

# Gulf of Alaska Other Rockfish stock complex updates

Kristen L. Omori, Chris R. Lunsford, Cindy A. Tribuzio  
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The harvest specifications for 2022-2023 for the Other Rockfish stock complex (OR) in the Gulf of Alaska (GOA) were rolled over from the 2019 harvest recommendations due to concerns regarding the 2021 GOA OR assessment. To address some of the concerns, we propose the following updates to the 2023 assessment:

1. Updating the Random Effects model using the REMA model
2. Expanding maximum catch time series for Tier 6 GOA OR species
3. Determining reliable survey biomass for Tier 4/5 GOA OR species
4. Updating weighted natural mortality (Wt M) for Tier 5 GOA OR species

## Updating the Random Effects model using the REMA model

The Random Effects Multi-area with Additional longline survey (REMA) model (Hulson et al. 2021, Monnahan et al. 2021, Sullivan et al. 2022) is a multivariate extension of the original Random Effects (RE) model. The REMA model was built to replace the RE model for assessment of AFSC Tier 4/5 stocks and apportion Annual Biological Catch (ABC) to NPFMC management regions. The REMA model went through extensive validation testing to ensure consistency and reproducibility of applications within the assessments. The REMA model was coded using Template Model Builder (TMB; Kristensen et al., 2016) and was developed into a R package (*rema*; Sullivan et al. 2022), while the predecessor RE model was built in AD Model Builder (ADMB; Fournier et al. 2012). Previous work was completed to demonstrate that the REMA model can produce the same (or very similar) results as the RE model when using the same assumptions and data inputs. The REMA model was supported and approved by the NPFMC PT and SSC in 2022 to use for Tier 4/5 stocks and apportionment.

*“The Teams recommended that stock assessment authors transition from the ADMB random-effects survey smoother to this package [REMA] which implements the same model with several improvements.”-* (NPFMC Joint Groundfish PT, September 2022)

To support the transition to the REMA model for the GOA OR stock complex assessment, we compared REMA model results with previous RE model results. More specifically, we applied the REMA model to the trawl survey catch for GOA OR Tier 4 (sharpchin), Tier 5 (aggregate of all Tier 5 OR species), and Tier 5 natural mortality groupings (5 natural mortality groupings used to calculate a single Tier 5 weighted natural mortality). Then compared REMA model biomass estimates with the previous RE model results from the last full GOA OR assessment in 2021. There was little difference (< 0.25% difference) between the RE and REMA biomass estimates across the time series for Tier 4, Tier 5, and Tier 5 natural mortality grouping models (Table 1; see Figure 1a for Tier 4- sharpchin rockfish example). Likewise, visual comparisons of the two models demonstrated no difference between biomass estimates and confidence intervals (see Figure 1b for Tier 4- sharpchin example). Therefore, we recommend using the REMA model in the GOA OR stock complex assessment beginning in the 2023 assessment cycle.

## **Expanding the maximum catch time series for Tier 6 GOA OR species**

The North Pacific Fishery Management Councils (NPFMC) Tier 6 stocks are managed based on catch history in the fishery. In 2017, the reliable catch history for Tier 6 GOA OR species was defined as the time series from 2013–2016, which corresponded to the years when species-specific discard estimates of non-target rockfish stocks were documented in the Catch Accounting System (CAS). Catch estimates prior to 2013 in CAS were not considered representative of the GOA OR catch due to bias in discard rates estimated using observer data. Since 2017, the 2013–2016 reliable catch time series has continued to be used to calculate the harvest limits for the Tier 6 GOA OR species (i.e., Model 17.1, Overfishing Limit (OFL) = maximum catch,  $ABC = 0.75 * OFL$ ; Tribuzio et al. 2021).

We propose expanding the reliable catch time series to 2013–2022. A ten-year time series better represents the catch history for these long-lived non-target rockfish species compared to a four-year time interval. Likewise, an expanded time series that includes the most current catches would better represent what the fishery is encountering, if any species distribution shifts have occurred, if there were major changes in abundance due to ecosystem changes, or if shifts in fishing patterns have occurred.

Using the catch time series from 2013 to 2022 results in a 90 t increase (35%) in the Tier 6 OFL compared to the 2013- 2016 time series (Table 2). The majority of species had minimal change in maximum catch with the exception of quillback and yelloweye rockfish, which were 13 t and 68 t increase, respectively (Table 2). Note that 7 of these Tier 6 GOA OR species belong to the Demersal Shelf Rockfish sub-group and are managed separately in the East Yakutat/Southeast management area. However, the total Tier 6 GOA OR OFL would account for 8% of the total (i.e., also including the Tier 4/5 species in this complex) 2022 GOA OR stock complex OFL (i.e., as calculated in the 2021 GOA OR assessment, Tribuzio et al., 2021) when using the 2013-2022 time series compared to 6% if using the 2013-2016 time series. Thus, the overall OFL for the GOA OR stock complex would only increase by ~ 2% if using the new catch time series for Tier 6 GOA OR species compared to the 2013-2016. Maximum catch did not substantially change in any one management region using the new time series for any specific Tier 6 GOA OR species. The minor increases in maximum catch spread across the different management areas for each of the Tier 6 GOA OR species suggest that the expanded ten-year time series better captures a stable fishing history in which to base the harvest limits compared to the previous four-year time series.

