	353	0			0			0		
1990	352	0			0			0		
1991	351	0			0			0		
1992	336	0			2	2,564	0.72	0		
1993	355	0			0			0		
1994	355	0			2	5,012	0.82	0		
1995	356	0			1	1,005	1.00	0		
1996	355	0			2	2,804	0.82	0		
1997	356	1	37	1	0			0		
1998	355	1	254	1	1	2,124	1.00	0		
1999	353	0			2	2,079	0.71	0		
2000	352	0			1	1,487	1.00	0		
2001	355	0			0			0		
2002	355	0			3	5,602	0.65	0		
2003	356	0			1	734	1.00	0		
2004	355	1	28	1.00	2	3,093	0.71	0		
2005	353	0			2	1,532	0.75	0		
2006	356	0			2	2,944	0.78	0		
2007	356	0			0			0		
2008	375	0			0			0		
2009	376	1	72	1	0			0		
2010	376	1	89	1.00	4	5,299	0.53	0		
2011	376	0			1	NA		0		
2012	376	0			1	NA		0		

Table 20.12. Research survey catch of sharks 1977 - 2011 in the Bering Sea/Aleutian Islands (BSAI). The AFSC LL and IPHC LL survey catches are provided in numbers prior to 2010. The total catch numbers from the IPHC survey are estimated based on the subsample of observed hooks, the estimated catch (t) is directly from the survey. Beginning in 2010 all research and other non-commercial catch is provided by the AKRO.

Year	Source	AFSC Trawl Surveys (t)	AFSC LL Survey (#s)	AFSC LL Survey (t)	IPHC LL Survey (#s)	IPHC LL Survey (t)	ADF&G (t) (includes sport and research)
1977		0					
1978							
1979		0.03	4	NA			
1980		0	4	NA			
1981		0.07	5	NA			
1982		0.16	15	NA			
1983		0.01	33	NA			
1984			40	NA			
1985		0.59	53	NA			
1986			52	NA			
1987		0.01	61	NA			
1988		1.06	30	NA			
1989		0.07	27	NA			
1990	Assessment of the sharks in the Bering Sea and Aleutian Islands (Tribuzio et al. 2010)	0	4	NA			
1991		0.56	18	NA			
1992		0.09	55	NA			
1993			75	NA			
1994		0.17	111	NA			
1995		0.04	0	NA			
1996		0.1	3	NA			
1997		0.11	59	NA			
1998		0.09	1	NA	207	NA	
1999		0.08	20	NA	152	NA	
2000		8.5	2	NA	723	NA	
2001			12	NA	164	NA	
2002		5.74	1	NA	169	NA	
2003		0.03	22	NA	368	NA	
2004		0.76	3	NA	251	NA	
2005		0	6	NA	237	NA	
2006		0	3	NA	241	NA	
2007		0	34	NA	170	NA	
2008		0.47	8	NA	208	NA	
2009		2.02	2	NA	234	NA	
2010	AKRO	0.43	2	<0.01	NA	8.38	<0.01
2011		2.76	5	0.03	NA	1.50	0.03

Table 20.13. Life history parameters for spiny dogfish, Pacific sleeper, and salmon sharks. Top: Length-weight coefficients and average lengths and weights are provided for the formula $W=aL^b$, where W = weight in kilograms and L = PCL (precaudal length in cm). Bottom: Length at age coefficients from the von Bertalanffy growth model, where L_∞ is PCL or the TL_{ext} (total length with the upper lobe of the caudal fin depressed to align with the horizontal axis of the body).

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

Species	Sex	L_∞ (cm)	κ	t_0 (years)	M	Max Age	Age at first Recruit
Spiny Dogfish	M	93.7 (TL_{ext})	0.06	-5.1	0.097	80-100	NA
Spiny Dogfish	F	132.0 (TL_{ext})	0.03	-6.4			
Pacific Sleeper Shark	M	NA	NA	NA	NA	NA	NA
Pacific Sleeper Shark	F	NA	NA	NA			
Salmon Shark	M	182.8 (PCL)	0.23	-2.3	0.18	30	5
Salmon Shark	F	207.4 (PCL)	0.17	-1.9			

Sources: NMFS GOA bottom trawl surveys in 2005; Wood et al. (1979); Goldman (2002); Sigler et al (2006); Goldman and Musick (2006); and Tribuzio and Kruse (2012).

Table 20.14. Analysis of ecosystem considerations for the shark complex.

Ecosystem effects on *GOA Sharks*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys, changes mean wt-at-age	Stable, data limited	Unknown
Non-pandalid shrimp and other benthic organism	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Composes the main portion of spiny dogfish diet	Unknown
Sandlance, capelin, other forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Salmon	Populations are stable or slightly decreasing in some areas	Small portion of spiny dogfish diet, maybe a large portion of salmon shark diet	No concern
Flatfish	Increasing to steady populations currently at high biomass levels	Adequate forage available	No concern
Walleye pollock	High population levels in early 1980's, declined to stable low level at present	Primarily a component of salmon shark diets	No concern
Other Groundfish	Stable to low populations	Varied in diets of sharks	No concern
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Not likely a predator on sharks	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	No concern
Fish (walleye pollock, Pacific cod, halibut)	Stable to increasing	Possible increases to juvenile spiny dogfish mortality	
Sharks	Stable to increasing	Larger species may prey on spiny dogfish	Currently, no concern
Changes in habitat quality			
Temperature regime	Warm and cold regimes	May shift distribution, species tolerate wide range of temps	No concern
Benthic ranging from inshore waters to shelf break and down slope	Sharks can be highly mobile, and benthic habitats have not been monitored historically, species may be able to move to preferred habitat, no critical habitat defined for GOA	Habitat changes may shift distribution	No concern

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

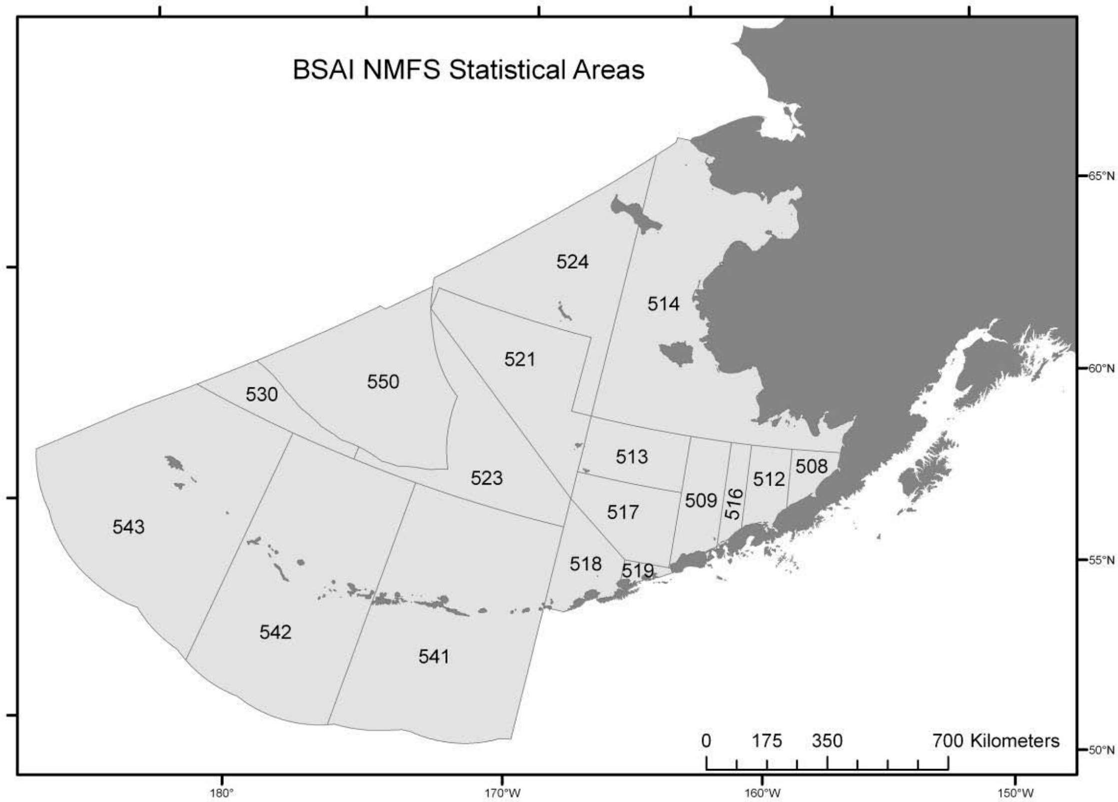


Figure 20.1. NMFS statistical areas in the Bering Sea and Aleutian Islands.

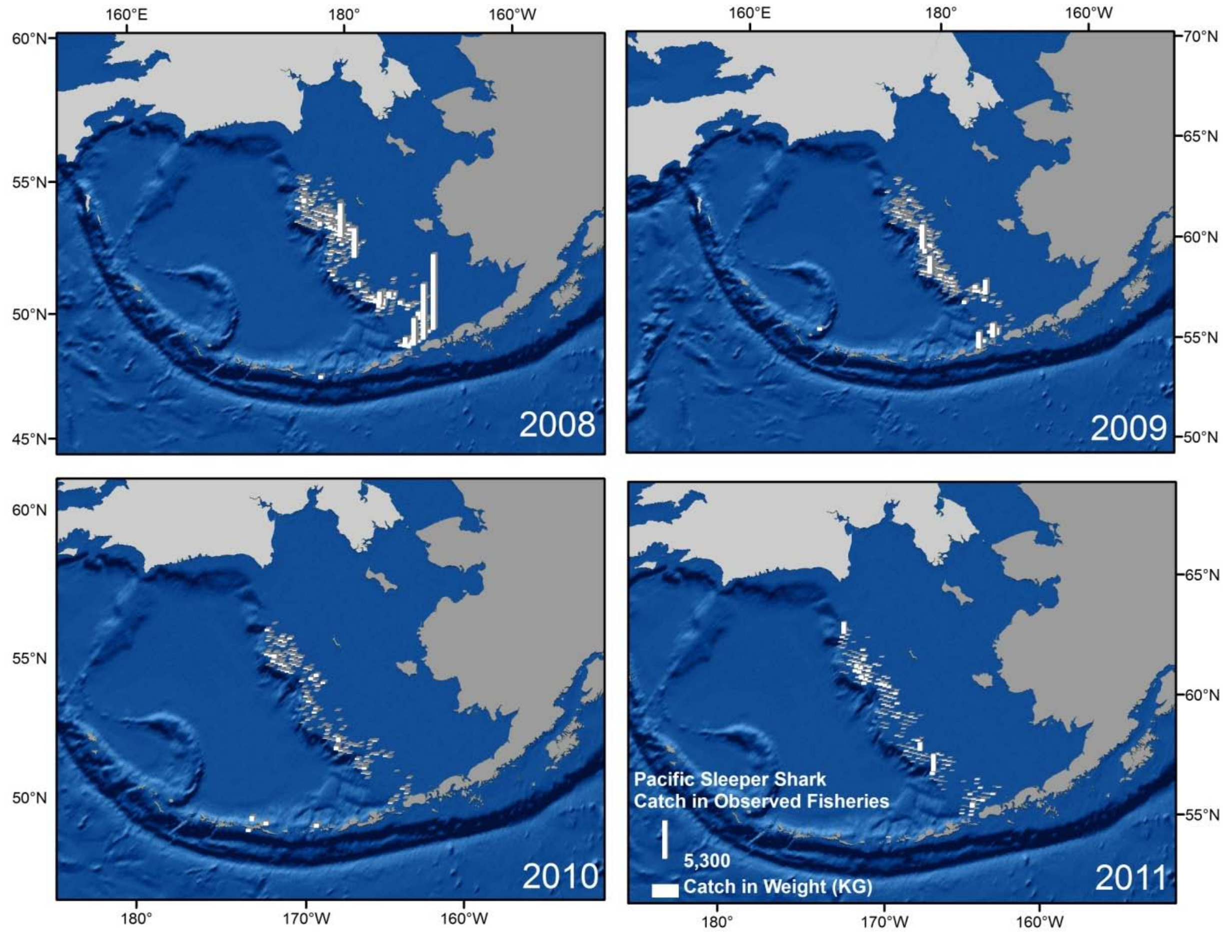


Figure 20.2. Spatial distribution of observed Pacific sleeper shark catch in the BSAI from 2008 - 2011. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2012 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

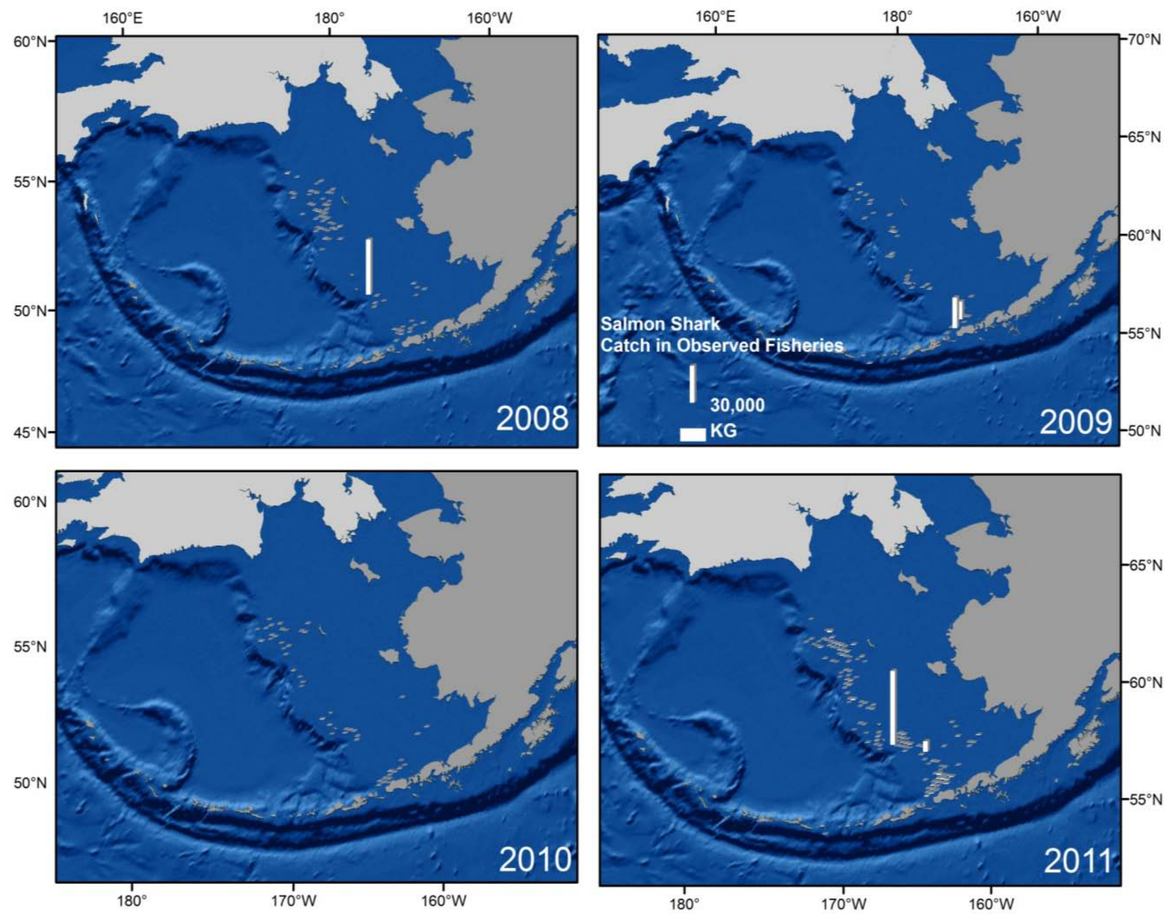


Figure 20.3. Spatial distribution of salmon shark catch in the BSAI from 2008 - 2011. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2012 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

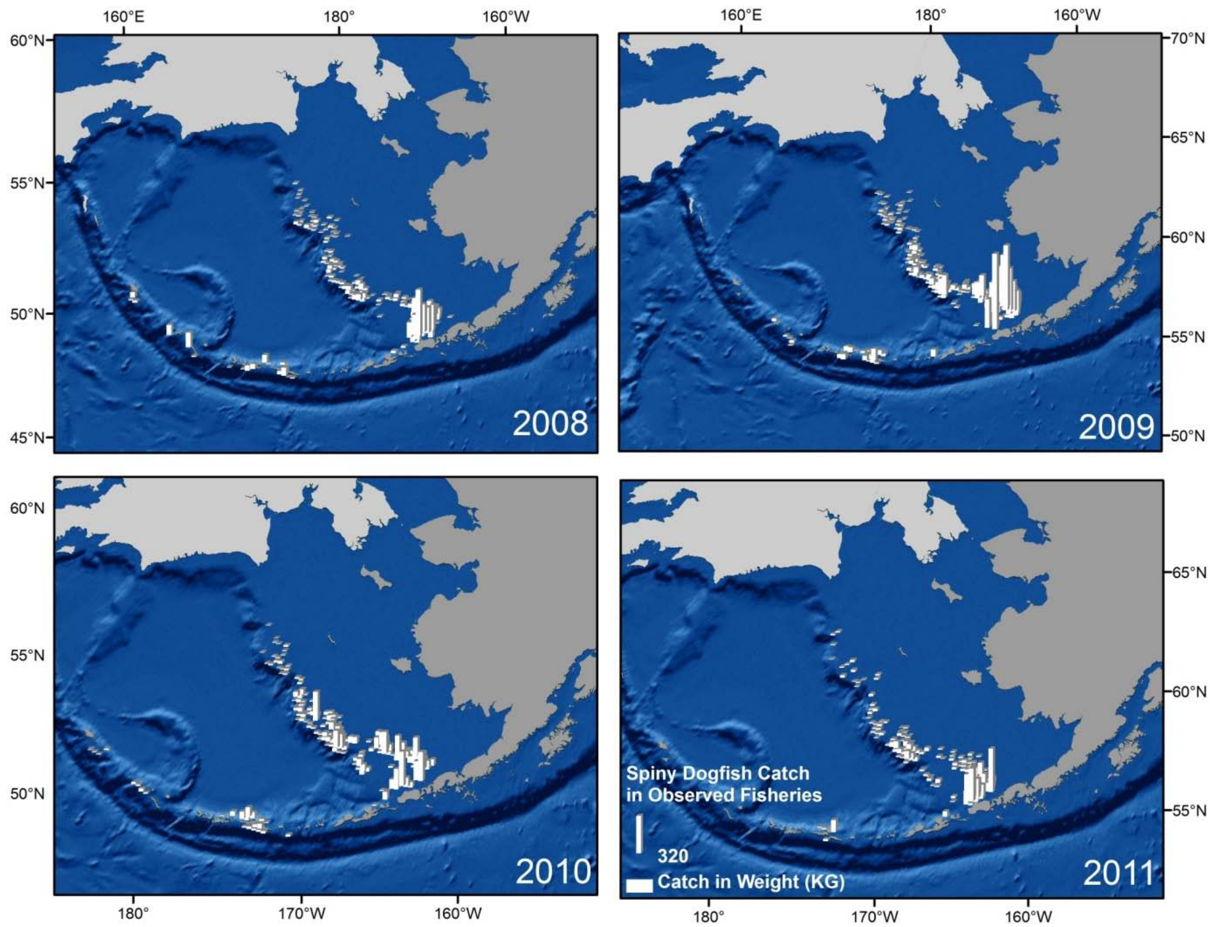


Figure 20.4. Spatial distribution of observed spiny dogfish catch in the BSAI from 2008 - 2011. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2012 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

