17. Using fishery independent and dependent indices for apportionment estimation of Bering Sea/Aleutian Islands Atka mackerel ABC

James Ianelli, Sandra Lowe, and Pete Hulson
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Introduction

Last year the 2018 Bering Sea Aleutian Islands (BSAI) Atka mackerel stock assessment incorporated the 2018 Aleutian Islands bottom trawl survey data. The 2018 survey indicated a 21% decrease in biomass for the overall survey area since the previous 2016 survey, including an unexpected 80% drop in biomass for the Central Aleutian Islands (Central AI). The updated Model 16.0b used last year, indicated an ongoing decline in spawning biomass from a peak in 2005 which is attributed to poor to average year class strengths since 2007. The 2019 spawning biomass was projected to be 106,800 t ($B_{38\%}$), just below $B_{40\%}$, and placing the stock into Tier 3b.

Since 2015, a random effects (RE) model has been fit to the bottom trawl survey to determine apportionments for the three Aleutian Islands subareas (Western, Central, and Eastern). Given the extreme drop in survey biomass for the Central AI, continued use of this method would have resulted in changes in apportionment for the Central AI that would have been reduced from 34.78% in 2018, to 10% for 2019 (a 71% decrease). We conducted a thorough investigation of survey and fishery data to try to explain the observed survey biomass decline in this area. Several aspects relating to observation error were evaluated for the 2014, 2016, and 2018 surveys (e.g., station location, timing, haul performance, etc.) and very few differences were noted. In addition, the survey protocols for the 2000 and 2018 surveys were compared (years of lowest Eastern and Central AI survey biomass estimates, respectively), and the only notable differences were the extreme low survey temperatures in 2000 in contrast to the high survey temperatures in 2018. It is puzzling that in the 2000 and 2018 surveys, the (low and high) temperatures were consistently observed across all areas in the Aleutian Islands, but only one area experienced an extreme decrease in biomass (Eastern AI in 2000, Central AI in 2018). NMFS fishery observer data indicated steady catch-per-unit effort (CPUE) trends in the Central AI with no obvious differences in catch rates, fishing dates and locations.

Since the fishery data were inconsistent with the drop in relative Atka mackerel abundance in the Central AI, we recommended an intermediate approach (the 2015 method of a weighted average of the previous four surveys) be used that roughly split the difference between the 2018 apportionment, and the estimates arising from the application of the RE model. This dampened the change between assessments—the 2018 apportionment estimate of 35% dropped to 21% instead of 10% for the 2019 Central AI. The SSC and Plan Team requested that we investigate alternative approaches. As such, we applied an alternative more integrated approach to the RE model following Hulson et al. *(in prep)*, which applies a common process error across regions and also allows for multiple indices.

Responses to 2018 SSC and Plan Team Comments Specific to the Atka Mackerel Assessment

1. The SSC noted: "…that having an apportionment method that is robust to large deviations in regional survey biomass estimates is critical." Specifically, they recommended:
    a. The PT recommended additional research to develop appropriate apportionment methods for this stock in the future, with an emphasis on investigating the application and validation of the autoregressive spatio-temporal modeling approach developed in the VAST modeling framework for such purposes. The SSC supports additional research into a more robust allocation method.
    b. Given the differences between the survey and fishery trends in the Central AI, the SSC recommends giving further consideration to the connections between temperature and Atka mackerel responses and availability to the survey. The SSC supports the idea of using habitat-based covariates and recognizes that the survey is a major source of uncertainty in this assessment.

Methods

The focus of this short discussion paper pertains primarily to item 1a above—a further investigation of how the area apportionments might best be specified. As a first step, we examined available NMFS observer data from the fishery. It was noted that only a handful of trawlers target Atka mackerel. Consequently, we focused only on the eight vessels that consistently operated from 2008-2019 (through Aug 15, 2019) and summarized their tow duration (Fig. 1), observed catch (Fig. 2), and mean nominal CPUE (computed as the sum of observed catch divided by hours fished; Fig. 3). The nominal CPUE by region shows a decline in rates since 2015 in areas 541 and 542, but has been stable but variable in area 543. The 2019 data point has only partial year's data and is not comparable to earlier years.

An option and approach provided by Hulson *et al*. *In prep* (draft available here) combines available survey data and a secondary index (in that case, region-specific estimates from the longline survey). The objective function that is minimized in the RE model is the sum of the process error and observation error negative log-likelihood functions. Within the RE model, the estimated biomass that results is intended to balance variability in biomass over time (process error) and the precision of the fit to the bottom trawl survey estimates (observation error). Adding an additional index requires an additional observation error component added to the objective function. Thus, the RE model as used here, includes region-specific fishery CPUE and an added observation error term. We note that in the RE model used in previous years in the Atka mackerel assessment, the process error variance term was freely estimated and treated independently among areas. In this analysis, a process error term is shared among regions.

We applied the same survey data as for the RE model in Lowe *et al*. (2018), but added the information on nominal CPUE from the fishery. We note that since the period 2011-2014 had limited fishing records due to fishery management area closures, data from that time period are included but downweighted in variance terms—the code currently requires data from all sub-areas (but can have annual and area specific variances specified).

