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 2014 (as of Nov 20, 2014)
2. IPHC survey RPNs have been calculated for 1997 – 2013
3. Biomass estimates have been updated for the Aleutian Islands and EBS shelf surveys for 2014

Changes in assessment methodology

The recommended method for calculating OFL and ABC has changed. We are now recommending OFL=Average catch (1997-2007) and ABC=0.75*OFL, rather than maximum historical catch from those years. This change is based on the recommendations made by the Center for Independent Experts (CIE) reviewers and concerns expressed by the Science and Statistical Committee (SSC) and Plan Team regarding declining catch trends for Pacific sleeper sharks. Recent catches are well below the average historical catch, thus shark catch is unlikely to limit the fishery. We recommend this more conservative approach until more data become available to justify setting a higher ABC/OFL.

Summary of Results

For 2014 we recommend the maximum allowable ABC of 454 t and an OFL of 605 t for the shark complex. Catch in 2013 was 116 t and 118 t in 2014 as of November 20, 2014. 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.

ABC and OFL calculations and Tier 6 recommendations for 2014 - 2015. OFL = average shark catch from 1997 - 2007. ABC = OFL*0.75.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
Tier	6	6	6	6
OFL (t)	1,363	1,363	**605**	605
maxABC (t)	1,022	1,022	454	454
ABC (t)	1,022	1,022	**454**	454
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Shark Complex	2013		1,363	1,022	100	116
	2014		1,363	1,022	125	118
	2015		605	454		
	2016		605	454		

[1]The shark complex in the BSAI is a Tier 6 complex with no reliable estimates of biomass
[2]Catch as of November 20, 2014

Responses to SSC and Plan Team Comments on Assessments in General

"*The Teams recommend that the whole time series of each category of "other" catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters.*" (Plan Team, November 2012)

This has been done and is reported in Table 20.12

SSC and Plan Team Comments Specific to this Assessment

"The SSC continues to encourage authors to pursue studies to collect life history information for sharks and to identify methods for estimating abundance of species that are rarely captured in standard surveys. The SSC remains concerned that the LL RPNs for Pacific sleeper shark stock remain low." (SSC, December 2012)

The authors agree and intend to investigate this further.

"The SSC encourages the authors to explore the possibility of advancing Pacific sleeper shark to a Tier 5 status. To accomplish this, the authors need to understand the absence of mature Pacific sleeper sharks in the surveys and fishery observations." (SSC, December 2012)

Data do not support moving the Pacific sleeper shark to Tier 5. Existing surveys do not sample Pacific sleeper sharks well and the life history is largely unknown. A life history working group has been formed to prioritize research and to foster and promote investigations into the life history of lesser known species, of which Pacific sleeper shark have been proposed as a priority species.

"In the future, the SSC encourages the authors to carefully consider whether the restructured observer program has impacted catch estimates for BSAI sharks, perhaps necessitating changes to the procedure for estimating average catches used in the catch specification process. The SSC also encourages the authors to address comments and suggestions made by the non-target CIE review team that are relevant to this assessment. (SSC, December 2013)

The authors presented a document to the September Plan Team, which is attached here as an appendix, detailing our current understanding of the changes in observer coverage and changes in catch estimation. There is limited data since restructuring and more years of data are needed before any adjustments to the catch time series can be investigated. In the future we would like to compare HFICE estimates to catch estimates post restructuring.

"*With respect to the historical catch time series, the Team recommends that authors complete an evaluation of a comparison of HFICE estimates to the new time series."* (Plan Team, September 2014)

The authors are expecting to do a comparison of the new catch time series and the HFICE catch estimates when more data become available.

"Team members also suggested that the authors look into the feasibility of establishing discard mortality rates for shark species and summarize what data and studies have evaluated this." (Plan Team, September 2014)

There is very little literature on the discard mortality of the shark species in the BSAI or GOA. The limited research that has been conducted on spiny dogfish was based on animals captured during

research trawls. Hook and line gear is the predominant gear type which catches both spiny dogfish and Pacific sleeper shark and research into the discard mortality from that gear type is necessary. There is ongoing research into the mortality of skates from hook and line gear type, which the authors will consider upon the completion of that project.

CIE Review of Non-Target Assessments, comments specific to this assessment

"Until recommendation 6 is addressed (review of bottom trawl survey) the bottom trawl surveys as combined are not generally useful as an absolute estimate of stock biomass; and further should not be used for management purposes until these issues (i.e. trawl survey review) are successfully resolved."
The authors agree and do not recommend moving any of the sharks in the BSAI to a Tier 5 method.

"That all shark stocks in the BSAI/GOA area are split to have separate OFL/ABC by species and region, and that the OFL be based on the Tier 6 approach as the average catch of each species individually."
Splitting the shark species in the BSAI may not be feasible, as the ABC/OFLs would be quite small and likely difficult to manage.

"Using the maximum or average catch for Tier 6 may not be appropriate; alternatives could be to use an upper bound of a one-sided 95% or 99% confidence interval."
Alternatives to average and maximum catch (e.g. percentiles of the maximum catch) have been presented in the past for the shark assessments (e.g. Tribuzio et al. 2010a). For this assessment, we present and recommend using the average historical catch. The concern about using average catch is that, by rule, the catch will exceed the average in half of years. In the case of BSAI sharks, current catch is well below the historical average (the historical time series used to calculate ABCs and OFLs is from 1997-2007), and unlikely to increase to that level. Thus, using the average catch is currently the most appropriate option.

Species Specific CIE comments

*"Dogfish: Clearly, there is some connection to the stock of dogfish residing the Pacific Northwest region just to the south. The connection with the assessed unit to the south should be explored further. One method of doing so would be to simply treat the BSAI through the NWP as a single unit. In the interim, average catch in the 1997-2007 should be feasible for both components. It is recognized that the GOA dogfish uses a biomass*M approach. However, in keeping with conclusion 1 the average catch is probably a more robust measure."*
A coast-wide assessment may be the most biologically appropriate strategy, but it is not possible at this time. In the BSAI, sharks have been managed using the maximum historical catch for the whole complex. The authors agree with the CIE reviewers that using average catch would be more conservative than maximum. Current catch is well below the historical average.

"Salmon shark: they might be better off being assessed outside of the AFSC jurisdiction as a highly migratory species. Regardless, catches and encounters with inshore fisheries needs to be addressed sooner rather than later for this stock. In the interim, average catch can serve as a good proxy, but that suggestion is made grudgingly given how little is known about this stock."
The authors agree that salmon shark (and the other shark species) may be more appropriately managed as highly migratory species; however, that system does not exist in the GOA or BSAI at this time. Further, catch in Alaska state fisheries is not accounted for, which needs to be addressed to accurately monitor the species.

"Pacific sleeper shark: What data are available is disturbing. While most of the individuals encountered are juvenile, the overall fishery dependent and independent data suggests a declining trend. As such, while average catch is probably the only measure available for informing an OFL, SSC and managers should be aware that more precaution is warranted until further information is gathered."

The authors agree with the CIE reviewers that trends in Pacific sleeper shark catches are concerning and a more conservative approach may be warranted.

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).

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. 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 ageing 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°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). 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

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

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 (67% and 82% discarded on average in the Aleutian Islands and Bering Sea, respectively, which is ~4 t on average) than identified shark species. 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 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.).

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 – present (Table 20.4). Shark catch by species was estimated by staff at the AFSC using a pseudo-blend approach for 1997 – 2002 and since has been estimated by the NMFS AKRO Catch Accounting System (CAS). 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).

The estimated catch of sharks is broken into four groups: Pacific sleeper shark, spiny dogfish, salmon shark and other/unidentified sharks. Historically, Pacific sleeper shark are the primary species caught in the BSAI (67% of total shark catch on average, 282 t on average, Table 20.4, Figure 20.2). The other/unidentified sharks, salmon sharks and spiny dogfish are smaller components of the complex (19% and 79 t, 11% and 48 t, and 3% and 11 t, on average, respectively).

Beginning in 2013, the restructured observer program added coverage on vessels under 60 ft as well as vessels operating in the Pacific halibut IFQ fishery. It is possible that this change to observer coverage may affect estimates of shark catch, but the magnitude is unknown at this time. In 2013 in the BSAI there was an increase in the proportion of total catch caught in the under 60 vessel category and there was also an increase in the estimate of shark catch in the Pacific halibut target group. An examination of the potential impacts of the 2013 change in observer coverage on the estimates of shark catch is included in Appendix 20.A.

Most of the shark catch in the BSAI occurs in the Pacific cod and walleye pollock fisheries. Pacific sleeper shark are caught primarily in the Pacific cod (37%, 93 t on average, Table 20.5) and the walleye Pollock (36%, 89 t on average) fishery. Salmon shark are almost entirely caught in the walleye pollock fishery (92%, 44 t on average, Table 20.6). The Pacific cod fishery catches about 87% of the spiny dogfish (10 t on average, Table 20.7). Similar to Pacific sleeper shark, the other/unidentified sharks are caught in both the walleye Pollock (48%, 27 t on average) and Pacific cod fisheries (25% and 14 t on average, Table 20.8).

Catches of Pacific sleeper shark have been declining and have been well below average since 2005 (Figure 20.2). Trends in catch of the other/unidentified sharks mirrors that of Pacific sleeper shark and it is likely that the majority of those are Pacific sleeper shark (Tribuzio et al. 2012). 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 is planned for future assessments.

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 2010 - 2013.

Bycatch of Pacific sleeper sharks (Figure 20.3) within observed commercial fisheries was relatively high on the EBS shelf to approximately longitude 178°50'W, northwest of St. Matthews Island.. While there were fewer hauls observed with Pacific sleeper shark bycatch in 2012, there were a higher number of hauls containing large amounts of Pacific sleeper shark. The same was observed in 2013, in addition to a higher amount of observed bycatch closer to Unimak Pass.

Observed bycatch of salmon shark in commercial fisheries in the Bering Sea is generally low, but occasional large catches occur (Figure 20.4). Most of the catch occurs along the EBS shelf, with a small amount occurring in the southern Bering Sea near the Pribilof and Bering Canyons, in addition to shelf waters in the EBS outside of Bristol Bay. Observed bycatch of salmon shark was noticeably higher in 2011, specifically in shelf waters in the EBS off the Alaska Peninsula and outside Bristol Bay.

Observed bycatch of spiny dogfish in commercial fisheries in the Bering Sea (Figure 20.5) 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 2013, specifically around Unimak Pass and heading northeast along the Alaska Peninsula.

Observed bycatch of other/unidentified sharks within commercial fisheries in the Bering Sea (Figure 20.6) 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 – 2014
Improved Pseudo Blend (AFSC)	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2014
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 – 2014
NMFS Longline Surveys	Catch Numbers	1989 - 2014
IPHC Longline Surveys	Catch Numbers	1997 - 2013

Fishery

Historical catch estimates 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 has and is being collected on surveys. The data presented here is from the AFSC bottom trawl surveys (GOA, EBS shelf, EBS slope and AI), AFSC and IPHC longline surveys, targeted research surveys, as well as special projects conducted by the Observer Program. We include GOA data because for both Pacific sleeper sharks and spiny dogfish, genetic evidence suggests that both species are a continuous stock within the eastern North Pacific Ocean. There is very little length data from the BSAI (i.e. a small number of sharks are caught each year). Therefore, for Pacific sleeper sharks lengths for the BSAI and GOA are combined for each data source (Figure 20.7, sexes combined). Despite summing both areas, data are still extremely limited. In even years (BSAI surveys only) the AFSC trawl survey catches smaller animals, many < 100 cm; while in odd years (GOA survey included) the surveys catch larger animals, some > 300 cm. None of the data sources report catching Pacific sleeper sharks at or greater than the reported size at maturity (365 cm for males, 397 cm for females). Length data collections are part of standard collections on the AFSC longline and trawl surveys, as well as regularly collected on the IPHC longline survery, thus a time series of length frequency data are being created. Due to a paucity of BSAI length data, only the GOA data for spiny dogfish is presented (Figure 20.8 & Figure 20.9). The length frequency data appears to cover the full size range of the species, with the IPHC longline survey tending to catch more of the larger females, likely due to sampling in near shore waters. Catch of salmon shark is extremely rare in surveys and length frequencies are not presented.

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 - 2012; Table 20.9 and Figure 20.10), Aleutian Islands (AI, 1980 – 2014, Table 20.10 and Figure 20.10), and the EBS shelf (1979 – 2014, Table 20.11 and Figure 20.10). 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. Thus trends in biomass estimates from trawl surveys are not informative. Spiny dogfish, for example, occurred 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 are very uncertain since 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 – 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) from 2002 through 2012 (Table 20.9 and Figure 20.10). 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 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 20.10). There were no Pacific sleeper sharks caught during the AI trawl survey in 2014, the first time that has occurred since 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 20.10). 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 during any of the NMFS bottom trawl surveys in the EBS or Aleutian Islands. 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 20.10). Spiny dogfish are caught sporadically in the Aleutian Islands survey and the resultant biomass is always low, ranging from 2 - 62 t (Table 20.10 and Figure 20.10). 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 20.10) and one in 1988 in the EBS shelf survey (Table 20.11 and Figure 20.10).

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 (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 20.11). 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 odd years (e.g., 2013) and the Aleutian Islands in even years. 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 LL (during years 2010 – 2013, Figure 20.12) and NMFS trawl surveys (Figure 20.13) with rare scattered catches in the Aleutian Islands. 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. The IPHC LL survey caught relatively higher numbers of sleeper sharks off Unimak Pass in 2010. Catch of sleeper sharks in the NMFS 2008 and 2010 trawl surveys was highest near Unimak Pass as well. There were no sleeper sharks caught on the NMFS trawl survey in 2014.

In contrast, spiny dogfish catch is mostly distributed throughout the Aleutian chain. Spiny dogfish occurrences are rare in both the NMFS trawl and IPHC longline surveys (Figure 20.14), but there are fewer spiny dogfish caught in the NMFS trawl survey.. Only one spiny dogfish was caught on the Bering shelf during the 2010 trawl survey, and three in 2014.

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, 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 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 (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 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 they are not targeted and biomass estimates are unreliable. 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.