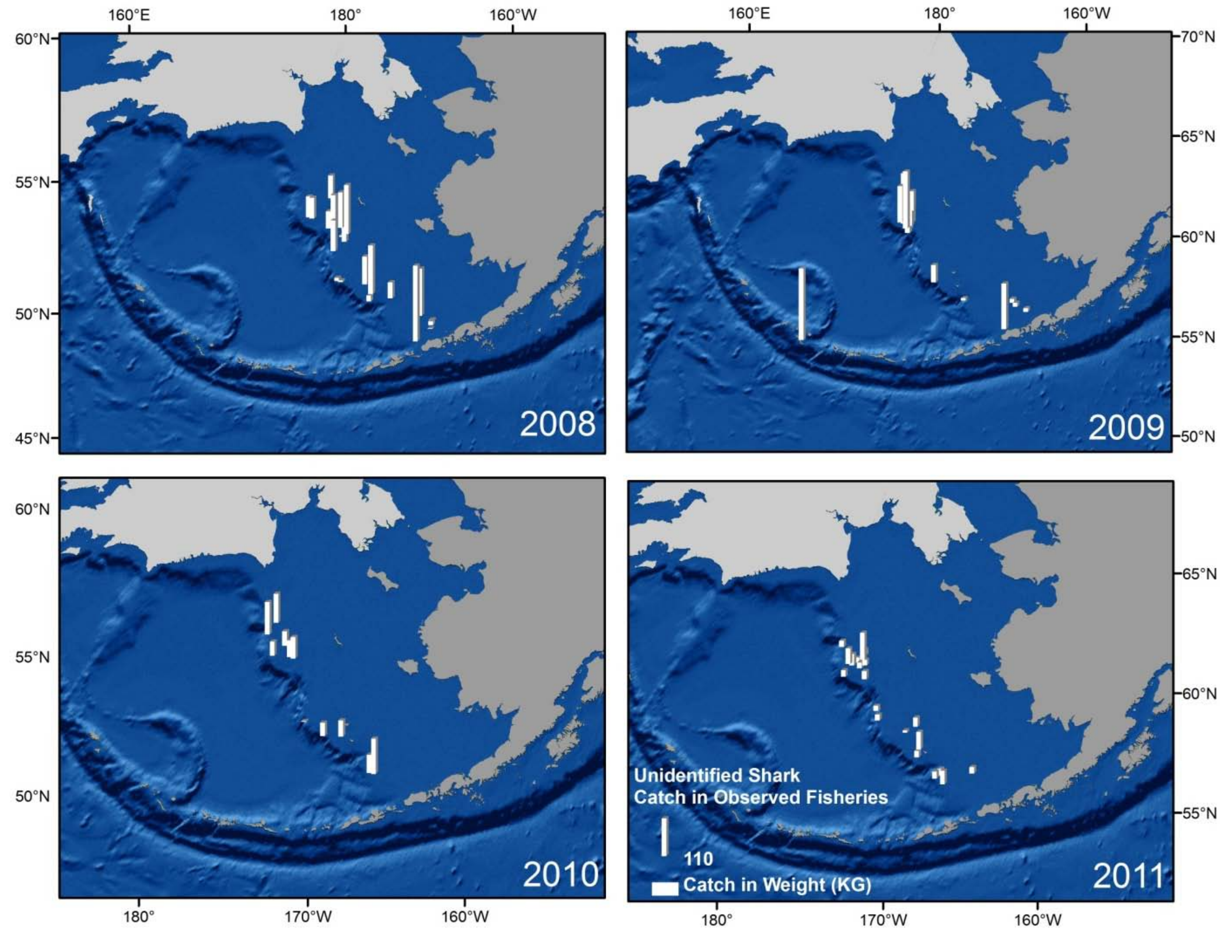


Figure 20.5. Spatial distribution of observed unidentified shark catch in the BSAI from 2008 - 2011. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2012 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

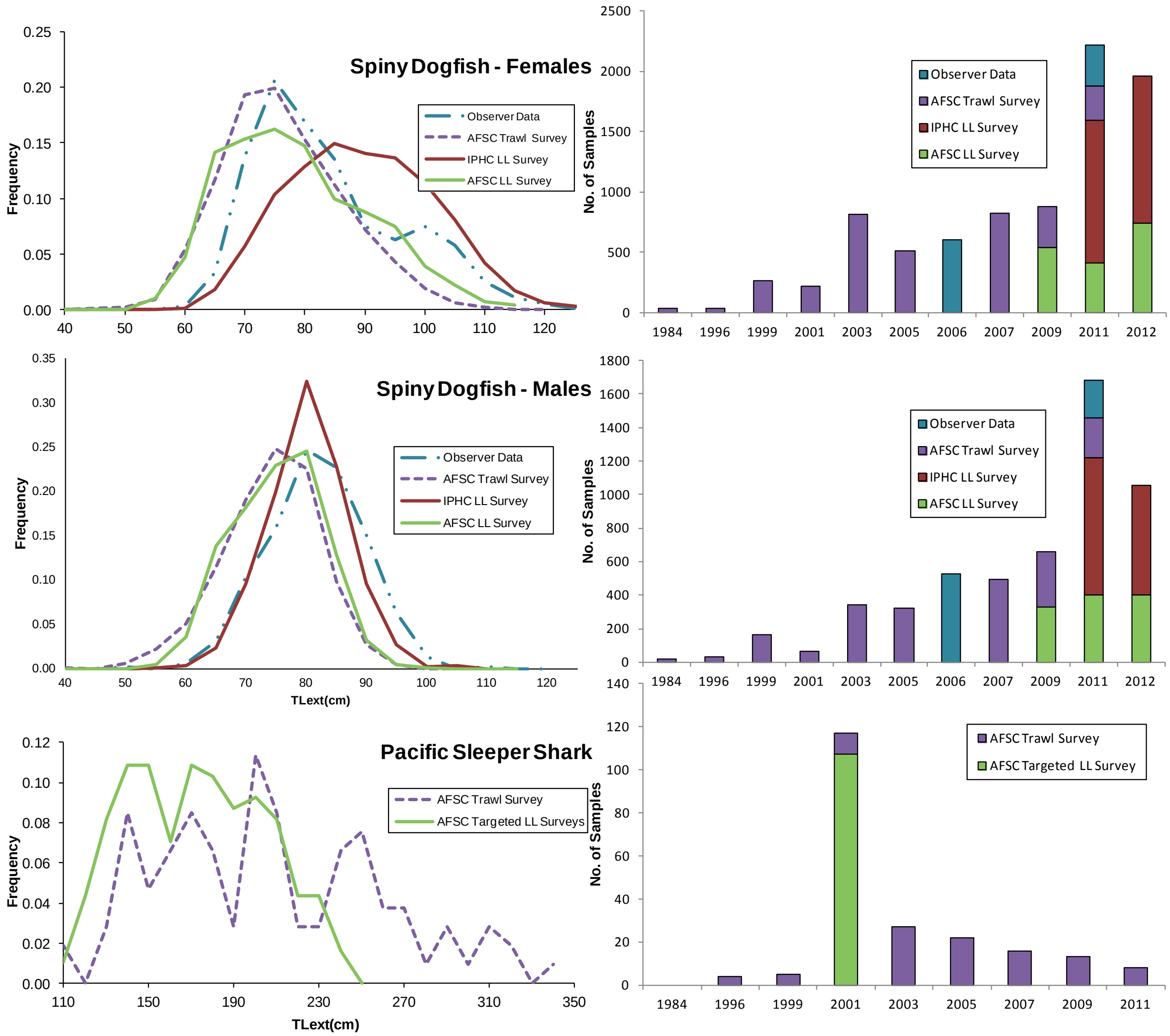


Figure 20.6. Observed length frequencies and sample sizes for sharks. Spiny dogfish females (top), spiny dogfish males (center) and Pacific sleeper sharks (sexes combined, bottom). Data for spiny dogfish is from the AFSC GOA biennial trawl (1984 - 2011) and longline (2010 – 2012) surveys, the IPHC longline survey (2011 - 2012), and special projects with the observer program in 2006 and 2011. Pacific sleeper shark length data is from all years of the AFSC GOA biennial trawl survey (1984 - 2011) and targeted a longline survey in 2001 near Kodiak Island (bottom).

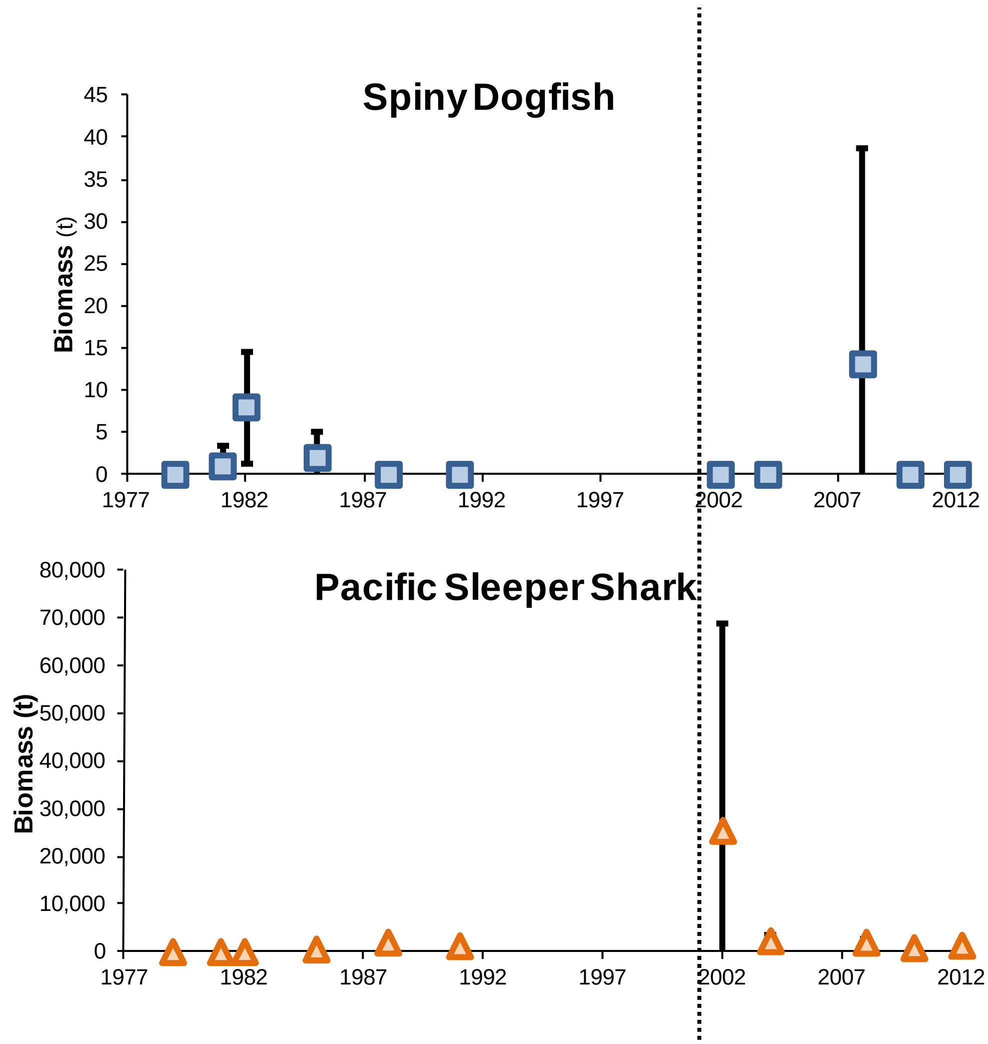


Figure 20.7. Time series of biomass estimates (t) in the eastern Bering Sea (EBS) slope AFSC bottom trawl surveys of spiny dogfish and Pacific sleeper sharks (salmon sharks are not encountered on the EBS slope survey), reported here as an index of relative abundance. Error bars are 95% confidence intervals. Dashed line indicates beginning of new EBS slope survey (2002). Analysis of EBS slope survey biomass trends is subject the following time series caveats: the slope survey was standardized in 2002 to its current gear type, survey strata, and survey design; biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey biomass (2002 - present) due to differences in stratification; and prior to 2002, the survey utilized a mix of commercial and research vessels with various gear configurations.

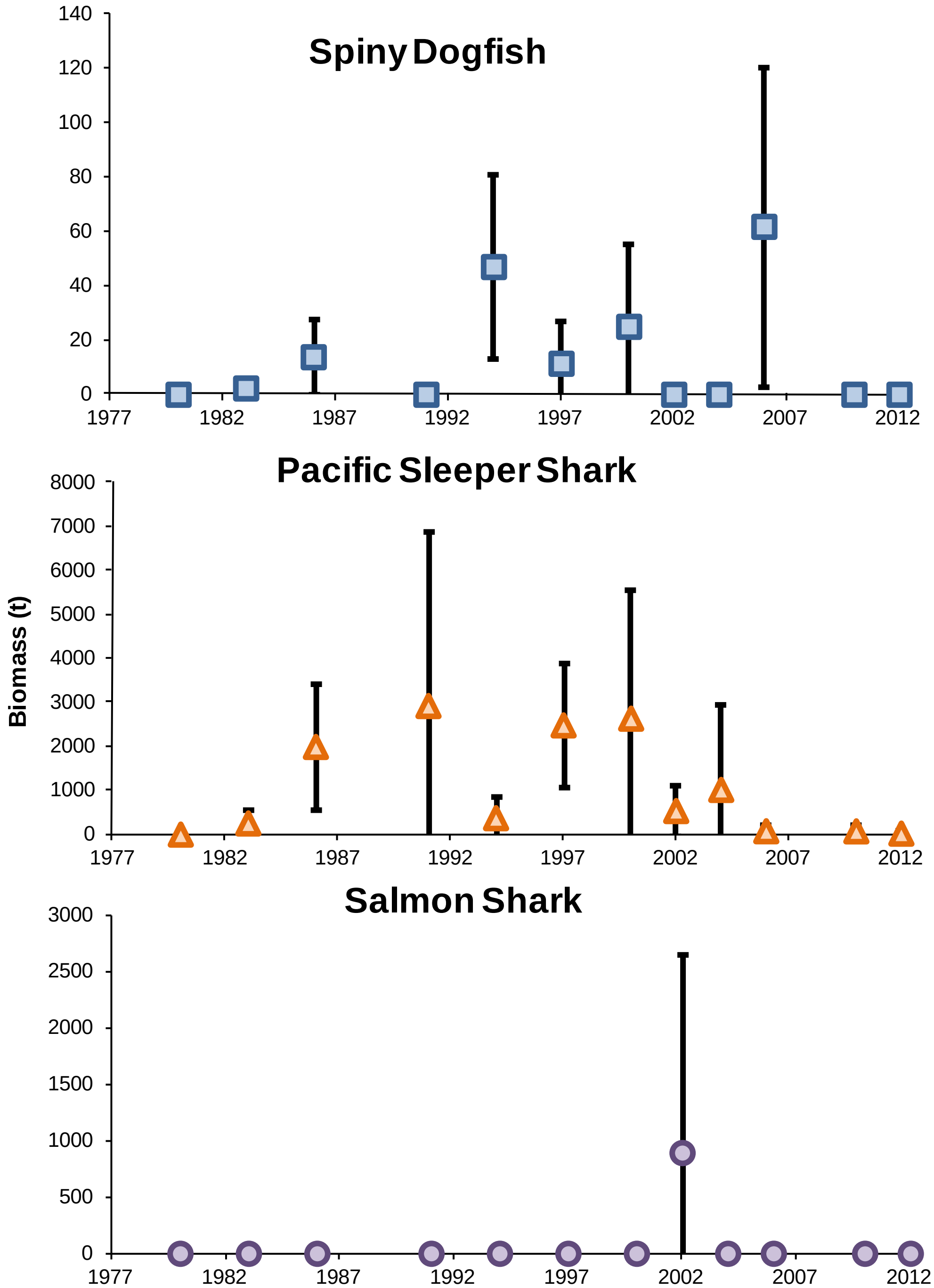


Figure 20.8. Time series of biomass estimates (t) for spiny dogfish, Pacific sleeper and salmon sharks in the Aleutian Islands (AI) AFSC bottom trawl surveys, reported here as an index of relative abundance. Error bars are 95% confidence intervals.

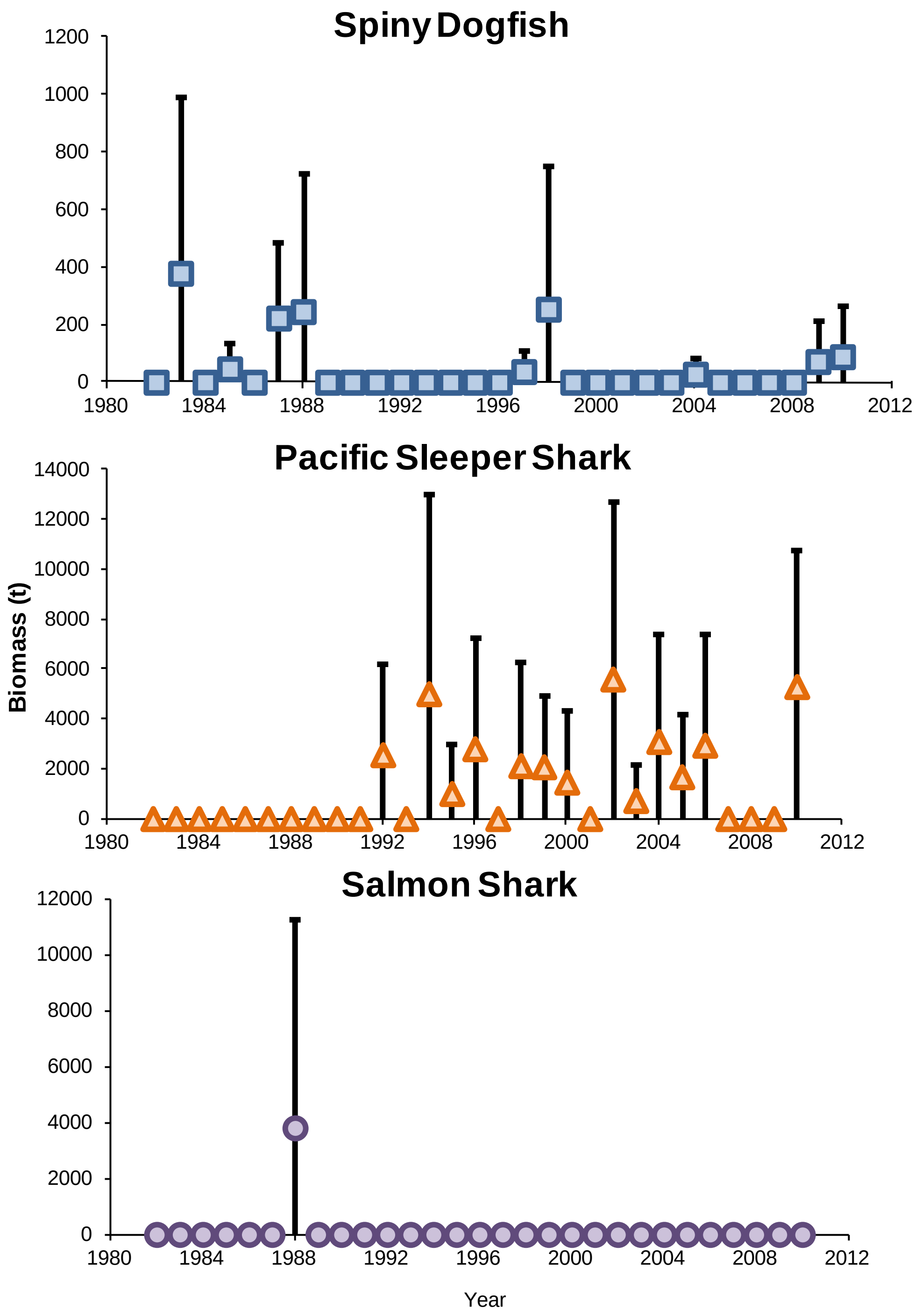


Figure 20.9. Time series of biomass estimates (t) in the eastern Bering Sea shelf AFSC bottom trawl surveys of spiny dogfish, Pacific sleeper and salmon sharks, reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS shelf biomass trends is subject to the following time series caveat: the survey was standardized in 1982 to its current gear type, fixed stations, and survey time period (June 1 – August 4). Biomass estimates were not provided for 2011 and 2012 because only one Pacific Sleeper shark was caught each year.

