INVESTIGATING ADDITIONAL POPULATION INDICES WITHIN THE TIER 5 RANDOM EFFECTS MODEL

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INTRODUCTION

Currently, species that fall under the Tier 5 category at AFSC are assessed with a random effects model that fits biomass estimates from the AFSC bottom trawl surveys. It has been noted that several of these species are also sampled in additional surveys, in particular, by surveys that deploy longline gear. This has led to several SSC and Plan Team comments, including:

"The SSC supports the author's plan to explore the feasibility of incorporating longline survey abundance indices for use in estimating biological reference points and possibly area apportionments. If the longline survey is added to the assessment, the SSC and the PT notes that methods will need to be developed to estimate area apportionments for assessments that utilize more than one survey." (SSC, December 2015)

"Secondly, a few assessments incorporate multiple indices that could also be used for apportionment. The Team recommends an evaluation on how best to tailor the RE model to accommodate multiple indices." (Plan Team, November 2015)

In this document, a method that allows for an additional population index to be included within the random effects model for Tier 5 species is presented. This method is applied to the Gulf of Alaska (GOA) shortspine thornyhead stock (the dominant species in biomass and catch within the GOA thornyhead stock complex) as an example for implementation of this method. For brevity, in this document we refer to the shortspine thornyhead stock as 'SST' rather than 'thornyhead' so that it will not be confused with the thornyhead stock complex.

DATA

The GOA bottom trawl survey biomass times series (either triennially or biennially from 1984 to present) for SST is the sole index used in the thornyhead stock complex assessment, and is the index used for all Tier 5 assessments in the GOA (this is also true of the bottom trawl surveys in the Aleutian Islands and Bering Sea for Tier 5 assessments in those regions). The biomass estimates for SST are very precise with coefficients of variation (CVs) that range from 5% to 12% (Figure 1). In the random effects model used in the 2015 assessment for SST, the bottom trawl

survey data was fit with random effects parameters that were estimated by region (Western/Central/Eastern GOA) and depth strata.

SST are also sampled by the AFSC longline survey, for which there is a Relative Population Weight (RPW) index that extends annually from 1992 to present. The CVs for the SST RPW index range from 5% to 10% (Figure 2). We use the RPW index rather than Relative Population Numbers (RPN) index because (1) it is more compatible with the random effects estimates of biomass, and (2) the random effects model typically has been used to estimate biomass rather than numbers. Because SST are frequently sampled with high precision by both the AFSC bottom trawl survey and longline survey this species was selected as an example case for application of a random effects model that incorporates the AFSC longline survey index as an additional index.

METHODS

Within the random effects model currently used for Tier 5 stocks at AFSC there are two types of parameters: (1) the random effects parameters that provide a time-series of estimates of the unobserved 'true' biomass, and (2) hyper-parameters that represent the variance of the random effects parameters and constrain the amount of process error (i.e., the amount if inter-annual variability) in the random effects parameters across time (hereon called the 'process error parameter'). Within the random effects model's objective function there are two components. The first component is the negative log-likelihood of the observation error, given by:

$$(1)\ -lnL_O^T = \sum_Y \sum_R \sum_S \frac{1}{2}\left[ln\left(2\pi\sigma_{T,y,r,s}^2\right) + \frac{1}{\sigma_{T,y,r,s}^2}\left(\hat{\theta}_{y,r,s} - lnI_{y,r,s}^T\right)^2\right]$$

where the subscript *O* denotes that this is the observation component to the objective function, the superscript/subscript *T* denotes that this observation error component is for the bottom trawl survey, subscripts *y* denote the year, *r* the region (Western GOA – WGOA, Central GOA – CGOA, Eastern GOA – EGOA), and *s* the depth strata for which the random effects are estimated, $\sigma_{T,y,r,s}^2$ is the variance of the bottom trawl survey biomass index, $\hat{\theta}_{y,r,s}$ is the random effects parameter estimate of biomass (on log-scale), and $I_{y,r,s}^T$ is the bottom trawl survey biomass index. The second component of the objective function is the negative log-likelihood of the process error, given by:

$$(2)\ -lnL_P = \sum_{y=2}^{Y} \sum_R \sum_S \frac{1}{2}\left[ln\left(2\pi\hat{\sigma}_\theta^2\right) + \frac{1}{\hat{\sigma}_\theta^2}\left(\hat{\theta}_{y-1,r,s} - \hat{\theta}_{y,r,s}\right)^2\right]$$

where the subscript *P* denotes that this is the process component to the objective function, the subscripts *y*, *r*, and *s* are as above, and $\hat{\sigma}_\theta^2$ is the estimated process error parameter.