The SSC, Plan Teams and CIE reviewers have all expressed concerns over the declining population trends in Pacific sleeper sharks. Further, the CIE recommended using an average catch, as a more conservative management strategy than the maximum historical catch. Below we present the OFL and ABC recommendations based on average catch as well as the maximum catch (status quo). Either approach is unlikely to constrain the fishery. Examining the catch history from 1997 to the present shows that catches are not likely to have exceeded the ABCs from either calculation (Figure 20.15), as catch estimates for the last 5 years have been < 20% of the ABC.

We recommend using the average historical catch=OFL (ABC=OFL*0.75) method for calculating OFL and ABC for all sharks until more data on Pacific sleeper shark abundance and biology is available. Tier 6 ABC and OFL calculations using both methods 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 2015-2016 (in bold).

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
Average Catch	8	422	48	126	605
ABC	6	317	36	95	**454**
OFL	8	422	48	126	**605**

*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. 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 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. Examine catchability for sharks on trawl surveys.
    a. Actions: Investigating methods of using tagging data to estimate q for sharks.
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. 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

The OFL catch limits of the shark complex have not been exceeded, thus overfishing is not occurring. 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: 2014	2015	As estimated or *recommended this* year for: 2015	2016
Tier	6	6	6	6
OFL (t)	1,363	1,363	**605**	605
maxABC (t)	1,022	1,022	454	454
ABC (t)	1,022	1,022	**454**	454
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
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
Avg catch (t) (1997-2007)	8	422	48	126	605
ABC (t)	6	317	36	95	**454**
OFL (t)	8	422	48	126	**605**

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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, 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	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		105	1,020	Shark Complex TAC
2012	200		96	1,020	Shark Complex TAC
2013	100		116	1,020	Shark Complex TAC
2014	125		118	1,022	Shark Complex TAC

Data Sources: TAC, ABC and management category came from AKRO catch statistics website. Catch data was queried from AKFIN on Nov 20, 2014.

Table 20.3. Estimated discard rates of sharks (by species) in the BSAI. Source: AKFIN database, Oct 1, 2014. 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%	
Average	100%	100%	95%	67%
	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%	47%
2009	99%	96%	100%	63%
2010	100%	95%	99%	60%
2011	100%	92%	96%	76%
2012	100%	95%	97%	90%
2013	100%	96%	100%	86%
2014	100%	97%	98%	95%
Average	95%	94%	96%	82%

Table 20.4. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 1, 2014. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2014 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	496	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	763	27,178	3%
2002	9	839	47	468	1363	26,296	5%
2003	13	343	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	257	44	28	332	26,829	1%
2008	17	127	41	8	194	29,439	1%
2009	20	51	71	10	151	27,852	1%
2010	15	28	12	6	60	23,362	0%
2011	8	48	47	5	107		
2012	20	47	26	3	96		
2013	24	69	23	1	116		
2014	10	54	52	2	118		
species % of total sharks	3%	68%	11%	19%			
Species avg. catch	11	282	48	17			
For ABC/OFL Calculations							
Avg. 1997 – 2007	8	422	48	126	605		
Max. 1997 – 2007	17	839	199	468	1,363		

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 - 2014 are from NMFS AKRO blend-estimated annual catches, as of Nov 20, 2014. 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	19.8	9.7	18.6	342.5
2004	2.0	37.3	230.0	144.0	0.7	2.3	2.7	1.1	420.2
2005	0.0	7.7	191.0	127.6	0.1	3.8	2.7	0.1	333.0
2006	0.0	9.5	123.1	178.1	0.1	1.0	1.3	0.1	313.2
2007	1.1	9.1	44.3	181.6	14.5	2.5	0.5	0.0	253.6
2008	0.1	6.3	20.0	97.9	1.2	1.3	0.4	0.0	127.2
2009	0.6	8.2	14.4	24.6	0.6	2.1	0.1	0.0	50.6
2010	0.0	1.2	15.1	10.4	0.1	1.2	0.2	0.0	28.2
2011	0.0	2.4	20.4	18.1	4.8	1.7	0.0	0.5	47.9
2012	0.9	8.2	9.8	27.5	0.6	0.2	0.1	0.0	47.3
2013	0.0	1.2	19.8	21.1	1.6	0.8	0.0	24.1	68.6
2014	0.0	1.1	28.0	23.5	0.8	0.0	0.0	0.5	53.8
Avg. Catch	2.1	23.0	93.0	88.6	1.9	14.3	22.9	2.7	
Avg. % of Total	1%	9%	37%	36%	1%	6%	9%	1%	
Avg. % 2013-2014	0%	2%	39%	36%	2%	1%	0%	20%	

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 - 2014 are from NMFS AKRO blend-estimated annual catches, as of Nov 20, 2014. 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	0.6	2.0	25.7	0	0	0	0	46.6
2006	0.2	25.9	1.2	36.2	0	0	0	0	63.4
2007	0.1	0.0	0.0	44.1	0	0	0	0	44.2
2008	0.0	0.3	0.0	40.7	0	0	0	0	40.9
2009	0.3	0.1	0.1	70.0	0	0	0	0	70.5
2010	0.1	0.0	0.0	11.1	0	0	0	0	11.2
2011	0.2	0.4	0.1	45.3	0	0	0	0	46.0
2012	0.3	0.0	0.0	25.4	0	0	0	0	25.7
2013	0.3	0.1	0.2	21.3	0	0	0	0	21.9
2014	0.6	0.1	0.0	51.0	0	0	0	0	51.7
Avg. Catch	1.2	1.8	0.7	40.2	0	0	0.1	0	
Avg. % of Total	3%	4%	2%	91%	0%	0%	0%	0%	
Avg. % 2013-2014	1%	0%	0%	98%	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 - 2014 are from NMFS AKRO blend-estimated annual catches, as of Nov 20, 2014. 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	0.2	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	6.2	17.1
2009	0.0	0.6	18.4	0.4	0.0	0.2	0.0	0.0	19.7
2010	0.0	0.7	13.8	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	19.6	0.1	0.3	0.0	0.0	0.0	20.1
2013	0.4	0.2	18.3	0.1	0.0	0.0	0.0	4.6	23.5
2014	0.0	0.8	6.8	0.1	0.0	0.0	0.0	2.4	10.1
Avg. Catch	0.2	0.3	10.0	0.1	0	0	0	1.1	
Avg. % of Total	2%	3%	87%	1%	0%	0%	0%	7%	
Avg. % 2013-2014	1%	3%	75%	0%	0%	0%	0%	21%	

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 - 2014 are from NMFS AKRO blend-estimated annual catches, as of Nov 20, 2014. 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	0.0	20.8	11.9	0	0.1	1.3	0	34.1
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	2.1	3.6	298.0	0	0.1	1.6	0	305.5
2007	0	5.9	2.1	19.8	0	0	0.0	0	27.8
2008	0	0.3	1.6	5.9	0	0	0.2	0	8.0
2009	0	0.0	4.5	5.5	0.2	0.0	0.0	0	10.2
2010	0	0.0	1.6	4.1	0	0	0.0	0	5.7
2011	0	0.0	2.6	2.0	0	0	0.0	0	4.6
2012	0	0.0	1.0	1.7	0	0	0.0	0	2.7
2013	0	0.0	0.8	0.4	0	0	0.0	0	1.1
2014	0	0.0	1.4	0.6	0	0	0.0	0	2.0
Avg. Catch	0.8	1.9	14.1	26.9	0.2	1.4	11.0	0	
Avg. % of Total	1%	3%	25%	48%	0%	2%	20%	0%	
Avg. % 2013-2014	0%	0%	70%	30%	0%	0%	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 (Jerry Hoff, pers. comm., October, 2012). There was no slope survey in 2014.

		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	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 2014).

		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		

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, 2014).

		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		

Table 20.12. Research survey catch of sharks 1977 - 2012 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	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	2	<0.01	NA	8.38	<0.01
2011		2.76	5	0.03	NA	1.50	0.03
2012		3	0	0	NA	1.62	0.12
2013							

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

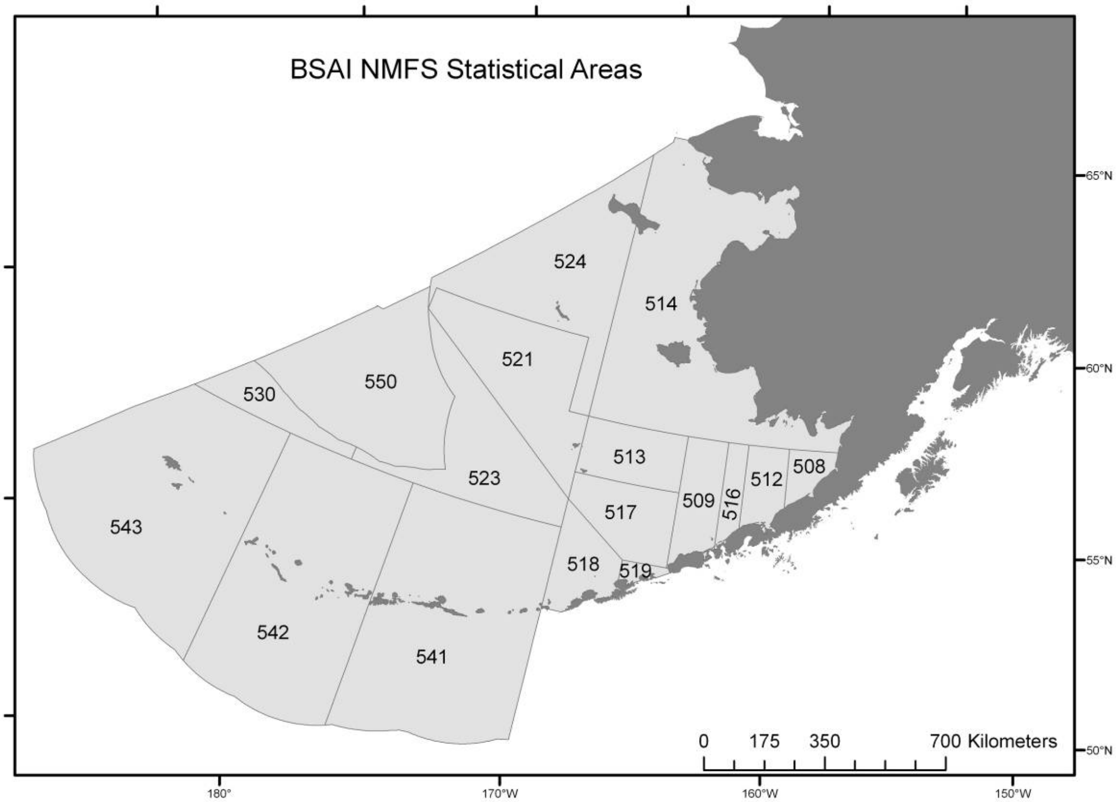

Figure 20.1. NMFS statistical areas in the Bering Sea (NMFS Areas 508-530) and Aleutian Islands (NMFS Areas 541-542).

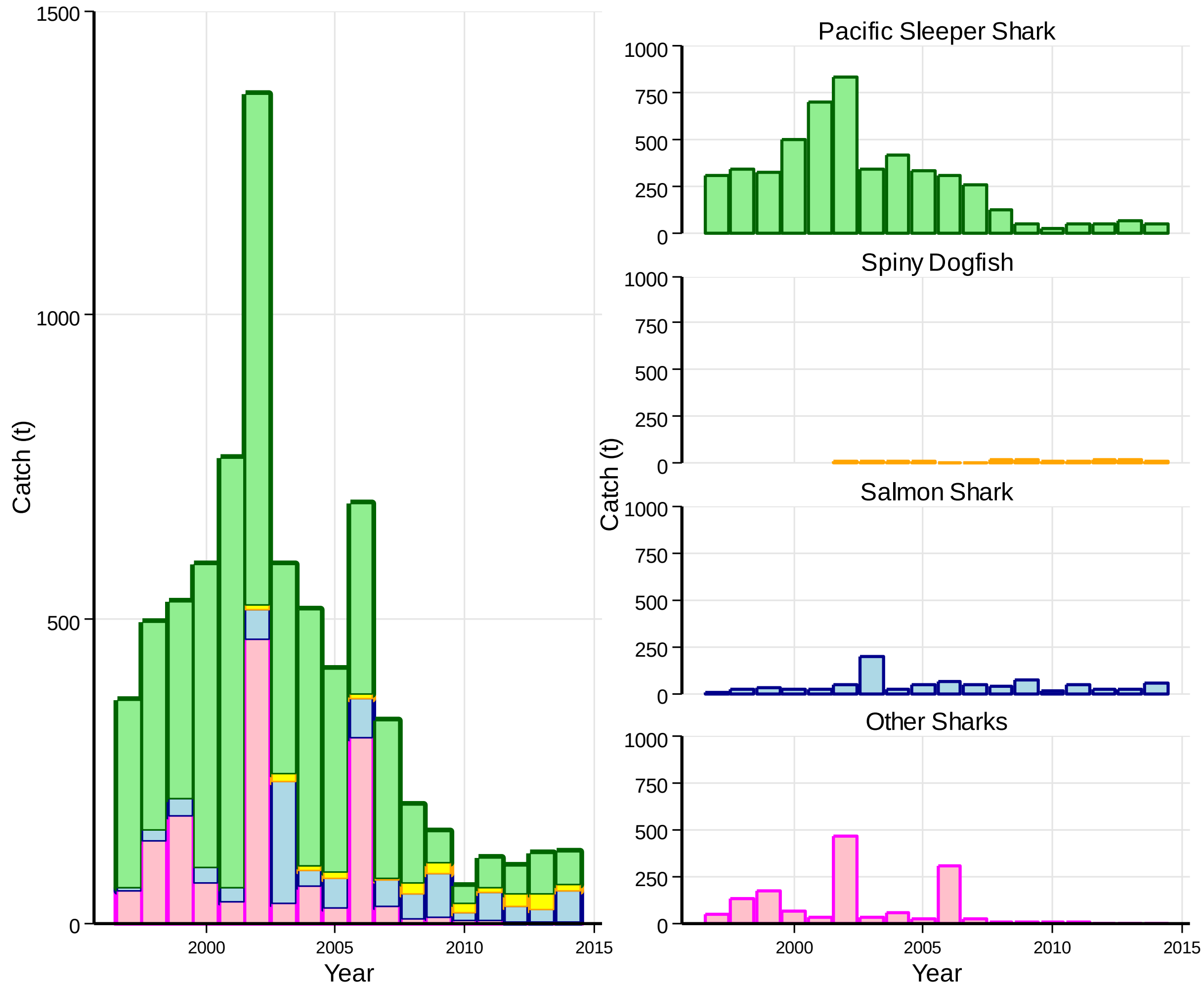

Figure 20.2. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 1, 2014. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2014 from NMFS AKRO blend-estimated annual catches.