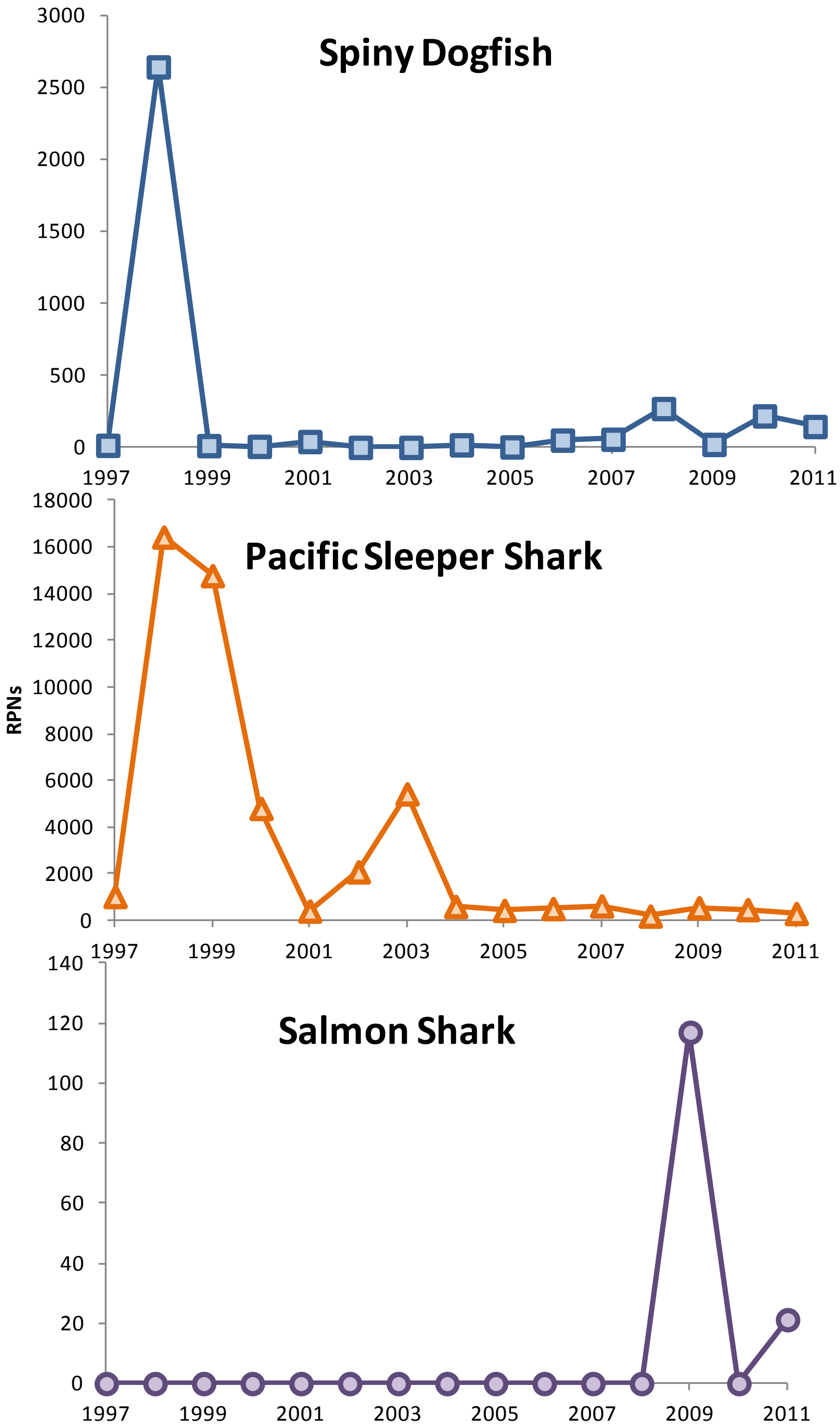


Figure 20.10. Estimated relative population numbers from the IPHC annual longline survey.

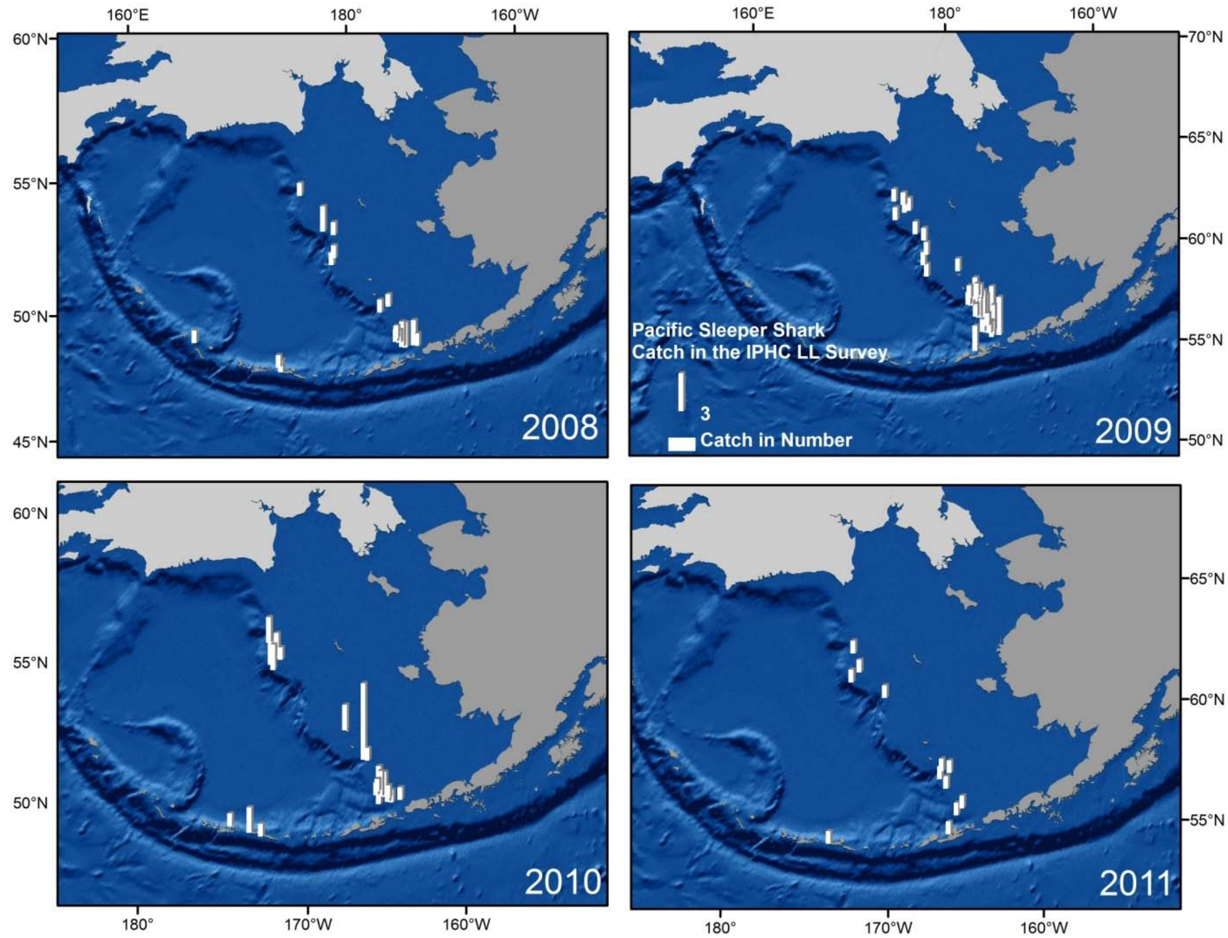


Figure 20.11. Spatial distribution of the catch of Pacific sleeper shark during the 2008 - 2011 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

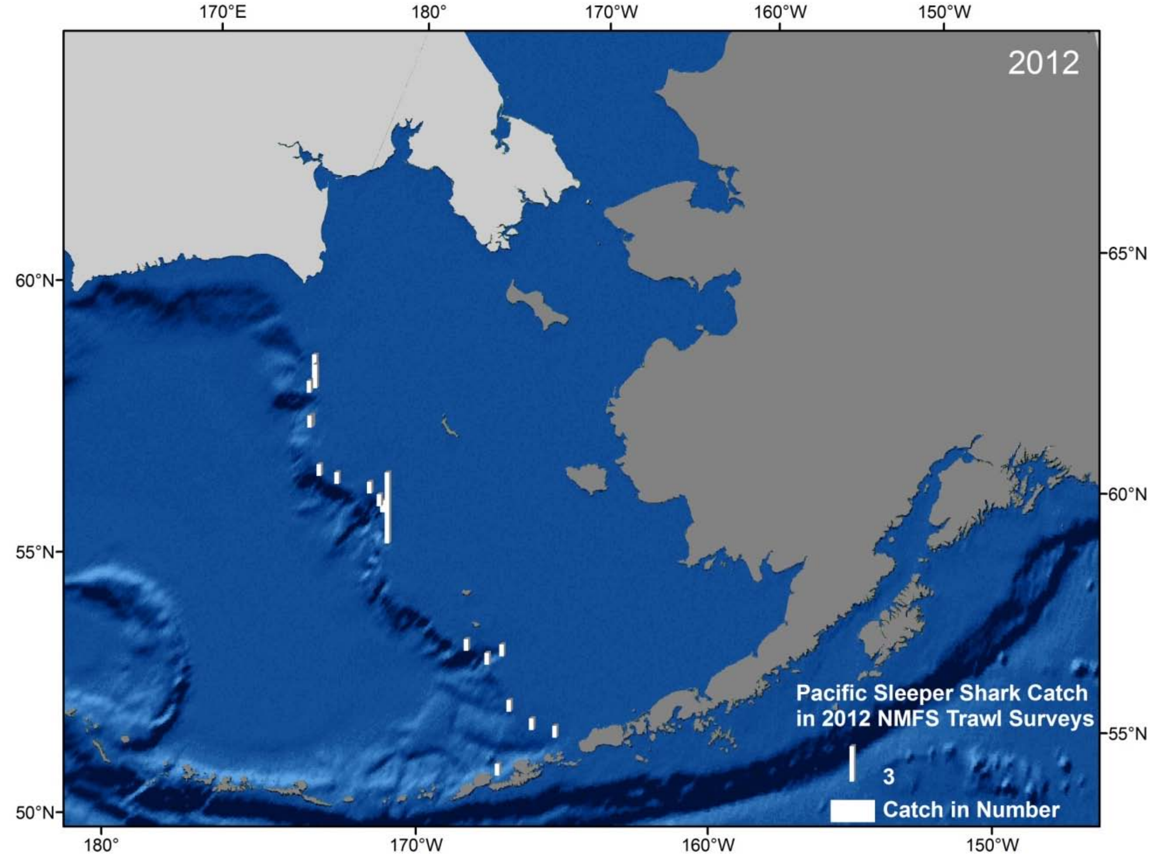


Figure 20.12. Spatial distribution of the catch of Pacific sleeper shark during the 2012 NMFS Bering Sea and Aleutian Islands trawl surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity. There were no other shark species caught during the 2012 surveys.

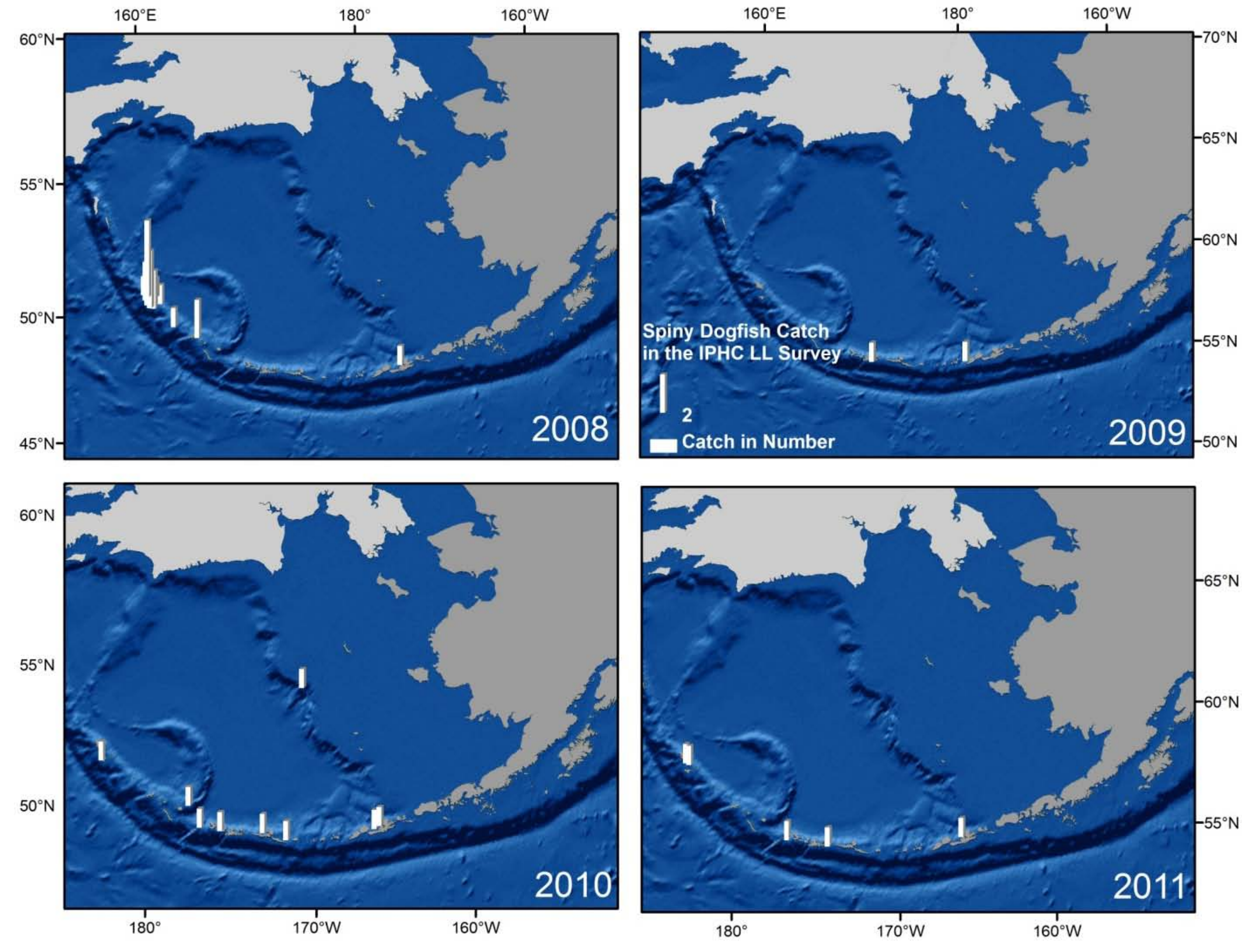
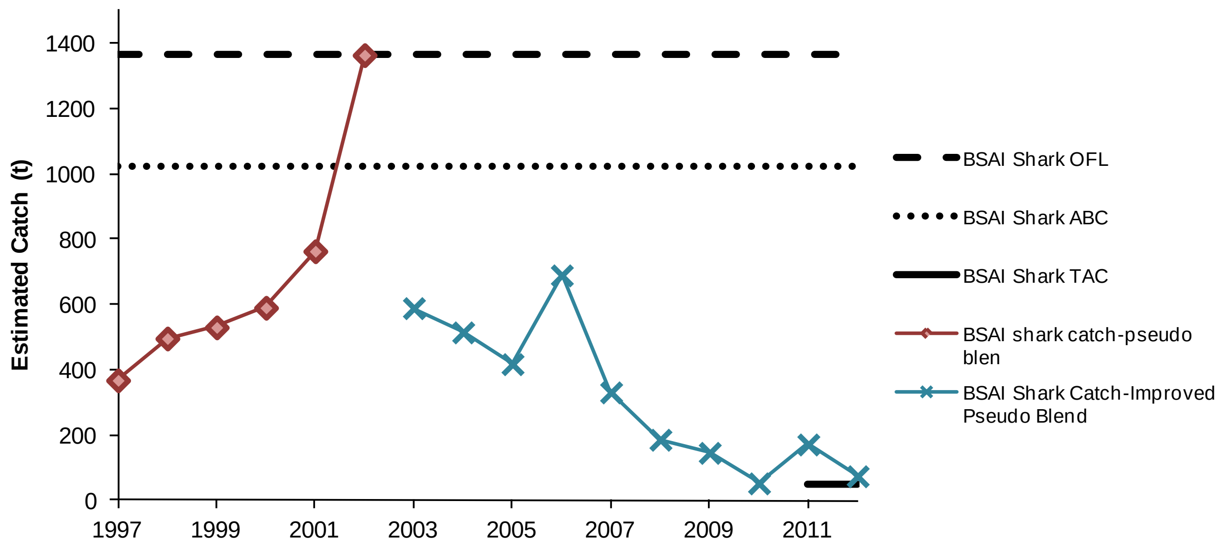


Figure 20.13. Spatial distribution of the catch of spiny dogfish during the 2008 - 2011 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.



