20. Assessment of the Shark stock complex in the Gulf of Alaska

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EXECUTIVE SUMMARY

The shark complex (spiny dogfish, Pacific sleeper shark, salmon shark and other/unidentified sharks) in the Gulf of Alaska (GOA) is assessed on a biennial stock assessment schedule. GOA sharks are a Tier 6 complex, however, the ABC and OFL for spiny dogfish are calculated using a Tier 5 approach with the survey biomass estimates considered a minimum estimate of biomass. The complex OFL is based on the sum of the Tier 5 and Tier 6 (average historical catch between the years 1997 - 2007) recommendations for the individual species. For this summary, we have updated the time series of catch through October 15, 2015 to reflect any changes that might have occurred in the Catch Accounting System (for the years 2003 – 2015).

Summary of Changes in Assessment Inputs

Changes to the input data

1. Total catch for GOA sharks from 2003 – 2015 has been updated (as of October 15, 2015).
2. NMFS bottom trawl, longline, and IPHC survey data have been updated.
3. ADF&G trawl and longline survey indices have been included for the first time.
4. A new biomass time series is presented based on the random effects approach to survey averaging.

Changes in assessment methodology

The random effects approach to survey averaging was used to estimate the minimum biomass of spiny dogfish used in ABC/OFL calculations. A maximum sustainable F (F_{max}), based on demographic modelling methods, was presented as an alternative to $F_{OFL} = M$.

Summary of Results

We recommend implementing the random effects model estimated biomass as opposed to using the status quo 3-survey average biomass for the spiny dogfish calculations and continuing to the $F_{OFL} = M$. We do recommend the $F_{OFL} = F_{max}$ based on the demographic model, however, we recommend delaying implementation of that F rate until concerns over the trawl survey gear efficiency can be addressed in the next assessment.

There is no evidence to suggest that over fishing is occurring for any shark species in the GOA because the OFL has not been exceeded. Total shark catch in 2014 was 674 t and catch in 2015 was 417 t as of October 15, 2015. We recommend that the shark complex be managed with spiny dogfish as a modified Tier 6 species (OFL = F_{OFL}(0.097)*random effect biomass, ABC = 0.75*OFL) and the remaining sharks as Tier 6 species (OFL = average catch 1997-2007, ABC = 0.75*OFL). **The recommended ABC is 4,514 t and OFL is 6,020 t for the shark complex combined.** This is a 25% reduction over the 2015 ABC of 5,989 t. This reduction is due to implementing the random effects model for exploitable biomass. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the GOA, and most incidental catch is not retained. Based on historical catch, the recommended ABC has a low probability of being exceeded, and if that were to occur, the impacts on other fisheries would be small. If the ABC were exceeded, the sharks would be put on non-retention status, of which they are rarely retained and are already on a bycatch only status.

ABC and OFL Calculations and Tier 6* recommendations for spiny dogfish for 2016-2017.

Spiny Dogfish Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
M (natural mortality rate)	0.097	0.097	0.097	0.097
Tier	6*	6*	6*	6*
Biomass (t)	76,452	76,452	56,181	56,181
F_{OFL}	0.097	0.097	0.097	0.097
$maxF_{ABC}$	0.073	0.073	0.073	0.073
F_{ABC}	0.073	0.073	0.073	0.073
OFL (t)	7,416	7,416	**5,450**	5,450
maxABC (t)	5,562	5,562	4,087	4,087
ABC (t)	5,562	5,562	**4,087**	4,087
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing		n/a		n/a

While spiny dogfish are a Tier 6 species, a Tier 5 approach is used, thus it is termed a “Tier 6”. They are not in Tier 5 because the trawl survey biomass is not considered reliable for the species.

ABC and OFL Calculations and Tier 6 recommendations for Pacific sleeper sharks, salmon sharks and other sharks for 2016-2017.

Pacific sleeper, salmon and other sharks Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
Tier	6	6	6	6
OFL (t)	571	571	**570***	570*
maxABC (t)	427	427	427	427
ABC (t)	427	427	**427**	427
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing		n/a		n/a

*The 1 t difference from the previous assessment is due to a rounding error that wasn't taken into account in this table previously, but the recommended OFL in the summary table does correctly reflect this rounding error.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL[2]	ABC[2]	TAC	Catch[3]
Shark Complex	2014	76,452	7,986	5,989	5,989	1,553
	2015	76,452	7,986	5,989	5,989	663
	2016	56,181	6,020	4,514		
	2017	56,181	6,020	4,514		

[1]This is spiny dogfish biomass only, because the biomass estimates for the remaining shark species in the complex are not used for ABC and OFL calculations. The biomass used for the spiny dogfish ABC and OFL calculations for 2015 - 2016 is the estimated biomass from the random effects approach to survey averaging.
[2]ABC and OFL are the sum of the individual species recommendations, Tier 6 (avg catch 1997-2007) for Pacific sleeper shark, salmon shark, and other/unidentified sharks and a modified Tier 6 (biomass * F_{max}) for spiny dogfish.
[3]Catch as of October 15, 2015.

Responses to SSC and Plan Team Comments on Assessments in General

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013)

We have included this table, however it is part of the main document (Table 20.13) because research catch is a significant source of removals. While it does not count against the TAC, it is appropriate to acknowledge this source of removals in the main body of the text.

"The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs" (SSC, December 2014)

"*The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas.*" (Joint Plan Teams, September 2015)

"*The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo. In addition, the Teams recommend that the working group examine autocorrelation in subarea recruitment when conducting spatial simulations for evaluating apportionment.*" (Plan Team, September 2014)

In response to the above three comments: we have included the biomass estimates based on the random effects approach to survey averaging (Table 20.14 and Figure 20.22) and these new

biomass estimates are used to estimate spiny dogfish ABC and OFL. The shark ABC is not apportioned by area.

SSC and Plan Team Comments Specific to this Assessment

"Develop biomass indices for lowest tier species (Tier 5 for crab, Tier 6 for groundfish), such as sharks, and conduct net efficiency studies for spiny dogfish. Explore alternative methodologies for Tier 5 and 6 stocks, such as length-based methods or biomass dynamics models." (SSC, June 2012)
These investigations are underway. The authors have a paper in review (Hulson et al., in review) which uses tag data to estimate survey catchability. We have not yet evaluated applying this catchability to the survey biomass. At this time, data do not support length-based models or biomass dynamics models. We have provided a brief discussion of the modelling efforts in the harvest recommendations section.

"The assessment authors indicated that they intend to compare results from this demographic modeling analysis with results from planned biomass dynamic models and length-based models. The SSC encourages these efforts and urges the authors to incorporate these models into an improved stock assessment for spiny dogfish in the near future." (SSC, December 2011)

"For the full assessment the next year, the SSC looks forward to a comparison of demographic modeling analysis, biomass dynamics models, and length based models for spiny dogfish (tier 5 approach), as well as average catch, maximum catch, and 95% or 99% confidence intervals around catch (tier 6) for both spiny dogfish and other shark species." (SSC, December 2014)
With regards to the above two comments: As mentioned above, after much investigation, we have determined that data do not support length based or biomass dynamics models for this species. We have included the results of the demographic model to compare to status quo.

The authors have presented alternatives to average catch for the traditional Tier 6 calculations in a previous assessment (Tribuzio et al. 2010). We have included the average, median, 95th and 99th percentile of the catch and maximum catch in (Table 20.6). Tier 6 options can be presented again in the next full assessment, but we ask for clarification if the SSC would like to see the confidence intervals around the mean, or a percentile of the catch, or both.

"The Team recommends that both the shark and skate assessments include a table of catches in inside waters for an historical time frame as available. If survey data exist in those areas then those data should also be included in the assessment." (Plan Teams, September 2014)

"The SSC supports the Plan Team's suggestion to include "other" removals as an appendix or calculate the impacts of these removals on reference points and specifications. The SSC continues to recommend that deducting catch from areas 649 (Prince William Sound) and 659 (Southeast Inside) from the Federal TACs for federally specified species (50 CFR part 679, Table 2a FMP Groundfish Species) that do not have State GHL fisheries be delayed until the biomass (for Tier 5) or catch (for Tier 6) in state waters can be appropriately accounted for in the stock assessment. Because of this, the SSC asks for next year that authors present catch estimates with and without catch from areas 649 and 659 and provide any results of methods that expand biomass of spiny dogfish to these areas." (SSC, December 2014)
With regards to the above two comments, the estimated catch from Prince William Sound (PWS) and Southeast Alaska inside (SEI) waters has been included in Table 20.3. Shark catches are presented as a total for GOA only and a total including the GOA, PWS, and SEI catches. Non-confidential catch by target group in these areas is presented in Table 20.8. The authors agree with the SSC that further investigation is needed to determine how best to account for these removals. The authors received survey data from ADF&G in both PWS and SEI in September, and plan to investigate those survey indices more in the future. The indices are presented here for informational purposes.

"The SSC supports Plan Team suggestions to investigate using a random effects model for calculating biomass. The SSC also asks that the authors include an explanation as to why each of these methods is or is not appropriate due to the restructured observer program." (SSC, December 2014)
Please see above for responses regarding the random effects biomass. The authors request that the SSC clarify what they are requesting by asking for an explanation of the appropriateness of random effects methods with regards to the restructured observer program.

"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 GOA. The limited research that has been conducted on a closely related species, *S. acanthias*, 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. Other Fishery Management Councils and management bodies do utilize discard mortality rates for elasmobranchs; however, often no rationale is provided for how the rate was selected, or the rates are based on efforts to influence fishing behavior. A review of rates available in literature and how they are used is provided in the Fishery section. At this time, the authors do not support applying a discard mortality rate to sharks, as there is a complete lack of information to inform decisions regarding rates.

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

"The Team recommended that the authors revisit the use of HFICE in 2016, once additional data area available from a longer time series (2013-2016)." (Plan Team, November 2014)

"When there are more data available for the restructured observer program, the SSC looks forward to an evaluation of a comparison of CAS and HFICE estimates, as well as an exploration of potential recreation of a historical catch time series". (SSC, December 2014)
With regards to the above three comments, the authors plan to revisit HFICE for the 2016 assessment cycle.

Introduction

Alaska Fisheries Science Center (AFSC) surveys and fishery observer catch records provide biological information on shark species that occur in the Gulf of Alaska (GOA) (Table 20.1 and Figure 20.1). The three shark species most likely to be encountered in GOA 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

Spiny Dogfish

Spiny dogfish occupy shelf and upper slope waters from the Bering Sea to the Baja Peninsula. They are considered more common off the U.S. west coast and British Columbia (BC) than Alaska (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 tagging data). Spiny dogfish are commonly found in the water column and at surface waters (Hulson et. al in review).

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). 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).

Life History Information

Sharks are long-lived species with slow growth to maturity, a large maximum size, and low fecundity (Table 20.1 and Table 20.2). 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.

Spiny Dogfish

Eastern North Pacific (ENP) 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).

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.

Very little is known about Pacific sleeper shark reproduction; very few mature adults and small juveniles have been documented. 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 Pacific sleeper shark.

Salmon Shark

Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures around 25 °C, which can be 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 ENP 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 von Bertalanffy growth coefficients (κ) 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).

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. There is insufficient life history data for any of the species to compare between or within the GOA and BSAI. Additionally, available genetic information suggests no genetic stock structure between or within areas.

Fishery

Management History and Management Units

The shark complex is managed as an aggregate species group in the GOA Fishery Management Plan (FMP). Prior to the 2011 fishery, sharks were managed as part of the "Other Species" complex, with sculpins, squid, and octopus (skates were removed from the Other Species complex in 2003, Gaichas et al. 2003). The breakout was in response to the requirements for annual catch limits contained within the reauthorization of the Magnuson Stevens Fishery Conservation and Management Act. The NPFMC passed amendment 87 (http://www.fakr.noaa.gov/sustainablefisheries/amds/95-96-87/amd87.pdf) to the GOA 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 20.3).

Directed Fishery, Effort and CPUE

Commercial

There are currently no directed commercial fisheries for shark species in federal or state managed waters of the GOA, and most incidentally caught sharks are not retained. There is an ADF&G Commissioner's Permit fishery for spiny dogfish in lower Cook Inlet; however, only one application has been received to date and the permit was not issued. Spiny dogfish are also allowed as retained incidental catch in some ADF&G managed fisheries with minimal landings reported.

Recreational (provided by Scott Meyer, ADF&G)

Spiny dogfish, salmon shark, and Pacific sleeper shark are caught in the recreational fisheries of Southeast and Southcentral Alaska. The State of Alaska manages recreational shark fishing in state and federal waters, and most of the catch occurs in state waters. The shark fishery is managed under a statewide regulation (5 AAC 75.012), which was modified in 2010 to liberalize limits for spiny dogfish. Effective 2010, the bag and possession limit for spiny dogfish is five fish and there is no size or annual limit. For all other species of the orders Lamniformes, Carcharhiniformes, and Squaliformes, the daily bag limit is one shark of any size with an annual limit of two sharks per year. The season is open year-round. Pacific sleeper sharks are uncommon in the recreational catch and rarely retained, thus estimates are not presented here.

Information on sport catch is obtained from the following: (1) the ADF&G statewide harvest survey (SWHS) provides estimates of catch (both retained and discarded fish combined) and harvest (retained fish only) of all shark species combined, in numbers of fish; (2) the mandatory charter logbook provides estimates of statewide charter harvest of salmon sharks (numbers of fish) since 1998; and (3) dockside monitoring in the Southcentral Region obtains reported retentions and discards and biological information for retained spiny dogfish and salmon shark.

Statewide estimates of retained sharks are available 1998 – 2014, and are presented in this report (Table 20.4). Estimated annual retention of sharks (all species combined) was in the range 0 - 17 fish (CV = 0 – 94%) the Western GOA, 126 – 1,353 fish (CV = 14 – 49%) in the Central GOA, and 46 - 748 fish (CV = 24 – 74%) in the Eastern GOA (Table 20.4). In addition to the retention estimates, numbers of fish discarded were obtained by subtracting estimated retention from estimated catch. Standard errors are not available for the release numbers. Estimated numbers of sharks discarded annually ranged from 0 - 410 in the Western GOA, 5,189- 45,209 in the Central GOA, and about 4,234 – 30,161 in the Eastern GOA. The contrasting retention and discard numbers indicate that most sharks are caught incidentally and are released.

There is a relatively small directed sport fishery for salmon sharks in Southcentral Alaska, mostly occurring in Prince William Sound. The fishery is primarily a charter boat fishery, with retention on charter boats accounting for over 90% of reported retention from dockside surveys. Logbook data for salmon sharks have not been rigorously edited, but indicate annual statewide charter retention in the range 7 - 284 fish over the years 1998 - 2014 (except 1999). Charter retention of salmon sharks appeared to increase in the late 1990s in response to media attention, but has declined since the peak in 2006. Average length (TL_{nat}) of salmon sharks sampled from retained sport catch in Southcentral Alaska from 1998 to 2014 ranged from 207 to 236 cm. Average predicted round wt ranged from 117 to 158 kg. Females have dominated the retained catch each year (56 - 97%, 1998 - 2011). Since 2011, only three salmon sharks have been sampled by dockside creel census samplers, all male. Ages of fish sampled from 1997 - 2000 ranged from 5 to 17 years, ages have not been reported from samples since 2000.

Spiny dogfish make up the vast majority of the recreational shark catch but are rarely targeted. Most of the catch is incidental to the sport halibut fishery. Catch rates can be quite high at certain times of the year, particularly in Cook Inlet, southwestern Prince William Sound, and Yakutat Bay. Anecdotal reports indicate that many spiny dogfish are handled poorly when released. Discard mortality is unknown but probably substantial. Only 85 spiny dogfish were retained and sampled from the Southcentral Alaska sport fishery from 1998 through 2014. The mean total length (TL_{nat}) of these fish was 93 cm and mean predicted round weight was 4.1 kg.

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 20.5. Generally, > 90% of sharks are discarded. About 29 t of sharks are retained on average annually (~19 t is spiny dogfish), and nearly all is used for fishmeal (T. Hiatt, pers. comm.).

Historical Catch

Historical catches of sharks in the GOA are composed entirely of incidental catch. This report summarizes incidental shark catches by species as three data time series: 1990 – 1998, 1997 – 2002 and 2003 – present (Table 20.6, Figure 20.2). Shark catch by species was estimated by staff at the AFSC using a pseudo-blend approach (1990 – 1998, Gaichas et al. 1999), an improved pseudo-blend (1997 – 2002, Gaichas 2002) and since has been estimated by the NMFS AKRO Catch Accounting System (CAS). There is a two year overlap (1997-1998) between the two catch estimation methodologies, in which the catches estimated from the earlier method were considerably lower than catches estimated by the later method. Therefore, these two data series are not directly comparable; however, the earlier time series is still valuable as an indicator of trends. Aggregate incidental catches of the shark management category from federally prosecuted fisheries for Alaskan groundfish in the GOA are tracked in-season by NMFS AKRO (Table 20.3 and Table 20.6). These estimates of catch do not include catch from state managed fisheries, such as the salmon gillnet fishery, which is thought to have high levels of spiny dogfish bycatch.

The estimated catch of sharks is broken into four groups: spiny dogfish, Pacific sleeper shark, salmon shark and other/unidentified sharks (Figure 20.2). Historically, spiny dogfish are the primary species caught in the GOA (70% of total shark catch on average since 2003, Table 20.6, Figure 20.2). The Pacific sleeper sharks, salmon sharks and other/unidentified sharks, are smaller components of the complex (21%, 6%, and 3%, on average since 2003, 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 GOA there was an increase in the proportion of total catch caught in the under 60 ft vessel category and there was also an increase in the estimate of shark catch in the Pacific halibut target group. Further, as a result of observer restructuring vessels operating under Federal fisheries permits in the Prince William Sound (NMFS area 649) and the inside waters of Southeast Alaska (NMFS area 659) are covered at a higher rate than previously, and thus estimated catch from these two areas has increased. These catches do not count against that TAC, but need to be monitored and are included in Table 20.3. 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.

Estimated catch of spiny dogfish has historically been variable, with peaks in estimated catches often resulting from a small number of large observer observations (such as in 2006 and 2009, Table 20.6, Table 20.7 and Figure 20.3). With observer restructuring, catch is based on a wider range of observed hauls, which are likely more representative of true catch. Catch in 2013, the first year of the restructured observer program, was the greatest of the historical time series for spiny dogfish (2,066 t, Table 20.6). Since 2013, estimated catch of spiny dogfish was primarily in the Pacific halibut (506 t, 39%, on average) and sablefish fisheries (489 t, 37%, on average, Table 20.7). Smaller amounts of spiny dogfish catch have come from the Pacific cod (152 t, 12% on average since 2013) and flatfish fisheries (123 t, 9% on average, Table 20.7). The restructured observer program provided in catch estimates from inside waters which, when combined with the GOA catch, results in the Pacific halibut fishery being responsible for 41% of the spiny dogfish catch and the sablefish fishery 35% (on average since 2013, Table 20.8).

Pacific sleeper shark estimated catch has been below average since 2007 (Table 20.6 and Figure 20.2). On average since 2013 43% (31 t) and 28% (20 t) of the catch has come from the Pacific halibut and flatfish fisheries, respectively (Table 20.9). If catch in NMFS areas 649 and 659 (Table 20.8) were included the Pacific halibut fishery represents 68% (102 t) of Pacific sleeper shark catch, on average. Salmon shark are almost entirely caught in the pollock fishery (92%, 68 t on average, Table 20.10). Catch of the other/unidentified sharks is highly variable and inconsistent with regards to which fisheries they are usually reported from (Table 20.11).

Catch distribution:
Distributions of catch of each of the four species in the shark complex are different (Figure 20.3). Catch distribution is likely more a function of the fisheries which catch these species as opposed to indicative of areas of high biomass. Spiny dogfish are generally caught primarily in NMFS area 630 and 650, with little catch in 640. Pacific sleeper shark are caught primarily in NMFS areas 620 and 630, while salmon sharks are in 610 and other/unidentified sharks in 630.

Observer catch data from the FMA website (http://www.afsc.noaa.gov/FMA/spatial_data.htm) was mapped to analyze spatial distribution of catch. Data presented here represent non-confidential data aggregated by 400 km^2 grids from fisheries that occurred during 2011 - 2014. The amount of salmon shark and unidentified shark bycatch within observed commercial fisheries is small and rarely available in non-confidential data. Therefore, we did not examine the spatial distribution of this catch.

Observed bycatch of spiny dogfish in commercial fisheries in the GOA (Figure 20.4) occurs predominately off Kodiak Island with some catch spread along the shelf. With observer restructuring, there were more observed sharks in the Eastern GOA and inside waters. Due to confidentiality restrictions, the non-confidential observed bycatch of Pacific sleeper shark is limited (Figure 20.5) and less informative. Catch occurs predominantly within Shelikof Strait in the Central GOA, and along the Alaska Peninsula.

Data

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Nontarget catch	2003 – 2015
AFSC Psuedo Blend	Nontarget catch	1990 – 1998
AFSC Improved Pseudo Blend	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –GOA (biennial)	Biomass Index	1979 – 2015
NMFS Longline Surveys	Survey catch numbers, CPUE and RPN	1989 - 2015
IPHC Longline Surveys	Survey catch numbers, CPUE and RPN	1997 - 2014
ADF&G	Sport catch	1998 - 2014
ADF&G Southeast Longline Surveys	Survey catch numbers and CPUE	1998 – 2015
ADF&G Prince William Sound Longline Survey	Survey CPUE	1997 – 2006
ADF&G Large Mesh Trawl Surveys	Survey CPUE	19889 – 2015

Fishery

Catch data by species from 1997 – 2007 is used for the harvest recommendations for Pacific sleeper shark, salmon shark and other/unidentified sharks (Table 20.6).

Discard mortality rates were investigated as part of an in-house review done in 2015. Below is a summary of how other councils treat shark discard mortality, in particular for spiny dogfish.