Area apportionment application results

The model can be implemented with varying the relative weights applied to the indices. For this case we specified five models with differing weights that spanned the range from 1) zero weight, 2) half the weight of the survey index, 3) equal weight to the survey index, 4) double the weight of the survey index, and 5) all the weight to the fishery CPUE data. For the zero weight configuration, this is essentially the basic RE model as presented in 2018 assessment, but shares a process error term over regions (Fig. 4). Increasing the relative weight on the fishery CPUE index improved the fit and resulted in better residual patterns (Figs. 5, 6, and 7). Relative to how biomass might be apportioned by region for this type of index, results range from just under 10% for the Central AI (no weight on the fishery CPUE index) to 26% if we only used the nominal fishery CPUE data (Table 1).

Discussion

While the application of nominal fishery CPUE data for abundance trends is problematic—for example data are unavailable for search time, and selectivity and catchability can differ—the relative patterns between regions may be a reasonable proxy for relative abundances. Incorporating auxiliary population information in the RE model (in this case nominal fishery CPUE) as presented in Hulson *et al. In prep* is a reasonable approach to explore. A next step would be to apply the vector-autoregressive spatio-temporal (VAST) modeling framework. To date, challenges using VAST for the Aleutian Islands (for Atka mackerel at least), remain. These apparently are related to how anisotropy is modeled (having to do with the geographic shape of the Aleutian Islands). In the meantime, the expanded RE model used here incorporates multiple indices in a simple, flexible, and straight-forward way. This approach can also be used to further explore the region-specific data conflicts between the bottom trawl survey and fishery CPUE, and also seems reasonable to use for apportionment of the BSAI Atka mackerel ABCs. Choice of weighting of the indices, and evaluating other sensitivities (e.g., the impact of differences in survey and fishery selectivity) could be examined via simulations. This would provide some indication of the robustness of alternative approaches. Also, the Council could then evaluate options for deviations from true abundance-based apportionments of ABCs. Presently, apportionments are done to mitigate uncertainty in stock structure and to avoid "localized" depletion.

Literature Cited

Hulson, P.-J. F. Ianelli, J. N., Spencer, P. D., and K. B. Echave. *In prep*. Using multiple indices for biomass and apportionment estimation of Alaska groundfish stocks, Alaska Fisheries Science Center, National Marine Fisheries Service 17109 Point Lena Loop Rd. Juneau, AK 99801.

Lowe, S., J. Ianelli, W. Palsson. 2018. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, Alaska, 99510.

Tables

Table 1. Apportionment percentages by Aleutian Islands management areas with different weightings of fishery CPUE data.

CPUE weight	Eastern	Central	Western
0.0	49.6%	9.3%	41.1%
0.5	43.8%	17.0%	39.2%
1.0	40.8%	20.4%	38.7%
2.0	38.0%	22.8%	39.2%
100	32.7%	26.2%	41.1%

