Improving the Stock Assessments for the Shark Stock Complexes in the BSAI and GOA

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Executive Summary

Two main issues are being addressed in this document. The first is the outstanding issue of spiny dogfish catchability in the bottom trawl survey. Catchability has been estimated as a function of vertical availability and applied to the trawl survey biomass estimates. The authors recommend Model 15.3A, which would move the spiny dogfish to Tier 5 from their current status as a "modified" Tier 6. The current Tier 6* assessment methods use the standard Tier 5 approach where the overfishing limit (OFL) is based on the survey biomass multiplied by F (assuming that F = M). The second issue is a discussion of the accuracy of catch estimates of Pacific sleeper shark in longline fisheries. Preliminary results of a special project are presented.

SSC and Plan Team Comments Addressed in This Document

"*The PT also noted that it continues to endorse the FOFL=Fmax rate for the spiny dogfish ABC/OFL calculations as opposed to FOFL=M. The Fmax rate is based on a demographic analysis conducted by the author and published in Tribuzio and Kruse 2011. The author recommended the improved F rate in this assessment, however, the author recommends delaying implementation of using this F rate until trawl survey selectivity can be addressed in the next assessment.*" – GOA PT November 2015

"The author recommended delaying implementation of the Fmax from the demographic model until *concerns over the trawl survey gear efficiency can be addressed in the next assessment. The SSC and PT agreed with this delay and look forward to seeing it again at that time. The SSC requests the author bring the status quo methodology forward, in addition to Fmax from the demographic model, next year and to include the methodology for the demographic model in an appendix. The SSC agrees with the use of M=0.097 for the Tier 5 harvest specifications for the interim."* - SSC December 2015

"The Team recommended continued work on this alternative approach to developing an F recommendation (demographic model) as well as continued work on improving biomass estimates to be considered during the 2017 cycle (this will be presented at the September 2017 Team meeting)." – GOA PT September 2016

"*The SSC asks the authors to follow up on the following outstanding issues in future assessments:*
- Incorporation of a net efficiency study (Hulson et al., in review) that uses tag data to estimate survey catchability" – SSC Dec 2015 (note: bullets that have either already been addressed or are not part of this document were removed)

The above comments are addressed in the GOA spiny dogfish trawl survey catchability section.

"The Team recommends that the authors continue development of catch of sleeper sharks by numbers, if possible back to 2003, and examine the potential bias in average weight as applied to observed longline caught sleeper sharks." – BSAI PT November 2016

"The Team recommends the author continue with efforts to estimate catch by numbers including expanding the time series back to 2003 and pursue investigations into the average weight estimates used for larger sharks as well as instances where no weights are available for observed sharks." – GOA PT November 2016

"The SSC supports the Plan Team request to provide catch of sleeper sharks in numbers to better evaluate average weight and catch trends." – SSC December 2016

The above comments are discussed in the GOA/BSAI Pacific sleeper shark accuracy of catch estimates section. This work is still ongoing.

"*In response, the Plan Team recommended:*

1. *Bringing forward a PSS stock structure document (across both FMPs) to the Joint Plan Team in September 2018 due to concerns that PSS in BSAI and GOA are one stock with a potentially small effective population size and that they are long-lived and slow maturing*
2. *Coordinating with AKRO catch accounting staff to extend the time series of PSS catch by number of animals back to 2003 (Catch by weight alone may miss high catches of small animals)*
3. *Continuing to work on PSS genetics*
4. *Developing ageing methods for PSS*
5. *Implementing a special project in the observer program to quantify sizes of PSS caught in hook-and-line fisheries*" – GOA PT November 2017

A research update addressing #'s 1, 3 & 4 is provided in the GOA/BSAI Pacific sleeper shark research update section, and #'s 2 & 4 are discussed in the accuracy of catch estimates section.

GOA Spiny Dogfish

Trawl Survey Catchability

Catchability (q) of any gear is a function of the availability of an animal to the survey gear and the selectivity (S) of the gear, or the ability of the gear to catch available animals. Availability can be further broken down into horizontal (a_h) and vertical availability (a_v). Hulson et al. (2015) examined spiny dogfish satellite tagging data to estimate the vertical availability of the species to the AFSC bottom trawl survey gear using two methods. The first method, developed for Pacific cod, used archival tag depth data, which did not have associated location estimates, and assumed that the deepest depth reading of the tag during a 24 hour period was a proxy for bottom depth (the "depth" method, Nichol et al. 2007). The second method utilized tag geolocation estimates from the satellite tags (including estimated location uncertainty) with associated bathymetry (the "location" method, Hulson et al. 2015). The Hulson et al. (2015) study was presented to the GOA PT in September 2016. The team supported this research effort, and suggested binning tag depth data to match survey strata. Binning the depth data to match the survey depth strata was tested, but there was no change in the resulting estimates of vertical availability.

