Updated model for the 2023 stock assessment of Shortraker rockfish in the Gulf of Alaska

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Executive Summary

Gulf of Alaska (GOA) shortraker rockfish is assessed on a biennial schedule in odd years and is managed as a Tier 5 stock. The current method for estimating the GOA-wide Acceptable Biological Catch (ABC) in the eastern, central, and western GOA management areas (i.e., EGOA, CGOA, WGOA) was first adopted in 2019 (Echave and Hulson 2019) and relies on the two-survey (i.e., bottom trawl and longline surveys) version of the random effects model (REMA; Hulson et al. 2021). This model (Model 19) was implemented in AD Model Builder (ADMB; Fournier et al. 2012), and an error was identified in this version and corrected in 2022 (Sullivan et al. 2022). A corrected version of Model 19 was used as a surrogate for the status-quo model, hence referred to as Model 19*. Model 19* estimates a single process error, three scaling coefficients (one for each management area), and fixes the weight of the longline survey at 0.5 relative to the bottom trawl survey at 1.0. Herein, we recommend several important updates to the underlying REMA model used for stock assessment and apportionment:

1) We recommend that the REMA model be implemented using the *rema* R library, which was endorsed by the GOA Groundfish Plan Team (GPT) and Scientific and Statistical Committee (SSC) in 2022. The *rema* R library uses Template Model Builder (TMB; Kristensen et al. 2016), and this package corrects the error introduced in Model 19 (Sullivan et al. 2022).
2) We recommend removing the 1984 and 1987 bottom trawl survey biomass estimates based on recommendations from the GOA GPT and SSC in 2022 (Figure 1).
3) We recommend not fixing the weight of the longline survey to 0.5 but giving both surveys an equal weight of 1.0 (Figure 2). Length compositions by survey indicate that the longline survey samples larger fish more, particularly in the CGOA and WGOA (Figure 3). The longline survey is annual and has less interannual variability in length compared to the biennial (previously triennial) bottom trawl survey (Figure 4). The bottom trawl survey effort is greatly diminished in the depths where shortraker are encountered (~250 to 500 m), while the longline survey adequately covers this range (Figure 5).
4) We considered alternative models that estimate additional observation error for only the bottom trawl survey, only the longline survey, and both surveys (Figures 6 and 7). Because the observation error of the bottom trawl survey is much larger than the longline survey, and the scale of additional observation error estimated in the model is quite large (Figure 8), we recommend a model that estimates additional observation error for the longline survey only (Figure 9).
5) We propose using the average of the proportion predicted biomass and proportion predicted relative population weights (RPWs) by area to inform apportionment instead of using only the standard proportion of predicted biomass. In the case of GOA shortraker rockfish, there is data conflict between the bottom trawl and longline survey indices. Specifically, the longline survey RPWs suggest higher proportions of biomass in the eastern and western GOA compared to the bottom trawl survey biomass (Figure 10). The proposed alternative approach has the benefit of utilizing information from the RPWs to inform relative scale of biomass among regions, thus striking a balance between the conflicting survey indices.

For the 2023 assessment, the authors recommend using the REMA model that estimates area-specific q, has a single shared process error, starts in 1990, and includes an estimated additional observation error for the longline survey. The authors recommend the new apportionment method that averages proportions of predicted RPW and biomass by area.

Summary of Methods

Changes in the input data:
Based on a recommendation from the GOA GPT (September 2022) and SSC (October 2022), we present alternative model results that exclude the 1984 and 1987 bottom trawl surveys and begins in 1990. We present the corrected version of the status quo model (the weight of the longline survey was fixed at 0.5) that includes the 1984 and 1987 bottom trawl survey (M19* w/ 84/87). We compare this to the same model starting in 1990 (M19*). Otherwise, all data presented in this document is identical to the data used in the 2021 assessment.

Changes in the assessment model methodology:
All models presented are fit using TMB in the *rema* R library, while the previous accepted model was fit using ADMB (Table 1). Detailed REMA model methods are available in Sullivan et al. (2022) and Hulson et al. (2021). All models estimate a single process error and three scaling coefficients (one for each management area). The first proposed model (M23.1) changes the weight of the longline survey from 0.5 to 1.0. Justification for down weighting this survey was included in the 2021 SAFE:

> *By region, the estimated uncertainty in the longline survey RPW index is consistently smaller than the uncertainty in the bottom trawl survey biomass. The ratio of coefficient of variation (CV) of the longline survey RPW compared to the bottom trawl survey biomass is 0.8 in the western and central GOA, and 0.5 in the eastern GOA, indicating that we estimate the RPW index to be more precise on average than the bottom trawl survey. However, as we note when describing these data sources they both suffer from sampling error that makes it difficult to consider one source to be more accurate or reliable than the other when determining the population size of shortraker rockfish. By reducing the weight of the longline survey to 0.5 what the model is inherently doing is equalizing the relative contribution of these two indices to the model estimates. By means of comparison, the relative CVs between biomass and RPWs is much more similar for shortspine thornyheads, the other Tier 5 assessment that uses these two indices. Granted, we recognize that the choice of 0.5 is subjective, but with this relative weighting we noted in the 2019 assessment that the model is slightly more responsive to the bottom trawl survey biomass index, although, these differences in estimates between a weight of 1 or 0.5 for the longline survey was small.*

The *rema* R library introduced in 2022 includes the option for the model to estimate additional observation error for each survey (Sullivan et al. 2022). As such, we wanted to see if the model could estimate additional observation error for the surveys as an alternative to arbitrarily assigning a weight of 0.5 to the longline survey. The three alternative proposals considered were M23.2 (M23.1 with additional observation error for the bottom trawl survey), M23.3 (M23.1 with additional observation error for the longline survey), and M23.4 (M23.1 with additional observation error for both surveys).