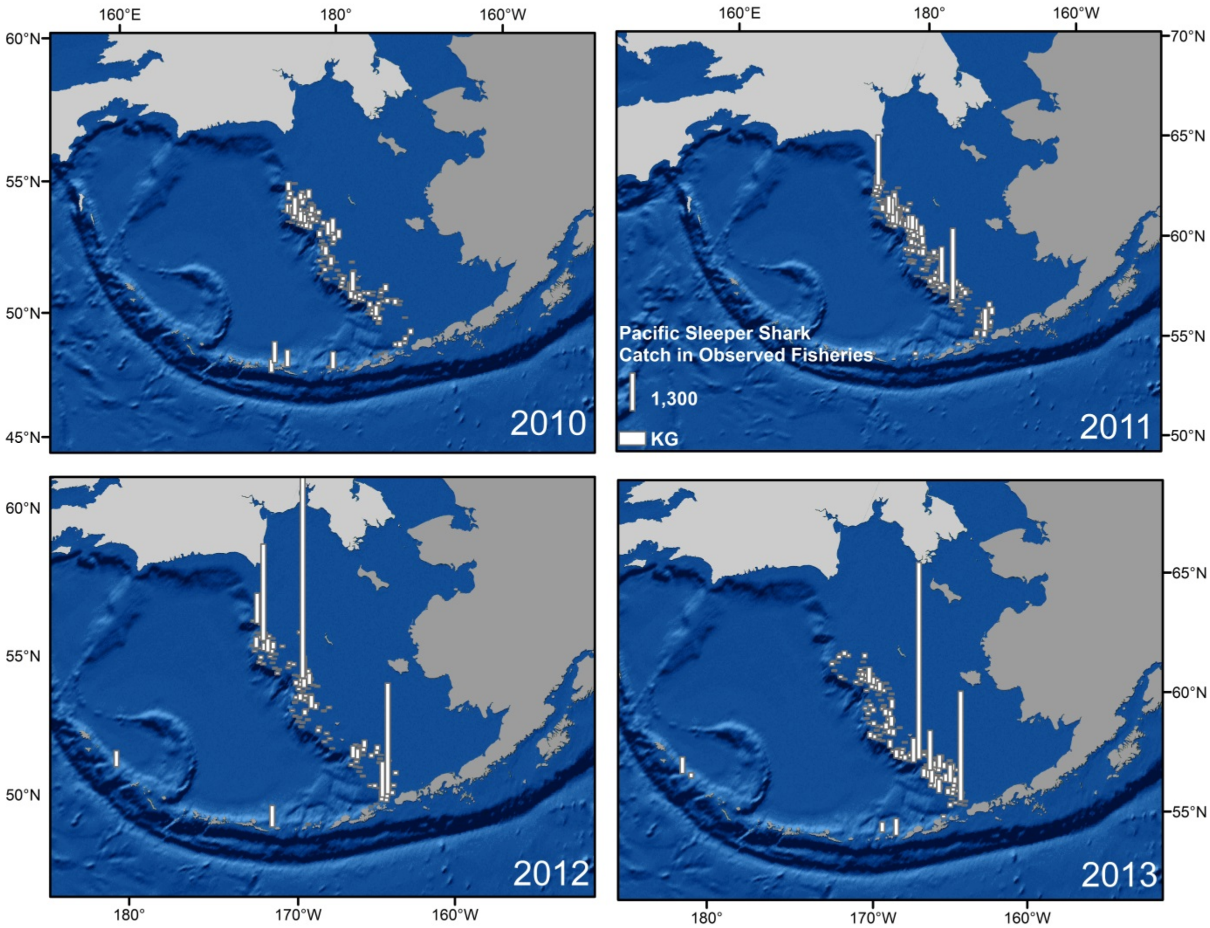

Figure 20.3. Spatial distribution of observed Pacific sleeper shark catch in the BSAI from 2010 - 2013. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2014 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

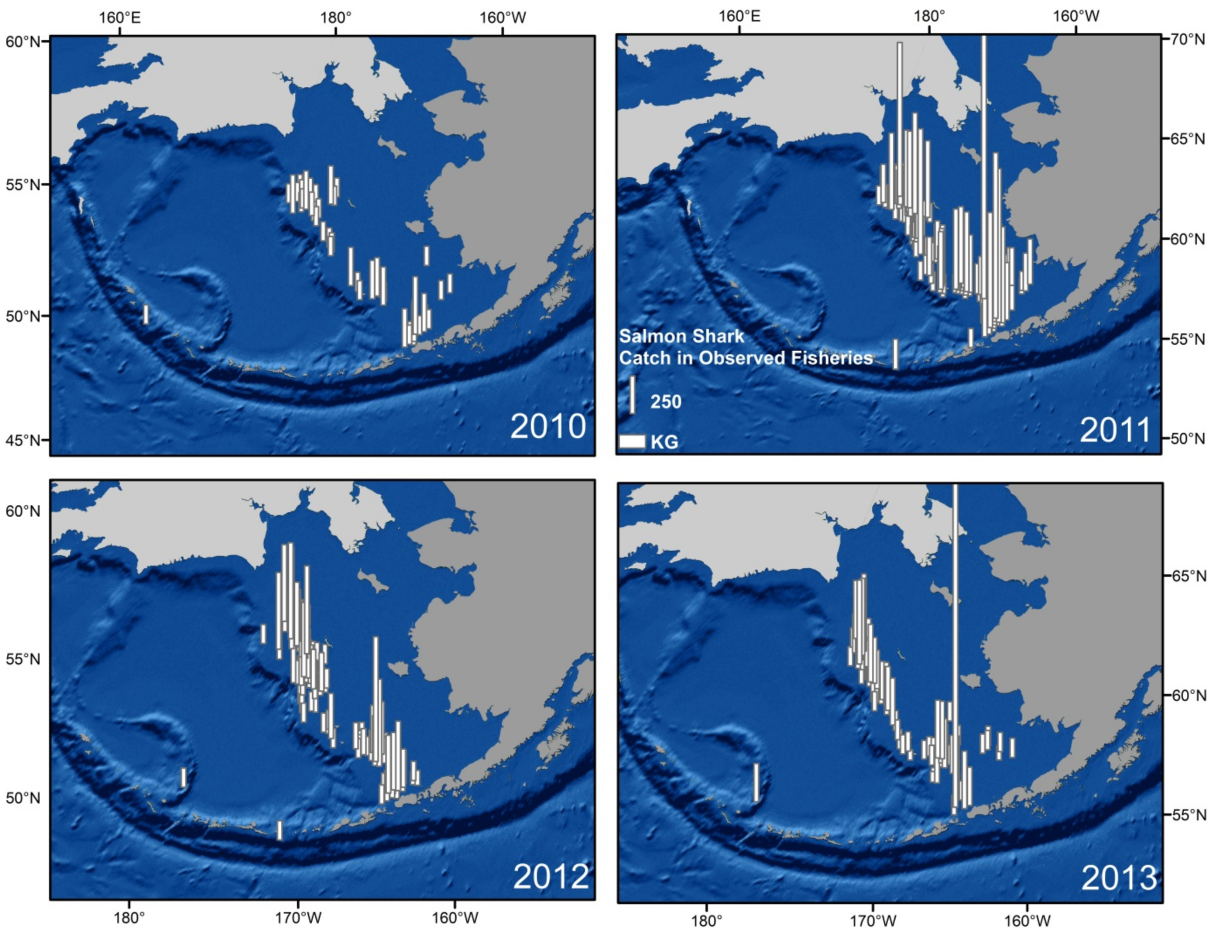

Figure 20.4. Spatial distribution of salmon shark catch in the BSAI from 2010 - 2013. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2014 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

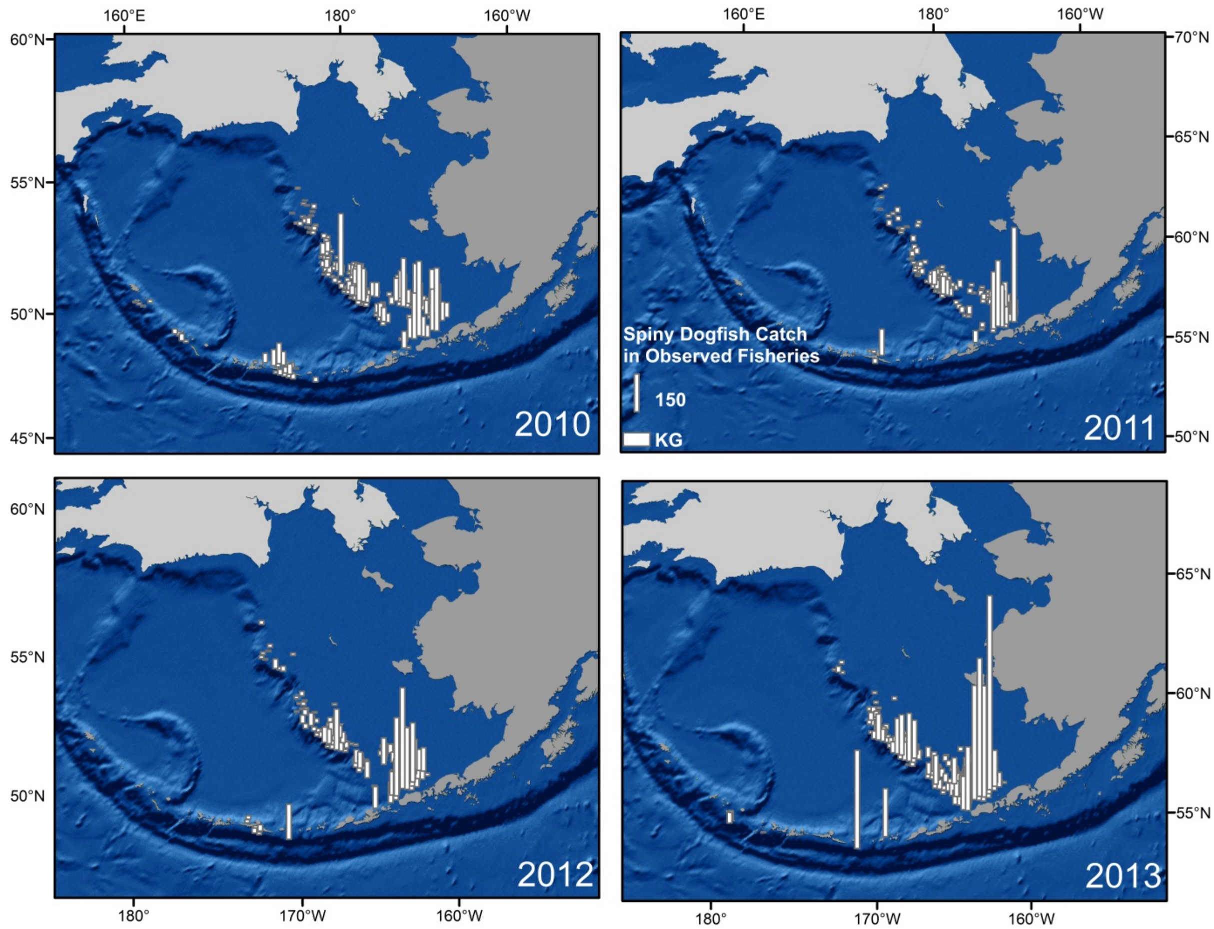

Figure 20.5. Spatial distribution of observed spiny dogfish catch in the BSAI from 2010 - 2013. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2014 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

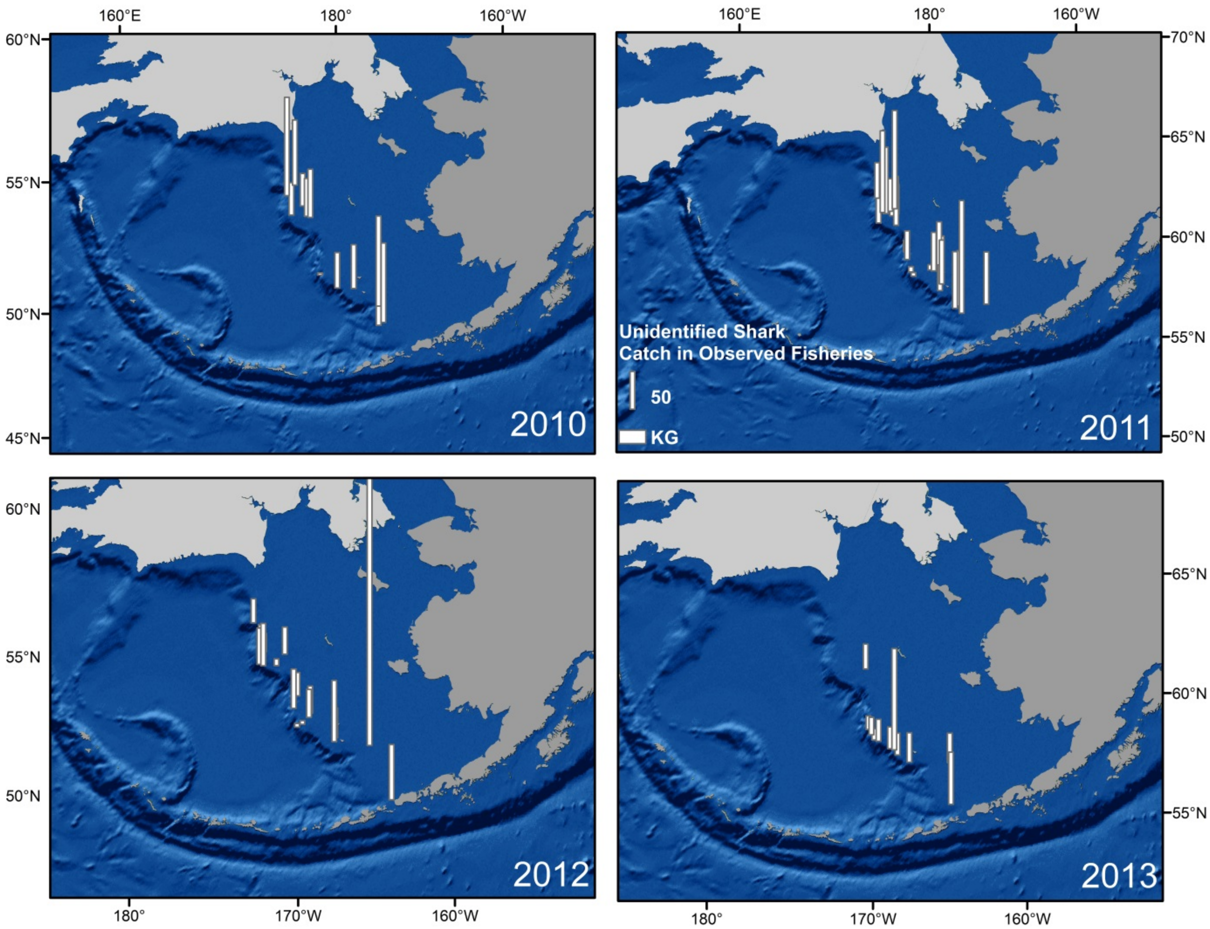

Figure 20.6. Spatial distribution of observed unidentified shark catch in the BSAI from 2010 - 2013. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 2, 2014 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