Figures

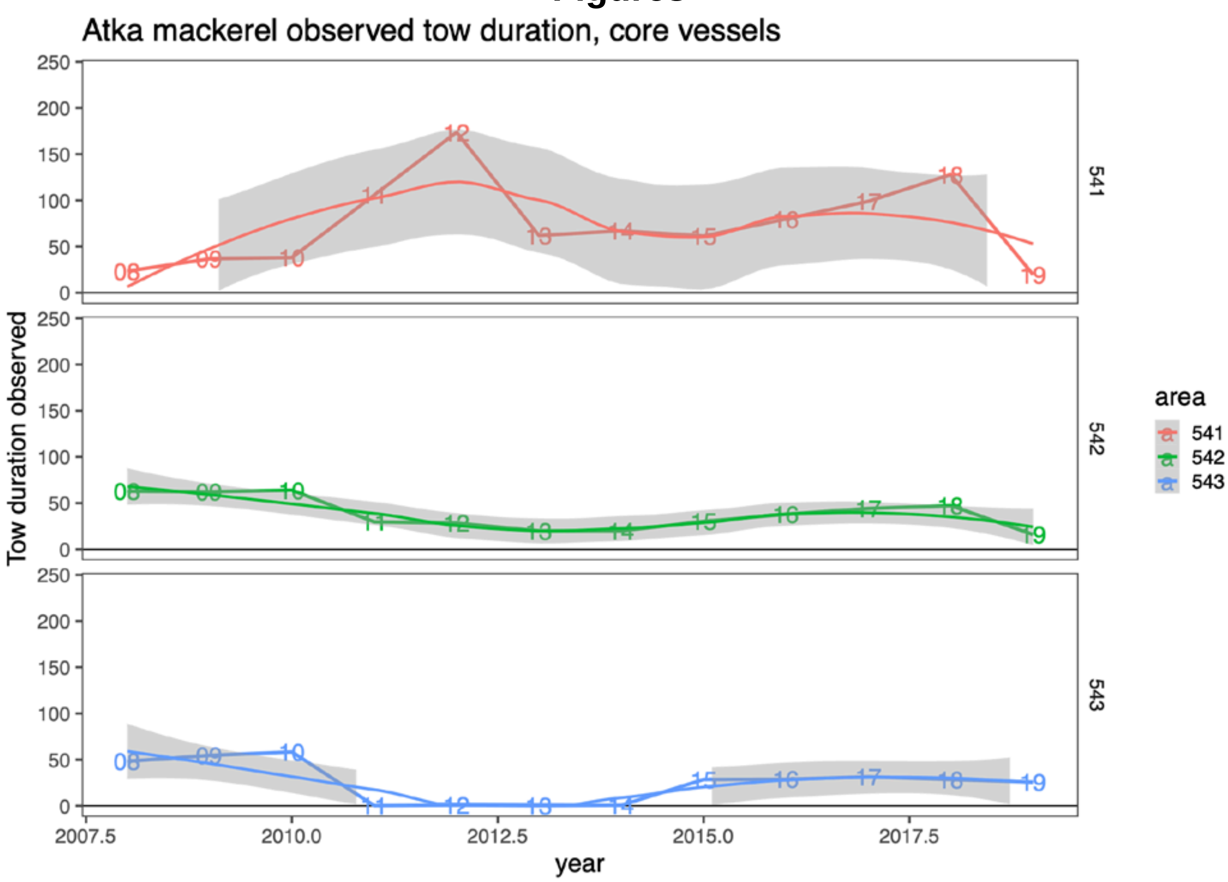


Figure 1. Annual sum of observed tow duration (hours) by Aleutian Islands management areas (541=Eastern, 542=Central, 543-Western) from the eight “core” vessels selected for analysis. Shaded regions generated by smoother through the data.

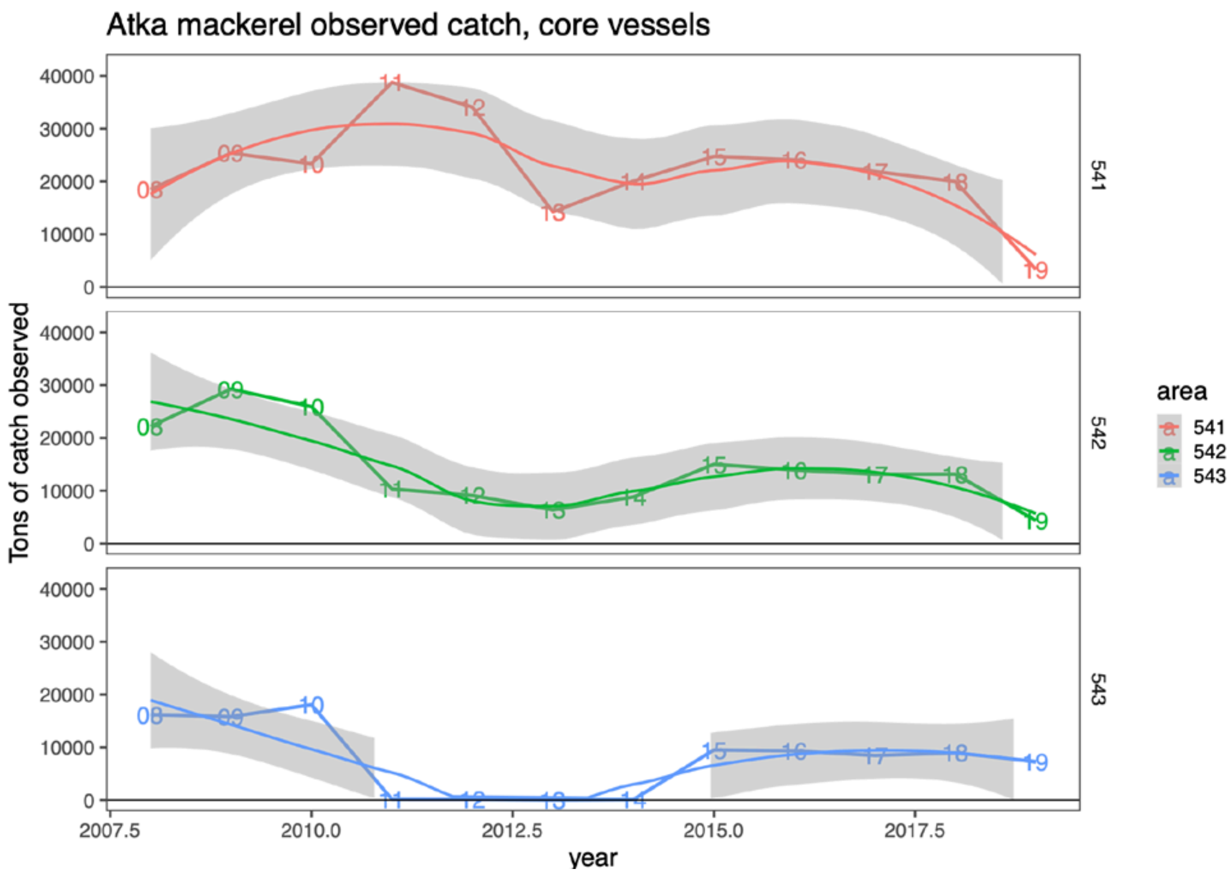


Figure 2. Annual sum of observed catch by Aleutian Islands management areas (541=Eastern, 542=Central, 543-Western) from the eight "core" vessels selected for analysis. Shaded regions generated by smoother through the data.

