Gulf of Alaska dusky rockfish updates

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Executive Summary

Gulf of Alaska (GOA) dusky rockfish is assessed as a Tier 3 stock. The currently accepted assessment model, 22.3a, uses a bespoke statistical age-structured assessment model in AD Model Builder (ADMB; Fournier *et al.* 2012) based on a generic rockfish model (Courtney *et al.* 2007). Model 22.3a incorporates the Groundfish Assessment Program's Vector Autoregressive Spatio-Temporal (VAST) model as the survey biomass estimate with a lognormal error distribution. This assessment year, the authors propose to make several corrective updates to the assessment model and propose an alternative apportionment method.

Assessment model changes

There are two minor changes in the model code that either were incorrectly specified or diverges with common practice. The changes that are being proposed are to rectify those oversights.

1. Model m22.4a: The current model estimates the trawl survey biomass likelihood with a normal error structure:

$$L = \lambda \sum_{y} \frac{\left(I_y - \widehat{I_y}\right)^2}{2SE\left(I_y\right)^2}$$

However, the trawl survey biomass likelihood will be updated to incorporate a lognormal error structure:

$$L = \lambda \sum_{y} \left[\log\left(\sigma_y\right) + 0.5 \left(\frac{\log\left(I_y / \widehat{I_y}\right)}{\sigma_y} \right)^2 \right],$$

where

$$\sigma_y = \sqrt{\log\left(1 + \frac{SE\left(I_y\right)^2}{I_y^2}\right)}$$

Here, y is year, I_y is the annual survey biomass observation, $\widehat{I_y}$ is the estimated annual survey biomass, σ_y is annual survey biomass log standard error, λ is the likelihood weight, and $SE\left(I_y\right)$ is the annual survey biomass standard error.

This change aligns this assessment with the common assumption used in stock assessment models that population index data follow a log-normal distribution, because the population index uncertainty is often skewed rather than symmetric. For the purposes of this document, the model correction for updating to the lognormal error in the survey biomass likelihood is shown as 'm22.4a_srv' and compared to the base (accepted m22.3a) model.

2. Model m22.5a: The model code mis-specifies the starting number at age values when estimating the abundance at the start of the first projection year and in the B_{100} and B_{40} calculations.

Currently, the start year is listed as 1979, but should be corrected to 1977 (established regime shift year) plus the recruitment age in order to start the predicted recruitment at the correct year. The recruitment age for dusky rockfish is age 4; thus, the start year should be listed as 1981 (1977+recruitment-age). The model correction for updating the start year with the recruitment age in the population projection model, B_{100}, and B_{40} will be built on the 'm22.4a_srv' model and shown as 'm22.5a_srvproj'.

Model comparisons are made between the currently accepted 'base' model, m22.3a, and the two updated models, m22.4a and m22.5a, with model likelihoods and key parameter estimates shown in Table 1 and 2, respectively. Model m22.5a with the lognormal error structure imperceptibly improves the fishery and survey age and lengths based on the negative log-likelihoods and visually appears to fit the observed survey data better than the base model (Table 1; Figure 1). Modifying the survey error structure to lognormal in model m22.4a did produce differences in the model results. The estimated survey catchability and biomass are higher in the model using the lognormal error structure (m22.4a) than the base model (m22.3a) by 6-23% (Figure 1), but yield lower female spawning biomass by up to 13% in the second half of the time series when the survey index starts (Figure 2A). The estimated fishing mortality rate is slightly higher in the updated model compared to the base in the latter half of the time series (Figure 2B). Consequently, the estimated biomass values and parameters (e.g., B_{100}, B_{40}, final year total biomass, and spawning biomass) are lower in the updated model with lognormal error than the base model (Table 2).

Adding the correction of the starting year for the predicted recruitment did not change most of the results and outputs from the model m22.4a (Figure 2). The likelihood values and majority of the key parameter estimates remained the same (Table 1 and 2). The parameters that are minimally affected by the projection model correction are the B_{100}, B_{40}, and associated biomass quantities, which changed by < 3% compared to the model m22.4a (Table 2).