The two-survey random effects models presented use the following naming conventions:

Model	Software	Model years	LLS weight	Scaling parameters (q)	Additional Obs. Error
M19	ADMB	1984-2023	0.5	Area-specific q	
M19* w/ 84/87	TMB	1984-2023	0.5	Area-specific q	
M19*	TMB	1990-2023	0.5	Area-specific q	
M23.1	TMB	1990-2023	1.0	Area-specific q	
M23.2	TMB	1990-2023	1.0	Area-specific q	BTS
M23.3	TMB	1990-2023	1.0	Area-specific q	LLS
M23.4	TMB	1990-2023	1.0	Area-specific q	LLS & BTS

Changes in the apportionment methodology:
We propose an alternative method for apportionment that bases apportionment on the mean proportions of predicted biomass and predicted RPW by area (“Biomass + RPW”). This approach is contrasted with the standard method of basing apportionment on the proportion of predicted biomass by area (“Biomass”).

Summary of Results

The alternative REMA models explored give equal weights to the longline and bottom trawl surveys. We feel this is justified by the quantity and quality of the data from longline survey. The longline survey catches several thousand shortraker rockfish each year compared to several hundred in the biennial (formerly triennial) bottom trawl survey. The resulting length compositions show similarities in the EGOA, with an increasing divergence to the west with the longline survey lengths indicating larger fish being sampled (Figure 3). The longline survey has relatively consistent mean lengths by region, while the bottom trawl survey lengths have more interannual variability (Figure 4). One reason that sample sizes differ so much is likely due to the amount of effort each survey has in the habitat (trawlable vs. untrawlable) and depths (between 250 and 500 m) that shortraker are found (Figure 5). As such, we recommend fixing both survey weights to 1, but as before, we acknowledge that the longline survey observation error is quite small relative to the bottom trawl survey. Additionally, the change from M19* to M23.1 does result in a larger process error (Table 1), so we do not recommend using M23.1.

The three additional models considered (M23.2, M23.3, and M23.4) allowed additional observation error to be estimated in the model. M23.2 and M23.4 were nearly identical, with a large additional observation error being estimated for the bottom trawl survey, and in the case of M23.4, ~ 0 additional observation error estimated for the longline survey. While these models had lower AIC values (Table 2), the already large observation error for the bottom trawl survey was inflated to such a degree that the trawl survey was not very informative, and the longline survey was driving the trend (Figures 6 and 7). M23.3 resulted in the highest AIC (Table 2), but this was the only model that actually balanced the survey inputs by increasing the relatively small observation error of the longline survey (Figure 9), resulting in a relatively low process error (Table 1), and allowing both surveys to reasonably contribute to the trend and scale of REMA model biomass estimates. We recommend that M23.3 be used for the 2023 GOA shortraker assessment.

The alternative REMA models and apportionment methods (“Biomass” = standard method based on proportion of predicted biomass by area; “Biomass + RPW” = proposed method for GOA shortraker based on the mean proportions of predicted biomass and predicted RPW by area) result in the following apportionment percentages by management area for 2022 and 2023 (author-recommended model and apportionment method in bold):

REMA model names	Apportionment Method	WGOA	CGOA	EGOA
M19*	Biomass	5.1%	38.5%	56.4%
M19*	Biomass + RPW	8.6%	27.6%	63.8%
M23.1	Biomass	5.5%	36.2%	58.3%
M23.1	Biomass + RPW	9.0%	25.9%	65.1%
M23.2	Biomass	5.4%	34.1%	60.5%
M23.2	Biomass + RPW	9.4%	24.9%	65.7%
M23.3	Biomass	5.4%	38.2%	56.4%
M23.3	**Biomass + RPW**	**9.2%**	**27.5%**	**63.3%**

Key results:

- The removal of 1984 and 1987 bottom trawl surveys has little impact on the model (Figure 1); authors recommend that time series henceforth begins in 1990.
- The longline survey samples shortraker quite well and should not be arbitrarily down weighted.
- The bottom trawl survey has relatively large observation error compared to the longline survey, and models that allow for additional observation error to be estimated for the bottom trawl survey tend to exacerbate this discrepancy.
- M19* and M23.3, have nearly identical fits to the data (Figures 6 and 7), and their estimates of process error are lower than the alternatives (Table 1). This is attributable to both allowing additional uncertainty for just the longline survey, albeit M19* doing so in a more subjective manner.
- All models using the combined method (biomass and RPW) have slightly increased the apportionment to the WGOA and EGOA with an associated decline from the CGOA compared to the standard method (Figure 10). These results are attributable to the mismatch in relative biomass or RPWs by area between the two surveys.

Recommendation and rationale:

For 2023 the authors recommend M23.3, which is implemented in TMB using the *rema* R library, has a single shared process error, area-specific scaling parameters, eliminates the 1984 and 1987 bottom trawl surveys (i.e., starts in 1990), changes the weight of the longline survey from 0.5 to 1.0, and estimates an additional observation error for longline survey. This alternative model is responsive to GOA GPT and SSC recommendations (implements model in REMA and removes 1980s surveys), and allows the model to estimate additional longline survey observation error rather than arbitrarily down weighting the longline survey. This model does not have the lowest AIC value (Table 2). However, it does strike a balance by allowing both surveys to inform the biomass trend and adding uncertainty to the longline survey with less subjectivity than M19*. Additionally, the proposed apportionment method, that averages the proportions of predicted biomass and RPWs ("Biomass + RPWs"), leverages information from both bottom trawl and longline surveys, which often show different patterns in terms of the stock's scale and trend.

M19* and M23.1 predict very similar shortraker biomass in the GOA. M19* had the lowest AIC, but the subjective nature of the 0.5 longline survey weight is not desirable. For comparison, if M19* is run with a longline survey weight 0.2, the ΔAIC is 27.3 lower than M19*. The model fits the data better as you disregard the highly informative longline survey, and thus we recommend setting the surveys at equal weights. M23.2 and M23.4 are identical models, with the latter estimating a zero for the additional observation error of the longline survey. While these models also have a lower AIC value than M23.3 (Table 2), the additional observation error estimated for the bottom trawl survey is quite large (0.45), and this only further increases the already large observation error of the bottom trawl survey relative to the longline survey. M23.3 treats the surveys equally, and increases only the longline survey observation error, which as reasoned in 2021, helps to equalize the relative contribution of the two indices to the model estimates (Echave et al. 2021).