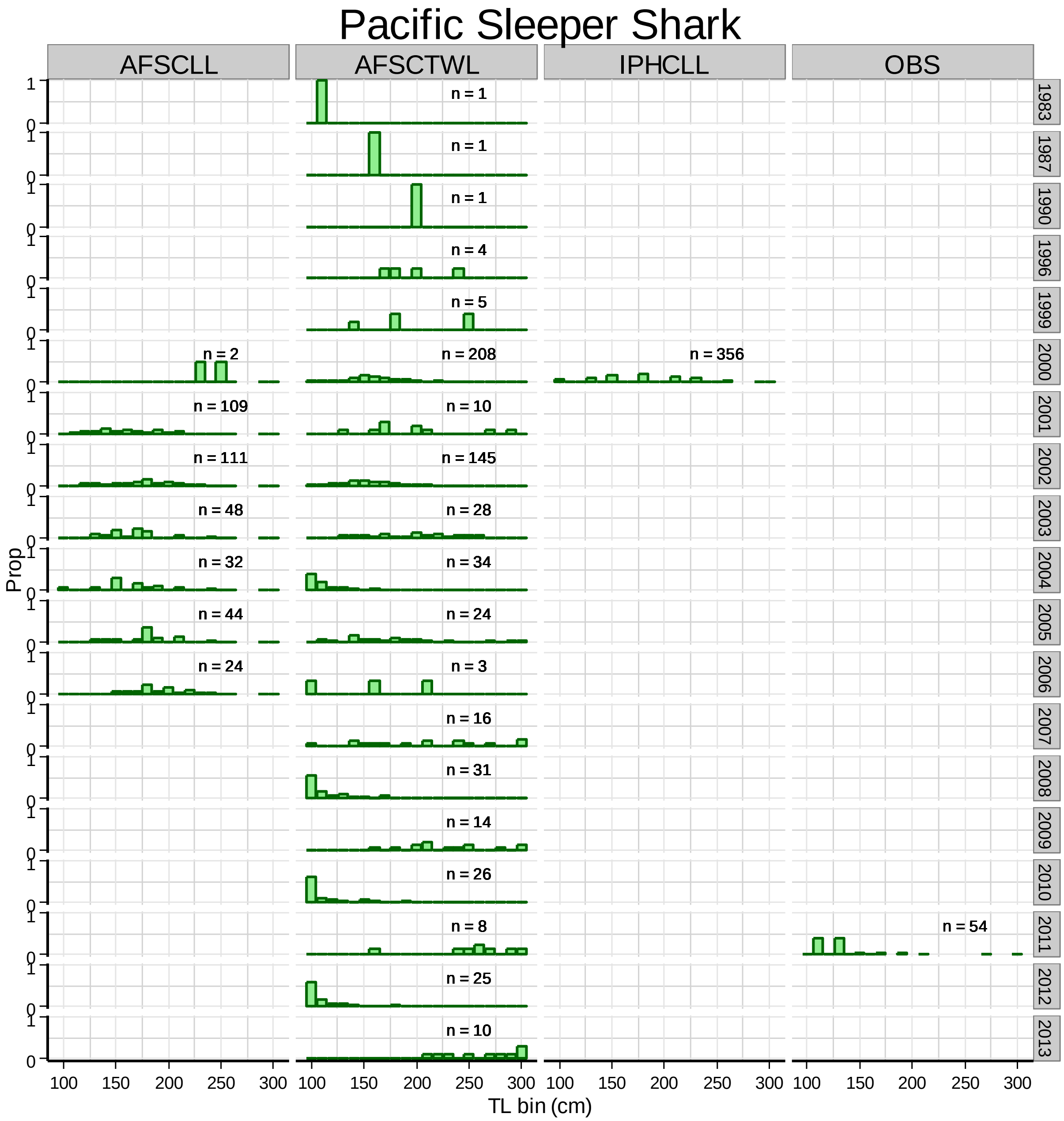

Figure 20.7. Observed length frequencies and sample sizes for Pacific sleeper shark. Data are limited, so sexes are combined as well as GOA and BSAI data. The AFSC longline survey data (AFSCLL) are from a number of targeted research surveys, AFSC trawl survey data (AFSCTWL) are from AFSC GOA, EBS shelf and slope, and AI trawl surveys, and the IPHC longline survey lengths (IPHCLL) are from a special project conducted in 2000. The OBS data are from a special project conducted by the Observer Program in 2011.

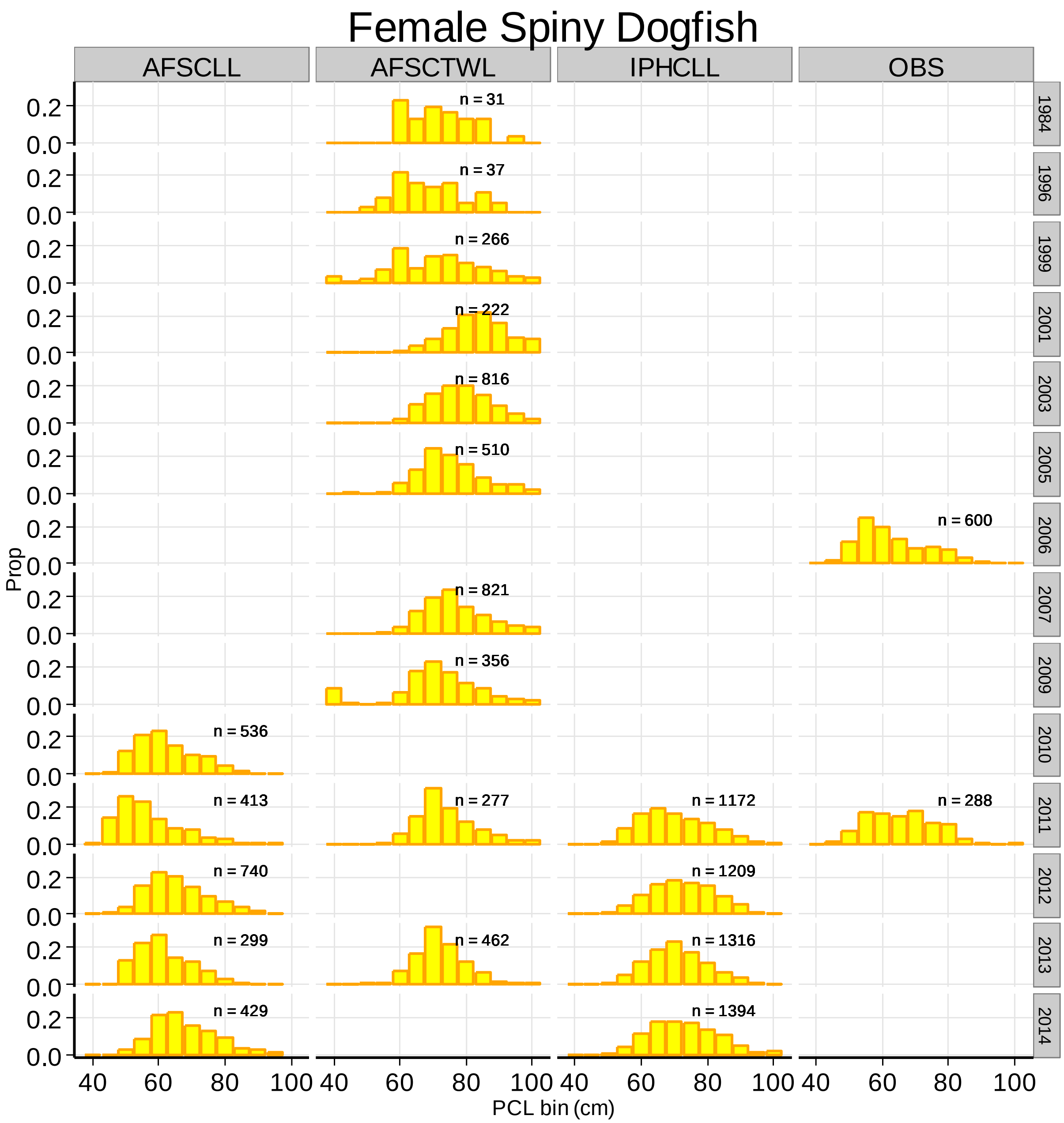

Figure 20.8. Observed length frequencies and sample sizes for female spiny dogfish. Data for spiny dogfish is rare in the BSAI, thus GOA data are presented here. The AFSC longline survey data (AFSCLL) and IPHC longline survey data (IPHCLL) are from the annual surveys operated by the AFSC and the IPHC. The AFSC trawl survey data (AFSCTWL) are from the biennial trawl survey. The Observer program data (OBS) are from a special project conducted by the Observer Program in 2006 and 2011.

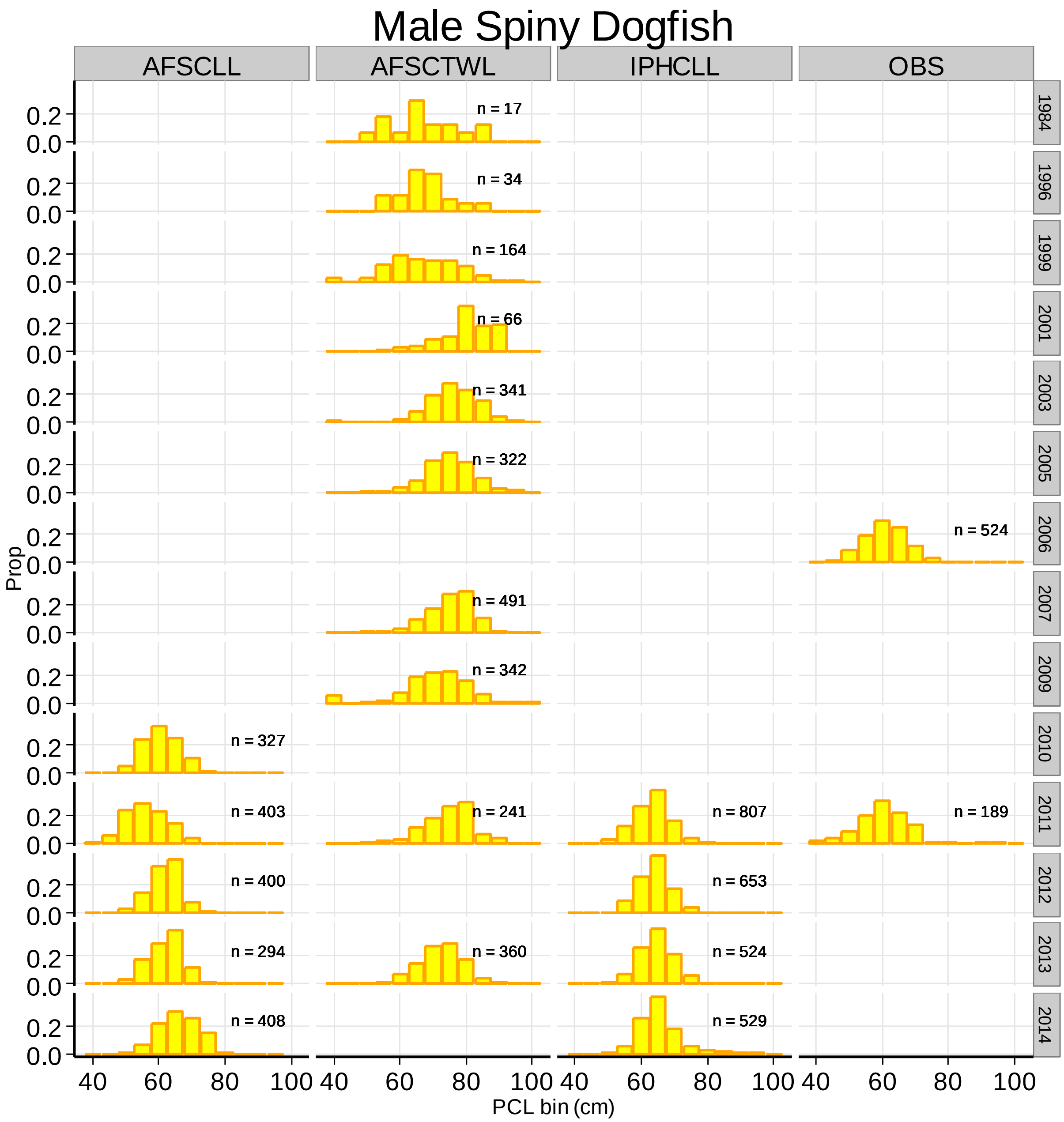

Figure 20.9. Observed length frequencies and sample sizes for male spiny dogfish. Data for spiny dogfish is rare in the BSAI, thus GOA data are presented here. The AFSC longline survey data (AFSCLL) and IPHC longline survey data (IPHCLL) are from the annual surveys operated by the AFSC and the IPHC. The AFSC trawl survey data (AFSCTWL) are from the biennial trawl survey. The Observer program data (OBS) are from a special project conducted by the Observer Program in 2006 and 2011.