The authors recommend using model 22.5a with both model changes.

Apportionment method update

Currently the ABC for GOA dusky rockfish is allocated to each of the three management areas, Western, Central, and Eastern (further partitioned), based on the proportion of biomass in each area. More specifically, the accepted apportionment method uses the area-specific proportions from the design-based bottom trawl survey abundance estimates that are smoothed by the random effects model (REMA model). Because dusky rockfish are patchily distributed and are often found in both survey 'trawlable' and 'untrawlable' habitat (Jones et al. 2012; Rooper and Martin 2012), the bottom survey catch and resulting area-specific estimated biomass can be variable (Figure 3). Thus, the allocated ABC for each management area can be prone to large fluctuations from year to year. Additionally, a model-based index of abundance (i.e., VAST index) was accepted in 2022 as the survey index in the assessment model, which uses a lognormal error structure and estimates each year independently.

For consistency with the stock assessment model, the authors propose to change the apportionment method to be based on the area-specific model-based (VAST) index of abundance using the same model structure as the assessment model. Apportionment method using the alternative model-based approach (VAST) is compared to the accepted design-based model smoothed by REMA (design-based, REMA model). For purposes of this comparison, apportionment methods use survey data from 1990 to 2023.

Both the current (REMA applied to design-based biomass) and alternative model (VAST) used for region-specific biomass estimates reduce the variability in trends compared to the "observed" design-based biomass (Figure 4). However, the results in apportionment using VAST reduce uncertainty both within any given year and across time as compared to the current apportionment method (Figure 5). For example, the proportion of biomass in the Central GOA ranges from 0.56 to 0.94 based on the currently accepted design-based, REMA model, whereas the proportion of biomass from the VAST model ranges from 0.62 to 0.70.

In addition to the differences in variability and fluctuations between the models, there are a few differences in the annual estimated biomass for each management area between the two models, thus affecting the proportion of biomass in each area (Figure 5). The proportions from 2021-2023 from each model are substantially different (Table 3). The proportion of biomass in the Western and Eastern GOA for the design-based, REMA model falls under 0.05 (i.e., < 5%), whereas the proportion of biomass from the VAST model ranges roughly around 0.10 to 0.20 (i.e., 10-20%). In contrast, the proportion of biomass in the Central GOA is notably smaller when using the VAST model (~0.65-0.67 or 65-67%) compared to the design-based model, REMA model (~0.93-0.94 or 93-94%).

Thus, the proportions based on the VAST model will lead to notable changes in the allocation of ABC. Backwards projecting the proportions from each allocation model using the historical ABC to each management area, the VAST model would have allocated a smaller proportion of ABC to the Central GOA, but higher proportion of ABC to the Western and Eastern GOA compared to the accepted methodology (Figure 6). While the historical catch does surpass the projected allocated ABC in one or two years for both the design-based, REMA model and VAST model, the total GOA-wide catch remains significantly under the ABC.

The authors recommend using the model-based, VAST model approach for apportionment in place of the design-based, REMA model. Switching to the VAST model would be consistent with the assessment model. Likewise, the VAST model produces less variable (i.e., smoother) estimated biomass and subsequent proportions compared to the design-based, REMA model. For management purposes, using the VAST model for the apportionment methodology can substantially change the proportions of ABC allocated to each management area, but, with the exception of one year, the catch for GOA dusky rockfish does not appear to surpass the historical projected allocation of ABC.

References

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Fournier, D.A., Skaug, H.J., Acheta, J., et al. (2012) AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27, 233-249.

Jones, D., Wilson, C.D., De Robertis, A., Rooper, C., Weber, T.C. and Butler, J.L. (2012) Evaluation of rockfish abundance un untrawlable habitat: Combining acoustic and complementary sampling tools. *Fishery Bulletin* 110, 332-343

Rooper, C. and Martin, M. (2012) Comparison of habitat-based indices of abundance with fishery-independent biomass estimates from bottom trawl surveys. *Fishery Bulletin* 110, 21-35.

