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

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EXECUTIVE SUMMARY

The shark complex (Pacific sleeper shark, spiny dogfish, salmon shark, and other/unidentified sharks) in the Bering Sea and Aleutian Islands (BSAI) is assessed on a biennial stock assessment schedule. In even years we present a full stock assessment document. BSAI sharks are a Tier 6 complex with the over fishing limit (OFL) based on maximum historical catch between the years 1997 – 2007 (acceptable biological catch, ABC is 75% of OFL). For this year's assessment, we present an alternative time series for the estimation of ABC and OFL. Three different time series of catch history are considered: (1) status quo (1997 – 2007), (2) Catch Accounting System (2003 – 2015), and (3) observer restructuring (2013 – 2015). We also evaluate using the maximum and average of the catch over the three time series. We recommend using the maximum catch during the years of modern catch accounting (2003 – 2015) because it is the longest and most representative time series of catch. We recommend that the time frame used for ABC and OFL specifications be monitored by the assessment authors, however, for now we recommend holding the time frame at 2003 – 2015 unless a management or conservation concern arises.

Summary of Changes in Assessment Inputs

Changes to the input data

1. Total catch for BSAI sharks is updated 2003 – 2016 (as of Oct 3, 2016)
2. IPHC survey RPNs are updated through 2015
3. Biomass estimates have been updated for the Aleutian Islands and EBS shelf/slope surveys through 2016

Changes in assessment methodology

This year we recommend using a new time series of catch for calculating OFL and ABC. We now recommend OFL = maximum catch (2003 – 2015) and ABC = 0.75*OFL, rather than OFL = maximum catch from the years 1997 – 2007.

Summary of Results

For 2017 – 2018 we recommend the maximum allowable ABC of 517 t and an OFL of 689 t for the shark complex. The recommended 2017 – 2018 ABC and OFL are 51% less than the 2015 – 2016 ABC and OFL, but the 2017 – 2018 recommended ABC is larger than the 2015 – 2016 total allowable catch (TAC). The TAC has been set well below the recommended ABC since the inception of the shark complex in 2011 due to the 2 million t cap in the BSAI. Thus, the recommended change in the ABC is unlikely to have implications on the TAC determinations. Total shark catch in 2015 was 107 t and catch in 2016 was 112 t, as of October 3, 2016. The stock complex was not subject to overfishing last year, and data do not exist to determine if the complex is overfished.

ABC and OFL calculations and Tier 6 recommendations for 2017 – 2018. OFL = maximum shark catch from 2003 – 2015. ABC = OFL*0.75.

Quantity	As estimated or *specified last* year for: 2016	2017	As estimated or *recommended this* year for: 2017	2018
Tier	6	6	6	6
OFL (t)	1,363	1,363	**689**	689
maxABC (t)	1,022	1,022	517	517
ABC (t)	1,022	1,022	**517**	517
Status	As determined *last* year for: 2014	2015	As determined *this* year for: 2015	2016
Overfishing	No	n/a	No	n/a

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Shark Complex	2015		1,363	1,022	125	107
	2016		1,363	1,022	125	112
	2017		689	517		
	2018		689	517		

[1] The shark complex in the BSAI is a Tier 6 complex with no reliable estimates of biomass
[2] Catch as of October 3, 2016

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC requests that stock assessment authors bookmark their assessment documents and commends those that have already adopted this practice." (SSC, October 2016)
This document has been formatted so that when it gets converted to a pdf for dissemination it should be bookmarked.

SSC and Plan Team Comments Specific to this Assessment

"The Team recommends that both the reference period and OFL/ABC levels be re-evaluated after a few years of data from the restructured Observer Program have accumulated." (BSAI Plan Team, November 2014)
See next comment.

"The SSC recommended keeping the Tier 6 calculation based on maximum catch and to reevaluate options at the next full assessment (2016), after similar options are explored by the authors for GOA sharks in 2015." (SSC, December 2014)
To address both of the above comments, we included an expanded list of Tier 6 alternatives in the Harvest Recommendations section of the Results. Alternate Tier 6 calculations have not been explored for the GOA.

"The SSC agrees that adjustments to the time series of estimated shark catch should be delayed until more data is available from the restructured observer program. When sufficient data is available, the SSC looks forward to an evaluation of a comparison of CAS and HFICE estimates, as well as an exploration of adjustments to the historical catch time series." (SSC, December 2014)
The HFICE authors presented a comparison on HFICE to CAS since observer restructuring went into effect (2013 – 2015) at the September 2016 Joint Groundfish Plan Team (PT) meeting. There was no document prepared; however, the September PT minutes reflected the Joint PT review of

the presentation. The Joint PT comment was: "The Teams recommend that HFICE estimates not be used for catch reconstruction." We concur with the Joint PT.

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 salmon shark (*Lamna ditropis*), and the spiny dogfish (*Squalus suckleyi)*.

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

The Pacific sleeper shark are the most commonly encountered shark in the BSAI ranging 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 Alaska and Pacific coast and possibly as far south as the coast of South America (de Astarloa et al. 1999). However, Yano et al. (2007) reviewed the systematics of sleeper sharks and suggested that sleeper sharks in the southern hemisphere and the southern Atlantic Ocean 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 Gulf of Alaska (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 BSAI, spending 72% of their time in water less than 50 m depth (Weng et al. 2005). While some salmon sharks migrate south during the winter months, others remain in Alaska waters throughout the year (Hulbert et al. 2005, Weng et al. 2005).

Spiny Dogfish

Spiny dogfish occupy shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the eastern North Pacific and south through the Japanese archipelago in the western 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). 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 in surface waters (Tribuzio, unpublished data).

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 (Tribuzio et al. 2012). 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. Genetic studies conducted on spiny dogfish have indicated that there is no significant stock structure within the GOA or BSAI (Ebert et al. 2010, Verissimo et al. 2010). Preliminary results of an ongoing genetics study of Pacific sleeper sharks show that there are two lineages of Pacific sleeper sharks, but they are evenly mixed across the range of the species (S. Wildes, NMFS, AFSC pers. comm.).

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). Ormseth and Spencer (2011) estimated the vulnerability of Alaska groundfish and found that 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 analyzed.

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). Ages are not readily available because the cartilage in sleeper sharks does not calcify to the degree of many other shark species. Methods of ageing are under investigation. Using a method of age approximation, a Greenland shark (*Somniosus microcephalus*), the North Atlantic congener of the Pacific sleeper shark, sampled in 1999 was determined to have been alive during the 1950's - 1970's because it had high levels of DDT (Fisk et al. 2002). Additionally, in a recent study a Greenland shark 220 cm total length (*TL*, tip of the snout to the upper lobe of the caudal fin) was estimated to be 49 years old, using bomb radiocarbon isotopes in the eye lens, and was still immature (Nielson et al. 2016).

Data on the length of sleeper sharks are not prevalent because of their large size, which makes handling difficult. The average length of *Somniosus* sp. captured in mid-water trawls in the Southern Ocean is 390 cm *TL* (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 *TL* for females and 400 cm *TL* for males (Mecklenburg et al. 2002). Pacific sleeper sharks as large as 430 cm *TL* 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 *TL*, avg. weight = 28.4 kg) than males (avg. length = 140 cm *TL*, avg. weight = 23.7 kg) (Orlov 1999).

Size at maturity is estimated based on limited reports of mature animals. 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 the 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 *TL* 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 *TL* long was caught off Trinidad, California (Gotshall and Jow 1965) with ovaries containing 300 large ova. Two 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 *TL*, 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* (pre-caudal length, measured from the tip of the snout to the dorsal pre-caudal notch, at the base of the tail) 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.

The authors have compiled length data for Pacific sleeper shark from standard and non-standard AFSC trawl surveys in the GOA and BSAI, the Northwest Fisheries Science Center (NWFSC) groundfish trawl survey off the U.S. west coast, and International Pacific Halibut Commission (IPHC) surveys. There may be additional data available from the West Coast in the future; authors are working with staff at Monterey Bay Research Institute and Moss Landing Marine Labs to recover data that may be archived by those organizations. The length data compiled thus far show that small animals (50 – 200 cm total length) are caught coast wide; larger fish, those >200 cm *TL*, have never been recorded in the BSAI and animals up to 400 cm *TL* have been caught, in small numbers, in all other regions (Figure 20.2). One study has examined the sizes of Pacific sleeper shark caught in the GOA, eastern Bering Sea (AFSC trawl survey data for both regions), western Bering Sea, along the Kamchatka Peninsula and in the Sea of Okhotsk (Russian survey and fishery data), and found that there were very few fish greater than 200 cm (Orlov and Baitalyuk 2014). These data indicate that the animals caught in the BSAI are all young and small, some possibly even being neonates, and are all likely immature. In all of the other regions, the animals being caught are also primarily small, but occasionally larger, possibly mature animals are captured.

Because few large, mature Pacific sleeper sharks are found in surveys or fisheries, it is possible that adults inhabit abyssal depths and are generally not available nor susceptible to fishing or survey gear. Another possibility is that adults inhabit the nearshore environments but are not susceptible to the gear. At this time, the only evidence of the presence of large presumably adult Pacific sleeper shark in any area comes from camera footage from deep water drop cameras (e.g., Monterey Bay Research Institute) or the occasional adult that has been reported in the literature (Ebert et al. 1987, Yano et al. 2007). It is possible that the larger animals (>350 cm TL) captured in the GOA or BSAI are mature, however, maturity is generally not collected during surveys because the animals are released alive and biological information is not routinely collected from animals caught in commercial fishing activities.

Salmon Shark

Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2°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). 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, Conrath et al. 2014). Salmon shark appear to have at least a two year reproductive cycle, with an extended resting period between pregnancies (Conrath et al. 2014). 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. 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. 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). Off of Washington State, spiny dogfish have a long pupping season, which peaks from October to November (Tribuzio et al. 2009). Pupping is believed to occur in estuaries and bays or mid-water over depths of approximately 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 (Ketchen 1972, Tribuzio et al. 2009, Tribuzio and Kruse 2012).

Fishery

Management History and 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).

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

The estimated catch of sharks is broken into four groups: Pacific sleeper shark, spiny dogfish, salmon shark, and other/unidentified sharks. 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. Over the last 10 years, 100% of the catch has been discarded in the Aleutian Islands, and >95% in the Bering Sea, with the exception of other/unidentified sharks, which are discard at a lower rate (74% on average, <3 t retained on average). The reason for the 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 (Tribuzio et al. 2012), but that does not explain why the discard rate is lower for this category than other categories. About 8 t of sharks has been retained on average over the last 10 years (~4 t is Pacific sleeper shark), and nearly all is used for fishmeal (T. Hiatt, NMFS, AFSC, pers. comm.).

Historical Catch

Historical catches of sharks in the BSAI are composed entirely of incidental catch. Incidental shark catches by species is best summarized by two distinct time series: 1997 – 2002 and 2003 – present (Table 20.4). Shark catch by species was estimated by staff at the AFSC using a pseudo-blend approach for 1997 – 2002 (Gaichas 2001, 2002) and since 2003 estimated by the NMFS AKRO Catch Accounting System (CAS). The pseudo-blend approach used between 1997 – 2002 may not be comparable to estimates since 2003 due to the limited data available at that time and that the analysis was a one-time analysis. Estimates generated by CAS are updated retroactively, as input data are error-checked and as improvements to CAS are made. Further, sharks were not always identified to species, thus, prior to 2003, there were high incidences of “unidentified sharks” in the observer records. Species identification has improved greatly since 2003 and “unidentified sharks” are only a very small part of the shark catch now.

