Assessment of the Yellowfin Sole stock in the eastern Bering Sea and Aleutian Islands

Document for September review

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In 2023, the authors examined a single fishery selectivity curve rather than separate parameterizations for males and females for the BSAI Yellowfin sole stock assessment model. The motivation for this change is a more parsimonious model (fewer parameters), responding to SSC comments on this topic (see Appendix 1, SSC November 2020 section), as well as removing parameters that cannot be estimated well. The SSC (December 2020) stated that the male and female fishery selectivity curves were very similar post 1980s, so there appears to be no measurable difference between the two sexes. Explorations with the mcmc *adnuts* package indicated that male and female fishery selectivity parameters in the early portion of the time series were poorly estimated.

To examine the effect of a single, time-varying fishery selectivity curve, a sensitivity analysis was run. The base model was Model 22.1, which was presented in 2022. The proposed model is Model 23.0, and differs from Model 22.1 in that there is a single fishery selectivity curve. This fishery selectivity curve was estimated using male and female data. In the likelihood, the difference between the observed and predicted age composition is optimized and the predicted age composition is a function of selectivity. The model changes the fishery selectivity parameters to optimize the fit for both males and females.

**Results**

Time-varying fishery selectivity curves for Models 23.0 and 22.1 showed similar patterns (Figures 1 and 2), including highly variable estimates during the early 1960s when the stock had declined to its lowest state in the time series. In Model 22.1, the variability is also present between males and females, primarily in early years of the time series (Figure 1). The single fishery selectivity parameter estimate in Model 23.1 are also variable in the early years of the time series, but less so in more recent decades (Figure 2). Estimates of total and spawning biomass, and numbers at age, did not differ between Model 22.1 and Model 23.0, except in years prior to ~1985 (Figures 3, 4, and 5). The total objective function value did not decrease in Model 23.0, but when the decrease in the number parameters was considered (518 to 378), the AIC estimate for Model 23.0 was lower than that of Model 22.1 (6,645 vs. 7,312) (Table 1). Overall, this analysis provides support for Model 23.0. The authors recommend moving forward with Model 23.0 for the 2023 Yellowfin Sole assessment.

Figure 1. Estimate of fishery selectivity for males and females, 1954-2022, Model 22.1.