Pacific Council

- Species: Spiny Dogfish (*Squalus suckleyi*)
- Rate: Trawl=100%, hook and line = 50% (Somers et al. 2014)
- Rationale: No studies performed on discard mortality of spiny dogfish in the Northeast Pacific Ocean for either bottom trawl or hook-and-line fleet. In spiny dogfish assessments conducted in other regions, different values of DMRs were assumed, from 5% to 50% for bottom trawl and from 6% to 75% for hook-and-line gears, but all sources noted considerable uncertainty in these estimates. For the Pacific Fishery Management Council, assumed trawl discard mortality to be 100% (mainly attributed to midwater trawls targeting Pacific hake), and hook-and-line discard mortality to be 50%. Given the uncertainty in assumed values, alternative assumptions regarding discard mortality in both fleets were explored via sensitivity analyses (Gertseva and Taylor 2012, see Section 7.1.3).
- Application: Rate is applied by the stock assessment authors

Department of Fisheries and Oceans Canada (DFO)-Pacific Region

- Species: Spiny Dogfish (*Squalus suckleyi*)
- Rate: Hook and Line or trap = 6%, Trawl: 5% mortality for the first two hours fished or portion thereof and, 5% for each additional hour. (DFO 2007)
- Rationale: No rationale given. The DMRs applied to longline and commercial fishery discards to estimate total fishing mortality are not verified by research studies. The trawl mortality is intended to be an incentive to reduce tow time and avoid by-catch. Gallucci et al. (2010) suspected that the DMRs are underestimated and, as such, the total fishing mortality is underestimated.
- Application: Rate is applied by the stock assessment authors

Mid Atlantic Council, jointly with New England Council

- Species: Spiny Dogfish (*Squalus acanthias*)
- Rate: Otter trawl=50%, sink gill net = 30%, scallop dredge = 75%, line gear = 10%, recreational = 20% (Rago and Sosebee. 2014)
- Rational: SARC 19 accepted provisional estimates of DMRs of 75% in gillnets and 50% in otter trawls but noted considerable uncertainty in these estimates. Preliminary information from discard mortality studies (Roger Rulifson, East Carolina State University, pers. comm.; Marianne Farrington and John Mandelman, New England Aquarium, pers. comm.) indicates that the mortality from gillnets may be much lower than previously assumed so an estimate of 30% was assumed in their assessment. The information from otter trawls also indicated a much lower mortality. However, the dogfish in various unpublished studies were all captured in relatively small tows. It was decided by the SARC Working Group that these may not be representative of the otter trawl fishery in all areas, especially when very large tows are encountered. Therefore, the value of 50% was retained for otter trawls. (NEFSC 2006)
- Application: Rate is applied by the stock assessment authors

DFO-Maritimes Region

- Species: Spiny Dogfish (*Squalus acanthias*)
- Rate: Assessment does not state, however it does state that discard mortality assumptions are a source of uncertainty. Likely that they adopt the same assumptions the Mid Atlantic uses
- Rationale: No rationale given.
- Application: Rate is applied by the stock assessment authors

Literature Values (Not currently in use for management)

Source	Species	Region	Mortality Rate	Gear	Comment
Rulifson 2007	Spiny Dogfish (*Squalus acanthias*)	Western North Atlantic	55%	sunk gill net	Research hauls, gentle handling
			0%	Trawl	Research hauls, short duration, small hauls, gentle handling
Mandelman and Farrington 2007	Spiny Dogfish (*Squalus acanthias*)	Western North Atlantic	25-29%	Trawl	Net pen likely caused stress and influenced results, tow weight was predictor of mortality
Braccinni et al 2012	Spiny Dogfish (*Squalus acanthias*)	Southern Australia	78.5%	Demersal gill net	Based on injuries recorded at time of capture
	Spikey Dogfish (*Squalus megalops*)		86.5%		
	Greeneye Dogfish (*Squalus chloraclus*)		31%		
	Non-Squalid chondrichthyans (including rays and chimeras)		6.6-100%		
Cosandey-Godin and Morgan 2011	All Elasmobranchs	Global	<30% 15-90% >70% 0-60% <=100%	Pelagic longline Bottom longline Gill net Trawl Purse seine	Meta-analysis
Campana et al. 2009	Blue Shark (*Prionace glauca*)	Western North Atlantic	19%	Pelagic longline	Excludes dead discards, weighted avg of healthy and injured release mortality rates
Courtney 2013	Black tip shark (*Carcharhinus limbatus*)	Gulf of Mexico	31%	Longline	Post-release live discard mortality rate only, used by SEFSC
	Sandbar shark (*Carcharhinus plumbeus*)		28.5-38%		
	Blacknose shark (*Carcharhinus acrnotus*)		50-71%		
	Dusky shark (*Carcharhinus obscurus*)		44.2-65%		

Catch at length (Fishery and Survey)

The data presented here are from the AFSC bottom trawl surveys (GOA, Eastern Bering Sea shelf and slope and Aleutian Islands), AFSC and International Pacific Halibut Commission (IPHC) longline surveys, targeted research surveys, as well as special projects conducted by the Observer Program (Figures 20.6 - 20.9). A formal stock assessment population model does not exist for the shark complex or any of the component species in the GOA; therefore, length frequency data are not used in the assessment specifications procedures. Length data collections are part of standard collections on the AFSC longline (spiny dogfish only) and trawl surveys, as well as regularly collected on the IPHC longline survey (spiny dogfish only), thus a time series of length frequency data for spiny dogfish and Pacific sleeper sharks are being created. We include BSAI data for Pacific sleeper sharks because genetic evidence suggests that the species is a continuous stock within the eastern North Pacific Ocean. Catch of salmon shark is extremely rare in surveys and length frequencies are not presented.

Length frequency data are presented for GOA spiny dogfish in Figure 20.6 (females) & Figure 20.7 (males). The three surveys provide a large sample size of spiny dogfish, for both males and females. Observer length data is limited and it would be useful to conduct another special project on length, especially with the restructured observer program. There are no significant differences in mean size between the surveys for females, however, the distributions of sizes on the IPHC and AFSC trawl survey are shifted to larger animals than the AFSC longline survey and the sizes from the observer species projects. The IPHC survey provides length data coastwide (Figure 20.8). Data from females suggests that animals sampled in the GOA and BSAI are smaller than those along the Canadian and U.S. west coast, a trend not seen in male length data (Figure 20.8).

There is very little length data Pacific sleeper sharks, therefore, lengths for the BSAI and GOA are combined for each data source (Figure 20.9, sexes combined). Despite summing both areas, data are still extremely limited. In even years (BSAI surveys only) the AFSC trawl surveys catch 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). Catch of Pacific sleeper shark in the trawl surveys along the west coast of the U.S. is limited and no more than 10 sharks sampled in the last 10 years, thus a comparison to coast wide sizes is not possible at this time.

Survey

Trawl Surveys

AFSC Trawl Survey Biomass Estimates

NMFS AFSC bottom trawl survey biomass estimates are available for the three primary shark species in the GOA (1984 - 2015, Table 20.12). Bottom trawl surveys were conducted on a triennial basis in the GOA in 1984, 1987, 1990, 1993, 1996, and a biennial survey schedule has been used since the 1999 survey. The surveys covered all areas of the GOA out to a depth of 1,000 m, with the following exceptions: the 1990, 1993, 1996, and 2001surveys did not sample deeper than 500 m.; the 2003, 2011 and 2013 surveys did not sample deeper than 700 m. Other important caveats are that the 2001 survey did not sample the Eastern GOA, thus removing an entire area of the estimation of biomass and the 2013 survey had a reduced number of stations, which will likely increase uncertainty in biomass estimates. It is unlikely that these survey caveats would impact the estimation of shark biomass, with the exception of the 2001 survey not sampling the Eastern GOA, however, it is important to note the potential for process error.

The 1984 survey results should be treated with some caution, as a different survey design was used in the eastern Gulf of Alaska. In addition, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed here, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 does introduce an element of uncertainty as to the standardization of these two surveys.

The efficiency of bottom trawl gear is not known for sharks, and these biomass estimates should be considered a minimum biomass estimate for shark species until more formal analyses of survey efficiencies by species can be conducted. It is likely that the trawl survey biomass estimate for spiny dogfish is an underestimate and should be considered a minimum biomass. Tagging data show that spiny dogfish spend a significant amount of time near the surface or shallow depths during the summer (Hulson et al. in review) and are thus likely poorly sampled. Pelagic species such as salmon shark are caught during net deployment and retrieval and thus biomass estimates are unreliable. Pacific sleeper sharks are large animals and may be able to avoid the bottom trawl gear. Spiny dogfish spend much of their time off-bottom and thus a large part of the population is likely not sampled. Biomass estimates for Pacific sleeper sharks are often based on a very small number of individual hauls and a very small number of individual sharks within a haul. Consequently, these biomass estimates can be highly uncertain. For the purposes of this assessment, only the spiny dogfish biomass is used in harvest recommendations; however, it is considered a minimum biomass, and not a reliable estimate.

Trawl survey catch of spiny dogfish is highly variable from year to year resulting in no obvious trend in biomass estimates (Figure 20.10). RACE trawl survey biomass estimates increased through 2003 to 98,744 mt and reached its peak in 2007 at 162,759 t. Biomass decreased again until 2013to 2003 levels. In 2015 the biomass estimate dropped again to 51,916 t (Table 20.12, Figure 20.10).

Pacific sleeper sharks are caught in a small number of hauls each year and is considered a poor indicator for this species. Biomass estimates increased through 2005. The biomass estimate is the highest in the time series in 2015, but has a very high SE (Table 20.12, Figure 20.10).

Salmon shark biomass has been relatively stable based on trawl survey biomass estimates, but CVs often overlap zero, as this survey does not sample this pelagic species well (Figure 20.10 and Table 20.12). No salmon sharks were encountered in either the 1999, 2001 or 2009 surveys. These sharks are caught in very few hauls (0-2 hauls since 1996, except for 3 hauls in 2015).

<u>ADF&G Trawl Surveys</u>

Data from three large mesh trawl surveys was provided by ADF&G Southcentral Region: Kachemack Bay (1989 – 2013), Kamishak Bay (1990 – 2012) and Prince William Sound (1190 – 2015). Of the three surveys, only the Kamishak Bay survey regularly caught spiny dogfish. Pacific sleeper sharks and salmon sharks are rare. The spiny dogfish CPUE from Kamishak Bay suggests an increasing trend in catch, with the exception of 2008, which only reported catching 1 shark (Figure 20.11). This survey was discontinued in 2012, thus limiting its usefulness for a spiny dogfish assessment.

Longline Surveys

<u>International Pacific Halibut Commission Annual Longline Survey</u>

The IPHC conducts a longline survey each year to assess Pacific halibut. This is a fixed station survey that samples down to 500 m in the Aleutian Islands, Eastern Bering Sea, and the GOA, as well as areas south of Alaska. More information on this survey can be found in Soderlund et al. (2009). Total catch of sharks in the IPHC survey in weight and numbers is presented in Table 20.13. Weight is derived from a length-weight relationship in 2010 – 2014. Only numbers are available from 1998 – 2009 because no lengths were taken.

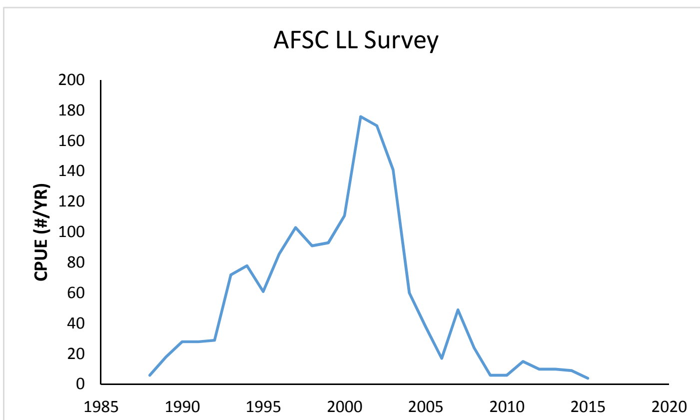
Relative population numbers (RPNs) for spiny dogfish and Pacific sleeper shark were calculated using the same methods have been used historically for the AFSC longline survey, the only difference being the depth stratum increments. An average CPUE was calculated by depth stratum for each FMP sub-area (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.

Spiny dogfish IPHC RPNs have been generally declining in the GOA since a peak in 2004 (Figure 20.11) with 2013 and 2014 having the lowest RPNs of the time series. Pacific sleeper shark RPNs have declined steeply since the late 1990s (Figure 20.12). Salmon shark are extremely rare in the IPHC survey, thus the RPNs do not provide useful information and are not presented.

The IPHC survey can be examined coastwide, from the Bering Sea through the west coast of the U.S. to examine if trends occurring in the GOA are mirrored elsewhere (i.e., BSAI, Canada = CAN, and the west coast of the U.S. = WC). The CPUE are calculated as the numbers of sharks per effective hooks, with confidence intervals estimated by bootstrap resampling the stations within each region. The CPUE indices for both species suggest declines in many of the regions (

AFSC Annual Longline Survey
The AFSC annual longline survey has a standard series of stations on the continental slope (each station samples depths from 150-1,000 m) and in select cross-shelf gullies fished every year and is a longer time series than the available IPHC survey data. Similar to the IPHC survey, the RPNs for spiny dogfish are variable and any trends are over short periods of time (e.g., the decline from 2006 – 2012, Figure 20.11). The 2014 spiny dogfish RPN was well above average and the highest since 2006. The 2015 RPN was substantially lower than 2014, and was below average, but was greater than the lowest of the time series (2013).

Pacific sleeper sharks are generally caught in low numbers, and can often cause entire skates to be deemed ineffective by rolling in the gear and causing snarls. Catch on these skates are removed from RPN calculations. Thus, the CPUE and subsequent RPNs may not be reflective of Pacific sleeper shark abundance. Work is ongoing to investigate the best way to calculate RPNs for Pacific sleeper sharks. The number of sharks caught per year could be considered a gross estimate of CPUE because of the standardization of the survey. Catch in numbers of Pacific sleeper sharks increased rapidly in the early 2000s followed by a steep decline (see below).



ADF&G Longline Surveys
Staff from the ADF&G Southecentral and Southeast regions provided data from three longline surveys: Prince William Sound (1997 – 2006), Chatam Strait (1998 – present) and Clarence Strait (1998 – present). Further discussions will treat the Chatam Strait and Clarence Strait surveys as one Southeast Alaska (SEAK) inside waters survey. The spiny dogfish index in SEAK has been trending downwards since 2009, and the Prince William Sound survey is highly variable (Figure 20.11).

With the exception of 1998, the Pacific sleeper shark index in the Prince William Sound survey appears stable, which is different from other survey data sources.(Figure 20.12). However, this survey ended in 2006. The SEAK longline survey trends mirror that from other surveys (Figure 20.12).

The downward trend in Pacific sleeper shark indices seen in these surveys indicate that either abundance is declining or sharks are become less available to the sampling gear. Some potential reasons could be that the number of immature sharks has declined (sharks the size of immature fish are caught in surveys) or that their depth distribution or behavior has changed. This trend in Pacific sleeper shark abundance indices across all surveys will require further investigation in future assessments. One caveat with all three longline surveys is that hook competition has not been examined for sharks.

Distribution of catch in surveys

The AFSC trawl survey catches spiny dogfish in few areas. During trawl surveys in 2013 and 2015 spiny dogfish were caught mostly on the Fairweather grounds in northern Southeast Alaska and in Cook Inlet (Figure 20.14). Spiny dogfish are commonly caught at many of the IPHC stations across the GOA, and in inside waters of Southeast Alaska and Prince William Sound (Figure 20.15), catch declines from Kodiak Island to the west. Spatial distribution of spiny dogfish catch on the AFSC longline survey is more limited than the IPHC survey, due in part to fewer stations (Figure 20.16). They are often caught at gully stations outside of Prince William Sound, Yakutat Bay and Southeast Alaska. New this assessment is information from the ADF&G longline survey in inside waters of Southeast Alaska, where spiny dogfish are caught primarily in the Clarence Strait portion of the survey (Figure 20.17).

The spatial distribution of Pacific sleeper shark catch on the bottom trawl survey is limited to Shelikof Strait and southwest of Kodiak Island (Figure 20.18). The IPHC and AFSC longline surveys also catch Pacific sleeper sharks often in Shelikof Strait, as well as scattered stations across the shelf (Figure 20.19 and Figure 20.20). The IPHC also catches Pacific sleeper shark in Prince William Sound and inside waters of Southeast Alaska. In contrast to spiny dogfish, Pacific sleeper shark are caught primarily in Chatam Strat during the SEAK longline survey (Figure 20.21).

Analytic Approach

Model Structure

Sharks in the GOA are managed under Tier 6 (harvest specifications based on the historical catch or alternatives accepted by the SSC), so no stock assessment modeling is performed. For Pacific sleeper shark, salmon shark, and other/unidentified sharks, the species specific ABC and OFL estimates are based on the mean historical catch from 1997 – 2007.

Data do not support age or length structured modeling for spiny dogfish at this time, thus alternative methods were investigated to: 1) estimate F_{OFL} for spiny dogfish using demographic modeling approach; and 2) use the random effects modelling approach to estimate minimum biomass.

The demographic model for spiny dogfish was first presented to the Plan Team in the 2010 SAFE (Tribuzio et al. 2011) and was published in Tribuzio and Kruse 2011. Thus, we are not going to go into detail of the methodology in this report, but the results relevant to the assessment are presented here.

The random effects model was put forth by the survey averaging working group. Recent assessments have all used a biomass-based approach based on trawl survey data to calculate ABCs. We continue to use this approach in the present assessment, however, following the recommendations by the Survey Averaging Plan Team and the SSC, methodology for calculating exploitable biomass has changed to the use of a random effects survey averaging approach. The process errors (step changes) from one year to the next are the random effects to be integrated over and the process error variance is the free parameter. The observations can be irregularly spaced; therefore this model can be applied to datasets with missing data. Large observation errors increase errors predicted by the model, which can provide a way to weight predicted estimates of biomass. Please see Survey Averaging Working Group document for more information on the random effects methodology and results across species (https://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2012/Sept/survey_average_wg.pdf).

Estimates and associated uncertainty based on the 1984 – 2015 GOA trawl survey time series was conducted using the random effects model. The random effects biomass model was fit separately by area (West, Central, and Eastern GOA) and then summed to obtain Gulfwide biomass. We fit the random effects model to regional data because the trawl survey did not sample the Eastern GOA in 2001, where a significant proportion of the spiny dogfish population resides within the GOA.

Parameter Estimates

Although a model is not used to provide stock assessment advice for GOA sharks, we provide estimates of life history parameters, where available (Table 20.1 and Table 20.2). 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 spiny 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).

Parameters Estimates Inside the Assessment Model

The demographic analysis provided estimates of population intrinsic rebound potential (*r*, which can be considered the maximum population growth rate), and a maximum sustainable fishing mortality (F_{max}), along with other demographic parameters.

Results

Model Evaluation

Sensitivity analyses were conducted as part of the development of the demographic analysis to evaluate the model sensitivity to uncertain input parameters (Tribuzio and Kruse 2011). Assuming an unfished stock at the beginning of the simulation, recruitment at age 0, and, $r = 0.03$ yr^{-1} (0.012 – 0.06 yr^{-1}, 95% CI). Maximum sustainable *F* was estimated to be $F_{max} = 0.03$ (0.01 – 0.06, 95% CI). If recruitment were assumed to occur at age 10, then $F_{max} = 0.04$ (0.01 – 0.08, 95% CI). An ageing study found no spiny dogfish less than 8 years of age in the GOA sampled from commercial trawl and longline gears. Thus, $F_{max} = 0.04$ is recommended.

The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in Figure 20.22. For illustration the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines). In general, the random effects model fits the area-specific survey biomass reasonably well. The time series of results from the random effects approach to survey averaging is presented in Table 20.14.

Harvest Recommendations

Sharks have been considered a Tier 6 species because they are not targeted and biomass estimates are unreliable. The current Tier 6 uses a mixture of methods and the species specific ABC/OFLs are summed for the complex ABC/OFL. The ABC for spiny dogfish is estimated using a Tier 5 like approach, but is not a true Tier 5 because the biomass is considered an index of minimum biomass. The remaining species ABCs are based on mean historical catch from 1997 – 2007. We present four potential options for calculating the spiny dogfish OFL (and subsequently the ABC): 1) Status quo ($F_{OFL} = M$ applied to the 3 survey average biomass); 2) $F_{OFL} = F_{max}$ applied to the 3 survey average biomass; 3) $F_{OFL} = M$ applied to the random effects biomass; and 4) $F_{OFL} = F_{max}$ applied to the random effects biomass.

		ABC	OFL
1) Status Quo		ABC	OFL
Spiny Dogfish	$F_{OFL} = M$, OFL = 0.097*Avg Biomass, ABC = 0.75*OFL	6,145	8,193
Pacific Sleeper Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	234	312
Salmon Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	52	70
Other Sharks	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	141	188
	Shark Complex Total	**6,572**	**8,763**
2) Status quo biomass with $F_{OFL} = F_{max}$			
Spiny Dogfish	$F_{OFL} = F_{max}$, OFL = 0.04*Avg Biomass, ABC = 0.75*OFL	2,534	3,379
Pacific Sleeper Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	234	312
Salmon Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	52	70
Other Sharks	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	141	188
	Shark Complex Total	**2,961**	**3,949**
3) Random effects biomass with status quo $F_{OFL} = M$			
Spiny Dogfish	$F_{OFL} = M$, OFL = 0.097*Rand Eff Bio., ABC = 0.75*OFL	4,087	5,450
Pacific Sleeper Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	234	312
Salmon Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	52	70
Other Sharks	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	141	188
	Shark Complex Total	**4,514**	**6,020**
4) Random effects biomass with $F_{OFL} = F_{max}$			
Spiny Dogfish	$F_{OFL} = F_{max}$, OFL = 0.04*Rand Eff Bio., ABC = 0.75*OFL	1,685	2,247
Pacific Sleeper Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	234	312
Salmon Shark	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	52	70
Other Sharks	OFL =avg Catch 1997-2007, ABC = 0.75*OFL	141	188
	Shark Complex Total	**2,112**	**2,817**

None of these options are likely to constrain the fishery, as current shark catches are generally lower than all of the ABC options presented above. In only one year since 2003 (2013) has shark catch exceeded the lowest ABC presented above (Option 4). The OFL options have not been exceeded. Exceeding the ABC would trigger the sharks being put on non-retention status, which has little effect on other fisheries because the sharks are already restricted to bycatch only and are rarely retained.

