Alternative Tier 6 Shark Stock Complex Models for the Bering Sea/Aleutian Islands and the Gulf of Alaska

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EXECUTIVE SUMMARY

The models for the Tier 6 components of the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Shark Stock Complexes are based on historical catch data. The Groundfish Plan Teams and the SSC have both requested explorations of data-limited assessment methods (DLMs) for these stocks. However, there are a number of considerations that need to be taken into account to apply DLMs to for some of the Tier 6 species, which cannot be remedied at this time.

This analysis examines the utility of two proposed models for Pacific sleeper sharks that focus on the most recent time series or utilize expert knowledge and accessory information. Additionally, an updated catch model is proposed for other/unidentified sharks in both FMPs and for spiny dogfish in the BSAI. This updated model reduces the influence of extreme or unlikely catch values due to rare occurrences or errors in the data series.

Introduction

There are two Shark Stock Complexes in Alaskan waters: the Bering Sea/Aleutian Islands (BSAI) Shark Stock Complex, which is comprised of all Tier 6 species; and the Gulf of Alaska (GOA) Shark Stock Complex, which is comprised of Tier 5 spiny dogfish and the remaining species are all Tier 6. The Tier 5 GOA spiny dogfish are not included in the analysis reported here. The Tier 6 Shark Stock Complexes in each of the Fishery Management Plans (FMPs) are assessed using historical catch data. However, the methodological approach of incorporating historical catch data for the Tier 6 species within the complexes is different between the FMPs. In the BSAI, the overfishing limit (OFL) is the maximum historical catch of all species within the complex. In the GOA the average catch is calculated for each species which are then summed to generate the OFL for the Tier 6 component of the complex. Different time series are used for each FMP due to limited availability of historical data (see previous assessments for details). Both the Plan Teams and the SSC have requested examinations of data-limited models (DLMs) for the Shark Stock Complexes:

"The Teams encourage continued exploration of utilizing data limited methods for this assessment." (JGPT September 2018)

"The SSC agrees with the JGPT for continued exploration of utilizing data limited methods for this assessment. The SSC further recommends in addition to sharks, it would be helpful for the Plan Teams and other authors of Tiers 5 and 6 stocks to explore the increasing number of methods available for data limited situations." (SSC October 2018)

"The Team accepted the author's choice of OFL and ABC (the same as 2017 and 2018) and looks forward to the author's new analysis with a greatly expanded set of data-limited methods for 2020" (PT November 2018)

"For the next full assessment in 2020, the SSC looks forward to the authors' new analysis with a greatly expanded set of data-limited methods." (SSC December 2018)

The analysis presented in this document addresses the above requests as well as recommendations brought forward in the Pacific sleeper shark stock structure document. Additionally, an updated catch model is proposed for other/unidentified sharks in both FMPs and for spiny dogfish in the BSAI. This updated model reduces the influence of extreme or unlikely catch values due to rare occurrences or errors in the data series.

The current approach to assessing the Pacific sleeper shark in both the BSAI and GOA uses rudimentary catch scalars. The model assumes that fishery behavior 20+ years ago is representative of fishery behavior today and that trends in catch are representative of trends in abundance. The historical average catch and subsequent maximum catch approaches, as defined by Restrepo et al. (1998), were meant to be based on a time period with evidence of stable abundance. At this point, there are no data supporting the assumption that abundances are stable during either the Pacific sleeper shark catch or index time series. Current data are not included in either of the Pacific sleeper shark models, and in some cases, current catches are consistently and substantially lower than historical catches. It is unlikely that historical fishery behavior adequately represents current fishery behavior or even data quality, and recent data need to be incorporated into the assessment model. Following the assumption that catch trends are representative of abundance also suggests that the current trends in catch need to be taken into consideration for the assessment model. Pacific sleeper shark are non-targeted and primarily discarded, however, they are generally not actively avoided either. Further, the IPHC survey index shows a similar trend to catch of Pacific sleeper shark, suggesting that the assumption that catch trends may represent abundance trends is not unreasonable. Lastly, the buffer between OFL and ABC is meant to be informed by expert judgement if quantitative data are not available (Restrepo et al. 1998, Berkson et al. 2011). Restrepo et al. (1998) recommended buffers from 25% - 75% and, based on simulations of more data informed species, recommended a default buffer of 75% *for stocks judged to be above* B_{MSY}. This buffer is meant to be based on the stock status relative to B_{MSY}, as informed by qualitative or quantitative information, and account for uncertainty in the OFL estimator. The current NPFMC Tier 6 models adopted the 75% buffer. These type of assessment frameworks have a high risk of resulting in overfishing (e.g. Carruthers et al. 2014) and may be improved upon by using contemporary data-limited methods (DLMs).