The AFSC longline survey RPW index is added to the random effects model by estimating a catchability coefficient parameter that scales the random effects biomass estimates to the

longline survey RPWs. The longline survey RPW index is available with associated uncertainty at the regional scale. To estimate the regional RPW index we sum the random effects parameters by depth strata prior to scaling by the catchability coefficient. The estimate of the longline survey RPW index by region is then given by:

(3) $\hat{I}^L_{y,r} = q \sum_S e^{\widehat{\theta}_{y,r,s}}$

where the superscript *L* in $\hat{I}^L_{y,r}$ denotes that the index is for the longline survey and q is the catchability coefficient parameter. An additional observation error component is then added to the objective function, which is the negative log-likelihood of the model fit to the longline survey RPWs, given by:

(4) $-lnL^L_O = \sum_Y \frac{1}{2}\left[ln\left(2\pi\sigma^2_{L,y,r}\right) + \frac{1}{\sigma^2_{L,y,r}}\left(ln\left(q\sum_S e^{\widehat{\theta}_{y,r,s}}\right) - lnI^L_{y,r}\right)^2\right]$

where $\sigma^2_{L,y,r}$ is the regional variance of the longline RPW index and $I^L_{y,r}$ is the observed longline RPW index. As in the use of *T* in the superscripts and subscripts in eq. 1 to denote the bottom trawl survey we use *L* in the superscripts and subscripts to denote that this index is from the longline survey. We refer to the random effects model that includes the longline survey RPW index as the 'combined model'. The random effects model that does not include the longline survey index is referred to as the 'current model'.

RESULTS

Comparison of fit to the GOA-wide AFSC bottom trawl survey biomass for SST between the current model and the combined model is shown in the top panel of Figure 3. In general, the combined model provides estimates of AFSC bottom trawl survey biomass index that are not as precisely fit to the index compared to the current model. This is particularly true for the 1990 and 2003 bottom trawl survey biomass values for which the current model is more sensitive to those years while in comparison the combined model smooths those biomass estimates. It is also interesting that the fit to the 1990 bottom trawl survey biomass is influenced by the longline RPW index when there is no RPW data in that year. It appears that to balance the process error component of the likelihood the combined model smooths this data point in order to fit the start of the RPW index time-series. The combined model fits the longline survey RPW index well in most years (bottom panel Figure 3). Comparing between the trawl survey biomass index and the longline RPW index observations there are some time periods in which the trajectories do not agree, in particular in the period between 2000 and 2005 and the period between 2010 and 2015 (Figure 3). The general result of dampening the response of the random effects model to the bottom trawl survey biomass index with the combined model also held for the WGOA and CGOA regional estimates, while the EGOA estimates of biomass were similar between the two model

structures (Figure 4). Regional fit to the longline index by the combined model was generally precise, with the exception of recent years in the WGOA in which the combined model fit resulted in estimated RPWs that were smaller than the observed index (Figure 5). Because we fit the longline survey RPW index by region the combined model provides a straight-forward way to estimate apportionment that is responsive to both the bottom trawl survey biomass index and the longline RPW index. As would be expected from the results of the fit to regional indices, the regional apportionment from the combined model was more stable across time than the apportionment estimated by the current model (Figure 6). The estimate of catchability for the longline survey RPW index from the combined model was 0.627.

CONCLUSIONS

The method presented in this document provides a simple and straight-forward approach to including additional population indices in the random effects model used to assess Tier 5 species at AFSC. Using the GOA SST stock as an example, the general result shown here was an increase in the stability of biomass estimates across time, reduced tendency for the random effects model to over-fit bottom trawl survey biomass values in some years, and more consistent regional apportionment across time. Further, this model exposed data differences between the bottom trawl survey biomass index and the longline survey RPW index over time that can now be integrated into the estimation of management quantities for SST.