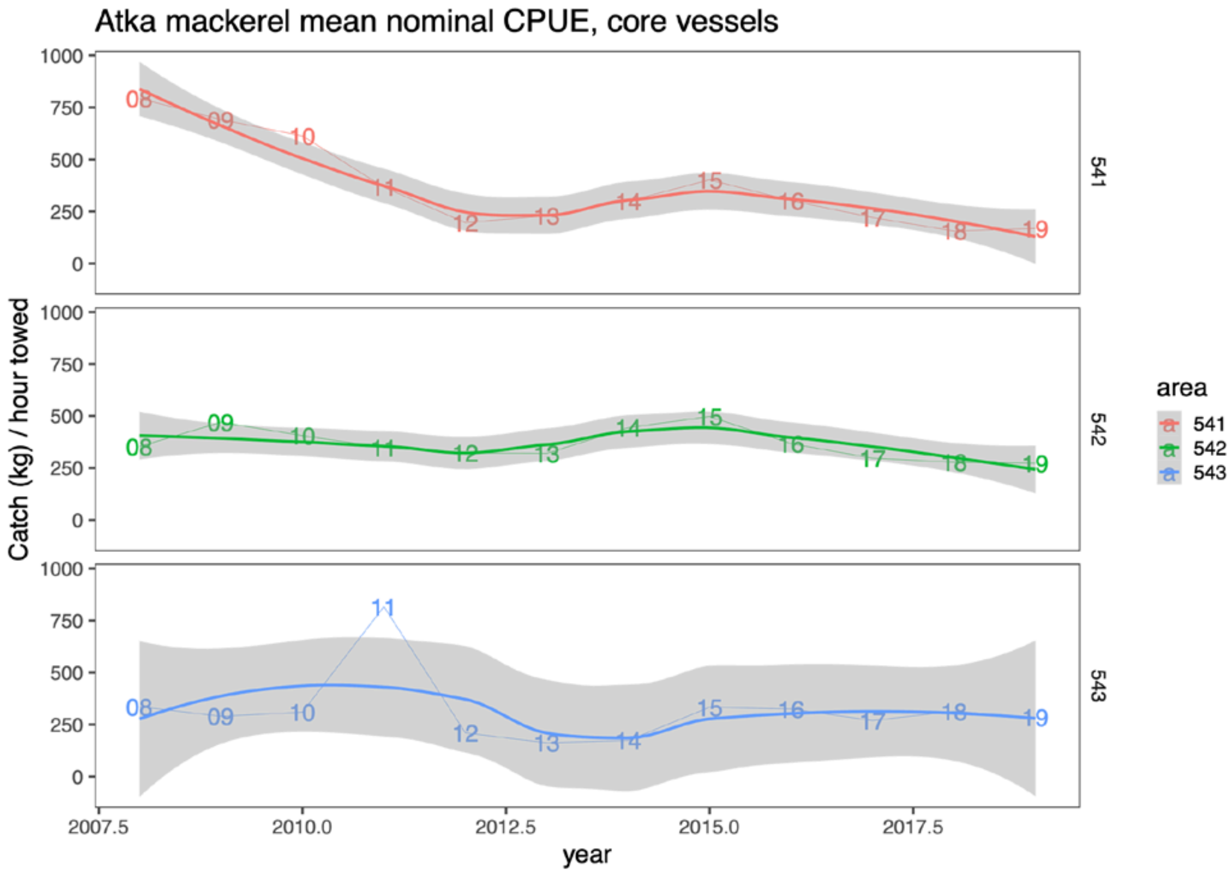


Figure 3. Mean nominal CPUE for Atka mackerel for Aleutian Islands management areas (541=Eastern, 542=Central, 543-Western) from the eight "core" vessels selected for analysis. Shaded regions generated by smoother through the data.