It is possible that the average catch metric used for Tier 6 calculations could be an overestimate of fishing mortality because some released fish likely survive, however, it is also possible that the catch data used to estimate the average catch is an underestimate of catch because of the difficulty in obtaining accurate weight estimates for large sharks. At this time it is impossible to clarify either issue.

For the 2016 fishery we recommend option 3 using the random effect biomass estimates be used for assessment of spiny dogfish following the guidance provided by the Groundfish Plan Teams. The $F_{OFL} = F_{max}$ would be an improvement over the $F_{OFL} = M$, and the authors support using this F rate, however, we recommend delaying implementing the improved rate until the trawl survey gear selectivity is discussed in the next assessment. Setting $F_{OFL} = F_{max}$ would treat the F_{max} as a limit reference point (as stated by the SSC in the December 2010 minutes) and $F_{ABC} = 0.75*F_{max}$ would be the target reference point.

The biomass for spiny dogfish used in the Tier 5 calculations is considered a minimum biomass because the species spends a substantial amount of time off-bottom and unavailable to the trawl survey gear. Methods to account for gear selectivity are being investigated (Hulson et al. in review) and will be presented for the next assessment cycle.

Data is limited for the GOA shark stock. The authors have investigated multiple approaches to modeling spiny dogfish biomass. In general, data do not support more sophisticated modelling approaches at this time. At the September 2011 Plan Team meeting we presented a preliminary Pella-Tomlinson surplus production model, but ultimately we decided against that because the historical time series (pre-1997) was problematic, and the model was a stretch given data available (i.e., large number of parameters relative to data observations and difficulty in convergence). At the 2012 September plan team meeting we presented the data challenges preventing modelling efforts at this time, which include: lack of reliable age data, short time series of length frequencies, surveys that may not sample the species well, and incomplete catch time series. The Non-target CIE review in 2013 further supported that data do not support a model at this time.

The west coast of the U.S. spiny dogfish stock has more data available for the assessment conducted by the Northwest Fisheries Science Center. That assessment suggests the B_{msy} is $B_{79.62\%}$, substantially greater than that for teleost species, for which the Tier system was designed around. Further, the west coast stock is estimated to be at 63% of B_{msy} and recommended $F_{msy} = 0.0053$, a full order of magnitude less than the recommendations in this assessment. For comparison, the relative exploitation rate of spiny dogfish in the GOA (catch/random effects biomass) has been 0.0057, on average, since 2013, which does not include observed catch in inside waters, nor does it include catch from any state managed fisheries (e.g. salmon gill net fisheries).

There is likely connectivity between the GOA and west coast of the U.S. stocks. Tagging studies have shown that fish tagged in British Columbia, Canada, Washington State and the Gulf of Alaska demonstrate substantial movement between regions (McFarlane and King 2003, Taylor et al. 2009 and Tribuzio unpublished data). The tags from nearly 60% of spiny dogfish tagged with pop-off satellite archival tags (i.e., fishery independent) were recovered in a different jurisdictional area than released (Tribuzio unpublished data). The stocks in British Columbia and the west coast of the U.S. have a long history of directed fisheries, which were active until recently. Thus, population level impacts occurring in those regions likely affect the GOA stock. In fact, Taylor et al. 2009 suggested that Northeast Pacific Ocean should be treated as one meta-population, as opposed to separate stocks.

The only consistent survey which covers the west coast of the U.S. through the Bering Sea is the IPHC longline survey. The CPUE data (with bootstrapped confidence intervals) in each region (GOA, Canada and the west coast) is variable, but suggests declines in the survey index in recent years (Figure 20.13). A similar trend is seen in the ADF&G Southeast Alaska survey. Thus, the management of spiny dogfish needs to be considered with caution.

The choice of F_{OFL} is based either on assuming that a status quo proxy ($F_{OFL} = M$) is sustainable, or a rate based on the best available data ($F_{OFL} = F_{max}$). We recommend the $F_{OFL} = F_{max}$ because the assumption that $F_{OFL} = M$ is sustainable is likely inappropriate for spiny dogfish. Inflection points (B_{MSY}) on population growth curves for sharks tend to occur at biomass values > $B_{50\%}$ (Corte´s 2007; Simpfendorfer *et al.* 2008) and it has been argued that management should strive to maintain biomass of less-productive shark populations, such as *S. suckleyi*, well above B_{MSY} levels owing to time lags associated with their delayed maturity and high longevity (Musick *et al.* 2000). The demographic analysis, combined with the information from the west coast assessment and the potential for connectivity between stocks suggests that using M as a proxy for F_{OFL} is risky.

The demographic model was initially presented in the 2010 GOA shark SAFE. The Plan Teams recommended F_{OFL} = 0.097 and using F_{ABC} = 0.04 as a more precautionary approach. However, the SSC expressed concerns over this approach for two reasons: 1) the Plan Teams and SSC had not reviewed the methods as of yet and the methods were from an unpublished manuscript; and 2) the recommended F from the demographic model might be interpreted as a limit reference point as opposed to a target reference point. The demographic model was presented in detail in the 2011 assessment along with references to the published manuscript to address the first concern. Recommendations based on the demographic model were delayed as efforts were underway to develop population dynamics models, and all models were planned to be compared before a decision was made. In the years since the last full assessment (2011), the SSC has repeatedly requested seeing the demographic model compared with other modeling approaches. The authors have explored numerous modeling approaches and have determined that data do not support more sophisticated population dynamics modelling approaches at this time, thus there are no other models to compare with the demographic model at this time.

Ecosystem Considerations

The ecosystem considerations for the GOA shark stock complex are summarized in Table 20.15.

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 GOA, 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. Investigate concerns regarding accuracy of catch estimates for Pacific sleeper shark due to difficulty of obtaining accurate weights.
    a. Actions: Working with AKRO to estimate catch in numbers, and with FMA to investigate the possibility of using average weight at length bins as a proxy for length or weight measures from longline vessels as an alternative to using an average weight.
2. Define the stock structure and migration patterns (i.e. tagging studies, genetics).
    a. Actions: Continued analysis of spiny dogfish popoff sattelite tag data; investigating population genetics of Pacific sleeper shark.
3. Investigate methods of improving the understanding of life history, for Pacific sleeper shark in particular.
    a. Actions: Continued exploration of new ageing methods to attempt to age Pacific sleeper sharks.

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Table 20.1. Biological characteristics and depth ranges for shark species in the Gulf of Alaska. Missing information is denoted by "?". Species in bold are the primary species in this assessment.

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]	30[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. 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	Age at first Recruit
Spiny Dogfish	M	93.7 (TL_{ext})	0.06	-5.1	0.097	NA
Spiny Dogfish	F	132.0 (TL_{ext})	0.03	-6.4		
Pacific Sleeper Shark	M	NA	NA	NA	NA	NA
Pacific Sleeper Shark	F	NA	NA	NA		
Salmon Shark	M	182.8 (PCL)	0.23	-2.3	0.18	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 20.3. Time series of Other Species and shark catches, total allowable catches (TAC), and acceptable biological catches (ABC) for sharks and Other Species in the Gulf of Alaska (GOA). Note that the decrease in TAC in 2008 was a regulatory change and not based on biological trends. The Other Species complex was dissolved and the shark complex created for the 2011 fishery. Catches in state waters (Prince William Sound Inside, PWSI, and Southeast Inside, SEI) are also included, but are not used in calculations of ABC, nor do those catches count against the TAC. The column "Est. Shark Catch GOA" only includes catch which counts against the TAC while the "Total Shark Catch" includes the state waters catch.

Year	TAC	Other Sp. Catch	Est. Shark Catch GOA	Est. Shark Catch PWSI	Est. Shark Catch SEI	Total Shark Catch	ABC	Management Method
1992	13,432	12,313	517				N/A	Other Species TAC (included Atka)
1993	14,602	6,867	1,027				N/A	Other Species TAC (included Atka)
1994	14,505	2,721	360				N/A	Other Species TAC
1995	13,308	3,421	308				N/A	Other Species TAC
1996	12,390	4,480	484				N/A	Other Species TAC
1997	13,470	5,439	1,041				N/A	Other Species TAC
1998	15,570	3,748	2,390				N/A	Other Species TAC
1999	14,600	3,858	1,036				N/A	Other Species TAC
2000	14,215	5,649	1,117				N/A	Other Species TAC
2001	13,619	4,801	853				N/A	Other Species TAC
2002	11,330	4,040	427				N/A	Other Species TAC
2003	11,260	6,262	715	25	9	749	N/A	Other Species TAC
2004	12,592	3,580	544	3	24	571	N/A	Other Species TAC*
2005	13,871	2,512	1,054	5	43	1,102	N/A	Other Species TAC
2006	13,856	3,882	1,557	13	82	1,652	N/A	Other Species TAC
2007	12,229	3,026	1,337	8	23	1,368	1,792	Other Species TAC
2008	4,500	2,984	617	1	5	623	1,792	Other Species TAC
2009	4,500	2,085	1,741	23	78	1,842	777	Other Species TAC
2010	4,500	1,724	689	10	3	702	957	Other Species TAC
2011	6,197	NA	522	4	4	530	6,197	Shark Complex TAC[#]
2012	6,028	NA	661	5	12	678	6,028	Shark Complex TAC
2013	6,028	NA	2,169	59	195	2,423	6,028	Shark Complex TAC
2014	5,989	NA	1,553	52	127	1,732	5,989	Shark Complex TAC
2015	5,989	NA	663	42	53	758	5,989	Shark Complex TAC

*Skates were removed from the GOA Other Species category in 2003.
[#]Other Species were broken up, Shark Complex is formed
Sources: TAC and Other Species catch from AKRO. Estimated shark catches from 1992-1996 from Gaichas et al. 1999, catches from 1997-2002 from Gaichas et al. 2003 and catches from 2003-2015 from AKRO Catch Accounting System (CAS, queried through AKFIN on Oct. 15, 2015).

Table 20.4. Estimated numbers of retained and discarded sharks in the Alaska Department of Fish and Game managed recreational fishery in the Gulf of Alaska. Estimates of total numbers of retained (with coefficient of variation) and discarded sharks are derived from the Statewide Harvest Survey. Estimates of retained salmon shark are derived from charter logbook and only reflect catch in the charter fleet. Recreational catch of sharks does not count against the total allowable catch (TAC). Source: Scott Meyer, ADF&G

All Sharks Combined

	Western			Central			Eastern			Total Est
Year	Retained	CV	Discarded	Retained	CV	Discarded	Retained	CV	Discarded	Catch
1998	0	--	0	595	0.14	10,151	168	0.30	4,650	15,564
1999	0	--	0	471	0.23	5,189	202	0.42	13,108	18,970
2000	0	--	0	403	0.25	9,301	351	0.46	15,543	25,597
2001	17	0.94	20	392	0.20	18,224	550	0.30	14,518	33,721
2002	0	--	0	347	0.27	7,242	239	0.41	4,234	12,062
2003	0	--	30	755	0.20	24,453	444	0.28	11,273	36,955
2004	0	--	37	399	0.22	16,351	346	0.33	9,193	26,326
2005	0	--	108	950	0.17	45,209	633	0.30	23,041	69,941
2006	0	--	0	554	0.22	38,868	313	0.24	19,235	58,970
2007	0	--	0	555	0.20	44,458	567	0.32	30,161	75,741
2008	0	--	410	559	0.22	22,750	358	0.39	28,923	53,000
2009	0	--	0	213	0.31	19,446	183	0.48	13,255	33,097
2010	0	--	13	286	0.31	19,080	46	0.74	10,348	29,773
2011	0	--	9	469	0.41	8,830	62	0.53	4,781	14,151
2012	0	--	7	126	0.49	6,531	75	0.49	6,517	13,256
2013	0	--	16	538	0.41	6,109	173	0.44	4,925	11,761
2014	0	--	0	1,353	0.44	14,100	748	0.57	13,909	30,110

Salmon Shark Retained Estimates

Year	Western	Central	Eastern	Total
1998	0	122	84	206
1999	no data	no data	no data	
2000	0	76	99	175
2001	1	98	85	184
2002	0	110	90	200
2003	0	86	97	183
2004	1	103	56	160
2005	3	202	38	243
2006	1	246	37	284
2007	0	207	37	244
2008	0	81	13	94
2009	0	50	13	63
2010	0	20	7	27
2011	0	1	7	8
2012	0	11	10	21
2013	0	3	4	7
2014	0	17	5	22

Table 20.5. Estimated discard rates of sharks (by species) caught in the Gulf of Alaska. Years with no data are left blank. Data queried through AKFIN on Oct 15, 2015

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark
1999	80%	100%	46%	
2000	64%	100%	0%	
2001	78%	78%	0%	
2002	15%	98%	86%	82%
2003	98%	100%	100%	93%
2004	96%	100%	100%	91%
2005	98%	99%	98%	69%
2006	96%	99%	97%	77%
2007	96%	100%	100%	90%
2008	93%	98%	94%	59%
2009	98%	98%	99%	7%
2010	95%	95%	98%	27%
2011	98%	96%	98%	37%
2012	97%	100%	99%	56%
2013	99%	100%	100%	69%
2014	99%	99%	100%	71%
2015	98%	100%	100%	61%
Average	88%	98%	83%	63%

Table 20.6. Estimated incidental catch (t) of sharks in the Gulf of Alaska GOA by species as of October 15, 2015. 1990-1998 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999). 1997 – 2002 from the pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2015 from the Alaska Regional Office Catch Accounting System. Breaks in the table represent different catch estimation periods. Also presented are the 1997 – 2007 average catches which are used to estimate Tier 6 OFL for Pacific sleeper shark, salmon shark and other/unidentified sharks.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unident shark	Total sharks	Total other species	% of Other Species Catch
1990	171	20	53	30	274	6,289	4%
1991	141	49	42	108	340	5,700	6%
1992	321	38	142	17	517	12,313	4%
1993	383	215	89	340	1027	6,867	15%
1994	160	120	25	56	360	2,721	13%
1995	141	63	55	49	308	3,421	9%
1996	337	66	28	53	484	4,480	11%
1997	233	118	25	59	436	5,439	8%
1998	298	161	79	132	669	3,748	18%
-	-	-	-	-	-	-	-
1997	657	136	124	123	1,041	5,439	19%
1998	865	74	71	1,380	2,390	3,748	64%
1999	314	558	132	33	1,036	3,858	27%
2000	398	608	38	74	1,117	5,649	20%
2001	494	249	33	77	853	4,801	18%
2002	117	226	58	26	427	4,040	11%
-	-	-	-	-	-	-	-
2003	357	270	35	53	715	6,266	12%
2004	183	282	41	39	545	1,705	34%
2005	443	482	60	69	1,054	2,513	44%
2006	1,188	252	34	83	1,557	3,881	41%
2007	794	295	141	107	1,337	3,035	46%
2008	531	66	7	12	617	2,967	21%
2009	1,653	56	9	24	1,742	3,188	37%
2010	405	168	107	9	689	1,724	28%
2011	484	26	7	5	522	NA	NA
2012	458	142	50	10	660	NA	NA
2013	2,066	95	3	6	2,170	NA	NA
2014	1,330	71	145	6	1,553	NA	NA
2015	544	48	57	14	663	NA	NA
1997 – 2007							
Average	528	312	70	188	1,096		
Median	443	270	58	74	845*		
95th Percentile	865	558	132	123	1,678*	*The total complex value is the sum of the individual species values	
99th Percentile	1,155	603	140	1,254	3,152*		
Maximum	1,188	608	141	1,380	3,316*		

Table 20.7. Estimated catch (t) of spiny dogfish in the Gulf of Alaska by fishery. 1990 – 1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999); 1997 – 2001 catch estimated with improved pseudo-blend (Gaichas 2002); and 2003 – present from the Alaska Regional Office Catch Accounting System (queried through AKFIN on Oct 15, 2015). Prior to 2003 the catch by fishery were estimated by a different procedure and do not sum to the total catch of spiny dogfish in Table 20.6. These values may be used to infer relative magnitude, but are not comparable to estimates beginning in 2003. Data do not include catch from Federal fisheries operating in inside waters of Prince William Sound or Southeast Alaska.

	Atka Mackerel	Flatfish	Halibut	Other	Pollock	Pacific Cod	Rockfish	Sablefish	Total
1990		13.5			36.0	57.6	1.8	59.0	167.9
1991		16.2			52.6	29.3	16.4	26.2	140.7
1992		116.0			50.5	84.4	22.4	40.7	314.0
1993		138.5			10.1	137.0	2.4	95.3	383.3
1994		83.4			16.9	22.0	2.5	35.4	160.2
1995		24.1			28.1	2.8	18.4	50.7	124.1
1996		182.6			15.3	2.9	19.8	79.5	300.1
1997		137.2			57.6	2.8	326.2	133.7	657.5
1998		69.0			727.2	4.9	3.1	59.6	863.8
1999		56.6			160.2	8.6	4.8	83.4	313.6
2000		66.3			29.4	18.7	146.6	136.6	397.6
2001		162.5			172.8	11.6	25.1	122.1	494.1
2002		1.3	0.0		0.7	12.2	0.4	0.3	13.7
2003	0	166.0	6.6	82.5	43.6	6.1	35.5	17.3	357.5
2004	0	15.5	13.4	1.3	19.6	9.2	2.3	121.7	182.9
2005	0	50.1	17.3	0.6	27.9	15.2	2.8	329.3	443.2
2006	0	122.9	725.9	23.6	113.2	49.3	2.0	150.6	1,187.6
2007	0	151.4	157.7	0	250.9	47.6	6.2	180.6	794.4
2008	0	86.1	0.2	0	289.6	59.6	4.8	91.1	531.4
2009	0	204.8	1,022.1	0	319.0	17.6	7.0	82.1	1,652.7
2010	0	162.3	25.0	0	120.7	19.8	3.5	73.2	404.6
2011	0	97.3	50.3	0	80.8	16.5	1.6	237.8	484.3
2012	0	97.5	32.4	0	19.0	19.1	4.1	285.7	457.8
2013	0.13716	194.8	611.7	0	45.0	11.4	90.0	1,112.6	2,065.6
2014	0	133.5	564.1	0	375.3	13.4	2.2	241.7	1,330.3
2015	0	42.4	342.2	0	36.8	9.7	0.5	112.6	544.2

Table 20.8. Estimated catch of Pacific sleeper shark and spiny dogfish in the inside waters of Prince William Sound (NMFS area 649) and Southeast Alaska (NMFS area 659) by fishery. These catch estimates do not count against the total allowable catch (TAC). Empty spaces are were no data is available. Greyed out boxes denote year and target fishery combinations where confidentiality restrictions preclude reporting catch. Pollock and rockfish target groups are not included in this table due to confidentiality restrictions in all years. The total catch is summed over all fisheries, even those which are not included here due to confidentiality. Salmon shark and Other/Unidentified sharks are not included because catch is rare.

Species	Year	Halibut	Pacific Cod	Sablefish	Total
Pacific sleeper shark	2003	1.1		3.9	27.4
	2004	0.5	0.1	2.5	4.6
	2005	0.0		1.3	4.6
	2006			2.3	2.4
	2007	0.3		2.2	2.5
	2008			1.9	1.9
	2009		0.5		1.5
	2010		1.6	0.0	7.7
	2011		0.6		0.6
	2012			0.2	0.3
	2013	136.1	1.2	0.0	137.9
	2014	37.5	0.1	2.6	40.2
	2015	26.1	1.1	0.2	27.5
spiny dogfish	2003	0.7		2.7	4.1
	2004	1.6	0.0	19.4	21.0
	2005	0.7		40.6	41.9
	2006	65.7		26.2	92.0
	2007	18.3	1.4	6.0	25.7
	2008		0.6	3.1	3.7
	2009	86.6	10.2	2.8	99.8
	2010	1.5	3.9	0.5	6.0
	2011	2.1	3.4	2.1	7.6
	2012	2.0	0.1	10.7	13.0
	2013	58.8	5.7	51.2	115.8
	2014	100.4	24.9	10.4	136.0
	2015	39.2	26.0	2.6	68.2

Table 20.9. Estimated catch (t) of Pacific sleeper shark in the Gulf of Alaska by fishery. 1990 – 1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999); 1997 – 2001 catch estimated with improved pseudo-blend (Gaichas 2002); and 2003 – present from the Alaska Regional Office Catch Accounting System (queried through AKFIN on Oct 15, 2015). Prior to 2003 the catch by fishery were estimated by a different procedure and do not sum to the total catch of Pacific sleeper shark in Table 20.6. These values may be used to infer relative magnitude, but are not comparable to estimates beginning in 2003. Data do not include catch from Federal fisheries operating in inside waters of Prince William Sound or Southeast Alaska.

	Atka Mackerel	Flatfish	Halibut	Other	Pollock	Pacific Cod	Rockfish	Sablefish
1990	0	0.4			2.9	9.9	4.3	2.2
1991	0	3.1			27.2	2.8	0.0	16.2
1992	0	2.7			1.1	27.4	0.0	6.4
1993	0	1.0			156.5	21.8	0.0	35.5
1994	0	0.8			79.6	16.6	1.3	21.2
1995	0	20.7			16.9	13.7	0.1	11.6
1996	0	12.1			14.5	11.9	0.0	26.4
1997	0	46.0			22.3	59.3	0.9	7.5
1998	0	10.1			32.4	19.6	0.2	11.3
1999	0	6.0			34.1	505.8	3.0	8.7
2000	0	35.9			178.4	376.8	0.3	16.7
2001	0	6.3			145.9	65.8	0.7	30.3
2002	0	41.7	0.0		0.8	5.6	0.0	0.0
2003	0	93.0	59.1	1.6	50.3	56.3	0.3	9.2
2004	0	73.7	8.4	0.5	168.9	25.5	0.8	4.1
2005	0	129.6	2.2	0.907	196.0	133.8	0.2	18.9
2006	0	60.4	0.8	0	153.3	13.5	0.4	23.2
2007	0	222.7	3.9	0	59.0	9.1	0.0	0.7
2008	0	2.1	0.0	0	47.5	13.2	1.1	2.0
2009	0	14.5	0.2	0	30.2	10.4	0.3	0.2
2010	0	7.9	0.0	0	149.5	9.6	0.0	0.5
2011	0	9.9	0.0	0	3.6	6.3	2.1	4.6
2012	0	131.8	0.0	0	3.6	0.2	0.0	6.7
2013	0	2.6	62.4	0	14.7	14.2	0.5	0.4
2014	1.0	39.2	22.2	0	6.3	1.7	0.0	1.7
2015	2.0	18.6	9.3	0	2.2	16.2	1.6	0.0

Table 20.10. Estimated catch (t) of salmon shark in the Gulf of Alaska by fishery. 1990 – 1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999); 1997 – 2001 catch estimated with improved pseudo-blend (Gaichas 2002); and 2003 – present from the Alaska Regional Office Catch Accounting System (queried through AKFIN on Oct 15, 2015). Prior to 2003 the catch by fishery were estimated by a different procedure and do not sum to the total catch of salmon shark in Table 20.6. These values may be used to infer relative magnitude, but are not comparable to estimates beginning in 2003. Data do not include catch from Federal fisheries operating in inside waters of Prince William Sound or Southeast Alaska.