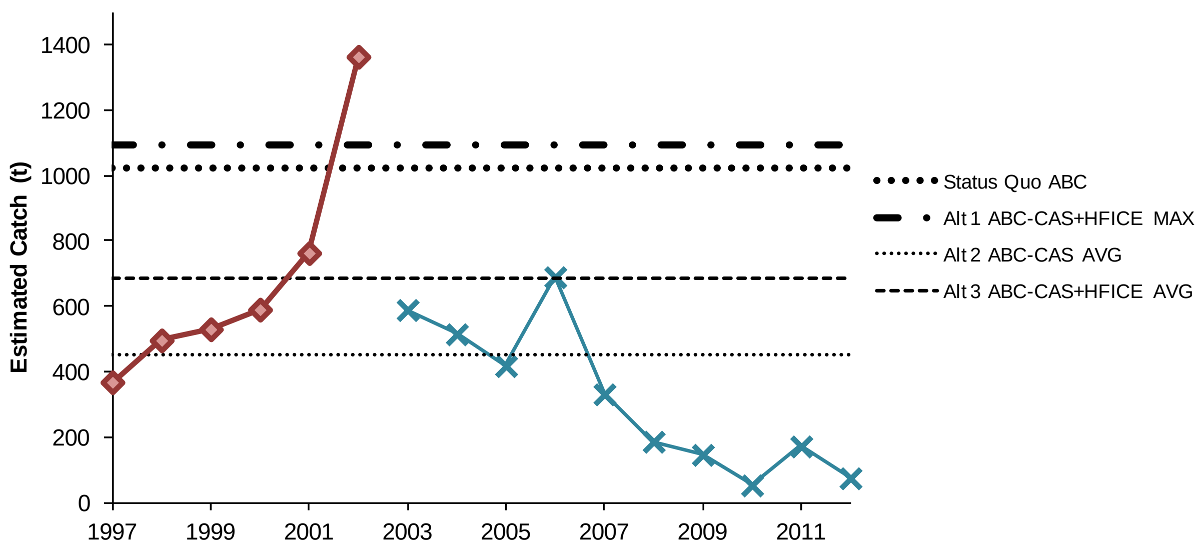


Figure 20.14. Top: total BSAI shark catch relative to the ABC, OFL and TAC. Bottom: BSAI total shark catch per year plotted relative to alternative Tier 6 options for ABC.

Appendix 20A.—Halibut Fishery Incidental Catch Estimation

The Halibut Fishery Incidental Catch Estimation (HFICE) is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011b). These catch estimates were first presented in the 2011 assessments (for the 2012 fishery) for all groundfish species (e.g. Tribuzio et al. 2011a).

The HFICE estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between “retained” or “discarded” catch. The CAS estimates of catch and the HFICE estimates should be considered as separate time series because there can be overlap in these two data sources. Thus, HFICE removals should not be added to the CAS produced catch estimates because of the potential for double counting. The section below explains this issue in detail.

The CAS relies on at-sea discard information collected by onboard observers. The observer information is used to create a bycatch rate that is applied to landed groundfish based on post-stratification procedures (Cahalan et al. 2010). Vessels retaining halibut are not required to have an onboard observer, but sometimes take observers if they are concurrently fishing in federal groundfish fisheries. This results in low observer coverage for vessels predominantly fishing for halibut and is the basis for several estimation issues when comparing CAS to the catch estimates discussed in this report. There are three scenarios of data in CAS that pertains to estimates of catch by vessels predominantly fishing for halibut:

- A vessel retains both halibut and groundfish on a fishing trip. Thus, an estimate of retained and discarded catch is generated through a fish ticket, regardless of observer coverage.
- Observer data does not represent halibut fishing activities because there is no coverage requirement; any directed halibut fishing in the observer data is essentially accidental, particularly in nearshore areas (i.e. non-federal fisheries/waters). This bias results in an underestimate of discard in CAS. For example, the limited amount of observer information results in discard information on only a few species; thereby estimating no discard for unobserved species. In this situation, CAS will contain incomplete discard information, but the extent to which the discards are underestimated is unknown.
- A combination of the previous two bullets is common, resulting in both retained groundfish and incomplete observer information. CAS provides information for retained and an incomplete accounting of discarded catch.

The first scenario results in an overlap between the CAS and the HFICE estimates. The second and third scenarios demonstrate how limited observer coverage creates a data poor situation that makes it impossible to determine the extent of the overlap. The authors considered several methods of removing landings that contained only halibut (i.e. no groundfish were landed with the halibut), but due to incomplete accounting of discards, this was an unacceptable solution. The extent of the overlap issue is likely significant given that between 2008 and 2011, approximately 93% of the total halibut landed in pounds also had associated groundfish in CAS.

The CAS data is useful for describing the magnitude of the overlap problem. The CAS does contain information on retained and discarded catch of Pacific cod and sablefish by vessels predominantly targeting halibut. Both species are valuable fishery targets that are commonly caught on trips where IFQ halibut is also retained. Pacific cod was estimated to make up 39% of the total landings (groundfish + halibut) reported by halibut fishing vessels, compared to 22% for the target species, halibut (NPFMC 2012). It is possible that the CAS estimates of catch in the halibut fleet may be representative of actual catch for valuable target species such as Pacific cod and sablefish, but it is impossible to evaluate with the current data.

For the above reasons it is not possible to simply add the CAS total with the HFICE estimate. Further, there are situations where the HFICE estimate includes groundfish caught in State waters/parallel fisheries (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered an exploratory analysis for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of shark catch by the BSAI halibut fishery are substantial relative to catch in the groundfish fisheries (ranging from 7% of the estimated groundfish catch of sharks in 2002 to 648% in 2010, average of 125%) and in 2011 represented approximately 11% of the 2011 shark ABC (Table 20A.1).

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Table 20A.1. Estimates of shark catch (t) by BSAI NMFS Regulatory Area from the Halibut Fishery Incidental Catch Estimation (HFICE) working group.

	AI		BS		Total		
	HFICE	CAS	HFICE	CAS	HFICE	CAS	HFICE+CAS
2001	124		347		471	763	1,234
2002	12		80		92	1,363	1,455
2003	6	36	491	553	497	589	1,086
2004	1	6	462	509	463	515	978
2005	3	23	214	395	217	417	634
2006	1	1	351	688	352	689	1,041
2007	1	17	86	316	86	332	418
2008	26	7	281	179	308	186	494
2009	0	3	185	143	185	146	331
2010	7	3	334	50	341	53	394
2011	2	4	113	168	116	172	288

Table 20A.2. Estimates of shark catch (t) by species in the BSAI from the Halibut Fishery Incidental Catch Estimation (HFICE) working group.

YEAR	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other Sharks	Total
2001	1	471	0	0	471
2002	0	92	0	0	92
2003	0	497	0	0	497
2004	1	463	0	0	463
2005	0	214	0	2	217
2006	1	351	0	0	352
2007	1	86	0	0	86
2008	4	304	0	0	308
2009	3	182	1	0	185
2010	2	339	0	0	341
2011	2	107	6	0	116
Total	13	3,104	7	2	3,127

Appendix 20B.—Evaluation of stock structure for the shark complex in the Gulf of Alaska and Bering Sea/Aleutian Islands

Cindy A. Tribuzio, Katy Echave, Pete Hulson, Cara Rodgveller, and S. Kalei Shotwell

Executive Summary

We present various types of information on the shark complexes in both the Gulf of Alaska (GOA) and the Bering Sea/Aleutian Islands (BSAI) Fishery Management Plan (FMP) areas to evaluate potential stock structure for these species. We followed the stock structure template recommended by the Stock Structure Working Group (SSWG) and elaborate on each category within this framework.

The shark complex in both areas consists of three main species: spiny dogfish (*Squalus suckleyi*), Pacific sleeper shark (*Somniosus pacificus*) and salmon shark (*Lamna ditropis*). All three species are broadly distributed across the GOA and BSAI. In both areas, sharks are currently managed as non-target species in groundfish fisheries. In the GOA, spiny dogfish are the primary species caught, whereas Pacific sleeper shark are the primary species encountered in the BSAI. Salmon shark are rarely caught in groundfish fisheries in either the GOA or BSAI.

There is very little data available to evaluate whether different stocks exist among regions within the GOA or BSAI for any of the three species. Sharks are generally long-lived and slow growing. Spiny dogfish have slow growth rates and very low population growth rates. Little information on growth and reproduction is available for Pacific sleeper sharks or salmon sharks. There is insufficient data regarding growth for any of the species to compare rates between or within the GOA and BSAI. Additionally, no genetic information is available to infer any genetic stock structure between or within areas.

In the GOA sharks are managed as a Tier 5 (spiny dogfish) or Tier 6 (all other sharks) species. In the BSAI the shark complex is managed as a Tier 6 species. Acceptable Biological Catch (ABC) and Overfishing Level (OFL) are set for the entire complex by summing the species-specific ABC/OFL recommendations. Sharks are non-target species in directed groundfish fisheries so no targeted effort occurs. Available catch data indicates no evidence of localized depletion. The risk of overfishing is unknown at this time because shark bycatch in unobserved fisheries is undocumented. Data on unobserved fisheries in federal waters is expected to be available after the 2013 observer restructuring. Harvest and trend data indicate population levels are stable and that fishing effort appears consistent with abundance distribution. We continue to recommend the current management specifications for the GOA and BSAI shark complexes.

Introduction

The Stock Structure Working Group (SSWG) was formed in 2009 to develop a set of guidelines to assist stock assessment authors in providing recommendations on stock structure for Alaska groundfish stocks. The framework was presented at the September 2009 joint Groundfish Plan Team and a report was drafted shortly thereafter that included a template for presenting various scientific data for inferring stock structure. In November, 2010, the Gulf of Alaska Groundfish Plan Team (GOA GPT) discussed the advantages of having all stock assessment authors evaluate stock structure characteristics of specific stocks. This analysis was deemed necessary for the shark complex because it has FMP-wide specifications and because it is a complex of multiple species.

The shark complex in both areas consists of three main species: spiny dogfish (*Squalus suckleyi*), Pacific sleeper shark (*Somniosus pacificus*) and salmon shark (*Lamna ditropis*). In the GOA, spiny dogfish are the primary species caught, whereas Pacific sleeper shark are the primary species in the BSAI. The shark complex is managed as an aggregate species group in both the GOA and BSAI FMPs. Prior to the 2011 fishery, sharks were managed as part of the “Other Species” complex, with sculpins, squid and octopus (skates were removed from the Other Species complex in the GOA in 2003, Gaichas et al. 2003). The breakout was in response to the requirements for annual catch limits contained within the reauthorization of the Magnuson Stevens Fishery Conservation and Management Act. The NPFMC passed amendment 87 (http://www.fakr.noaa.gov/sustainablefisheries/amds/95-96-87/amd87.pdf) to the FMPs, requiring sharks to be managed as a separate complex and Annual Catch Limits (ACLs) be established annually by the SSC starting in the 2011 fishery. The total allowable catch (TAC), acceptable biological catch (ABC), and overfishing limits (OFL) for the shark complex are set in aggregate.

Included here is a summary of what is known regarding the populations of spiny dogfish, Pacific sleeper shark and salmon shark in the GOA and BSAI FMPs relevant to stock structure concerns along with an evaluation of the stock structure template, author recommendations, and potential management implications to be considered. The majority of this information is excerpted from the most recent full stock assessments and can be found in more detail there (Tribuzio et al. 2010a, Tribuzio et al. 2011).

Distribution

Spiny Dogfish

Spiny dogfish occupy shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the North Pacific. They are considered more common off the U.S. west coast and British Columbia (BC) than in the GOA or BSAI (Hart 1973, Ketchen 1986, Mecklenburg et al. 2002). Spiny dogfish inhabit both benthic and pelagic environments with a maximum recorded depth of 677 m (Tribuzio, unpublished data). Spiny dogfish are commonly found throughout the water column and at surface waters (Tribuzio, unpublished data).

Pacific Sleeper Shark

Pacific sleeper sharks range as far north as the Arctic Circle in the Chukchi Sea (Benz et al. 2004), west off the Asian coast and the western Bering Sea (Orlov and Moiseev 1999), and south along the Alaskan and Pacific coast and possibly as far south as the coast of South America (de Astarloa et al. 1999). Pacific sleeper sharks have been documented at a wide range of depths, from surface waters (Hulbert et al. 2006) to 1,750 m. They are generally found in relatively shallow waters at higher latitudes and in deeper waters in temperate regions (Yano et al. 2007).

Salmon Shark

Salmon sharks range in the North Pacific from Japan through the Bering Sea and GOA to southern California and Baja, Mexico. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Salmon sharks tend to be more pelagic and surface oriented than the other shark species in the GOA and BSAI, spending 72% of their time in water shallower than 50 m (Weng et al. 2005). Tagging studies have shown both seasonal migrations to southern pelagic waters and overwintering migrations within the GOA and BSAI (Weng et al. 2005, Hulbert et al. 2005). Further, these studies have also shown that salmon shark tagged in the GOA rarely cross the 170°W line.

Life History

In the sections below, biological information is referred to as coming from two regions (with sub-areas contained within): eastern North Pacific (ENP) and western North Pacific Ocean (WNP). The ENP is the U.S. waters of the GOA/BSAI, British Columbia (BC), and U.S. west coast. The WNP is primarily Russian and Japanese waters. This is a common delineation in shark literature for the North Pacific Ocean.

Spiny Dogfish

In the ENP spiny dogfish grow to a maximum size of 160 cm (Compagno 1984), but they also are the slowest growing of all studied sharks (Tribuzio and Kruse 2011). Recent studies in the GOA estimated ages-at-50% maturity to be 36 years (97.3 cm pre-caudal length, PCL, measured from the tip of the snout to the dorsal pre-caudal notch, in a straight line) for females and 21 years (74.5 cm PCL) for males

(Tribuzio and Kruse 2012), which are similar to estimates from BC of 35 years and 19 years respectively (Saunders and McFarlane 1993). Longevity in the ENP is between 80 and 100 years (Campana et al. 2006). Growth coefficients for this species are 0.03 for females and 0.06 for males with an L_∞ of 111.2 cm and 87.7 cm, respectively (Tribuzio et al. 2010b).

The mode of reproduction for spiny dogfish is aplacental viviparity. Embryos are nourished by their yolk sac while being retained in utero for 18 - 24 months. Pupping is believed to occur in estuaries and bays or mid-water over depths of about 165 - 370 m (Ketchen 1986). Small juveniles and young-of-the-year are believed to inhabit the water column near the surface, or in areas not fished commercially (Beamish et al. 1982, Ketchen 1986). These smaller spiny dogfish are not available to commercial fisheries or bottom trawl or longline surveys until they grow or migrate to fished areas (Beamish et al. 1982, Tribuzio and Kruse 2012). The average litter size is 8.5 pups for spiny dogfish in the GOA (Tribuzio and Kruse 2012), 6.9 in Puget Sound, WA (Tribuzio et al. 2009), and 6.2 in BC (Ketchen 1972). The number of pups per female also increases with the size of the female, with estimates ranging from 0.20 - 0.25 more pups for every centimeter in length after the onset of maturity (Ketchen 1972, Tribuzio et al. 2009, Tribuzio and Kruse 2012).

<u>Pacific Sleeper Shark</u>
Little data exists on the life history of Pacific sleeper sharks, with most of the information coming from studies of closely related species of the genus *Somniosus* (in general termed "sleeper sharks"). Sleeper sharks attain large sizes, most likely exhibit slow growth, and are likely long-lived (Fisk et al. 2002). A Greenland shark (*Somniosus microcephalus*), the North Atlantic congener of the Pacific sleeper shark, was sampled in 1999 and was determined to have been alive during the 1950's - 1970's because it had high levels of DDT, which was used as an insecticide during this period (Fisk et al. 2002). Large *Somniosus* sharks observed in photographs from deep water have been estimated at lengths up to 700 cm (Compagno 1984). The maximum lengths of captured Pacific sleeper sharks were 440 cm for females and 400 cm for males (Mecklenburg et al. 2002). Pacific sleeper sharks as large as 430 cm have been caught in the WNP, where the species exhibits sexual dimorphism, with females being shorter and heavier (avg. length = 138.9 cm, avg. weight = 28.4 kg) than males (avg. length = 140 cm, avg. weight = 23.7 kg) (Orlav 1999). The cartilage in sleeper sharks does not calcify to the degree of many other shark species, therefore methods to determine accurate ages have not been developed.

Published observations suggest that mature female Pacific sleeper sharks are in excess of 365 cm total length (TL), mature male Pacific sleeper sharks are in excess 397 cm TL, and that size at birth is approximately 40 cm TL (Gotshall and Jow 1965, Yano et al. 2007). The reproductive mode of sleeper sharks is thought to be aplacental viviparity. Three mature females 370 - 430 cm long were opportunistically sampled off the coast of California. One of these sharks had 372, large vascularized eggs (24 - 50 mm) present in the ovaries (Ebert et al. 1987). Another mature Pacific sleeper shark 370 cm long was caught off Trinidad, California (Gotshall and Jow 1965) with ovaries containing 300 large ova.

<u>Salmon Shark</u>
Salmon shark are the only species where studies have shown differences in life history characteristics between the ENP and WNP (Goldman and Musick 2006), however the biological delineation between these populations is not well known. Tagging data suggest that ENP salmon shark do not cross to the WNP. However, the ENP has an extremely female dominated sex ratio (10.4:1, Goldman and Musick 2006), and studies in the WNP have noted male dominated embryo sex ratios in utero (2.2:1, Nagasawa 1998) suggesting that there must be some mixing.

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 et al. 2004). Adult salmon sharks typically range in size from 180 - 210 cm PCL (Goldman and Musick 2006) in the ENP and can weigh upwards of 220 kg. Age -at-50%-maturity in the WNP has been estimated to occur at approximately 8 - 10 years (170

– 180 cm PCL) and 5 years (140 cm PCL) for females and males, respectively (Tanaka 1980). Age -at-50%-maturity in the ENP has been estimated to occur at approximately 6 - 9 years (160 – 180 cm PCL) and 3 - 5 years (125 - 145 cm PCL) for females and males, respectively (Goldmand and Musick 2006). Tanaka (1980, see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP salmon shark is at least 25 years for males and 17 years for females with growth coefficients of 0.17 and 0.14, respectively. Goldman and Musick (2006) gave maximum ages for ENP salmon shark (also from vertebral analysis) of 17 years for males and 30 years for females, with growth coefficients of 0.23 and 0.17 for males and females, respectively. 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 greater than approximately 140 cm PCL and females greater than approximately 110 cm PCL in the ENP are of a greater weight-at-length than their same-sex counterparts in the WNP (Goldman and Musick 2006).

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage when embryos feed on eggs produced by the ovary (Tanaka 1986 cited in Nagasawa 1998). In the ENP, one record of a pregnant female salmon shark caught near Kodiak Island had four pups, two males and two females (Gallucci et al. 2008). Size-at-parturition is between 60 - 65 cm PCL in both the ENP and WNP (Tanaka 1980, Goldman and Musick 2006).

Fishery

Fishery catch statistics for the shark complexes are available from the Alaska Regional Office blend estimates and catch accounting system from 2003 to the present. Prior to 2003, catch statistics were estimated by stock assessment authors and details are presented in Tribuzio et al. 2010a and 2011. In both FMP areas shark are non-target species and are limited to bycatch only status. Therefore the description of the fishery is that of a bycatch only fishery and does not reflect targeted fishing behavior. The catch accounting system estimates of catch do not include catch from unobserved fisheries such as the halibut IFQ fleet or state managed fisheries.

