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BSAI Yellowfin sole September 2025

Meaghan Bryan, Ingrid Spies

Proposed modifications to the yellowfin sole assessment model:

1. Consideration of Tier level: Investigating Tier 1 vs. Tier 3 for estimating recruitment.
2. Time-varying q should use survey start date, but not temperature.
3. Bridging the bespoke model to SS3 v3.30.23.2 (Methot et al. 2020).

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Bridging exercise

- Model 23.0: This is the accepted model from 2024,

- mSS3deter: Deterministic version of Model 23.0 in SS3 v3.30.23.2, with parameters fixed at values from Model 23.0.

Estimation models

Model 25.0: Estimation version of mSS3deter.

Model 25.0a: This is the proposed model for 2025 which builds on Model 25.0 (minor change in data weighting).

SSC comments

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The SSC supports the authors' plan to bridge to a Stock Synthesis model for the next assessment (SSC December 2024).

Authors' response: We have completed a bridge from the bespoke model 23.0 to SS3 v3.30.23.2 that provides a nearly exact match, and discrepancies are explained below. We are presenting here the bridged model, in anticipation of a full model in November.

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The SSC encourages evaluation of the information content of the stock-recruitment relationships for BSAI yellowfin sole … around the use of Tier 1 versus Tier 3 harvest specifications …[similar to] EBS pollock (SSC December 2024).

Authors' response:
We have evaluated the benefits of retaining a Tier 1 vs. Tier 3 level and consider Tier 3 to be preferable based on the information content in the data that informs recruitment subsequent to the 1977 regime change.

1. Tier level

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NPFMC tier system:

- Tier 1 - assumptions about stock recruitment relationship (SRR) providing a reliable pdf of F_{MSY}.

- Tier 3 - estimate recruitment using a normal distribution with estimated mean and variance

Estimating a stock recruitment curve requires periods of low + high SSB

- Contrast in the data is needed (Zhou 2007, He and Field 2019).
- Years with low stock sizes are important to detect behavior.
  - Compensatory density dependence - reproduction decreases at low densities.
  - Depensatory density dependence – opposite effect (Rose and Cowan 2000).

He, X. and Field, J.C., 2019. Effects of recruitment variability and fishing history on estimation of stock-recruitment relationships: two case studies from US west coast fisheries. Fisheries Research, 217, pp.21-34.

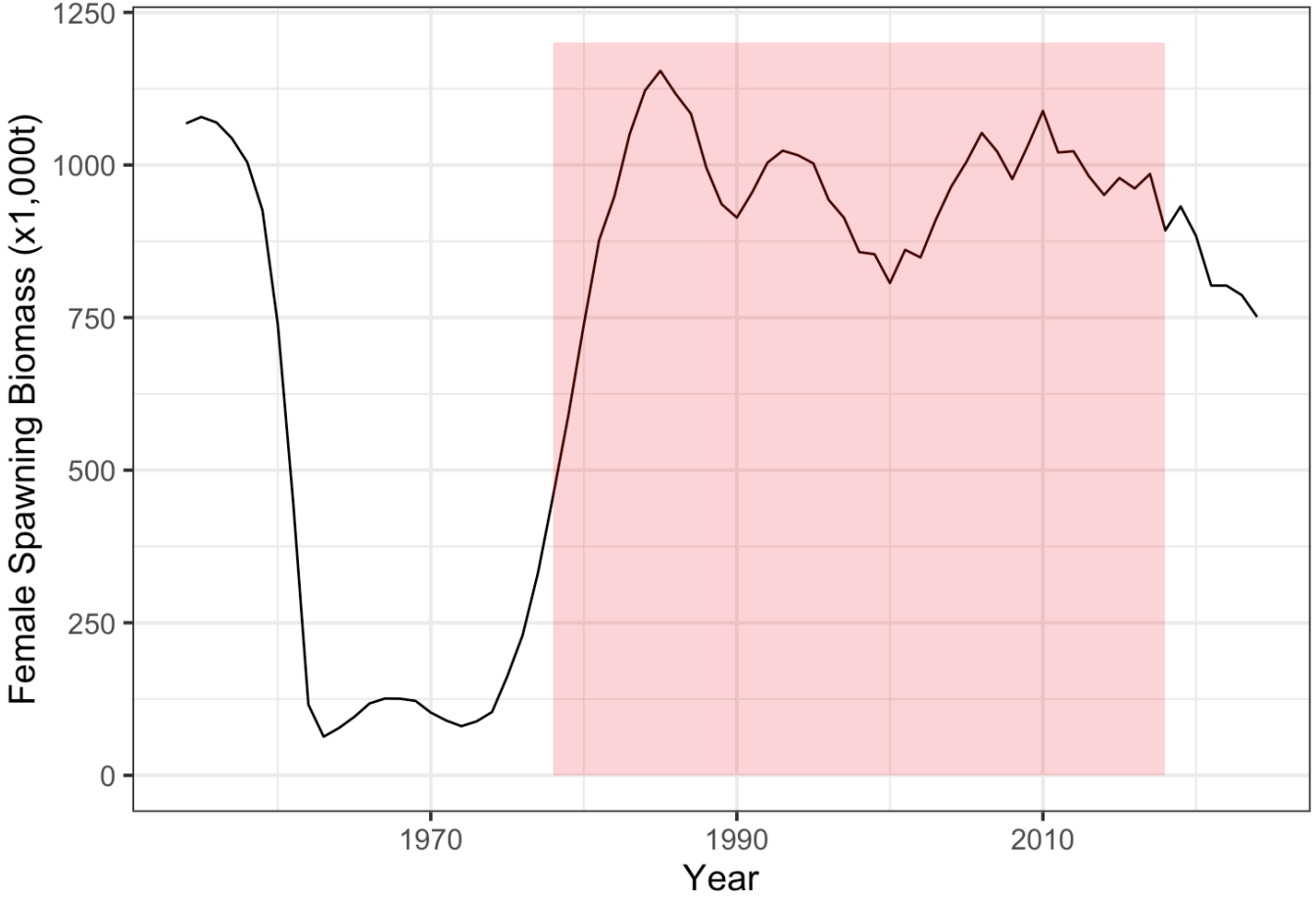
Rose, K.A., Cowan Jr, J.H., Winemiller, K.O., Myers, R.A. and Hilborn, R., 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries, 2(4), pp.293-327.

Zhou, S., 2007. Discriminating alternative stock–recruitment models and evaluating uncertainty in model structure. Fisheries Research, 86(2-3), pp.268-279.

In 2024 the EBS pollock assessment moved from a Tier 1 to a Tier 3 approach, due to:

- Uncertainty in recruitment curve parameters, and
- Lack of information in the data.

Does yellowfin sole assessment present a similar case as walleye pollock?



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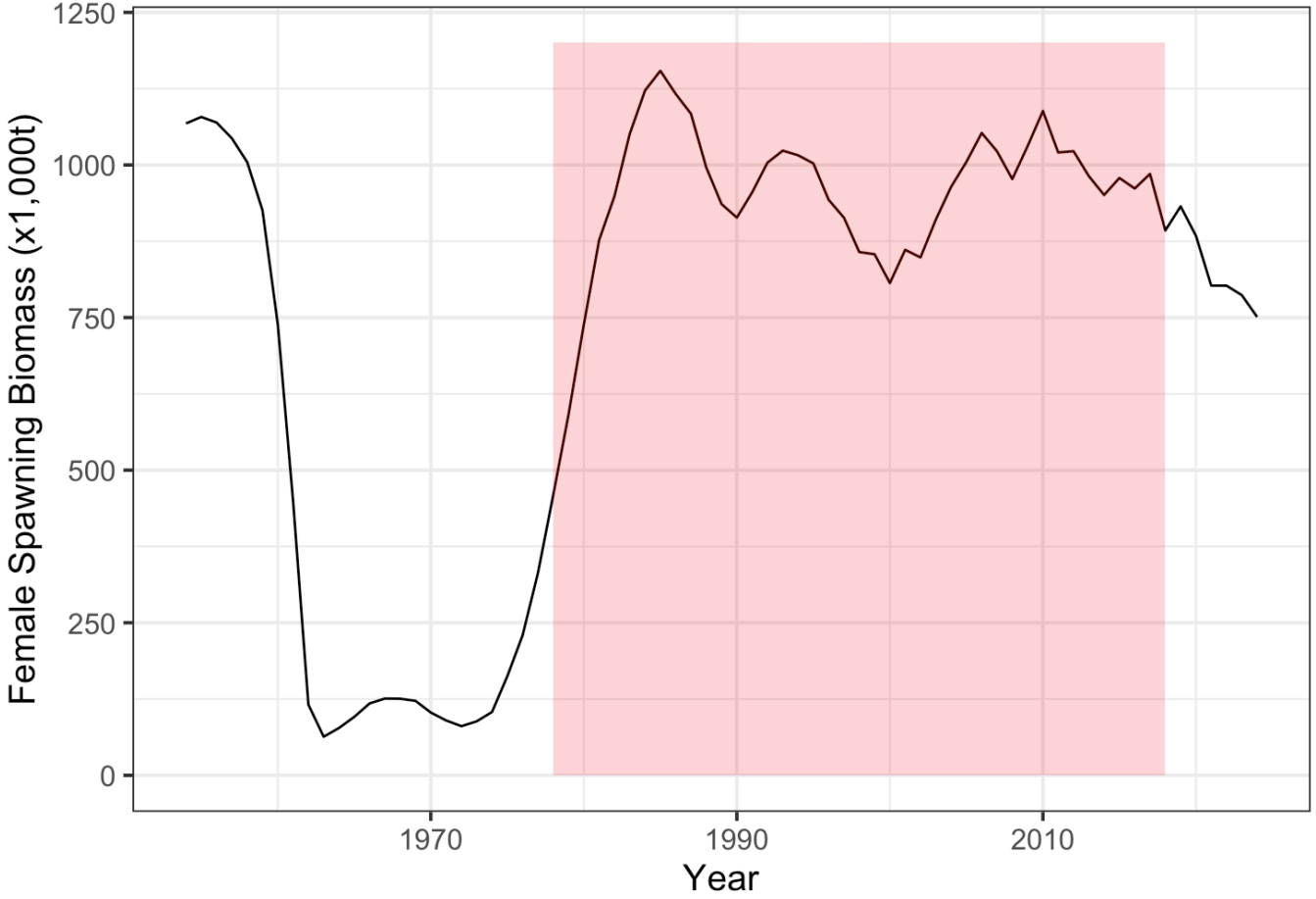
The most informative data are survey age comps- 1980 is the first year of the standard survey.