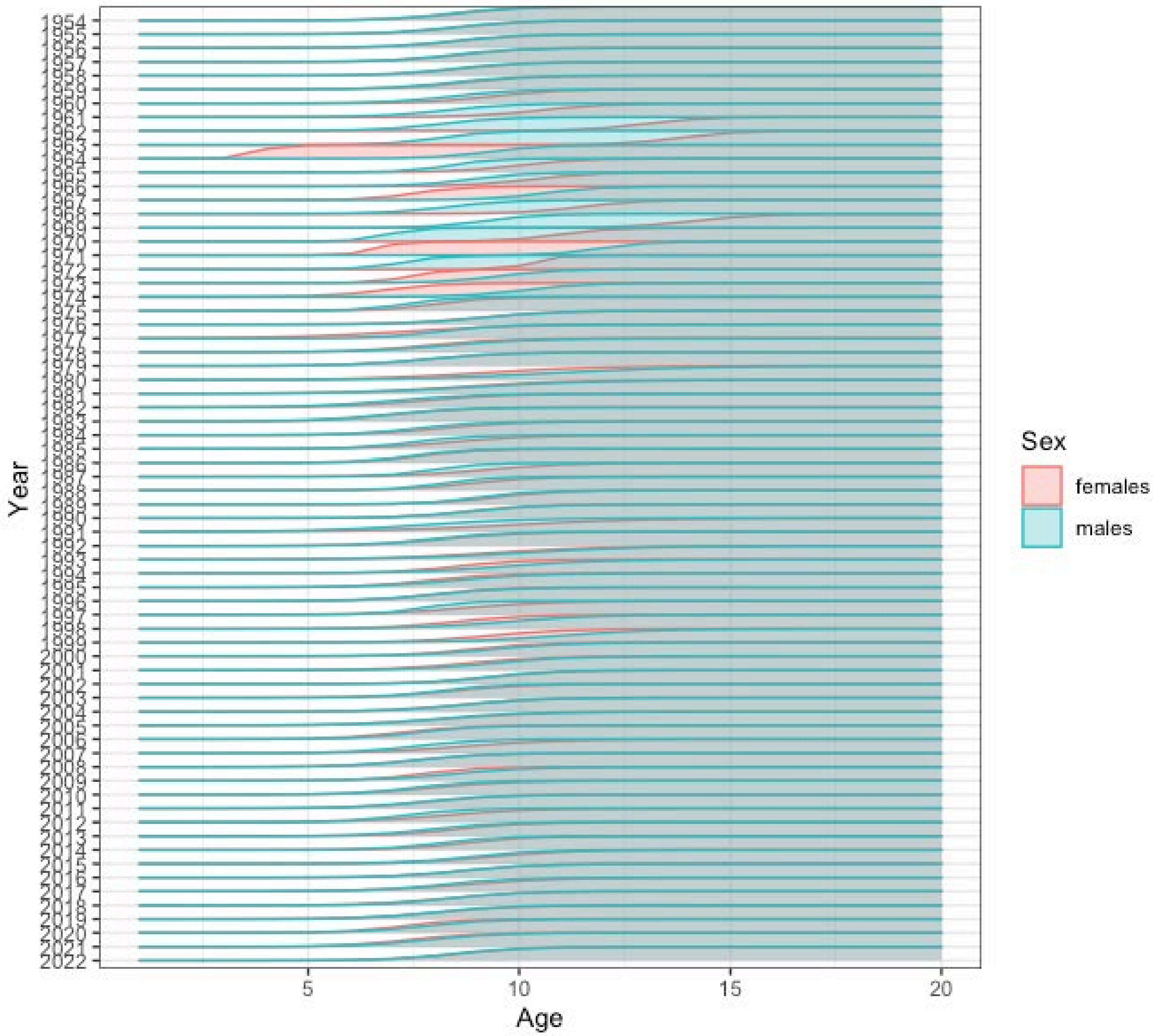

Figure 2. Estimate of fishery selectivity for males and females, 1954-2022, Model 23.0.