The vertical availability was estimated to be 3.1% (0-21%, 95% CI, location method) or 60.9% (4.2% - 100%, 95% CI, depth method). The location method is an improvement over the depth method for spiny dogfish for several reasons. The first is that while it may be a reasonable assumption that Pacific cod are on the bottom at some point during the day, this assumption is unlikely for spiny dogfish. Another is that the location method provided more precise estimates of vertical availability compared to the depth method. Thus, we do not recommend using the depth method. However, it is noted in Hulson et al. (2015) that there is substantial uncertainty in the location data. For this reason, we included the point estimate as well as the upper 95% confidence limit of the vertical availability, to capture the uncertainty surrounding the point estimate, (as a proxy of catchability) to compare with the status quo scenario, where all spiny dogfish are available (i.e., a_v = 0.031, 0.21 or 1).

Horizontal availability is based on the proportion of the GOA spiny dogfish population that is present within the survey area. Based on the tags used in the Hulson et al. (2015) study, about 55% of the point estimates of location during the survey time period were outside of the survey area, however, these point estimates were associated with considerable uncertainty, which often overlapped with surveyed areas. While this suggests that more than half of the spiny dogfish that were tagged within the survey area and during the survey months moved outside of the survey area for at least part of the survey months, an unknown number of spiny dogfish likely also move into the survey area. For example, a small number of spiny dogfish were tagged with satellite tags in Canadian waters, of which 11% (2 of 18 tagged fish) moved into the AFSC bottom trawl survey area during the summer months. Due to the limitations of the size of animal that can be tagged, these estimates may not be representative of the movement patterns for the full size range. Archival tag recoveries from fish that would have been too small for satellite tags suggests that smaller dogfish also have high potential for movement (>5,000 km, Voirol et al. in prep). Results of a tagging study conducted in Canadian waters, where a large number of spiny dogfish were tagged with conventional tags, also showed movement from Canadian waters into the GOA (McFarlane and King 2003). For the purposes of this estimation procedure we use $a_h = 1$ because there are data showing movement both into and out of the survey area.

A study of *Squalus acanthias* (a closely related species, previously considered the same species) suggested that trawl net efficiency is a function of how the swept area biomass is estimated (Rago and Sosebee 2009). In short, half of the *S. acanthias* encountered between the trawl doors escape capture, while all of the *S. acanthias* encountered between the trawl wings are captured. Rago and Sosebee (2009) suggest that the net efficiency is 100% when the swept area biomass is estimated using only the area between the wings, but that net efficiency is 50% when the area between the doors is included. The AFSC trawl survey estimates are based on the areas between the wings only, thus for estimating q for spiny dogfish, we are assuming that net efficiency is 100%.

We present the status quo model (15.1) and a series of scenarios based on the assumptions described above for the estimate of catchability (Model 15.2 - 15.3). To incorporate catchability into the biomass estimate of spiny dogfish we use the equation: B = q x Ba, where B is the AFSC trawl survey biomass (as estimated by the random effects model), q is the estimate of catchability, and Ba is the biomass adjusted by catchability that would be used to determine the overfishing limit and acceptable biological catch (OFL and ABC). Thus, Ba = B/q. In Model 15.1 (status quo), q = 1 and so Ba = B/q = B, where B is the random effects estimate of biomass. Models 15.2 - 15.3 are the different scenarios of 15.1, such that Ba = B/q. The biomass estimate, 56,181 t (35,484 – 88,950 t, 95% CI), from the most recent assessment (Tribuzio et al. 2015) is used.