	Atka Mackerel	Flatfish	Halibut	Other	Pollock	Pacific Cod	Rockfish	Sablefish	Total
1990	0	0.2		0	45.3	3.2	0.7	2.1	51.5
1991	0	0.0		0	36.2	0.0	0.0	5.3	41.5
1992	0	0.2		0	123.1	16.5	0.0	2.1	141.9
1993	0	2.5		0	86.7	0.0	0.0	0.0	89.2
1994	0	0.0		0	24.2	0.0	0.0	0.0	24.2
1995	0	3.2		0	25.9	21.6	0.2	3.1	54.0
1996	0	0.0		0	26.9	0.0	0.0	0.2	27.1
1997	0	0.0		0	19.8	0.1	0.0	0.0	19.9
1998	0	0.8		0	69.7	0.0	0.4	0.0	70.9
1999	0	0.7		0	111.8	0.7	0.0	18.4	131.6
2000	0	3.7		0	32.7	0.0	0.8	0.6	37.8
2001	0	1.5		0	29.5	0.0	1.8	0.0	32.8
2002	0	0.3		0	0.0	0.0	0.0	0.0	0.3
2003	0	0.3	0.0	0.262	34.6	0.0	0.0	0.1	35.2
2004	0	5.4	0.0	0	33.1	1.7	0.1	0.4	40.7
2005	0	15.7	0.0	0	43.1	0.8	0.5	0.0	60.1
2006	0	1.6	0.0	0	31.4	0.6	0.6	0.0	34.3
2007	0	9.0	0.1	0	130.9	0.0	0.5	0.0	140.6
2008	0	0.1	0.0	0	6.4	0.0	0.7	0.0	7.2
2009	0	2.0	0.0	0	6.9	0.0	0.4	0.0	9.2
2010	0	1.0	0.1	0	103.7	0.0	2.4	0.0	107.2
2011	0	0.9	0.0	0	5.7	0.0	0.1	0.0	6.7
2012	0	0.1	0.0	0	49.6	0.0	0.4	0.0	50.1
2013	0	0.1	0.0	0	2.8	0.0	0.0	0.0	2.9
2014	0	0.6	0.1	0	144.0	0.0	0.0	0.2	144.9
2015	0	0.0	0.0	0	56.2	0.0	0.4	0.0	56.7

Table 20.11. Estimated catch (t) of other/unidentified sharks in the Gulf of Alaska by fishery. 1990 – 1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999); 1997 – 2001 catch estimated with improved pseudo-blend (Gaichas 2002); and 2003 – present from the Alaska Regional Office Catch Accounting System (queried through AKFIN on Oct 15, 2015). Prior to 2003 the catch by fishery were estimated by a different procedure and do not sum to the total catch of other/unidentified sharks in Table 20.6. These values may be used to infer relative magnitude, but are not comparable to estimates beginning in 2003. Data do not include catch from Federal fisheries operating in inside waters of Prince William Sound or Southeast Alaska.

	Atka Mackerel	Flatfish	Halibut	Other	Pollock	Pacific Cod	Rockfish	Sablefish	Total
1990	0	0.8			4.1	21.3	1.4	2.9	30.5
1991	0	35.5			17.8	36.7	4.4	13.7	108.1
1992	0	3.5			3.3	8.4	0.1	1.5	16.8
1993	0	3.7			138.3	38.1	0.0	159.3	339.4
1994	0	3.0			41.6	2.3	0.0	8.9	55.8
1995	0	10.6			4.0	3.4	9.7	14.3	42.0
1996	0	17.8			14.2	3.1	1.9	16.0	53.0
1997	0	9.0			8.9	13.4	47.5	43.9	122.7
1998	0	17.9			24.2	10.2	2.3	1,325.2	1,379.8
1999	0	8.1			6.1	12.3	0.1	6.4	33.0
2000	0	34.0			12.3	3.5	4.8	18.7	73.3
2001	0	1.5			35.0	1.4	1.4	37.7	77.0
2002	**0**	4.6	0.0		2.8	8.9	0.1	0.4	16.8
2003	0	18.2	17.5	0.156	7.6	6.4	0.2	3.1	53.1
2004	0	18.8	2.6	0	11.1	2.7	0.2	3.3	38.7
2005	0	21.5	0.2	0	34.7	1.2	0.2	11.0	68.8
2006	0	24.4	0.0	0	40.9	11.9	1.6	4.4	83.2
2007	0	49.6	0.0	0	13.8	38.3	0.4	4.9	107.0
2008	0	2.4	0.0	0	4.3	2.4	0.0	2.9	12.1
2009	0	10.6	0.0	0	10.4	2.7	0.0	0.0	23.7
2010	0	4.0	0.2	0	3.7	0.2	1.2	0.0	9.3
2011	0	2.3	0.0	0	1.1	0.2	0.9	0.1	4.7
2012	0	1.9	0.0	0	3.7	0.1	0.1	4.6	10.4
2013	0	0.2	1.1	0	1.0	0.2	2.7	0.4	5.7
2014	0	0.3	0.0	0	2.2	0.2	0.1	3.4	6.3
2015	0	0.0	3.9	0	5.8	0.0	0.0	4.9	14.5

Table 20.12. Gulf of Alaska, Alaska Fisheries Science Center trawl survey estimates of individual shark species total biomass (t) with coefficient of variation (CV), and number of hauls with catches of sharks. The three survey average is presented which is used in the Tier 5-like calculations for spiny dogfish. Data updated October, 2015 (RACEBASE).

		Spiny Dogfish			Sleeper Shark			Salmon Shark			
Year	Survey Hauls	Haul w/ catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Total Shark Biomass
1984	929	125	10,143.0	0.206	1	163.2	1	5	7,848.8	0.522	18,155.0
1987	783	122	10,106.8	0.269	8	1,319.2	0.434	15	12,622.5	0.562	24,048.5
1990#	708	114	18,947.6	0.378	3	1,651.4	0.660	13	12,462.0	0.297	33,061.0
1993#	775	166	33,645.1	0.204	13	8,656.8	0.500	9	7,728.6	0.356	50,030.5
1996#	807	99	28,477.9	0.736	11	21,100.9	0.358	1	3,302.0	1	52,880.8
1999	764	168	31,742.9	0.138	13	19,362.0	0.399	0	0	NA	51,104.9
2001*,#	489	75	31,774.3	0.450	15	37,694.7	0.362	0	0	NA	69,469.0
2003$	809	204	98,743.8	0.219	28	52,115.6	0.247	2	3,612.8	0.707	154,472.2
2005	839	156	47,938.8	0.170	25	57,022.0	0.263	1	2,455.3	1.00	107,416.1
2007	820	161	162,759.4	0.349	15	41,848.9	0.406	2	12,339.7	0.752	216,948.0
2009	884	176	27,879.9	0.120	8	39,687.7	0.446	0	0	NA	67,567.6
2011$	670	97	41,093.0	0.218	5	29,496.1	0.540	1	3,765.9	1.00	74,355.0
2013$	548	58	160,384.3	0.404	6	40,848.1	0.457	1	3,978.5	1.00	205,210.9
2015	772	81	51,916.4	0.254	6	70,932.6	0.570	2	5,930.9	0.875	128,779.9
3 yr AVG			84,464.6			40,092.3			4,558.4		

#Survey maximum depth was 500m
$Survey maximum depth was 700m
*Survey did not sample the Eastern Gulf of Alaska

Table 20.13. Research survey catch of sharks 1977 - 2014 in the Gulf of Alaska. The Alaska Fisheries Science Center (AFSC) longline (LL) and International Pacific Halibut Commission (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 Alaska Regional Office.

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 Gulf of Alaska (Tribuzio et al. 2010)	0.14					
1978		1.44					
1979		1					
1980		0.86					
1981		2.23					
1982		0.36					
1983		1.03					
1984		3.12					
1985		0.96					
1986		1.38					
1987		3.55					
1988		0.27					
1989		0.87	751	NA			
1990		3.52	583	NA			
1991		0.15	2,039	NA			
1992		0.12	3,881	NA			
1993		5.03	2,557	NA			
1994		0.43	2,323	NA			
1995		0.57	3,882	NA			
1996		3.48	2,206	NA			
1997		0.52	2,822	NA			
1998		0.58	7,701	NA	42,361	NA	
1999		NA	1,185	NA	21,705	NA	
2000		NA	1,212	NA	29,257	NA	
2001		0.45	1,726	NA	34,227	NA	
2002		NA	1,576	NA	22,028	NA	
2003		7.36	2,372	NA	68,940	NA	
2004		NA	1,964	NA	48,850	NA	
2005		7.13	3,775	NA	44,082	NA	
2006		0	6,593	NA	41,355	NA	
2007		14.06	3,552	NA	34,023	NA	
2008		0.73	3,606	NA	24,655	NA	
2009		4.03	4,709	NA	29,299	NA	
2010	AKRO	0.50	2,622	6.26	NA	399.86	9.66
2011		2.76	2,108	4.39	NA	150.95	5.70
2012		3.01	1,835	5.45	NA	188.92	6.17
2013		8.54	1,017	2.74	NA	293.22	5.32
2014		1.95	2,844	8.09	NA	153.85	14.70

Table 20.14. Estimated random effects biomass of spiny dogfish with 95% confidence intervals (CI).

	Est. Biomass	Lower 95% CI	Upper 95% CI
1984	10,121.3	6,874.2	14,902.2
1985	9,972.8	4,459.4	22,302.7
1986	9,894.8	4,400.3	22,250.1
1987	9,953.8	6,297.7	15,732.3
1988	9,832.5	4,746.2	20,369.4
1989	11,078.0	5,271.4	23,280.4
1990	14,356.5	8,098.9	25,448.9
1991	16,290.3	7,724.6	34,354.4
1992	20,950.9	10,230.7	42,904.1
1993	30,514.7	21,026.5	44,284.5
1994	28,676.6	12,242	67,173.9
1995	27,141.6	10,181.7	72,352.5
1996	25,850.5	10,806.0	61,840.4
1997	26,137.8	10,324.7	66,170.1
1998	28,066.7	13,170.4	59,811.3
1999	32,515.0	24,941.6	42,388.0
2000	42,207.8	21,279.9	83,717.4
2001	54,951.8	27,859.5	108,390.0
2002	68,416.2	34,104.0	137,250.0
2003	85,242.7	59,115.7	122,917.0
2004	65,968.9	35,574.4	122,332.0
2005	53,095.5	38,981.3	72,320.3
2006	73,287.7	37,270.7	144,110.0
2007	10,2551	60,401.2	174,113.0
2008	54,575.7	28,232.5	105,499.0
2009	29,773	23,725.4	37,362.0
2010	35,807.9	19,199.5	66,783.3
2011	43,145.3	29,518.3	63,063.0
2012	64,360.6	31,205.3	132,743.0
2013	99,836.4	54,456.8	183,031.0
2014	73,793.9	35,060.3	155,319.0
2015	56,181.2	35,484.4	88,949.7

Table 20.15. 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

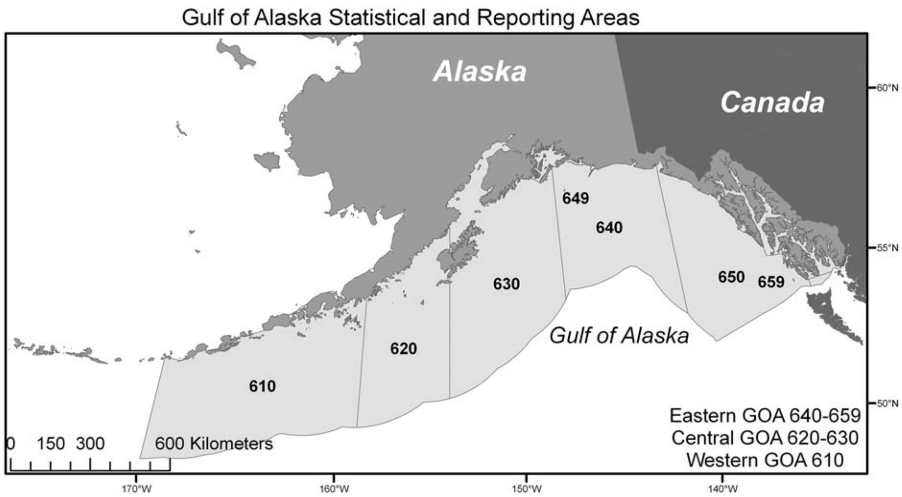

Figure 20.1. NMFS statistical and regulatory areas in the Gulf of Alaska.

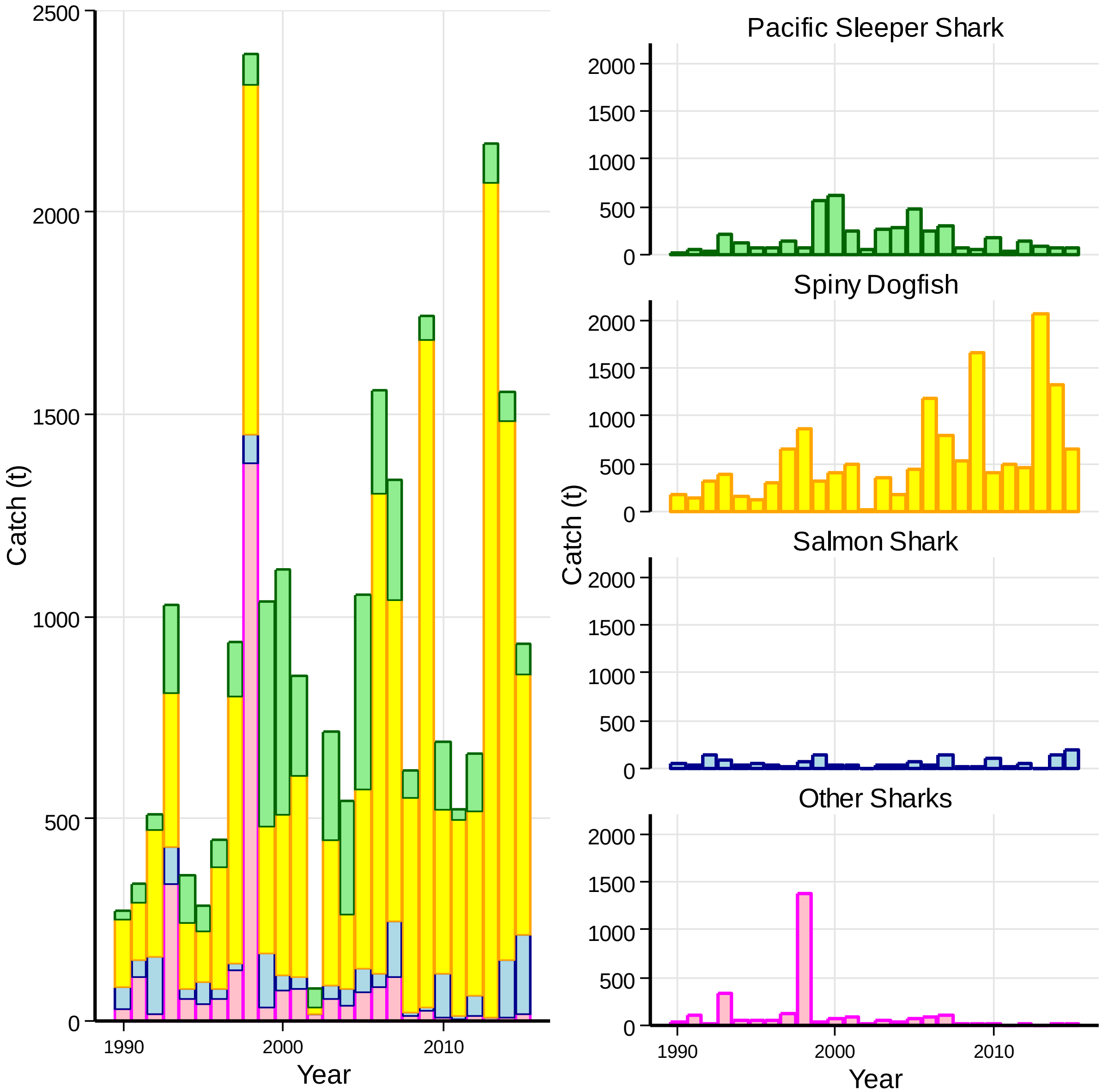

Figure 20.2. Estimated incidental catch (t) of sharks in Gulf of Alaska (GOA) by species. 1990 – 1996 catch estimated by pseudo-blend estimation procedure (Gaichas et al. 1999); 1997 – 2001 catch estimated with improved pseudo-blend (Gaichas 2002); and 2003 – present from the Alaska Regional Office Catch Accounting System (queried through AKFIN on October 15, 2015).

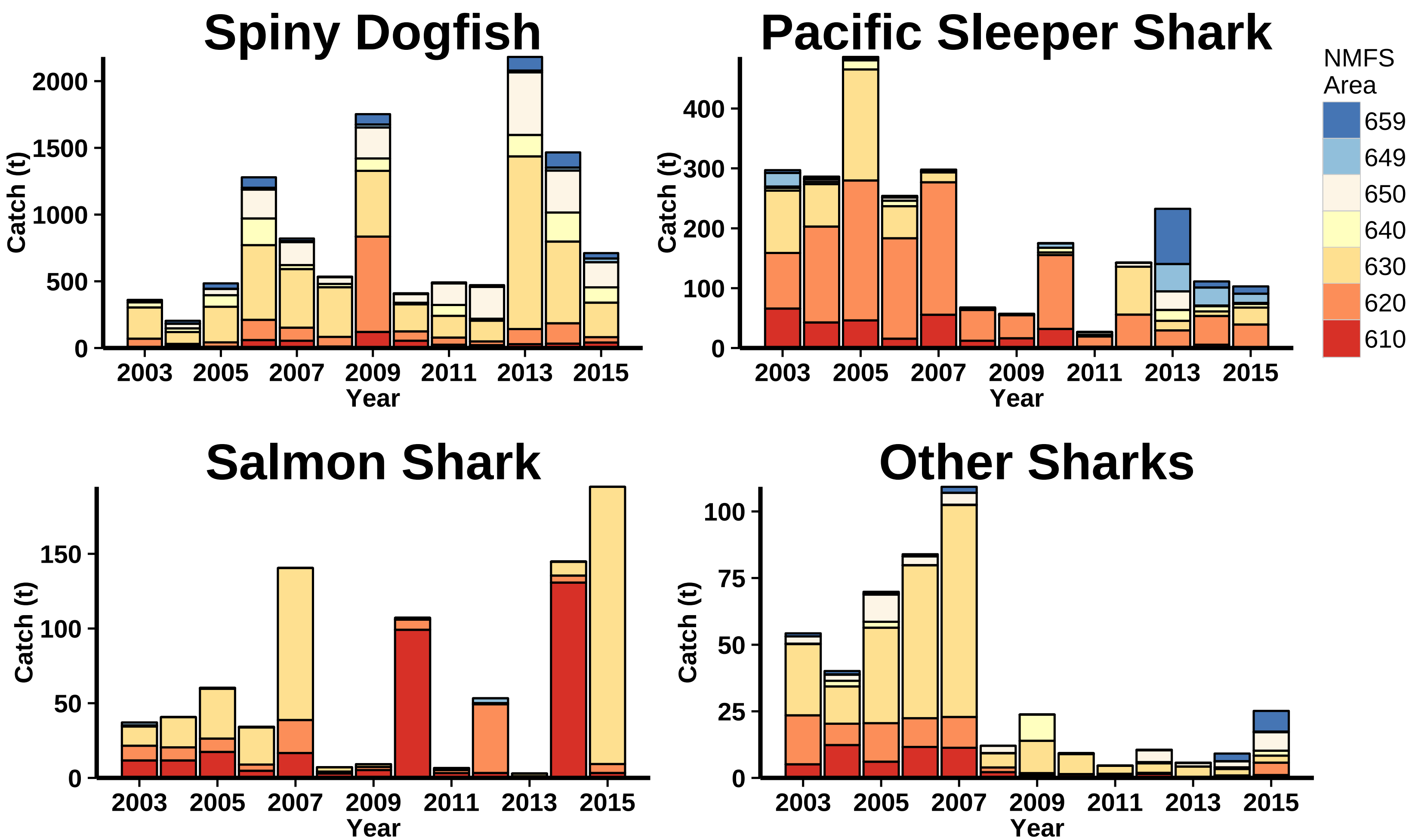

Figure 20.3. Estimated catch of sharks by NMFS area in the Gulf of Alaska. Only data from 2003 – present, Alaska Regional Office Catch Accounting System (queried through AKFIN on October 15, 2015) are presented. Catch occurring in NMFS areas 649 (Prince William Sound) and 659 (Southeast Alaska inside waters), those areas in shades of blue, are presented here to show presence of catch, but do not count against the total allowable catch (TAC). Only areas in shades of yellow/red count against the TAC.