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Tables

Table 1. Fixed effects parameter estimates, standard errors (SE), and 95% lower and upper confidence intervals (LCI and UCI, respectively) for the models considered in this analysis. Process error (PE) variances are listed first, followed by area-specific scaling parameters (q) and additional observation errors (+OE) by survey (i.e., bottom trawl survey = BTS and longline survey = LLS).

Model Name	Parameter	Estimate	SE	LCI	UCI
M19* w/ 84/87	PE	0.17	0.04	0.11	0.27
M19* w/ 84/87	CGOA q	0.41	0.04	0.33	0.51
M19* w/ 84/87	EGOA q	1.21	0.11	1.02	1.45
M19* w/ 84/87	WGOA q	2.12	0.3	1.6	2.81
M19*	PE	0.17	0.04	0.11	0.26
M19*	CGOA q	0.42	0.05	0.34	0.52
M19*	EGOA q	1.21	0.11	1.01	1.44
M19*	WGOA q	2.28	0.33	1.71	3.03
M23.1	PE	0.2	0.03	0.15	0.28
M23.1	CGOA q	0.42	0.04	0.35	0.51
M23.1	EGOA q	1.2	0.1	1.02	1.42
M23.1	WGOA q	2.25	0.3	1.74	2.91
M23.2	PE	0.19	0.03	0.14	0.27
M23.2	CGOA q	0.42	0.06	0.31	0.56
M23.2	EGOA q	1.05	0.15	0.79	1.4
M23.2	WGOA q	2.2	0.37	1.57	3.07
M23.2	BTS +OE	0.46	0.11	0.27	0.69
M23.3	PE	0.17	0.04	0.1	0.27
M23.3	CGOA q	0.42	0.04	0.35	0.52
M23.3	EGOA q	1.19	0.11	1	1.42
M23.3	WGOA q	2.27	0.3	1.75	2.95
M23.3	LLS +OE	0.15	0.07	0.06	0.36
M23.4	PE	0.19	0.03	0.14	0.27
M23.4	CGOA q	0.42	0.06	0.31	0.56
M23.4	EGOA q	1.05	0.15	0.79	1.4
M23.4	WGOA q	2.2	0.37	1.57	3.07
M23.4	BTS +OE	0.46	0.11	0.27	0.69
M23.4	LLS +OE	0	0.34	0	1.5

Table 2. Model selection results for candidate models that use the two-survey random effects model (REMA) fit to the full time series (1990-2021).

Model Name	**Objective Function**	**Number of Parameters**	**AIC**	**Δ AIC**
M19*	76.26	4	160.5	0
M23.1	83.58	4	175.2	14.7
M23.2	75.38	5	160.8	0.3
M23.3	82.94	5	175.9	15.4
M23.4	75.38	6	162.8	2.3

Figures

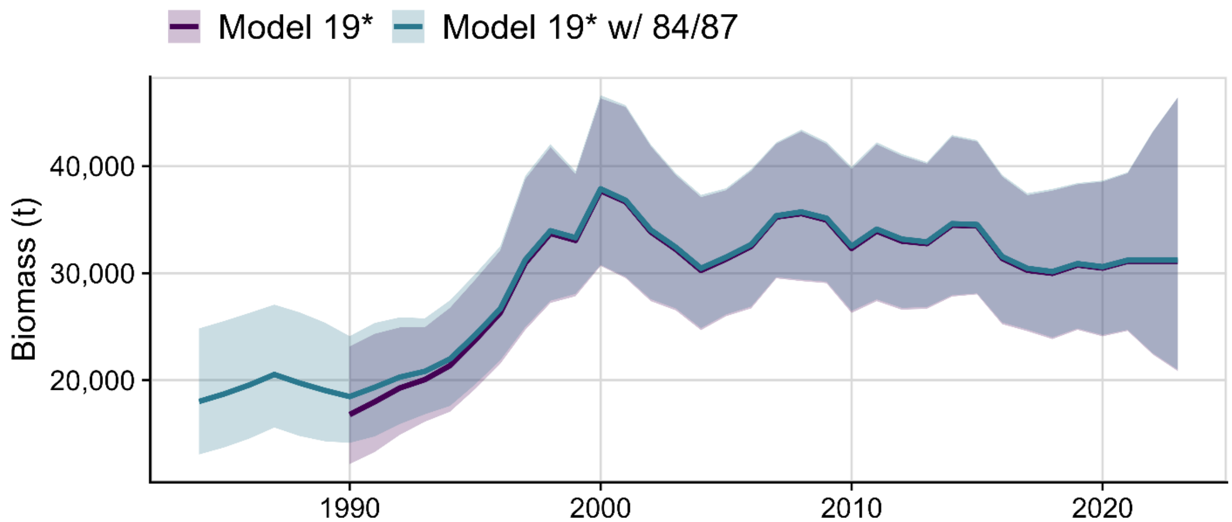

Figure 1. Two-survey random effects (REMA) model fits to Gulf of Alaska shortraker rockfish bottom trawl survey biomass and longline survey relative population weights. Results are shown for Model 19* (starting in 1990) in purple and Model 19* w/ 84/87 (identical to Model 19*, but starting in 1984) in blue.