Tables

Table 1. Likelihood values from currently accepted 'base' model, m22.3a_base, and alternative models, m22.4a_srv and m22.5a_srvproj.

Likelihood	m22.3a_base	m22.4a_srv	m22.5a_srvproj
Catch	25.72	26.95	26.95
Trawl survey	30.03	31.43	31.43
Fishery ages	41.52	41.19	41.19
Survey ages	138.14	138.01	138.01
Fishery lengths	60.03	59.87	59.87
Recruitment devs	36.21	31.49	31.49
sigmaR	0.41	0.54	0.54
q prior	0.50	0.16	0.16
Data LL	295.43	297.44	297.44
Total LL	431.54	428.83	428.83

Table 2. Key parameter estimates from the currently accepted 'base' model, m22.3a_base, and alternative models, m22.4a_srv and m22.5a_srvproj.

Parameter	m22.3a_base	m22.4a_srv	m22.5a_srvproj
sigmaR	1.003	0.943	0.943
q	0.638	0.776	0.776
avg rec	2.702	2.705	2.705
F_{40}	0.091	0.092	0.092
Total Biomass	107,186	93,488	93,531
SSB	44,468	38,464	38,465
B_{100}	65,565	60,343	61,962
B_{40}	26,226	24,137	24,785
ABC	7,921	6,863	6,863

Table 3. Apportionment proportions each management area for each model (accepted design-based, REMA model [db+rema] and VAST model) from 2021-2023.

Year	Area	db+rema (base)	vast
2021	Western	0.029	0.138
2021	Central	0.939	0.674
2021	Eastern	0.033	0.187
2022	Western	0.031	-
2022	Central	0.929	-
2022	Eastern	0.040	-
2023	Western	0.033	0.137
2023	Central	0.918	0.651
2023	Eastern	0.049	0.212