This method could easily be extended to assess other Tier 5 species that are sampled by longline gear as well as aid in the estimation of apportionment for Tier 3 species that include multiple population indices within the assessment. However, while the general method shown here can be used for the assessment of other species, considerations should be made by the individual stock assessment authors on how best to apply this method. For example, while the basic population dynamics are similar across the age-structured assessments used for Tier 3 stocks at AFSC, each model can be parameterized and implemented in much different manners. This would also hold with the combined model presented here, in which assessment authors may want to consider alternatives in weighting between the trawl survey and an alternative index, the spatial structure of the data, the amount or type of process error or catchability parameters estimated, the potential for differing selectivities between the indices and what that could mean, and the differences in the uncertainty for each index. We fully expect that while the general method of including the longline survey RPW index for SST can be used for other stocks at AFSC, the particular implementation to the GOA SST stock shown here would need to be adjusted for other stocks. In addition, future investigations and refinements will be made to this specific implementation to the GOA SST stock.

FIGURES

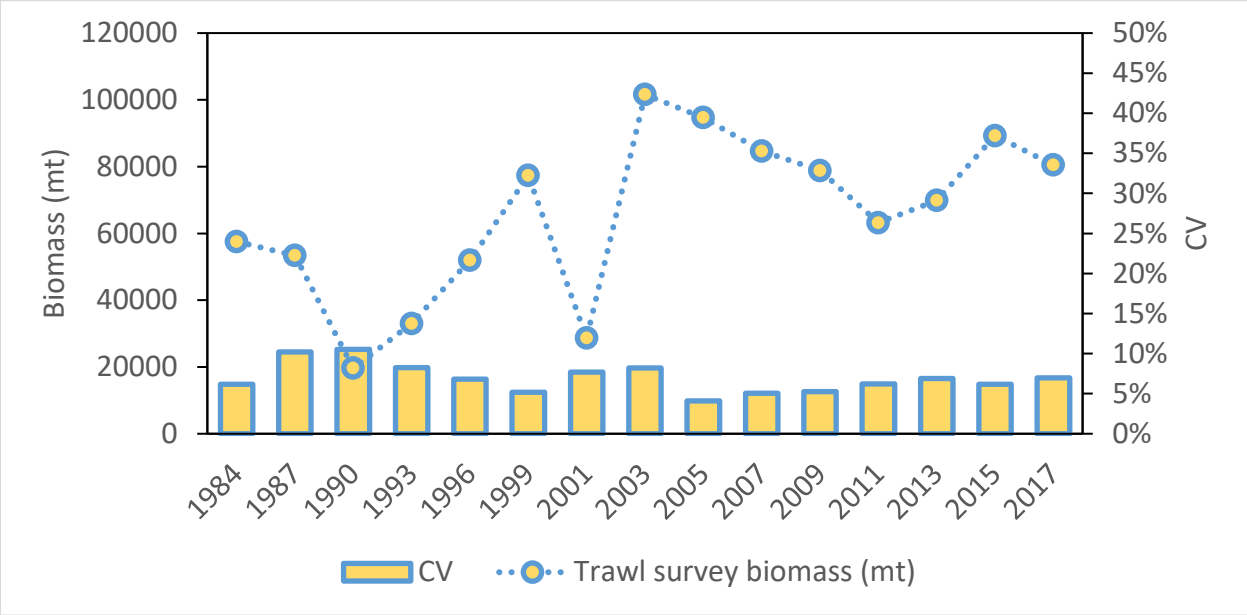

Figure 1. GOA bottom trawl survey biomass with the coefficient of variation (CV) for SST.