Aggregate incidental catches of the shark management category from federally prosecuted fisheries for Alaska groundfish in the BSAI are tracked in-season by NMFS AKRO (Table 20.2 and Table 20.4). The restructured observer program went into effect in 2013. This restructuring increased observer coverage on vessels < 60ft in length as well as incorporating those participating in the Pacific halibut IFQ fishery into the program. Thus, the catch time series beginning in 2013 may not be comparable to the catch time series prior for sharks because a large portion of shark catch originates from the vessels now included in the observer program. Prior to observer restructuring, ~32% of the shark catch came from vessels <60ft (average 2003 – 2012), since 2013 ~60% of the shark catch originates from vessels <60ft. Even though vessels participating in the Pacific halibut IFQ fishery in the BSAI are now included, the majority of the change in the composition of catch after observer restructuring went into effect was due to increased coverage in small vessels targeting Pacific cod.

Historically, Pacific sleeper shark are the primary species caught in the BSAI (260 t on average, Table 20.4, Figure 20.3). Since 1997 the other/unidentified sharks (71 t on average), salmon sharks (44 t on average) and spiny dogfish (11 t on average) are smaller components of the complex. However, if only the time series of catch since observer restructuring is considered, on average Pacific sleeper sharks are

65 t, salmon shark are 37 t, spiny dogfish are 14 t, and other/unidentified sharks are 2 t of the total shark catch.

Most of the shark catch since 2013 in the BSAI occurs in the Pacific cod and walleye pollock fisheries. Pacific sleeper shark are caught primarily in the Pacific cod (31 t on average, Table 20.5) and the walleye Pollock (21 t on average) fishery. Salmon shark are almost entirely caught in the walleye pollock fishery (34 t on average, Table 20.6). The Pacific cod fishery catches about 43 t of the spiny dogfish (Table 20.7). The other/unidentified sharks are also caught primarily within the Pacific cod fishery (1 t), but also commonly in the walleye pollock fishery (<1 t, Table 20.8). Of note is that catch of Pacific sleeper sharks in the Pacific halibut target fishery increased from 1 t to 9 t (Table 20.5) after 2013. Similarly, spiny dogfish catch in the Pacific halibut fishery increased from < 1 t to 2 t (Table 20.7). These results suggest that the catch estimates prior to observer restructuring were not representative of the actual catch occurring in the BSAI. An increase in catch was also seen in the Pacific cod fishery starting in 2013, likely from an increase of coverage on smaller vessels.

Catch distribution: Observer data 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 2012 – 2015 (data can be found here: http://www.afsc.noaa.gov/FMA/spatial_data.htm).

Bycatch of Pacific sleeper sharks (Figure 20.4) within observed commercial fisheries was relatively high on the EBS shelf west to approximately longitude 178°50’W, northwest of St. Matthews Island. In 2013 the largest observed hauls were near Unimak Pass. In comparison, observed catches in 2015 were fairly small and evenly spread north along the shelf edge.

Observed bycatch of salmon shark in commercial fisheries in the Bering Sea is generally low, but occasional large catches occur (Figure 20.5). Most of the catch occurs along the EBS shelf, with a small amount in the southern Bering Sea near the Pribilof and Bering Canyons, and the shelf waters in the EBS outside of Bristol Bay. Each year since 2013 there have been a small number of hauls with large estimates of catch, all in the southern Bering Sea, near Unimak Pass or along the Alaska Peninsula.

Observed bycatch of spiny dogfish in commercial fisheries in the Bering Sea (Figure 20.6) is less than both Pacific sleeper and salmon shark bycatch, with a slightly different spatial distribution. Spiny dogfish bycatch occurs throughout the EBS shelf, generally along the shelf break heading northwest from Unimak Pass; however, the majority of observed catch is farther south, near Unimak Pass and along the Alaska Peninsula.

Observed bycatch of other/unidentified sharks within commercial fisheries in the Bering Sea (Figure 20.7) is generally patchy and small in recent years, owing to improved species identification. Hauls reporting catch of other/unidentified sharks is generally near the shelf edge, with some larger hauls occurring near the southern end of the shelf.

Data

Data for sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Nontarget catch	2003 – 2016
Improved Pseudo Blend (AFSC)	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2016
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope (Historical)	Biomass Index	1979 – 1991
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope	Biomass Index	2002 - 2016
NMFS Bottom Trawl Surveys –Aleutian Islands	Biomass Index	1980 – 2016
NMFS Longline Surveys	Catch Numbers	1989 - 2016
IPHC Longline Surveys	Abundance Index	1997 - 2015

Fishery

Historical catch estimates are presented in Table 20.4 for the shark complex and by species in Table 20.5 - Table 20.8.

Catch at length (Fishery and Survey)

A formal stock assessment population model does not exist for the shark complex or any of the component species in the BSAI; therefore, length frequency data are not used in the assessment specifications procedures. However, length data is available from surveys. The data presented here are from the AFSC bottom trawl surveys (GOA, EBS shelf, EBS slope and AI), AFSC and IPHC longline surveys, NWFSC trawl surveys on the U.S. West Coast (Pacific sleeper shark only) and targeted research surveys. Catch of salmon shark is extremely rare in surveys and length frequencies are not presented. A detailed description of the Pacific sleeper shark catch at length is included in the Life History section and Figure 20.2. Due to limited samples collected each year, and inconsistent surveys each year, there is not sufficient information to examine length frequencies over time for Pacific sleeper sharks.

Spiny dogfish length data collections are part of standard collections on the AFSC longline and trawl surveys, as well as regularly collected on the IPHC longline survey, thus a time series of length frequency data are being created. Lengths are not part of observer collections and the only fishery length data available is from a few special projects. Length data for spiny dogfish are rare in the BSAI, thus it is not presented in this assessment. A detailed description of spiny dogfish length data is in the GOA shark complex assessment (Tribuzio et al. 2015, http://www.afsc.noaa.gov/REFM/Docs/2015/GOAshark.pdf).

Survey

AFSC Trawl Survey Biomass Estimates

Biomass estimates are available for shark species from NMFS AFSC bottom trawl surveys conducted in the BSAI on the eastern Bering Sea (EBS) slope (1979 - 1991 and 2002 - 2016; Table 20.9 and Figure 20.8), Aleutian Islands (AI, 1980 – 2016, Table 20.10 and Figure 20.8), and the EBS shelf (1979 – 2016, Table 20.11 and Figure 20.8). The EBS shelf survey is annual, but the EBS slope and AI 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. Thus trends in biomass estimates from trawl surveys are not informative. Spiny dogfish, for example, occurred in < 1% of survey hauls for all 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 are uncertain because the gear may not efficiently capture this species. These surveys are not 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 – 2016). Consequently, surveys from 2002 – 2016 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, NMFS, AFSC, 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; however, the number of hauls catching Pacific sleeper sharks has declined since 2008, with only 5 of 175 hauls catching them in 2016 and the lowest biomass estimate of the time series (251 t, Table 20.9 and Figure 20.8). There have been large fluctuations in biomass estimates over the time series, ranging from the current low to 25,445 t in 2002. 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 in the AI, but biomass estimates in this area are based on a small number of hauls (at most 10 hauls in 1997, 2.5% of the survey hauls) and biomass estimates are generally lower than in the EBS slope area (22 t in the AI in 2012, Table 20.10 and Figure 20.8). There were no Pacific sleeper sharks caught during the AI trawl survey in 2014 and 2016, prior to that, the species had been caught in each survey, with the exception of the first year, 1980. Pacific sleeper sharks are not often caught during the annual EBS shelf survey and biomass estimates range from zero to 5,602 t (2002) (Table 20.11 and Figure 20.8).

Spiny dogfish and salmon shark are rarely captured during any of the NMFS bottom trawl surveys in the EBS or AI. Often, catches are zero, with a resultant zero biomass estimates or are based on very few hauls with catch. During the EBS slope survey, spiny dogfish have only been caught in one haul (in 2008) and no other spiny dogfish have been caught since the new survey design in 2002 (Table 20.9 and Figure 20.8). Spiny dogfish are caught sporadically in the AI survey and the resultant biomass is always low, ranging from 2 - 62 t (Table 20.10 and Figure 20.8). Salmon shark have never been caught in the EBS slope survey (Table 20.9). One salmon shark was caught in 2002 in the AI survey (Table 20.10 and Figure 20.8) and one in 1988 in the EBS shelf survey (Table 20.11 and Figure 20.8).

Longline Surveys

The 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 AI, EBS, and the GOA, 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 (RPNs) 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 from the IPHC survey have declined steeply since the late 1990s and have remained at low levels since 2005 (Figure 20.9). 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 AI.

The AFSC longline survey samples stations in the EBS in odd years (e.g., 2013) and the AI in even years (survey protocol can be found here: http://www.afsc.noaa.gov/ABL/MESA/pdf/LSprotocols.pdf). Overall shark catch is low on the AFSC longline survey. For this reason, RPNs from the AFSC longline survey are not presented. The AFSC longline survey samples fewer stations with longer sets along the slope, whereas the IPHC survey samples many stations with less gear set at shallower depths across the shelf. The AFSC longline survey likely 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 in low numbers throughout the EBS shelf in the IPHC longline survey (during years 2012 – 2015, Figure 20.10) and NMFS trawl surveys (Figure 20.11) with rare scattered catches in the AI. The distribution of Pacific sleeper sharks spreads from Unimak Pass and follows the shelf break northwest beyond the Pribilof Islands, until approximately longitude 178°40’W.

In contrast, spiny dogfish catch is mostly distributed throughout the Aleutian chain (Figure 20.14). The IPHC survey catches spiny dogfish regularly out the Aleutian chain, but in small numbers. Spiny dogfish are rarely caught in the AFSC trawl or longline surveys in the BSAI and are not included here.

Analytic Approach

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. 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 ageing 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, and due to the size were all likely immature (Fisk et al. 2002). Further, a recent study reported an individual that was approximately 49 years old and still immature (Nielson et al. 2016). If we assume that a minimum estimate of maximum age is 49 and we assume that they mature at about 50% of their total age, then a range for maximum age could be 49 – 98. Thus, a range of natural mortality (M) estimates can be calculated using Hoenig’s (1983) equation, resulting in $M = 0.047 – 0.092$. There are 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. (2010b) report the youngest dogfish encountered in fishery dependent sampling was 8 years old.

Salmon shark are a fairly well studied species. Natural mortality has been estimated to be M = 0.18 (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 the biomass estimates are unreliable. The current Tier 6 method adopted in 2010 for sharks uses the catch time series from 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.

The SSC and Plan Team have expressed concerns over the declining population trends in Pacific sleeper sharks in both the BSAI and GOAand have requested an examination of alternative OFL/ABC options. The SSC and Plan Team also recommended that the reference period and OFL/ABC levels be re-evaluated after a few years of data from the restructured Observer Program have accumulated. In the table below we present the OFL and ABC recommendations based on average catch as well as the maximum catch for three different time series: 1) status quo (1997 – 2007); 2) Catch Accounting System (2003 – 2015); and 3) since observer restructuring went into effect (2013 – 2015). The time series of catch specified in the FMP for Tier 6 assessments is 1977 – 1995. However, data on catches of sharks does not exist prior to 1997. At the time of implementation of the Tier 6 time frame for evaluating catch (2008) the longest time series of catch for sharks available was selected, from 1997 – 2007. The third time series is included for consideration because with the implementation of observer restructuring, a portion of the fleet that generally catches sharks (i.e., small catcher vessels and Pacific halibut IFQ vessels) is now included, thus catch estimates beginning in 2013 are likely the most representative of true shark catch. Note, however, that the second time series examined for ABC and OFL recommendations (2003 – 2015) also includes the catch estimates from the restructured observer program.