Figures

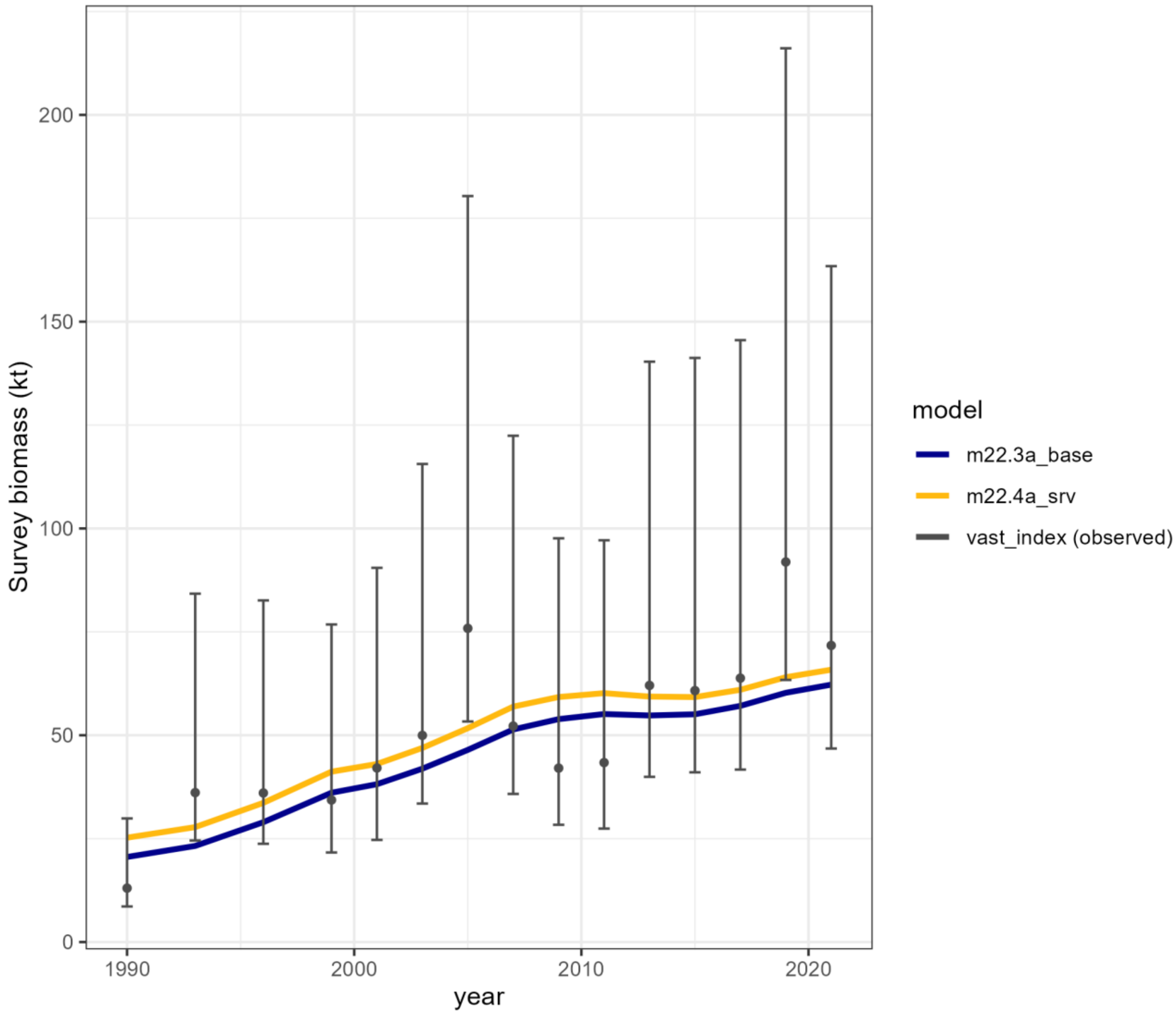

Figure 1. Estimated survey biomass (smooth lines) from the currently accepted ‘base’ model, m22.3a_base, and the alternative model, m22.4a_srv, with the VAST survey index (observed) values with confidence intervals.