## **Determining reliable survey biomass for Tier 4/5 GOA Other Rockfish species**

### *Background*

The species in the GOA OR stock complex are divided into three tier levels that align with their original management assemblage designations (i.e., demersal shelf, pelagic shelf, and slope assemblages). This stock complex originated in 1991 as the Other Slope assemblage, but has since had several stock composition changes (i.e., additions and removals of species) throughout its management history. Beginning with the 2012 SAFE cycle, the Other Slope and Pelagic Shelf (excluding dusky rockfish) stock complexes were combined to the current OR stock complex. The Other Slope and Pelagic Shelf rockfish species were all assessed using Tier 5 methodologies. In 2013, the assessment author identified an oversight in the previous OR stock complex assessments. Mainly, the Demersal Shelf Rockfish (DSR) species, which occurred west of the Southeast Outside area (i.e., NMFS Area 650), were not included in the assessment. However, catch from these DSR species were counted against the TAC for the OR stock complex. The DSR species were integrated into the assessment of the OR complex during the 2013 SAFE. Because the DSR species were poorly sampled by (or completely absent from) the trawl survey gear (i.e., the basis of the Tier 5 assessments), they were assigned a Tier 6 status using fishery catch to determine ABCs and OFLs. Additionally, two slope species, aurora and shortbelly, that have low or no catch, were included in the 2019 GOA OR assessment as Tier 6 species due to an oversight in previous assessments. Tier

designations for GOA OR have not been re-evaluated since their original assignments (i.e., Tier 4/5 assignment for species that belonged to the slope and pelagic shelf assemblages and Tier 6 for species in demersal shelf assemblage).

For the Tier 4/5 GOA OR species, the AFSC GOA bottom trawl survey biomass time series is the primary data input for the random effects assessment model and its successor REMA (Hulson et al. 2021, Sullivan et al. 2022). The resultant REMA generated biomass estimates from the assessment are then used to derive GOA-wide harvest limits. A primary requirement for Tier 4/5 stocks in the NPFMC OFL Control Rule System is that a reliable point estimate of biomass exists (<https://www.npfmc.org/fisheries-issues/fisheries/goa-groundfish-fisheries/>). For OR Tier 4/5 species, the current assessment paradigm is that trawl survey biomass accurately represents the species biomass across the assessment region (i.e., across the GOA for Tier 4/5 OR species). However, there are a number of factors that could violate the assumption that the trawl survey “reliably” samples a given species and tracks the population trends for many rockfish species, including: 1) the trawl survey does not survey all ‘trawlable’ habitat types that are fished in the commercial rockfish fisheries, thus, only partially surveying suitable rockfish habitat (e.g., harlequin), 2) patchy distributions contribute to highly variable catches, 3) many of the GOA OR species are rare and difficult to survey, and 4) the survey was not optimized for these non-target rockfish species.

Many of the GOA OR species are either never caught or captured infrequently by the trawl survey. Five of the Tier 4/5 GOA OR species comprise 95% of the total survey biomass catch for these species (Figure 2). Furthermore, many of the GOA OR species are found in higher abundance in the Eastern GOA compared to the low and infrequent survey catches in the Western and Central GOA. While, conversely, the majority of the commercial fisheries catch for GOA OR species are from the rockfish target trawl fishery in the Central GOA (see Table 16.8 and Figure 16.6 in last full assessment, Tribuzio et al. 2021). The inability of the trawl survey to adequately sample GOA OR species (i.e., due to their patchy and spatially unbalanced spatial distribution along with the large number of stocks with low survey catch) warrants further investigation as to whether the AFSC GOA bottom trawl survey can be reliably used to assess Tier 4/5 species that comprise the GOA OR complex.

#### *Metrics for reliable trawl survey biomass*

The time series spanning 1984 to 2021 (totaling 17 years) for the AFSC GOA bottom trawl survey is used to examine the reliability of the trawl survey to assess the Tier 4/5 GOA OR species. All Tier 4/5 species from the GOA OR stock complex are included in this analysis as well as additional Tier 3/4/5 GOA rockfish species (i.e., that are assessed and managed on a single-species basis) as a basis for comparison (Table 3). Because the GOA OR stock complex is assessed and managed using a GOA-wide OFL, we use a GOA-wide analysis. However, the average annual proportion of survey catches in the combined Western and Central GOA compared to the total GOA are also examined to determine biomass distribution between Western/Central and Eastern GOA.