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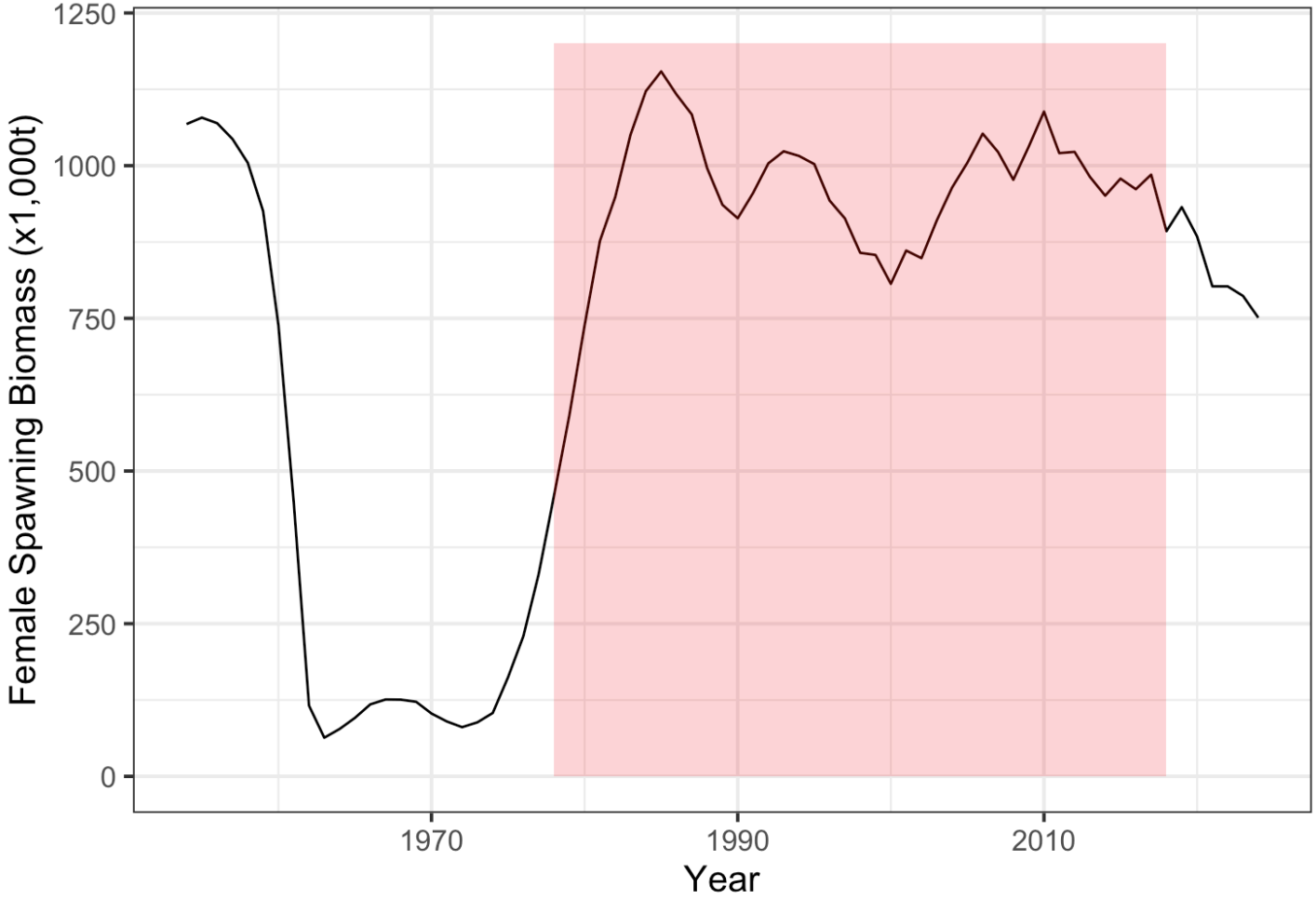
Recruitment should be evaluated within thermal regimes (Wooster and Zhang 2004).



Therefore, the first year used to estimate recruitment is 1978, which includes sex-specific fishery ages (starting in 1978) and survey ages (starting in 1979).

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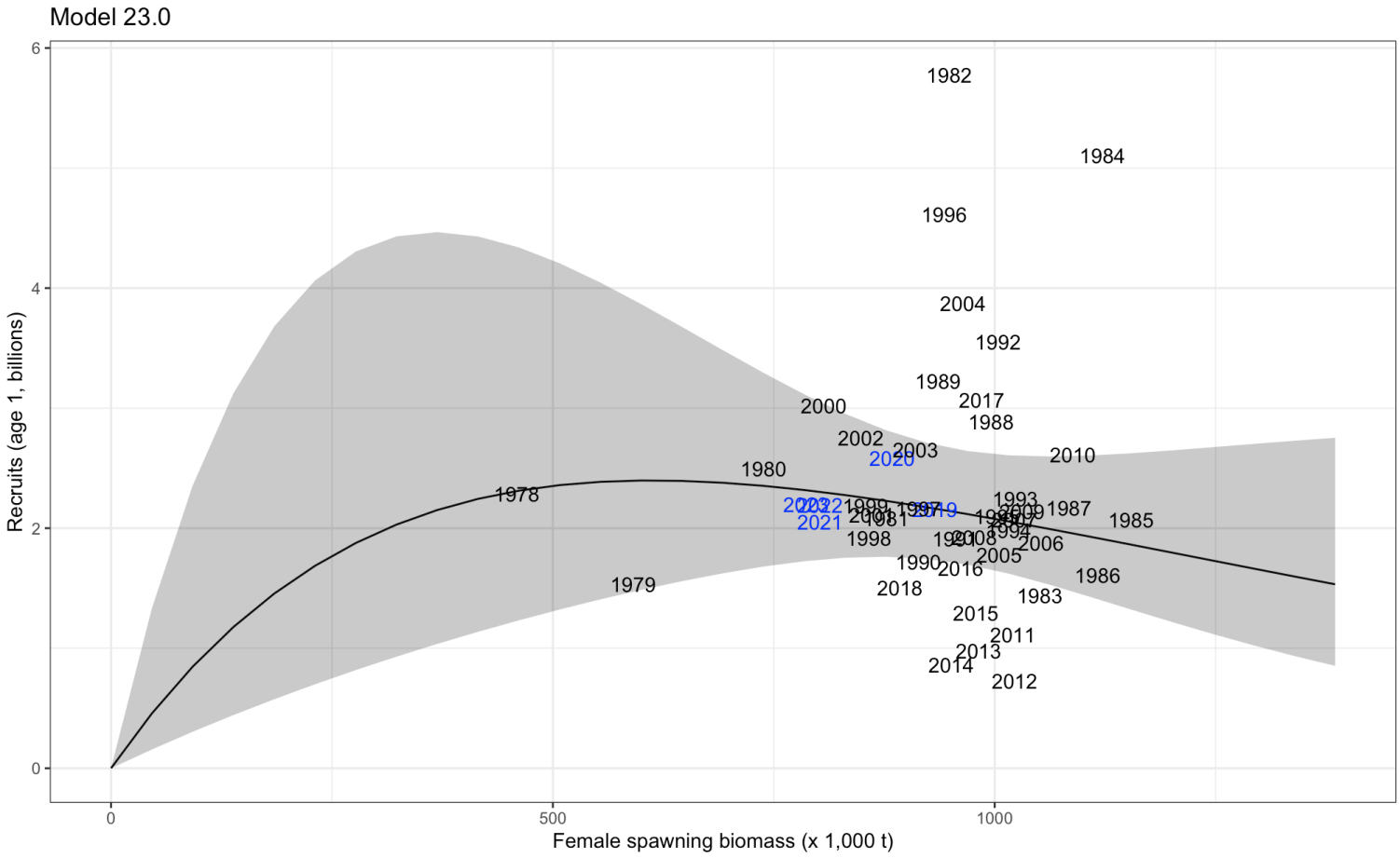
Recruitment estimates are based post-regime-shift years (1978 – 2018)