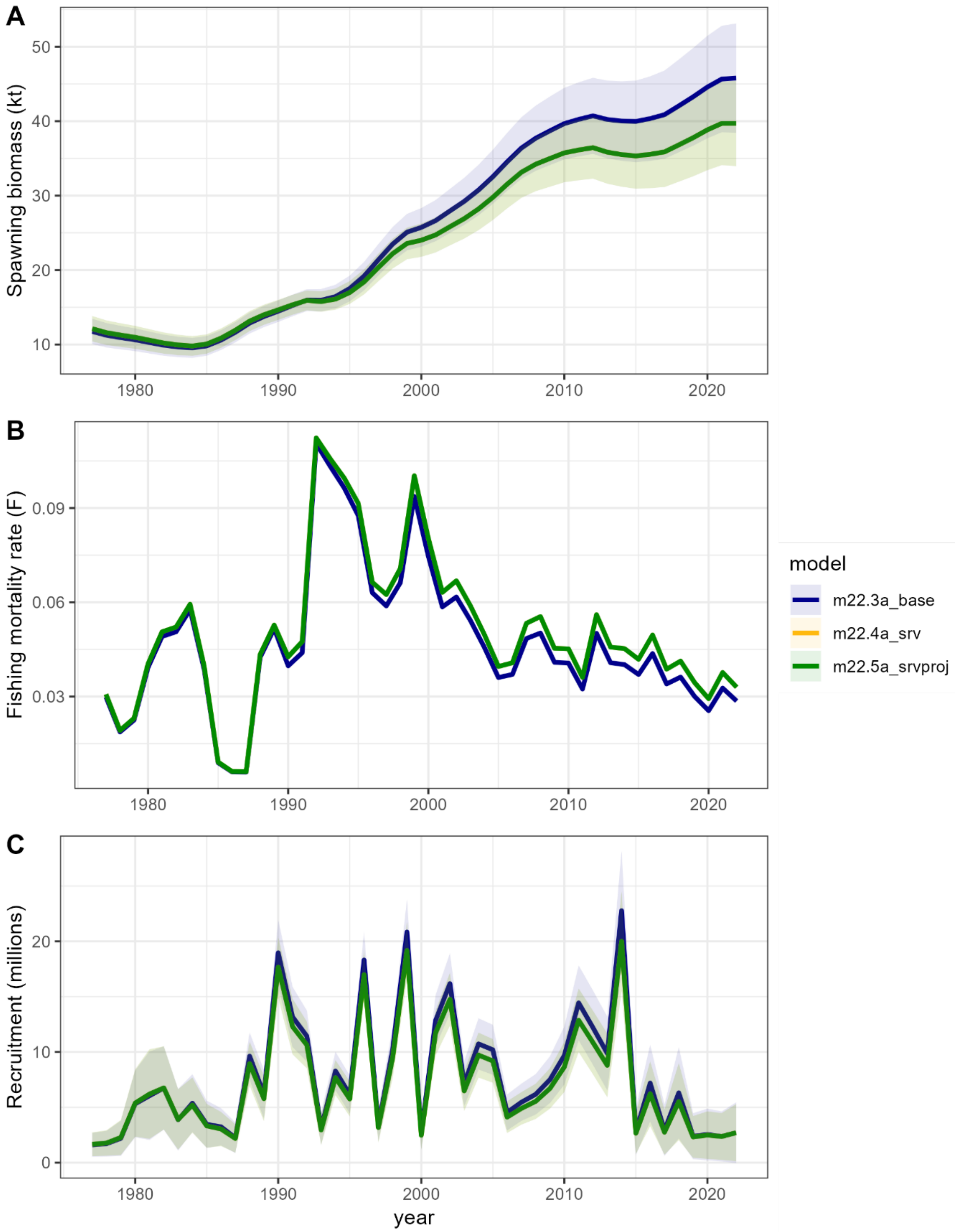

Figure 2. Time series estimates of A) female spawning biomass, B) fishing mortality rate, *F*, and C) recruitment for the accepted 'base' model (m22.3a_base) and alternative models with lognormal error in the survey biomass likelihood (m22.4a_srv) and correction of starting year in the projection module (m22.5a_srvproj). Note: there is no discernable difference between the updated models (m22.4a_srv and m22.5a_srvproj) in the time series of estimates.