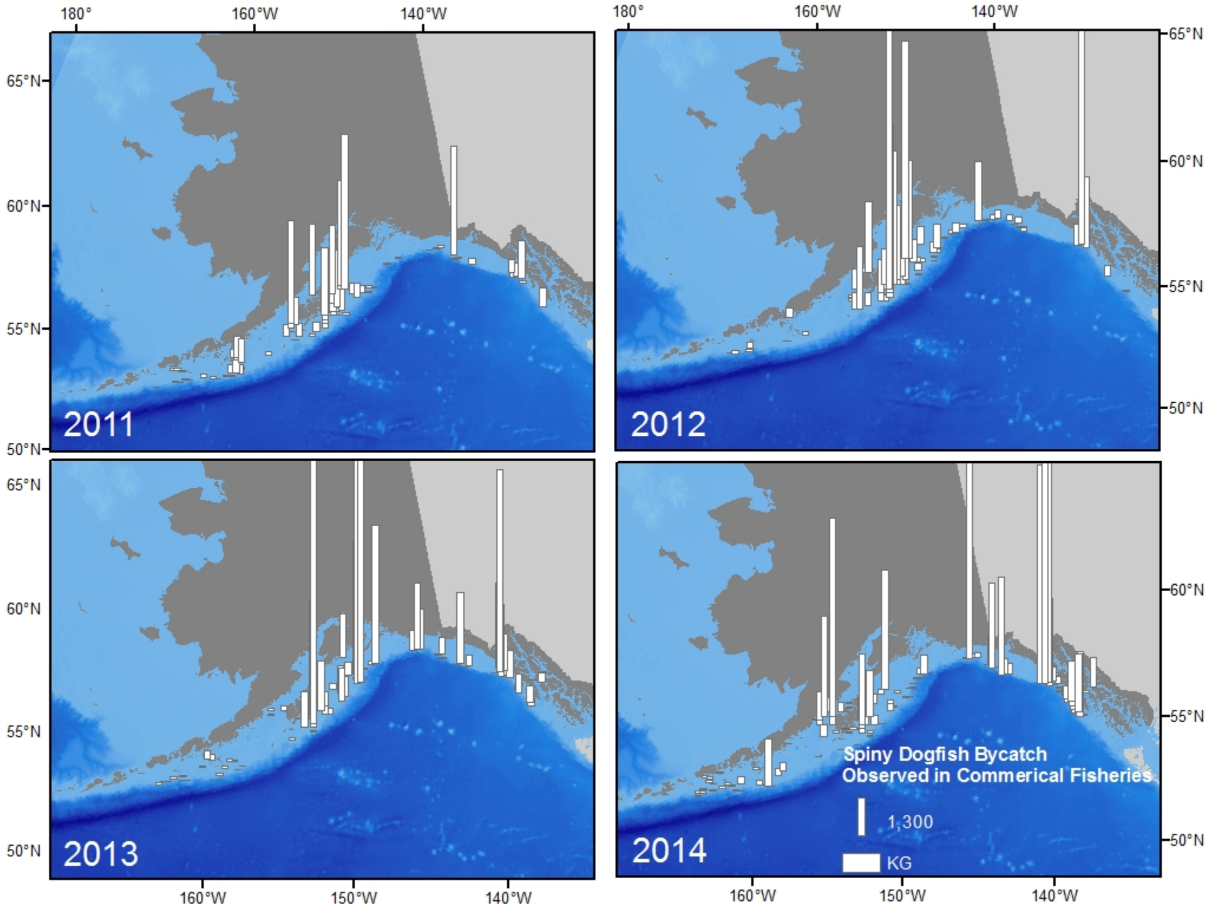

Figure 20.4. Spatial distribution of observed spiny dogfish catch in the Gulf of Alaska from 2011 – 2014. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400 km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 1, 2015 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

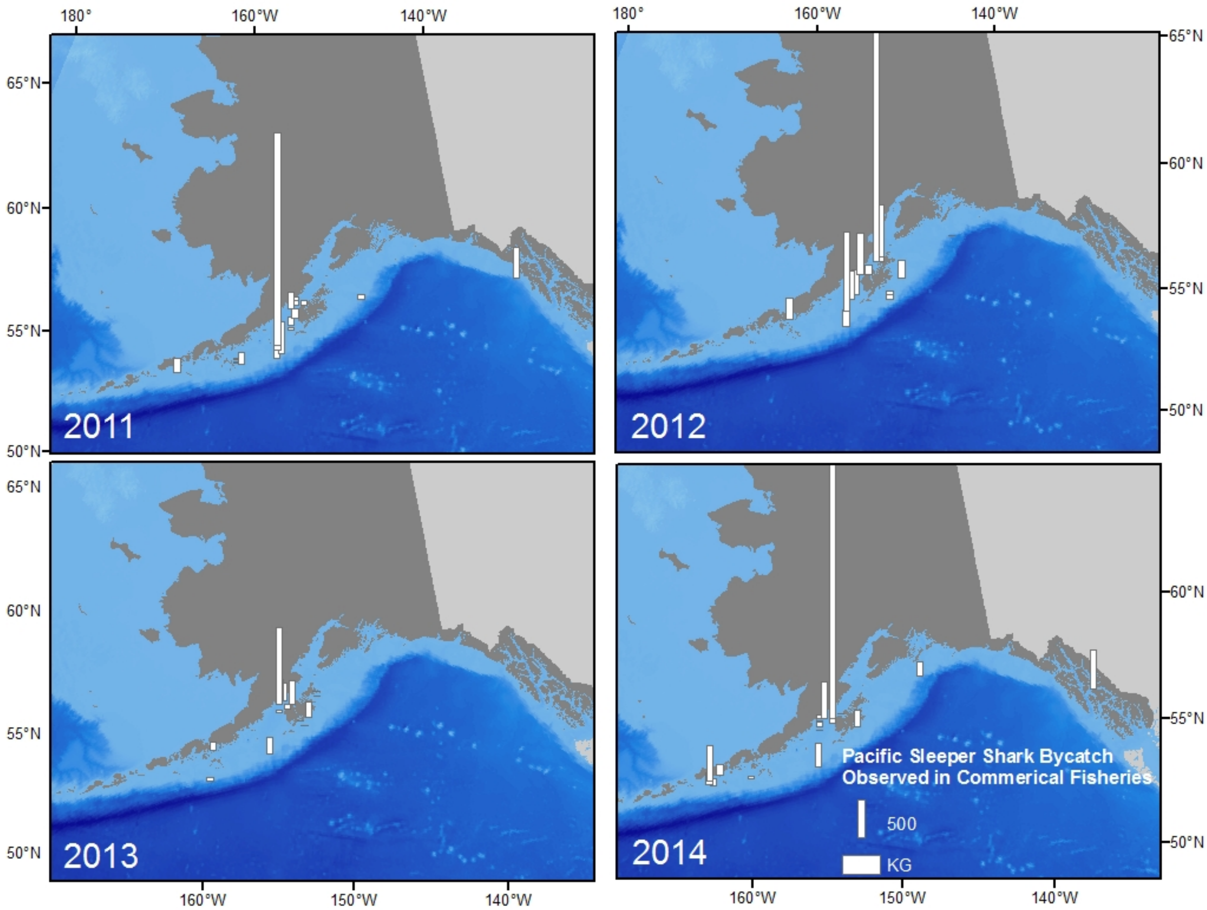

Figure 20.5. Spatial distribution of observed Pacific sleeper shark catch in the Gulf of Alaska from 2011 – 2014. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400 km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 1, 2015 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

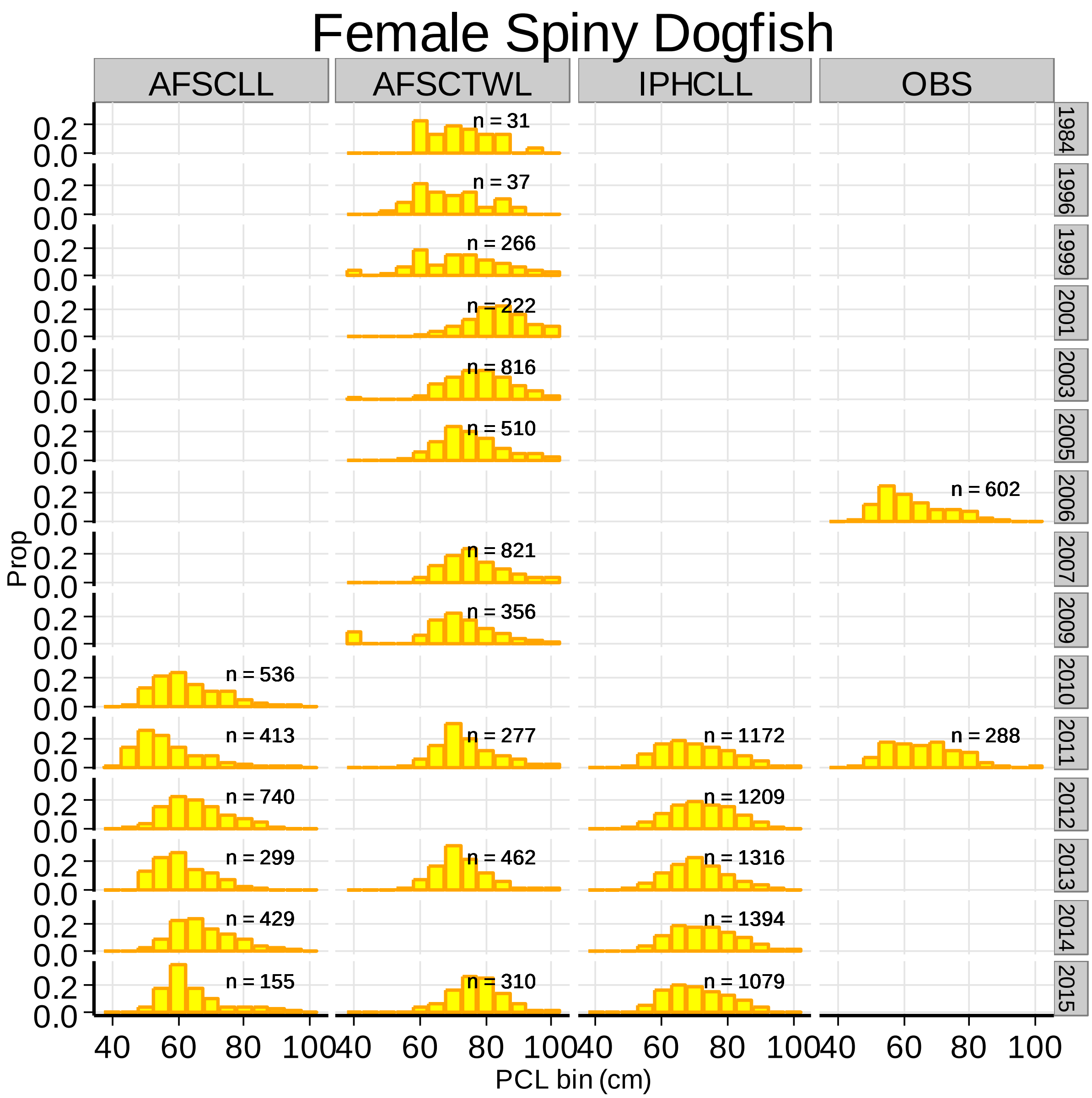

Figure 20.6. Observed length frequencies and sample sizes for female spiny dogfish in the Gulf of Alaska. The Alaska Fisheries Science Center longline survey data (AFSCLL) and International Pacific Halibut Commission longline survey data (IPHCLL) are from the annual surveys operated by the AFSC and the 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.

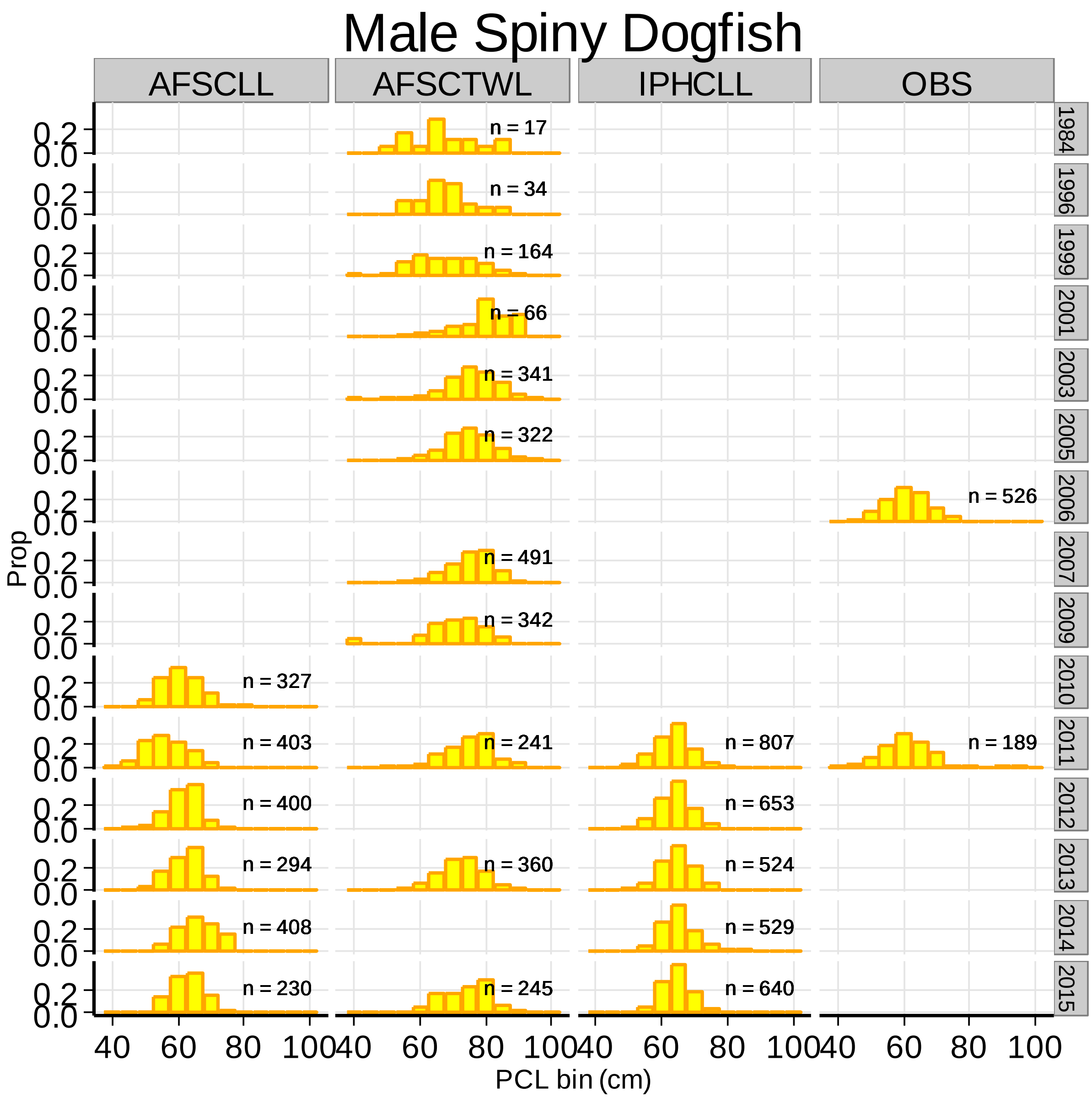

Figure 20.7. Observed length frequencies and sample sizes for male spiny dogfish in the Gulf of Alaska. The Alaska Fisheries Science Center longline survey data (AFSCLL) and International Pacific Halibut Commission longline survey data (IPHCLL) are from the annual surveys operated by the AFSC and the 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.

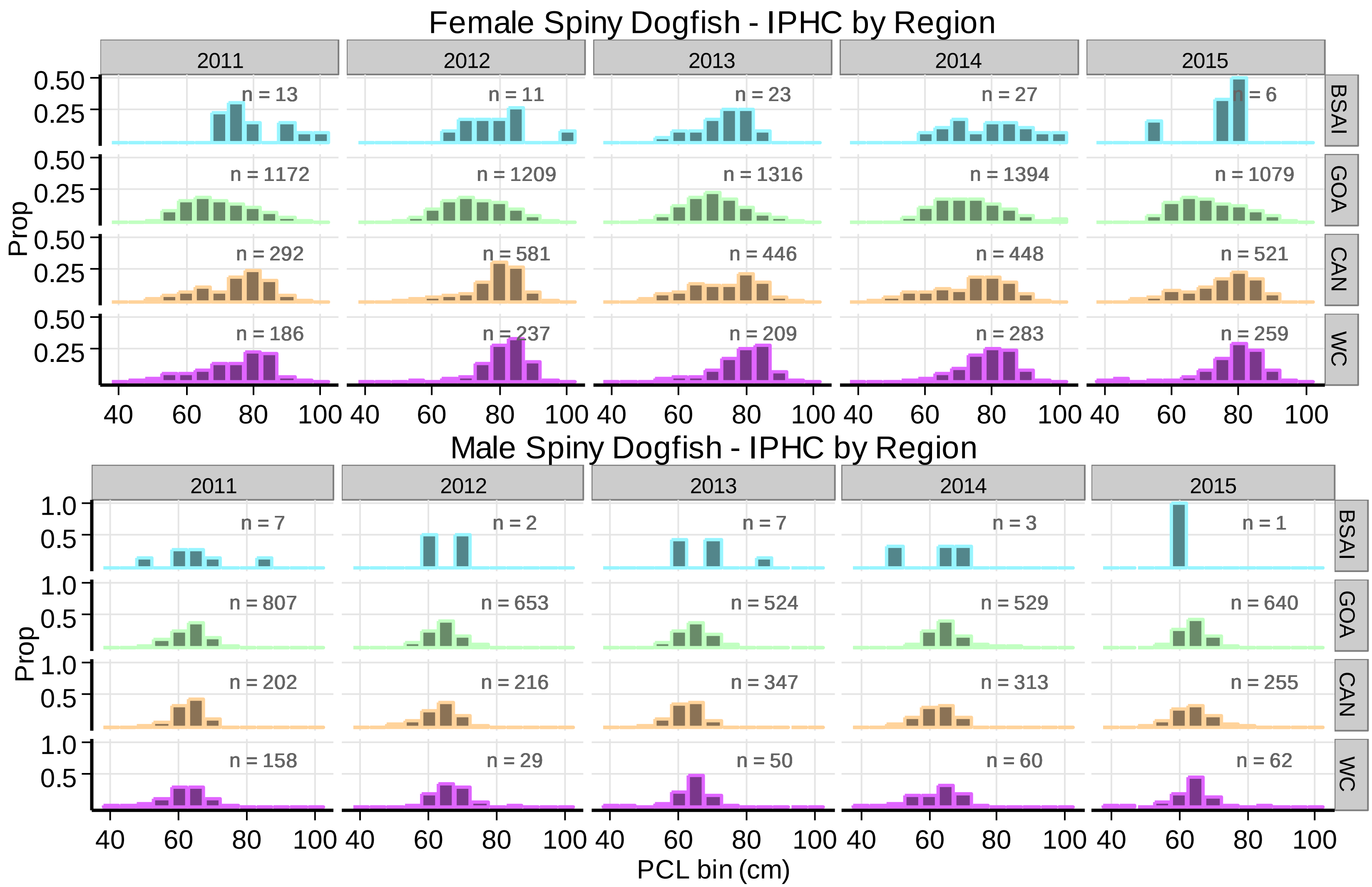

Figure 20.8. Observed length frequencies and sample sizes for male and female spiny dogfish sampled in the International Pacific Halibut Commission longline survey by region of capture. BSAI = Bering Sea and Aleutian Islands, GOA = Gulf of Alaska, CAN = Canadian west coast and WC = U.S. west coast.

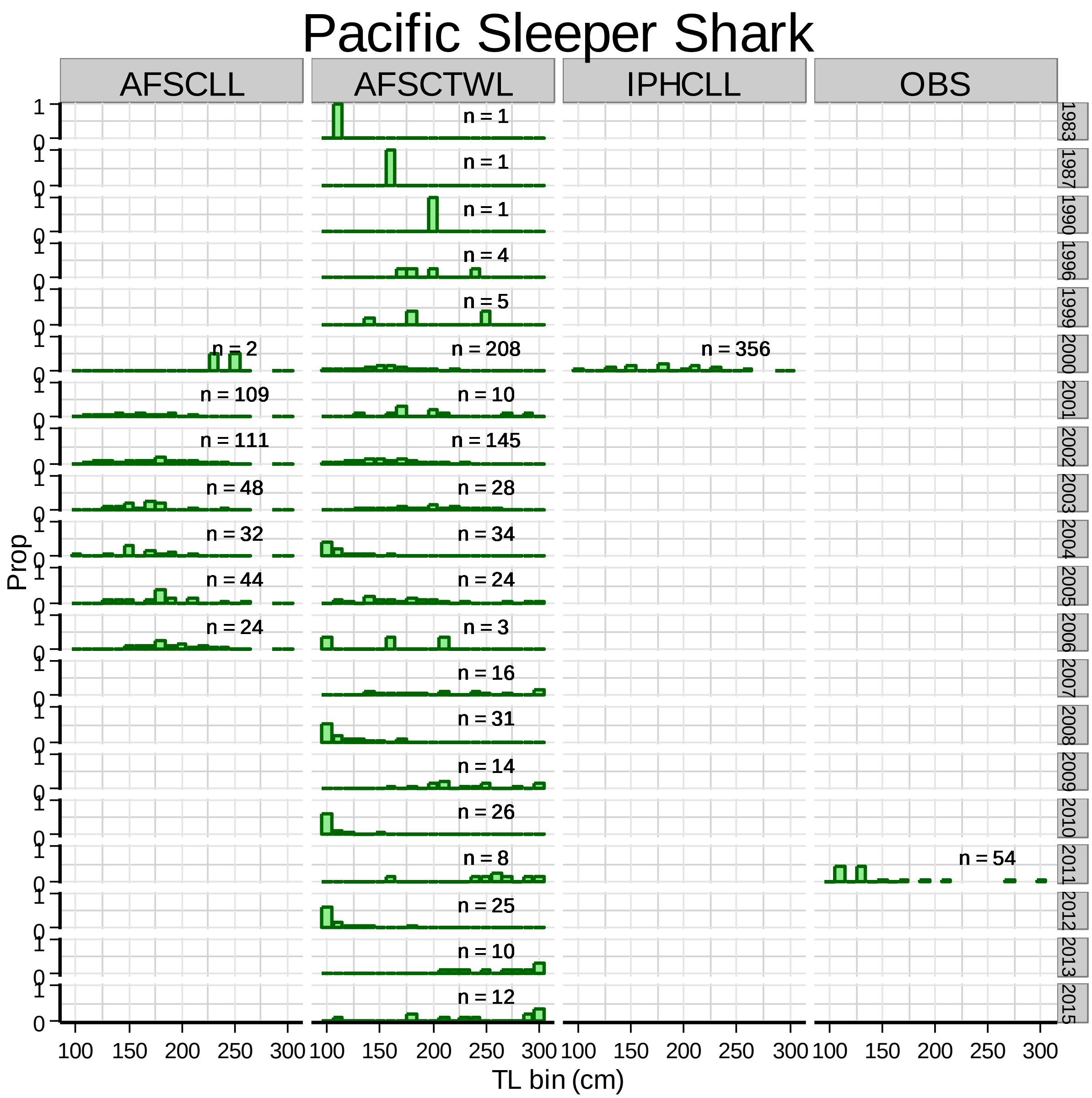

Figure 20.9. Observed length frequencies and sample sizes for Pacific sleeper shark. The Alaska Fisheries Science Center longline survey data (AFSCLL) and International Pacific Halibut Commission longline survey data (IPHCLL) are from the annual surveys operated by the AFSC and the IPHC. The AFSC trawl 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.