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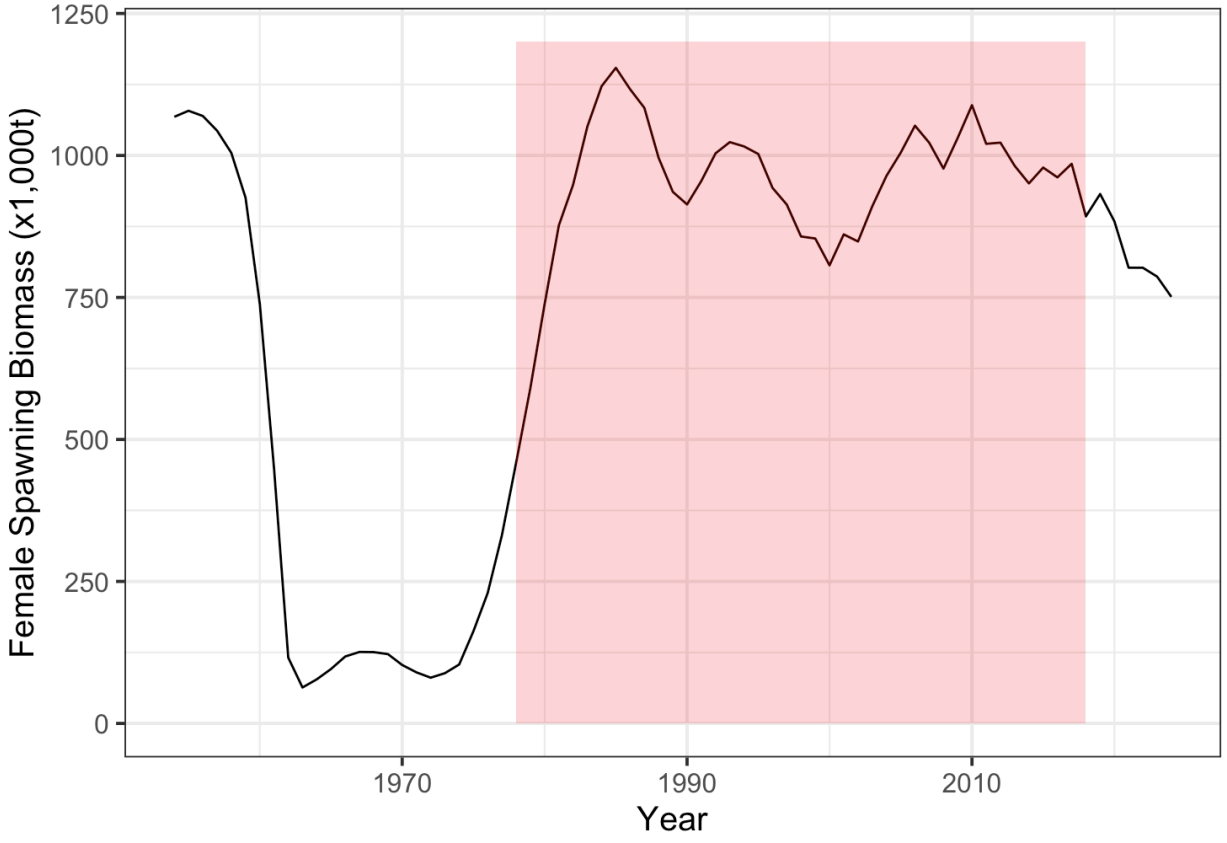
Some information may be available to estimate recruitment during the early 1970s when the stock was smaller, because yellowfin sole is somewhat long-lived.

- However, these years cannot be incorporated because recruitment patterns are not expected to be consistent across regimes (Wooster and Zhang 2004).

- Therefore, similar to EBS pollock, the data used to fit the stock recruitment curve for yellowfin sole do not include contrasting population size at low stock sizes (<500,000 t).

Years with a strong contrast in the stock size are not included in the stock recruitment curve.



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2. Time-varying q should use survey start date, but not temperature.

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Subsequent to the introduction of the VAST survey index and age compositions, we were double counting temperature with q (catchability).

- Since 2018, the BSAI YFS assessment annually varying catchability has used both EBS bottom temperature and survey start date, as shown below.
- In the yellowfin sole VAST methodology, the mean bottom temperature within specific strata is used in biomass indices and survey age compositions.

$$q_t = e^{-\alpha + \beta T + \gamma S + \mu T:S},$$

where α is time-invariant q, β is a time-varying covariate based on temperature, γ is a time-varying covariate based on survey start date, and μ is time-varying based on the interaction between temperature and survey start date.

The rationale for the use of survey start date and temperature as covariates on the catchability parameter

- Earlier survey start dates usually encounter colder water.
- Since the timing of the survey start date is positively correlated with bottom water temperature, improvement in fitting the survey biomass estimates was gained by estimating μ and γ.
- The AIC improvement in fit from the additional variables (S and T:S) was more than offset by the additional two parameters (Nichol et al. 2019).

$$q_t = e^{-\alpha + \beta T + \gamma S + \mu T:S}$$

Nichol, D.G., Kotwicki, S., Wilderbuer, T.K., Lauth, R.R. and Ianelli, J.N., 2019. Availability of yellowfin sole Limanda aspera to the eastern Bering Sea trawl survey and its effect on estimates of survey biomass. Fisheries Research, 211, pp.319-330.

We recommend removal of the temperature component of time-varying q and present sensitivity to this update.

Correlated or redundant predictor variables in a statistical model, also referred to as collinearity, can lead to reductions in model accuracy and reference point estimation (Dormann et al. 2013, De Marco and Nóbrega 2018).

De Marco, P. and Nóbrega, C.C., 2018. Evaluating collinearity effects on species distribution models: An approach based on virtual species simulation. PloS one, 13(9), p.e0202403.

Dormann, C.F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J.R.G., Gruber, B., Lafourcade, B., Leitão, P.J. and Münkemüller, T., 2013. Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography, 36(1), pp.27-46.

Therefore, we recommend the use of only the survey start date as a covariate on the catchability parameter in future BSAI YFS assessment models.

- To eliminate the double counting of temperature, we used an index of survey start date (1982 – 2023) as the environmental link on catchability for the bridging analysis.

3. Bridging Model 23.0 to SS3

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3. Bridging Model 23.0 to SS3

Model 23.0: This is the accepted model from 2024, a bespoke model ('flatfish model') written in ADMB.

mSS3deter: This is the deterministic version of Model 23.0 in SS3 v3.30.23.2, with parameters fixed at values from Model 23.0.

Why SS3?

- Consistency.
- Easy to transition from Synthesis to FIMS.
- Working group support among colleagues.
- Adding growth ~ temperature.

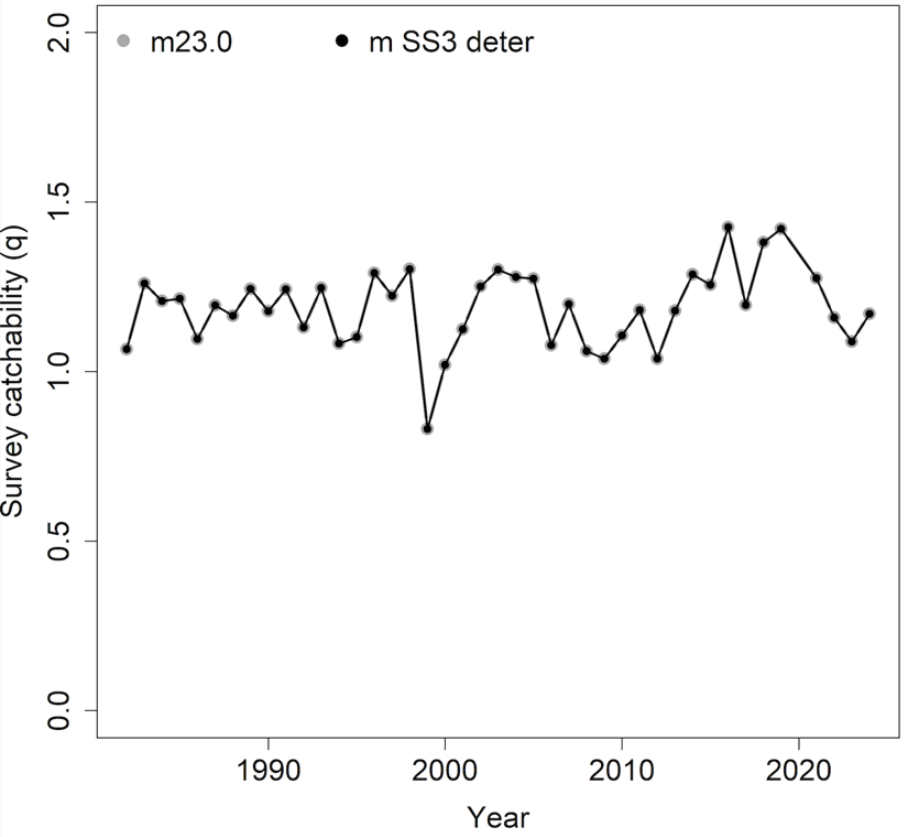
Consistency: The majority of flatfish assessments have moved to SS3. Yellowfin Sole and northern rock sole currently use the bespoke 'flatfish' model.