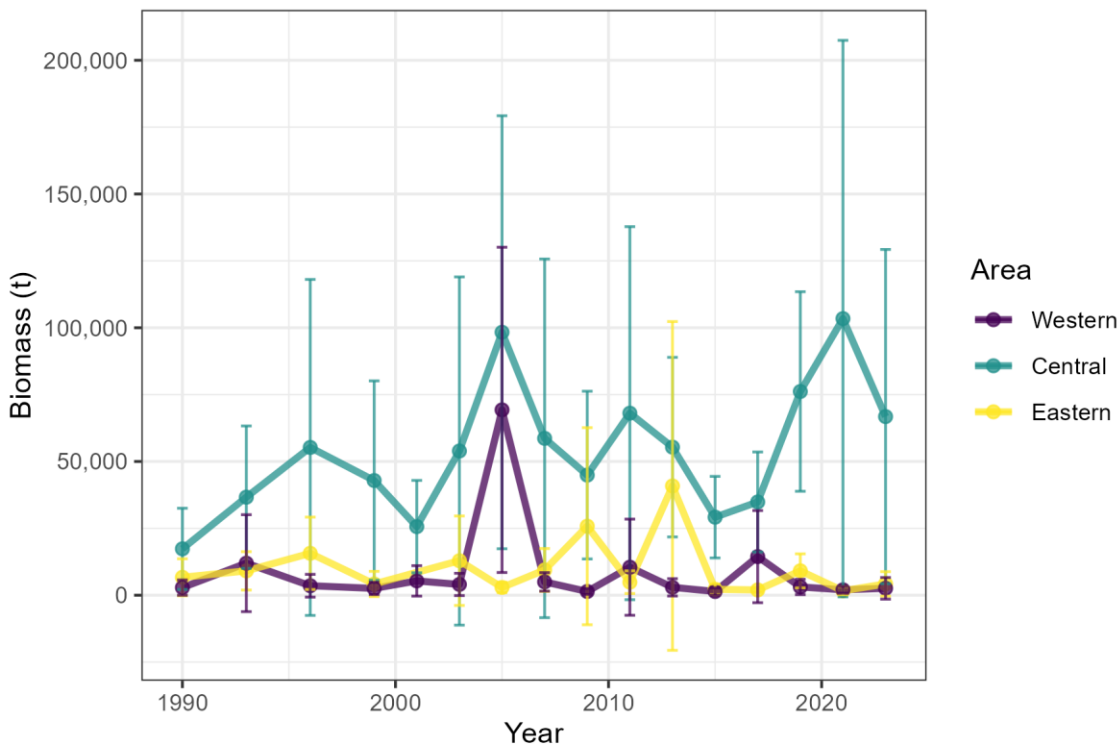

Figure 3. Design-based estimated biomass from the AFSC Groundfish Assessment Program bottom trawl survey for GOA dusky rockfish by management area.