Model	$q=a_v$	B (95% CI)	Ba (95% CI)
15.1	1	56,181 (35,484 – 88,950)	56,181 (35,484 – 88,950)
15.2	0.031	56,181 (35,484 – 88,950)	1,812,290 (1,144,645 – 2,869,355)
15.3	0.21	56,181 (35,484 – 88,950)	267,529 (168,971 – 423,571)

Due to the large uncertainty associated with the geolocation estimates, Hulson et al. (2015) recommended that using the point estimate of vertical availability may not be appropriate but that the uncertainty in the vertical availability estimate should be used as well, for example, as a prior for catchability estimation. In the current examples, a more conservative approach would be to use the upper confidence limit of vertical availability (0.21). For further examples of applying different fishing mortality rates we use 15.1 and 15.3 and do not present results from 15.2. Using the approach that incorporates q into the biomass estimation allows for the adjustment of biomass, as it is well recognized that the trawl survey biomass estimate of spiny dogfish should be considered as a minimum biomass estimate. For comparison, the NWFSC spiny dogfish assessment uses model estimated q for various trawl surveys ranging from 0.16 – 0.55 (Gertseva and Taylor, 2012).

Spiny dogfish are currently a Tier 6 species, but a Tier 5 approach is used because of the biomass challenges, which preclude it from meeting the requirements for Tier 5. In the 2015 full assessment the authors proposed using a different calculation for F than is standard for Tier 5 methods, where the fishing mortality rate (F) = natural mortality (M). The PT endorsed using F = Fmax from the demographic model, where F = Fmax = 0.04 (0.01-0.08, 95% CI, Tribuzio and Kruse 2011). Based on the authors' recommendation, the GOA PT delayed implementing that change until further investigations of q could be conducted (GOA GF Plan Team Minutes November 2015). Below is a comparison of the ABCs for status quo (15.1) and the alternative q case 15.3, along with using both the F = M and F = Fmax rates. For the sake of brevity, only Fmax = 0.04 is used; the confidence levels are not included. The ABC is calculated using the standard Tier 5 approach, ABC = Ba*F*0.75.

Model	F	Ba (95% CI)	ABC (95% CI)
15.1	0.097	56,181 (35,484 – 88,950)	4,087 (2,581 – 6,471)
15.1A	0.04	56,181 (35,484 – 88,950)	1,685 (1,065 – 2,669)
15.3	0.097	267,529 (168,971 – 423,571)	19,463 (12,293 – 30,815)
15.3A	0.04	267,529 (168,971 – 423,571)	8,026 (5,069 – 12,707)

Model 15.3A is the author recommended model for determining ABC/OFL for spiny dogfish. It should be noted that if Model 15.3A is accepted spiny dogfish could be moved to Tier 5. Model 15.3A accounts for the portion of the spiny dogfish present within the GOA that are not available to the survey, thus creating a "reliable" biomass estimate and meeting Tier 5 criteria. Model 15.3A also incorporates improved estimates of a sustainable F rate.

GOA/BSAI Pacific Sleeper Shark

Research Update

A Pacific sleeper shark (PSS) stock structure document across both FMPs was scheduled for September 2018, but will be delayed pending results of genetic analysis. Microsatellites have been developed and a publication is being prepared on the methods. A more detailed population genetics analysis is underway examining close kin mark recapture to estimate population size and examine relatedness.

A pilot study was begun to investigate the use of C14 in the eye lens as a means of ageing PSS, based on methods used to age Greenland sharks (Nielsen et al. 2016). Results are expected within two months. The investigators plan to apply for grant funding to support a student to take a more detailed look at the biochemistry of the eye and the uptake of C14 to validate the method.

Accuracy of Catch Estimates

A special project is being conducted during the 2018 longline fishery, where observers are classifying PSS into a size class (small, medium or large) based on measurements that they can take at the rail. To date, data from 28 PSS have been returned. Table 1 includes the size class of each specimen, the weight range associated with the size class (determined from length/weight conversion equations), and the mean weight used by CAS to estimate total catch for the haul the specimen was sampled on. The preliminary results suggest that the weight of medium and large sharks is being underestimated in longline fisheries. Further, except for when large animals are able to be brought aboard to be measured, the mean weight used in each of the size classes is similar. In the data available so far, 14 of 28 PSS were classified as either medium or large. These results suggest that the weight is underestimated for half of the PSS observed, and that the magnitude of the underestimation increases with the size of the shark. Therefore, the total catch estimates are likely biased low. The authors plan to request to continue this project for the 2019 fishery and to expand it to all gears. Expanding this project will hopefully provide information on the sizes of fish that the fisheries are encountering.