<u>GOA Fishery</u>

Spiny dogfish are the most commonly encountered shark in GOA fisheries. Based on the 1997 – 2011 GOA catch estimates, spiny dogfish were caught primarily in the Pacific cod (27%, 153 t on average) and sablefish (23%, 129 t on average) fisheries. The predominant gear used in these fisheries is hook-and-line bottom longline gear. Pacific sleeper sharks were caught primarily in the Pacific cod (37%, 92 t on average) and walleye pollock (36%, 91 t on average) fisheries, and salmon sharks were caught primarily in the walleye pollock (90%, 48 t on average) fishery. The walleye pollock fishery is predominantly a trawl gear fishery. Examining the catch by week of the year shows that shark catch for the last four years has tended to occur in two seasons. The first season occurs around week 11 (March), which is mostly driven by spiny dogfish catch in the sablefish fishery, but also some Pacific sleeper shark catch in the walleye pollock fishery. The second season occurs around week 36 (September) and consists mostly of spiny dogfish caught in the Pacific cod fishery.

<u>BSAI Fishery</u>

Pacific sleeper shark are the most common shark caught in BSAI fisheries. From 1997 to 2011, spiny dogfish catch in the BSAI was rare occurring primarily in the Pacific cod longline fishery (88%, 9 t on average), while Pacific sleeper sharks were caught primarily in the walleye pollock fishery (36%, 102 t on average) and the Pacific cod fishery (37%, 107 t on average). Much of the salmon shark catch occurred in the walleye pollock fishery (91%, 47 t on average). Other sharks and unidentified sharks occurred primarily in walleye pollock fisheries (48%, 35 t on average).

Survey

<u>GOA Surveys</u>

Bottom Trawl Survey
Similar to fisheries, spiny dogfish are the primary species caught in the GOA surveys. Trawl survey catch of spiny dogfish is highly variable from year to year. The species tends to form schools, which can lead to patchy and variable catch. Further, tagging data show that spiny dogfish spend a significant amount of time in near surface waters or shallow depths during the summer (Tribuzio, unpublished data) and thus may not be available to the bottom trawl gear. The 1984 - 2011 GOA bottom trawl surveys indicate an increasing biomass trend for spiny dogfish through 2007 (Figure 20B.1, top panel). The 2009 survey biomass estimate for spiny dogfish was the lowest since 1987 and had the lowest CVs of any previous biomass estimate.

Pacific sleeper sharks are caught in a small number of hauls each year. Biomass estimates increased through 2005 and have decreased steadily since then (Figure 20B.1, center panel).

Salmon shark biomass has been relatively stable based on trawl survey biomass estimates, but there are very wide 95% confidence intervals with CVs ranging 30 – 100%, as this survey does not sample this pelagic species well. Survey catches are generally low and no salmon sharks were encountered in the 1999, 2001 or 2009 surveys (Figure 20B.1, bottom panel).

IPHC Annual Bottom Longline Survey
The International Pacific Halibut Commission (IPHC) annual bottom longline samples the continental shelf, both nearshore and offshore waters in depths from 10 – 700 m. This survey provides the best survey data for sharks because of the spatial coverage and consistent catch of spiny dogfish and Pacific sleeper sharks. Examination of the spatial distribution of both spiny dogfish and Pacific sleeper shark catch in the IPHC survey shows these species are widely distributed (Figure 20B.2 & 20B3). During 2008 – 2011 spiny dogfish were caught at most stations across the continental shelf, with fewer caught west of Kodiak Island. The highest catches were in waters between Yakutat Bay and Southeast Alaska (Figure 20B.2). Pacific sleeper shark catch is generally greatest in Shelikof Strait, but high catches also occur in Prince William Sound and inside Southeast Alaska (Figure 20B.3).

AFSC Annual Longline Survey
The AFSC annual longline survey has a standard series of stations fished every year and has a longer time series than the available IPHC survey data; however, because this survey primarily samples deep waters along the continental slope, it is not optimal for shark species. Spiny dogfish are regularly caught at several gully stations near Prince William Sound, Yakutat Bay and Southeast Alaska. However, catch rates are variable among years. Pacific sleeper sharks are commonly caught at gully stations near Shelikof Strait, and occasionally at stations in the eastern GOA.

<u>BSAI Surveys</u>
Bottom Trawl Surveys
As with the BSAI fisheries, Pacific sleeper sharks have the highest catch of all shark species caught during the BSAI trawl surveys. Pacific sleeper sharks are most consistently caught on the annual EBS slope survey (biennially from 2002 – 2010, except no survey in 2006) relative to the EBS shelf and the AI surveys, and occur in between 10-13% of hauls. Biomass estimates in the EBS slope survey range from 833 t (2010) to 25,445 t (2002). Pacific sleeper sharks are rarely encountered in the annual EBS shelf survey (<2% of hauls), and biomass estimates in this survey range from 734 t (2003) to 5,602 t (2002). The survey of the Aleutian Islands (triennially from 1980-1986, 1991-2000, biennially 2000-2006, 2010-present) catches Pacific sleeper shark in <3% of hauls with biomass estimates ranging from 74 t (2010) to 2,927 t (1991). Spiny dogfish and salmon shark are rarely captured in any of the NMFS bottom trawl surveys in the EBS or Aleutian Islands. Often there is no catch and therefore a biomass estimate of zero.

Longline Surveys

The AFSC longline survey samples stations in the EBS in odd years and the eastern Aleutian Islands in even years. Pacific sleeper shark catch is generally greater in the Aleutian Islands than the EBS, but overall shark catch is low.

The IPHC annually samples the EBS and the AI. Like other surveys, shark catch consists mostly of Pacific sleeper shark. An examination of the spatial distribution of survey catches shows that catch of spiny dogfish mostly occurs in the Aleutian Islands in the IPHC longline survey with highest concentrations of catch occurring near the western end of the Aleutian Chain (Figure 20B.4). In contrast, Pacific sleeper shark are consistently caught throughout the EBS shelf (Figure 20B.5) with a few scattered catches in the Aleutian Islands.

Management

GOA

The shark complex has one ABC and TAC set for the entire complex. The ABC is a sum of the individual species recommended ABCs. Spiny dogfish are Tier 5, which uses the last three years of the bottom trawl survey biomass multiplied by 75% of the estimated natural mortality (M). The remaining shark species are Tier 6, with each species' ABC based on 75% of the average historical catch for the years 1997 - 2007. There is currently no apportionment of the ABC to smaller areas within the GOA.

BSAI

All shark species in the BSAI are Tier 6. Thus, the complex ABC is based on the sum of the species recommended ABCs, which are based on the average historical catch for the years 1997 - 2007. There is currently no apportionment of the ABC to smaller areas within the BSAI.

Application of Stock Structure Template

To address stock structure concerns, we utilize the existing framework for defining spatial management units introduced by Spencer et al. (2010) (Table 20B.1). In the following sections, we elaborate on the available information used to respond to specific factors and criterion for defining shark stock structure.

Harvest and trends

Fishing mortality

Currently, fishing mortality is difficult to estimate for the shark species due to lack of abundance data and unobserved catch data. The time series of observed catch (1997 – 2011) are presented in Figure 20B.6. These catch estimates do not incorporate removals from sources other than groundfish fisheries (i.e. research and sport catch) or unobserved fisheries. Estimated catch is variable for spiny dogfish and salmon shark with no apparent trends. The estimated catch of Pacific sleeper shark appears to be in decline in both the GOA (since 2000) and BSAI (since 2002).

Spatial concentration of fishery relative to abundance

Observed fishery catch and IPHC longline survey data were used to generate a series of spatial distribution maps of spiny dogfish and Pacific sleeper shark concentrations. Data on salmon sharks were extremely rare for both the observed fishery and trawl or longline surveys, thus maps were not created for this species. An interpolated raster image of the mean survey data (1998 – 2011) was used to identify long-term patterns in species distribution (Figure 20B.7 – 20B.10) and to facilitate comparison to fishery data. This block of years from the IPHC survey provided the most complete and consistent spatial coverage and catch (in numbers) was available by station. Aggregated data from the Observer Program were available in 400 km^2 blocks to satisfy the requirements of confidentiality. From this data, mean fishery catches were calculated by aggregating the observed fishery data in a raster image and converting the centroids of each raster cell to points at a 50 km grid resolution. Observed fishery data were available from 1993-2011.

GOA

The mean IPHC survey map suggests that spiny dogfish are in the greatest abundance in the continental shelf region from Cross Sound to Prince William Sound, but are still common across much of the eastern and central GOA shelf (Figure 20B.7). In contrast, bycatch of spiny dogfish within observed groundfish fisheries occur predominately between Prince William Sound and Kodiak Island with some catch spread along the shelf throughout the rest of the GOA (Figure 20B.7). However, it is important to note that due to limitations in observer coverage, there are relatively few observed hauls in the eastern GOA and that the fishery effort may be more patchy than surveys. For Pacific sleeper sharks, peak survey and fishery abundance appear to coincide in the Shelikof Strait area, with some catch along the Alaska Peninsula and occasionally along the slope region throughout the GOA (Figure 20B.8).

BSAI

The spatial extent of the IPHC survey in the Bering Sea is limited to the slope break region and some limited areas along St. Matthews Island and the Pribilof Islands. Therefore, the comparison between the observed commercial fishery data, which extends much farther into the Bering shelf region and the IPHC survey, is somewhat difficult. Given this caveat, spiny dogfish are rarely caught in the IPHC survey in the BSAI region, however, small pockets of dogfish are sampled throughout the Aleutian Islands (Figure 20B.9). In contrast, spiny dogfish caught in the fishery are more often observed along the Bering Sea shelf region and sometimes in the Aleutian Islands (Figure 20B.9). Pacific sleeper shark are most often observed near the edge of the Bering Sea shelf and in pockets along the Aleutian Islands, which coincides with areas where the species is caught in the IPHC survey (Figure 20B.10).

Population trends

GOA

The IPHC survey goes back to 1998 and provides the best data for spiny dogfish and pacific sleeper sharks. Relative population numbers (RPNs), calculated by multiplying depth strata specific catch rates and area sizes, were calculated for the IPHC survey for the time period from 1998 – 2011 (Figure 20B.11). There does not appear to be a trend in the spiny dogfish RPNs when the entire time series is examined, but for Pacific sleeper shark the RPNs have decreased steadily since a peak in 2001, with 2008 - 2011 being the lowest values of the entire time series. Salmon shark population trends cannot be inferred from available data. Salmon shark RPNs are highly variable and no trend is apparent.

The NMFS bottom trawl surveys have been conducted in the GOA since 1984 providing the longest time series of data. These surveys may not sample these species well and biomass estimates are likely unreliable. However, trend information may be inferred (Figure 20B.1). The biomass trend of spiny dogfish population levels appear to be relatively stable. Pacific sleeper shark biomass estimates increased until 2005 and have declined since. The biomass estimates for salmon shark show no apparent trend, however, the estimates are highly uncertain and confidence intervals often overlap zero.

BSAI

The RPNs calculated from the IPHC survey data from 1998 to present in the Bering Sea suggest that abundance of Pacific sleeper shark has been consistently low since 2004 (Figure 20B.11). Prior to 2004, the index is variable from year to year, with very high peaks in 1998 and 1999. Data do not support inferring trends for the other shark species from survey indices because of very low catch rates. Population trends cannot be inferred from the various NMFS bottom trawl surveys in the BSAI.

Barriers and phenotypic characters

Generation time

Sharks are generally slow growing, long lived, and late maturing. The mean generation time for spiny dogfish was estimated at 46 years for an unfished population (Tribuzio and Kruse 2011). Data do not exist to estimate a generation time for Pacific sleeper shark. Generation time for salmon shark was estimated to be 13 years (Courtney et al. 2006 Appendix B)

Physical limitations

There are no known physical limitations. These species are large at all life stages and not subject to larval drift and circulation patterns.

Growth differences

Growth studies of spiny dogfish and salmon shark have not found differences in growth within either the GOA or BSAI. A study by Vega et al. (2009) suggested that there were substantial growth differences between spiny dogfish in two regions of the west coast of the U.S., divided roughly at northern Oregon. Growth data from GOA spiny dogfish were not significantly different from that of published studies in British Columbia or Washington State (Tribuzio et al. 2010b). Studies have suggested differences in mean growth rate between inshore and offshore animals; however, small sample sizes preclude confidence in these results. Differences in life history and growth parameters between the ENP and WNP suggest that there may be differences between those regions, but no studies have investigated differences within the ENP (and thus GOA or BSAI).

Age/size structure

The best available knowledge on the size structure of spiny dogfish in the GOA and BSAI comes from bottom trawl survey data. However, the AFSC and IPHC longline surveys are now collecting length frequency data for spiny dogfish (Figure 20B.12). Shark species are difficult to age and are not part of the production AFSC ageing program; thus age data is not available. Because of the slow growing nature of these species, low fecundity and large size at birth, it is unlikely to see recruitment events in length frequency data, thus length data was combined over years. There are no evident differences in size or age compositions among different regions in the GOA or BSAI.

Spawning time differences

There is no evidence of differences in spawning time within the GOA and there is no data in the BSAI for any of the shark species. In the GOA, pupping of spiny dogfish may occur during winter months, based on the size of embryos observed during summer and fall sampling (Tribuzio and Kruse 2012). Ketchen (1972) reported timing of parturition in BC to be October through December, and in the Sea of Japan, parturition occurred between February and April (Kaganovskaia 1937, Yamamoto and Kibezaki 1950). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio et al. 2009).

Spawning data is extremely limited for Pacific sleeper sharks. Two recently born 74 cm Pacific sleeper sharks were caught off the coast of California at depths of 1300 and 390 m; one still had an umbilical scar (Ebert et al. 1987). A newly born Pacific sleeper shark of 41.8 cm was also caught at 35 m depth off Hiraiso, Ibaraki, Japan (Yano et al 2007). Additionally, three small Pacific sleeper sharks, 65 - 75 cm long, have been sampled in the Northwest Pacific (Orlov and Moiseev 1999). Unfortunately, the date of capture for the above records was not reported. In summer 2005, an 85 cm PCL female was caught during the annual AFSC bottom longline survey near Yakutat Bay and in spring 2009 another 85 cm PCL female was caught by a commercial halibut fisherman inside Chatham Strait in Southeast Alaska (Tribuzio unpublished data). Because of a lack of observations of mature or newly born sharks, and the absence of dates in the literature, the spawning and pupping season is unknown for Pacific sleeper shark.

Salmon shark are believed to give birth in the spring at lower latitudes in the North Pacific. 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 (Nagasawa 1998, Tribuzio 2004, Goldman and Musick 2006).

Maturity-at age/length differences

Age and length at maturity data is only available for spiny dogfish and salmon shark. Age at 50% maturity was estimated at 36 for female and 21 for male spiny dogfish (Tribuzio and Kruse 2012). Length at 50% maturity was 97.3 cm and 74.5 cm PCL for females and males, respectively, and length at 50% maternity was 99.5 cm PCL for females. The age at 50% maturity are similar to those for studies conducted in British Columbia and Washington State (Saunders and McFarlane 1993, Tribuzio et al. 2009), however the length at 50% maturity and length at 50% maternity were significantly larger in the GOA (Tribuzio and Kruse 2012). Salmon shark females reach 50% maturity at 6 - 9 years (160 - 180cm) and males at 3 - 5 years (125 - 145cm, Goldman and Musick 2006). Differences have not been detected within the eastern North Pacific, but there may be differences between eastern and western North Pacific (Goldman and Musick 2006).

Morphometrics

Regional variation in morphometric measurements have not been studied for any of the species.

Meristics

Regional variation in meristics have not been studied for any of the species.

Behavior and movement

Spawning site fidelity

Little is known regarding the spawning habits of any of the shark species in the GOA. Mating likely occurs a few months post-spawning in spiny dogfish, as most adult females have fully developed ova coincident with spawning. Embryos in the earliest stages of gestation were observed in late winter through early summer sampling (Tribuzio unpublished data, Tribuzio and Kruse 2012). There is no information as to where mating occurs or if migrations occur for breeding or spawning. Harvest or catch data from this time period (fall/winter) is sparse from fisheries or surveys so annual distribution changes are difficult to detect. Spawning behavior has not been studied in salmon shark, but females at early stages of pregnancy have been observed in the fall. There is no data on reproductive behavior in Pacific sleeper shark.

Mark-recapture data

Satellite tagging studies are ongoing for spiny dogfish. Previous conventional tagging studies have shown that spiny dogfish can undertake large scale migrations, but most tag recoveries were from within the region of tag release or nearby regions (McFarlane and King 2003). Salmon shark are highly migratory species, with many animals moving between summer grounds in the GOA/BSAI to winter grounds in central Pacific Ocean (Hulbert et al. 2005, Weng et al. 2006). Salmon shark also may over winter in Alaska, but it is not known if these differences in seasonal behavior are tied to life history. Satellite tagging data for Pacific sleeper sharks suggest a more sedentary behavior and fish do not move more than a few kilometers from tagging locations (Hulbert et al. 2006). It is unknown, however, if they undertake large scale migrations over time (i.e. satellite tags generally have a less than 1 year battery life).

Natural tags

No studies have addressed spine or vertebrae microchemistry, or parasites of sharks in the GOA or BSAI.

Genetics

No studies have been done to determine if the GOA or BSAI populations of sharks are single stocks, or if subpopulations occur. Genetics studies of spiny dogfish have shown that the North Pacific spiny dogfish is a distinct species from those in the South Pacific and Atlantic Oceans (Ebert et al. 2010, Verissimo et al. 2010), but no studies have identified genetically distinct populations within the North Pacific (Hauser 2009, Ebert et al. 2010, Verissimo et al. 2010). Genetic analysis of Pacific sleeper shark and salmon shark have not been conducted.

Factors and criterion specific to genetics of sharks are:

Isolation by distance

Not Available

Dispersal distance

Not Available

Pairwise genetic differences

Not Available

Summary, Implications, and Recommendations

We summarize the available information on stock structure for the shark species in the GOA and BSAI in Table 20B.2. Data do not exist to adequately evaluate harvest and population trends for any of the species. In the GOA, spiny dogfish fishery catch is distributed differently from the survey catch (Figure 20B.7b), for Pacific sleeper shark in both FMP areas and for spiny dogfish in the BSAI the survey and fishery catch do not appear to differ substantially. Spiny dogfish have a long generation time, and while such parameters for Pacific sleeper shark are unknown, it is likely that they also have a long generation time and are slow growing like spiny dogfish (both of the family Squalidae). Salmon shark have a much shorter generation time compared to the other sharks in the complex. Little information is available regarding reproductive behavior, seasonality, and critical habitat (i.e. nursery areas) in the GOA or BSAI. There are no known growth differences among regions in the GOA or BSAI. No information is available regarding spawning movements although some seasonal or large-scale movement patterns have been elucidated for salmon shark and spiny dogfish. No genetic information is available to infer any genetic stock structure components that might exist.

The current management regime does not apportion the stock and catch within the FMP areas. While survey and fishery information suggest that abundance levels may differ among the regions, there is no indication that there are different stocks within either FMP. Because sharks are a non-target species complex, with bycatch only status, there is no obvious biological need to apportion catch to areas smaller than the FMP level.