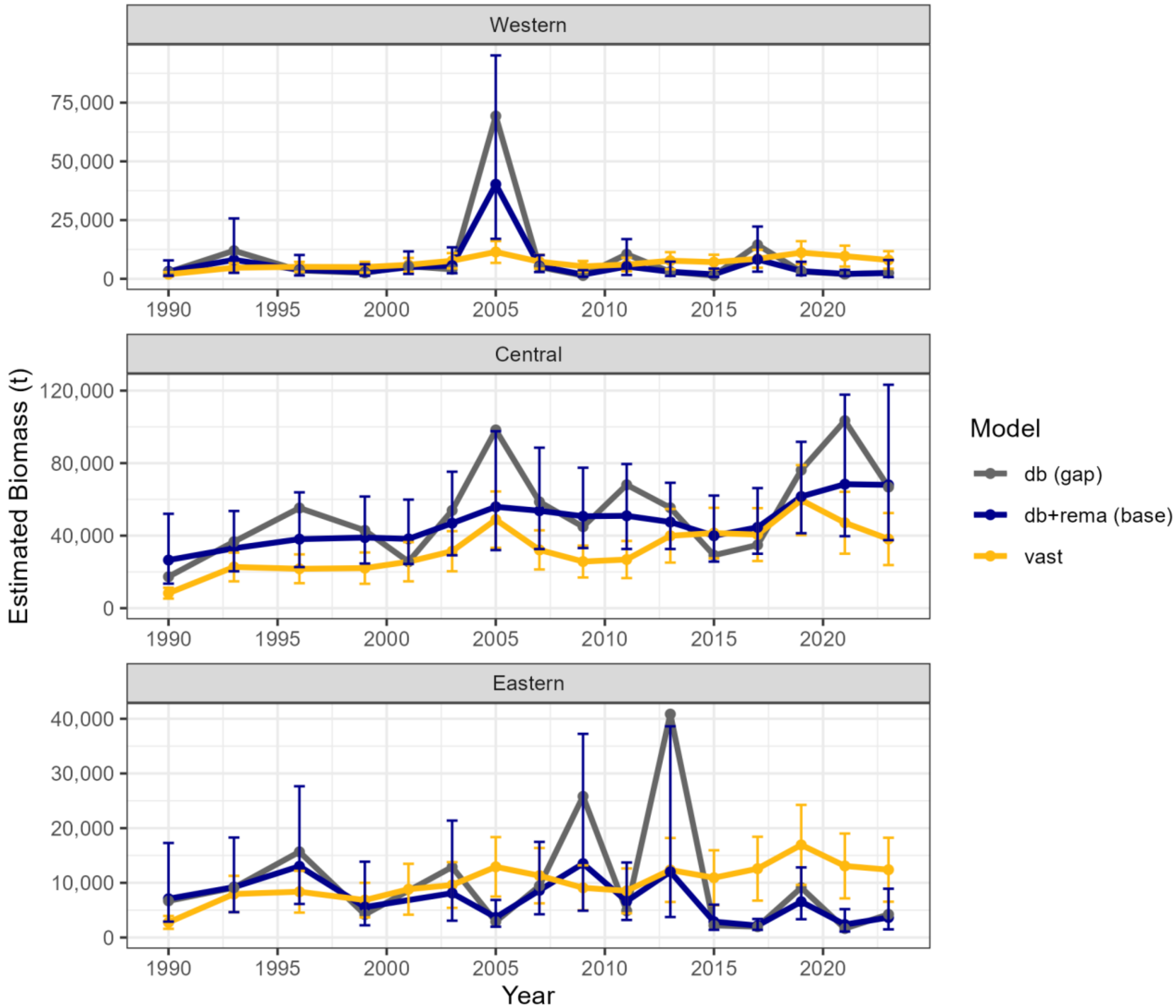

Figure 4. GOA dusky indices of abundance for each management area from the two model types, design-based model smoothed by REMA (db+rema) and VAST, with the associated uncertainty. Biomass point estimates from the Groundfish Assessment Program design-based model (df (gap)) are overlaid on each panel for comparison.