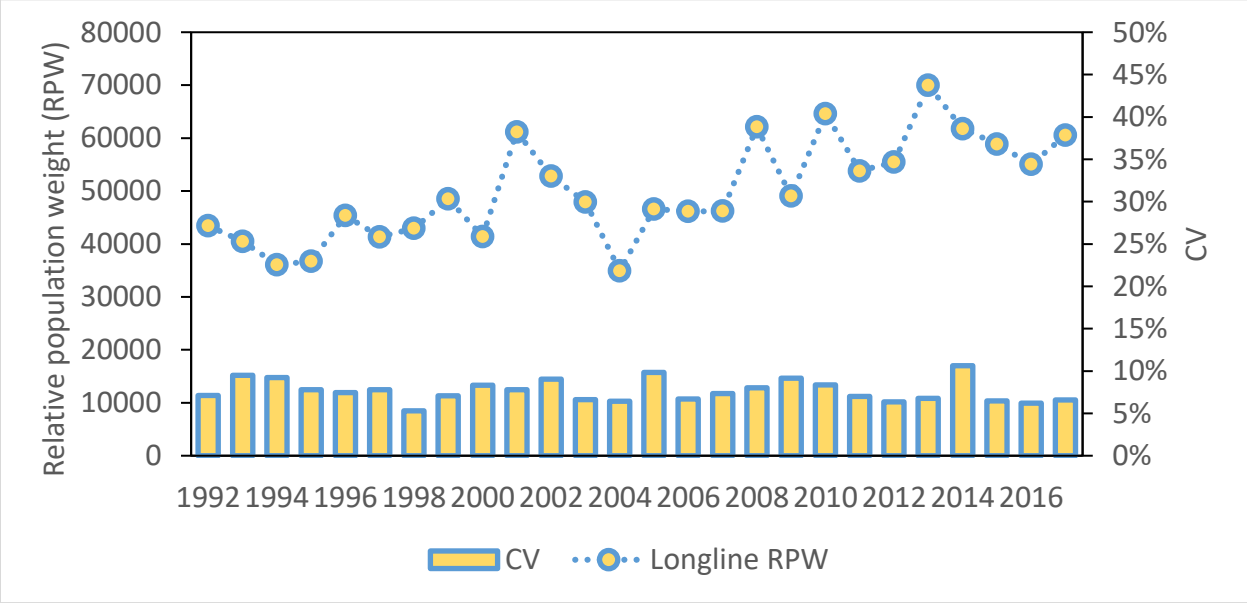

Figure 2. AFSC Longline survey Relative Population Weight (RPW) with the coefficient of variation (CV) for SST in the GOA.