We selected three main metrics to assess the ability of the AFSC GOA bottom trawl survey to detect and sufficiently represent biomass trends for GOA rockfish including: REMA model diagnostics (i.e., ability of a single stock model application to converge); proportion of hauls with positive catch; and the coefficient of variation (CV) on survey catch. The three metrics were selected because they provide general insight into data availability (i.e., frequency), consistency, and reliability, and are sensitive to infrequently caught species. The REMA model is run on individual GOA species as a diagnostic test to determine if there were sufficient data to successfully run the REMA model. If there are not enough data available to run the REMA model, the model would fail to estimate a process error and biomass. The indicators that examine catch consistency and frequency are: proportion of hauls with positive catch is based on the number of hauls with positive catch compared to the total number of hauls each year. In addition to the time series of the proportion of hauls with positive catch, the proportion of years that a species is caught (across all hauls) on

the survey (i.e., proportion of years with positive survey catch; *propyrs*), the average annual proportion of hauls that a species is caught in (*avg\_pos*), and the proportion of years that a species is caught in more than 5% of hauls (*pos\_above.05*). Conversely, survey catch stability and variability are indicated by: the CV time series, the average CV across the time series, and the proportion of years that have a CV below 0.5 (*CV\_below.5*). The CV cutoff of 0.5 was selected here, because large CVs indicate high variability and instability in catch (e.g., issues with sampling stocks with patchy distributions) and can be used to identify a time series for which variability might be too great to provide insight into trends.

## *Results*

Based on all GOA rockfish, a tentative baseline (i.e., loose criteria) has been established from the metrics to identify those rockfish species that support the use of the trawl survey to their assessment (i.e., criteria of a ‘reliable survey biomass’ for rockfish species). The criteria include: being caught each year in the survey and in high enough frequency (successful REMA model, *propyrs*  $\approx$  1, and *avg\_prop*  $>$  0.01) and relatively consistently (*avg\_CV*  $<$  0.5). In comparison to many of the GOA OR species, the GOA rockfish stocks that are assessed and managed on a single species basis have been caught in each trawl survey year, demonstrate higher survey catch and frequency of presence, have average CVs  $<$  0.5, and are more evenly distributed spatially (Table 3). For GOA OR species, consistency across metrics support the use of the GOA bottom trawl survey in assessments for five of the Tier 4/5 OR species that are most frequently caught in the survey (i.e., sharpchin, harlequin, redbanded, redstripe, and silvergray), while the use of trawl survey should be reconsidered for the remaining GOA OR species (Table 3; Table 4). All species that have positive survey catches appear to have sufficient GOA-wide catch data to run the REMA models, except for vermilion rockfish (Table 3). Vermilion rockfish was only encountered by the survey in one year. Additionally, there were three OR species (i.e., stripetail, blackgill, and chilipepper) that were not caught in the trawl survey during the specified time series (Table 4).

Of the remaining Tier 4/5 species that are caught by the GOA bottom trawl survey, five species (i.e., silvergray, sharpchin, redstripe, harlequin, and redbanded) are present in the survey every year and on average occur in over 1% of hauls (Table 3, Figure 3). The GOA-wide time series of proportion of positive hauls metrics suggest that when species are caught every year in the survey and have above 0.01 average proportion of positive hauls, the survey has the potential to detect biomass trends for the given species. The CV metrics (i.e., average and proportion of years with a CV  $<$  0.5) have more variable results. The general patterns suggest more consistent catches (i.e., lower CVs) equate to more reliable survey biomass when examining across all GOA rockfish species for comparison. Both harlequin and redstripe have an average CV  $>$  0.5, but both are caught in relatively high frequency (i.e., based on *propyrs* and avg proportion of hauls with positive catch) and are caught throughout the GOA. Greenstriped partially met the CV criteria, with an average annual proportion of hauls with positive catch near 0.01 and an average CV around 0.5, but the vast majority of catch is in the Eastern GOA and are infrequently caught in the Western or Central GOA.

## *Recommendations*

We recommend moving 12 OR species (i.e., greenstriped, pygmy, darkblotched, yellowtail, yellowmouth, bocaccio, splitnose, vermilion, widow, stripetail, blackgill, and chilipepper) from Tier 5 to Tier 6 (Table 4). These species did not meet the three criteria examined for having a reliable survey biomass. The recommended 12 OR species have  $<$  1% average annual hauls where the species is observed in the GOA-wide survey, typically result in an average CV around or greater than 0.5, and are infrequently found in the Western/ Central GOA. The total combined biomass of these 12 rockfish species comprise about 5% of the total GOA OR complex bottom trawl survey biomass. For these 12 OR rockfish species, we recommend

using existing Tier 6 maximum catch methods to calculate the harvest specification along with the other Tier 6 OR species.

## **Updating Weighted Natural Mortality as a Proxy for FOFL for Tier 5 GOA OR Species**

### *Background*

The GOA OR stock complex was last assessed in 2021. However, the current harvest specifications are based on the 2019 assessment, because the resultant OFL was deemed unsuitable for management advice. This occurred because of three compounding issues: 1) the AFSC GOA bottom trawl survey had very low catches of many of the GOA OR species; 2) there was a shift in the dominant species from those with high natural mortality values ( $M$ ) to those with low  $M$  values, resulting in a substantial decrease in the weighted  $M$  used for estimating the OFL; and 3) the spatial distribution of the biomass shifted such that there was minimal biomass in the Western/Central GOA (Tribuzio et al. 2021). This report is in response to Plan Team and SSC requests to explore alternative methods of estimating a weighted  $M$  value for the Tier 5 species within the complex so that it is less sensitive to fluctuations as experienced in 2021.