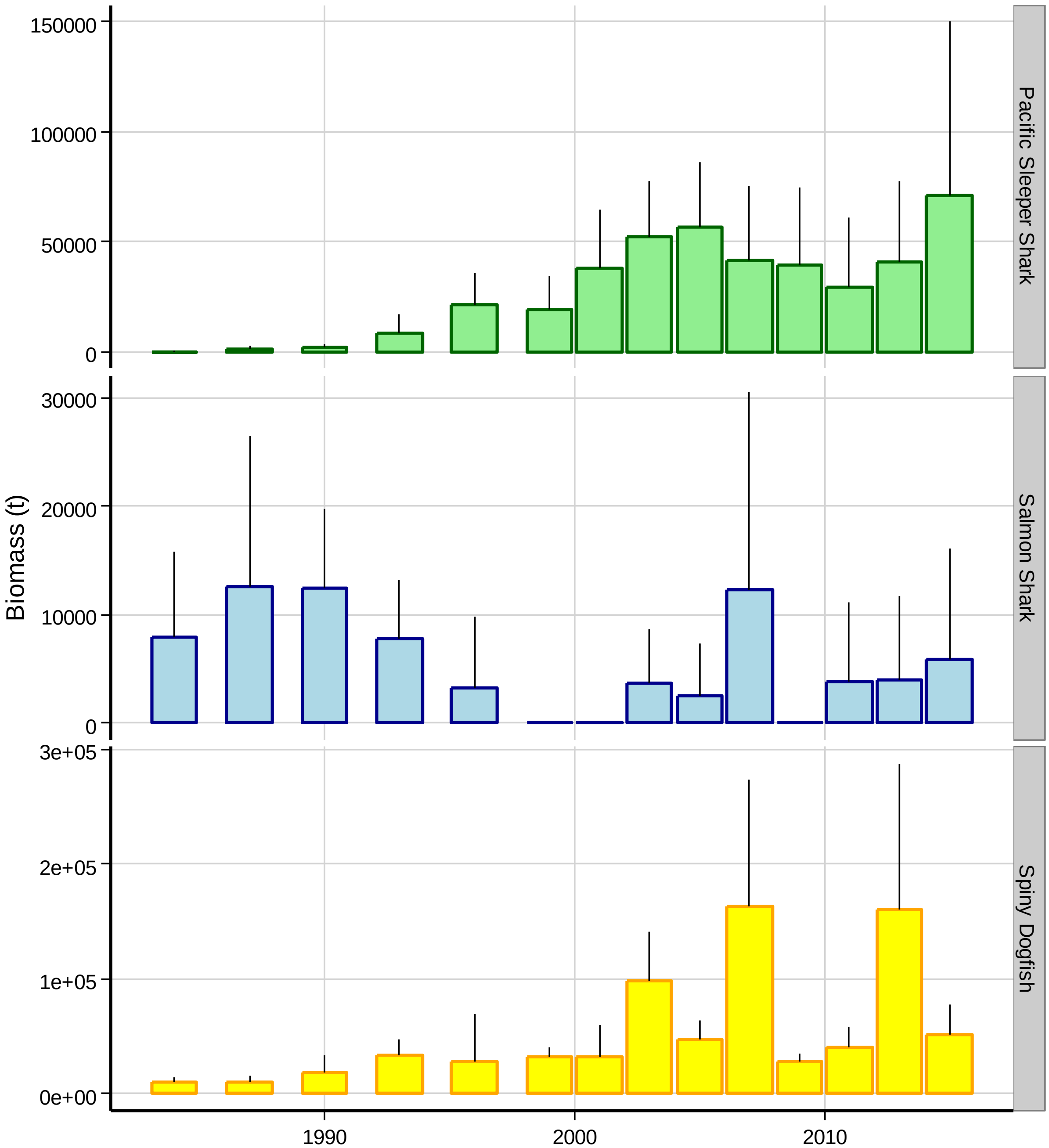

Figure 20.10. Time series of individual species biomass estimates (t) of sharks in the Alaska Fisheries Science Center Gulf of Alaska (GOA) bottom trawl survey reported here as an index of relative abundance. Error bars are 95% confidence intervals. Source: RACEBASE, queried through AKFIN on October 1, 2015.

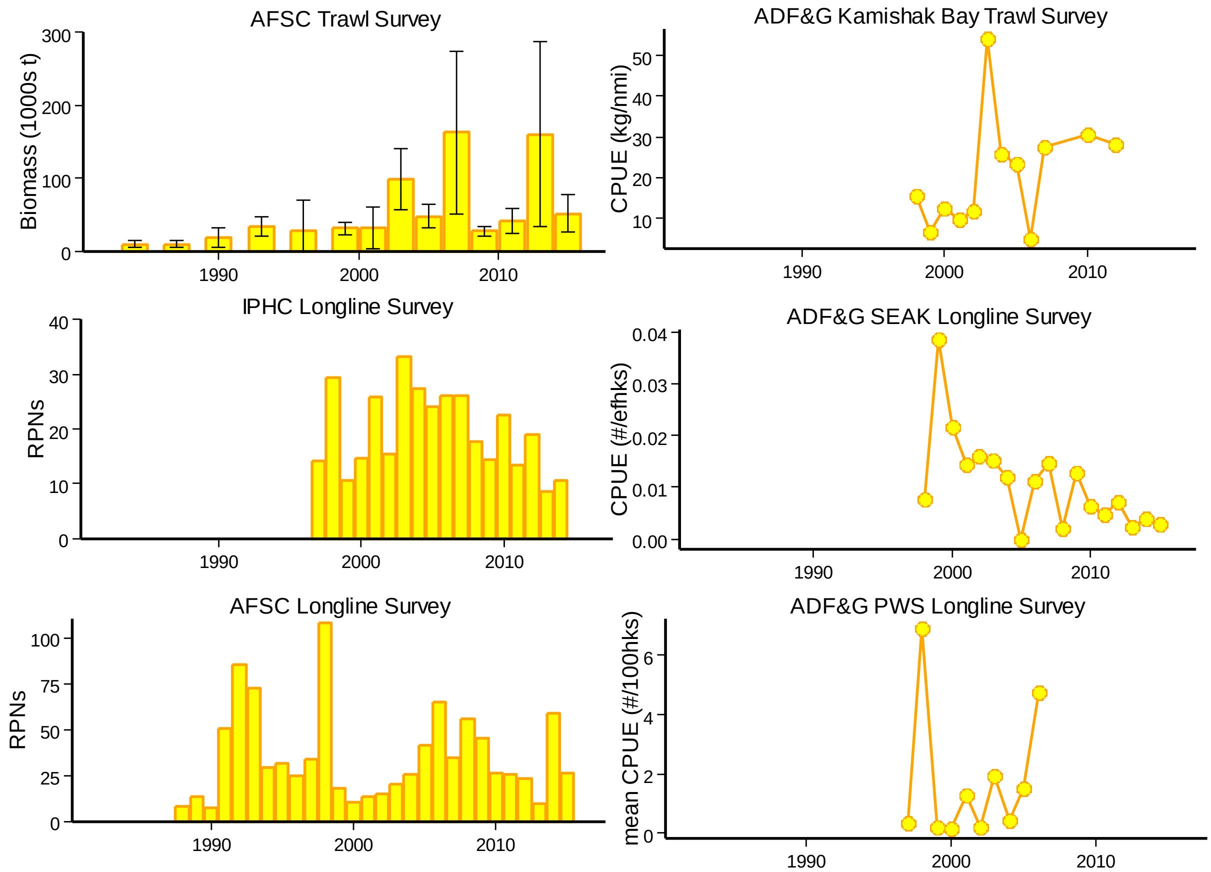

Figure 20.11. Survey indices available for spiny dogfish in the Gulf of Alaska. Catch per unit of effort (CPUE) is available for Alaska Department of Fish and Game (ADF&G) surveys in Prince William Sound, Kamishak Bay and Southeast Alaska. The Alaska Fisheries Science Center (AFSC) trawl survey provides an index of biomass. The AFSC and International Pacific Halibut Commission (IPHC) longline surveys provide relative population numbers (RPNs).

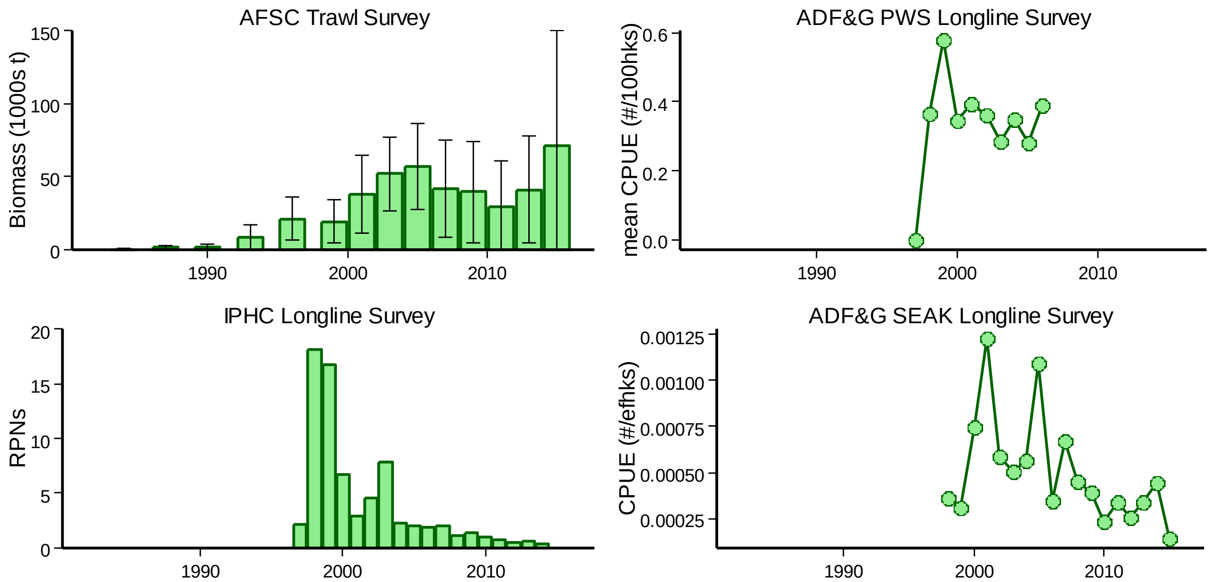

Figure 20.12. Survey indices available for Pacific sleeper shark in the Gulf of Alaska. Catch per unit of effort (CPUE) is available for Alaska Department of Fish and Game (ADF&G) surveys in Prince William Sound and Southeast Alaska. The Alaska Fisheries Science Center (AFSC) trawl survey provides an index of biomass. The International Pacific Halibut Commission (IPHC) longline survey provides relative population numbers (RPNs).

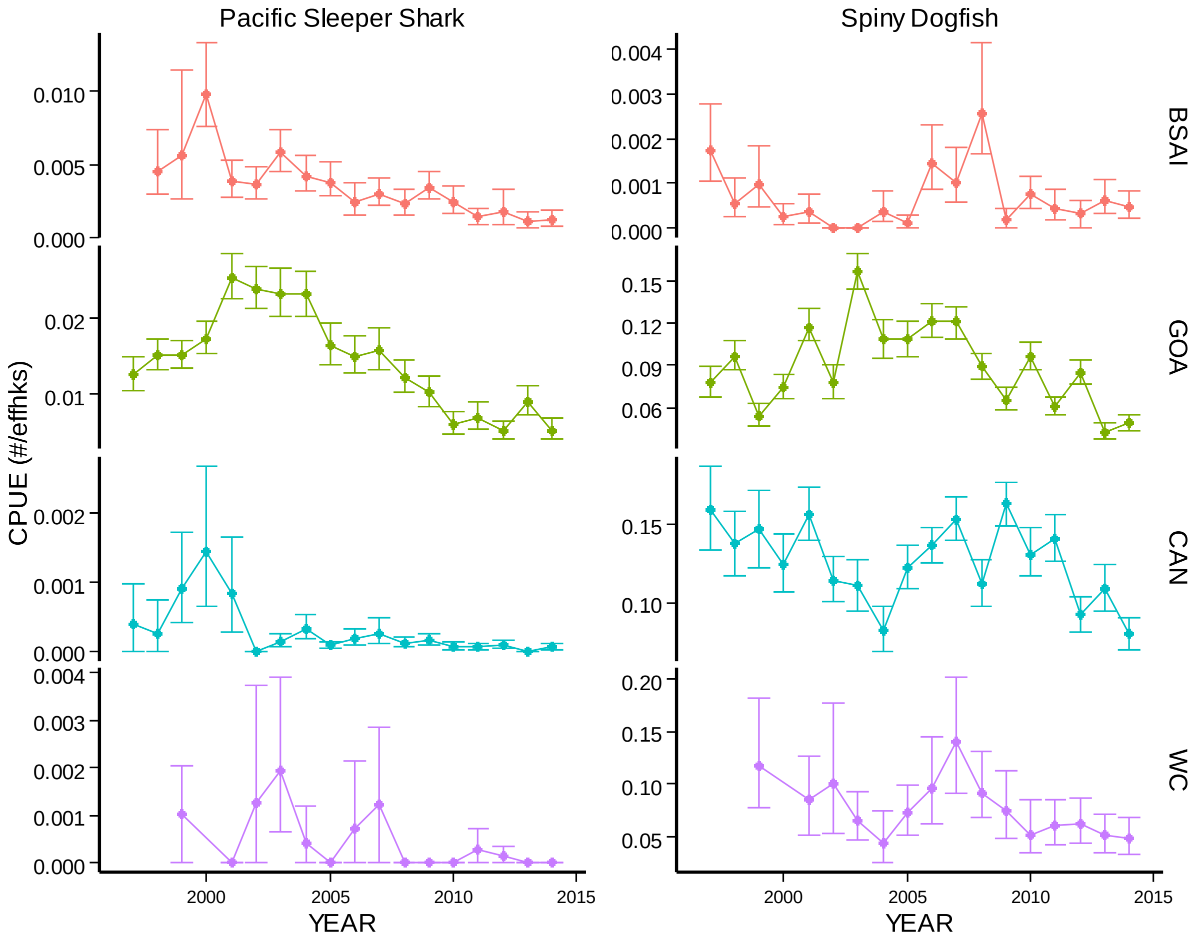

Figure 20.13. Catch per unit of effort (CPUE) with bootstrapped 95% confidence intervals for each region of the International Pacific Halibut Commission annual longline survey. BSAI = Bering Sea and Aleutian Islands, GOA = Gulf of Alaska, CAN = Canada, and WC = the west coast of the United States

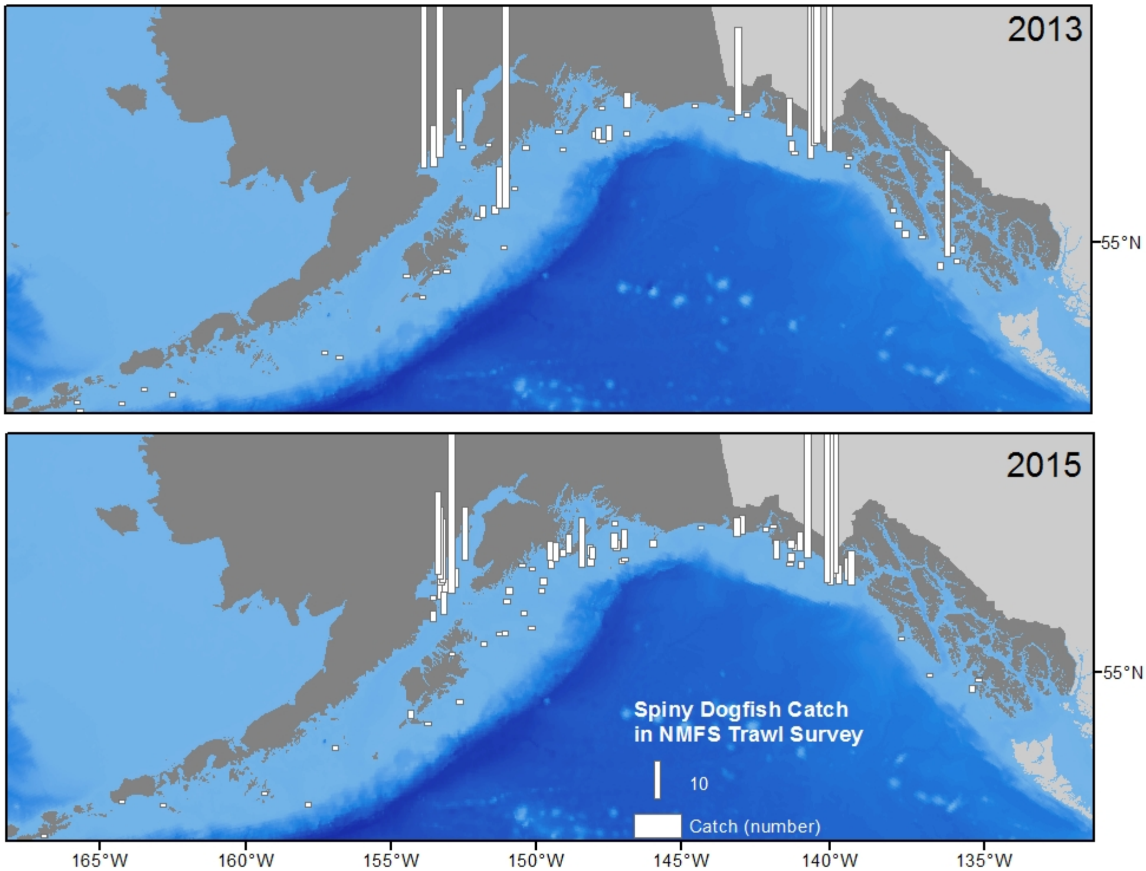

Figure 20.14. Spatial distribution of the catch of spiny dogfish during the 2013 and 2015 Alaska Fisheries Science Center biennial trawl survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

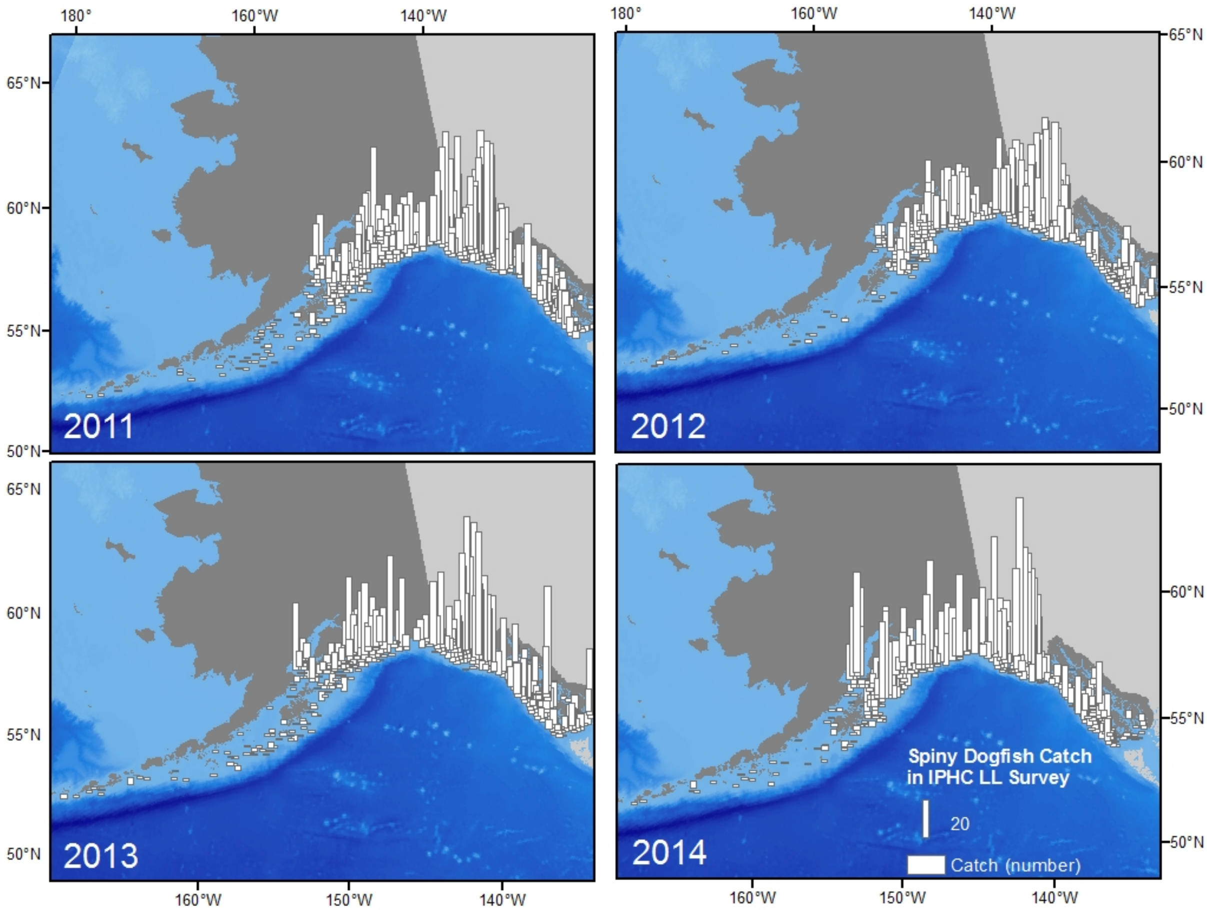

Figure 20.15. Spatial distribution of the catch of spiny dogfish during 2010 - 2014 International Pacific Halibut Commission (IPHC) longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