SS3	ADMB (Bespoke)
BSAI Greenland Turbot	BSAI Kamchatka
BSAI Flathead Sole	BSAI + GOA ATF (rceattle)
GOA Flathead Sole	BSAI Northern Rock Sole
GOA Northern & Southern Rock Sole	
GOA Rex Sole	
BSAI Alaska Plaice	
GOA deepwater flatfish	

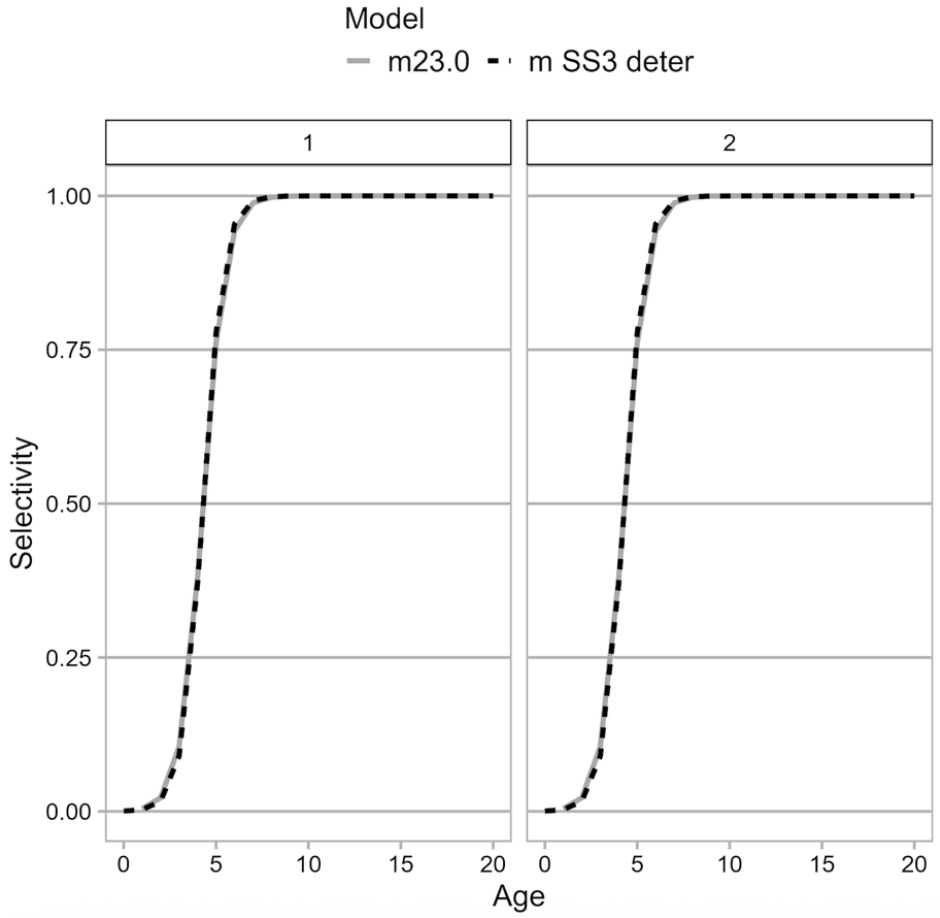
Why SS3?

- Consistency.
- Easy to transition from Synthesis to FIMS.
- Working group support among colleagues.
- Adding growth ~ temperature.

All parameter values were fixed in a deterministic model run based on the 2024 yellowfin sole assessment Model 23.0

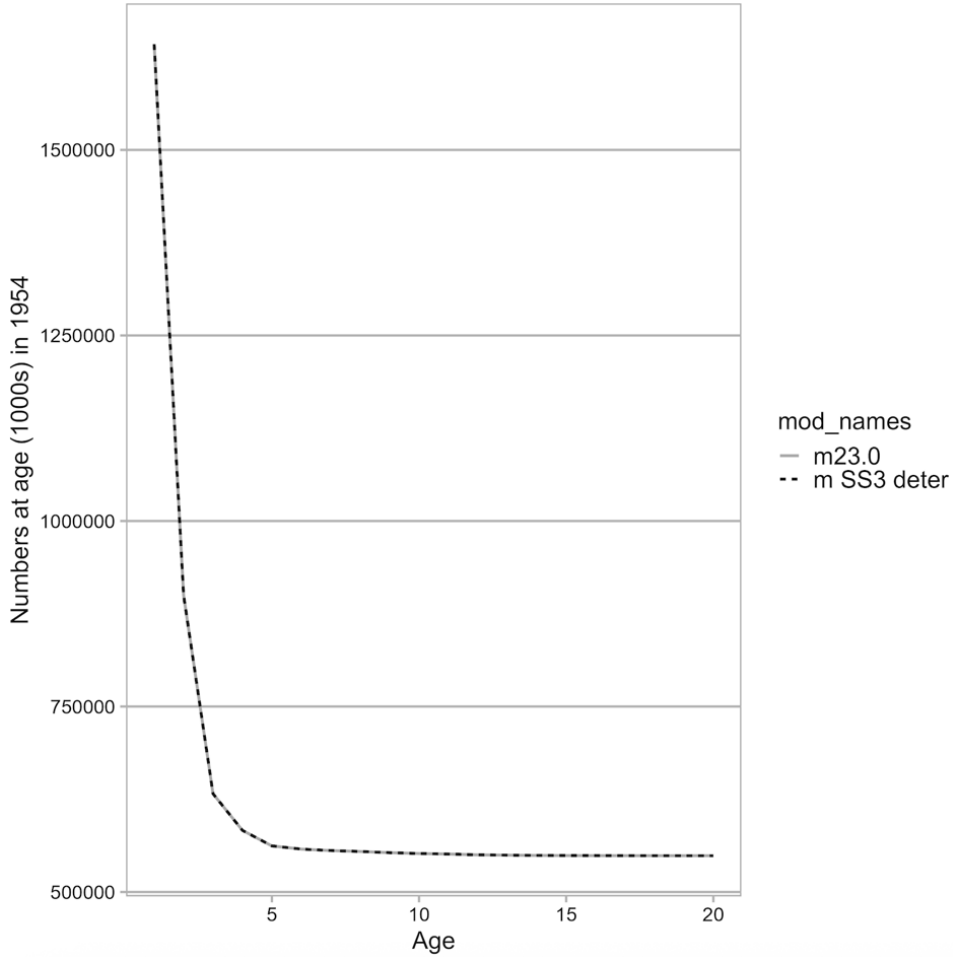


Survey catchability

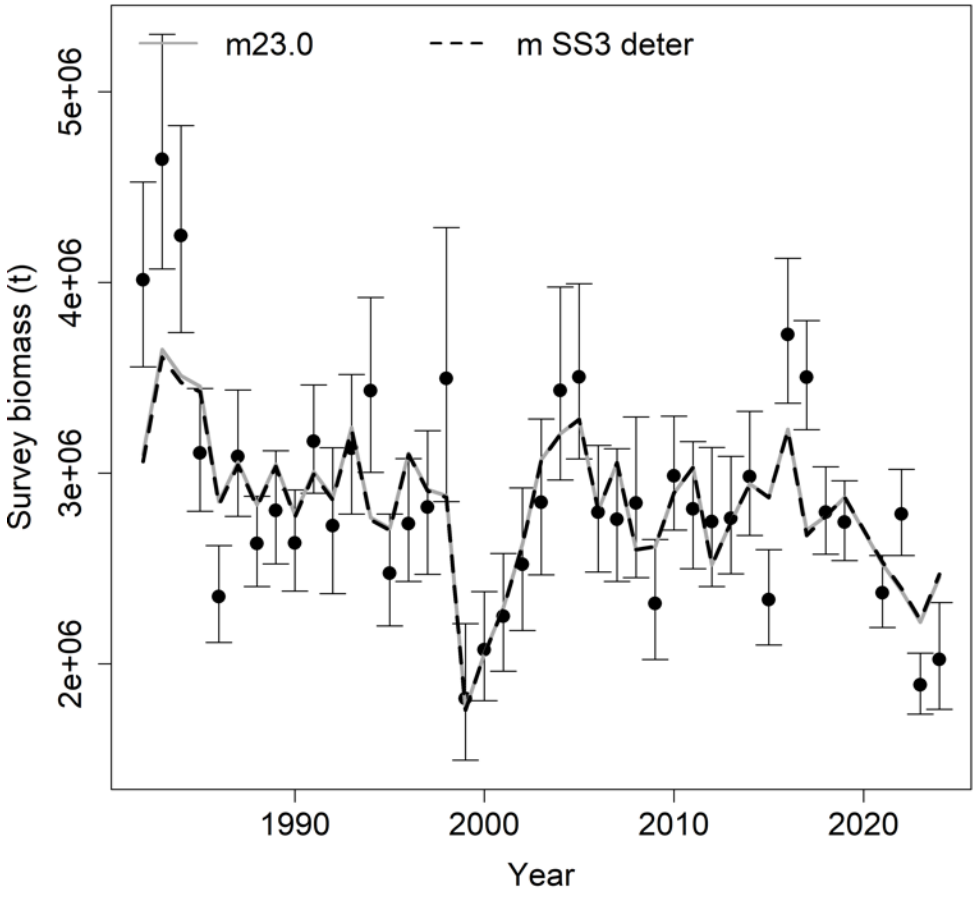


Survey selectivity

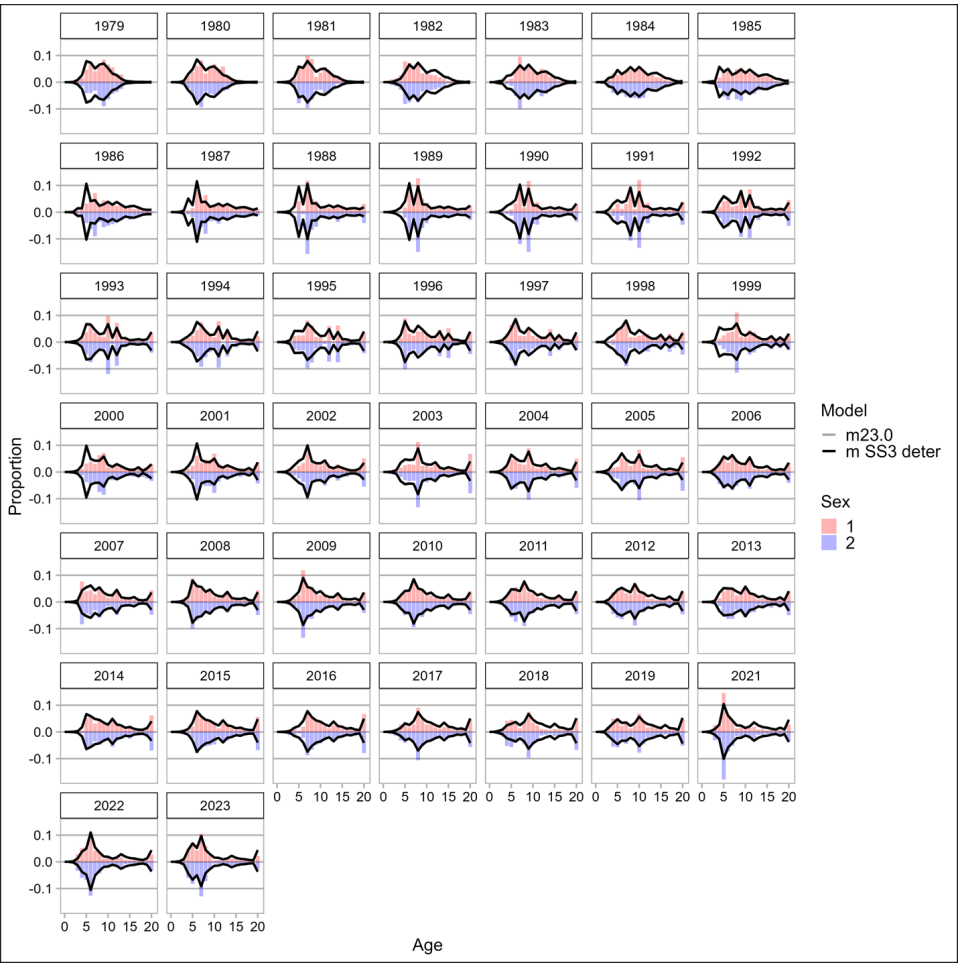
Initial numbers at age (males and females combined) for Model 23.0 and SS3 model (mSS3deter).