*“the Team recommended rolling over harvest recommendations from 2021 due to the discrepancy between catch and survey biomass and the estimation of weighted  $M$  being influenced by a few species that have patchy distributions and survey catchability/availability issues.*

*The Team recommends the author further explore issues with using the current method of weighted  $M$  biomass estimates.” – (NPFMC Joint Groundfish PT, November 2021)*

The GOA OR harvest specification approach assigns the Tier 5 species into natural mortality ( $M$ ) sub-groupings based on similar assumed  $M$  values. For each  $M$  sub-group, the RE or REMA model is applied to the aggregated AFSC GOA bottom trawl survey catch to obtain GOA-wide  $M$  sub-group biomass estimates. A single Tier 5 biomass-weighted  $M$  is then computed by averaging across  $M$  sub-groups. The RE/REMA model is then applied to the aggregated survey catch of all Tier 5 GOA OR stocks to compute the Tier 5 GOA-wide biomass estimate. Finally, the  $F_{OFL}$  is set equal to the weighted  $M$  and the OFL is calculated as weighted  $M$  multiplied by the Tier 5 total biomass. For each assessment cycle, a new weighted  $M$  is calculated based on the terminal year trawl survey catches. Thus, the weighted  $M$ , which drives the harvest specifications, has a high dependency on the GOA trawl survey data in the terminal year.

However, the AFSC GOA bottom trawl survey poorly samples the Tier 5 GOA OR species. As previously noted, the GOA trawl survey was not optimized to sample non-target rockfish stocks. Sampling inefficiencies lead to uncertain and variable biomass estimates (Tribuzio et al., 2021), which was one impetus for the proposed ABCs and OFLs from the last full GOA OR assessment in 2021 to not used for final harvest specifications. More specifically, the estimated biomass increased in the lower value  $M$  sub-group (i.e.,  $M = 0.05$ , mainly silvergray), while the estimated biomass decreased in the higher value  $M$  sub-groups (i.e.,  $M = 0.092$ , harlequin, and  $M = 0.1$ , redstripe). The switch in species composition dominance in the survey catch from higher to lower value  $M$  sub-groups ultimately caused the combined weighted  $M$  for the Tier 5 GOA OR species to decline by 21% and the OFL to decline by 962 t from the 2019 to the 2021 assessment (see Fig. 16.3, 16.11 in 2021 assessment; Tribuzio et al., 2021).

We propose an alternative method to calculate weighted  $M$  for Tier 5 GOA OR species that uses a three-year average survey catch approach, which is less sensitive to yearly variability in survey catches of OR species. Although the proposed weighted  $M$  still changes each assessment cycle, the effects of sudden shifts in survey species composition are dampened by averaging across the three most recent survey years. Moreover, long-term changes in the species composition are still captured.

### *Weighted M Calculation Methods*

#### **Status quo Weighted M:**

The status quo method to calculate the weighted M (Wted M) as a proxy for  $F_{OFL}$  is described in Tribuzio et al., (2021), where the biomass-weighted M value for terminal year  $z$  is based on estimated current year biomass from the trawl survey:

$$F_{OFL} = \text{Wted M} = \sum_i p_{i,z} * F_i,$$

where  $p_i$  is the proportion of GOA-wide biomass for each  $i$  sub-group with a shared M (e.g., M sub-groups: 0.05, 0.06, 0.07, 0.92, 0.10) for survey,  $z$ , and  $F_i$  is the sub-group specific fishing mortality with M value as a proxy (i.e.,  $F_i \approx M_i$ ) as established for NPFMC Tier 5 stocks.

#### **Alternative Weighted M:**

The alternative weighted M ( $\overline{\text{Wt\_M}}$ ) is based on a “moving” average biomass, where the time series shifts to accommodate new survey data. The alternative weighted M is calculated using the average survey biomass from the previous three GOA trawl surveys:

$$F_{OFL} = \overline{\text{Wt\_M}} = \sum_i \overline{p_{i,z-2:z}} * F_i,$$

where the proportion of GOA-wide biomass is now averaged from the 3 most recent surveys (i.e.,  $z-2$  to  $z$ , representing the trawl surveys for 2017, 2019, and 2021) for each M sub-group.

### *Comparing Weighted M methods*

The status quo weighted M from 2012 to 2021 ranges from 0.055 (2021) to 0.072 (2017; Figure 4). As previously mentioned, the sudden decrease in weighted M in 2021 was due to the change in species composition dominance in the GOA trawl survey from harlequin and redstripe (M sub-groups = 0.092 and 0.1, respectively) to silvergray (M sub-group = 0.05). In comparison, the alternative weighted M ranges from 0.061 (2012) to 0.069 (2018, 2019) when calculated for the time period from 2012 to 2021. Averaging the proportional biomass from the past three surveys for each of the M sub-groups allows subtle changes to occur, but minimizes the impact of a single survey on the weighted M calculation.