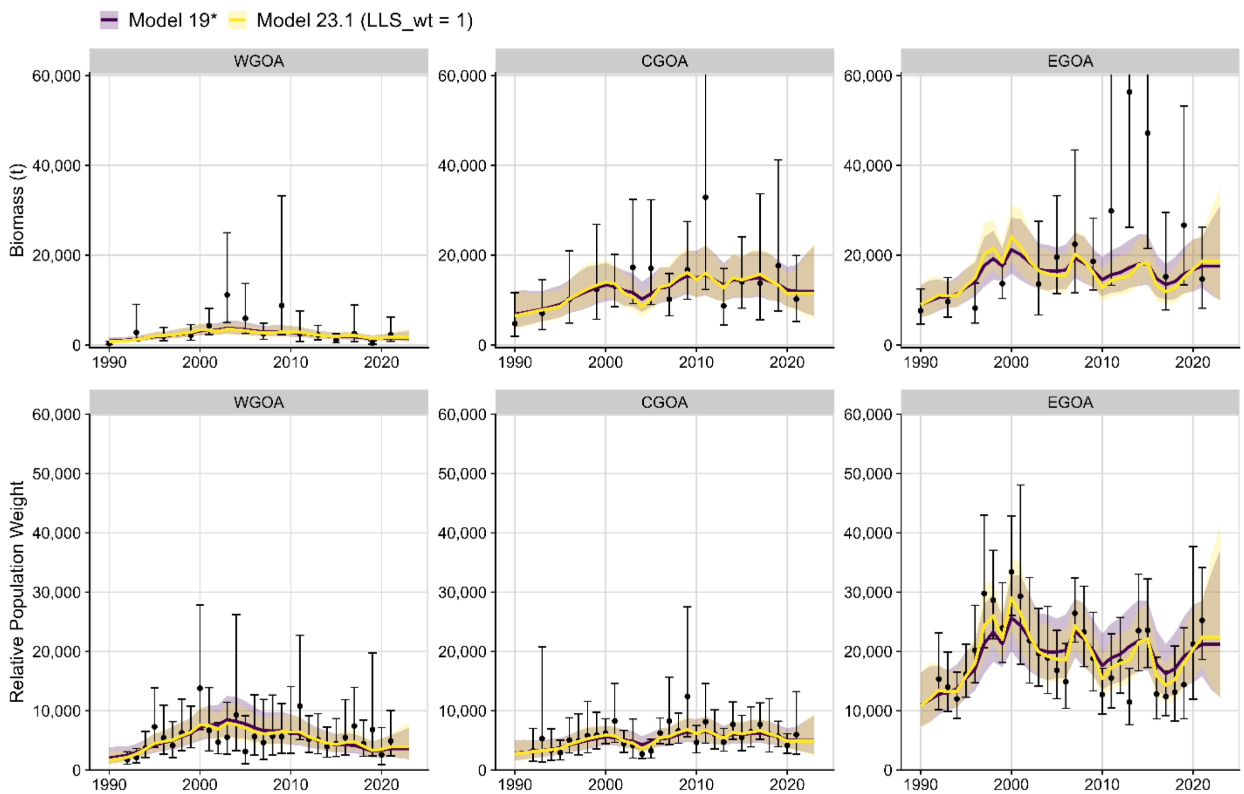

Figure 2. Two-survey random effects (REMA) model fits to Gulf of Alaska (GOA) shortraker rockfish bottom trawl survey biomass (top panels) and longline survey (LLS) relative population weights (bottom panels) by western, central, and eastern GOA (WGOA, CGOA, and EGOA) management area, where the points and error bars are the design-based survey estimates and the lines with shaded regions are the model predictions and 95% confidence intervals from the REMA model. Results are shown for Model 19* (LLS weight = 0.5) in purple and Model 23.1 (LLS weight = 1.0) in yellow.