Two DLMs for Pacific sleeper shark are reviewed, the Only Reliable Catch Series (ORCS) model (Berkson et al. 2011, later updated and refined by Free et al. 2017) allows for qualitative information to be used in the assessment model. In this framework the assessor averages the scores of several stock attributes to determine the stock status as: underexploited, fully exploited or overexploited. The OFL is calculated from the catch statistic appropriate to the stock status multiplied by a scalar selected based on the percentile value that satisfies the risk tolerance. Additionally a constant catch (CC) method is explored that provides stability to data-limited OFLs while accounting for recent trends in catch. The CC method OFLs are scaled most recent 5-year mean catch (Geromont and Butterworth 2015). The CC methods assume that catch data are known without error and that trends in catch data reflect trends in species abundance (Geromont and Butterworth 2015).

Catch estimates of rare species such as other/unidentified sharks or BSAI spiny dogfish are sensitive to the occasional "large haul" which results in large and unlikely estimated catch. For example, in 2006, there were two hauls which reported unusually high catches of unidentified sharks and resulted in an annual estimated catch well outside the range for that species category (Figure 1). By using the 90th percentile of the catch time series instead of the maximum historical values it is possible to avoid the influence of "large hauls".

Analytic Approach

Model Structure

The status quo models for the BSAI and GOA Tier 6 Shark Stock Complexes are described below. The entire complex models are included here because the BSAI model does not consider the individual species. The time series of estimated catch is *C* of species *s*. The BSAI model is 16.0 and the GOA model is 11.0, signifying the first year each of those models went into effect. The more recent and abbreviated time series in the BSAI is due to substantial concerns regarding the accuracy of catch estimates prior to 2003.

FMP	Tier 6 Model	OFL	Equation
BSAI	16.0	Max complex catch 2003–2015	$OFL = max(C_{2003-2015})$
GOA	11.0	Sum of species specific mean catch from 1997–2007	$OFL = \sum_{1}^{s} \bar{C}_{1997-2007}$

Description of Alternative Models

Pacific sleeper shark models

The below models are intended for use in both FMPs and are named by the species, PSS for Pacific sleeper shark, year, and model number. The Only Reliable Catch Series (ORCS) model (Berkson et al. 2011; later updated and refined by Free et al. 2017) is based on an assessor evaluated score for a number of stock attributes (Table 1). These scores are then averaged to determine the stock status as: underexploited, fully exploited or overexploited. The OFL is calculated from the catch statistic appropriate to the stock status multiplied by a scalar selected based on the percentile value that satisfies the risk tolerance (Table 2). The model structure is as follows:

Model	OFL	Equation
PSS22.0	Refined ORCS	$OFL = \begin{cases} s * C_{under}, C_{under} = \; ith\ observation = \; 0.9(n_{all\ years} + 1) \\ s * C_{fully}, C_{fully} = \; ith\ observation = \; 0.25(n_{prev\ 10yrs} + 1) \\ s * C_{over}, C_{over} = \; ith\ observation = \; 0.1(n_{all\ years} + 1) \end{cases}$

where *C* represents catch statistics for under, fully, and overexploited status, *s* is the risk tolerance scalar from Table 2 and *n* is the number of years in the time series. Pacific sleeper shark in each FMP were given conservative and liberal scores for each attribute then the stock status determined from the mean score. In this analysis, the percentile scalar that should promote a 50% probability of overfishing if the stock status is correctly identified was chosen.

In the constant catch (CC) model (Geromont and Butterworth 2015) the OFL is a scaled most recent 5-year mean catch with the scalar reduced as risk aversion increases. The model structure is as follows:

Model	OFL	Equation
PSS22.1	CC1: OFL is average historical catch from recent 5 years	$OFL = x\bar{C}, x = 1\ and$ $\bar{C} = \frac{\sum_{y=t-4}^{t} C_y}{5}$
PSS22.2	CC2: OFL is 90% of average historical catch from recent 5 years	Same as 22.1 with x = 0.9
PSS22.3	CC3: OFL is 80% of average historical catch from recent 5 years	Same as 22.1 with x = 0.8
PSS22.4	CC4: OFL is 70% of average historical catch from recent 5 years	Same as 22.1 with x = 0.7
PSS22.5	CC5: OFL is 60% of average historical catch from recent 5 years	Same as 22.1 with x = 0.6

Other/unidentified sharks and BSAI spiny dogfish

Using the 90th percentile of the catch time series instead of the maximum historical values will avoid undue influence from large or misreported hauls. The model BSAI22.0 would be applied to other/unidentified sharks and spiny dogfish in the BSAI and the GOA22.0 model would be only for other/unidentified sharks in the GOA. The years of the historical catch time series are maintained from previous assessments, i.e., BSAI is from 2003 – 2015 and the GOA is from 1997 – 2007.