Using the total biomass estimated for the Tier 5 GOA OR species from the 2021 assessment, the OFL applying the alternative weighted M method would be ~20% greater than the status quo weighted M method (i.e., OFL with  $\overline{\text{Wt\_M}}$  = 3,873 t, OFL with Wted M = 3,228 t; Table 5). Because both approaches utilize the same biomass estimates for this analysis, the increase in the OFL from using the alternative weighted M solely reflects the impact of averaging the survey species composition across three surveys instead of using the just the terminal survey proportion.

We recommend the alternative weighted M approach using the three most recent survey years, because: 1) these GOA OR species are long-lived, later maturing species with high survey variability, thus averaging the last three-survey data points (~ 6 years) would dampen survey uncertainty yet capture population trends; and 2) prior to the implementation of the random effects model for determining biomass, several GOA rockfish assessments including GOA OR used a three survey averaging method to determine exploitable

biomass and apportionment, which is similar to this approach and provides consistency with the proposed alternative weighted M approach.

### Summary of recommendations

In summary, to improve the GOA OR stock complex assessment and in response to the SSC/PT comments, we propose the following updates:

1. Replace the RE model with the REMA model; no differences were observed when both models were applied to the same inputs, though REMA is preferred due to improved functionality and code base.
2. Expand the time series used to define Tier 6 GOA OR species' maximum catch from the current 2013-2016 time block to a ten-year time period of 2013-2022.
3. Use the methodology (i.e., being caught each year in the survey and in high enough frequency [successful REMA model,  $propyrs \approx 1$ , and  $avg\_prop > 0.01$ ] and relatively consistently [ $avg\_CV < 0.5$ ]) to determine 'reliable' survey biomass for Tier 4/5 GOA OR species, and move the 12 Tier 5 GOA OR species (Table 4) that did not have 'reliable' survey biomass estimates to Tier 6.
4. Update the weighted natural mortality (Wt M) methodology for Tier 5 GOA OR species using the alternative method based on an average weighed M using the 3 most recent surveys, as opposed to basing the weighted M on only the most recent survey values.

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## Tables

**Table 1.** Average differences between yearly biomass estimates from the REMA (TMB) model compared to the predecessor RE (ADMB) model along with number of years with > 0.5% difference between the two model results for Tier 4/5 groups, and each Tier 5 natural mortality grouping (Tier 5: M).

Group	Average Difference (t)	No. of years with > 0.5% difference
Tier 4: Sharpchin	-0.0073	0
Tier 5: All species	-0.0084	0
Tier 5: M=0.1	-0.0033	0
Tier 5: M=0.05	-0.0065	0
Tier 5: M=0.06	-0.0029	0
Tier 5: M=0.07	-0.0011	0
Tier 5: M=0.092	-0.0055	0



**Table 2.** Maximum catch for Tier 6 Gulf of Alaska Other Rockfish (GOA OR) species for each time series (current: 2013-2016; proposed: 2013-2022).

Tier 6	Maximum Catch (t)							
	2013-2016				2013-2022			
	Western GOA	Central GOA	West Yakutat	Total 2013-2016	Western GOA	Central GOA	West Yakutat	Total 2013-2022
aurora	0	<1	0	0	0	<1	<1	0
<sup>1</sup> canary	<1	1	<1	1	<1	1	<1	2
<sup>1</sup> china	<1	1	<1	1	<1	3	<1	3
<sup>1</sup> copper	<1	<1	<1	0	<1	<1	<1	0
<sup>1</sup> quillback	1	25	1	27	1	25	14	40
<sup>1</sup> rosethorn	<1	1	1	2	<1	2	2	5
shortbelly	0	0	0	0	0	0	0	0
<sup>1</sup> tiger	1	4	<1	5	1	6	1	7
<sup>1</sup> yelloweye	57	124	40	221	82	155	53	290
Total OFL				257				347

<sup>1</sup> Stocks that belong to the Demersal Shelf Rockfish (DSR) sub-group that are managed in a separate DSR stock complex in the East Yakutat/Southeast management area, but currently belong to the GOA OR in the other GOA management regions; thus, no max catch or ABCs are calculated for the DSR sub-group stocks in East Yakutat/Southeast.

**Table 3.** Reliable survey biomass metrics for Gulf of Alaska (GOA) Other Rockfish Tier 4/5 stocks and additional GOA rockfish stocks (in italics) for comparison. Metrics include the REMA diagnostic (1= successfully estimates a process error, 0= model fails), proportion of positive years (propyrs), average proportion of hauls with positive catch (avg\_pos), proportion of years that have above 0.05 proportion of hauls with positive catch (pos\_above.05), average CV (avg\_CV), proportion of years with a CV below 0.5 (CV\_below.5), , and average annual proportion of survey catch in Western/ Central GOA compared to GOA-wide. The rockfish stocks above the red dashed line are caught more frequently and are more represented by the GOA bottom trawl survey compared to stocks below the red dashed line. Note: stripetail, blackgill, and chilipepper rockfish are not included in the table because these stocks were not caught in the GOA bottom trawl survey during the time series.