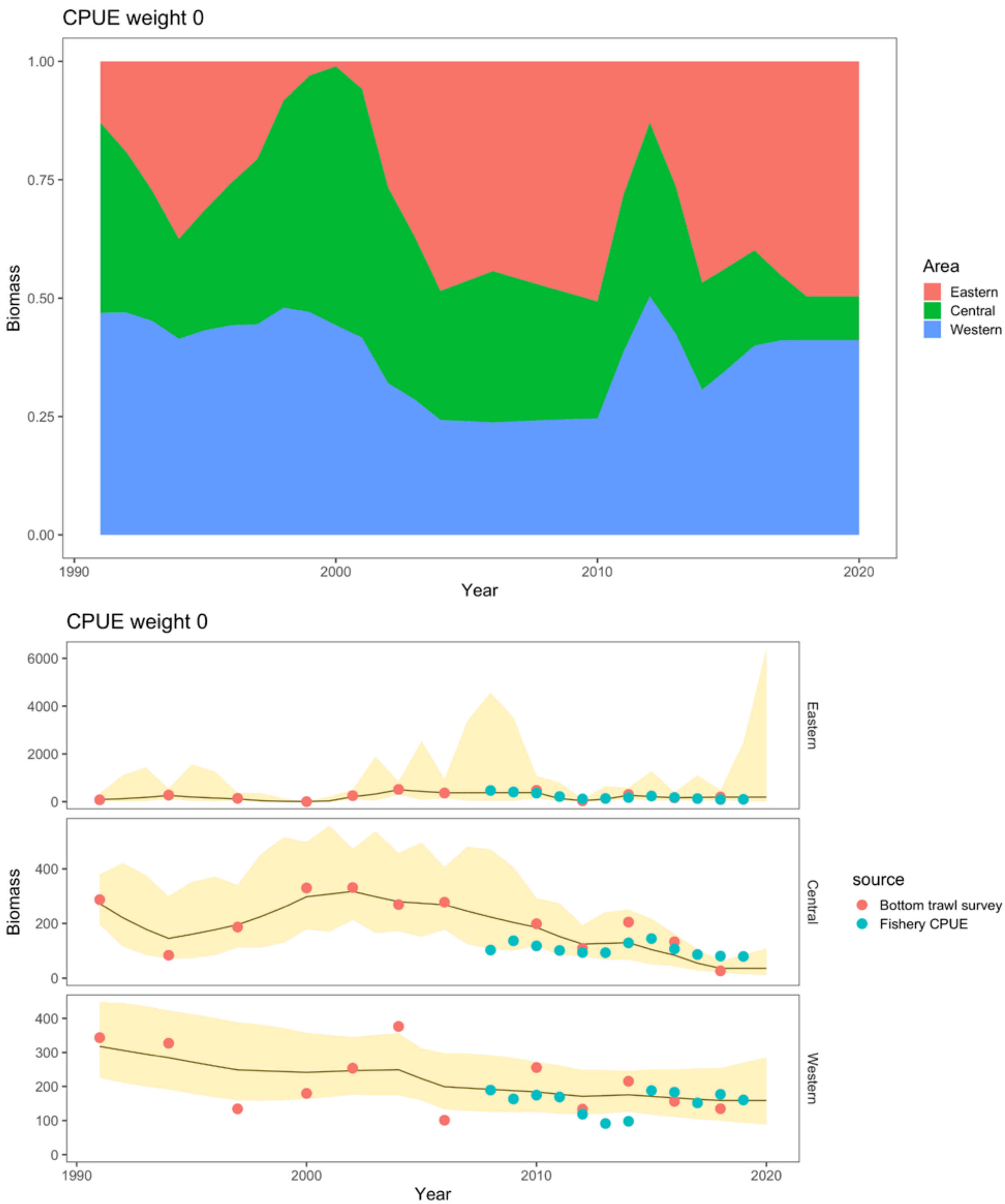


Figure 4. Atka mackerel area-apportionment results fit with the random-effects model with proportions by region over time (top) and fit to both survey and nominal fishery CPUE data (with the western data from 2011-2014 downweighted). In this case, the weight is given to only the bottom trawl survey data for illustration purposes.