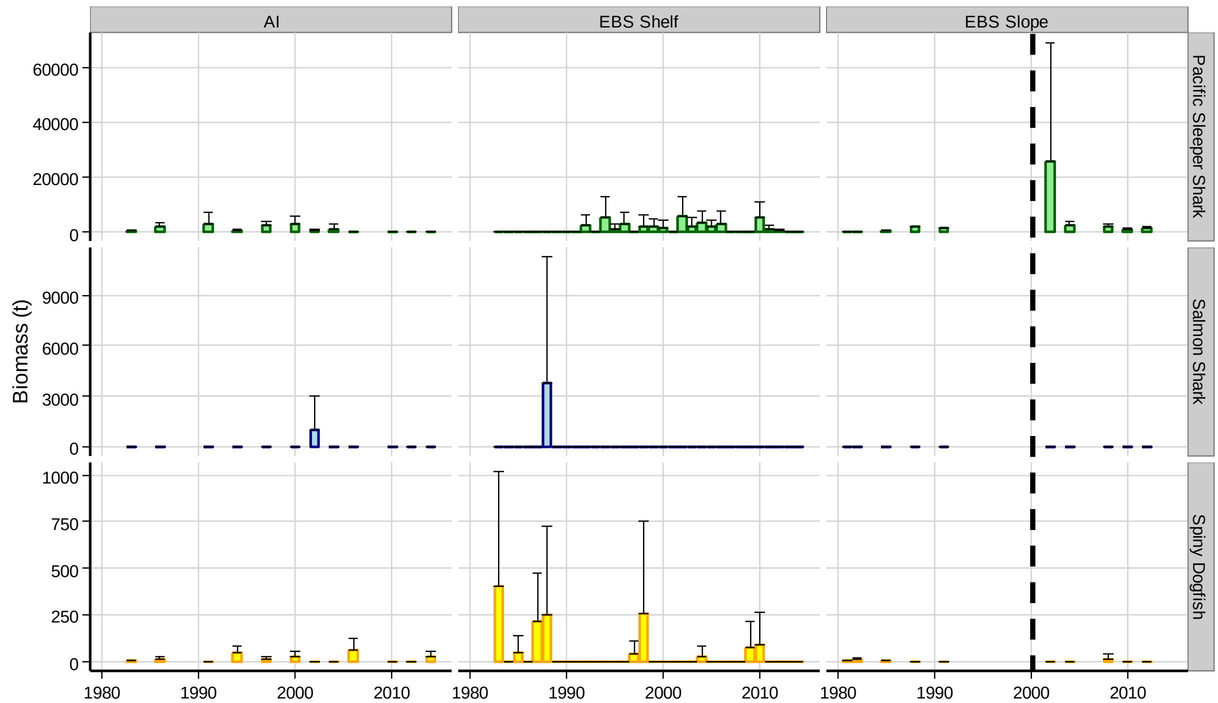

Figure 20.10. Time series of biomass estimates (t) of sharks in the AFSC eastern Bering Sea (EBS) slope, shelf, and Aleutian Islands (AI) bottom trawl surveys. Biomass values are reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS slope survey biomass 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.

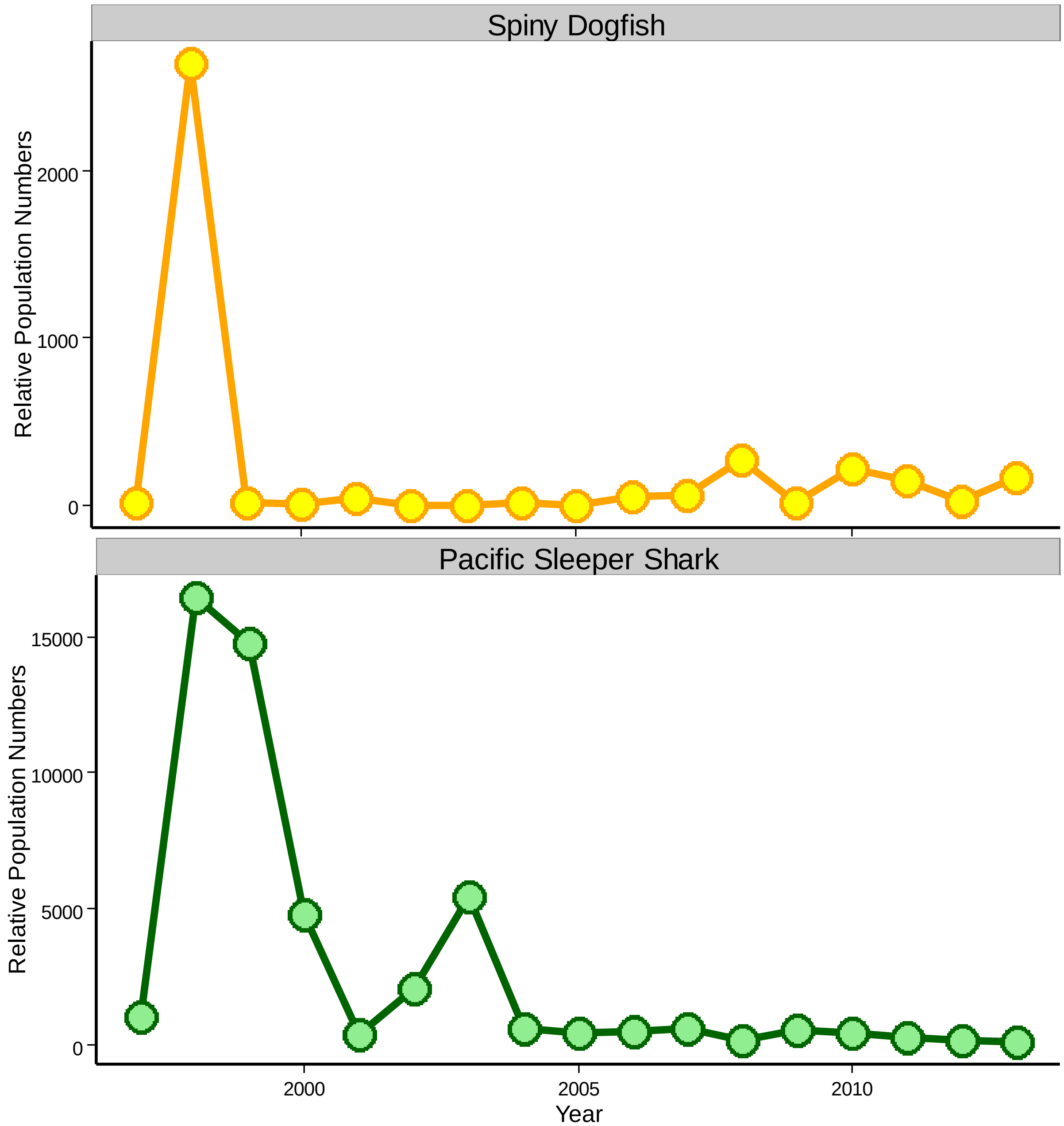

Figure 20.11. Estimated relative population numbers from the IPHC annual longline survey in the BSAI.

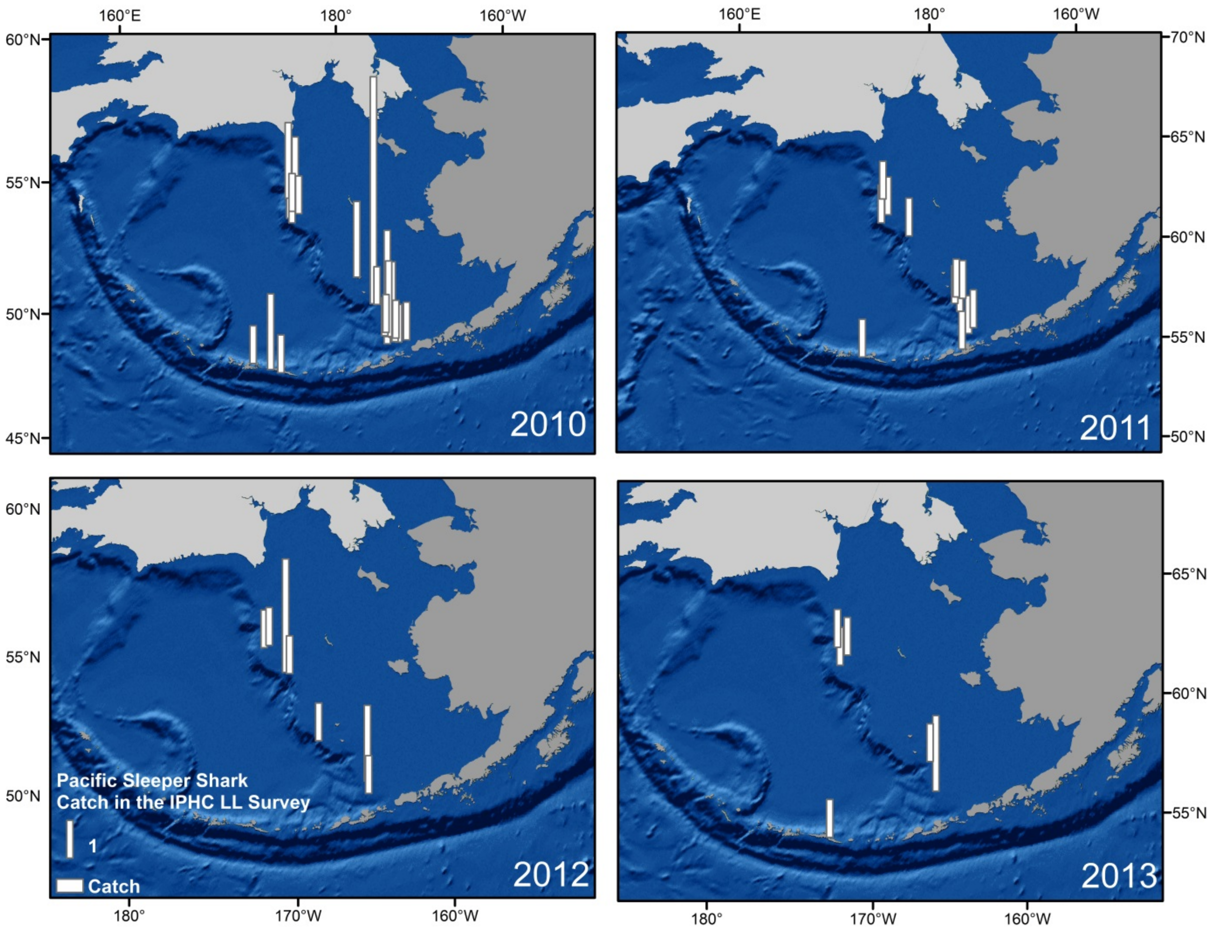

Figure 20.12. Spatial distribution of the catch of Pacific sleeper shark during the 2010 - 2013 IPHC longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

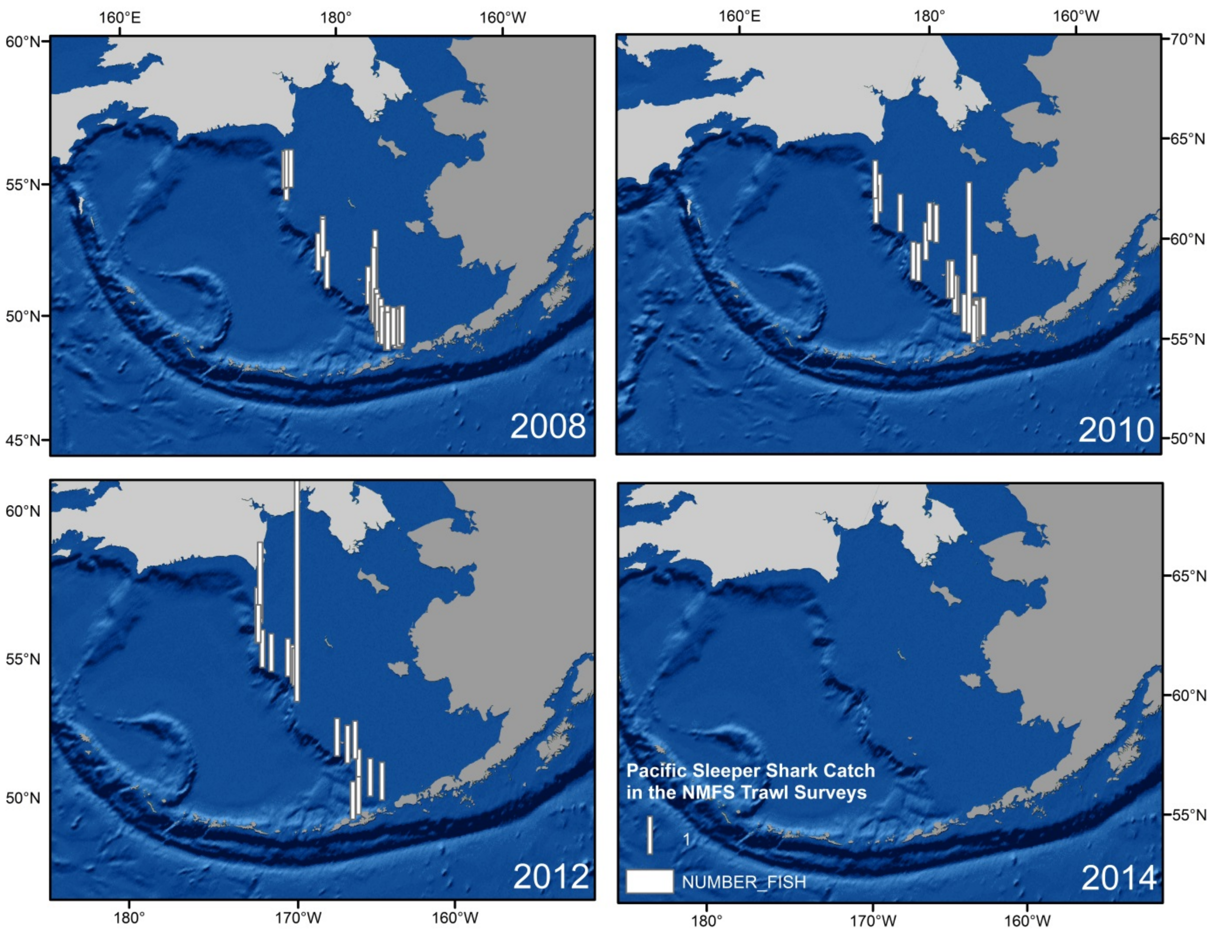

Figure 20.13. Spatial distribution of the catch of Pacific sleeper shark during the 2008-2014 NMFS Eastern Bering Sea (EBS) and Aleutian Islands trawl surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity. There was not Aleutian Islands survey in 2008 and no Eastern Bering Sea slope survey in 2014. Neither the Aleutian Islands nor the EBS shelf survey caught any Pacific sleeper sharks in 2014.