The shark catch time series was compared to each the status quo ABC/OFL as well as the proposed alternative ABCs (Figure 20.13). Catch of sharks over the last ten years would have only exceeded the ABC (either based on maximum or average catch) once using either the status quo (1997 – 2007) or the 2003 – 2015 time series. In comparison, catch over the last ten years would have exceeded the ABC in most years if the ABC were based on the 2013 – 2015 time series.

Both the 1997 – 2007 (status quo) and the 2013 – 2015 time series have significant concerns. The 1997 – 2002 series of catch estimates is based on limited shark data and is not updated. Estimates since 2003 are created by the Catch Accounting System in which the input data are being error checked retroactively for enhanced accuracy of catch estimates and the time series since 2003 is relatively data rich. For sharks, this can have significant impacts on estimates of catch because there are generally few incidents of observed shark catch. Further, the 2002 catch, which is the maximum value over the full time series and the value which the OFL and ABC are set under the status quo, is suspect. The 1997 – 2002 catch estimates were created as part of the “Other Species” assessment in 2003, and were intended to mimic the blend estimation procedure used for target species at that time. In 2002, there was an observed haul that reported a large extrapolated catch of basking shark onboard a longline vessel, a highly unlikely scenario because the species is planktivorous and the BSAI is well outside it's normal range. Mostly likely it was misidentified. In the blend method of catch estimation, this large of an estimate of "other/unidentified shark" could have inflated the catch estimate. If, for example, the catch had been identified as Pacific sleeper shark, the impact of such a large extrapolated catch may have been reduced because the number of observations of that species are much larger. Lastly, the actual number of sharks recorded by observers in 2002 was substantially lower than the other years with large estimates of shark catch (2,811 sharks in 2002, compared to >3,255 sharks between 2000 – 2006), yet total fishing effort in the BSAI was relatively constant (due to the 2 million t cap), suggesting that the large increase in the estimated shark catch may have been an extrapolation issue and was not due to an actual in increase in the numbers of sharks. We do not recommend the 1997 – 2007 time series because the catch prior to 2003 was easily influenced by species misidentification and because it is static and difficult to recreate we cannot easily go back and examine the catch estimates.

Catch estimates since the implementation of observer restructuring (2013 – 2015) should be considered the most representative estimates of catch, and include vessels under 60 ft. This fleet is comprised primarily of longline vessels that target Pacific cod and halibut. These fleets typically catch sharks and should be included for the most representative time series of shark catch. However, the time series is very short and the full range of possible shark catches is likely not reflected in two years of data. While we feel these two years are very informative and are the most representative of the estimates of shark catch, we do not recommend using only the years 2013 – 2015 to set OFL and ABC.

In this assessment **we recommend computing the OFL and ABC using the maximum catch of the time series from 2003 – 2015** as this time series includes more recent catch trends and provides the more representative estimates of catch available.

Tier 6 ABC and OFL calculations for all options 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 options by species and total of all species (t) and recommendations for 2017-2018 (in bold).

	Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark Complex
1997-2007	Maximum Catch	17	839	199	468	1,363*
	ABC	13	629	149	351	1,022
	OFL	17	839	199	468	1,363
	Average Catch	8	422	48	126	605
	ABC	6	316	36	95	454
	OFL	8	422	48	126	605
2003-2015	**Maximum Catch**	24	421	199	305	689*
	ABC	18	315	149	229	**517**
	OFL	24	421	199	305	**689**
	Average Catch	14	166	53	38	270
	ABC	10	125	40	28	203
	OFL	14	166	53	38	270
2013-2015	Maximum Catch	24	65	52	3	138*
	ABC	18	49	39	2	103
	OFL	24	65	52	3	138
	Average Catch	17	64	36	2	120
	ABC	13	48	27	2	90
	OFL	17	64	36	2	120

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

Ecosystem Considerations

The ecosystem considerations for the BSAI shark stock complex are summarized in Table 20.14.

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. The only known predator of Pacific sleeper sharks is the orca. One study observed two events between the ‘offshore’ ecotype of orcas and Pacific sleeper sharks, where they killed the shark and ate the liver only (Ford et al. 2011). In each event multiple shark prey were DNA identified. This is likely a specialized behavior in specific areas where the sharks must swim shallow to pass over sills between water bodies, which puts them in the diving range of the orca. Incidents of Stellar sea lions feeding on what appeared to be Pacific sleeper shark liver have been reported in Southeast Alaska, near Juneau, but identity of the prey was not confirmed, nor was it able to be confirmed if the sea lions predated or were opportunistically foraging (J. Moran, NMFS, AFSC pers. comm.). 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 (e.g., large unmeasurable species), unreliable biomass estimates, lack of fishery 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 on sharks in the fisheries and surveys. Future shark research priorities will focus on the following areas:

1. Catch estimation for large, hard to measure species.
    a. Actions: Investigating catch by numbers for Pacific sleeper sharks and exploring management options.
2. 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; investigating population genetics of Pacific sleeper shark.
3. Explore ageing methods for difficult to age species
    a. Actions: Began sample collection for an examination of new ageing methods for Pacific sleeper shark, such as eye lens radio carbon and vertebra microchemistry.

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Tables

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, and ABC for sharks and the shark 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	25,498	589	N/A	Other Species TAC
2004	27,205	29,455	515	N/A	Other Species TAC
2005	29,000	29,483	417	N/A	Other Species TAC
2006	29,000	27,018	689	N/A	Other Species TAC
2007	37,355	26,800	332	463	Other Species TAC
2008	50,000	29,474	194	463	Other Species TAC
2009	50,000	27,883	151	447	Other Species TAC
2010	50,000	23,374	60	449	Other Species TAC
2011	50		107	1,020	Shark Complex TAC
2012	50		96	1,020	Shark Complex TAC
2013	100		114	1,020	Shark Complex TAC
2014	125		138	1,022*	Shark Complex TAC
2015	125		107	1,022	Shark Complex TAC
2016	125		112	1,022	Shark Complex TAC

*The change from 1,020 t to 1,022 t was due to the Plan Team recommending and the SSC accepting the use of a rounded value in the assessments prior to the 2013 assessment. The rounded value was converted to the actual value for the 2014 fishery, as per the 2013 assessment.

Data Sources: TAC, ABC and management category came from AKRO catch statistics website. Catch data was queried from AKFIN on Oct 3, 2016.

Table 20.3. Estimated discard rates of sharks (by species) in the BSAI. Source: AKFIN database, Oct 3, 2016. Blanks are where there was no catch reported.

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%	0%
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%	
2013	100%	100%	100%	
2014	100%	100%	100%	
2015	100%	100%	100%	
2016	100%	100%	100%	
10 YR Average	100%	100%	100%	100%
	Bering Sea			
1999	60%	98%	99%	100%
2000	96%	95%	97%	100%
2001	100%	96%	84%	100%
2002	96%	86%	91%	97%
2003	100%	100%	100%	
2004	100%	100%	100%	
2005	83%	78%	98%	87%
2006	98%	98%	94%	97%
2007	99%	96%	97%	74%
2008	98%	95%	98%	97%
2009	98%	93%	99%	47%
2010	100%	94%	97%	47%
2011	99%	96%	100%	63%
2012	100%	95%	99%	60%
2013	100%	92%	96%	76%
2014	100%	95%	97%	90%
2015	100%	96%	100%	86%
2016	100%	97%	96%	96%
10 YR Average	99%	95%	98%	74%

Table 20.4. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 3, 2016. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2016 from NMFS AKRO blend-estimated annual catches. Note that the restructured observer program went into effect in 2013. The maximum is the maximum of the complex combined, if the maximum were the sum of the individual species maximums the Max. 1997-2007 = 1,523 and the Max. 2013–2015 = 144.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unidentified shark	Total sharks
1997	4	304	7	53	368
1998	6	336	18	136	496
1999	5	319	30	176	530
2000	9	490	23	68	590
2001	17	687	24	35	763
2002	9	839	47	468	1,363
2003	13	342	199	34	589
2004	9	421	26	60	515
2005	11	333	47	26	417
2006	7	313	63	305	689
2007	3	257	44	28	332
2008	17	127	41	8	194
2009	20	51	71	10	151
2010	15	28	12	6	60
2011	8	48	47	5	107
2012	20	47	26	3	96
2013	24	65	23	1	114
2014	20	63	52	2	138
2015	8	63	33	3	107
2016	3	71	37	0	112
Species % of total sharks	3%	67%	11%	18%	
Species avg. catch	11	260	44	71	
For all Alternative ABC/OFL Calculations					
Avg. 1997 – 2007	9	422	48	126	605
Max. 1997 – 2007	17	839	199	468	1,363
Avg. 2003-2015	14	166	53	38	270
Max. 2003-2015	24	421	199	305	689
Avg. 2013-2015	17	64	36	2	120
Max. 2013-2015	24	65	52	3	138

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 - 2016 are from NMFS AKRO blend-estimated annual catches, as of Oct 3, 2016. 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. Note that the restructured observer program went into effect in 2013. "NR" denotes target categories not reported.

Year	Atka Mackerel	Flatfish	Halibut	Other Species	Pacific Cod	Pollock	Rockfish	Sablefish	Total
1997	0.1	0.9	NR	NR	74.8	105.2	0.9	45.3	227.2
1998	0.0	0.9	NR	NR	146.7	74.4	0.0	0.0	222
1999	2.4	39.4	NR	NR	103.3	76.8	3	15.1	240
2000	0.3	42	NR	NR	114.7	103.8	2.7	143.7	407.2
2001	27.8	179.6	NR	NR	252.7	205.7	0.0	1.8	667.6
2002									
2003	0.7	45.4	18.6	0.1	172.6	85.0	0.5	19.7	342.5
2004	2.0	40.0	1.1	0.2	230.1	144.0	0.7	2.3	420.5
2005	0.0	10.4	0.1	0.0	191.2	127.6	0.1	3.8	333.2
2006	0.0	10.8	0.1	0.0	123.2	178.1	0.1	1.0	313.4
2007	1.1	9.6	<0.1	3.7	44.3	181.6	14.5	2.5	257.3
2008	0.1	6.7	0.0	0.0	20.0	97.9	1.2	1.3	127.2
2009	0.6	8.3	0.0	0.0	14.4	24.6	0.6	2.1	50.6
2010	0.0	1.3	0.0	0.0	15.1	10.5	0.1	1.1	28.1
2011	0.0	2.3	0.5	0.1	20.2	18.2	4.8	1.5	47.7
2012	0.9	8.3	0.0	0.0	9.8	27.6	0.6	0.2	47.4
2013	0.0	1.2	20.8	0.0	19.8	20.9	1.6	0.8	65.1
2014	0.0	1.1	0.4	<0.1	36.9	23.7	0.8	0.0	62.9
2015	0.0	2.3	2.1	0.1	36.0	20.2	1.7	0.3	62.6
2016	0.0	6.0	13.6	0.0	29.6	20.2	1.6	0.0	71.0
Avg. Catch 2003-2012	0.5	14.3	2.3	0.4	84.1	89.5	2.3	3.6	
Avg. % 2003-2012	0%	7%	1%	0%	43%	45%	1%	2%	
Avg. Catch 2013-2015	0.0	1.7	8.0	0.0	5.9	1.2	0.3	0.3	
Avg. % 2013-2015	0%	2%	12%	0%	49%	34%	2%	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 - 2016 are from NMFS AKRO blend-estimated annual catches, as of Oct 3, 2016. 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. Note that the restructured observer program went into effect in 2013. "NR" denotes target categories not reported.