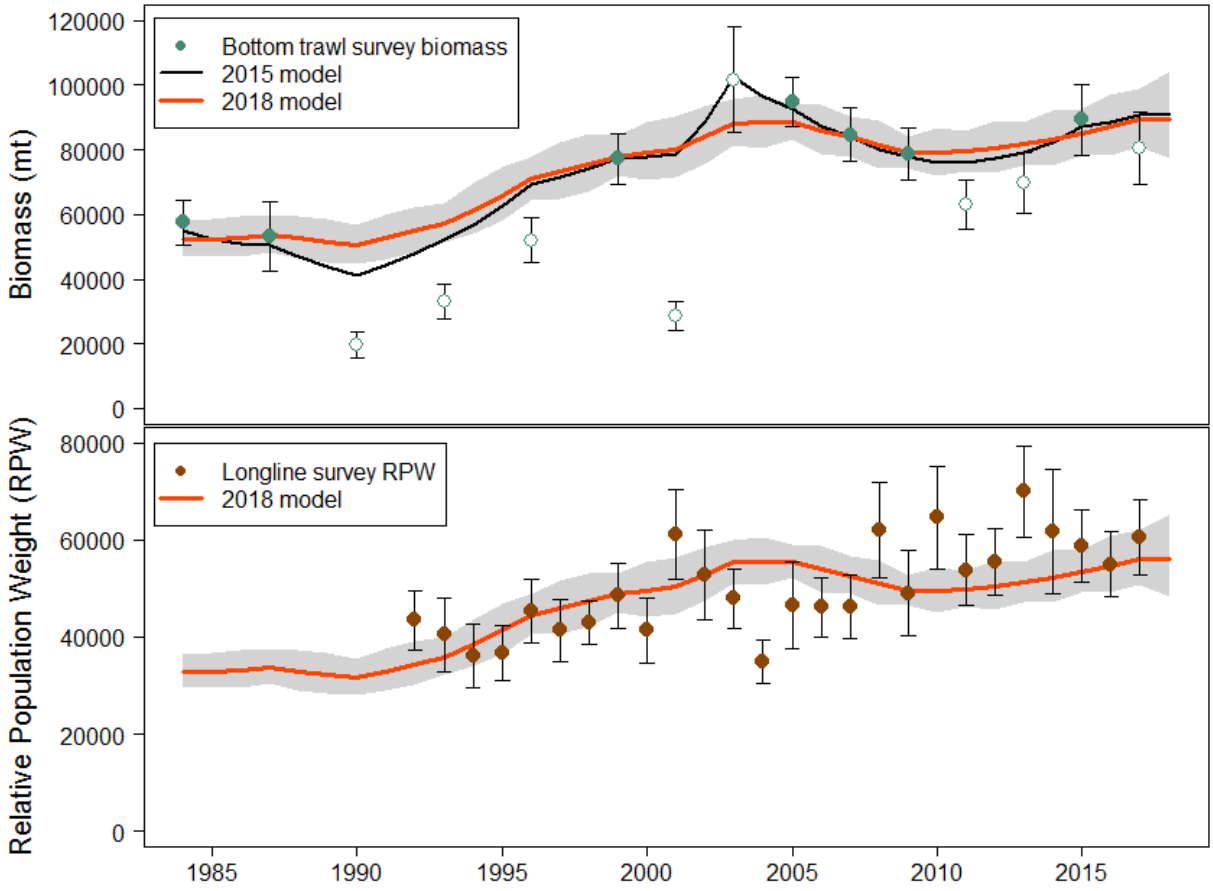

Figure 3. Comparison of fit to the GOA-wide AFSC bottom trawl survey biomass for SST between the current model and the combined model (top panel). Open circles in the bottom trawl survey biomass index indicates years in which a region or depth strata was not sampled. Fit to the GOA-wide AFSC longline survey RPWs for SST is shown in the bottom panel.