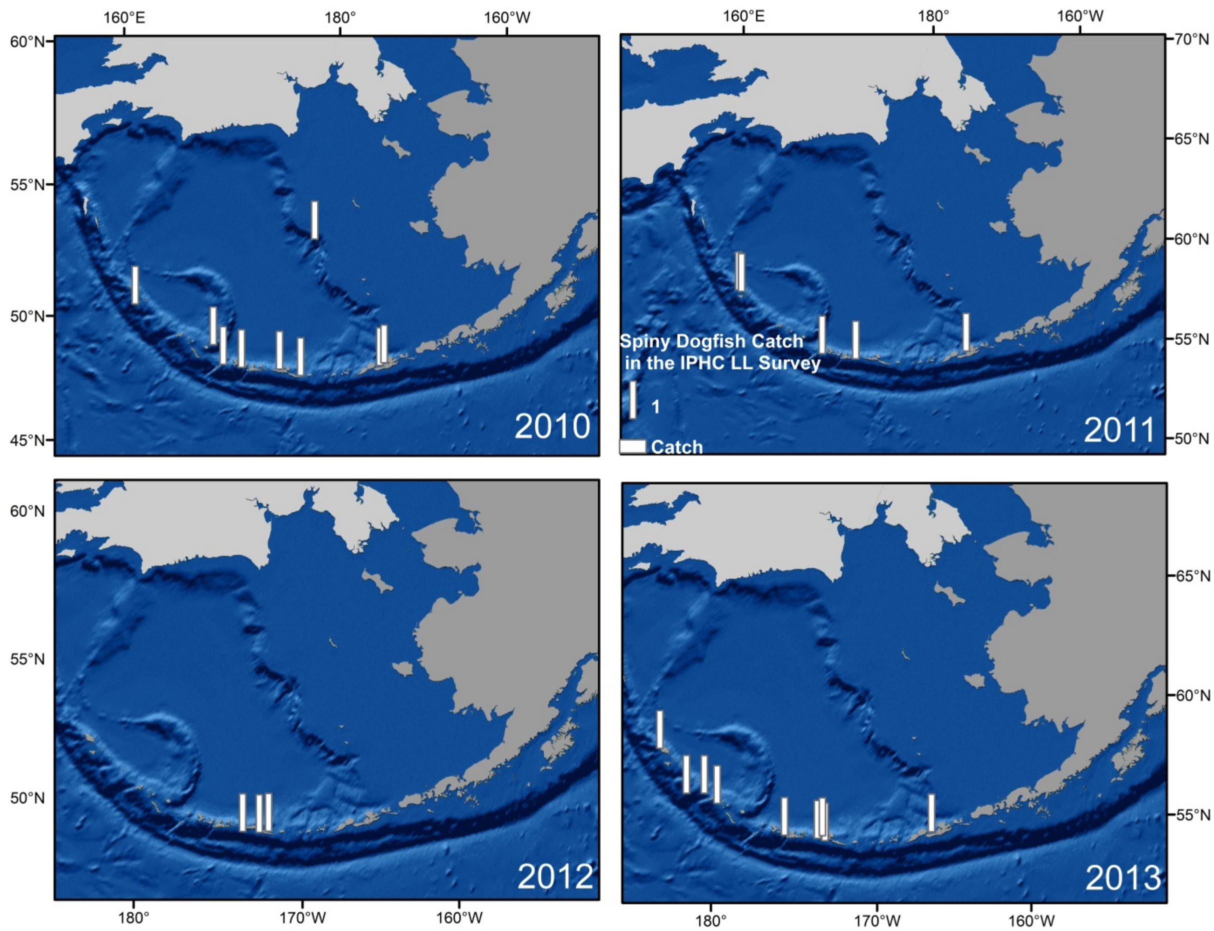

Figure 20.14. Spatial distribution of the catch of spiny dogfish during 2010 - 2013 IPHC longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

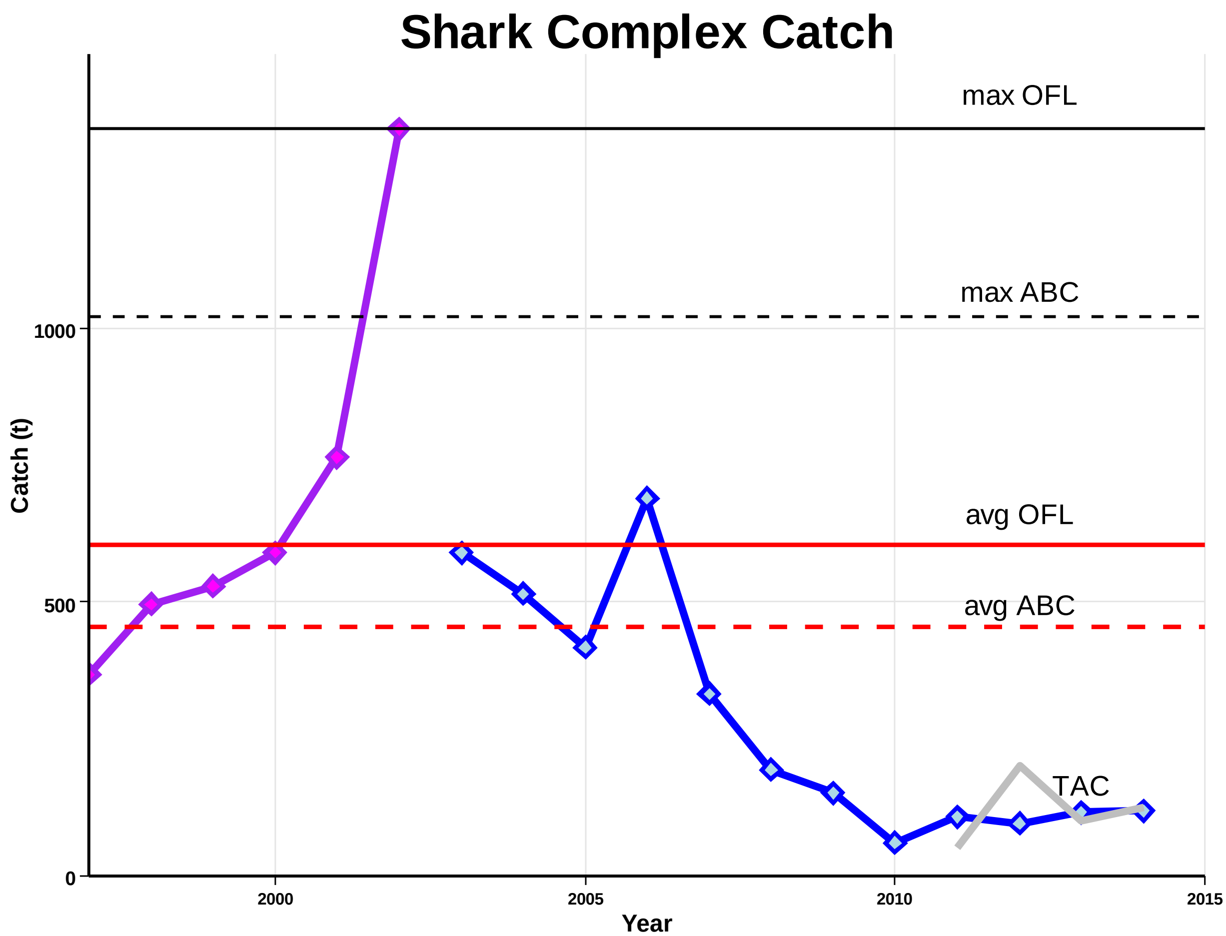

Figure 20.15. Total BSAI shark catch represented as two time series: the pseudo-blend (purple line, 1997 - 2002): and Catch Accounting (blue line, 2003 - present). Catch is shown relative to the OFL/ABCs calculated from using the maximum catch ("max OFL" and "max ABC", black solid and dashed lines, respectively) and the average catch ("avg OFL" and "avg ABC", red solid and dashed lines, respectively) over 1997-2007. The 2014 TAC (grey line) is included for reference.

Appendix 20A. GOA and BSAI Shark Assessments

Cindy A. Tribuzio, Cara Rodgveller, and Pete Hulson
September 2014

Executive Summary

At the December, 2013 council meeting, the SSC requested a full Gulf of Alaska (GOA) shark assessment for the 2014 assessment cycle (typically full assessments for the GOA sharks are conducted in odd years) to address questions specific to the assessment regarding the catch estimates based on data from the newly restructured observer program. We are presenting this document in lieu of a full assessment to address SSC comments for the following reasons: 1) there was no GOA survey in 2014; 2) the shark complex is dominated by spiny dogfish in the GOA and ABC/OFL calculations are based on the survey biomass for that species; 3) the contribution to the ABC/OFL from the remaining Tier 6 species (catch history) is small (~7% in 2013), thus the impacts to the complex from adjustments (if any) in the ABC/OFL from the observer restructuring would be small; and 4) with only 1 year of the new time series of catch estimates, it is not reasonable to make comparisons to the old time series. A full assessment for the Bering Sea/Aleutian Islands (BSAI) sharks is planned, as is normal for an even year.

Aside from the request for a full GOA assessment, the SSC made the below comments:

"The SSC discussed observed increases in shark catch in 2013 and the implications of incorporating shark catches in areas 649 and 659 in the assessment. With respect to adding catch from areas 649 and 659, the SSC recognizes that if the authors account for catch from additional regions, then they will need to consider how they will adjust the historical catch time series for shark removals from areas 649 and 659. Furthermore, the authors will need to consider the connectivity of the subset of the population in areas 649 and 659 to the other regions in the GOA. Finally, the authors will need to consider whether the catch reported in 2013 is representative of the historical catch or whether it was impacted by the new observer deployment program. The SSC requests a full stock assessment in 2014 because of the importance of these issues when estimating biological reference points for a species managed in Tier 6.

The SSC notes that the CIE non-target review provided comments on the utility of continued exploration of the length-based and surplus production models. The SSC requests that the authors consider these comments and that they report to their justification for continuing or dropping this line of research. The SSC looks forward to the authors' responses to the CIE review comments."

The sections below address these comments. We address the above comments in regards to the BSAI areas as well.

SSC Comments Regarding The Impacts Of Observer Restructuring On The Shark Assessments

The SSC comments can be paraphrased into four questions:

1) Are the 2013 estimates of shark catch comparable to the historical time series of estimated shark catch?
2) Will (how will) the catch history time series be adjusted if areas 649/659 are included in assessment?
3) Is there connectivity between sharks in 649/659 and the other regions of the GOA?
4) How do these issues affect Tier 6 (catch history) species ABC/OFL estimates?

1) Are the 2013 estimates of shark catch comparable to the historical times series of estimated shark catch?

The restructured observer program was put into effect to address longstanding concerns associated with the old program about data quality and cost equity among participants (77 FR 770062). Implementation of this program is considered an improvement over the previous observer system and an analysis of the first year under the restructured program was presented at the June 2014 council meeting (Faunce et al. 2014). The report presented to the Council explains how the observer program changed, thus we will not be covering the finer points of the restructured observer program in this document. The change from the previous observer deployment regime may result in relatively small changes in estimated catch for target species, but for sharks, there is potential for significant additional estimated catch. In particular, the restructuring includes newly available catch estimates from the Pacific halibut (*Hippoglossus stenolepis*) IFQ fishery, which was not available prior to 2013 due to the lack of observer coverage on vessels participating in this fishery. Here we report the estimated catch from 2003-2012 (historical time series) and from 2013 (restructured observer program data). However, we make no conclusions here regarding changes in the catch time series because of confounding issues in the catch estimates which may or may not be a result of observer restructuring.

The shark assessments include three main species of sharks: spiny dogfish (*Squalus suckleyi*), the Pacific sleeper shark (*Somniosus pacificus*) and the salmon shark (*Lamna ditropis*). However, the salmon shark is rare in federal fisheries and thus this response will focus on spiny dogfish and Pacific sleeper shark. The majority of shark catch occurs in the GOA, hence this response focuses primarily on the GOA region, but for informational purposes we are also including data for shark species in the BSAI.

The restructured observer program covers previously unobserved vessels operating in the Pacific halibut IFQ fishery and small vessels (40-60 ft). In previous assessments we have speculated that these sectors of the fleet (smaller vessels, Pacific halibut IFQ vessels) were a substantial source of catch for sharks in the GOA (Tribuzio et al. 2014), and that the catch estimates from the Alaska Regional Office Catch Accounting System (CAS) were not representative of true catch because of the lack of observer coverage on those vessels and because CAS programming procedures did not include Pacific halibut-only landings. In 2013, modifications were made to CAS so that catch and bycatch estimates could be made for the IFQ Pacific halibut fishery. These changes resulted in shark catch being estimated for all IFQ trips, including those on vessels <60 ft, which comprise a substantial portion of the IFQ fleet and those vessels which do not also land federal groundfish species (which were included prior to 2013). Estimates of shark catch in CAS (both spiny dogfish and Pacific sleeper sharks) on vessels <60 ft substantially increased in the GOA in 2013 (Figure 1) and proportionally contributed to the total catch more than in any other year (Figure 2). In the BSAI, the increase in estimated catch in 2013 was relatively small, but the portion of the catch resulting from vessels <60 ft was substantially larger (Figures 1 & 2).