Year	Atka Mackerel	Flatfish	Halibut	Other Species	Pacific Cod	Pollock	Rockfish	Sablefish	Total
1997	0.1	0.0	NR	NR	0.0	6.7	0.0	0.0	6.8
1998	0.0	0.1	NR	NR	0.8	16.2	0.0	0.0	17.1
1999	0.2	2.5	NR	NR	1.2	24.7	0.0	0.0	28.6
2000	0.0	0.0	NR	NR	3.8	19.5	0.0	0.0	23.3
2001	0.4	0.4	NR	NR	1.2	22.5	0.0	0.0	24.5
2002									
2003	0.2	0.5	0.0	0.0	1.2	197.4	0.0	0.0	199.3
2004	0.0	0.1	0.0	0.0	0.1	25.5	0.0	0.0	25.6
2005	18.2	0.7	0.0	0.0	2.0	25.7	0.0	0.0	46.7
2006	0.2	25.9	0.0	0.0	1.2	36.2	0.0	0.0	63.4
2007	0.1	0.0	0.0	0.0	0.0	44.1	0.0	0.0	44.2
2008	0.0	0.8	0.0	0.0	0.0	40.7	0.0	0.0	41.4
2009	0.3	0.4	0.0	0.0	0.1	70.0	0.0	0.0	70.8
2010	0.1	0.4	0.0	0.0	0.0	11.0	0.0	0.0	11.5
2011	0.2	1.5	0.0	0.0	0.1	45.3	0.0	0.0	47.2
2012	0.3	0.0	0.0	0.0	0.0	25.4	0.0	0.0	25.6
2013	0.3	0.8	0.0	0.0	0.2	22.1	0.1	0.0	23.5
2014	0.6	0.7	0.0	0.0	0.0	51.0	0.0	0.0	52.4
2015	0.1	1.4	0.0	0.0	1.1	30.7	0.0	0.0	33.3
2016	0.7	2.3	0.0	0.0	0.1	33.7	0.4	0.0	37.3
Avg. Catch 2003-2012	2.0	3.0	0.0	0.0	0.5	52.1	0.0	0.0	
Avg. % 1997-2012	3%	5%	0%	0%	1%	91%	0%	0%	
Avg. Catch 2013-2015	0.3	1.0	0.0	0.0	0.4	34.6	0.0	0.0	
Avg. % 2013-2015	1%	3%	0%	0%	1%	95%	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 - 2016 are from NMFS AKRO blend-estimated annual catches, as of Oct 3, 2016. 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. Note that the restructured observer program went into effect in 2013. "NR" denotes target categories not reported.

Year	Atka Mackerel	Flatfish	Halibut	Other species	Pacific Cod	Pollock	Rockfish	Sablefish	Total
1997	0.0	0.0	NR	NR	4.1	0.0	0.0	0.0	4.1
1998	0.2	0.4	NR	NR	5.6	0.1	0.0	0.0	6.3
1999	0.0	0.0	NR	NR	4.9	0.0	0.0	0.0	4.9
2000	0.0	0.2	NR	NR	8.6	0.0	0.0	0.0	8.8
2001	2.8	1.6	NR	NR	12.7	0.1	0.0	0.1	17.3
2002									
2003	0.1	<0.1	<0.1	<0.1	13.1	<0.1	0.0	0.0	13.3
2004	0.0	0.2	<0.1	<0.1	8.3	<0.1	0.0	0.1	8.6
2005	<0.1	0.1	0.0	<0.1	11.2	<0.1	0.0	<0.1	11.4
2006	<0.1	0.1	<0.1	0.0	6.6	0.2	0.0	0.2	7.1
2007	0.0	0.3	0.0	0.0	2.5	0.2	0.0	0.1	3.0
2008	0.1	0.2	6.2	0.0	10.2	0.2	0.1	<0.1	17.1
2009	<0.1	0.6	0.0	0.0	18.4	0.4	0.0	0.2	19.7
2010	<0.1	0.7	0.0	0.0	13.8	0.3	0.0	<0.1	14.9
2011	0.0	0.4	0.0	<0.1	7.3	0.2	0.0	0.0	7.8
2012	0.1	0.0	0.0	0.0	19.6	0.1	0.3	0.0	20.1
2013	0.4	0.2	4.9	0.0	18.3	0.1	0.0	<0.1	23.9
2014	0.0	1.0	3.4	0.0	15.8	0.1	0.0	0.0	20.2
2015	0.0	0.5	0.3	0.0	7.1	0.3	0.0	0.0	8.3
2016	0.0	0.2	0.2	0.0	2.0	0.6	0.0	0.0	2.9
Avg. Catch 2003-2012	0.1	0.3	0.9	0.0	11.1	0.2	0.0	0.1	
Avg. % 1997-2012	0%	2%	7%	0%	90%	2%	0%	1%	
Avg. Catch 2013-2015	0.1	0.6	2.9	0.0	13.7	0.2	0.0	0.0	
Avg. % 2013-2015	1%	3%	13%	0%	64%	1%	0%	0%	

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 - 2016 are from NMFS AKRO blend-estimated annual catches, as of Oct 3, 2016. 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. Note that the restructured observer program went into effect in 2013. “NR” denotes target categories not reported.

Year	Atka Mackerel	Flatfish	Halibut	Other Species	Pacific Cod	Pollock	Rockfish	Sablefish	Total
1997	0.0	0.4	NR	NR	26.8	15.6	2.5	1.2	46.5
1998	13.1	0.0	NR	NR	48.4	45.4	0.0	2.1	109.0
1999	0.0	0.2	NR	NR	18.8	10.3	0.0	1.8	31.1
2000	0.0	1.2	NR	NR	56.1	0.1	0.0	7.2	64.6
2001	0.0	0.0	NR	NR	19.6	2.3	0.0	10.4	32.3
2002									
2003	0.0	1.3	0.0	0.0	20.8	11.9	0.0	0.1	34.1
2004	0.0	22.2	0.0	0.0	20.2	17.6	0.0	<0.1	60.1
2005	0.0	0.0	0.0	0.0	10.1	16.0	0.0	<0.1	26.2
2006	0.0	3.7	0.0	0.0	3.6	298.0	0.0	0.1	305.5
2007	0.0	5.9	0.0	0.0	2.1	19.8	0.0	0.0	27.8
2008	0.0	0.5	0.0	0.0	1.6	5.9	0.0	0.0	8.0
2009	0.0	0.0	0.0	0.0	4.5	5.5	0.2	<0.1	10.2
2010	0.0	0.0	0.0	0.0	1.6	4.1	0.0	0.0	5.7
2011	0.0	0.0	0.0	0.0	2.6	2.0	0.0	0.0	4.6
2012	0.0	0.0	0.0	0.0	1.0	1.7	0.0	0.0	2.7
2013	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.0	1.1
2014	0.0	0.0	0.0	0.0	1.7	0.5	0.0	0.0	2.3
2015	0.0	0.0	0.0	0.0	1.8	1.2	0.0	0.0	3.0
2016	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.5
Avg. Catch 2003-2012	0.0	3.4	0.0	0.0	6.8	38.3	0.0	0.0	
Avg. % 2003-2012	0%	7%	0%	0%	14%	79%	0%	0%	
Avg. Catch 2013-2015	0.0	0.0	0.0	0.0	1.4	0.7	0.0	0.0	
Avg. % 2013-2015	0%	0%	0%	0%	47%	23%	0%	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 (AKFIN, queried October 12, 2016).

		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	2,282	0.34	0		
2008	207	1	13	1	28	1,968	0.27	0		
2010	200	0			19	833	0.27	0		
2012	189	0			16	1,337	0.28	0		
2016	175	0			5	251	0.49	0		

Table 20.10. Aleutian Islands AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls (AKFIN, queried October 12, 2016).

		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	249	0.66	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	1,021	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		
2014	410	2	23	0.72	0			0		
2016	419	1	7	1.00	0			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 (Dan Nichol, pers. comm., October, 2016).

		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	403	0.78	0			0		
1984	355	0			0			0		
1985	353	1	47	1.00	0			0		
1986	354	0			0			0		
1987	342	3	216	0.60	0			0		
1988	353	1	246	1.00	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	1.00	0			0		
1998	355	1	254	1.00	1	2,124	1.00	0		
1999	353	0			2	2,079	0.71	0		
2000	352	0			1	1,463	1.00	0		
2001	355	0			0			0		
2002	355	0			3	5,602	0.65	0		
2003	356	0			1	2,104	0.74	0		
2004	355	1	28	1.00	2	3,093	0.71	0		
2005	353	0			2	1,679	0.76	0		
2006	356	0			2	2,944	0.78	0		
2007	356	0			0			0		
2008	375	0			0			0		
2009	376	1	72	1.00	0			0		
2010	376	1	89	1.00	4	5,300	0.53	0		
2011	376	0			1	760	1.00	0		
2012	376	0			1	267	1.00	0		
2013	376	0			0			0		
2014	376	0			0			0		
2015	376	1	91	1.00	2	2,581	0.85	0		
2016	376	0			3	3,057	0.84	0		

Table 20.12. Research survey catch of sharks 1977 - 2015 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 (AKFIN, queried October 18, 2016). Data is lagged by one year.

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	Assessment of the sharks in the Bering Sea and Aleutian Islands (Tribuzio et al. 2010a)	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		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	0	0	NA	8.38	<0.01
2011		0.05	5	0.29	NA	1.5	0.03
2012		3.01	0	0	NA	1.62	0.12
2013		<0.01	5	0.18	NA	4.96	<0.01
2014		0.01	1	<0.01	NA	5.93	<0.01
2015		0.09	2	0.12	NA	2.55	<0.01