tier	species	avg annual biomass (t)	REMA	Proportion of hauls with positive catch			CV		Avg (WG+CG) GOA
				propyrs	avg_pos	pos_ above.05	avg_CV	CV_below.5	
3	<i>POP</i>	783138	1	1	0.44	1	0.23	0.94	0.75
3	<i>Northern</i>	160574	1	1	0.17	1	0.40	0.82	1
3	<i>Dusky</i>	71074	1	1	0.17	1	0.35	1	0.84
4	Sharpchin	23258	1	1	0.07	0.82	0.45	0.71	0.21
5	<i>Thornyheads</i>	66513	1	1	0.25	1	0.07	1	0.63
5	<i>Shortraker</i>	36578	1	1	0.08	1	0.25	1	0.52
5	Silvergray	29898	1	1	0.07	0.94	0.38	0.88	0.11
5	Redstripe	14734	1	1	0.03	0.12	0.55	0.41	0.27
5	Harlequin	12639	1	1	0.07	0.77	0.52	0.59	0.71
5	Redbanded	4988	1	1	0.11	0.94	0.27	1	0.27
5	Yellowtail	2075	1	0.77	<0.01	0	0.66	0.23	0.08
5	Yellowmouth	1067	1	0.82	<0.01	0	0.79	0	0.02
5	Greenstriped	477	1	0.94	0.01	0	0.43	0.81	0
5	Darkblotched	213	1	0.94	<0.01	0	0.57	0.44	0.03
5	Widow	165	1	0.77	<0.01	0	0.71	0	0.16
5	Pygmy	106	1	0.82	<0.01	0	0.79	0	0.35
5	Bocaccio	89	1	0.65	<0.01	0	0.83	0	0.09
5	Splitnose	47	1	0.77	<0.01	0	0.71	0.08	0.05
5	Vermilion	1	0	0.06	0	0	1.00	0	1

**Table 4.** Current and suggested tier assignments for Gulf of Alaska Other Rockfish Tier 4/5 stocks with current associated natural mortality (M) group and reason for recommended Tier.

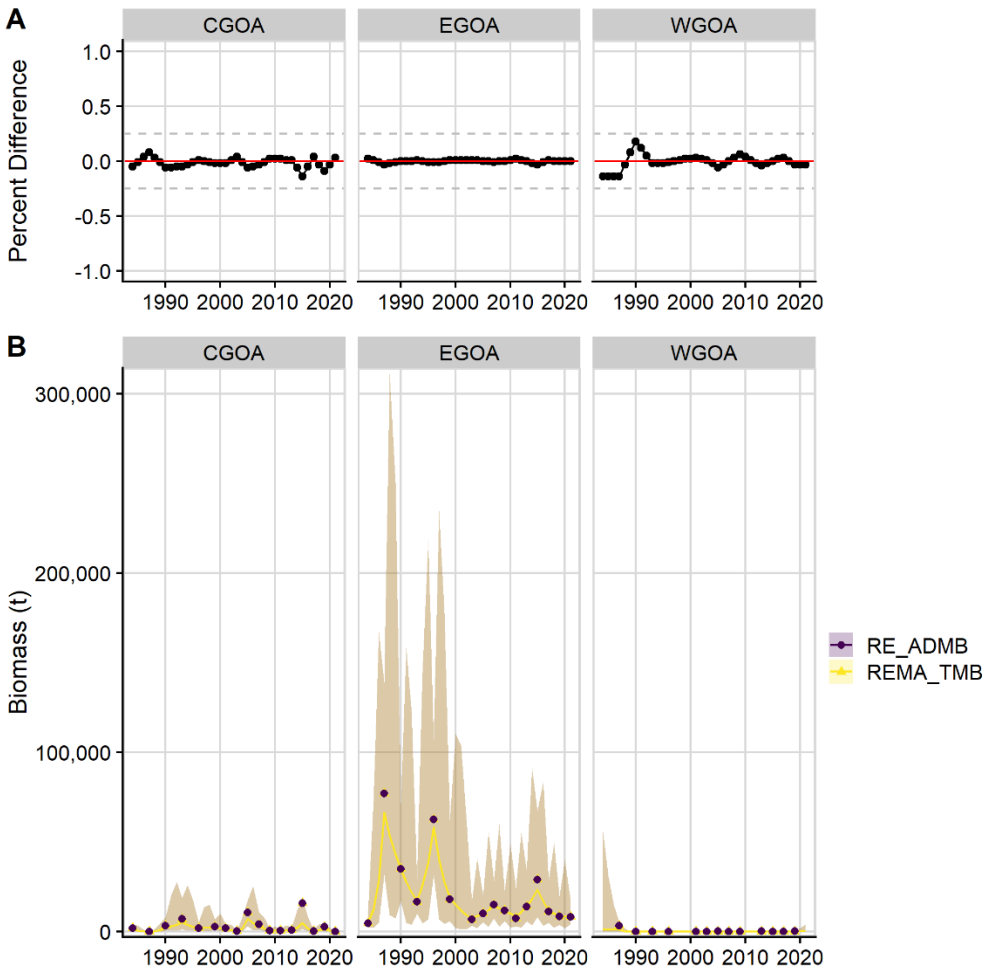
Species	Current Tier	Suggested Tier	M group	Reason
sharpchin	4	4 (no change)	sharpchin	Meet criteria
harlequin	5	5 (no change)	0.092	Meet criteria; High biomass in WG/CG
redbanded	5	5 (no change)	0.06	Meet criteria
redstripe	5	5 (no change)	0.1	Meet criteria; Present GOA-wide
silvergray	5	5 (no change)	0.05	Meet criteria
greenstriped	5	6	0.07	Partially met criteria; Driven by EG
pygmy	5	6	0.06	Did not meet criteria
darkblotched	5	6	0.07	Did not meet criteria
yellowtail	5	6	0.07	Did not meet criteria
yellowmouth	5	6	0.06	Did not meet criteria
bocaccio	5	6	0.06	Did not meet criteria
splitnose	5	6	0.06	Did not meet criteria
vermillion	5	6	0.06	Did not meet criteria
widow	5	6	0.05	Did not meet criteria
stripetail	5	6	0.06	Not caught in survey
blackgill	5	6	0.06	Not caught in survey
chilipepper	5	6	0.06	Not caught in survey