FMP	Model	OFL	Equation
BSAI	BSAI22.0	90th Percentile of historical catch 2003 - 2015	$OFL = \ ith\ observation = \ 0.9(n+1)$
GOA	GOA22.0	90th Percentile of historical catch 1997 -2007	Where n is number of years

Results

Model Evaluation

Pacific sleeper shark models

The current Tier 6 models are different between the FMPs and the two FMPs treat the complexes differently, therefore any model evaluation must consider the full complement of Tier 6 species. In the BSAI Tier 6 model (16.0) the OFL equals the maximum historical catch of the full complex, whereas the GOA model (11.0) is the summed species-specific OFLs, which are equal to the mean catches for the individual Tier 6 species. Results of the Tier 6 models from the most recent assessment are below.

FMP	Tier 6 Model	OFL	ABC
BSAI	16.0	689	517
GOA	11.0	570	427

About a decade ago, a NOAA working group evaluated catch-only stock assessments and provided guidance based on DLMs available at that time (Berkson et al. 2011). While the DLM resources available today are substantially expanded from those available to Berkson et al. (2011), the guidance is still relevant. In cases where depletion-based stock reduction or depletion-corrected average catch are not available, the ORCS approach is warranted. The time series of catches for the Tier 6 sharks in Alaska are too short for any of the depletion estimators. The ORCS approach follows the concept of “pretty good yield” (Hilborn 2010) and assigns stocks to one of three exploitation categories using evidence-based scoring (Table 1), then calculates and OFL by using statistically supported catch metrics and scalars (Table 2, Free et al. 2017). The ORCS approach was reviewed and updated with extensive simulation testing, resulting in the refined ORCS (Free et al. 2017).

For this analysis, Pacific sleeper shark were scored in each FMP with both liberal and conservative scores. In all cases, the mean score placed the species in the "Fully Exploited" category, regardless of liberal or conservative approaches to scoring. For the remaining discussion only one score per FMPs will be referenced. Because Pacific sleeper sharks were "Fully Exploited" in both FMPs, an OFL was calculated for each FMP using the 25th percentile of the most recent 10 years of catch and a default scalar that should promote 50% probability risk of overfishing assuming the stock status was correctly identified. The 75% ABC buffer was retained in this analysis assuming that because all stocks were considered "Fully Exploited" they are at or above B_{MSY}. This assumption is worth revisiting should this model proceed, given the low productivity of the stock. See Table 3 for the detailed results. The refined ORCS summary results are below.

FMP	Model	OFL	ABC
BSAI	PSS22.0	117	88
GOA	PSS22.0	197	148

The CC models also assume that catch trends represent abundance trends, but go further to assume that annual changes in catch are not due to noisy data and catches are known without error (Geromont and Butterworth 2015). The first two assumptions are reasonable for Pacific sleeper shark, however, preliminary ongoing research has demonstrated that catch is likely not known without error. Catch estimates are likely underestimated due to the challenges of accurately weighing such large species (K. Fuller unpublished data, Tribuzio et al. 2020). The summarized CC model results are below:

FMP	Model	OFL	ABC
BSAI	PSS22.1	59	44
	PSS22.2	53	40
	PSS22.3	47	35
	PSS22.4	41	31
	PSS22.5	35	26
GOA	PSS22.1	134	100
	PSS22.2	121	91
	PSS22.3	107	80
	PSS22.4	94	70
	PSS22.5	80	60

Other/unidentified sharks and BSAI spiny dogfish

Using the 90th percentile of the historical times series for GOA and BSAI other/unidentified sharks and BSAI spiny dogfish, results are:

FMP	Model	OFL	ABC
BSAI	BSAI22.0 (Other)	55	41
	BSAI22.0 (Spiny)	20	15
GOA	GOA22.0 (Other)	123	92

Recommendations

For the full 2022 assessment we recommend bringing forward the below Tier 6 models:

Species	FMP	Model
Pacific sleeper shark	BSAI	16.0 (Status Quo) PSS22.0
	GOA	11.0 (Status Quo) PSS22.0
Other/unidentified sharks	BSAI	16.0 (Status Quo) BSAI22.0
	GOA	11.0 (Status Quo) GOA22.0
Spiny dogfish	BSAI	16.0 (Status Quo) BSAI22.0

The CC models for Pacific sleeper shark are not recommended because of the assumption that catch is known without error, and because those models do not take into account accessory information.