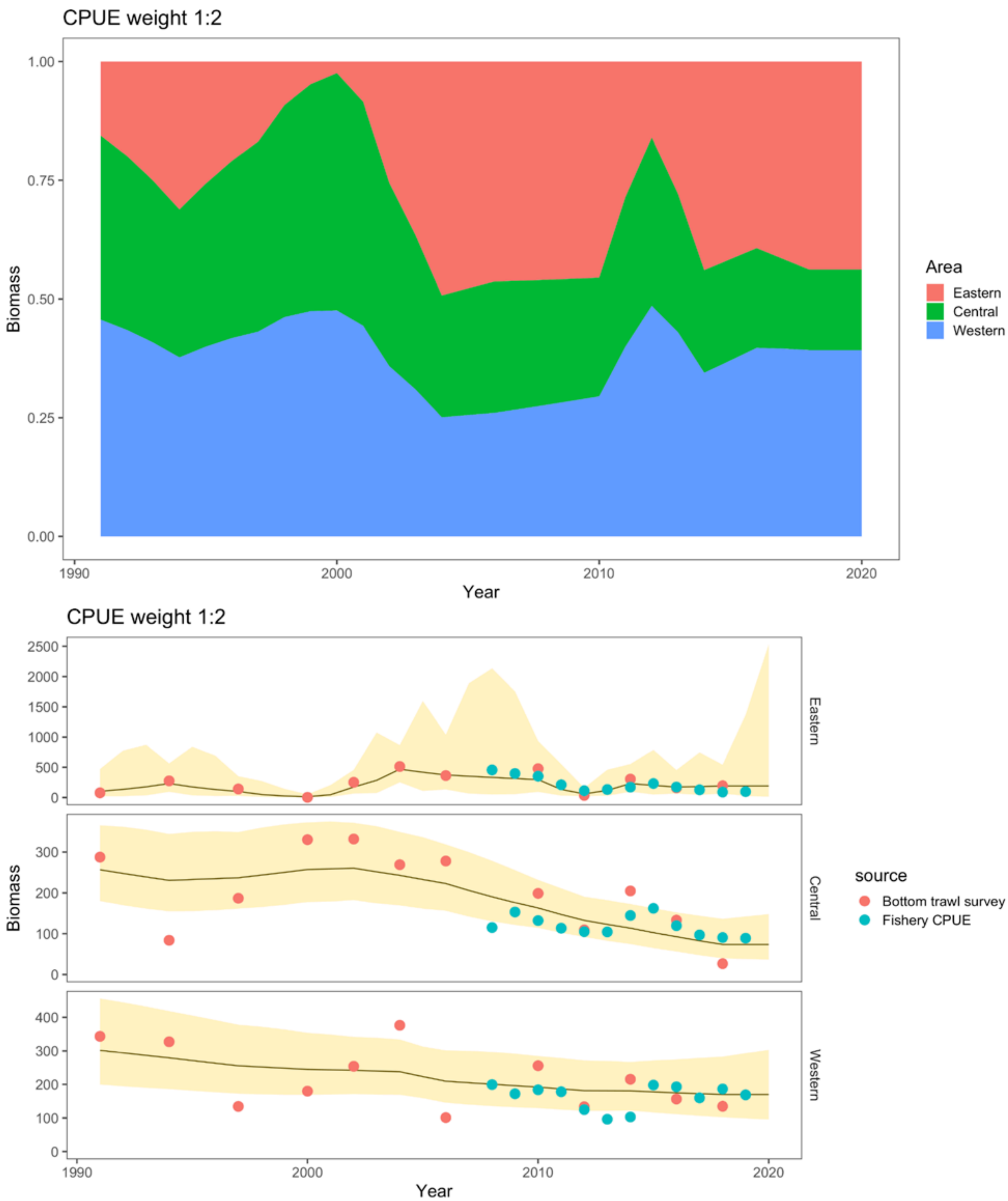
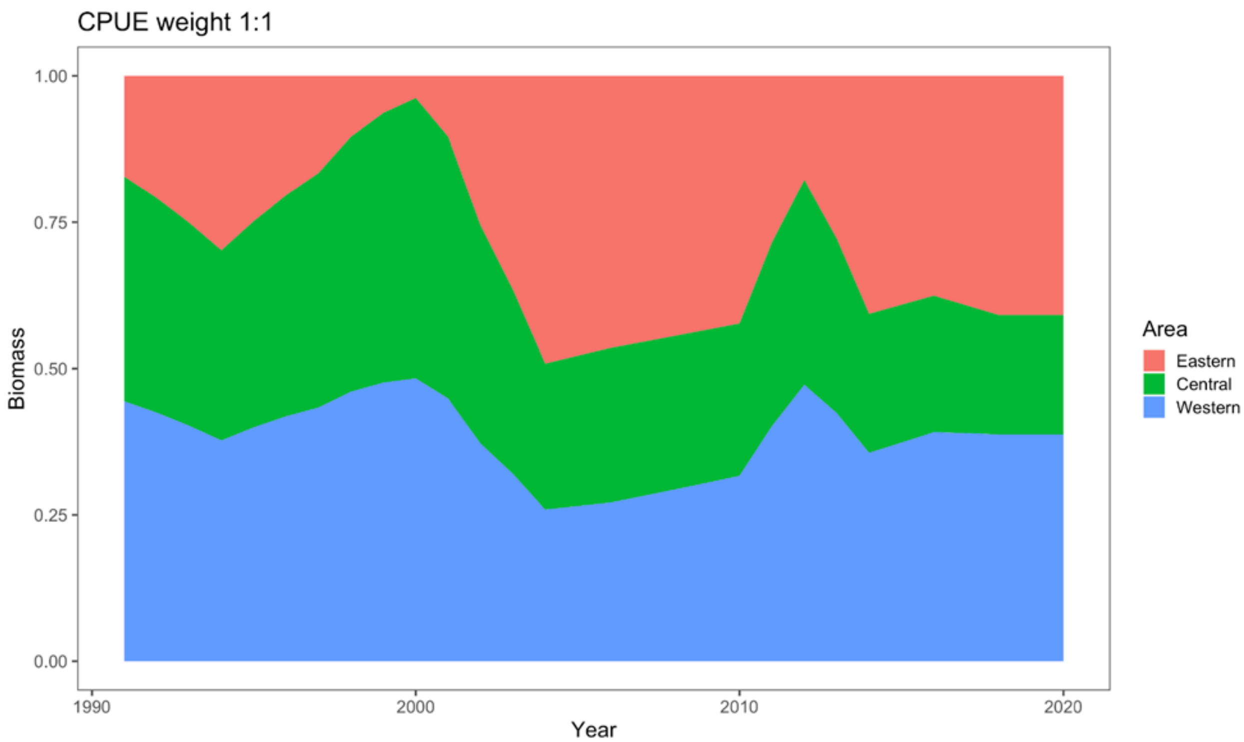


Figure 5. Atka mackerel area-apportionment results fit with the random-effects model with proportions by region over time (top) and fit to both survey and nominal fishery CPUE data (with the western data from 2011-2014 downweighted). In this case, the weight is given to only the bottom trawl survey data for illustration purposes.