Current management practices set FMP wide ABC and OFL. Shark catch in the GOA and BSAI is well below the complex ABC and risk of overfishing is low (by the current management definition for the complex). However, current catch estimates do not include unobserved fisheries, which may be a significant source of mortality for shark species. Based on available data, initiating area-specific ABC’s and OFL’s is not recommended at this time. Given the available evidence of a lack of stock structure for any of the shark species within either the GOA or BSAI FMP ares, the current resolution of spatial management is likely adequate and consistent with management goals.

Research Priorities

Data limitations are severe for shark species in the GOA and BSAI, and it is extremely difficult to determine whether current management is appropriate with the current limited information. Gaps include inadequate catch estimation, unreliable biomass estimates, lack of size frequency collections, and a lack of life history information including age and maturity, especially for Pacific sleeper shark. Regardless of future management decisions regarding the shark complex management category, improving biological sampling of sharks in fisheries and surveys is essential. Future shark research priorities will focus on the following areas:

1. Biological data from commercial fishery bycatch.
2. Define the stock structure and migration patterns (i.e. tagging studies, genetics): Ongoing satellite tagging study of spiny dogfish and genetic study of Pacific sleeper shark.
3. Determine or clarify existing estimates of life history parameters for use in models: An NPRB funded ageing study began Jan 2012 to include improving aging of spiny dogfish and investigate potential methods to age Pacific sleeper shark.

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Table 20B.1. Framework of types of information to consider when defining spatial management units (from Spencer et al. 2010).

Factor and criterion	Justification
	Harvest and trends
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	If this value is low, then conservation concern is low
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem.
Population trends (Different areas show different trend directions)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions
	Barriers and phenotypic characters
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased.
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Temporally stable differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change.
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages.
	Behavior & movement
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal
	Genetics
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.

Table 20B.2. Summary of available data on stock structure evaluation of the GOA and BSAI shark complex. Template from Spencer et al. 2010.

Factor and criterion	Justification
Harvest and trends	
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	NA
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Fishing appears to be distributed similar to survey abundance and distribution.
Population trends (Different areas show different trend directions)	Overall population trend is relatively stable for spiny dogfish and appears to be declining for PACIFIC SLEEPER SHARK. Unknown for salmon shark. No evidence of different trends among areas for any species
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	Generation time is long (>10 years) for spiny dogfish and salmon shark, unknown for PACIFIC SLEEPER SHARK
Physical limitations (Clear physical inhibitors to movement)	No physical limitations known.
Growth differences (Significantly different LAA, WAA, or LW parameters)	No major differences in growth within the GOA or BSAI for spiny dogfish or salmon shark. Unknown for PACIFIC SLEEPER SHARK.
Age/size-structure (Significantly different size/age compositions)	No known differences in age/size structure within the GOA or BSAI.
Spawning time differences (Significantly different mean time of spawning)	No known differences in spawn timing within the GOA or BSAI.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	No known differences in maturity within the GOA or BSAI.
Morphometrics (Field identifiable characters)	No significant regional variation.
Meristics (Minimally overlapping differences in counts)	No significant regional variation.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Salmon shark are pelagic and highly migratory. Spiny dogfish can undertake large scale migrations (outside the GOA), but most appear to stay within the GOA. PACIFIC SLEEPER SHARK appear to move relatively small distances.
Natural tags (Acquired tags may show movement smaller than management areas)	Unknown
Genetics	
Isolation by distance (Significant regression)	Unknown
Dispersal distance (<<Management areas)	Unknown
Pairwise genetic differences (Significant differences between geographically distinct collections)	Unknown

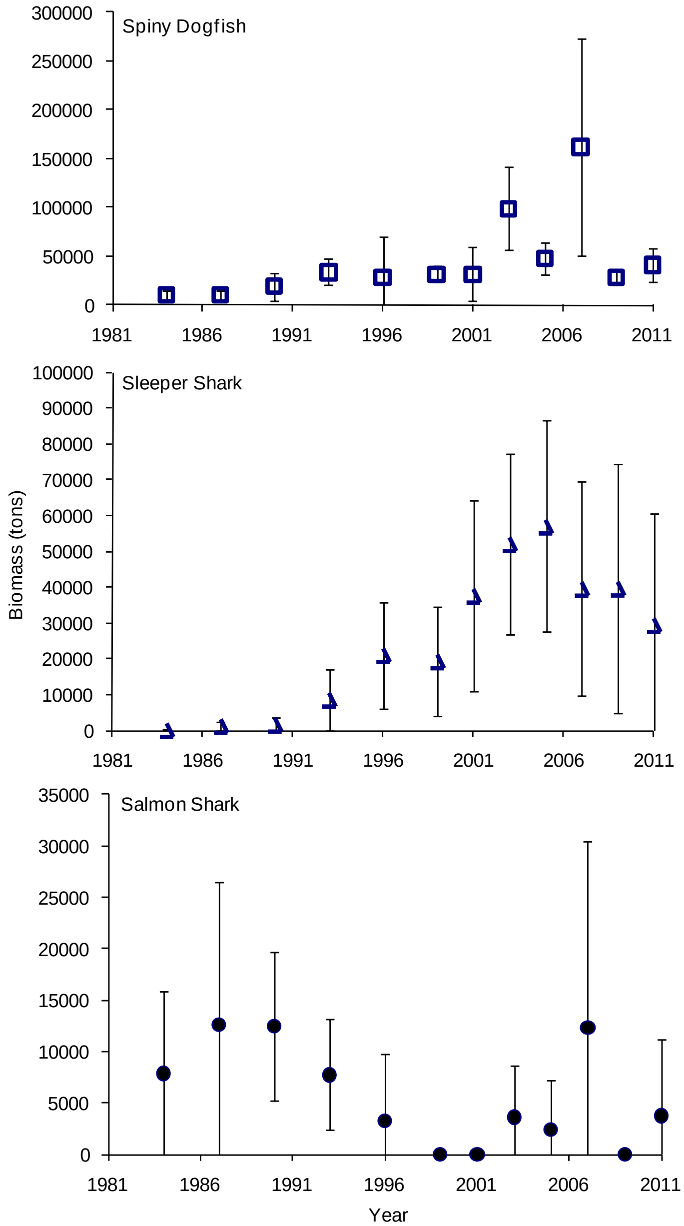


Figure 20B.1. Trends in Gulf of Alaska (GOA) AFSC bottom trawl survey estimates of individual shark species total biomass (t) reported here as an index of relative abundance. Error bars are 95% confidence intervals. Source: RACEBASE.

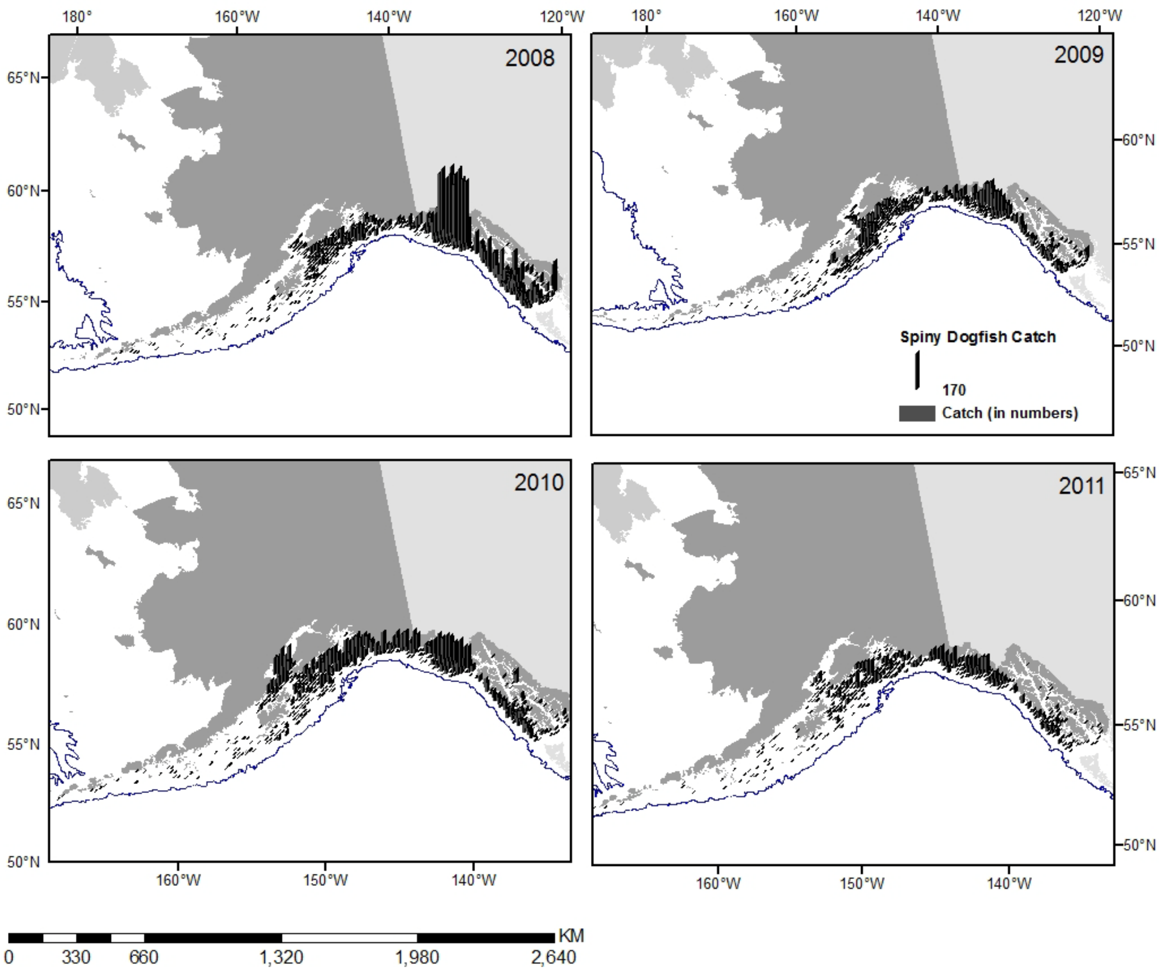


Figure 20B.2. Spatial distribution of the catch of spiny dogfish during the 2008 - 2011 IPHC longline surveys in the Gulf of Alaska. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

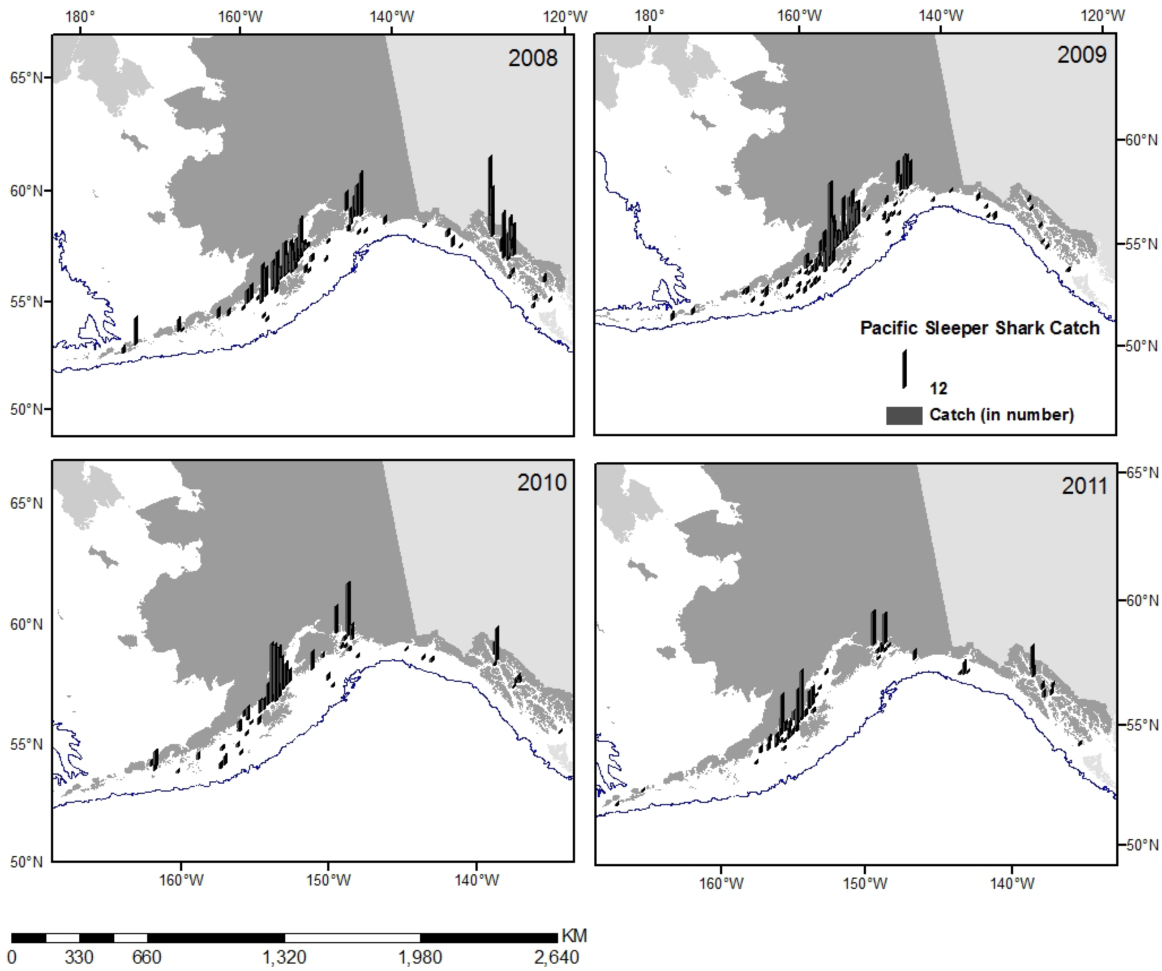


Figure 20B.3. Spatial distribution of the catch of Pacific sleeper shark during the 2008 - 2011 IPHC longline surveys in the Gulf of Alaska. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

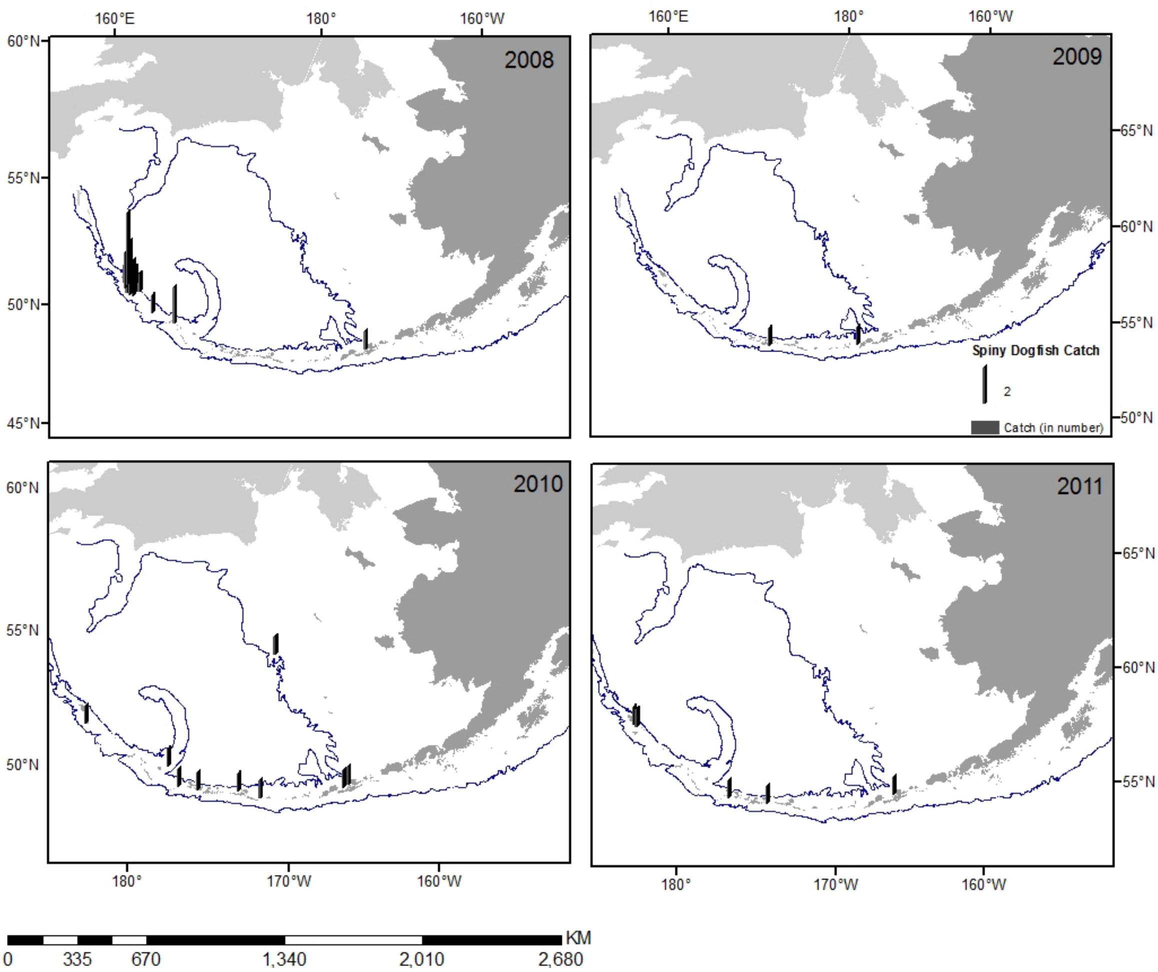


Figure 20B.4. Spatial distribution of the catch of spiny dogfish during the 2008 - 2011 IPHC longline surveys in the Bering Sea and Aleutian Islands. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