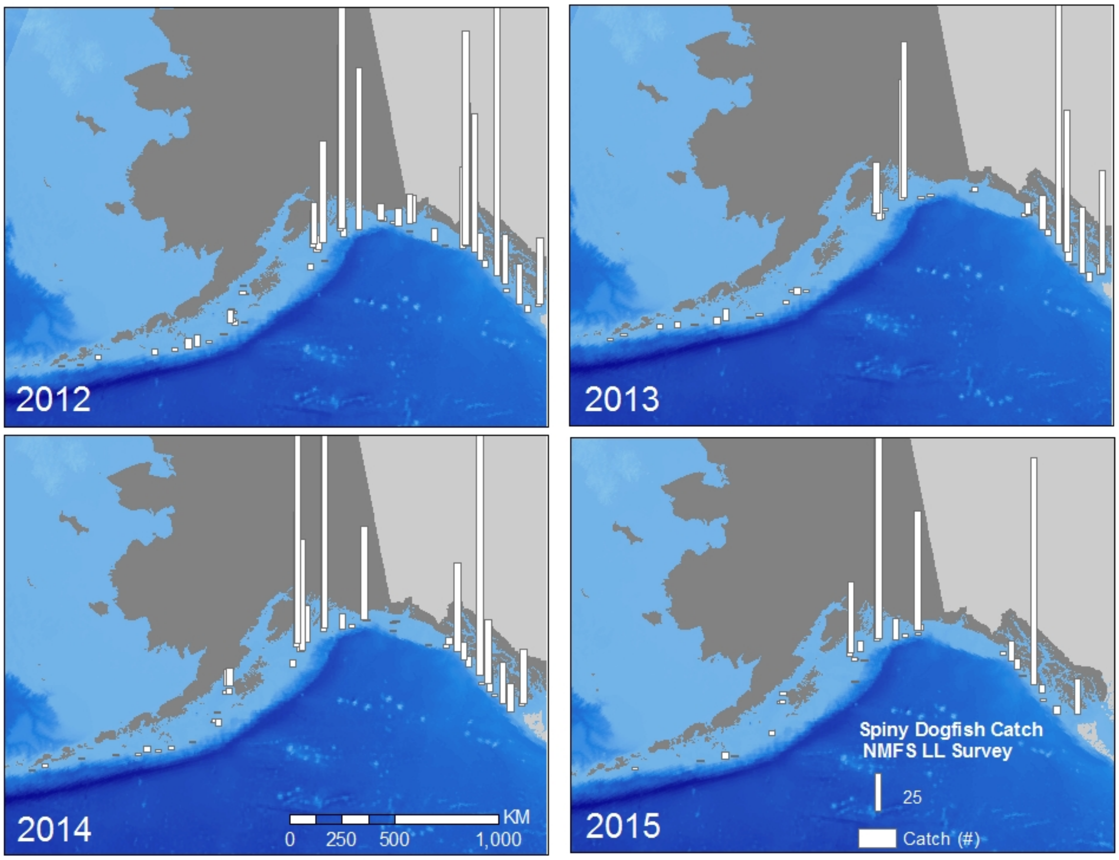

Figure 20.16. Spatial distribution of the catch of spiny dogfish during 2012 - 2015 Alaska Fisheries Science Center longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

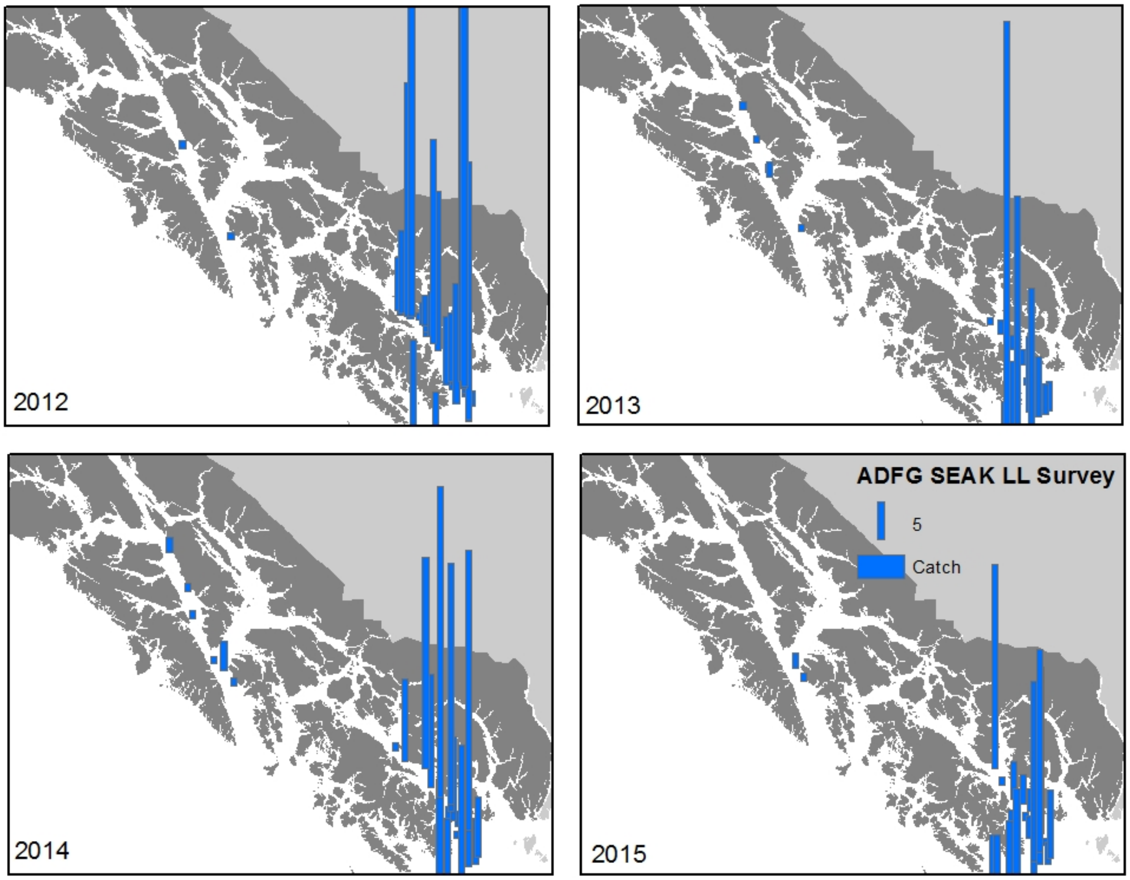

Figure 20.17. Spatial distribution of the catch of spiny dogfish during the 2012 - 2015 Alaska Department of Fish and Game (ADFG) longline surveys in Southeast Alaska. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

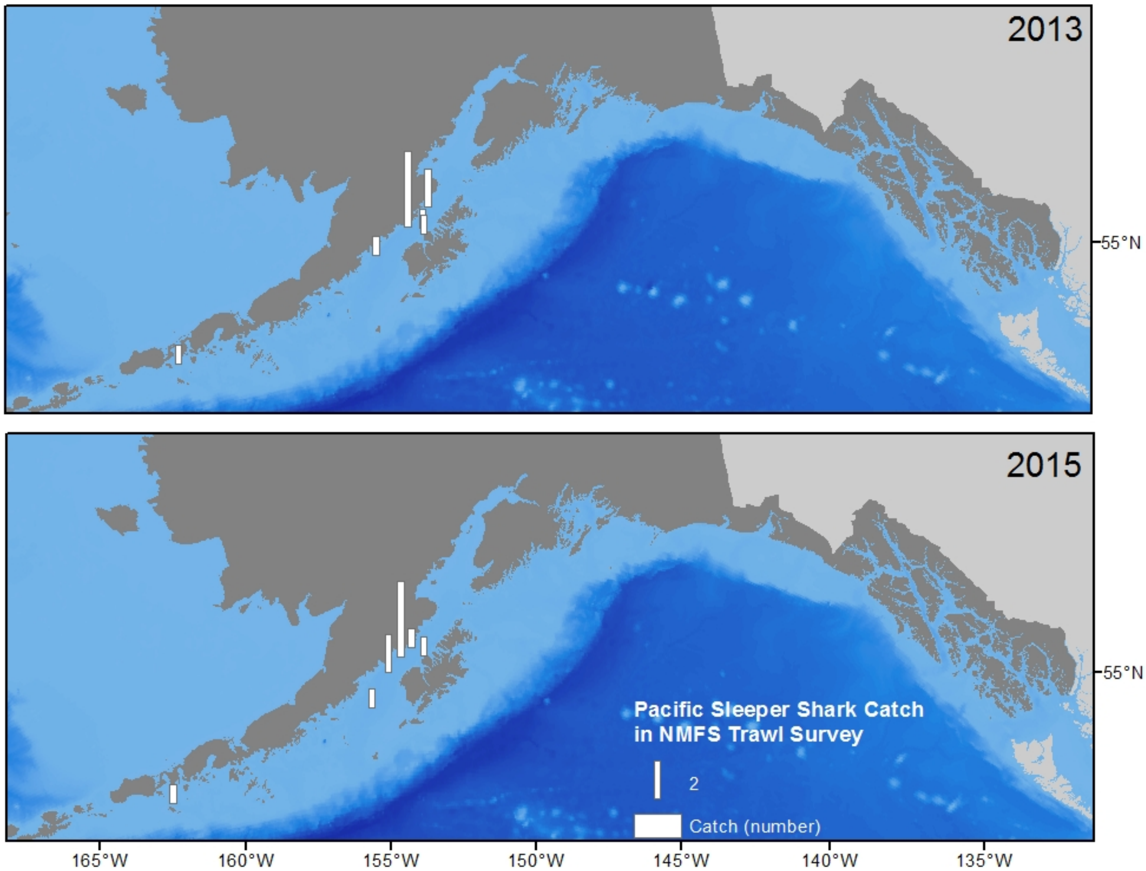

Figure 20.18. Spatial distribution of the catch of Pacific sleeper shark during 2013 and 2015 Alaska Fisheries Science Center biennial trawl surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

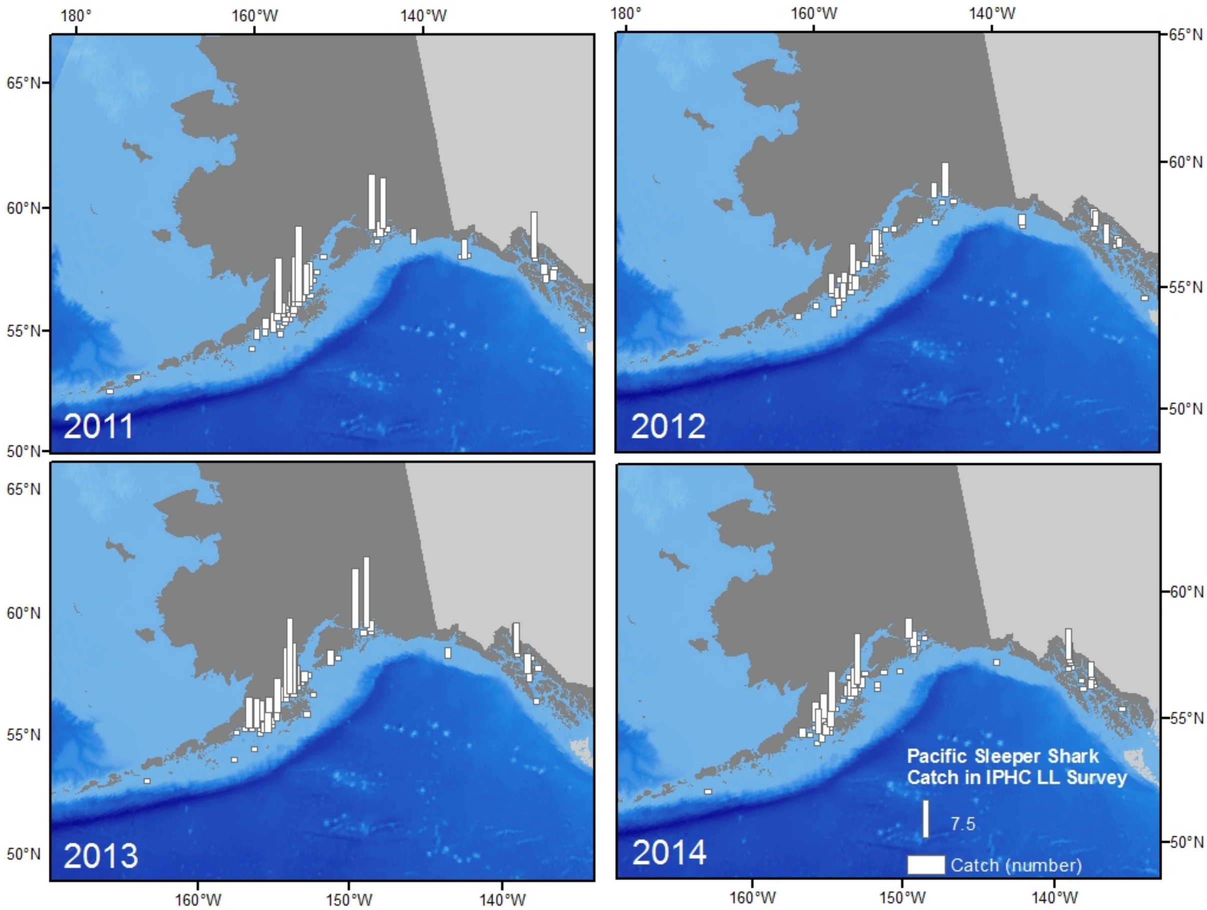

Figure 20.19. Spatial distribution of the catch of Pacific sleeper shark during the 2010 - 2013 International Pacific Halibut Commission (IPHC) longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

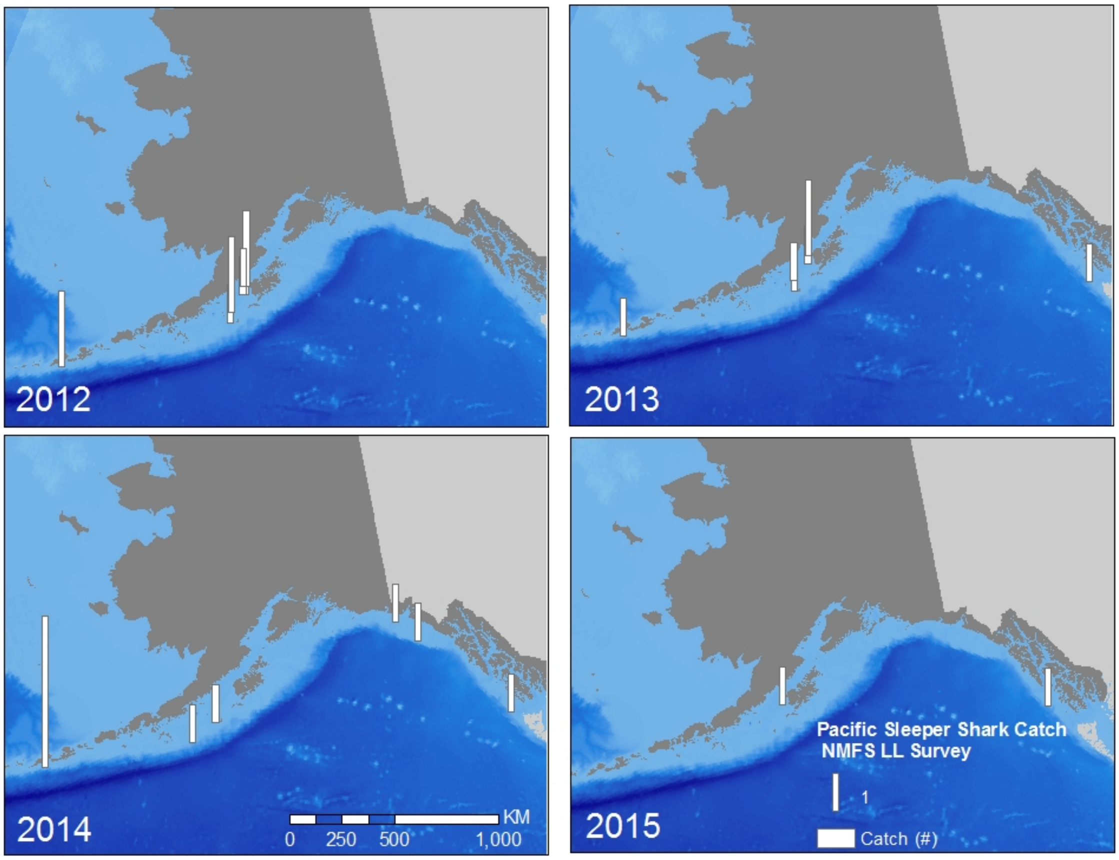

Figure 20.20. Spatial distribution of the catch of Pacific sleeper shark during the 2012 - 2015 Alaska Fisheries Science Center longline surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

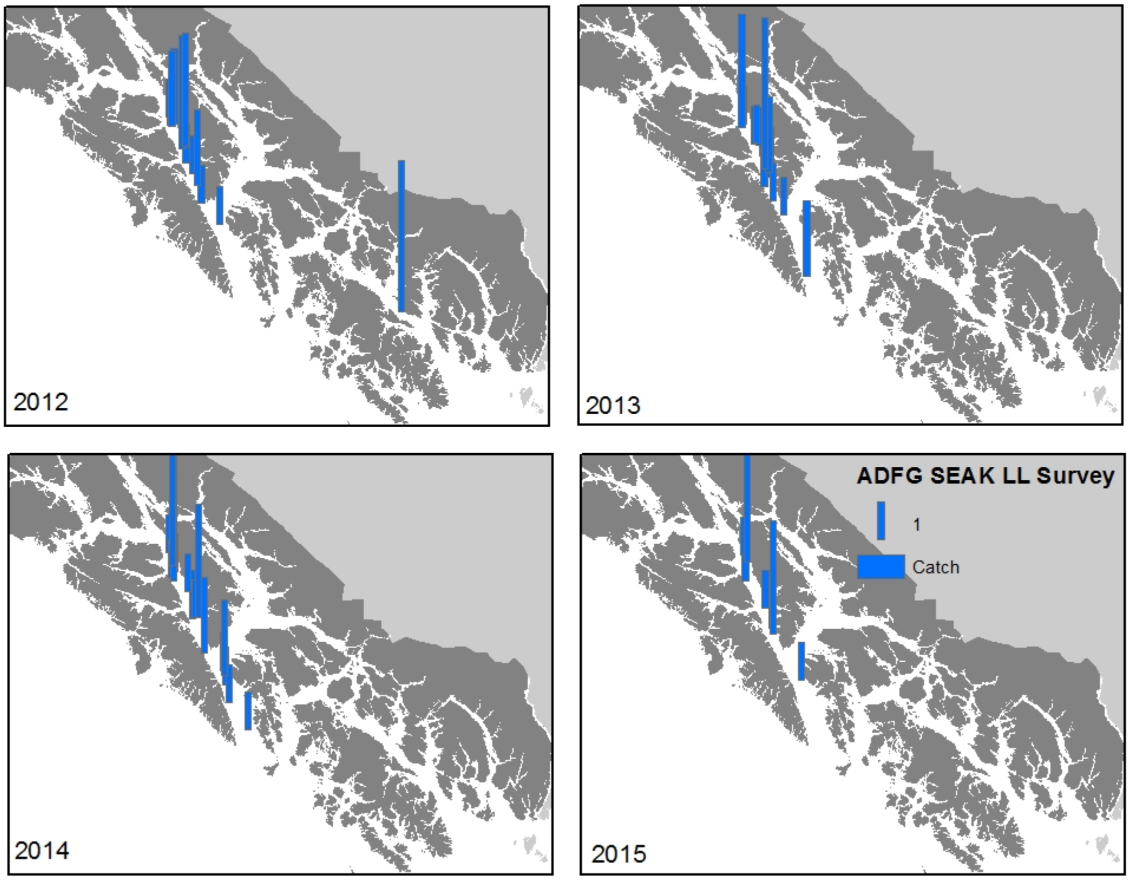

Figure 20.21. Spatial distribution of the catch of spiny dogfish during 2012 - 2015 Alaska Department of Fish and Game (ADFG) longline surveys in Southeast Alaska. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

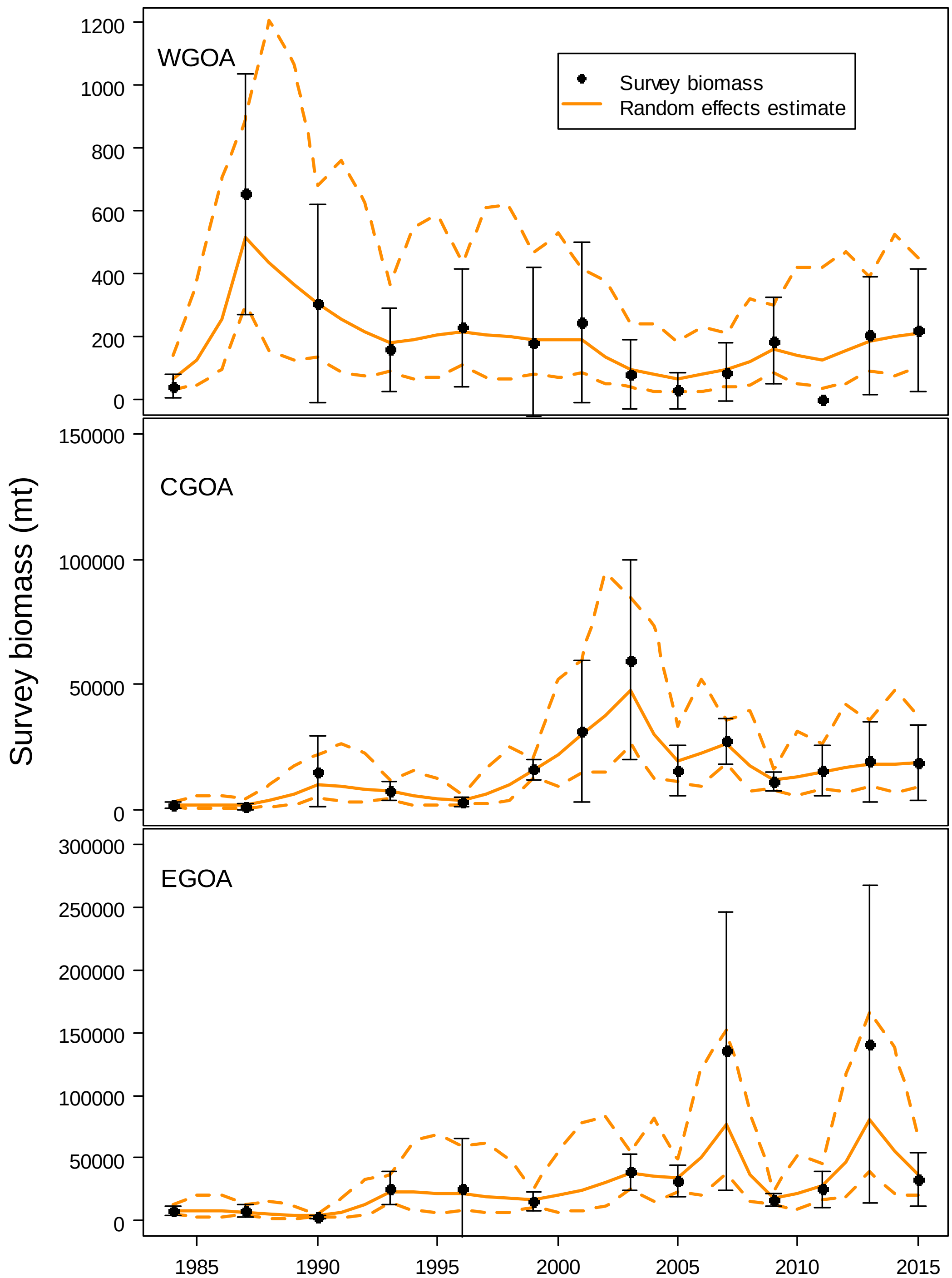

Figure 20.22. Fit of the random effects survey averaging to the Alaska Fisheries Science Center Gulf of Alaska (GOA) trawl survey biomass estimates by regulatory area (Western GOA, WGOA, Central GOA, CGOA and Eastern GOA, EGOA) for spiny dogfish. The black solid points are the survey biomass with 95% confidence intervals, orange line is the random effects estimated biomass and the dashed orange lines are the confidence intervals from the model.