The status quo harvest recommendations from the 2020 full assessments are below. The BSAI total Shark Complex maximum, OFL and ABC are not the sum of the species, but the value for the complex in aggregate. The species-specific values are shown for comparison.

BSAI	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Spiny dogfish	Total shark Complex*
Tier	6	6	6	6	6
Model	16.0	16.0	16.0	16.0	
Maximum Catch (t)	421	199	305	24	689
OFL	421	199	305	24	689
ABC	315	149	229	18	517

The GOA Shark Stock Complex harvest recommendations are the sum of the individual species recommendations and spiny dogfish is a Tier 5 species.

GOA	Pacific Sleeper Shark	Salmon Shark	Other/Unid Sharks	Spiny Dogfish	Total Complex
Tier	6	6	6	5	5/6
Model	11.0	11.0	11.0	15.3A	
Mean Catch (t)	312	70	188		
OFL	312	70	188	4,436	5,006
ABC	234	53	141	3,327	3,755

Based on the data from the 2020 full assessments, the proposed alternative model harvest recommendations are below. In this case, all Tier 6 species are using the same methods and the same approaches to complexes across both FMPs.

BSAI	Pacific sleeper shark	Salmon shark	Other sharks	Spiny dogfish	Total Complex
Tier	6	6	6	6	6
Model	PSS22.0	16.0	BSAI22.0	BSAI22.0	
Stock Status	Fully Expl.				
Catch Statistic	53.99				
50th Percentile Scalar	2.16				
OFL	117	199	55	20	451
ABC	88	149	41	15	293

GOA	Pacific sleeper shark	Salmon shark	Other sharks	Spiny dogfish	Total Complex
Tier	6	6	6	5	5/6
Model	PSS22.0	11.0	GOA22.0	15.3A	
Stock Status	Fully Expl.				
Catch Statistic	53.99				
50th Percentile Scalar	2.16				
OFL	197	70	123	4,436	4,826
ABC	148	53	92	3,327	3,620

One of the recommendations that came out of the Pacific sleeper shark stock structure document was to separate the GOA spiny dogfish ABC from the Tier 6 species ABCs within the GOA Shark Stock Complex assessment. The stock structure document discussed separating the Pacific sleeper shark ABC from the rest of the BSAI species, however, it is confounded with other/unidentified sharks because many of the unidentified sharks are believed to be Pacific sleeper shark; therefore, separation is not recommended in that FMP. The proposed GOA spiny dogfish and Tier 6 ABCs based on the 2020 full assessment are below and catch relative to the status quo ABC and the below alternative ABCs are in Figure 2.

GOA	Spiny Dogfish	Tier 6	Total Complex
OFL			4,826
ABC	3,327	293	3,620

References

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Tables and Figures

Table 1. ORCS Table of attributes used in this analysis. Adapted from Table 1, Free et al. (2017).

#	Attribute	Stock status[a]		
		Underexploited (1)	Fully exploited (2)	Overexploited (3)
1	Status of assessed stocks in fishery	<10% overfished	10–25% overfished	>25% overfished
2	Behavior affecting capture	----------	No aggregation behavior	Exhibits aggregation behavior
3	Discard rate	Discards <10% of catch	Discards 10–25% of catch	Discards >25% of catch
4	Targeting intensity	Not targeted	Occasionally targeted	Actively targeted
5	M compared to dominant species[b]	Higher mortality rate	Equivalent mortality rates	Lower mortality rate
6	Occurrence in catch	Sporadic *(in <10% of efforts)*	Common *(in 10–25% of efforts)*	Frequent *(in >25% of efforts)*
7	Value (US$/lb, 5-year mean)	<$1/lb	$1-$2.25/lb	>$2.25/lb
8	Recent trend in catch	Increasing last 5 years	Stable last 5 years	Decreasing last 5 years
9	Habitat loss	No time in threatened habitats	Part time in threatened habitats *(full time in partially threatened habitats)*	Full time in threatened habitats
10	Recent trend in effort	Decreasing last 5 years	Stable last 5 years	Increasing last 5 years
11	Recent trend in abundance index	Increasing last 5 years	Stable last 5 years	Decreasing last 5 years
12	Proportion of population protected	Most of resource is protected *(size limits AND time/space closures)*	Some of resource is protected *(size limits OR time/space closures)*	None of resource is protected *(no size limits or time/space closures)*

[a] In the original ORCS approach, stock status is estimated as the mean of the TOA scores (<1.5=underexploited; 1.5–2.5=fully exploited; >2.5=overexploited).