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

Figures

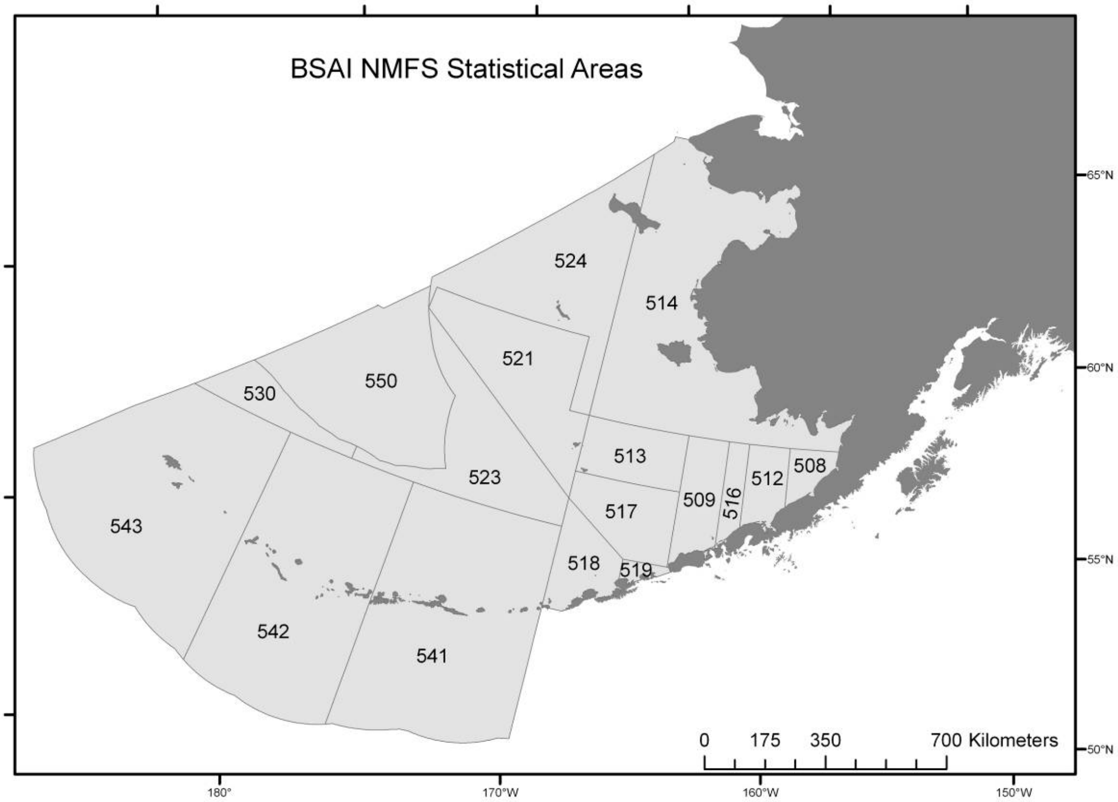

Figure 20.1. NMFS statistical areas in the Bering Sea (NMFS Areas 508-530) and Aleutian Islands (NMFS Areas 541-542).

Figure 20.2. Size distribution of Pacific sleeper shark collected in the Aleutian Islands (AI), Bering Sea (BS), Gulf of Alaska (GOA) and the U.S. West Coast (WC). Data is compiled from standard NMFS groundfish trawl surveys, non-standard NMFS surveys (i.e., opportunistic sample collection), directed research surveys, and special projects on IPHC surveys.

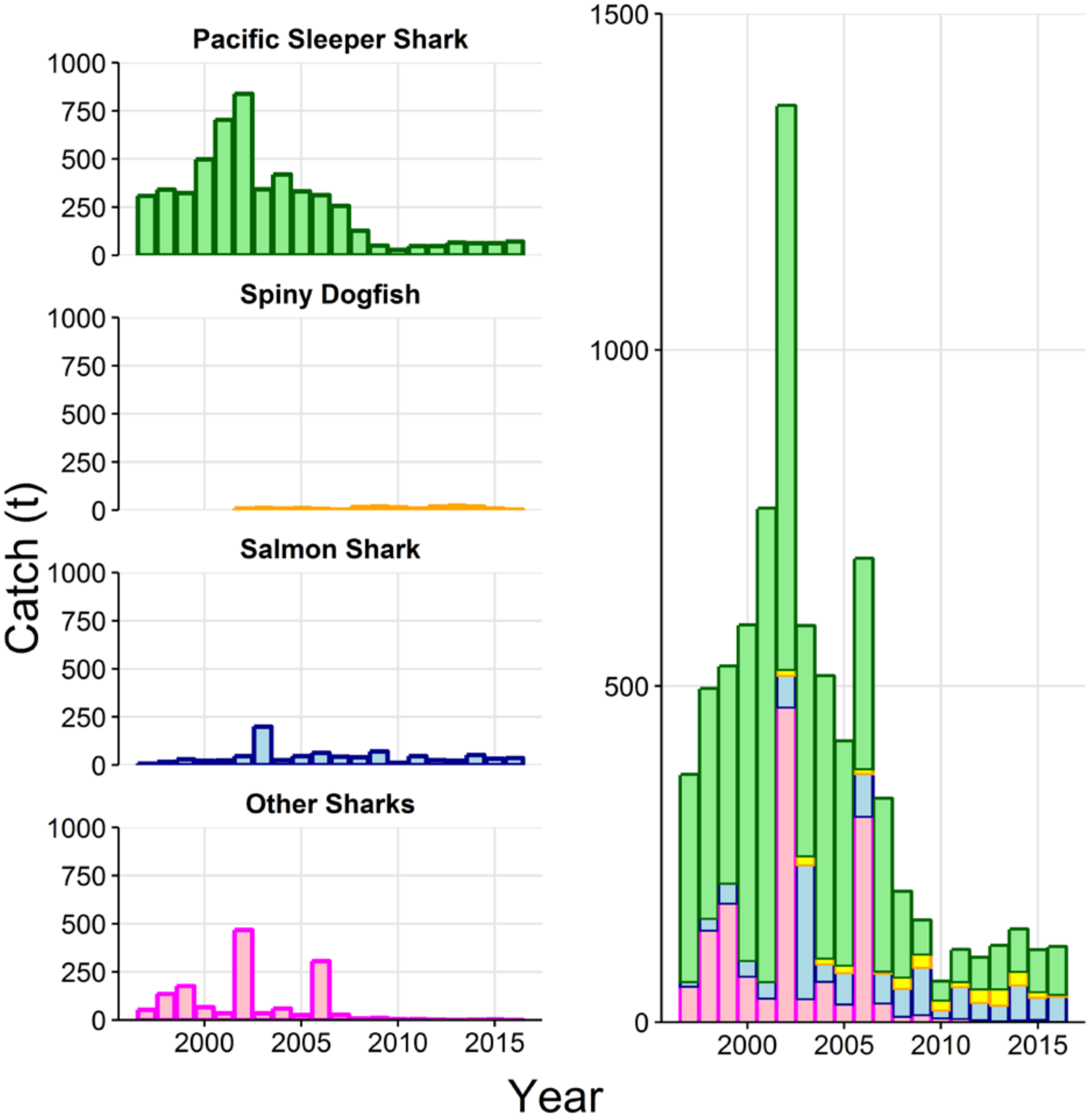

Figure 20.3. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 3, 2016. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2016 from NMFS AKRO blend-estimated annual catches.

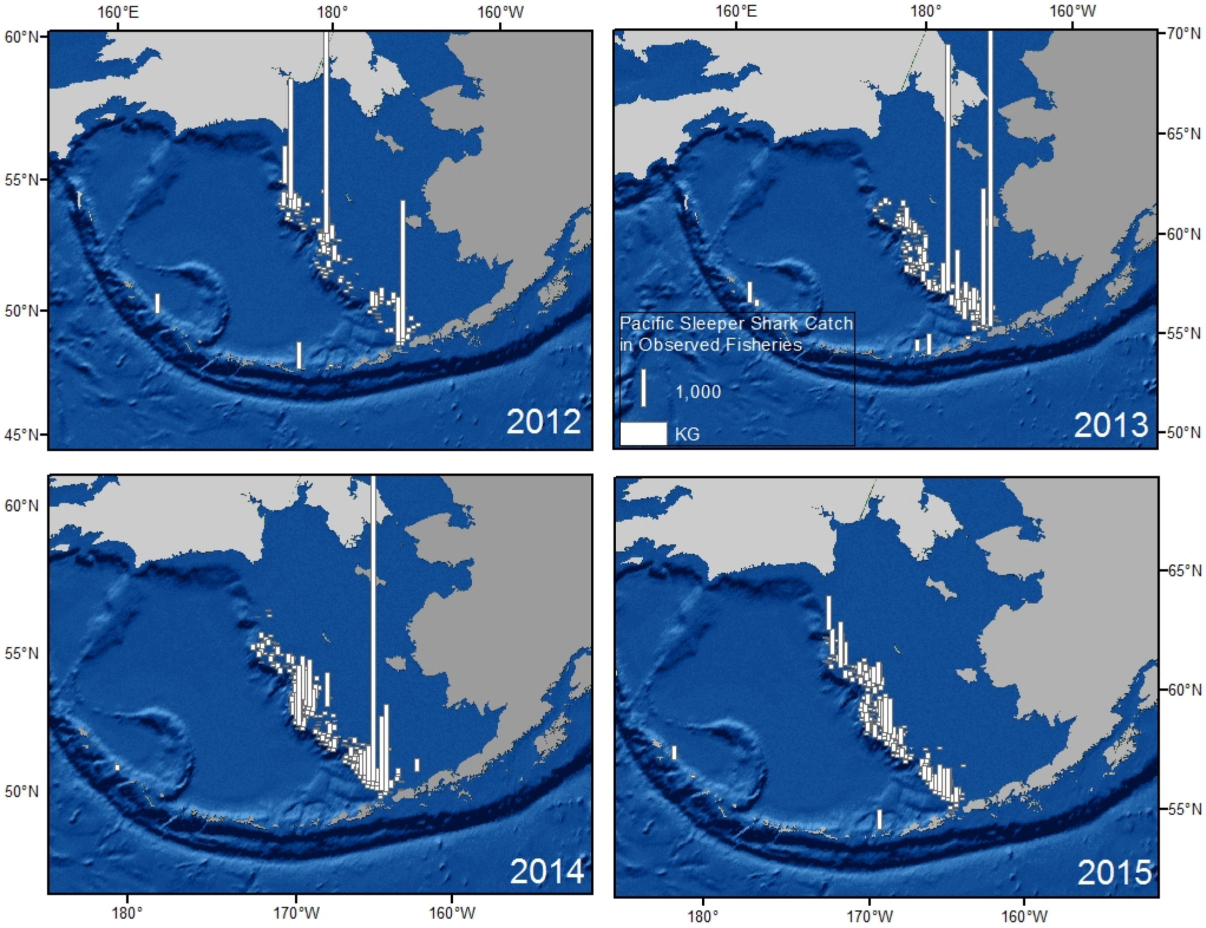

Figure 20.4. Spatial distribution of observed Pacific sleeper shark catch in the BSAI from 2012 - 2015. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 18, 2016 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