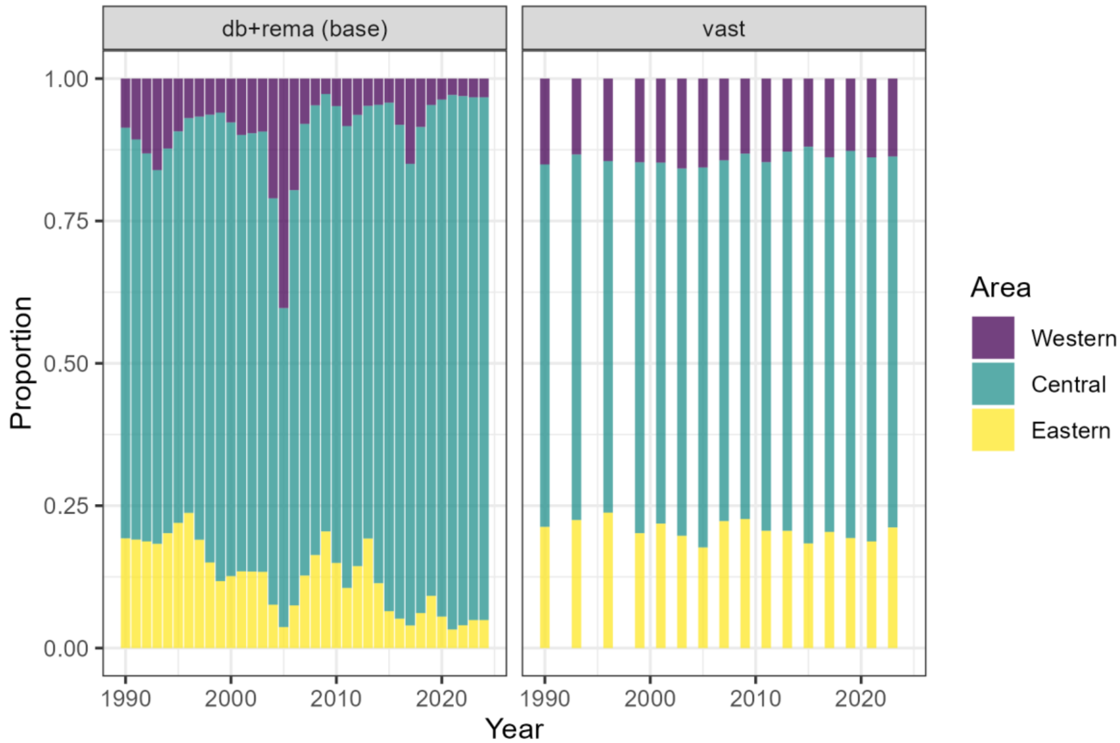

Figure 5. Proportion of biomass in each Gulf of Alaska (GOA) management area, Western, Central, and Eastern, based on the two model types, currently accepted design-based model smoothed by REMA (db+rema) and the alternative design-based VAST model.

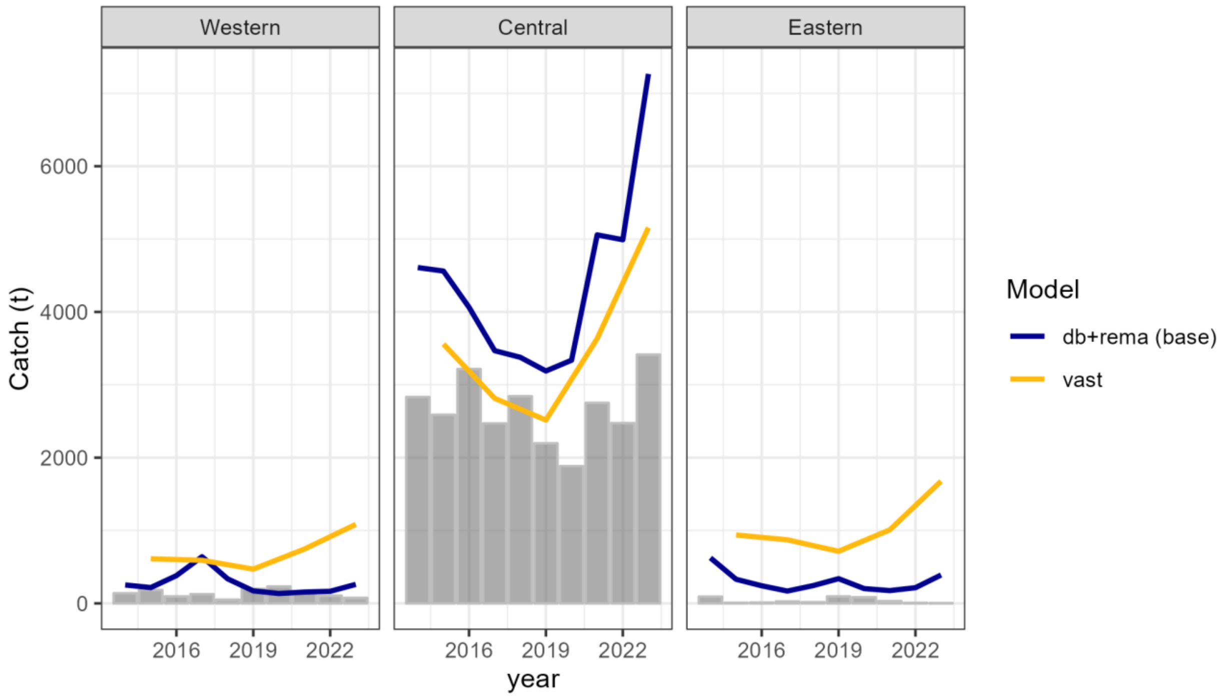

Figure 6. Historical projection of ABC allocated to each management area based on the proportions from each model types (accepted design-based, REMA model and alternative VAST model) with total fisheries catch for GOA dusky rockfish. Note: the allocation of ABC to the Eastern GOA is further divided into West Yakutat and Southeast and does not represent current management spatial areas. This panel is for visual purposes only.