Appendix 20A. Shark Catch After Observer Restructuring

Executive Summary

During the 2014 assessment cycle the authors of the shark assessment were requested to present an analysis of how the restructuring of the observer program impacted catches of sharks. The format of that analysis was well received and while not specifically requested in the Plan Team minutes, members have requested an update to that analysis in the 2015 assessment. The document presented here is the same as that from last year, with 2014 and 2015 (to date) catch estimates included. This analysis includes both the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) fishery management plan areas (FMP).

Questions regarding how shark catch may or may not have been impacted by observer restructuring can be paraphrased into four questions:

1) Is the new time series of estimates of shark catch comparable to the historical time series of estimated shark catch (pre – 2013)?
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) Is the new time series of estimates of shark catch comparable to the historical times series of estimated shark catch (pre – 2013)?

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 two analyses of the first years under the restructured program were presented at the June 2015 council meeting (Faunce et al. 2015, Gasper et al. 2015). The reports presented to the Council explain how the observer program changed and an evaluation of the data quality which resulted, 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 – 2015 (restructured observer program data, through October 15, 2015). 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 analysis will focus on spiny dogfish and Pacific sleeper shark. The majority of shark catch occurs in the GOA, hence this analysis 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 fishery discards – only landings. In 2013, modifications were made to CAS so that catch and bycatch estimates could be made for the Pacific halibut IFQ 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, but have declined since (Figure 20A.1) and the proportion of catch by the < 60 ft vessels has been greater since 2013 (Figure 20A.2). In the BSAI, the increase in estimated catch in 2013 was relatively small, and not persistent in the following years, similarly, the portion of the catch resulting from vessels < 60 ft was substantially larger in 2013 and declined in the following years (Figure 20A.1 & Figure 20A.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 (Figure 20A.1). 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 20A.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 catch 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 since 2013 than prior years.

With the exception of the 2006 and 2009 anomalies which were results of a single rate expansion, the estimated catch of sharks in areas 649/659 is increased since 2013 (Figure 20A.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 catch estimates since 2013 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 11% since (including catch of salmon shark and other/unidentified sharks because the TAC is at the complex level).

The catch estimates since 2013 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 the two time series. 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 federal 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 federal groundish species were landed, and estimates are based on both Pacific halibut and federal 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 estimates 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 no accounting of shark catch by the State of Alaska (other than in the recreational fishery, which is managed by the State) 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, as described above. The estimated shark catch in 649/659 over the entire time series is small relative to the other areas of the GOA (Figure 20A.4), however, since 2013 (including the current year thorugh October 15, 2015) has consistently been about 11 % of the total shark catch. Regardless, including the historical estimated catch from those areas, will have a small impact on the total estimated shark 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. As requested in the Plan Team minutes from both September and November 2014, the authors plan on re-running the HFICE estimates for the 2016 assessment cycle.

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 a short time series 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 GOA, 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 2014 was 1,552 t, of which 1,330 t was spiny dogfish, Figure 20A.5), as well as much of the ABC and OFL coming from that species (2014 ABC = 5,989 t, of which 5,562 t was from 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 (2014 total estimated shark catch = 136 t, of which 44 t was Pacific sleeper shark) is substantially lower than the ABC of 1,022 t (Figure 20A.5). Thus, the potential increase in catch from observer restructuring is unlikely to cause the shark catch in the BSAI to approach the ABC.

Acknowledgements

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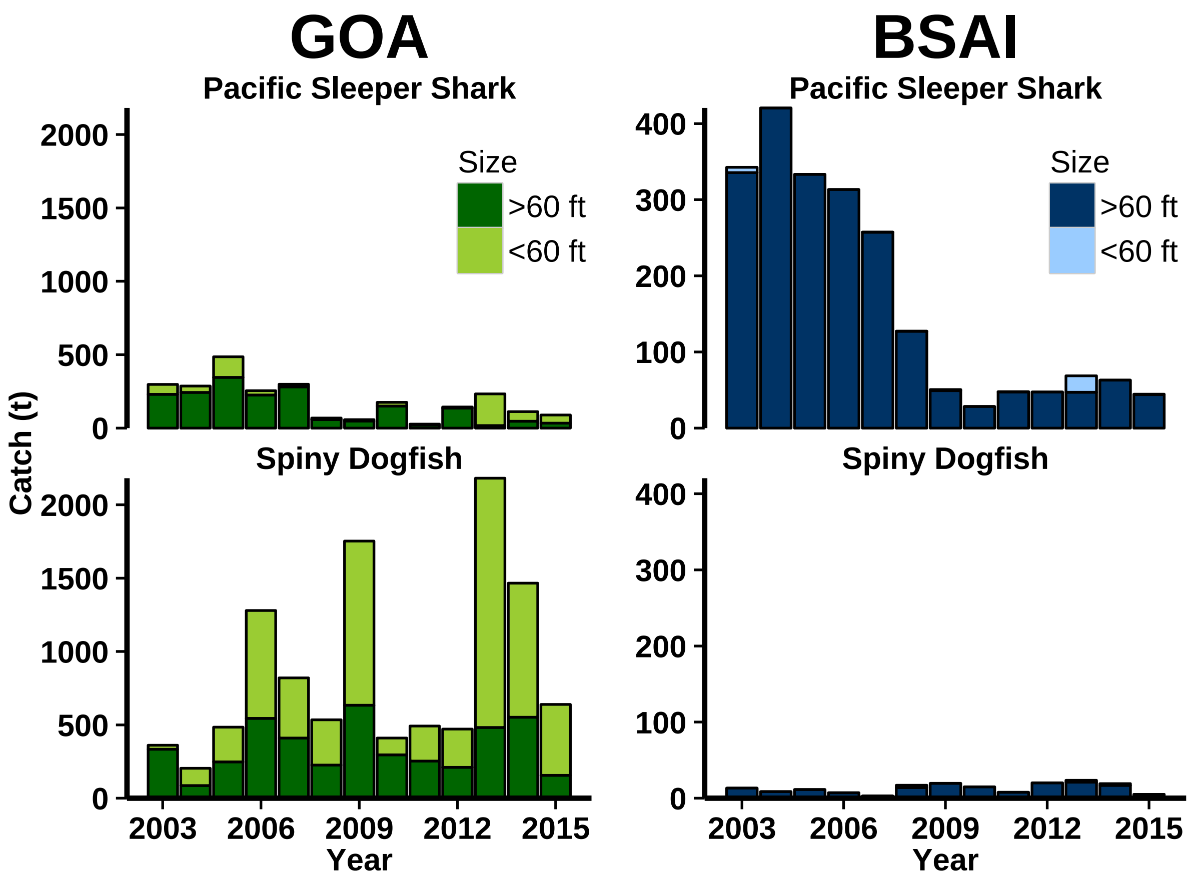

Figure 20A.1. Catch accounting system catch estimates (t) for Pacific sleeper shark and spiny dogfish in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) by vessel size class. Data queried on October 15, 2015, AKFIN.

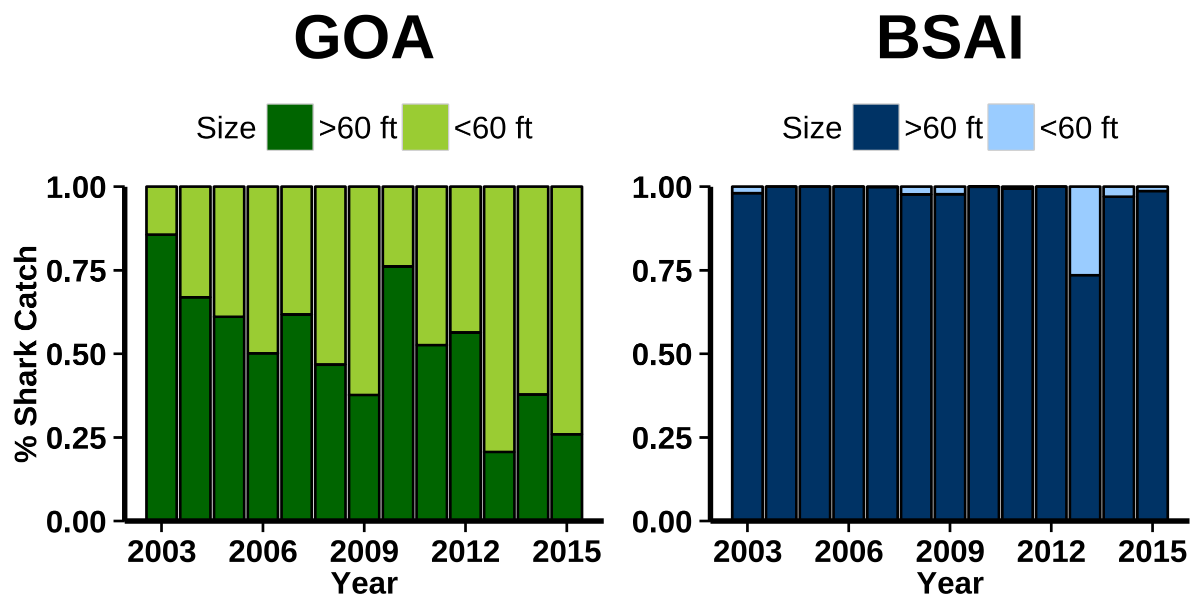

Figure 20A.2. Proportional representation of shark catch by vessel size in the Gulf of Alaska (GOA) and the Bering Sea/Aleutian Islands (BSAI). Data queried on October 15, 2015, AKFIN.

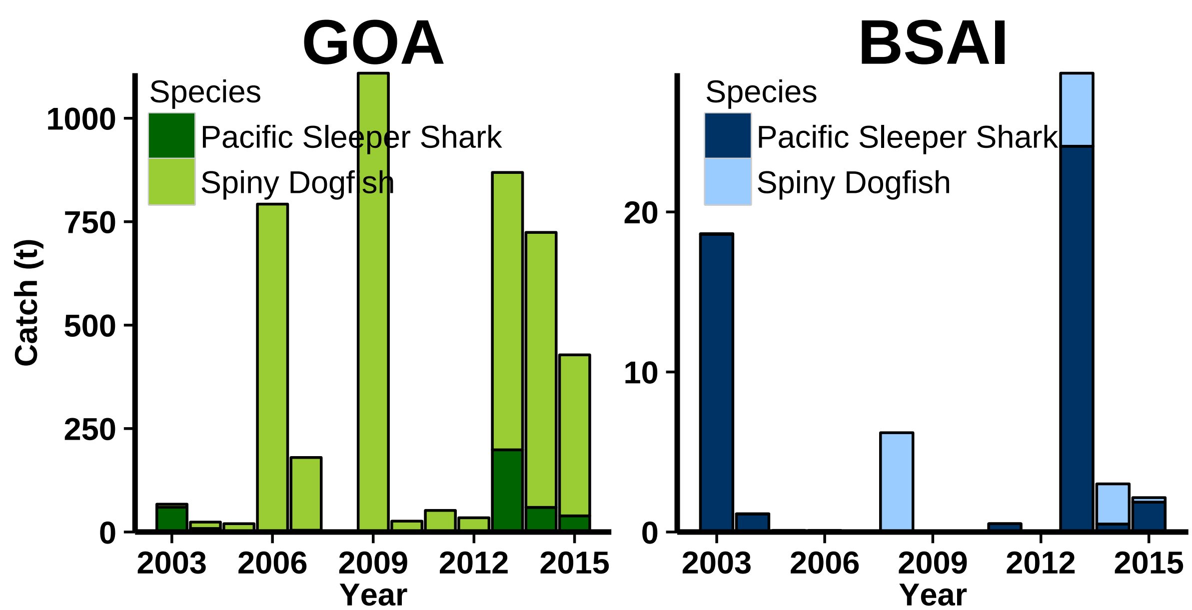

Figure 20A.3. Catch Accounting System catch estimates (t) of spiny dogfish and Pacific sleeper shark in the Pacific halibut target category in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI). Prior to 2013, estimated catch in the Pacific halibut target category results from vessels fishing both Pacific halibut and federal groundfish (generally sablefish IFQ), beginning in 2013 the estimated catches include vessels fishing only Pacific halibut IFQ. Data queried on October 15, 2015, AKFIN.

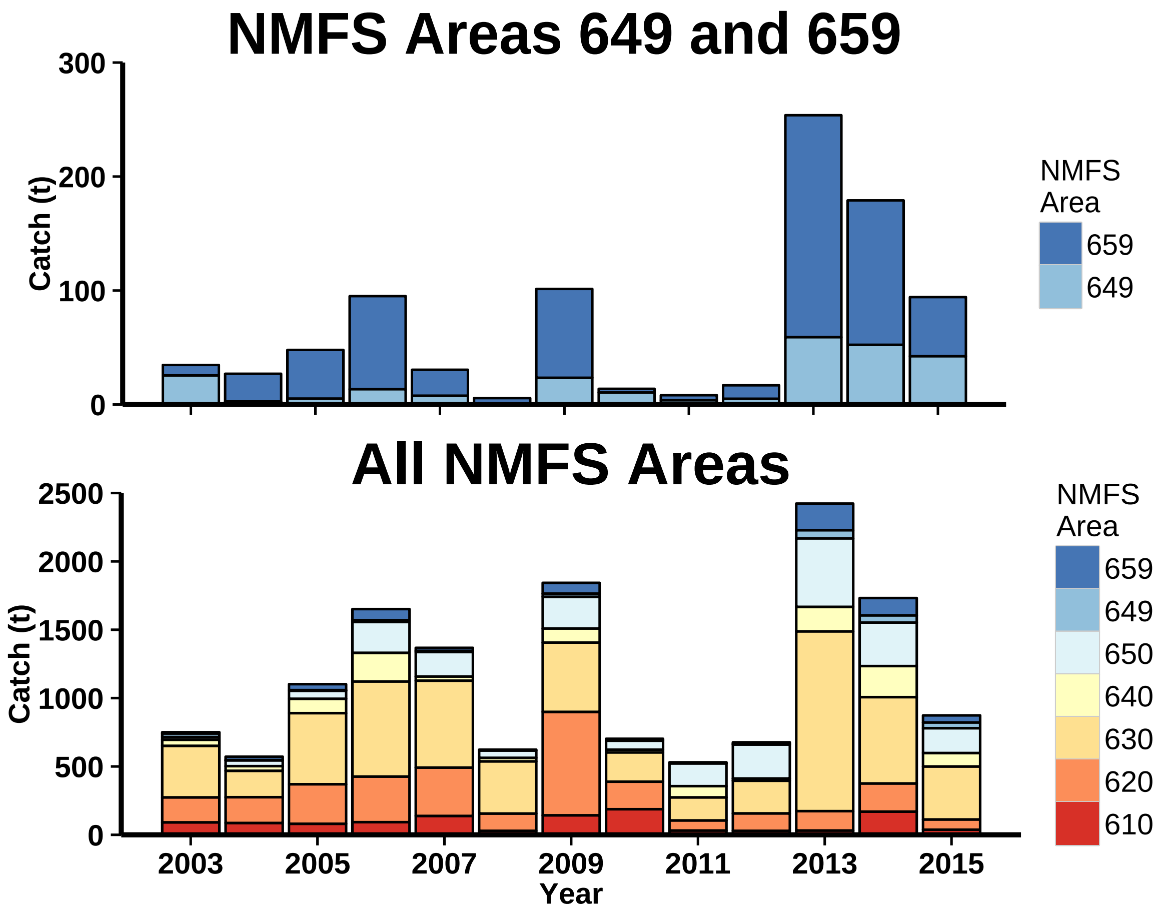

Figure 20A.4. Top panel: Catch accounting system catch estimates (t) for all sharks in the Gulf of Alaska NMFS Areas 649 and 659. Bottom panel: Catch accounting system catch estimates (t) for all sharks in all Gulf of Alaska NMFS Areas. Data queried on October 15, 2015.

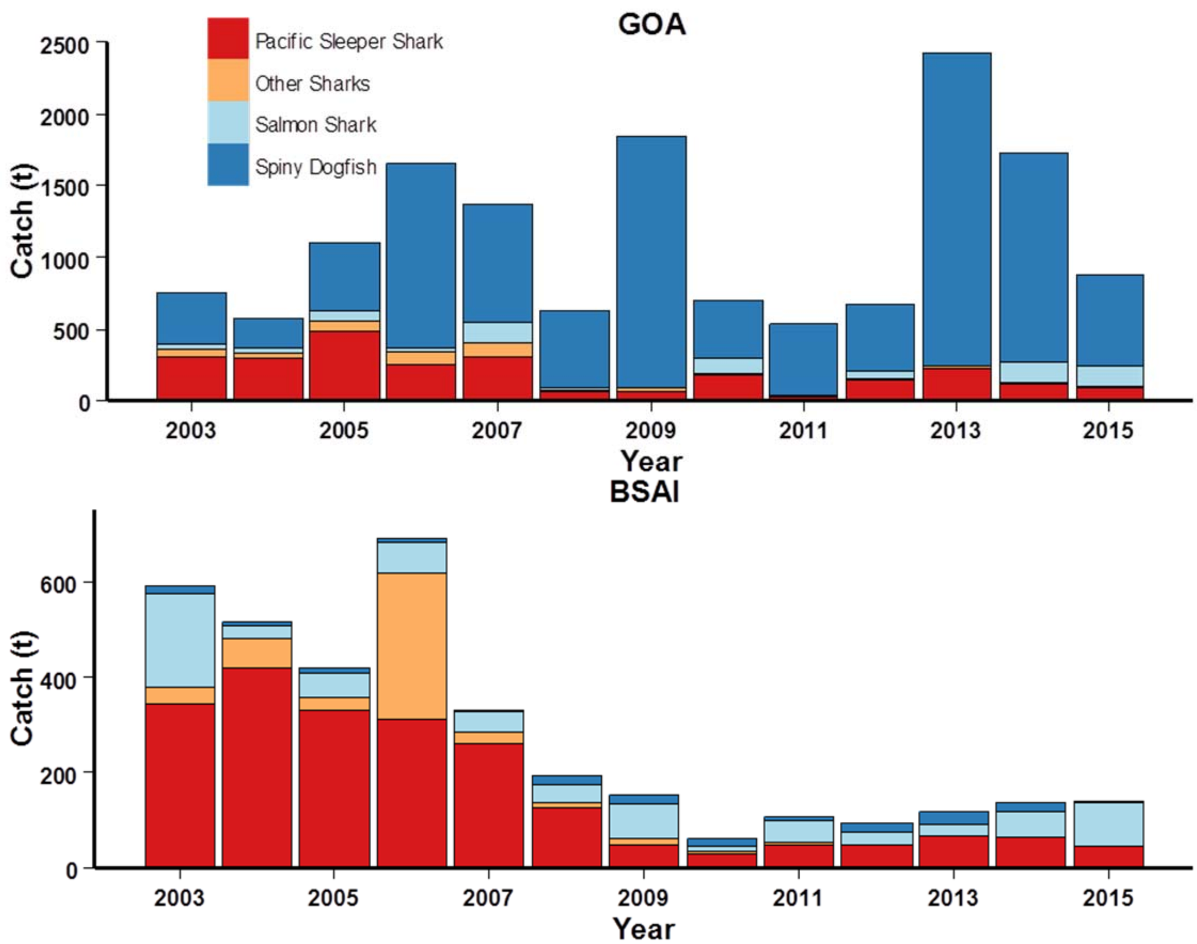

Figure 20A.5. Catch accounting system catch estimates (t) for all sharks in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI). Data queried on October 15, 2015, AKFIN.

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