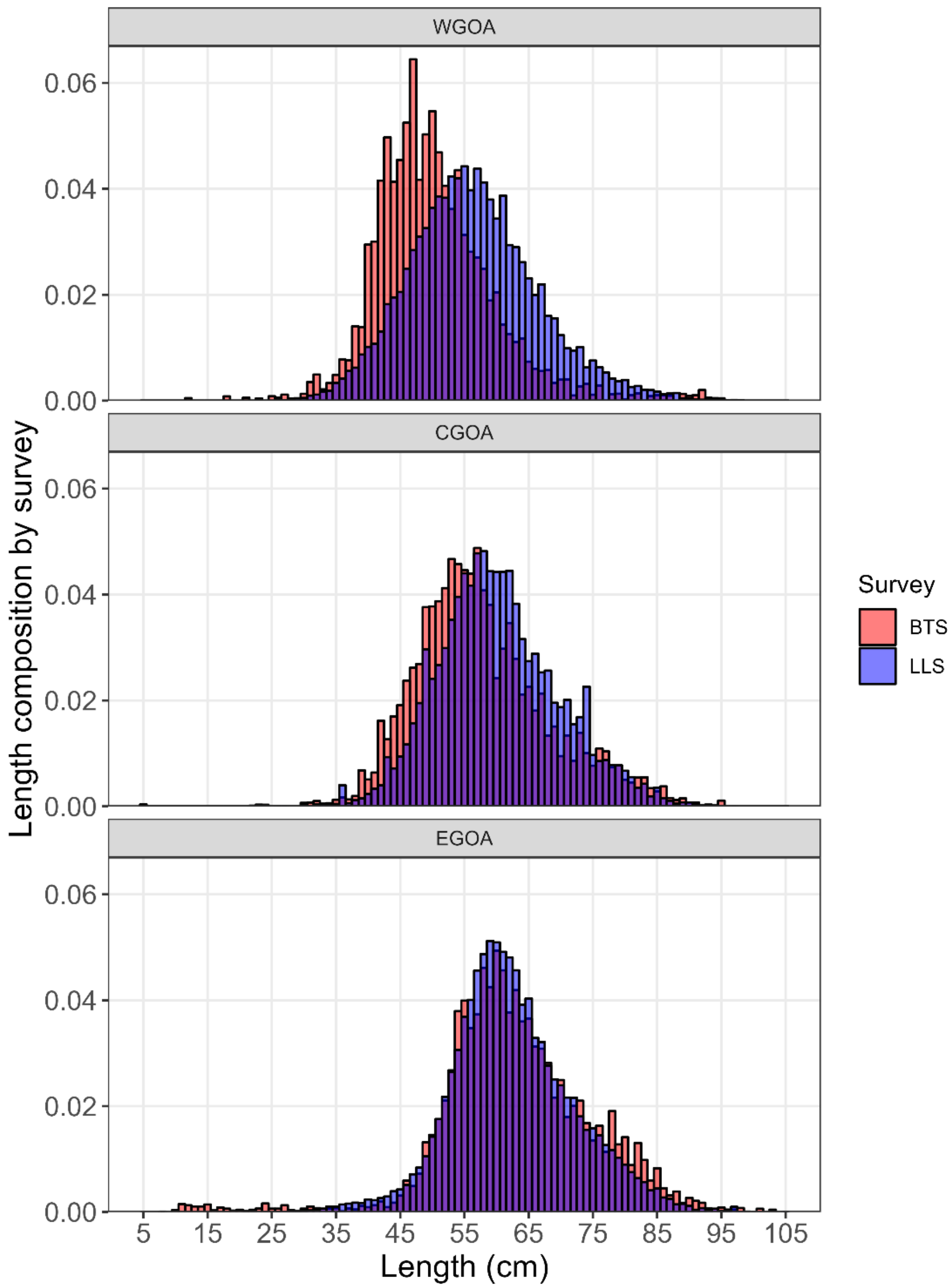

Figure 3. Length compositions for Gulf of Alaska (GOA) shortraker rockfish by bottom trawl survey (BTS, red) and longline survey (LLS, blue) by central, eastern, and western GOA (WGOA, CGOA, and EGOA) management area.

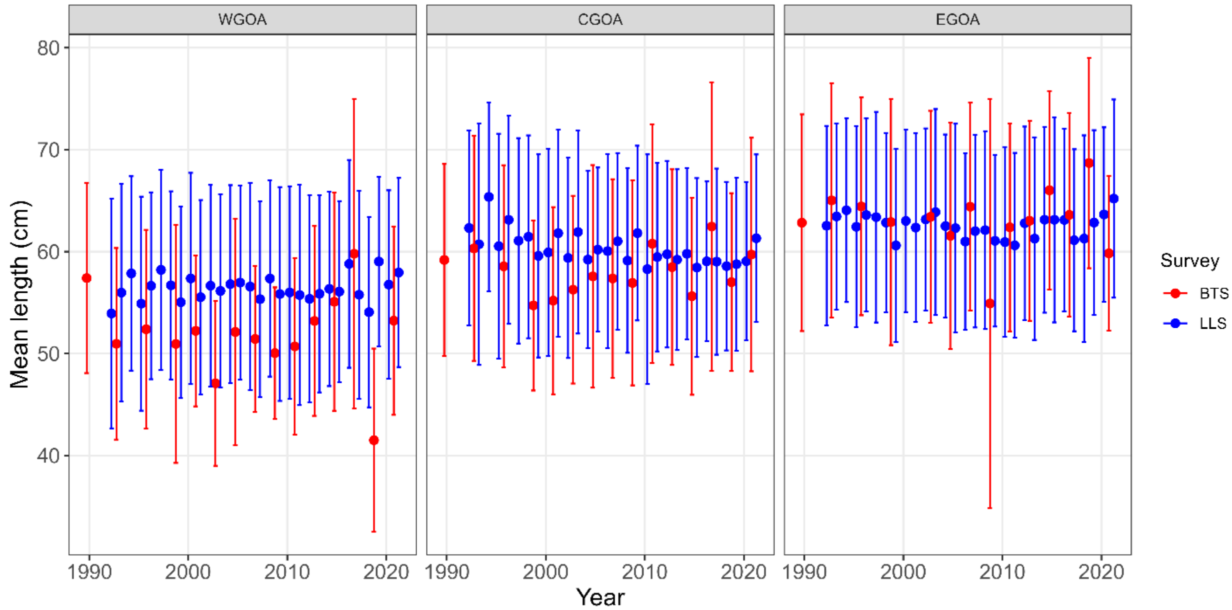

Figure 4. Mean length (error bars = ± 1 SD) through time for Gulf of Alaska (GOA) shortraker rockfish by bottom trawl survey (BTS, red) and longline survey (LLS, blue) by central, eastern, and western GOA (WGOA, CGOA, and EGOA) management area.