**Table 5.** Resultant OFL for the Tier 5 GOA OR species derived from the status quo weighted M (*Wted M*) method and alternative weighted natural mortality using an average of 3 most recent surveys ( $\overline{Wt\_M}$ ) method based on the estimated Tier 5 biomass from the 2021 GOA OR Assessment.

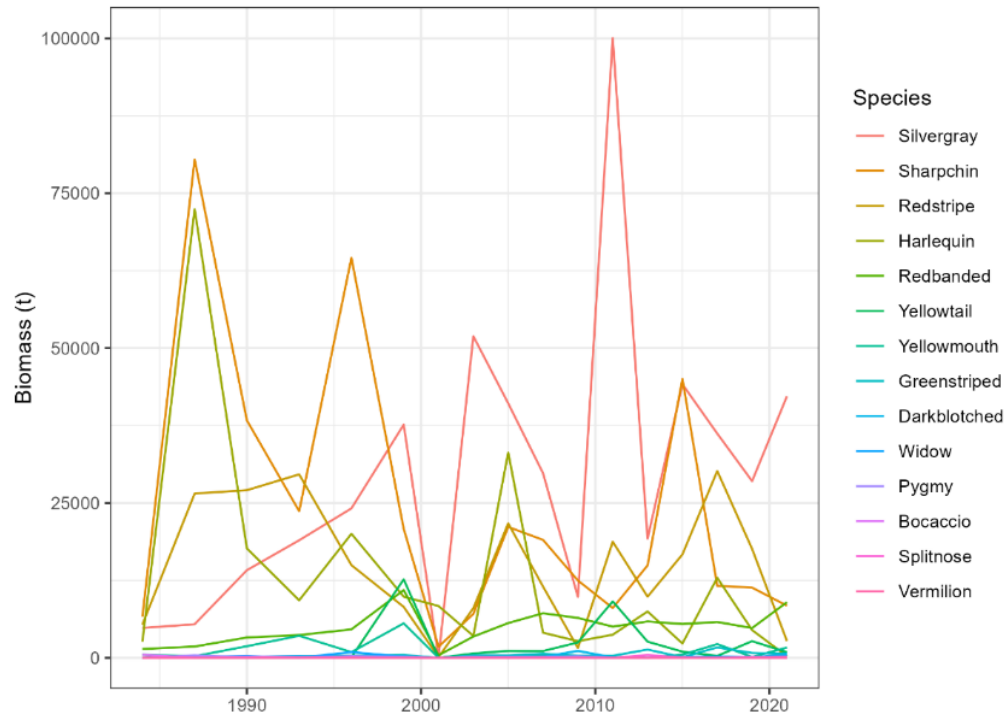
	Year	Estimated Biomass <sup>1</sup>	Weighted M Method	Wted M	OFL
Tier 5	2021	58,687	<i>Wted M</i>	0.055	3,228
Tier 5	2021	58,687	Alt. $\overline{Wt\_M}$ : 3 survey avg	0.066	3,873

<sup>1</sup>Estimated biomass is from the 2021 GOA OR Assessment, Tribuzio et al., 2021