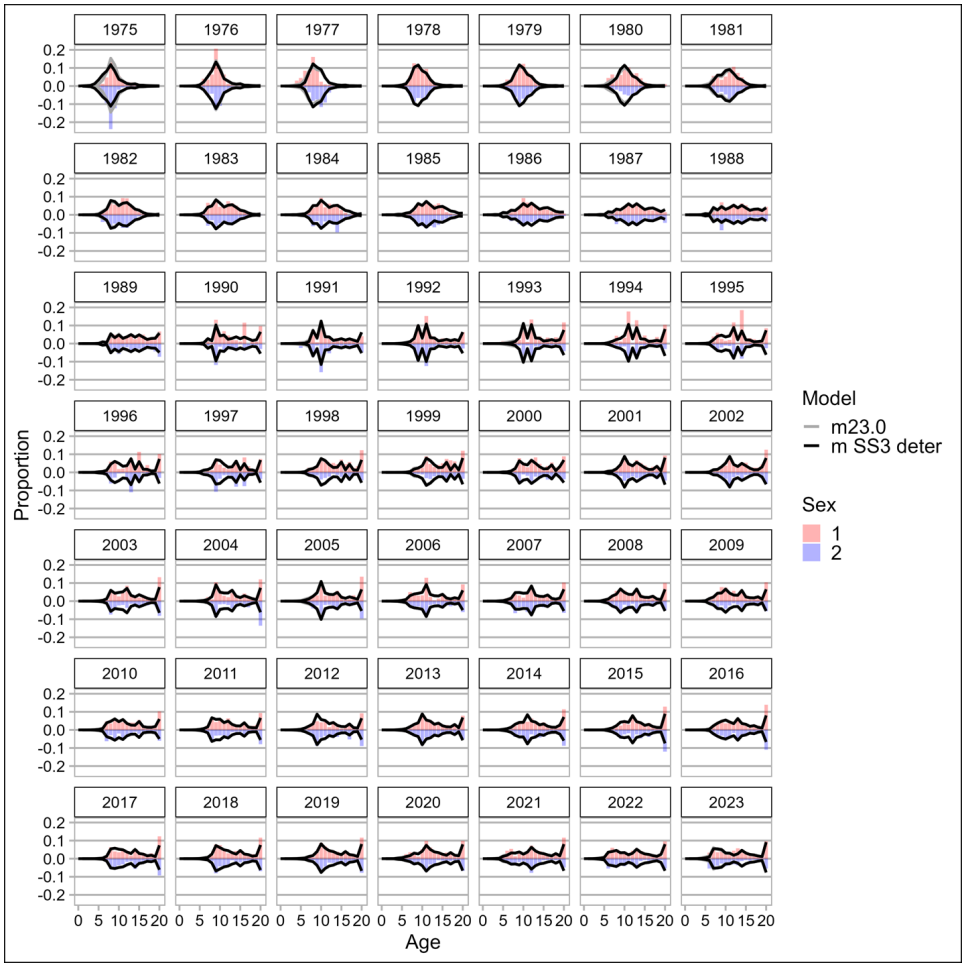


Deterministic run showing survey biomass estimate for Model 23.0 and mSS3deter

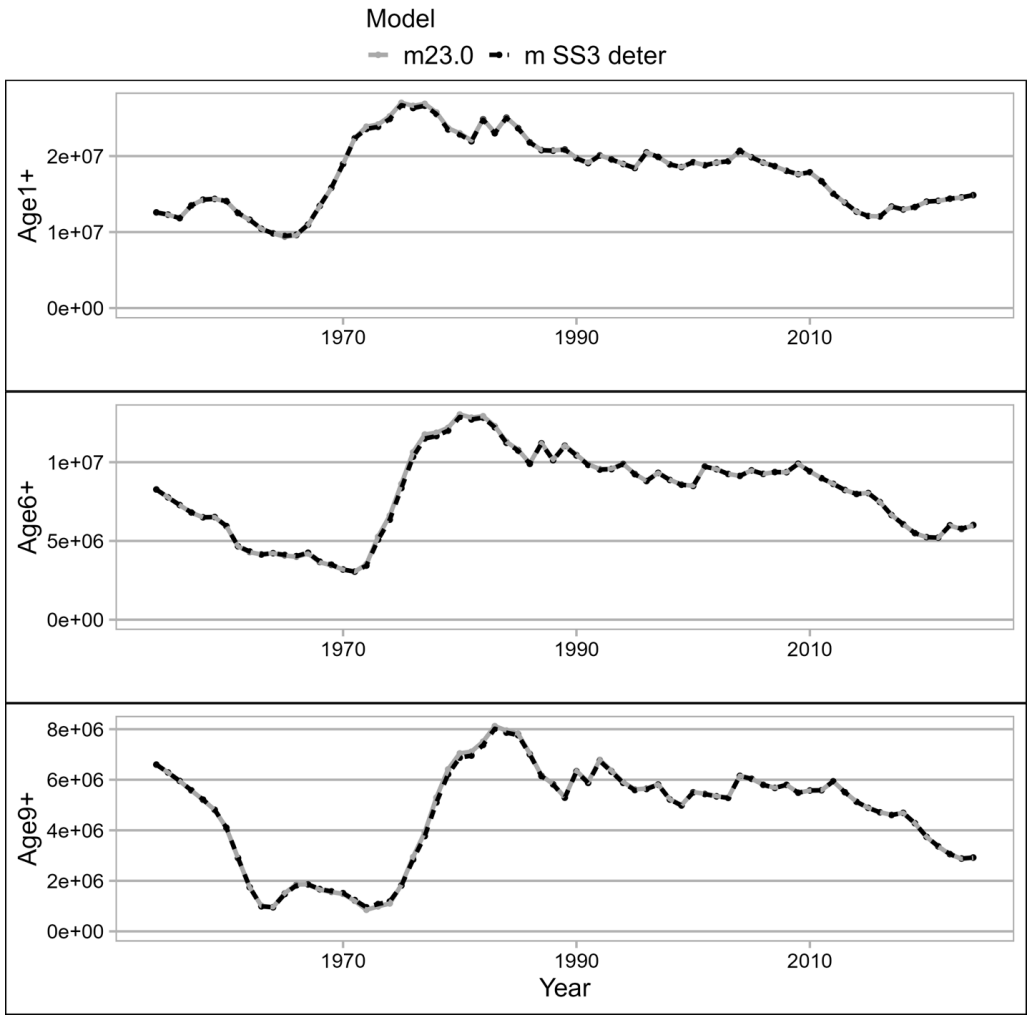


Deterministic run showing fits to survey (left) fishery (right) age composition for males and females for Model 23.0 and mSS3deter.