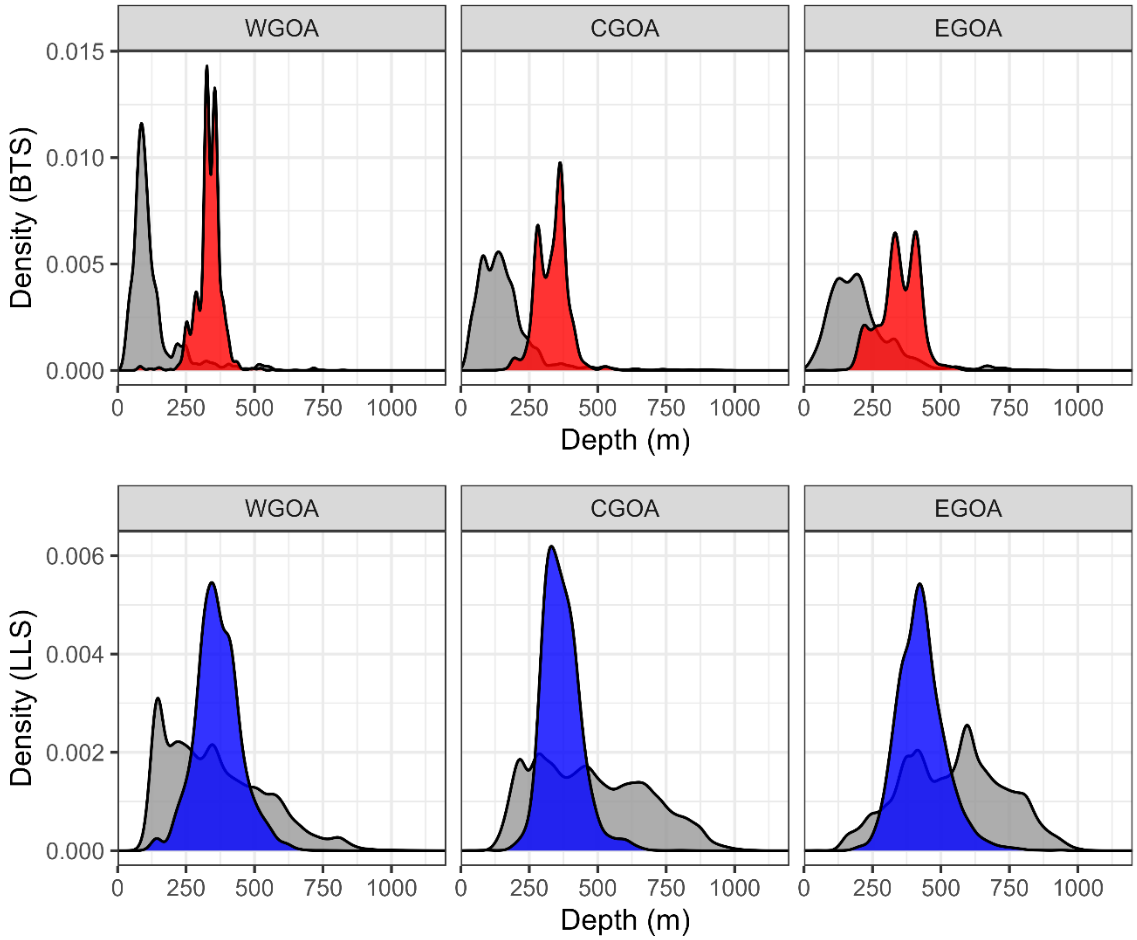

Figure 5. Survey effort (gray) relative to catch of shortraker rockfish by depth in the Gulf of Alaska (GOA) from the bottom trawl survey (BTS, top panel, red) and longline survey (LLS, bottom panel, blue) by central, eastern, and western GOA (WGOA, CGOA, and EGOA) management area.

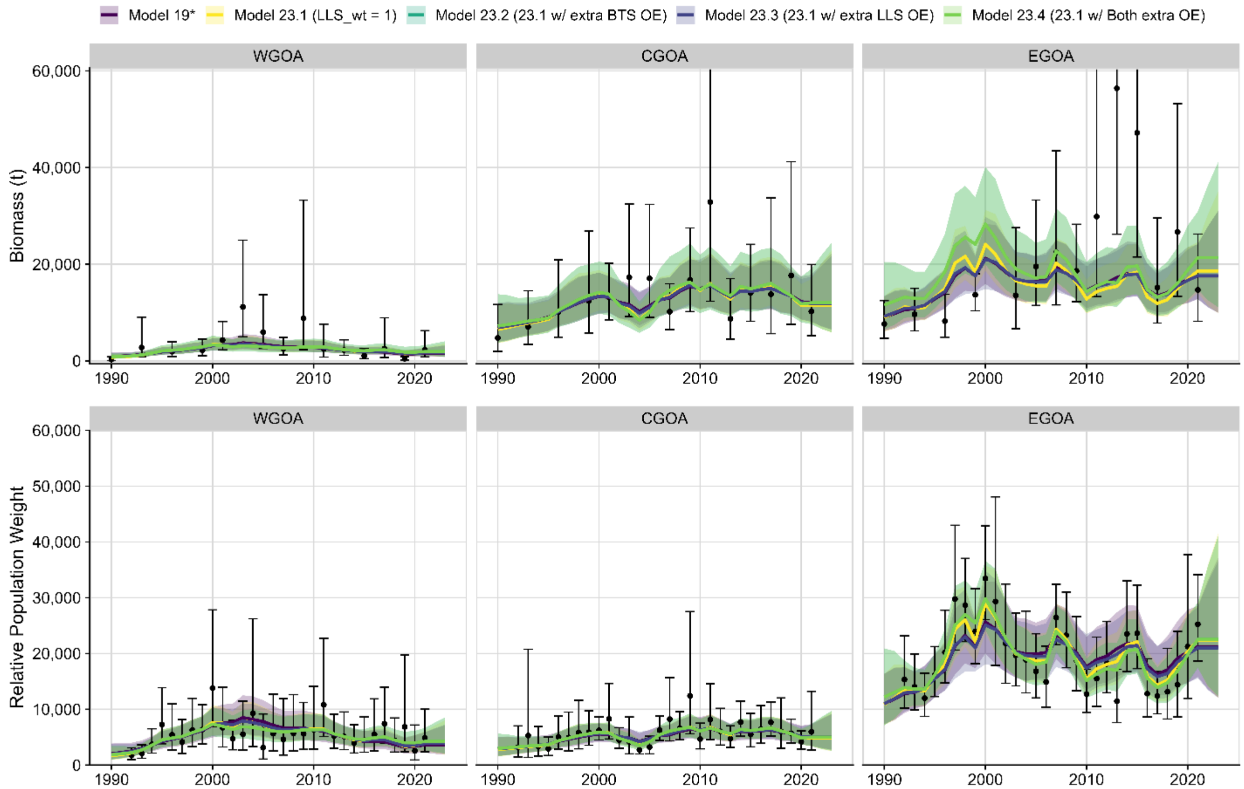

Figure 6. Two-survey random effects (REMA) model fits to Gulf of Alaska (GOA) shortraker rockfish bottom trawl survey (BTS) biomass (top panels) and longline survey (LLS) relative population weights (bottom panels) by western, central, and eastern GOA (WGOA, CGOA, and EGOA) management area, where the points and error bars are the design-based survey estimates and the lines with shaded regions are the model predictions and 95% confidence intervals from the REMA model. Results are shown for Model 19* (LLS weight = 0.5) in purple, Model 23.1 (LLS weight = 1.0) in yellow, Model 23.2 (M23.1 with extra BTS observation error) in dark green, Model 23.3 (M23.1 with extra LLS observation error) in blue, and Model 23.4 (M23.1 with extra observation error for both surveys) in light green.