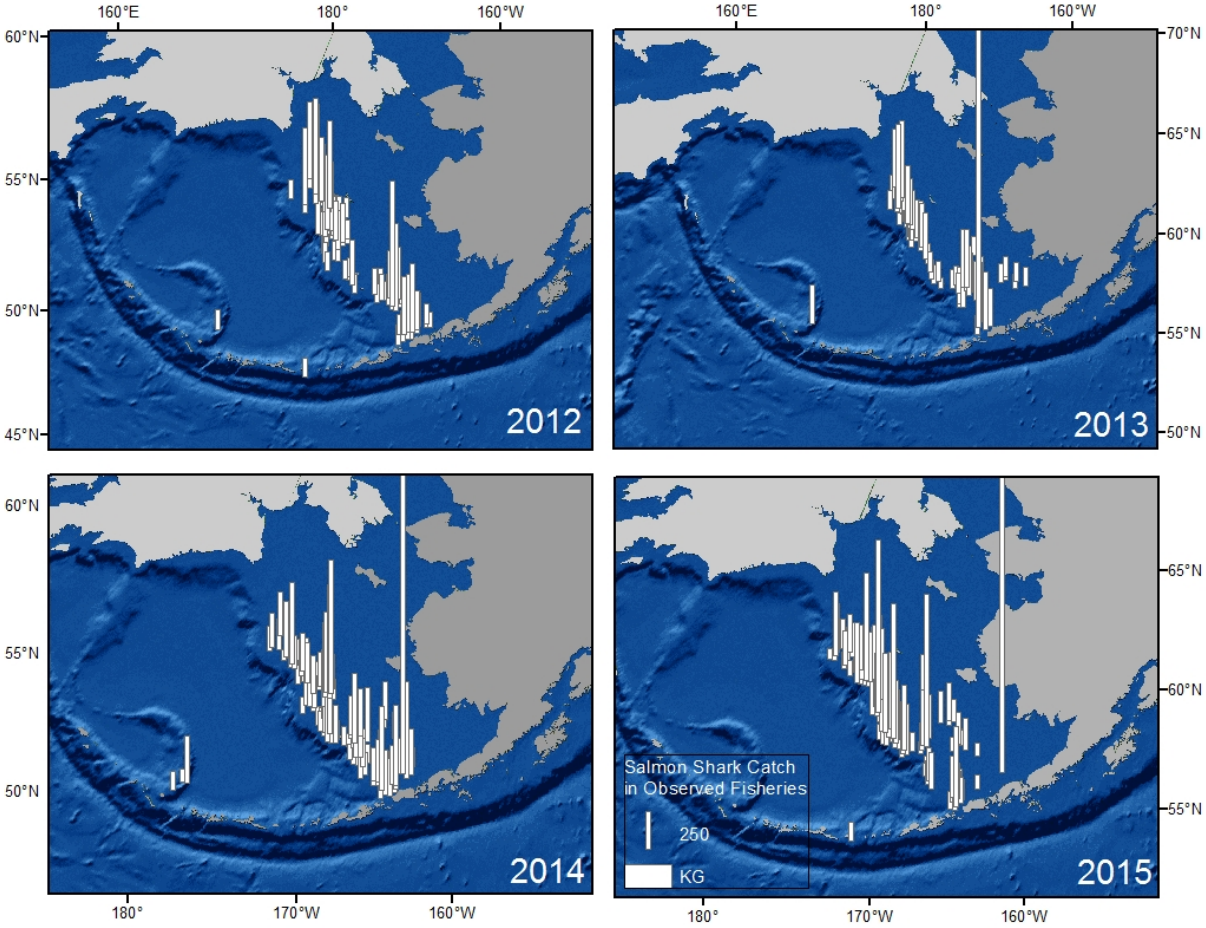

Figure 20.5. Spatial distribution of salmon shark catch in the BSAI from 2012 - 2015. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 18, 2016 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

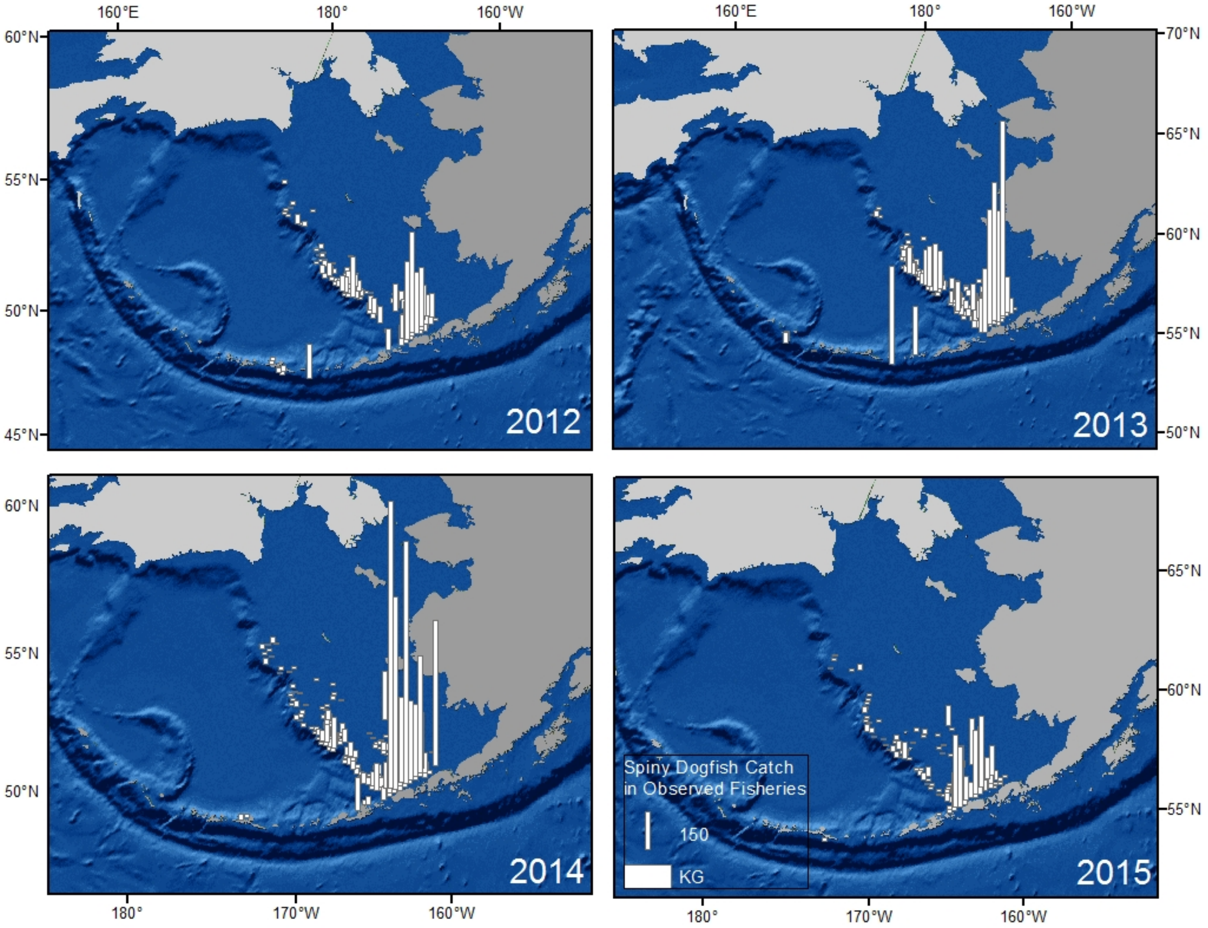

Figure 20.6. Spatial distribution of observed spiny dogfish catch in the BSAI from 2012 - 2015. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 18, 2016 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

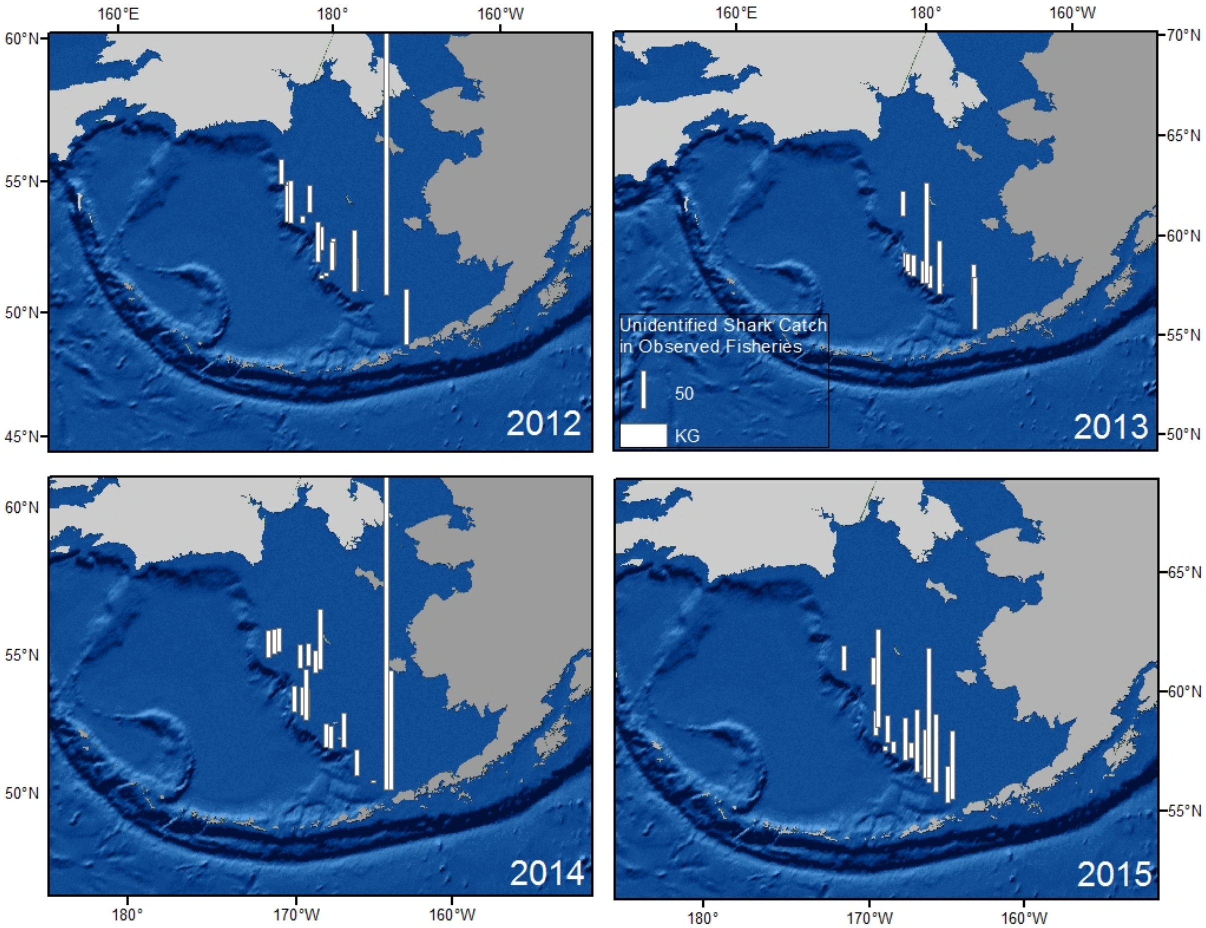

Figure 20.7. Spatial distribution of observed unidentified shark catch in the BSAI from 2012 - 2015. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 18, 2016 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