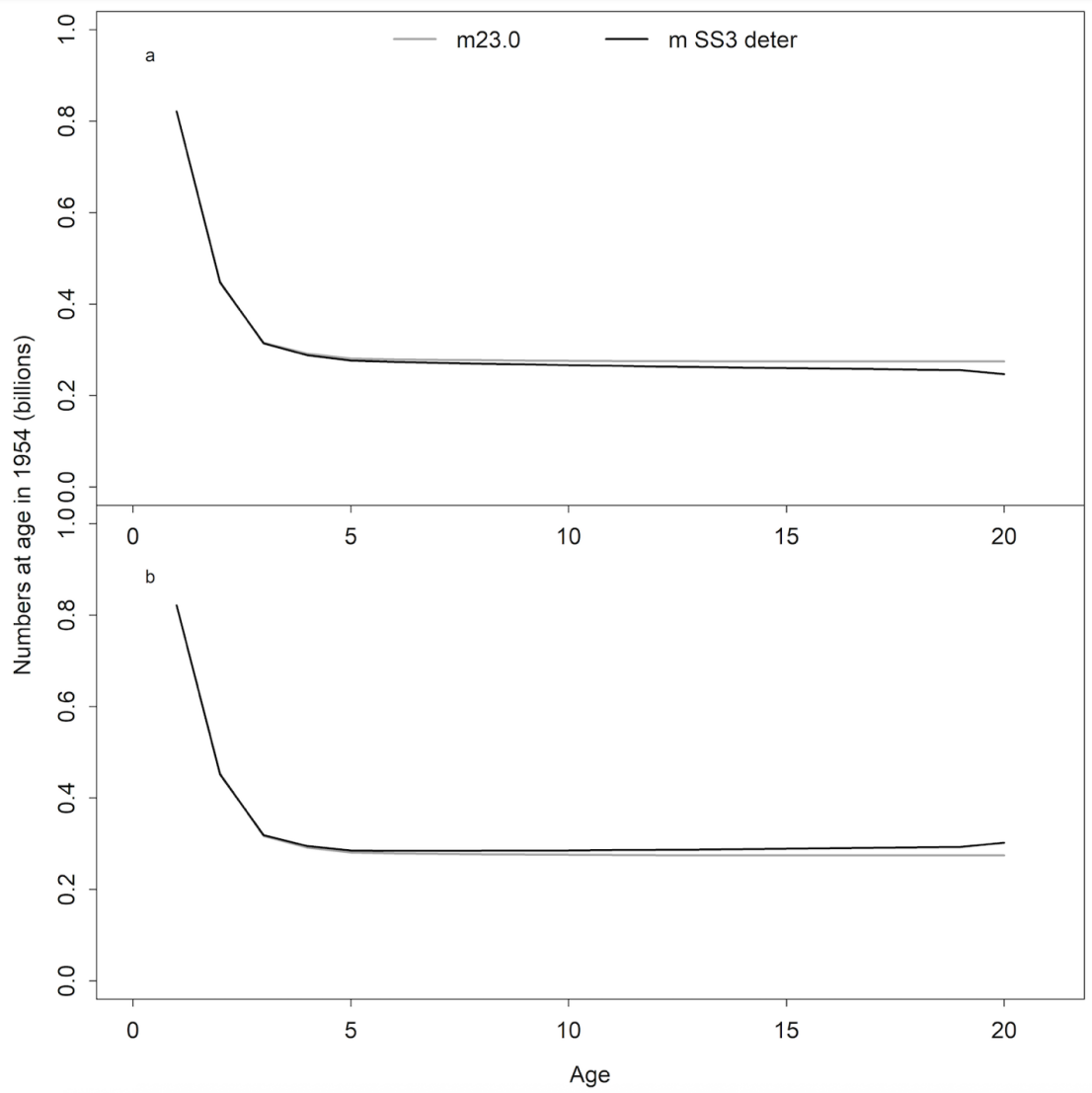




Deterministic runs of Model 23.0 and mSS3deter showing numbers for ages 1 and older (Age 1+), Age 6+ and Age 9+.

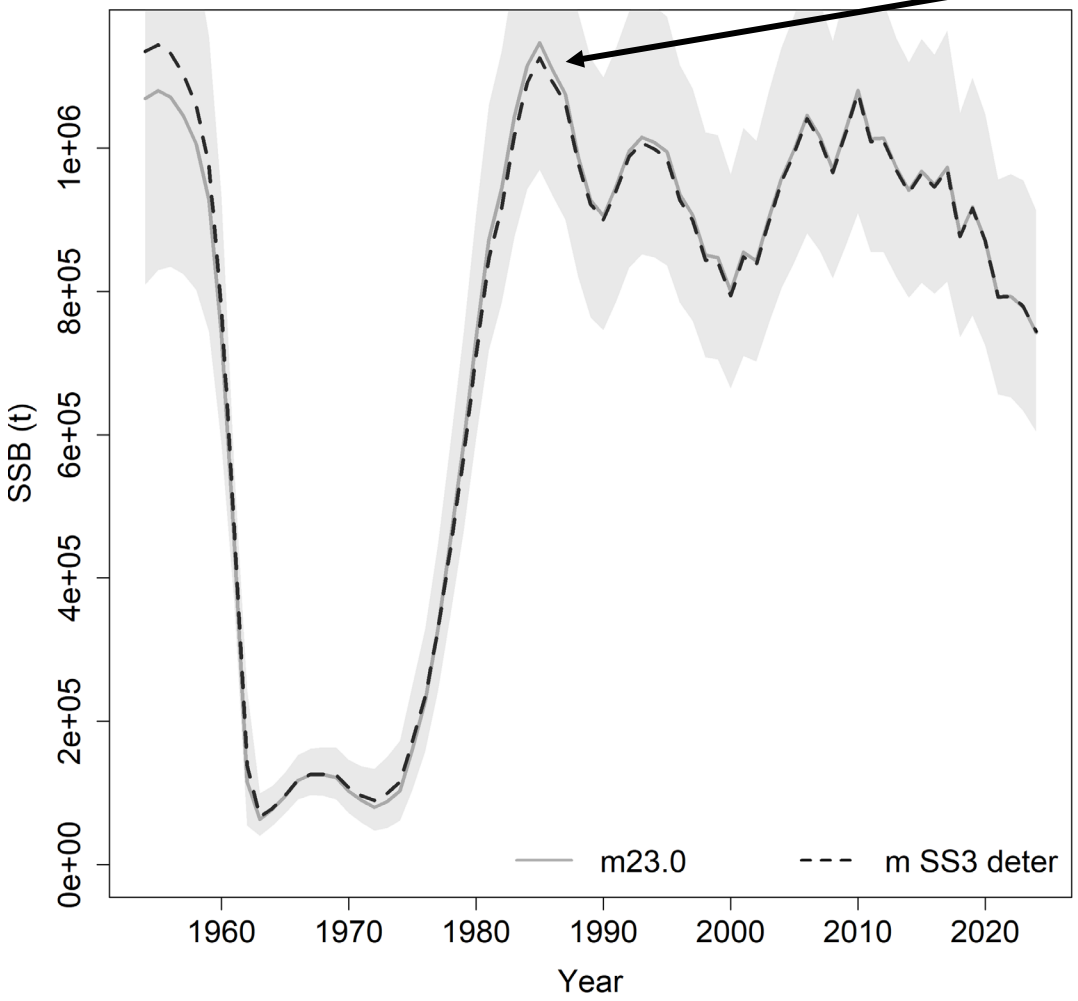


Initial numbers at age for males (above), and females (below)



These figures show that SS3 (mSS3deter) incorporates different natural mortality for males and females (see Eq. 3). Model mSS3deter has fewer males (panel a.) than Model 23.0 but more females (panel b.), because males have higher natural mortality than females.

Deterministic runs of Model 23.0 and mSS3deter showing spawning stock biomass.



Initial difference is due to SS3 incorporates mortality to initial numbers at age.

SS3 and Model 23.0 employ different approaches to initializing the population.

SS3 initializes the population assuming equilibrium and includes a plus group:

$$\text{Eq. 3: } N_{0,a,s} = \begin{cases} cR_0 e^{-aM_s} & a = 0 \text{ to } 3A-1 \\ \sum_{a=A}^{3A-1} N_{0,a,s} + \frac{N_{0,3A-1,s}e^{-Ms}}{1-e^{-Ms}} & a > A \end{cases}$$

where $N_{0,a,s}$ is the sex-specific initial numbers at age, c is the assumed sex-ratio at recruitment and fixed at 0.5, R_0 is mean recruitment, and M is sex-specific natural mortality. The numbers in 1954 are then derived as:

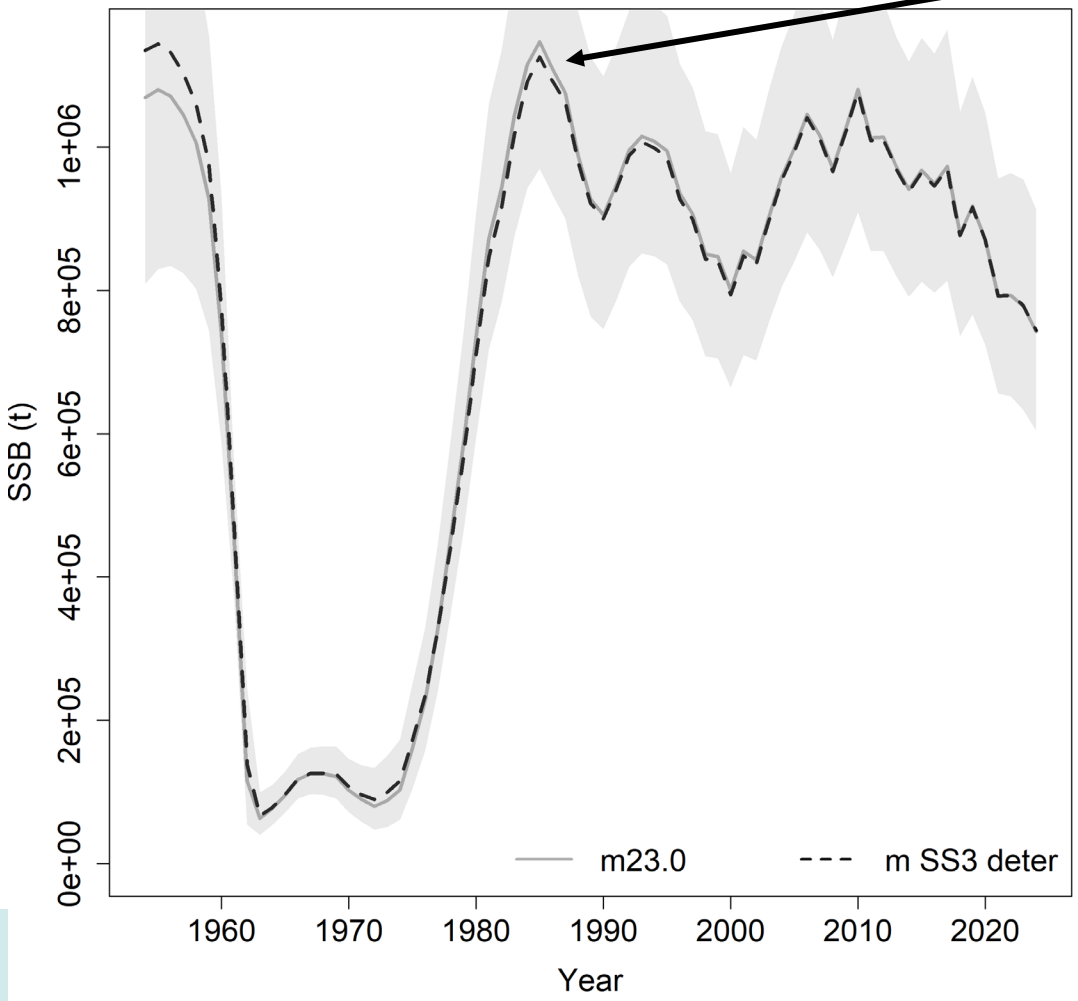
Model 23.0 initializes the population in 1954 as:

$$\text{Eq. 5: } n_{1954,a,s} = \begin{cases} 0.5e^{\bar{R}} & a = 1 \\ e^{\bar{I} + \varepsilon_{a,s}} & a > 1, \end{cases}$$

where $\bar{R}$ is mean recruitment, $\bar{I}$ represents the mean number of age 2+ in 1954, and $\varepsilon_{a,s}$ is the sex and age specific deviation.