In 2013, the estimated shark catch in the Pacific halibut fishery was relatively large, possibly due to the new observer coverage and changes in the estimation methods made in CAS. In the GOA, 2006 and 2009 (similarly in 2003 and 2008 in the BSAI) also had large catch estimates of sharks in the Pacific halibut fishery (Figure 3). While the Pacific halibut IFQ fleet was unobserved prior to 2013, catch estimates from vessels landing Pacific halibut would be generated by CAS when those vessels would also land federal groundfish and the catch estimates were based only on the federal groundfish. The anomalous catches have been investigated by staff at the Alaska Regional Office. In general, prior to 2013, there is little to no observer data available to calculate a rate of shark catch for the Pacific halibut target fishery, thus data were from observed mixed sablefish (*Anoplopoma fimbria*) and Pacific halibut IFQ trips. The observer data were used to estimate shark discards when a groundfish species was landed using post-strata described in Cahalan et al. (2010). In brief, post-stratification rules in CAS aggregate observer data to create discard rates using information of the highest possible resolution of spatial and temporal scale that corresponds with the trip characteristics of landed catch. However, when observer data with similar characteristics to the landed catch are lacking, discards must still be estimated. The post-stratification rules in CAS allow estimates to be made using available observer information, which may require observer data to be aggregated across an entire FMP area to create a bycatch rate and estimate (Cahalan et al. 2010). For example, in 2006 and 2009 in the GOA and 2003 and 2008 in the BSAI, the aggregated post-stratification discard rates were driven by a small number of observed hauls in which there were relatively large catches of sharks and a small amount of groundfish retained, resulting in a large shark to groundfish rate. This rate represented the best available information from which to estimate, but it also resulted in relatively large estimates of shark catches. This scenario is not the case in 2013, where there was observer data available to create estimates of shark catch from the Pacific halibut fleet and CAS incorporates landing and discard information from the Pacific halibut fishery. However, it is not possible to determine if the large estimated shark catch in the 2013 Pacific halibut target group was an anomaly, a change in fishing behavior, or a result of the restructured observer program. Regardless, the catch accounting is more comprehensive in 2013 than prior years.

In 2013, the estimated catch of sharks in areas 649/659 also substantially increased (Figure 4). These areas also include the Pacific halibut IFQ fishery, which may occur in conjunction with state managed fisheries (e.g., a trip may include both Chatham sablefish and Pacific halibut). Shark discards are estimated on any trips where a groundfish species or Pacific halibut are landed, thus estimates were made regardless of whether the primary species landed was a state-managed species. It is not possible to determine if the increased 2013 catch estimates are a result of change in fishing behavior or the observer restructuring since discards were estimated for a portion of Pacific halibut fleet prior to 2013. The catch in these two areas is relatively small when compared to the total shark catch: on average, 3% of total shark catch prior to 2013 and 10% in 2013. A longer time series is needed to understand catch trends.

The 2013 catch estimates are not directly comparable to the prior 2013 catch estimates. The methods CAS uses to estimate catch of non-retained species have changed. Not only are trips where only Pacific halibut is landed included in CAS, but Pacific halibut is included in the calculation of discard rates. Two procedures would need to be completed to accurately compare 2013 catch estimates to historical catch estimates. First, the estimated catch resulting from Pacific halibut only landings will have to be removed. Second, a new discard rate will have to be calculated which does not include Pacific halibut. Such an analysis is beyond the scope of this document, but may also not be feasible given the structure of CAS.

2) Will (how will) the catch history time series be adjusted if areas 649/659 are included in the federal catch?

Catch of sharks in the Prince William Sound and inside waters of Southeast Alaska (NMFS areas 649/659) comes from a mixture of federal and state managed fisheries that are sometimes landed on the same trip, including Pacific halibut IFQ. Prior to 2013, if a vessel landed both Pacific halibut IFQ and groundfish on the same trip, a discard estimate was generated based on the federal groundfish landings only. However, if a vessel only landed Pacific halibut,discard estimates were not calculated. Starting in 2013, discards were estimated for all trips where Pacific halibut or groundish species were landed, and estimates are based on both Pacific halibut and groundfish landings. The only trips where discards were not estimated are those containing only non-groundfish species (e.g., lingcod). Due to the complex mixture of fishing activity in state waters, and the lack of observer information on Pacific halibut vessels prior to 2013, the estimated catch in federal fisheries in 649/659 has historically not been included in the shark assessment. While it is not possible to determine if the recent increase in catch in these areas is a result of the observer restructuring and changes to CAS, an anomaly (meaning not representative of the time series), or a change in fishing behavior, these catch estiamtes are generated when landings of groundfish and Pacific halibut occur (i.e. federal landings) and we recommend that they be included in the GOA federal shark assessment. Further, there is not accounting of shark catch by the State of Alaska and the sharks occurring in areas 649/659 are not biologically distinct from the other regions of the GOA (see below).

Estimates of shark catch in federal groundfish fisheries in areas 649/659 are available for the historical time series. The estimated shark catch in 649/659 over the entire time series is small relative to the other areas of the GOA (Figure 4). At this point, it is unknown if the higher magnitude of 649/659 shark catch estimates (10% of total GOA shark catch) is representative of the new time series or an anomaly. Regardless, including the historical estimated catch from those areas, will have a small impact on the total estimated shark estimated catch.

The addition of estimated catch from the Pacific halibut IFQ fishery may result in an increase in estimated shark catch, particularly in areas 649/659, in which case the historical time series of catch used will need to be adjusted. At this time, we are not prepared to speculate on the appropriate method for making adjustments. Any adjustment methods will need to consider separating estimated catch from vessels fishing only Pacific halibut (added to CAS in 2013) from those that landed both Pacific halibut and groundfish on a trip (in CAS prior to 2013), as well as compare HFICE catch estimates (currently only available 2001-2011, Tribuzio et al. 2014) to the 2013 and forward time series.

We recommend delaying adjusting the time series of estimated shark catch in areas 649/659 for three reasons: 1) it would be unwise to conduct such a calculation based on one year of data under the restructured observer program, and it is unknown how the restructured time series compares to the period prior to restructuring; 2) the estimated shark catch in areas 649/659 is small relative to the estimated shark catch in the rest of the GOA and the impact of including that catch in the total estimated shark catch is small; and 3) it appears likely the observer program restructure will continue to evolve over the next several years. Therefore, it is preferable to delay until sufficient data are available to better assess the magnitude of additional catches and the best method of adjustment.

3) Is there connectivity between sharks in 649/659 and the other regions of the GOA?

There are a number of biological justifications for including 649/659 estimated catches into the assessment. Research on the movement and genetics of the shark species has indicated that the populations are mixed across the full extent of the Gulf of Alaska, including areas 649/659, and much of the North Pacific Ocean. A stock structure analysis was presented for the GOA and BSAI shark assessments in September, 2012 (Tribuzio et al. 2012). The stock structure analysis demonstrated that there is no biological justification for managing the shark species as separate stocks within the GOA (including areas 649/659).

Tagging studies have provided an indication of the connection of these species within and outside of 649/659. Spiny dogfish are highly migratory, with some animals overwintering in GOA waters and others undertaking large migrations as far south as southern California and west to Japan. Spiny dogfish moved both into and out of area 659, and while no fish were tagged in area 649, tagged fish did move into area 649 (Tribuzio, unpublished data). Tagging studies of Pacific sleeper sharks suggested that they had potential for movements into and out of 649/659. Hulbert et al. (2006) showed Pacific sleeper sharks moving into 649 and the data suggested that they likely move regularly in and out of the area. Tagging of Pacific sleeper sharks within area 659 showed that they are highly mobile and have potential to move between areas. Detailed analysis of the tagging effort in area 659 is still underway (D. Courtney, NMFS, SEFSC, pers. comm.).

Genetic analyses support the tagging data, suggesting that the shark species are mixed across the extent of the eastern North Pacific Ocean. For example, Verissimo et al. (2010) did not find any discrete stocks across the range in the North Pacific Ocean for spiny dogfish. Similarly, preliminary results of an ongoing genetics study of Pacific sleeper sharks show that there are two lineages of Pacific sleeper sharks, but that they are evenly mixed across the range of the species, including areas 649/659 (S. Wildes, NMFS, AFSC pers. comm.).

4) How do these issues affect Tier 6 (catch history) species ABC/OFL estimates?

The ABC/OFLs for the shark complex in the GOA are calculated using a blend of Tier 5 and 6 approaches. The spiny dogfish ABC and OFL are calculated using a Tier 5-like approach (but they are still considered a Tier 6 species), where OFL=survey biomass*M and ABC =OFL*75%, which is then summed with the average catch history ABCs and OFLs of other shark species to arrive at a combined ABC and OFL for the whole complex. The majority of the estimated shark catch in the GOA is from spiny dogfish (total GOA estimated shark catch in 2013 was 2,420 t, of which 2,178 t was spiny dogfish, Figure 5), as well as much of the ABC and OFL coming from that species (ABC = 6,028 t, of which 5,600 t was spiny dogfish). Therefore, adjustments to the catch history in the GOA will likely have a small impact on the complex ABC/OFL because the tier 5-like approach for spiny dogfish is based on survey biomass rather than catch history and this component represents the majority of ABC/OFL.

In the BSAI, the entire complex ABC/OFL is based on the maximum of the catch history. However, the impacts of the observer restructuring are likely less substantial. Estimated shark catch in the BSAI (2013 total estimated shark catch = 116 t, oh which 69 t was Pacific sleeper shark) is substantially lower than the ABC of 1,022 t (Figure 5). Thus, the potential increase in catch from observer restructuring is unlikely to cause the shark catch in the BSAI to approach the ABC. When there is sufficient data (i.e. more years of catch estimates from the restructured observer program), the historical time series of catch may need to be corrected. It is not appropriate at this time to correct the historical time series based on only one year of data.

CIE Comments Regarding The Shark Assessments

The CIE reviewers did not have extensive comments regarding the shark assessments. Below are the key comments made in both the reviewers' documents and discussions during the meeting.

From reviewer comments:

1) *Until the relative biomass from the various trawl surveys can be appropriately converted to absolute biomass, it may be better to use Tier 6 methods for sharks.*

   Spiny dogfish ABC and OFLs in the GOA are calculated based on a Tier 5-like approach (but still considered a Tier 6 species). All other species specific ABCs and OFLs are catch history based (average catch in the GOA and maximum historical catch in the BSAI). The Tier 5-like approach for spiny dogfish was adopted for the 2011 fishery (see the SSC minutes from the 2010 December Council meeting: http://www.npfmc.org/wp-content/PDFdocuments/minutes/SSC1210.pdf), based on the 2010 stock assessment (Tribuzio et al. 2010). The justification was that due to pelagic and transitory nature of spiny dogfish it was likely that trawl catchability was low and that the survey biomass estimates were like a minimum biomass estimate.

2) *If using the Tier 5 methods, investigate appropriate means of converting survey biomass to absolute biomass (i.e. catchability) and alternative Fmsy proxies besides F=M.*

   The authors are investigating approaches for converting survey biomass estimates to absolute biomass. These include length based and surplus production models, as well as age-structured models. We are not presenting these models for PT and SSC review yet, as we plan to incorporate results of ongoing projects. These include results of an NPRB funded ageing study and an investigation into trawl catchability using tag data.

   An alternative F_{msy} proxy of F=0.04 was presented in the 2010 and 2011 assessment, based on demographic analyses (Tribuzio and Kruse 2011), and were not accepted by the PT and SSC. If the alternative were applied to the most recent 3 year biomass, the ABC/OFL for spiny dogfish would be 2,294 and 3,058 t, respectively (down from 5,562 and 7,416 t, respectively). The resultant total complex ABC/OFL would be 2,722 and 3,629 t, respectively.

3) *Using the maximum or average catch for Tier 6 may not be appropriate; alternatives could be to use an upper bound of a one-sided 95% or 99% confidence interval.*

   Alternatives to average and maximum catch have been presented in the past (e.g. Tribuzio et al. 2010), for the shark and other assessments (e.g. GOA Octopus). However, this is an issue we hope to revisit for the 2015 GOA assessment. A recent study came out demonstrating how static catch history methods have a high probability of resulting in overfishing (Carruthers et al. 2014). Catch based methods with a dynamic adjusted scalar or depletion correction methods resulted in a substantially improved probability of resulting in an overfished population (defined as $B/B_{msy}<50\%$). We plan to explore these depletion methods for Tier 6 alternatives.

4) *Other suggestions: species specific ABC/OFLs; incorporating state of Alaska survey data; coast wide spiny dogfish assessment; move salmon sharks to a highly migratory group for management*

   Unfortunately, many of these suggestions are not possible at this time. Species specific ABC/OFLs are likely too small to be managed for many of the shark species and moving the salmon shark to a highly migratory group is not possible because we do not have such a group in the Alaska region. We are beginning to compile data from state of Alaska surveys to incorporate into the assessment. A coast wide assessment for spiny dogfish makes sense biologically, but the infrastructure is not in place for such a management plan at this time.

Other items that came up during presentations/discussions

5) *Data does not support building a spiny dogfish model at this time*

   See response to #2 above.

6) *Need to continue efforts to improve age estimates*

   The authors are involved in a project attempting to improve age estimates. This project is funded by the North Pacific Research Board and is scheduled to conclude January of 2015. The goals of the project are to investigate a new method for ageing spiny dogfish and determine if growth estimates can be improved (i.e. reduce the uncertainty in the age estimates and growth parameters).

7) *Need to get more years of new observer data before constructing catch history to use in model*

   The authors agree with this comment, see discussion above.

8) *Investigate Pacific sleeper shark declining catches and survey indices.*

   This is an important topic that is currently under investigation.