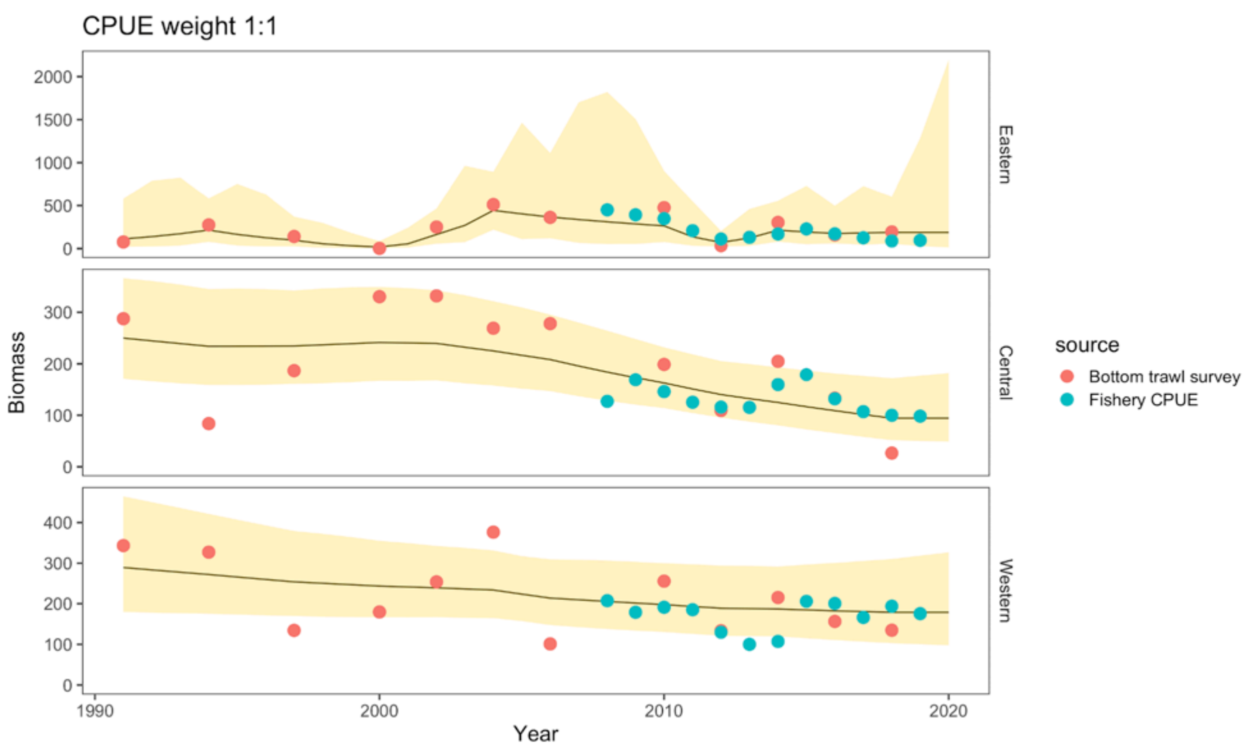
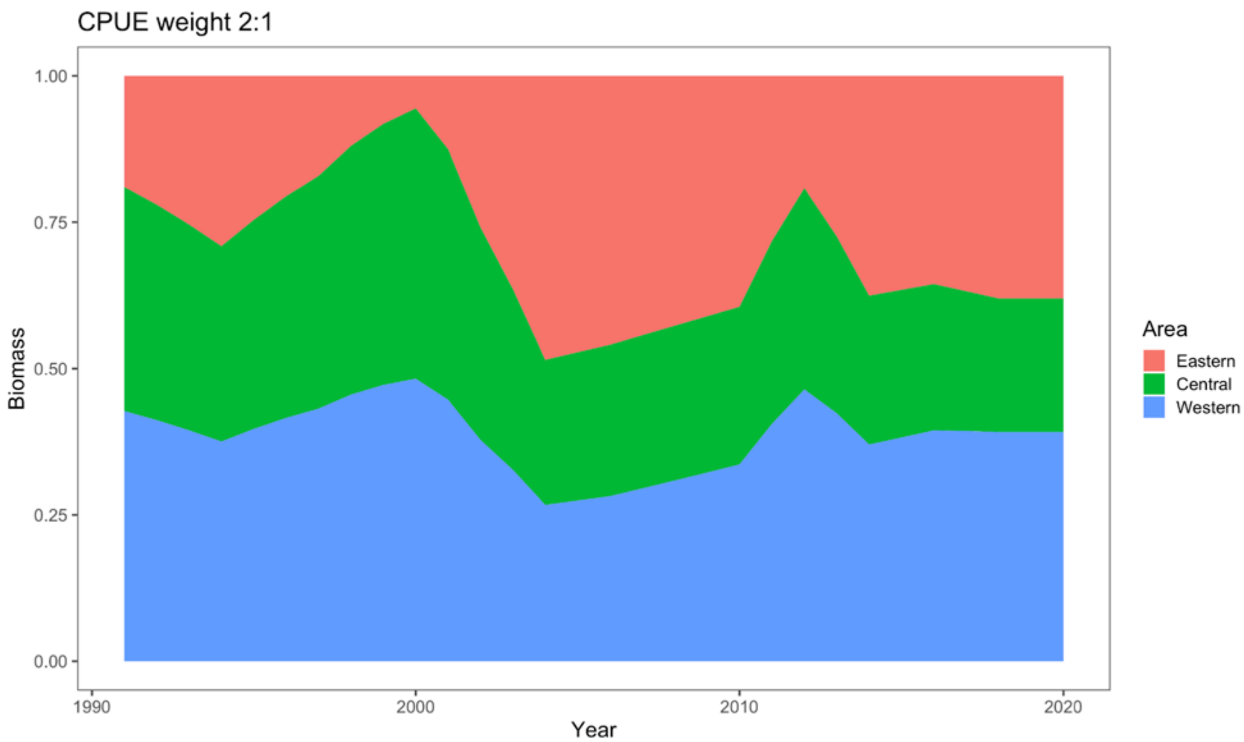