Deterministic runs of Model 23.0 and mSS3deter showing spawning stock biomass.

Initial difference is due to SS3 incorporates mortality to initial numbers at age.



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Estimation runs

Model 23.0: This is the accepted model from 2024.

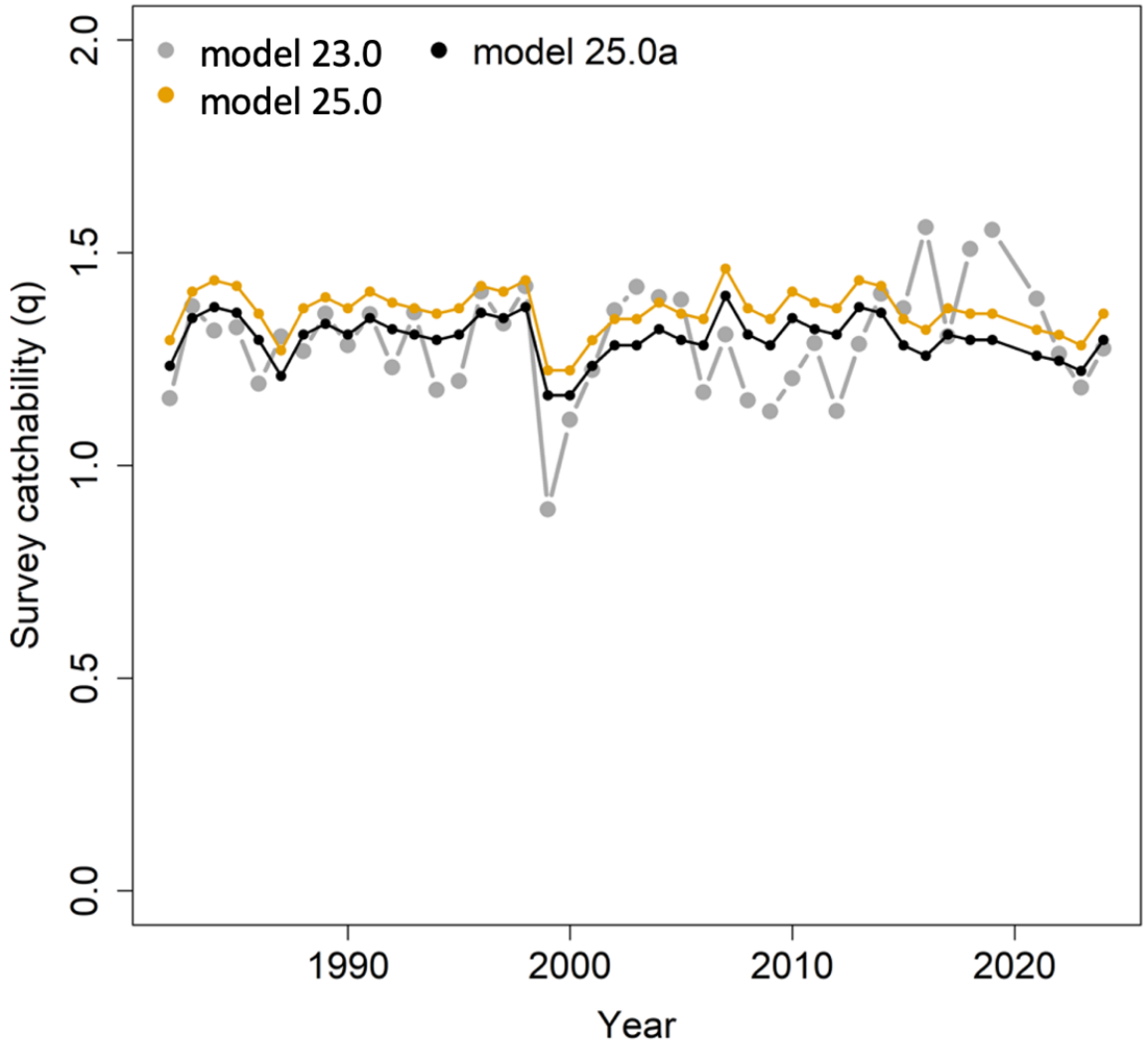
Model 25.0: This is the estimation version of mSS3deter, with the following features:

- EBS survey catchability *q* incorporates the survey start date (but not EBS bottom temperature) as an environmental covariate.
- Data weighting for survey age composition is based on the number of hauls from which otoliths were collected and used for constructing age compositions, as in Model 23.0.

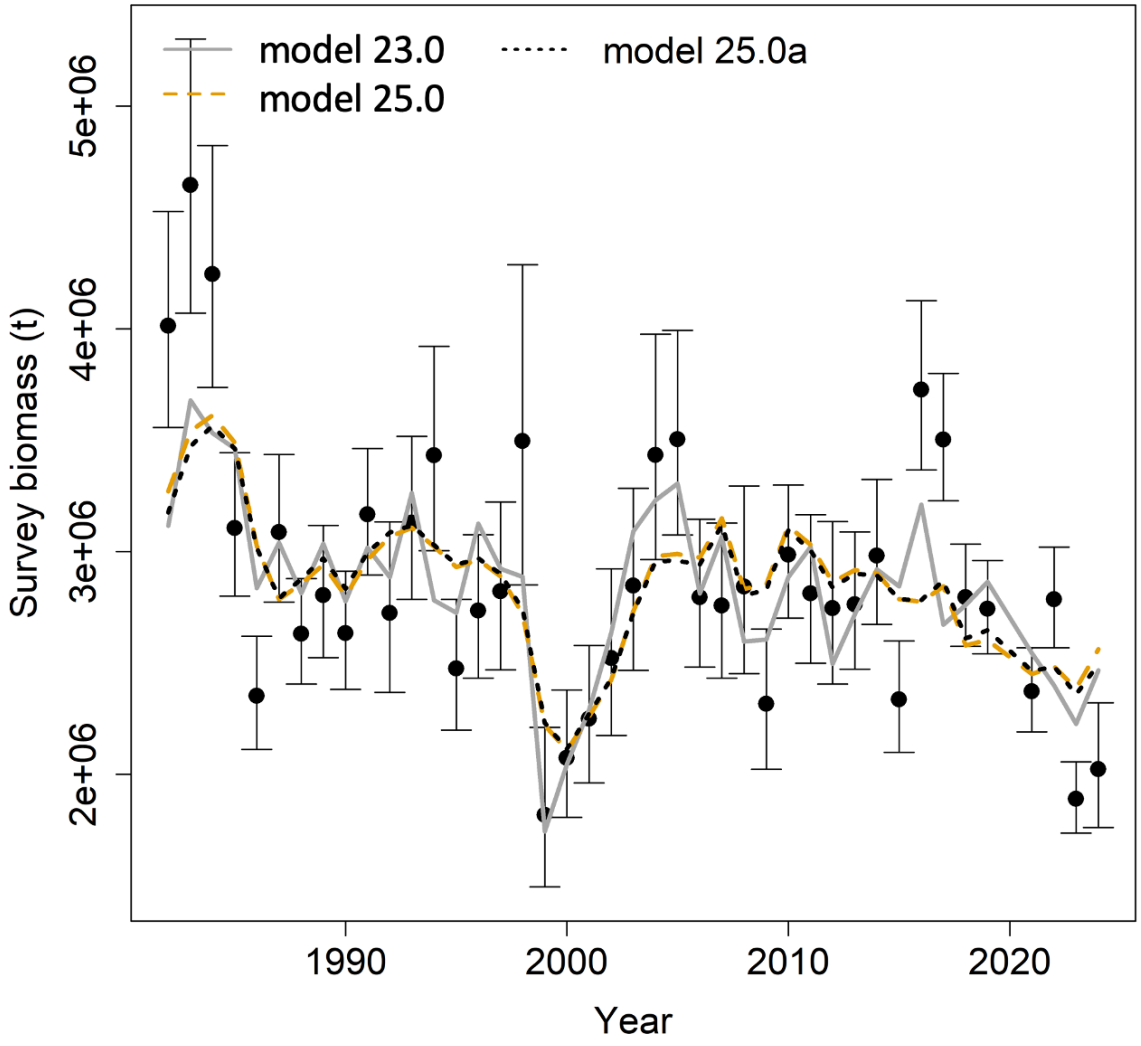
Model 25.0a: This is the proposed model for 2025 which builds on Model 25.0, except:

- Data weighting for survey age composition is based on the input sample size (ISS) methodology R package *surveyISS* (Hulson et al. 2024).