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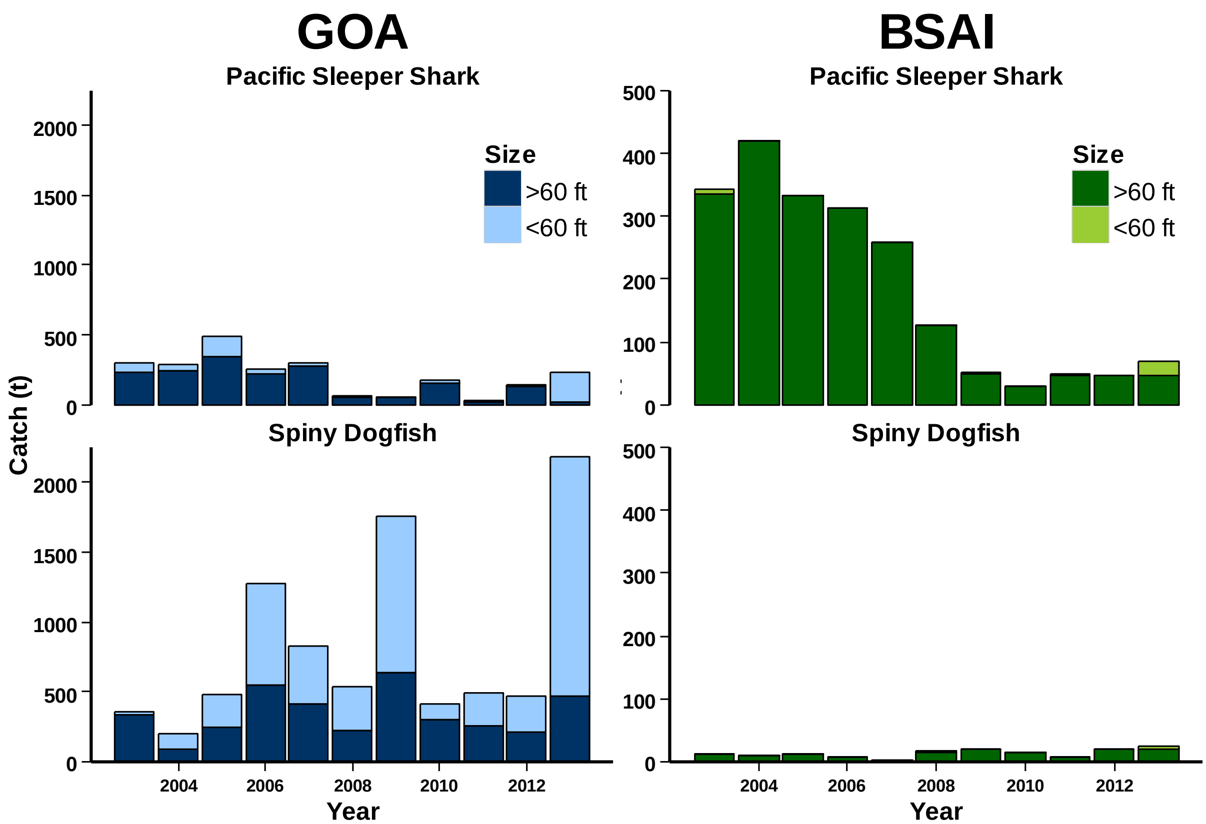

Figure 20A.1. Catch accounting system catch estimates (t) for Pacific sleeper shark and spiny dogfish in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) by vessel size class.

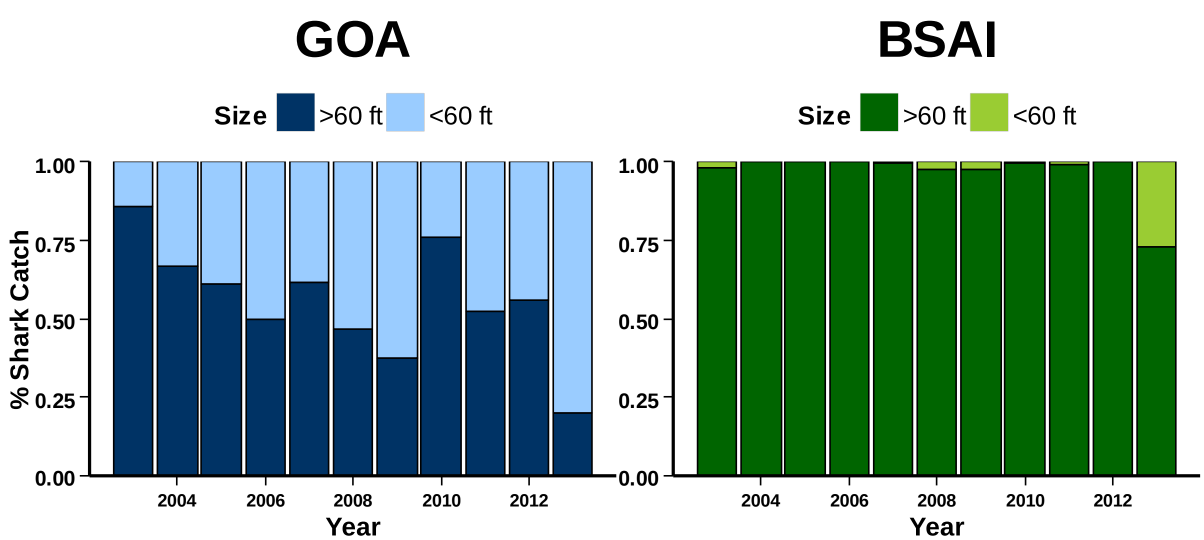

Figure 20A.2. Proportional representation of shark catch by vessel size.

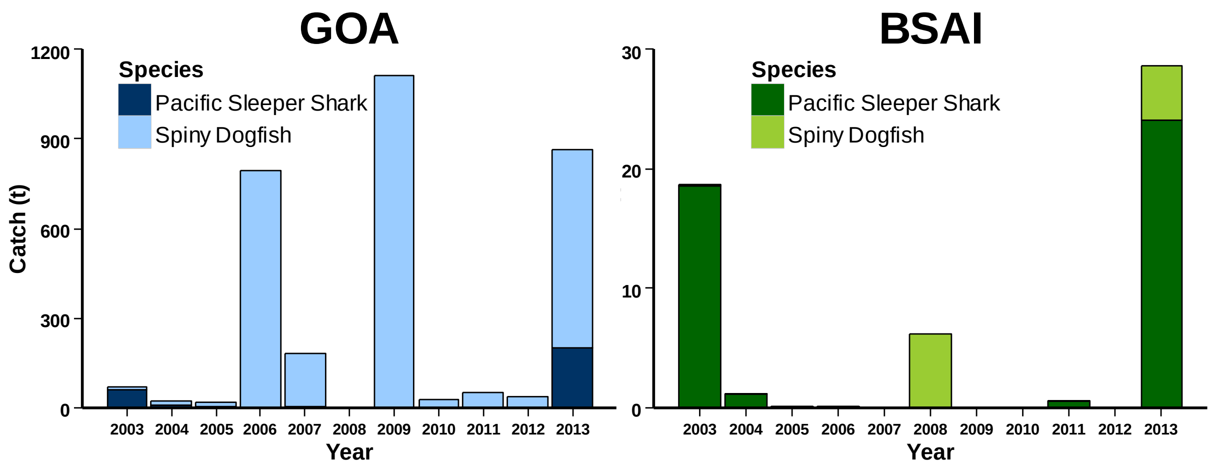

Figure 20A.3. Catch Accounting System catch estimates (t) of spiny dogfish and Pacific sleeper shark in the Pacific halibut target category. Prior to 2013, estimated catch in the Pacific halibut target category results from vessels fishing both Pacific halibut and groundfish (generally sablefish IFQ), beginning in 2013 the estimated catches include vessels fishing only Pacific halibut IFQ.

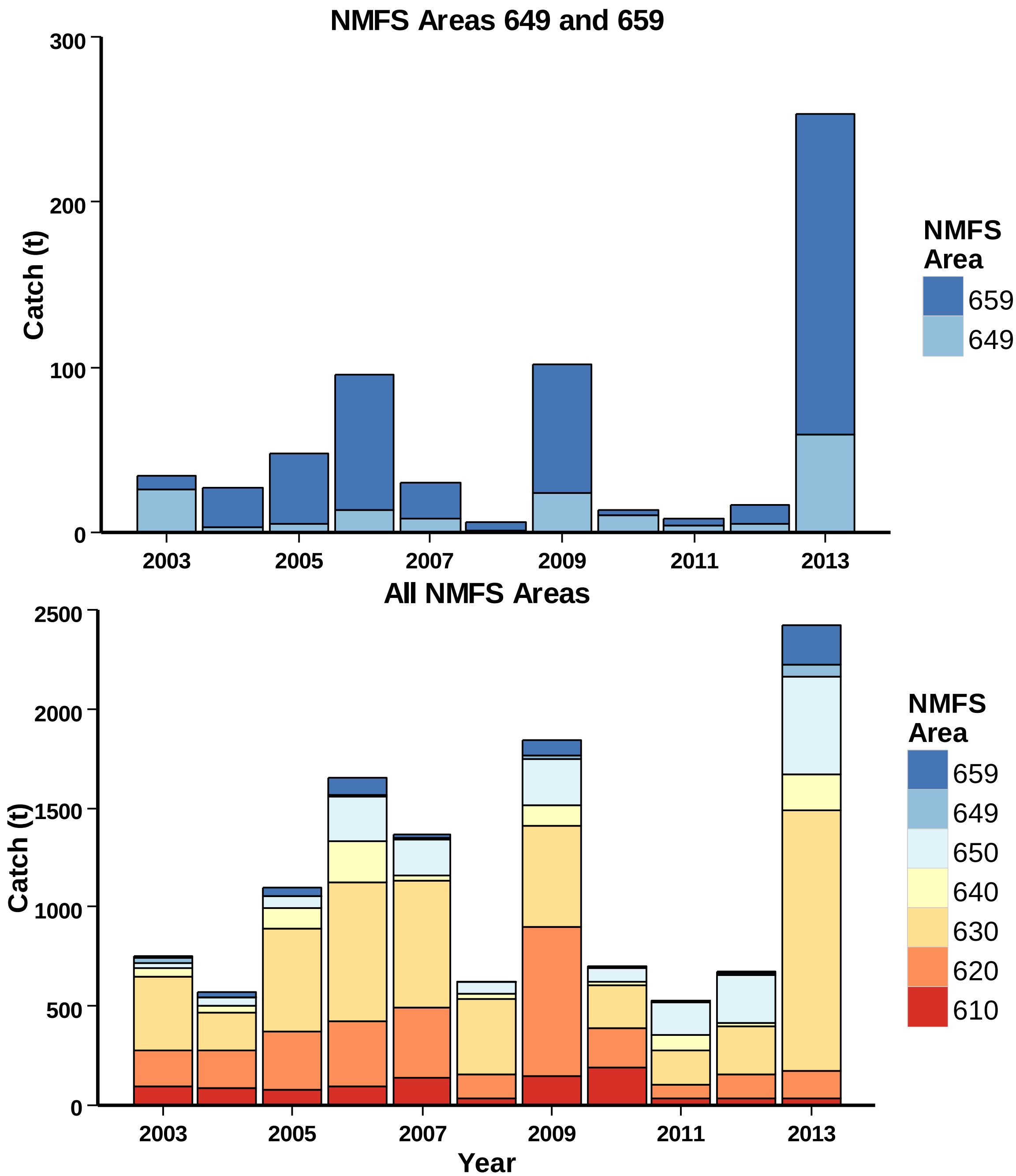

Figure 20A.4. Top panel: Catch accounting system catch estimates (t) for all sharks in NMFS Areas 649 and 659. Bottom panel: Catch accounting system catch estimates (t) for all sharks in all Gulf of Alaska NMFS Areas.

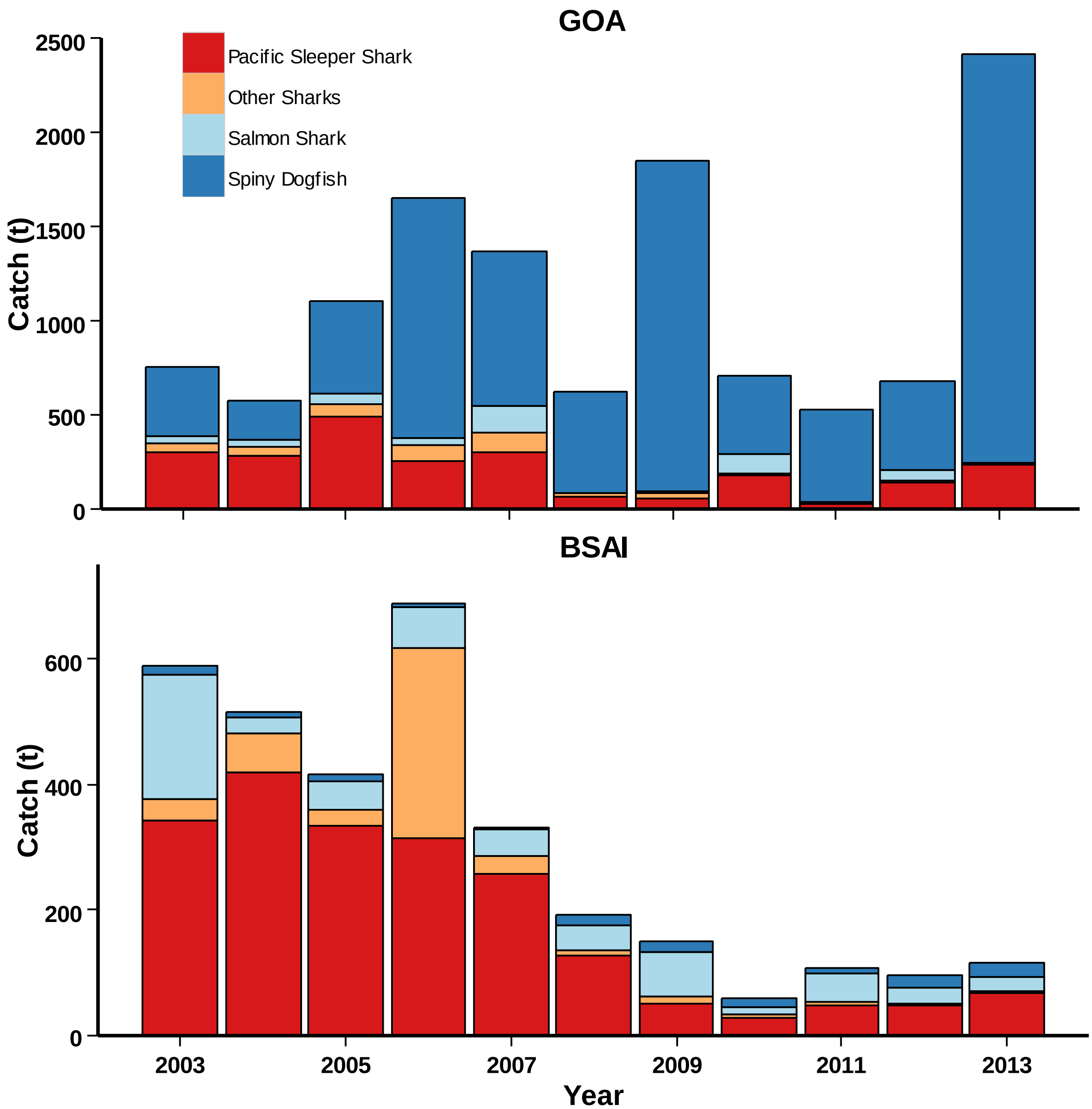

Figure 20A.5. Catch accounting system catch estimates (t) for all sharks in the GOA (top) and BSAI (bottom).

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