The AKRO have provided total catch estimates in numbers and in weight for PSS from 2011 – 2017. Preliminary investigations into total catch estimates of PSS by size suggest that much of the catch is composed of small PSS, especially in the BSAI, on both trawl and longline gears (Figure 1). While the reported small weight on longline gear is likely a function of the difficulty of weighing the large animals. It is unlikely that the trawl size estimates are biased because PSS caught on trawl vessels should be able to be measured more easily (either length converted to weight, or weight directly). Because the size of PSS are likely biased in longline gear fisheries, we are examining catch estimates in number. Efforts are underway to extend that time series back to 2003, however the structure of CAS is different prior to 2011 and estimating catch numbers prior to 2011 will require creating a separate estimation program, which is labor/time intensive and a low priority for the AKRO. Therefore, catch estimates in numbers may not be possible prior to 2011. In future work we plan to investigate how mean weight is utilized within NORPAC and CAS, if there are improved options for estimating mean weight on longline vessels (such as utilizing size bins), if utilizing catch by numbers in the assessment would be informative, and the biological impacts of catching large numbers of small animals as opposed to smaller numbers of large animals.

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Figures

Table 1. Summary of PSS observed size data, to date. Each shark_ID is an individual animal. In all but one case, the sampled shark(s) were a complete census of the PSS caught on the haul. The Obs_size is the observer estimated size class, Obs_wt is the weight range associated with that size class and the NORPAC_meanwt is the mean weight of sharks used to estimate total catch.

Shark_ID	Obs_size	Obs_wt	NORPAC_meanwt
1	L	>287	101.586667
2	L	>287	12.52
3	L	>287	13.35
4	L	>287	7.7
5	M	50-287	12.781429
6	M	50-287	12.355
7	M	50-287	15.783333
8	M	50-287	12.782
9	M	50-287	7.21
10	M	50-287	15.783333
11	M	50-287	6.274
12	M	50-287	6.274
13	M	50-287	6.274
14	M	50-287	7.5
15	S	<50	15.636667
16	S	<50	9.776667
17	S	<50	12.78
18	S	<50	9.663333
19	S	<50	15.635556
20	S	<50	14.1675
21	S	<50	16.876667
22	S	<50	15.883333
23	S	<50	5.95
24	S	<50	15.635
25	S	<50	15.783333
26	S	<50	15.636667
27	S	<50	16.083333
28	S	<50	15.635556

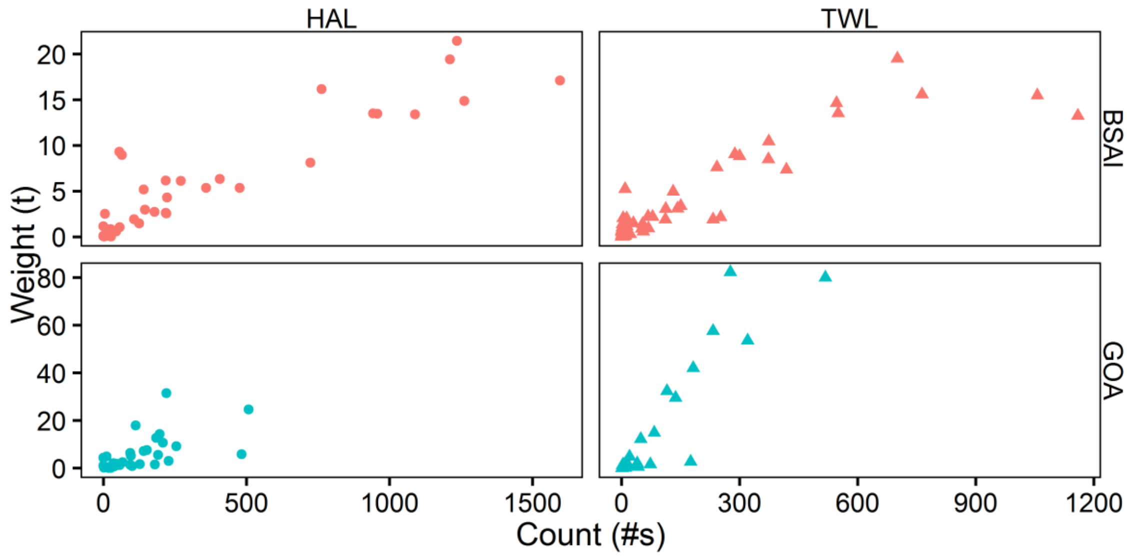

Figure 1. Total estimated catch in tons and numbers. Each dot is a NMFS area and year.