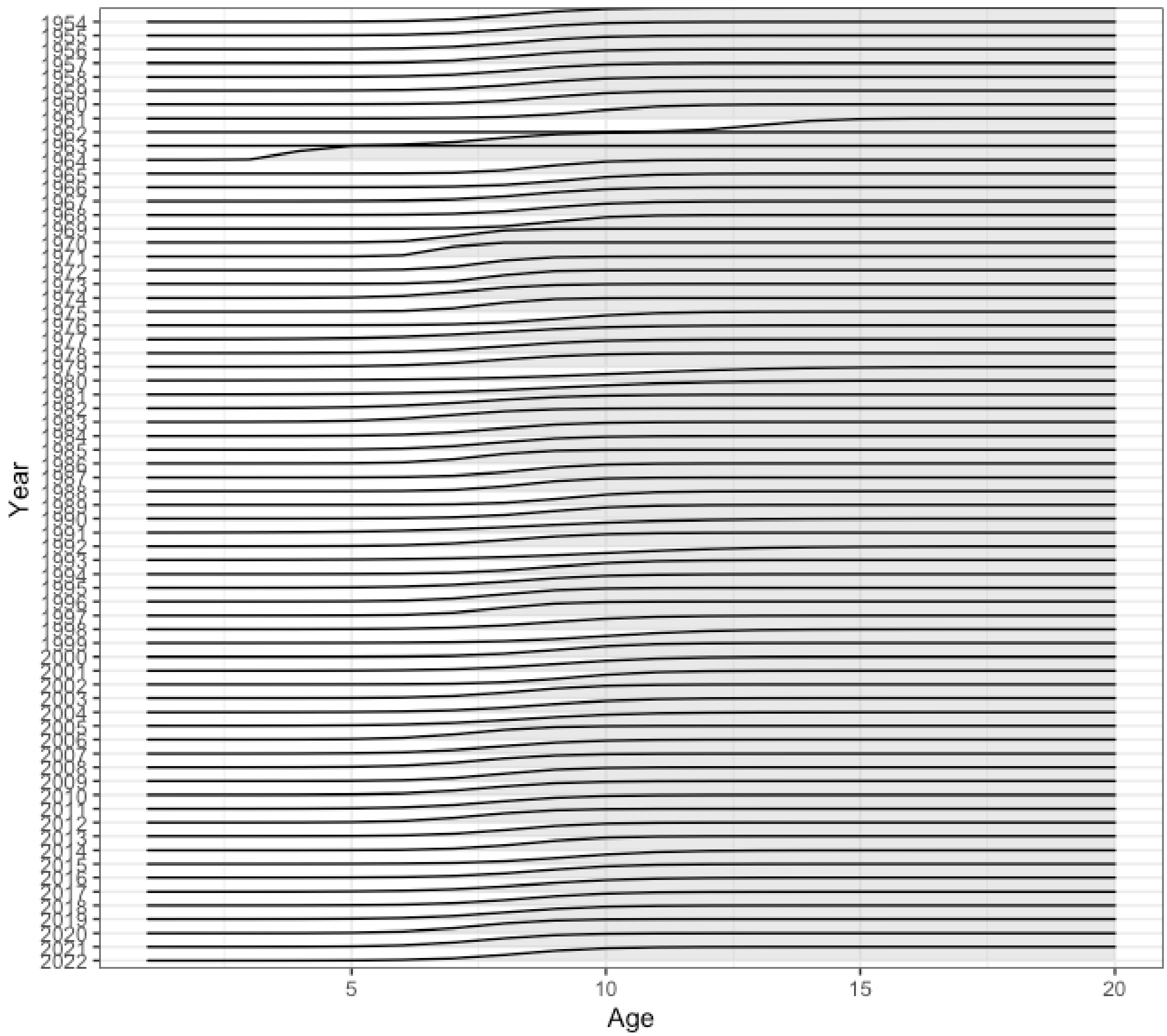

Figure 3. Total (age 2+) biomass for yellowfin sole, using Model 22.1 and Model 23.0.

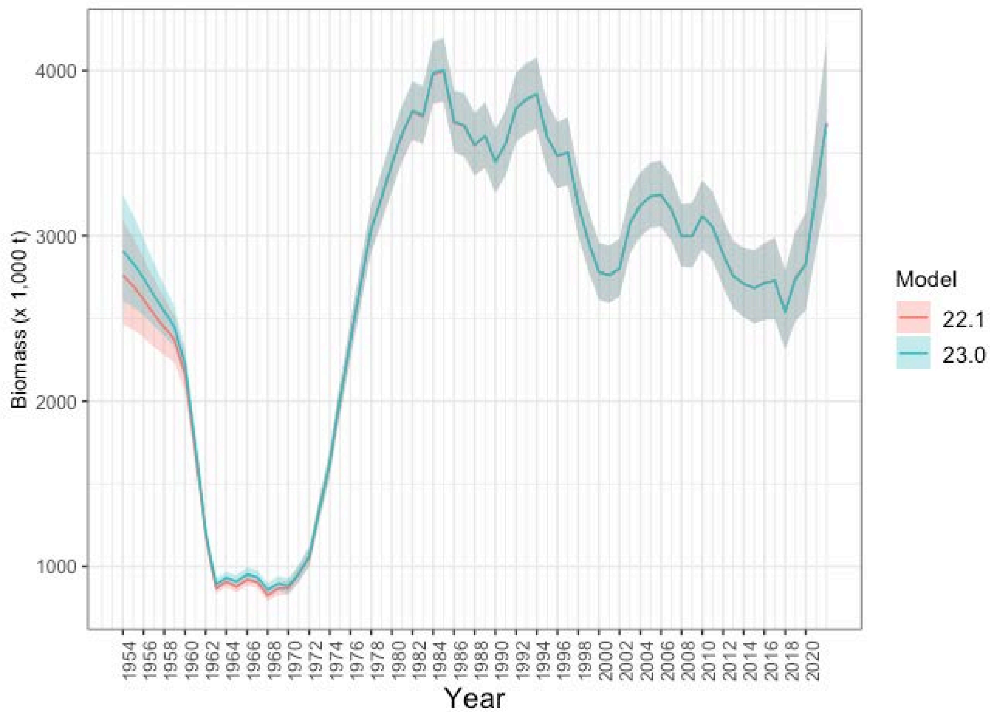


Figure 4. Total (age 2+) spawning biomass for yellowfin sole, using Model 22.1 and Model 23.0.