[b] Removed ambiguity of score descriptions in the original table and specified that M's must differ by >20% to be considered different.

Table 2. Status-specific historical catch statistics and potential status-specific catch scalars for relating the best catch statistic to the overfishing limit (OFL). The 50th percentile scalars should promote a 50% probability of overfishing if stock status is correctly identified. The other, more conservative scalars may be useful for buffering against classification uncertainty. From Table 3 in Free et al. 2017.

		OFL Scalars								
Stock status	Catch statistic	50th	45th	40th	35th	30th	25th	20th	15th	10th
Underexploited	90th percentile, whole time series	1.90	1.78	1.62	1.53	1.41	1.34	1.29	1.11	0.88
Fully exploited	25th percentile, previous 10 years	2.16	1.84	1.77	1.57	1.41	1.22	1.15	1.02	0.85
Overexploited	10th percentile, whole time series	1.56	1.53	1.49	1.00	0.52	0.51	0.50	0.45	0.41

Table 3. ORCS results for the BSAI

	Attribute Description	BSAI Cons	BSAI Lib	GOA Cons	GOA Lib
1	Status of assessed stocks in fishery	3	1	3	1
2	Behavior affecting capture	2	2	2	2
3	Discard rate	3	3	3	3
4	Targeting intensity	1	1	1	1
5	M compared to dominant species	3	2	3	2
6	Occurrence in catch	3	1	3	1
7	Value	1	1	1	1
8	Recent trend in catch	2	1	3	2
9	Habitat loss	2	1	2	1
10	Recent trend in effort	3	2	3	2
11	Recent trend in abundance index	2	3	2	3
12	Proportion of population protected	3	3	3	3
Mean Score		2.33	1.75	2.42	1.83
Stock Status		Fully Exploited			
Catch Statistic		53.99		91.02	
Scalar		2.16		2.16	
OFL		117		197	
ABC		88		148	