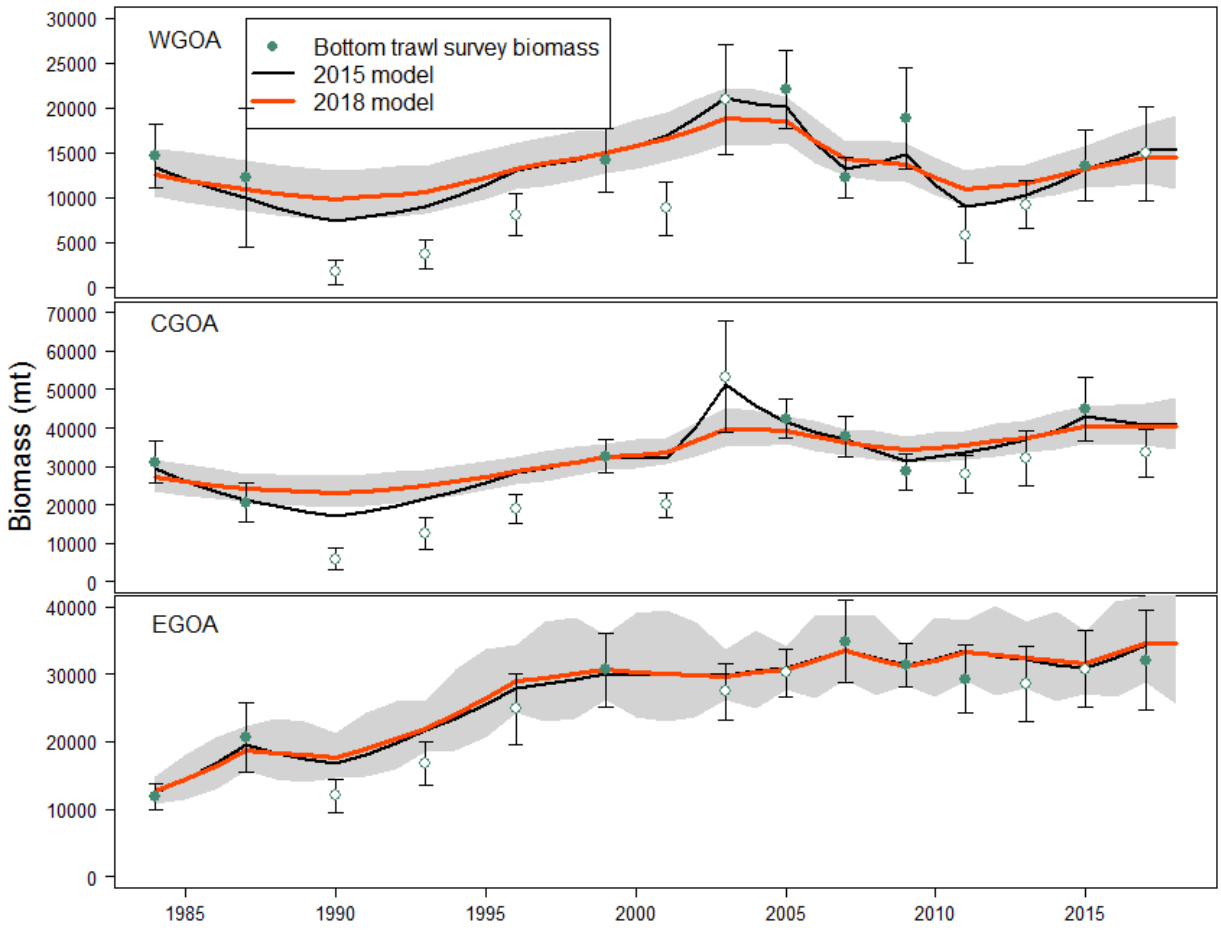

Figure 4. Comparison of fit to regional AFSC bottom trawl survey biomass within the GOA for SST. Open circles in the bottom trawl survey biomass index indicates years in which a depth strata was not sampled.