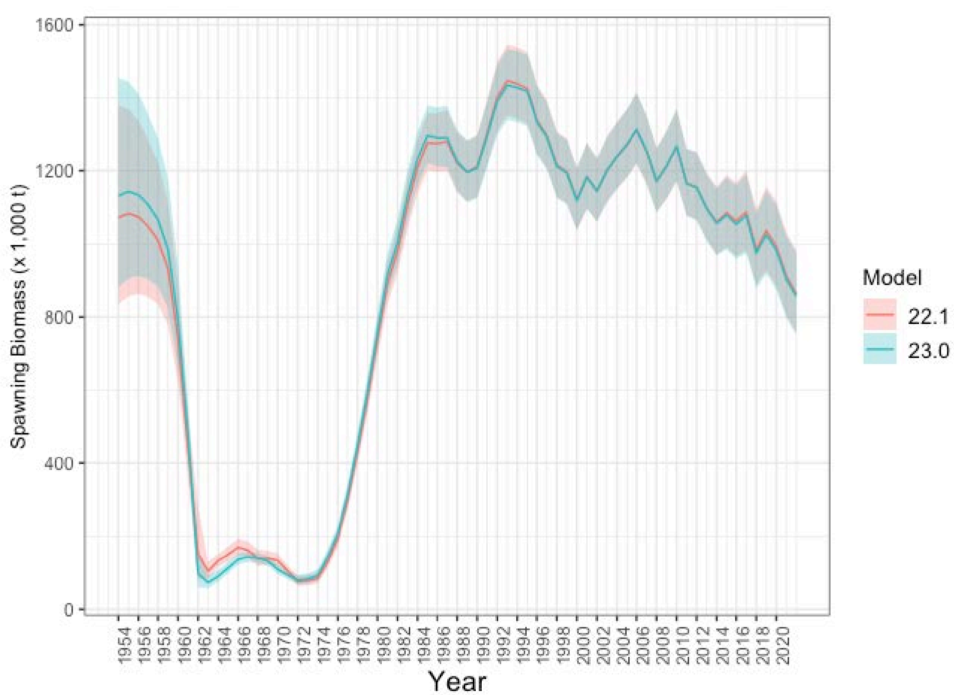

Figure 5. Numbers at age for yellowfin sole, using Model 22.1 and Model 23.0.

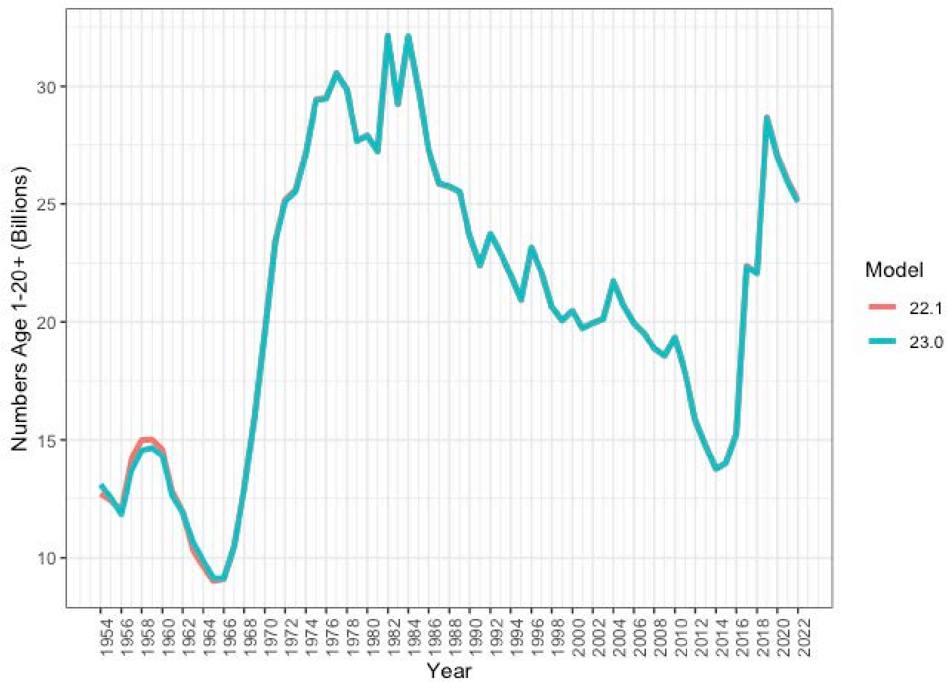

Table 1. Likelihood components, number of parameters, and AIC for Models 22.1 and 23.0.