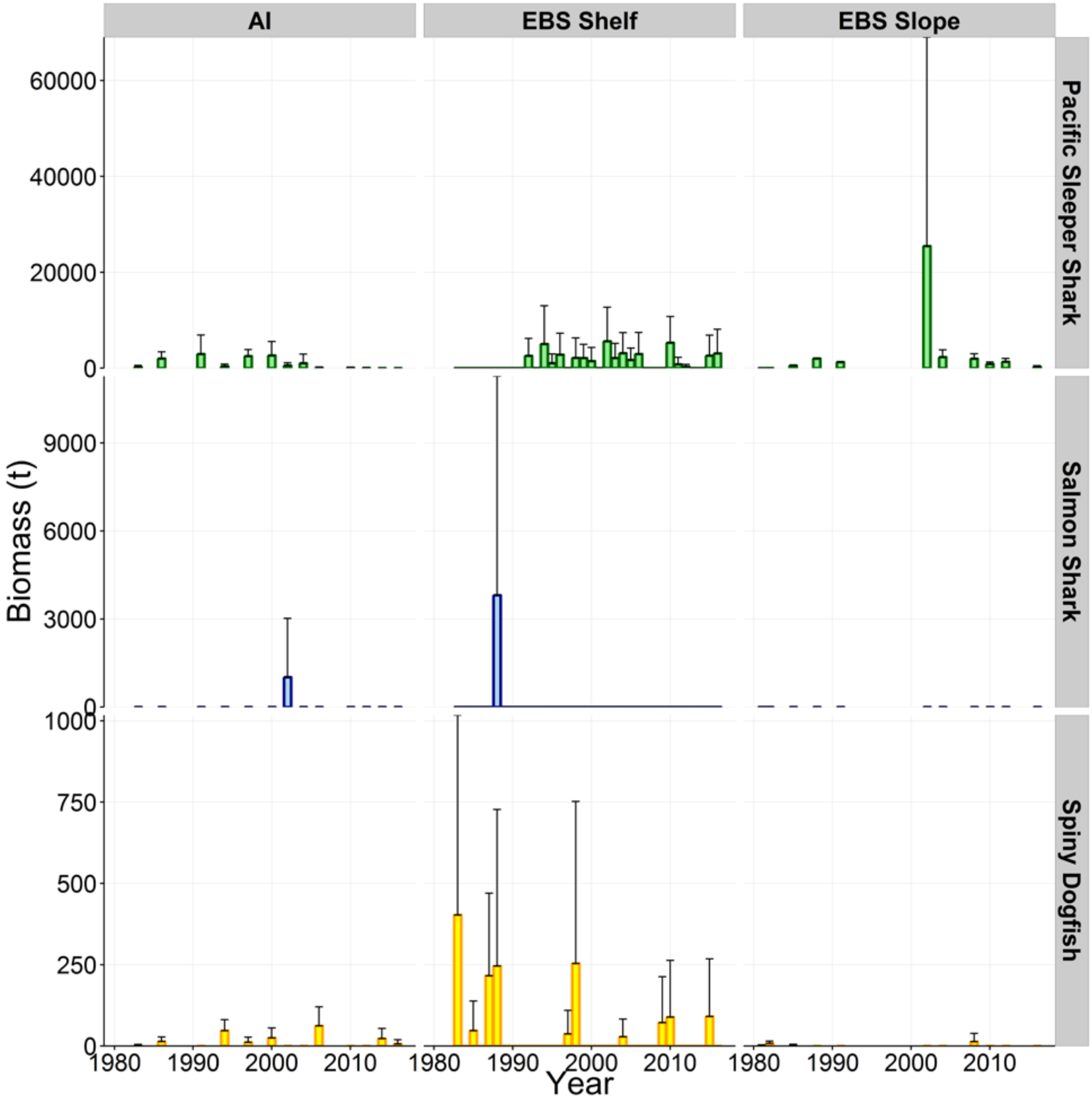

Figure 20.8. Time series of biomass estimates (t) of sharks in the AFSC eastern Bering Sea (EBS) slope, shelf, and Aleutian Islands (AI) bottom trawl surveys. Biomass values are reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS slope survey biomass 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. The break in the time series is signified by the dashed line.

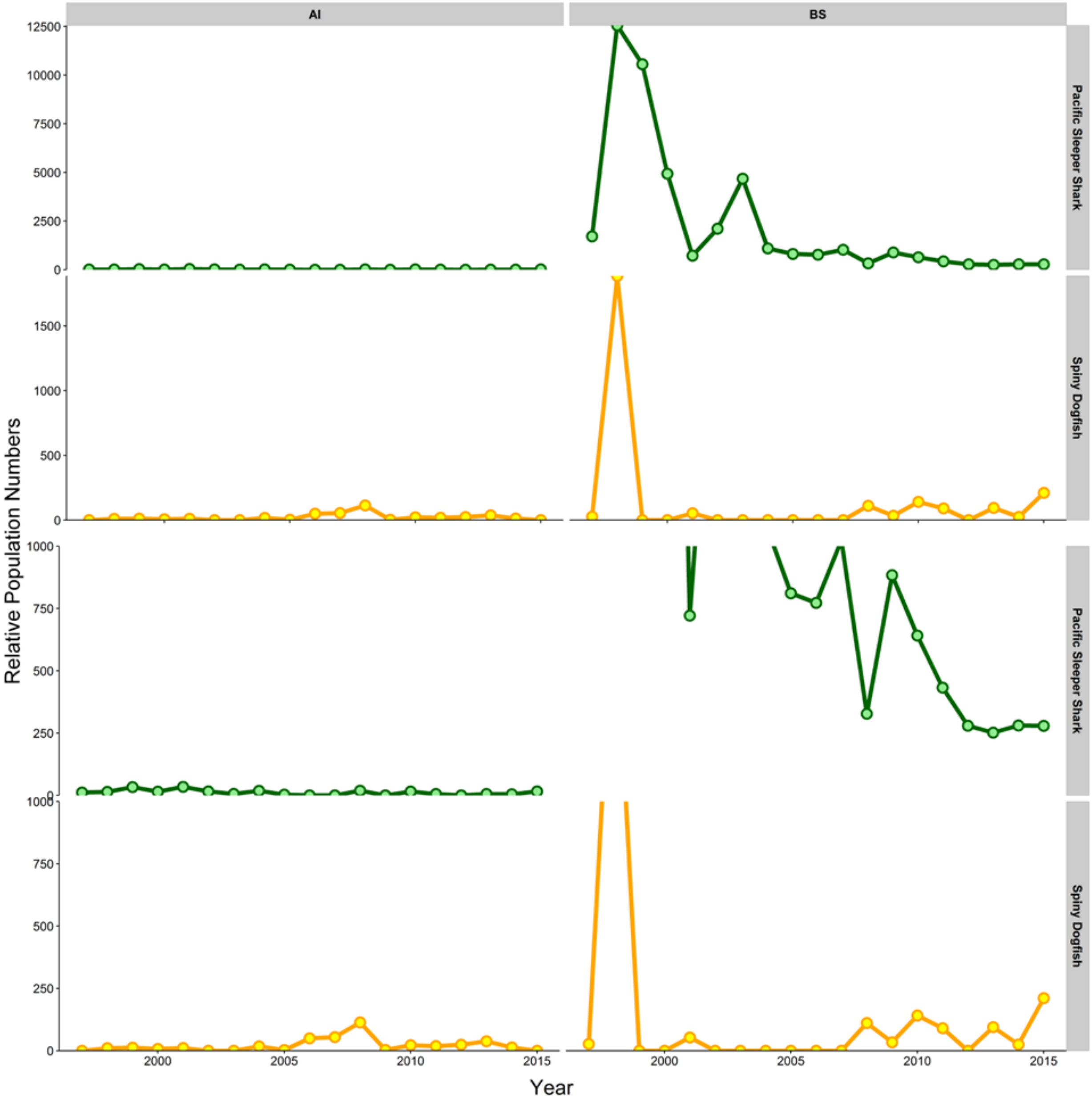

Figure 20.9. Top: Estimated relative population numbers from the IPHC annual longline survey in the BSAI. Bottom: Same as top panel, but zoomed in to show recent trends.

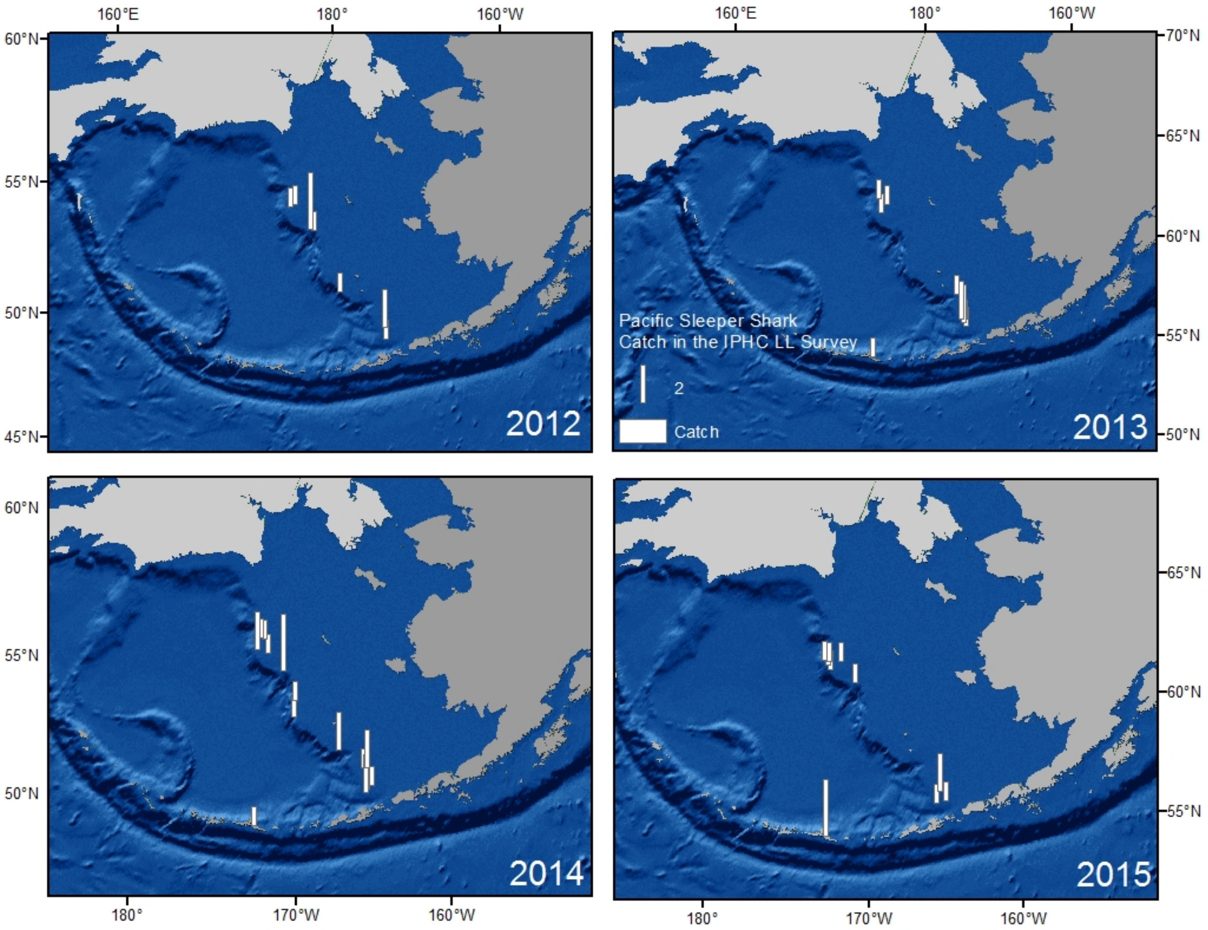

Figure 20.10. Spatial distribution of the catch of Pacific sleeper shark during the 2012 - 2015 IPHC longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