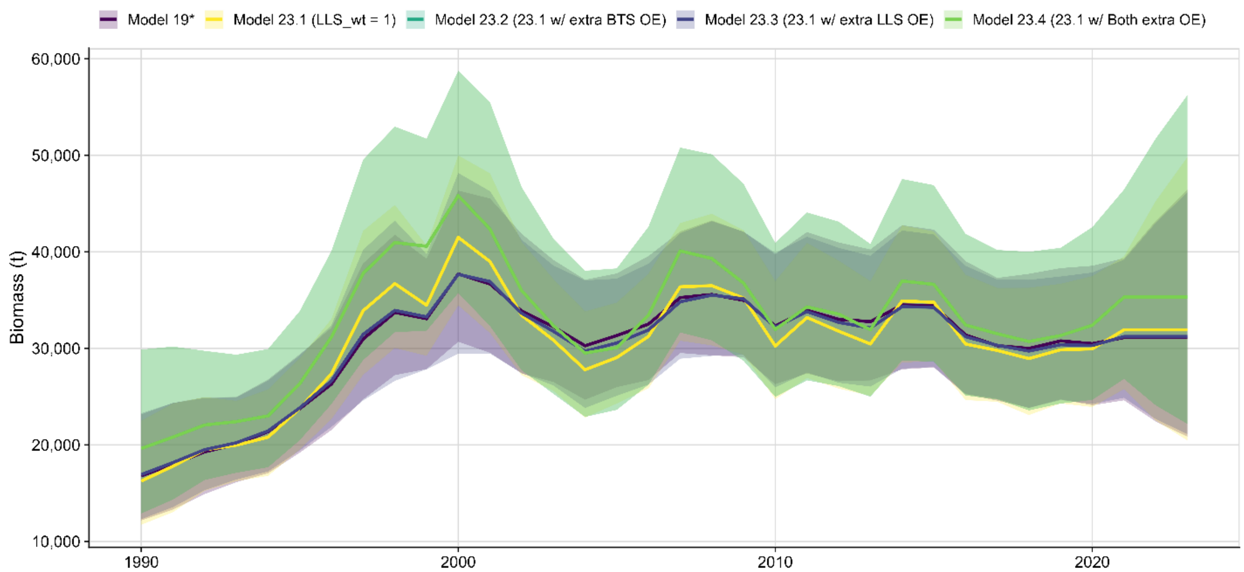

Figure 7. Two-survey random effects (REMA) model fits to Gulf of Alaska (GOA) shortraker rockfish bottom trawl survey (BTS) biomass and longline survey (LLS) relative population weights, where the shaded regions are the model predictions and 95% confidence intervals from the REMA model. Results are shown for Model 19* (LLS weight = 0.5) in purple, Model 23.1 (LLS weight = 1.0) in yellow, Model 23.2 (M23.1 with extra BTS observation error) in dark green, Model 23.3 (M23.1 with extra LLS observation error) in blue, and Model 23.4 (M23.1 with extra observation error for both surveys) in light green.

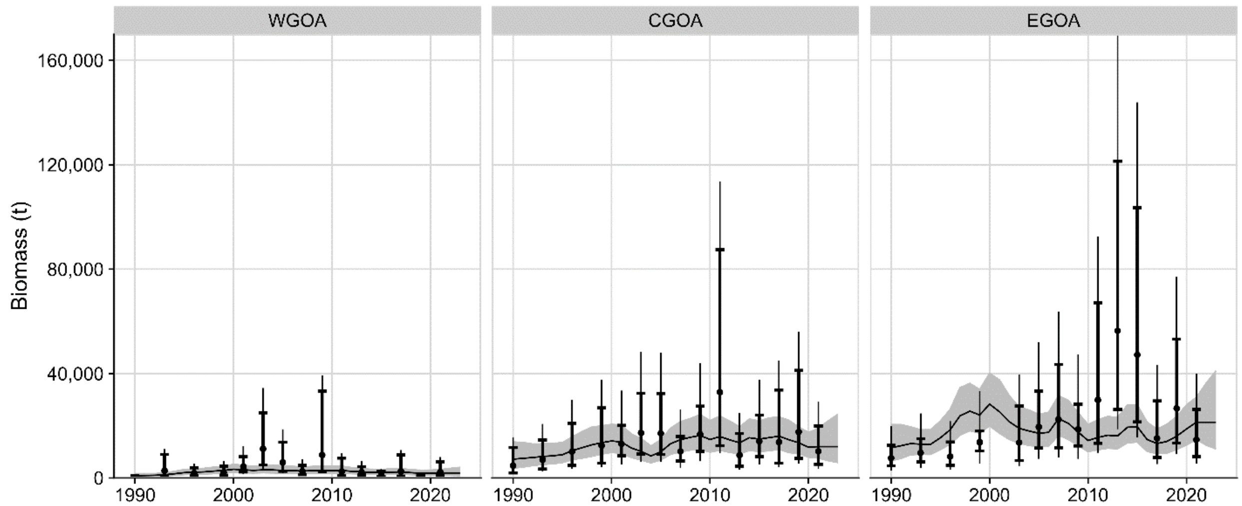

Figure 8. An illustration of the additional observation error estimated in Model 23.2 where the points and bolded error bars are the design-based bottom trawl survey estimates, the shaded regions are the model predictions and 95% confidence intervals, and the line extending beyond the bolded error bars showing the additional observation error estimated in the model.