| Likelihood component | Model 22.1 | Model 23.0 |
|---|---|---|
| Survey | 88.756 | 88.288 |
| Catch | 0.00920865 | 0.00892912 |
| Age fishery | 627.251 | 744.951 |
| Age survey | 1091.88 | 1092.95 |
| Recruitment | 37.355922 | 38.482537 |
| Selectivity (fishery) | 70.6177 | 34.4224 |
| Q prior | 1.32593 | 1.33293 |
| Objective fxn value | 1920.27 | 2003.38 |
| Number of parameters | 518 | 378 |
| AIC | 7312.153 | 6645.048 |

**Appendix 1**

*SSC Comments, December 2022*

Yellowfin sole is assessed annually and therefore a full assessment was presented this year. Three models (18.2, 22.0, and 22.1) were presented for this Tier 1 assessment. Model 18.2 was the accepted model in 2021, Model 22.0 included a single-sex survey selectivity, and Model 22.1 included the single-sex survey selectivity and VAST estimates for the EBS and NBS. Updated data included fishery age compositions for 2021; total catch for 2021; estimated catch for 2022; shelf trawl survey biomass estimates, standard errors, and survey length composition for 2021. Additionally, VAST estimates and standard errors were included. There was no public testimony.

Overall, there was an increase in total and spawning biomass compared to last year, much of this was due to the inclusion of the NBS in the author's preferred model (22.1). The spawning biomass was estimated to be 1.86 times greater than BMSY, which qualifies it for management under Tier 1a. However, the long general decline in spawning biomass continues, but a relatively large recruitment in 2017 is predicted to mediate this decline over the next few years.

The risk table has a level 1 in all categories as many of the previous modeling concerns have been improved and many of the ecosystem considerations have returned to near baseline conditions.

- **The SSC accepts the BSAI GPT's and authors' recommended model (22.1) with its associated OFL and ABC and no reduction from maxABC for 2023 and 2024.** The SSC commends the author for thoroughly addressing previous SSC comments as demonstrated by the acceptance of Model 22.1 as a notable improvement over the previous base model (18.2).

- **The SSC supports the November 2022 BSAI GPT recommendations and suggests continued examination of the role of temperature, especially with the addition of the NBS survey data**. This suggestion is not solely for model improvements, but also as a way to improve our understanding of the impacts of climate change on Bering Sea stocks. Given demonstrated links between yellowfin sole and water temperatures, a stable assessment, and low catch/biomass ratios, this avenue of research could provide a large step forward.
- **The SSC recommends a more detailed examination of the role of including the NBS survey data with and without VAST estimates to better understand the relative importance of these two changes, and a comparison of VAST model-based indices with and without the NBS.**
- **The SSC also recommends the examination of the large 2017 recruitment through a retrospective analysis.** The SSC requests retrospective estimates of the estimated recruitment timeseries be included in all future SAFE documents for this stock.

*SSC November 2020*
*The SSC recommends further investigation of previously noted issues as time allows, including possible further adjustments to estimating separate natural mortality for males and females, explorations of the sex ratio relative to the timing of annual spawning migrations as an alternative explanation for a high proportion of females, a potential link between wave height and catchability, and a single selectivity curve for both sexes. We note that the latter is supported by survey selectivity estimates that are virtually indistinguishable in Model 18.2 (2020 Assessment, Fig. 4.17) and by time-varying fishery selectivities that are very similar between males and females since the early 1980s, but diverge widely and inconsistently in some earlier years (2020 Assessment, Fig. 4.18).*

**Appendix 2**

*Calculating AIC from the hessian and objective function value (ADMB output)*

The hessian, the matrix of second mixed derivatives in transformed space, is created as output from each ADMB model run. The hessian was transformed back into the original parameter space ($Hess_T$) by taking the log of the determinant of the hessian, and the marginal likelihood ($Likelihood_{MAR}$) was estimated (Thorson et al. 2015) as follows, where OFV is the objective function value from the ADMB .par file:

$\text{likelihood}_{MAR} = -0.5\,Hess_T - OFV$. Note: log(2pi) not necessary…

The marginal likelihood can be used to calculate AIC, as follows:

$AIC = 2k - 2 * likelihood_{MAR}$, where k is the number of parameters used in the model.