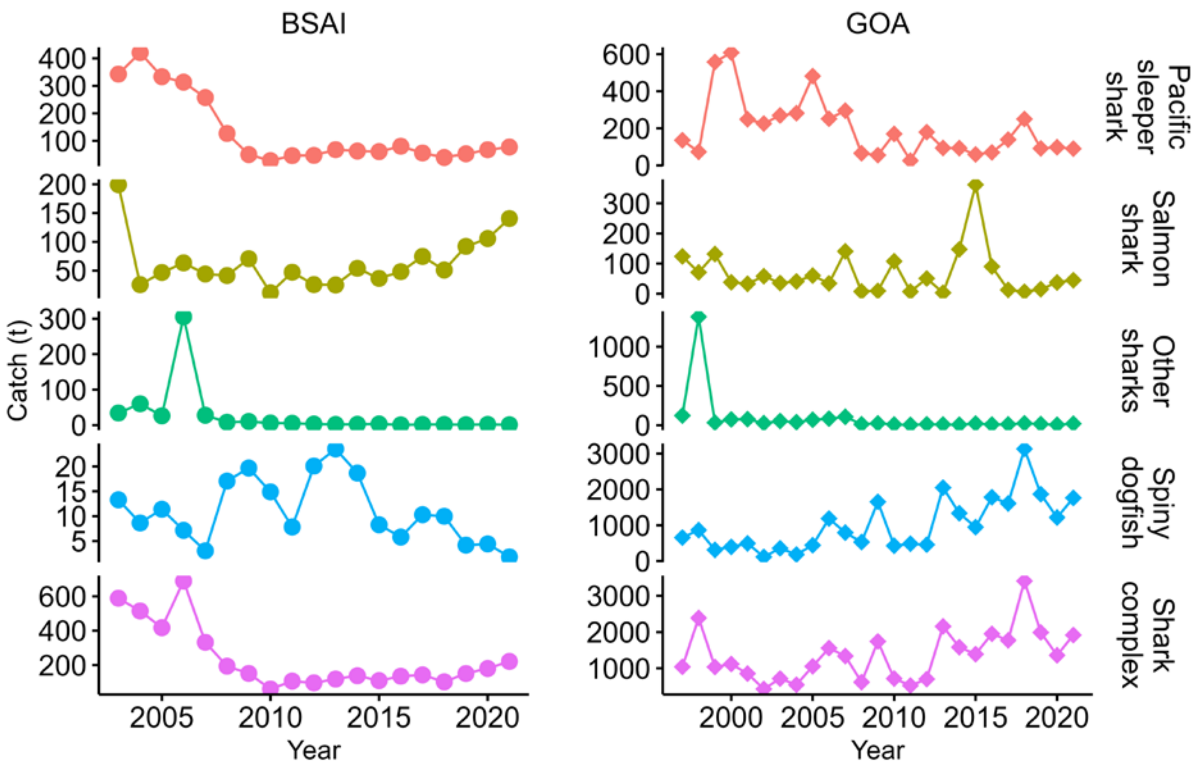

Figure 1. Estimated catch (metric tons) time series for each of the shark species or species groups in the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA).

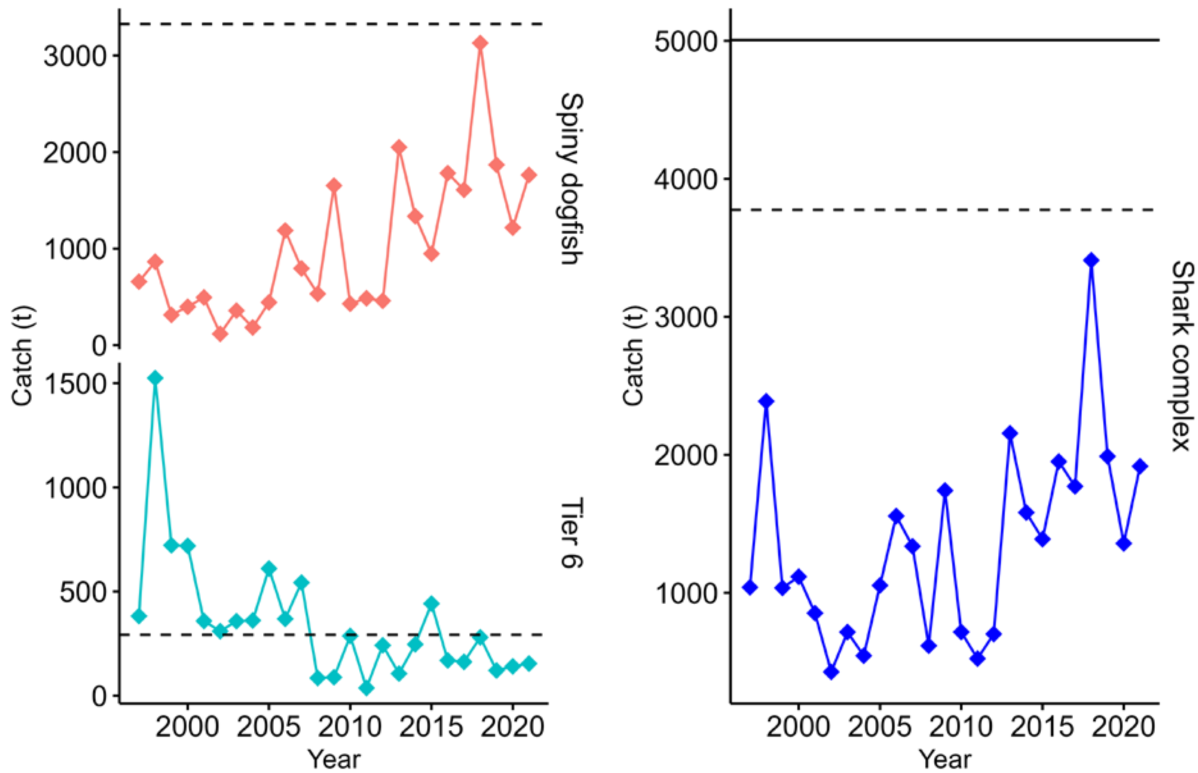

Figure 2. Estimated catch times series of the proposed GOA sub-complex ABC groups: spiny dogfish and Tier 6 sharks (left panel) and the total shark complex (right panel). The solid line is the status quo ABC and the dashed lines represent the sub-complex ABCs (left) and the sum of the two sub-complex ABCs (right). The majority of the Tier 6 catch in the GOA is Pacific sleeper shark.