Figure 6. Atka mackerel area-apportionment results fit with the random-effects model with proportions by region over time (top) and fit to both survey and nominal fishery CPUE data (with the western data from 2011-2014 downweighted). In this case, the both indices are given equal weight.



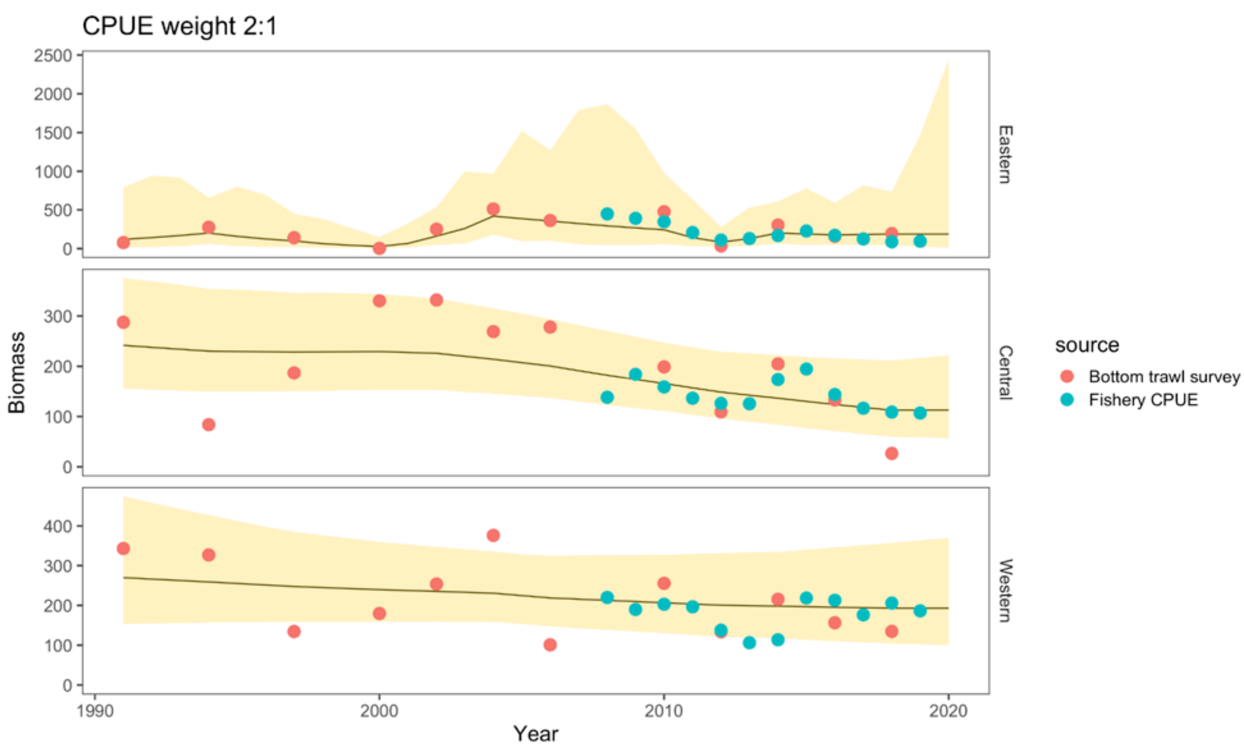


Figure 7. Atka mackerel area-apportionment results fit with the random-effects model with proportions by region over time (top) and fit to both survey and nominal fishery CPUE data (with the western data from 2011-2014 downweighted). In this case, the weight is given to only the bottom trawl survey data for illustration purposes.