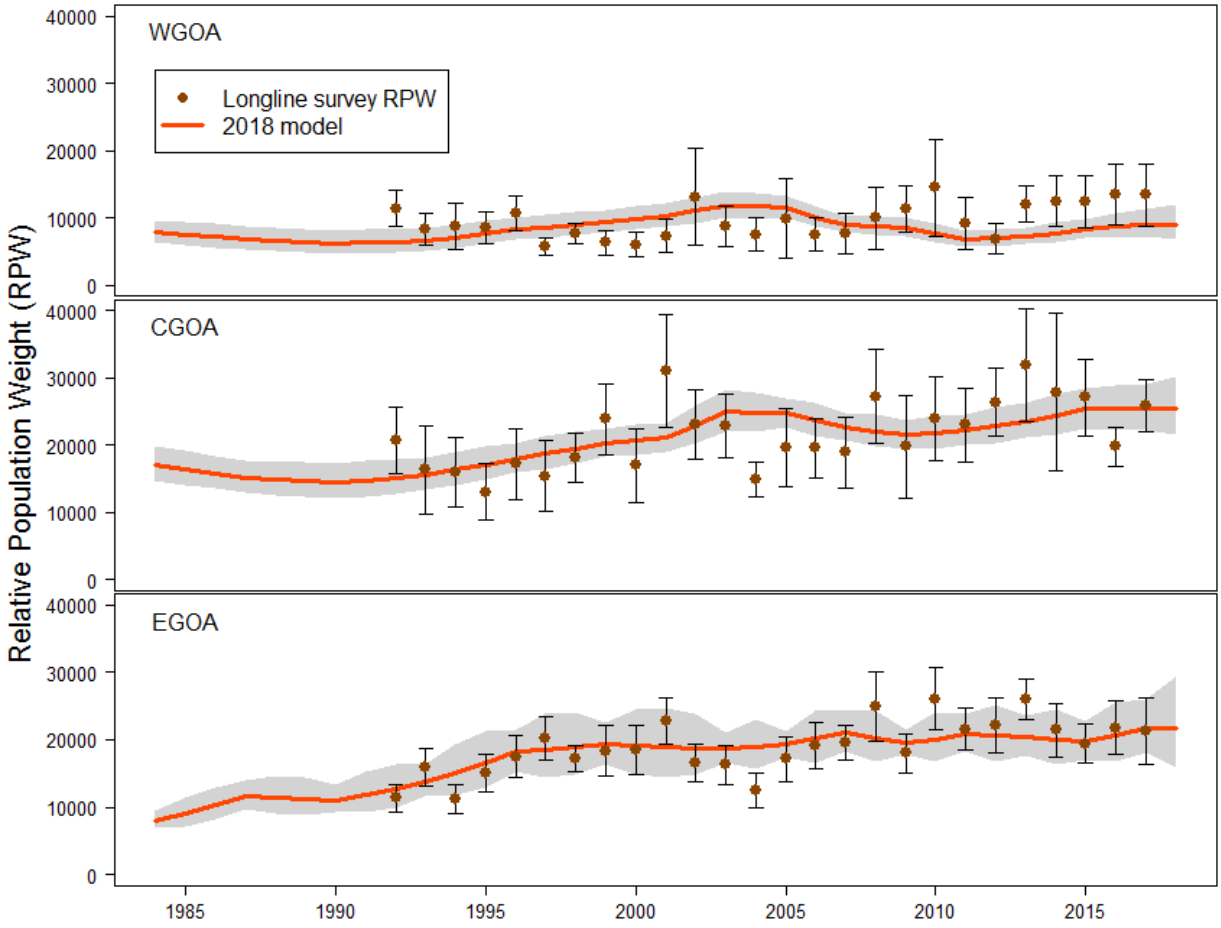

Figure 5. Random effects model fit to regional AFSC longline survey RPWs within the GOA for SST.

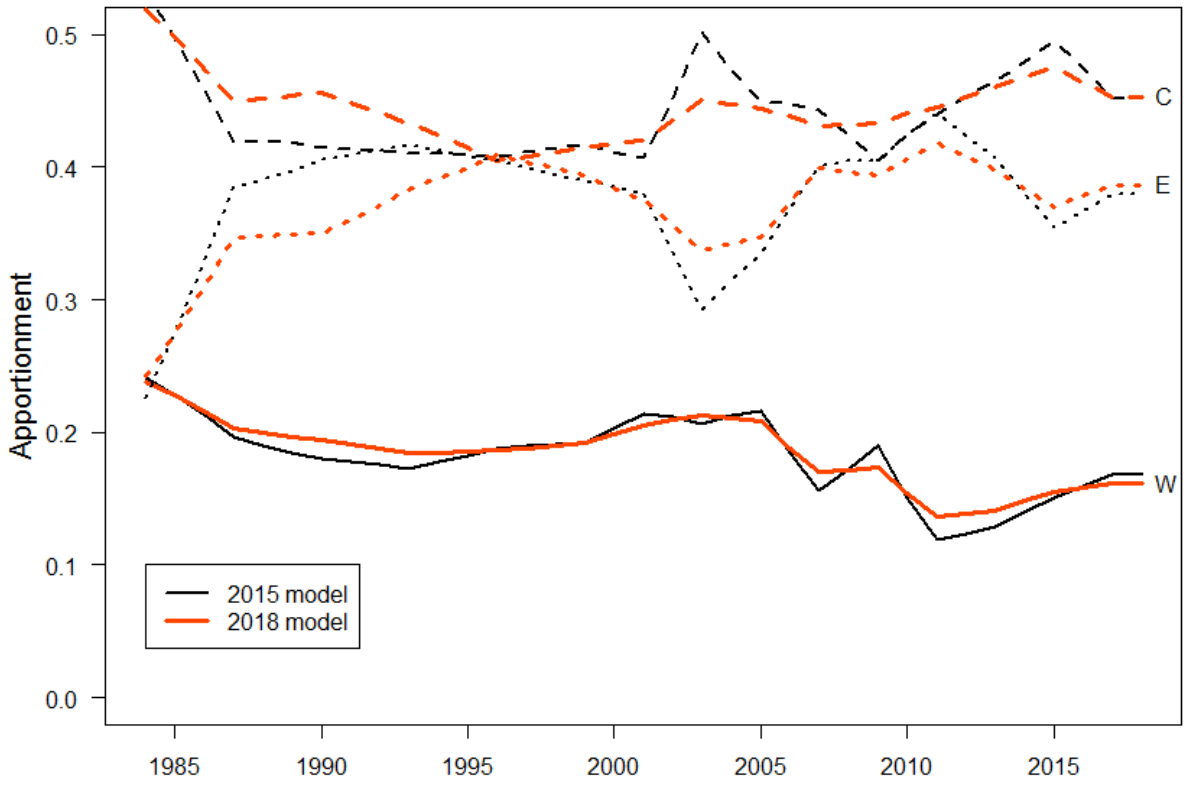

Figure 6. Comparison of regional apportionment within the GOA for SST between the current model and the combined model (C = Central GOA, E = Eastern GOA, and W = Western GOA).