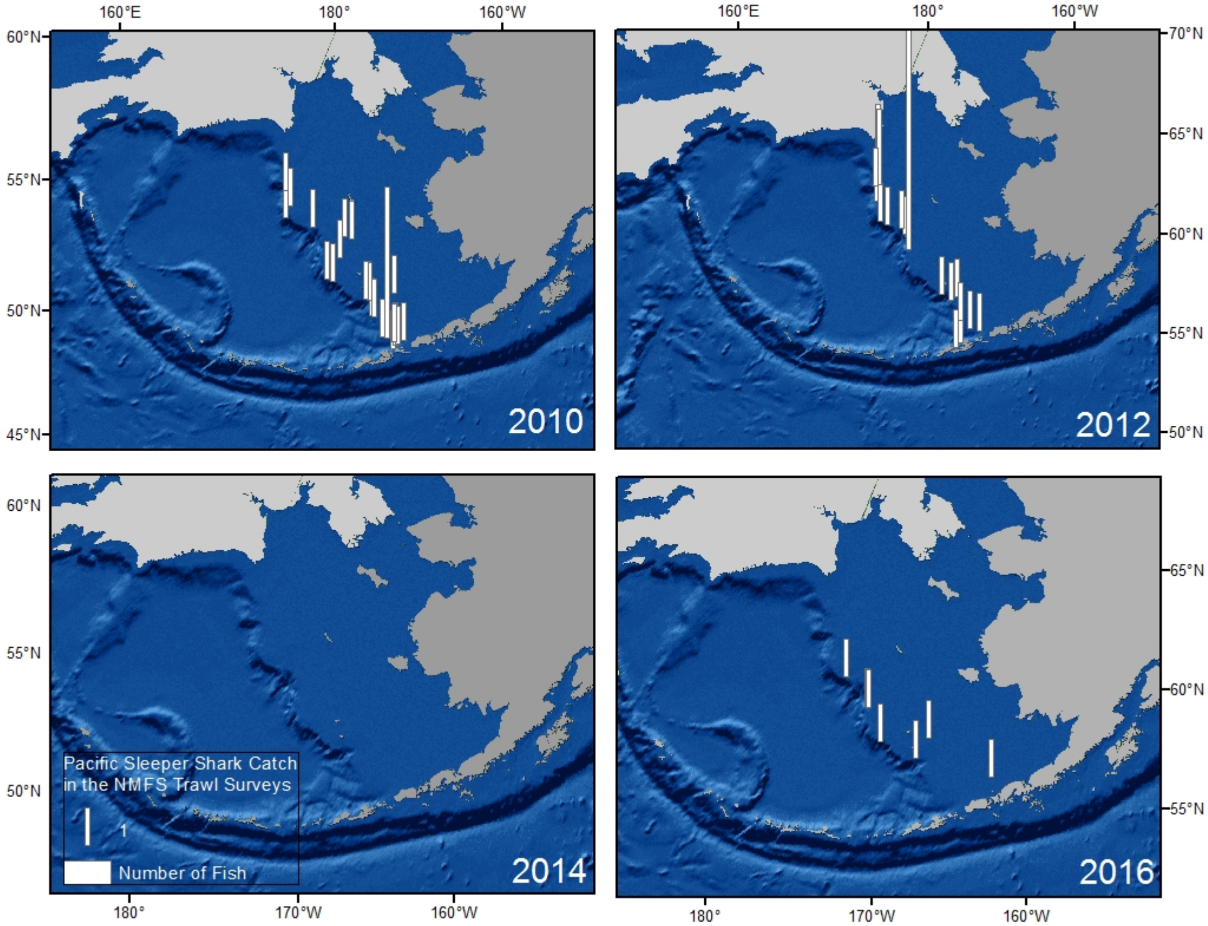

Figure 20.11. Spatial distribution of the catch of Pacific sleeper shark during the 2010-2016 NMFS Eastern Bering Sea (EBS) and Aleutian Islands trawl surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity. There was no EBS slope survey in 2014 and no sharks were caught during the EBS shelf or the Aleutian Islands survey that year. Years in which only the EBS shelf survey was conducted (odd years) are not included because that survey has inconsistent catch of sharks.

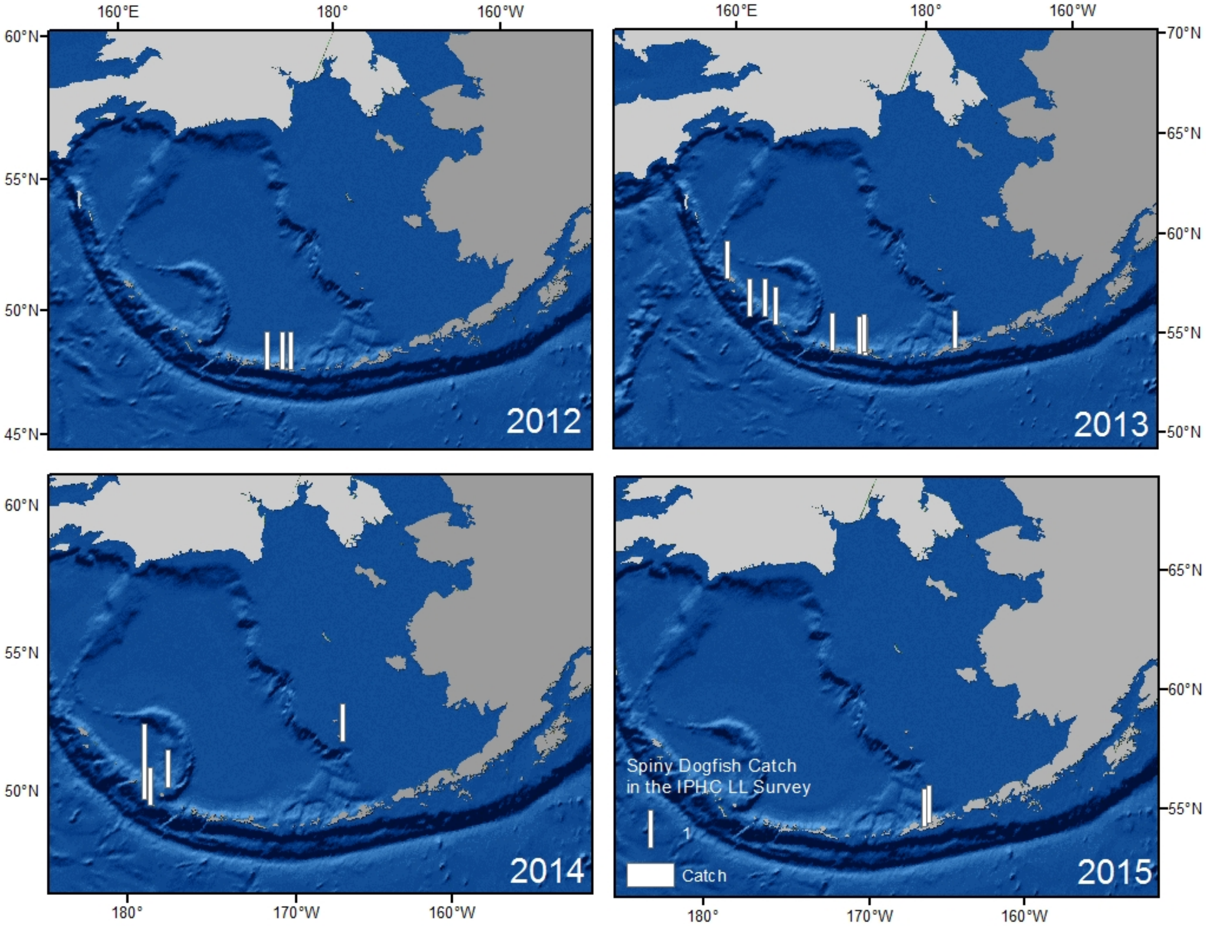

Figure 20.12. Spatial distribution of the catch of spiny dogfish during 2012 - 2015 IPHC longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

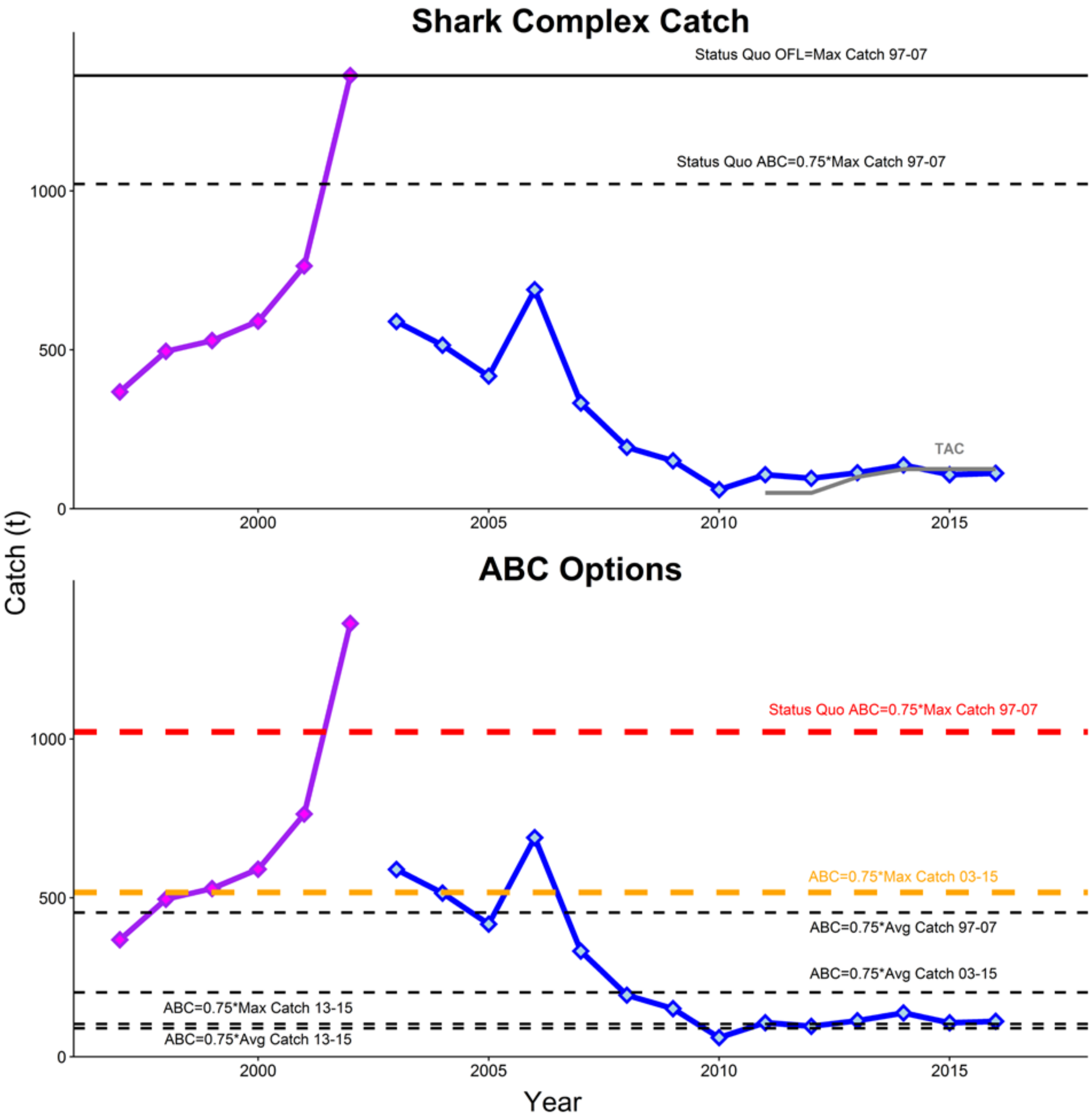

Figure 20.13. Total BSAI shark catch represented as two time series: the pseudo-blend (purple line, 1997 - 2002): and Catch Accounting (blue line, 2003 - present). Top: Catch is shown relative to the status quo, where the OFL and ABC was calculated using the maximum catch (“max OFL” and “max ABC”, black solid and dashed lines, respectively). The TAC (grey line) is included for reference. Bottom: Five alternative Tier 6 ABCs, using the maximum or average catch from three time series: status quo time (1997 – 2007), blend Catch Accounting System (2003 – 2015), and since observer restructuring went into effect (2013 – 2015). The status quo ABC is in red and the recommended ABC is in orange.

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