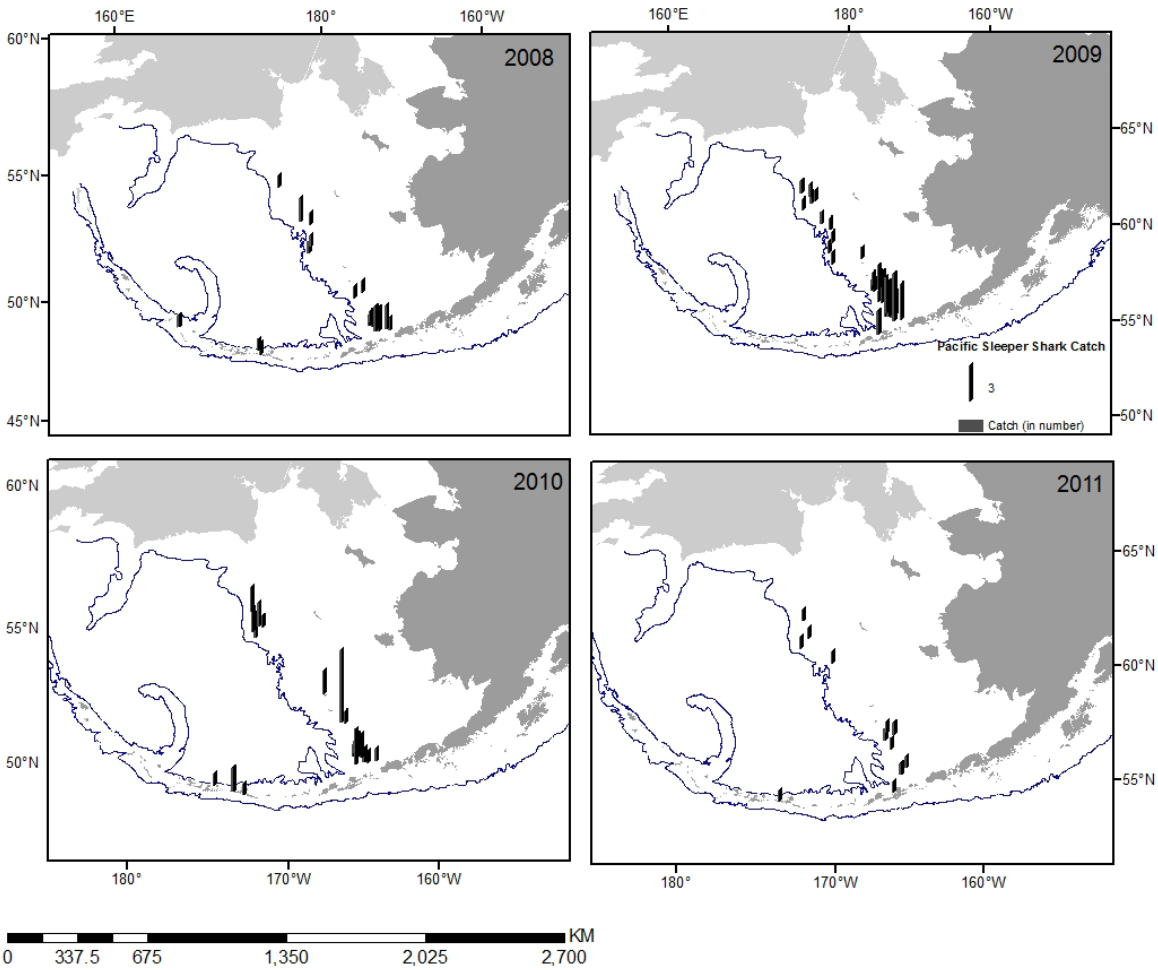


Figure 20B.5. Spatial distribution of the catch of Pacific sleeper shark during the 2008 - 2011 IPHC longline surveys in the Bering Sea and Aleutian Islands. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

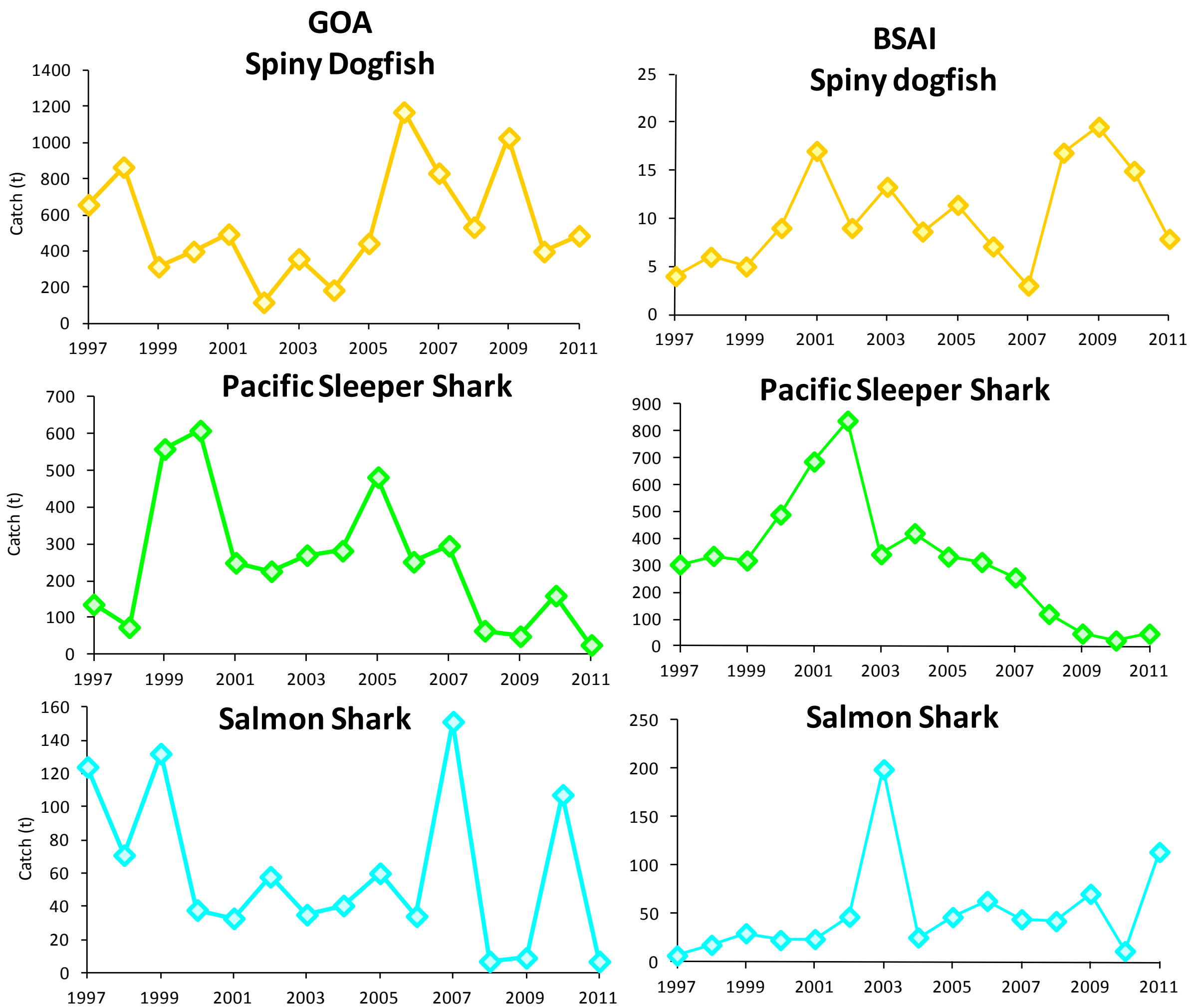
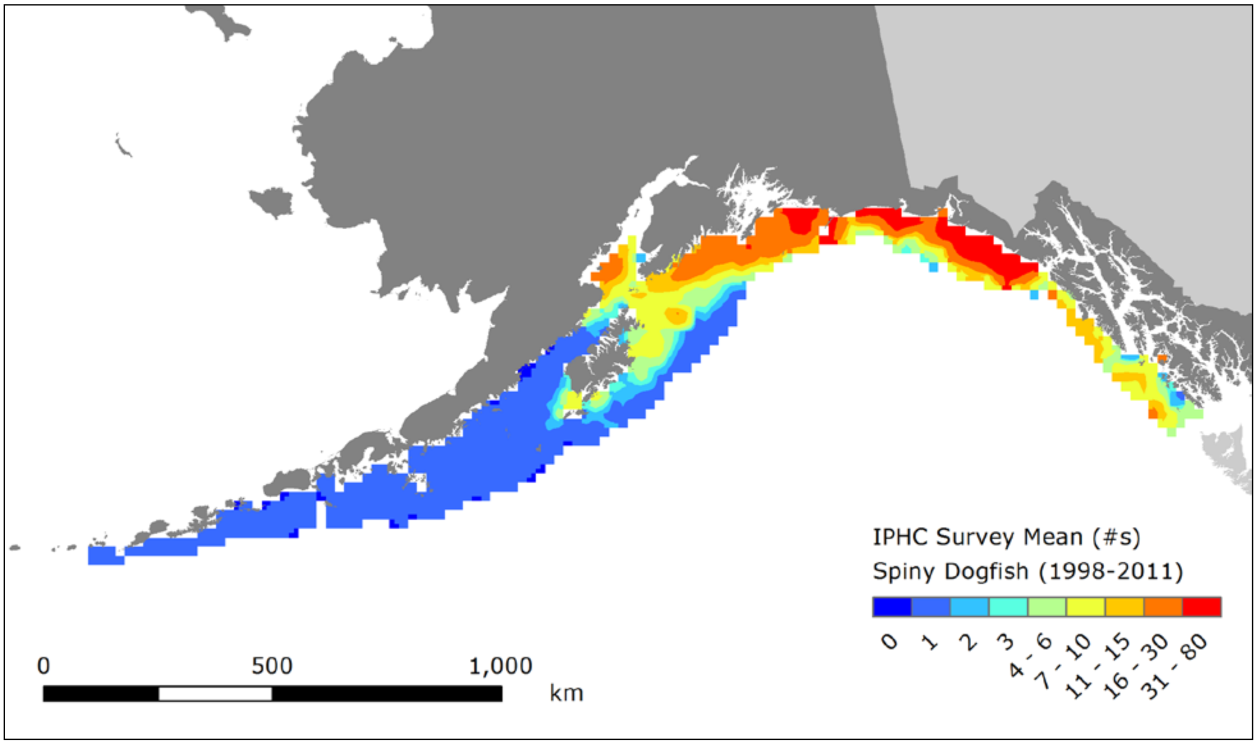


Figure 20B.6. Estimated commercial catches for GOA and BSAI sharks.



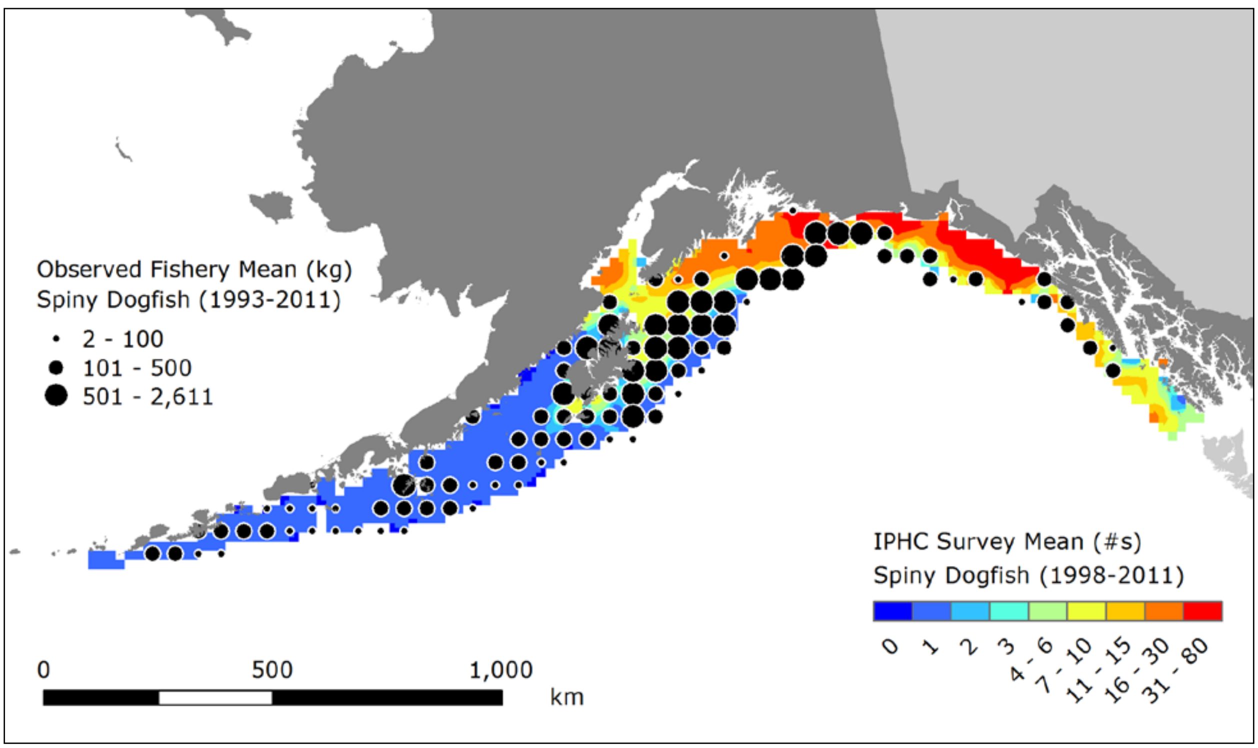
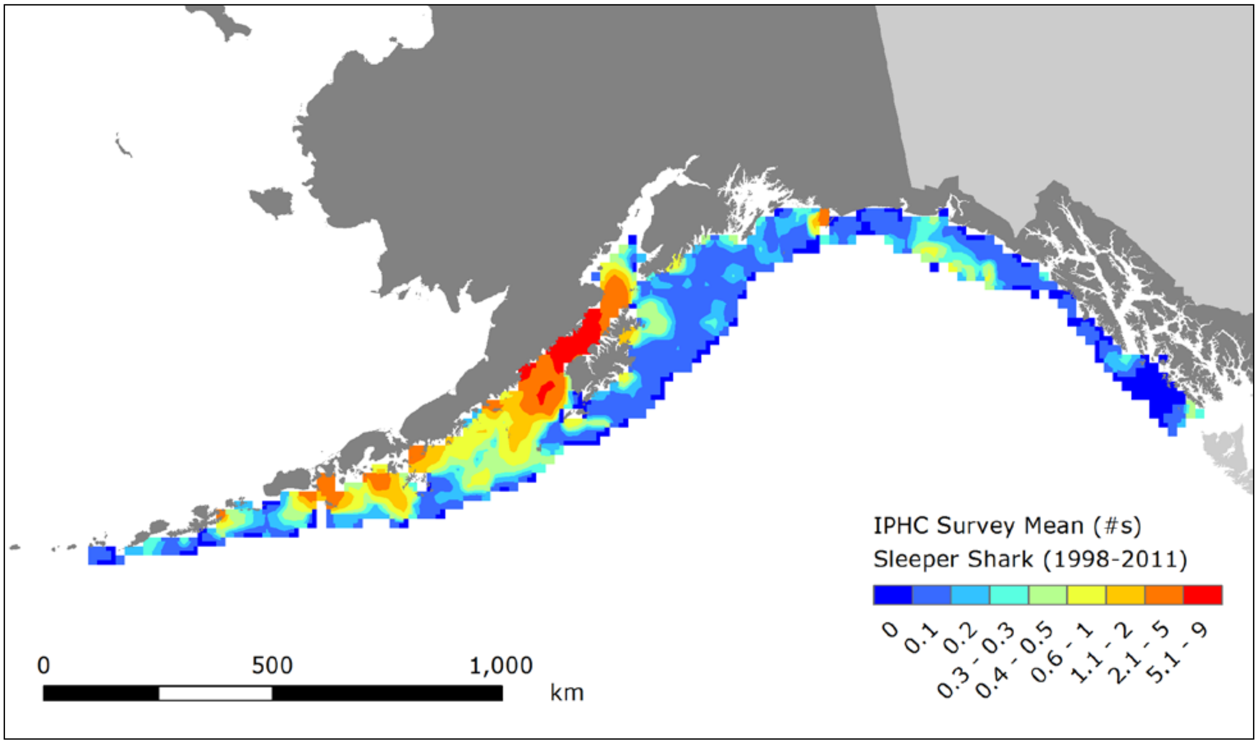


Figure 20B.7. Distribution maps of GOA spiny dogfish for IPHC survey mean conditions from 1998-2011 (top) and observed fishery catch mean (1993-2011) with IPHC survey mean (bottom).



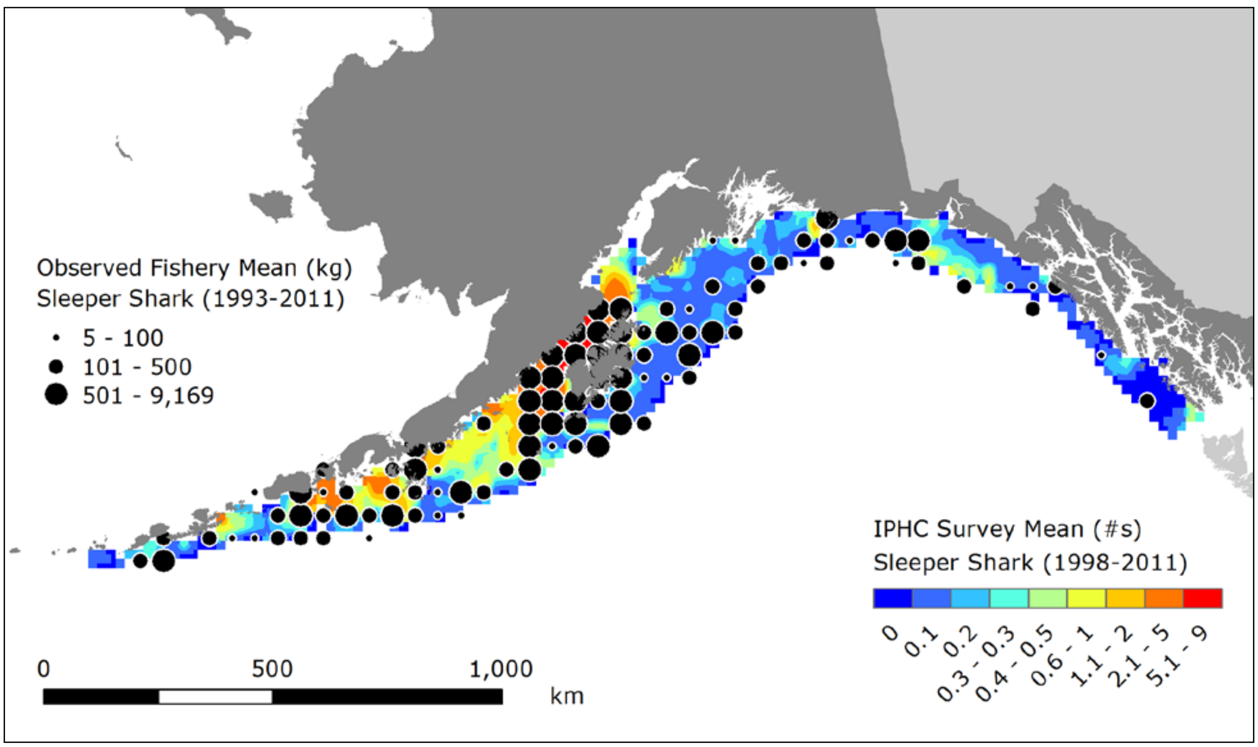
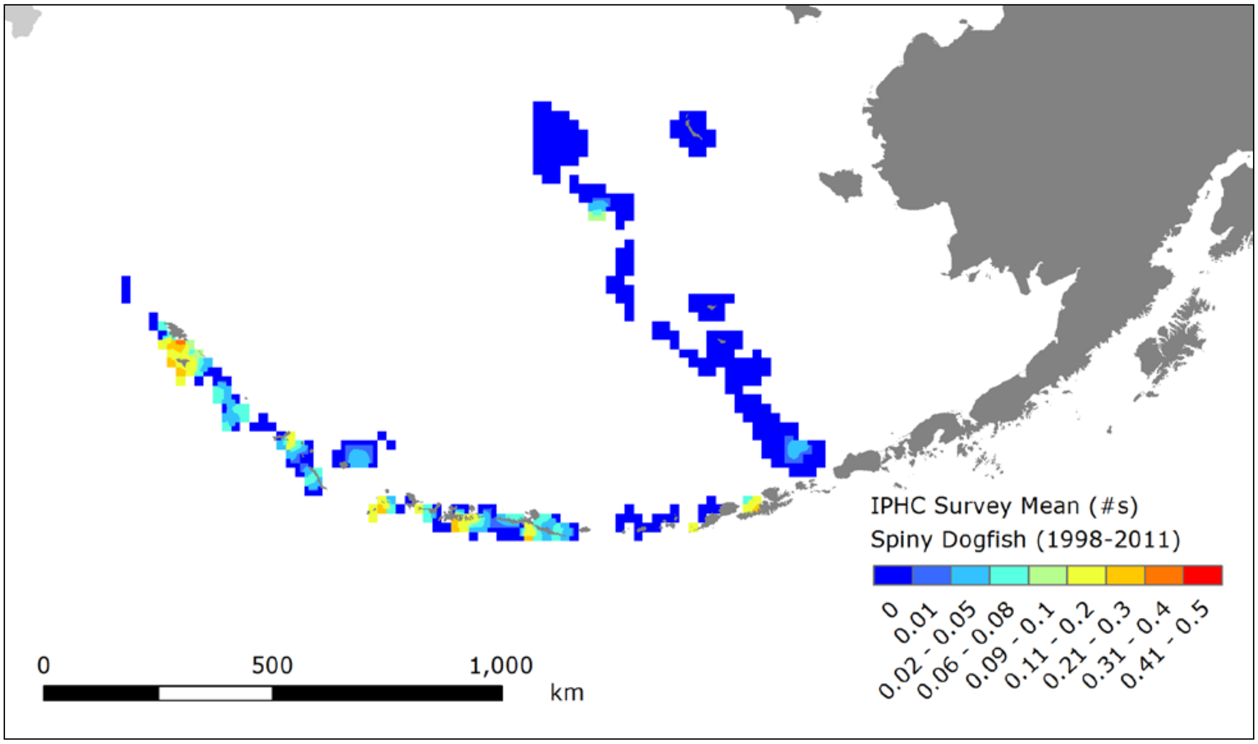


Figure 20B.8. Distribution maps of GOA sleeper shark for IPHC survey mean conditions from 1998-2011 (top) and observed fishery catch mean (1993-2011) with IPHC survey mean (bottom).