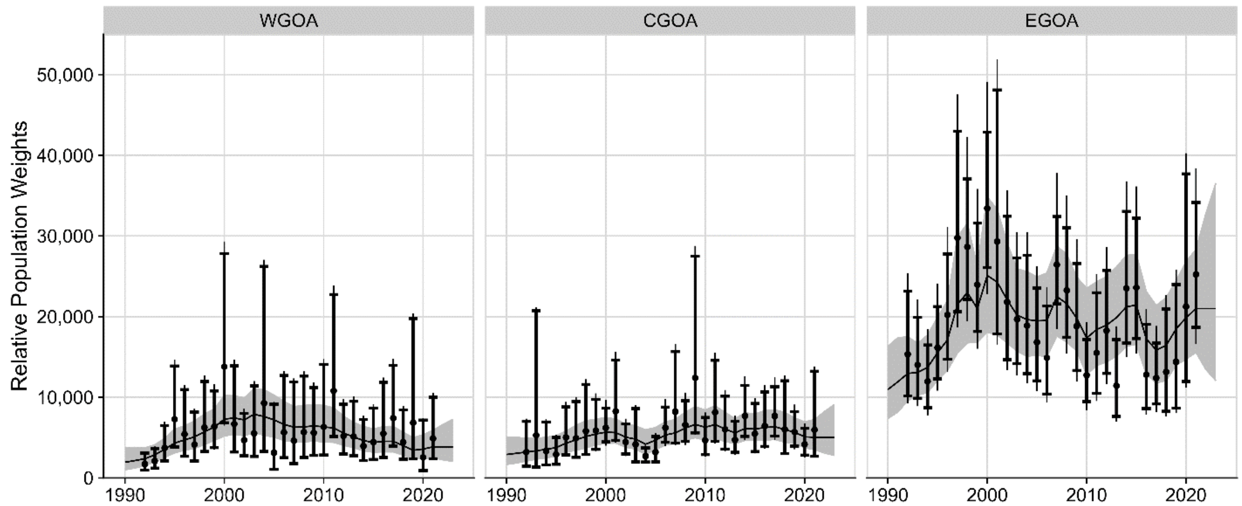

Figure 9. An illustration of the additional observation error estimated in Model 23.3 where the points and bolded error bars are the design-based longline survey estimates, the shaded regions are the model predictions and 95% confidence intervals, and the line extending beyond the bolded error bars showing the additional observation error estimated in the model.

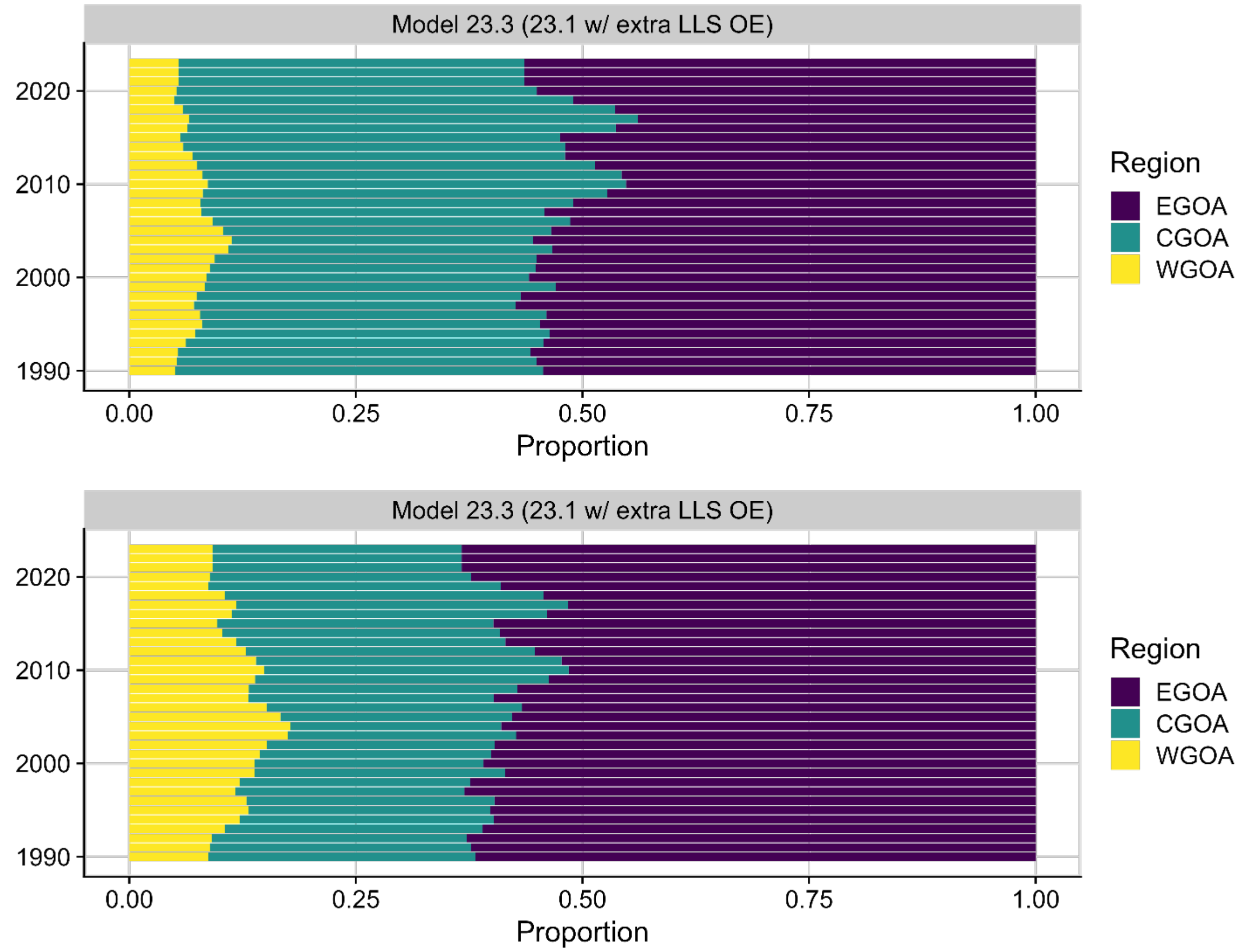

Figure 10. Apportionment results (i.e. the proportion of Acceptable Biological Catch that would be apportioned to each management area) for 2000-2023 based on the alternative method of apportionment and two-survey random effects (REMA) model used. Top panel: results from the author-recommended model (M23.3) and current apportionment method based on proportions of predicted biomass by area. Bottom panel: results from the author-recommend model (M23.3) and proposed apportionment method based on the average proportions of predicted biomass and predicted relative population weights (RPWs) by area.