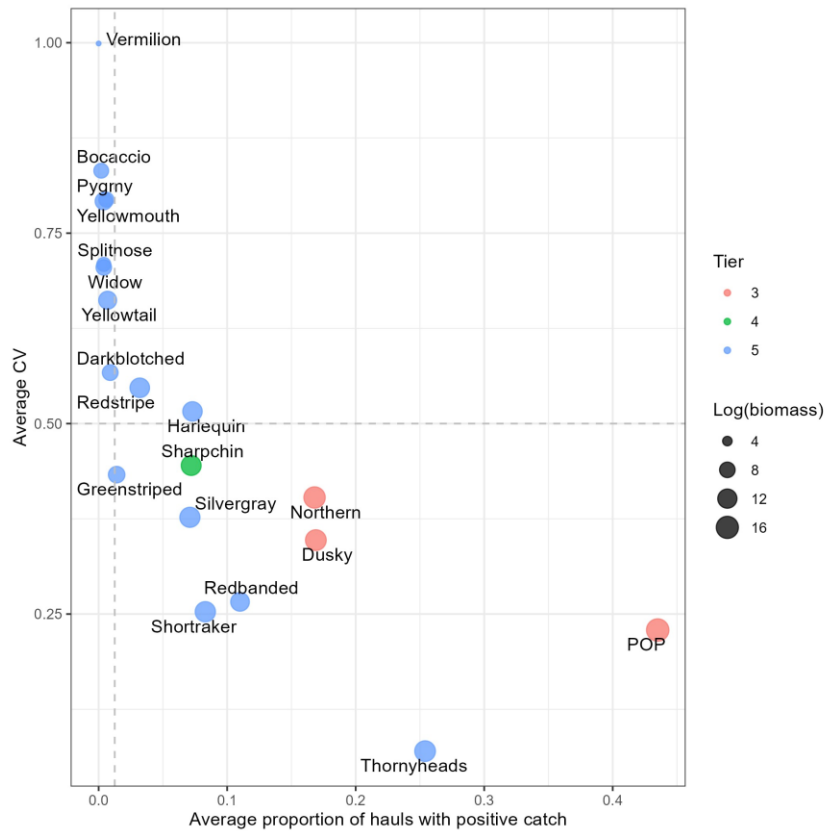
## Figures



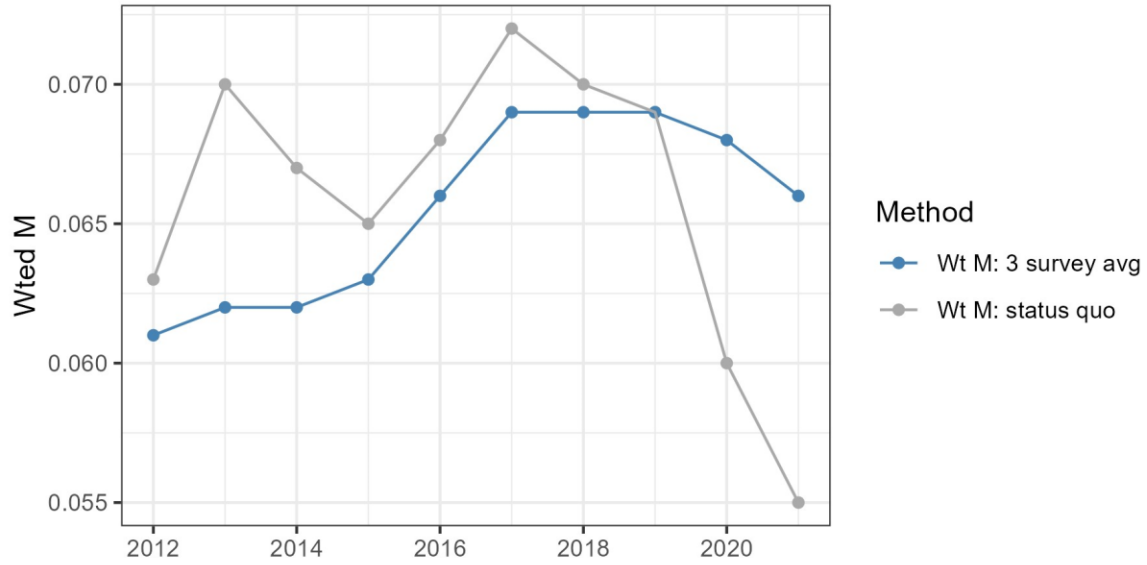
**Figure 1.** A) Time series of the percent difference between RE (ADMB) and REMA (TMB) biomass estimates and B) time series of biomass estimates from the RE (ADMB; purple points and shading) and REMA (TMB; yellow points and shading) models for Tier 4- sharpchin rockfish as an example from the GOA OR complex. The black points are the biomass estimates. The shading represents the confidence intervals (CI), where the CI overlap significantly represented by the tan shading.



**Figure. 2.** Time series of the Gulf of Alaska bottom trawl survey biomass for Tier 4/5 rockfish species in the Gulf of Alaska Other Rockfish stock complex.



**Figure 3.** Average annual proportion of hauls with positive catch compared to the average CV from the GOA bottom trawl survey for GOA rockfish species by status quo Tier designation (point color). Size of points indicate relative total biomass caught in the GOA bottom trawl survey. Dashed gray lines represent reference lines for an average proportion of hauls with positive catch = 0.01 and average CV = 0.5.



**Figure 4.** Comparison of Tier 5 Weighted Natural Mortality (Wted M) calculation methods for Tier 5 GOA OR species. The status quo Wted M method is calculated based on the yearly M sub-group proportional biomass (i.e., biomass- weighted M), whereas the proposed alternative method, Wt\_M: 3 survey avg, is based on a three year recent survey average proportional biomass (i.e., average of about last three surveys biomass- weighted M). Note the GOA trawl survey occurred in years: 2013, 2015, 2017, 2019, and 2021; biomass and weighted M were estimated for each year by the REMA model.