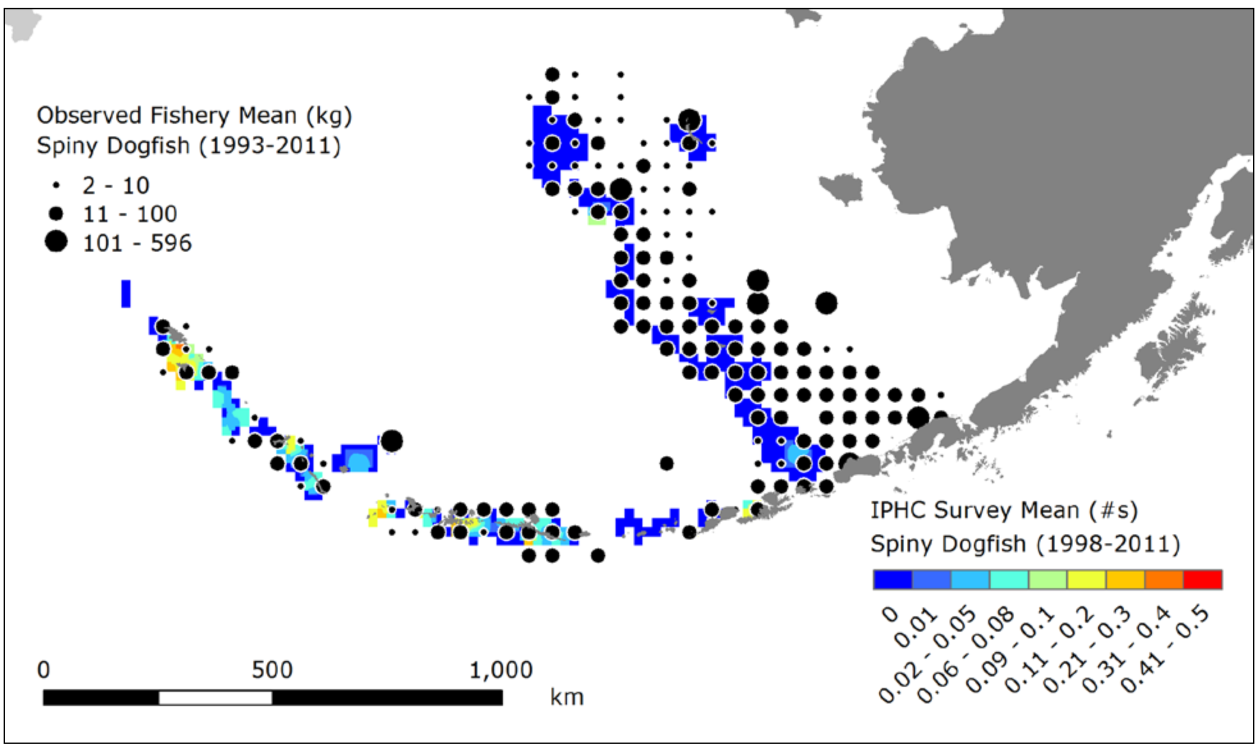
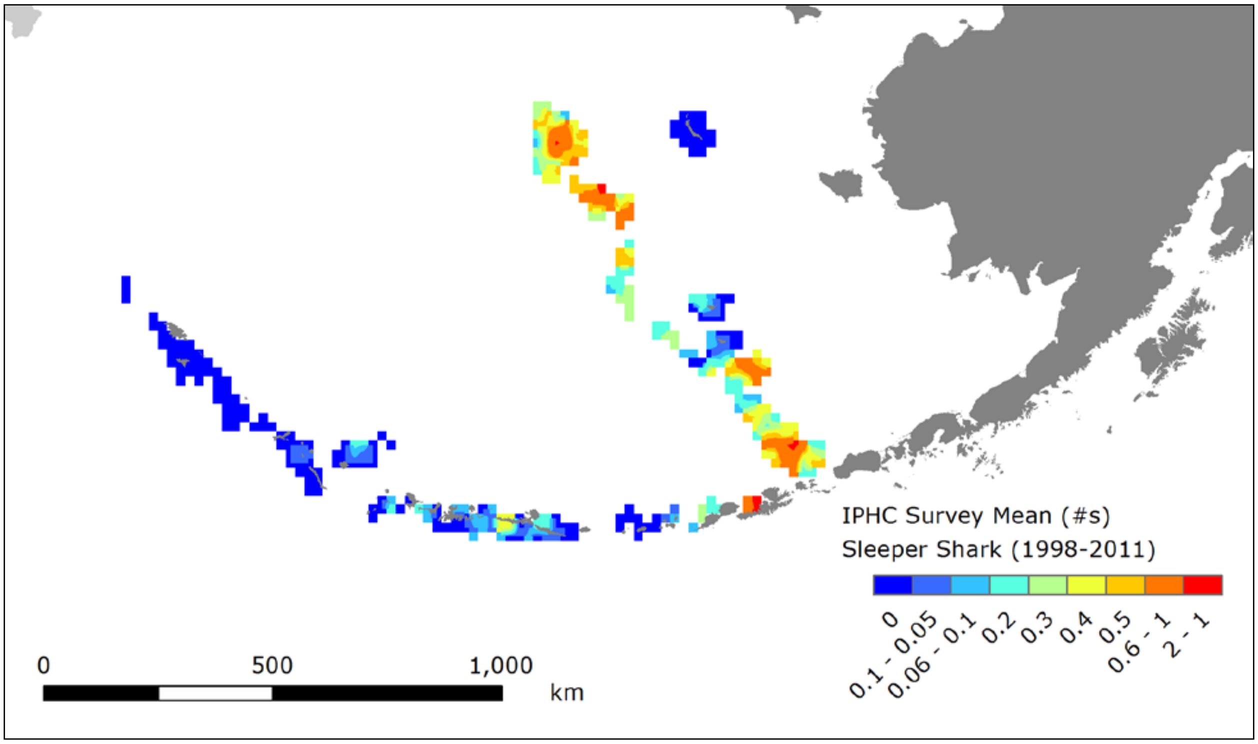


Figure 20B.9. Distribution maps of BSAI spiny dogfish for IPHC survey mean conditions from 1998-2011 (top) and observed fishery catch mean (1993-2011) with IPHC survey mean (bottom).



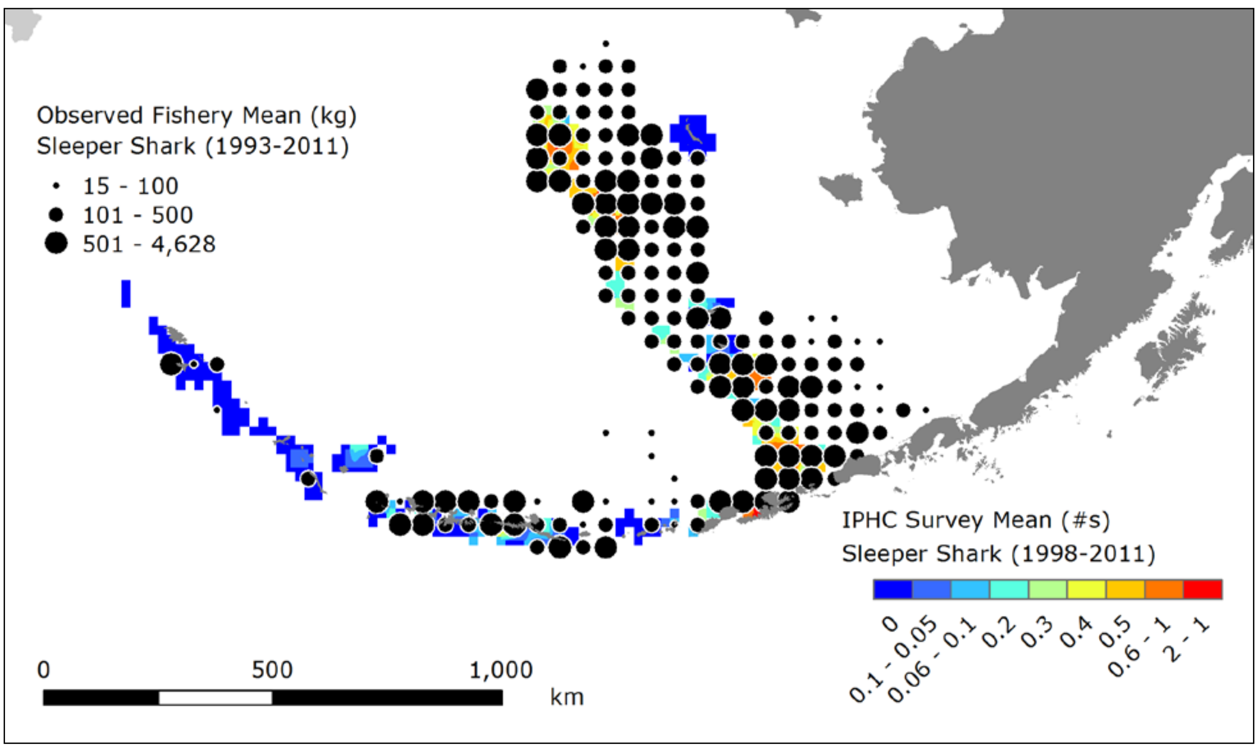


Figure 20B.10. Distribution maps of BSAI sleeper shark for IPHC survey mean conditions from 1998-2011 (top) and observed fishery catch mean (1993-2011) with IPHC survey mean (bottom).

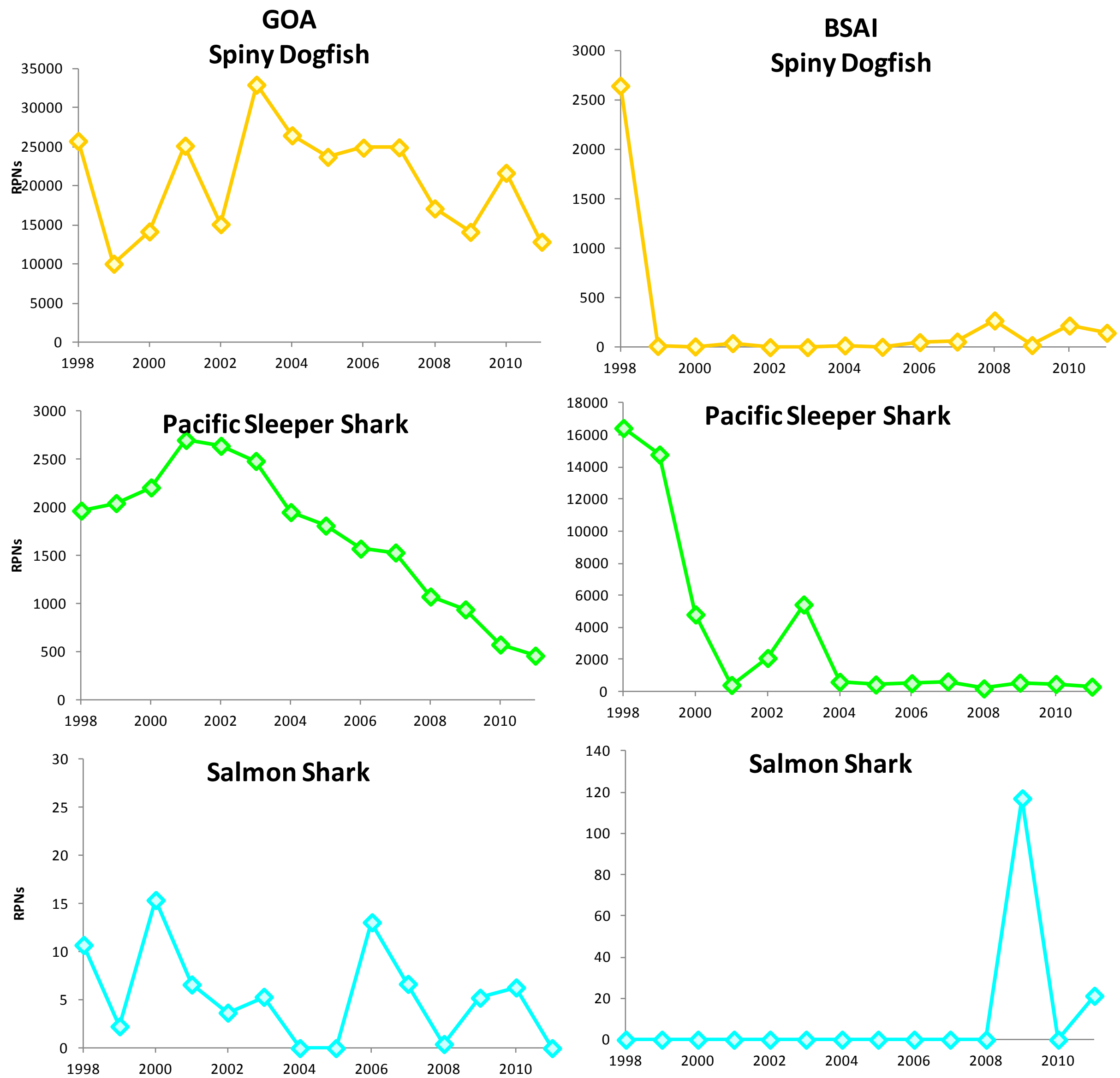


Figure 20B.11. Estimated relative population numbers from the IPHC annual longline survey.

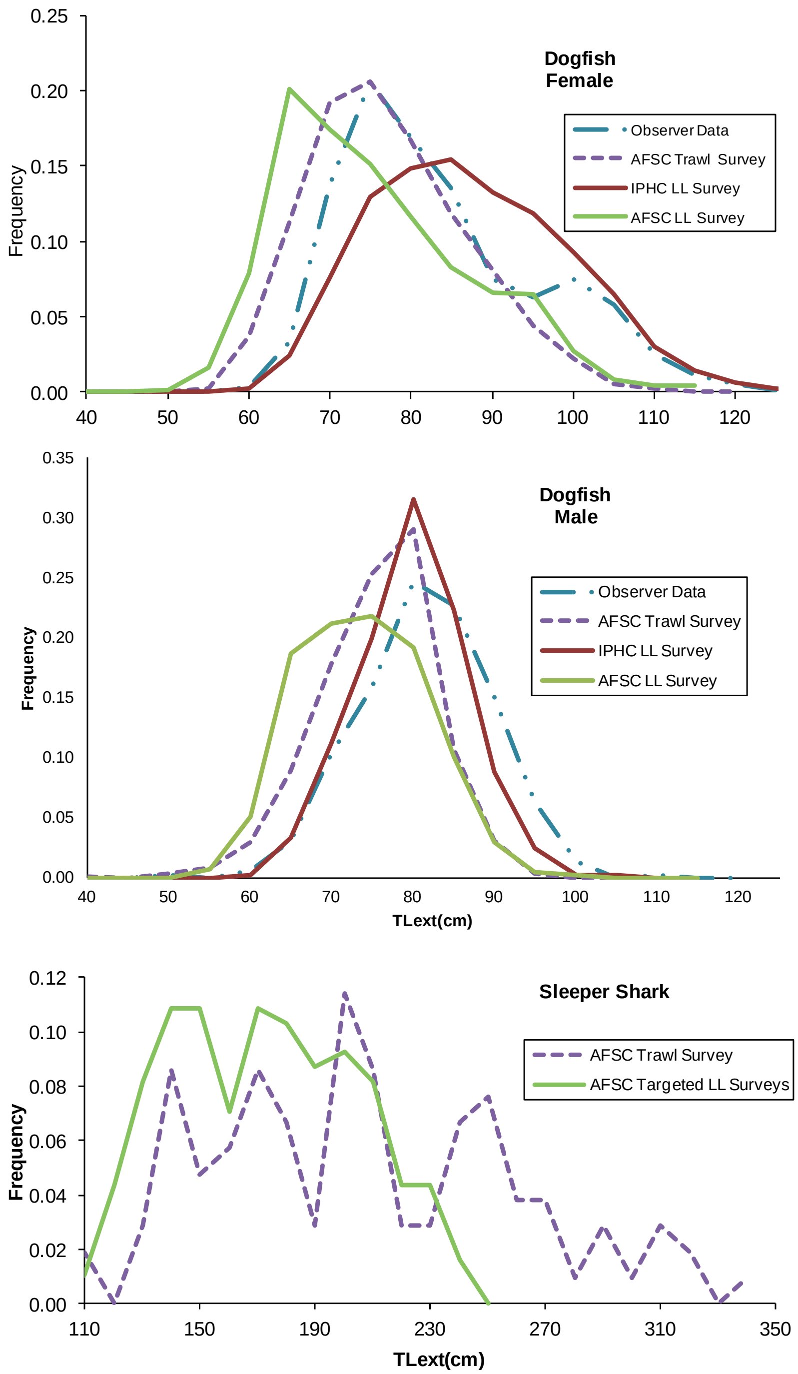


Figure 20B.12. Observed length frequencies for female spiny dogfish (top) and male spiny dogfish (center) from the NMFS trawl (triennially/biennial 1984-2010) and longline surveys (2010-2011), the IPHC longline survey (2011) and observer special projects (2006 and 2011). Pacific sleeper shark (bottom) length frequencies from all years of the NMFS trawl survey and a targeted longline survey in 2001 near Kodiak Island. Note that all years of data were combined for each data source.

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