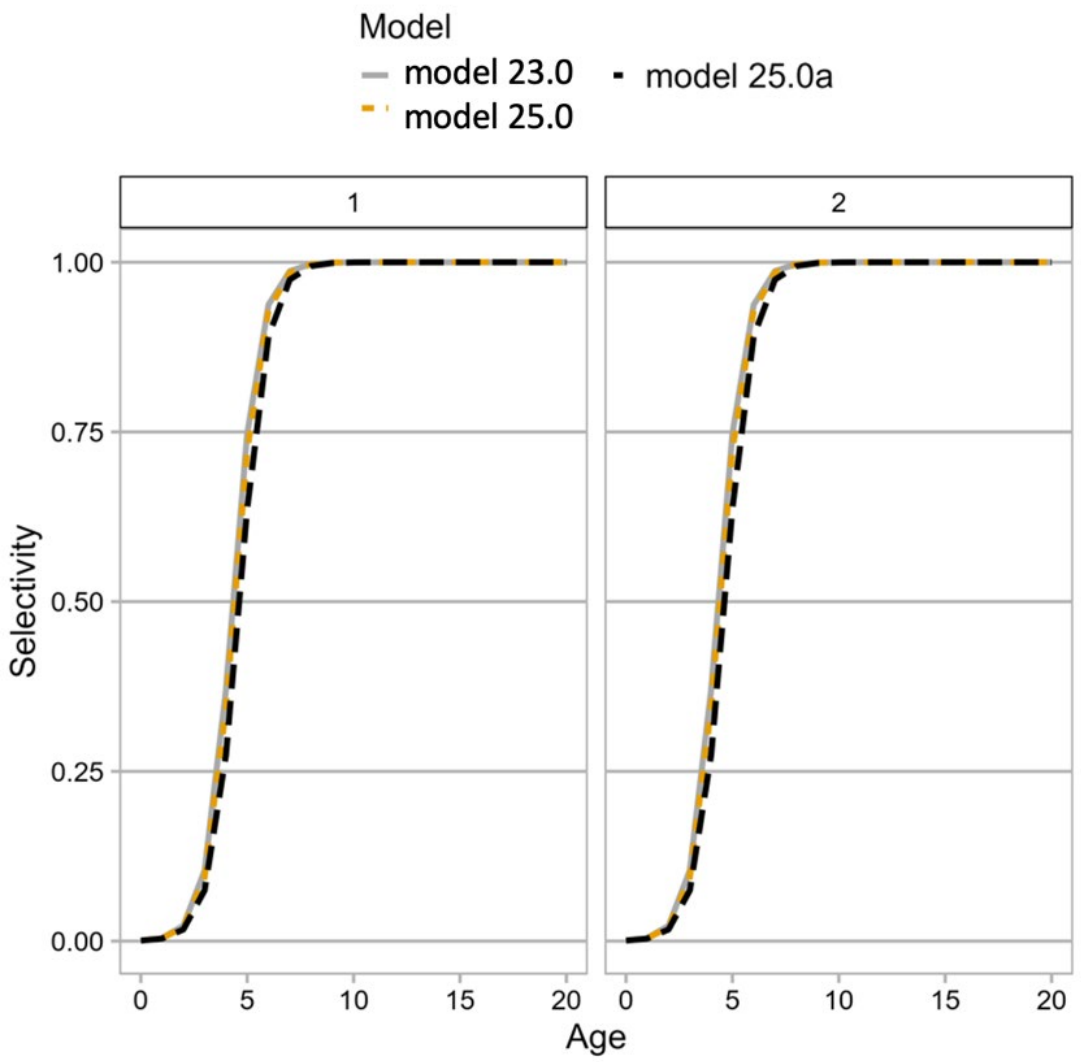
Estimation runs showing catchability for Model 23.0, Model 25.0, and Model 25.0a.



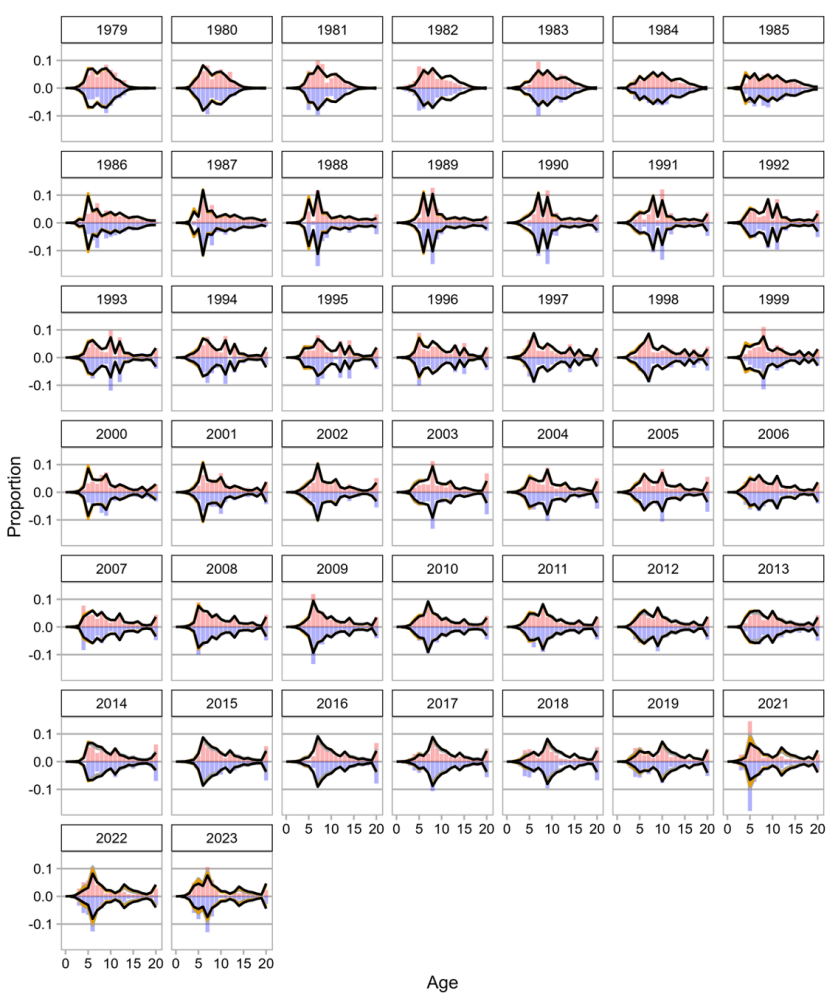
Estimation runs showing fit to survey biomass for Model 23.0, Model 25.0, and Model 25.0a.

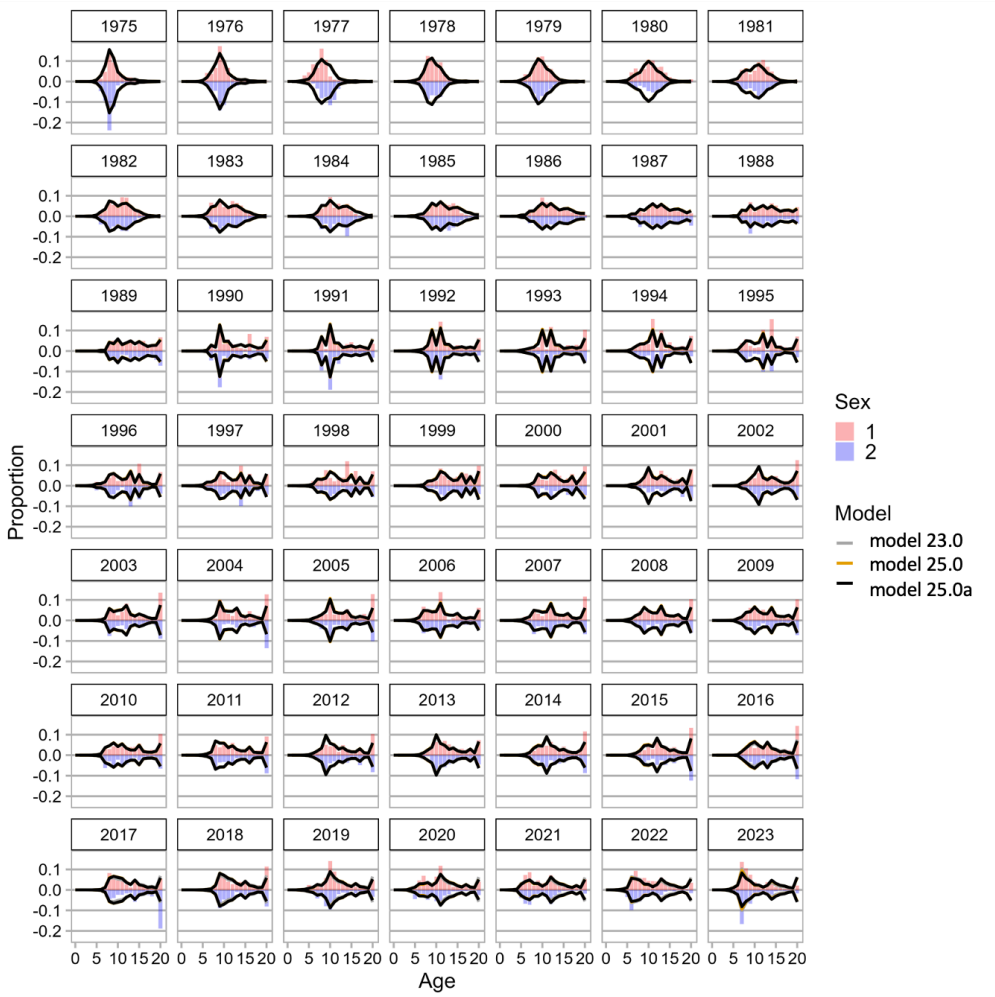


Estimation run showing survey selectivity for males and females for Model 23.0, Model 25.0, and Model 25.0a.

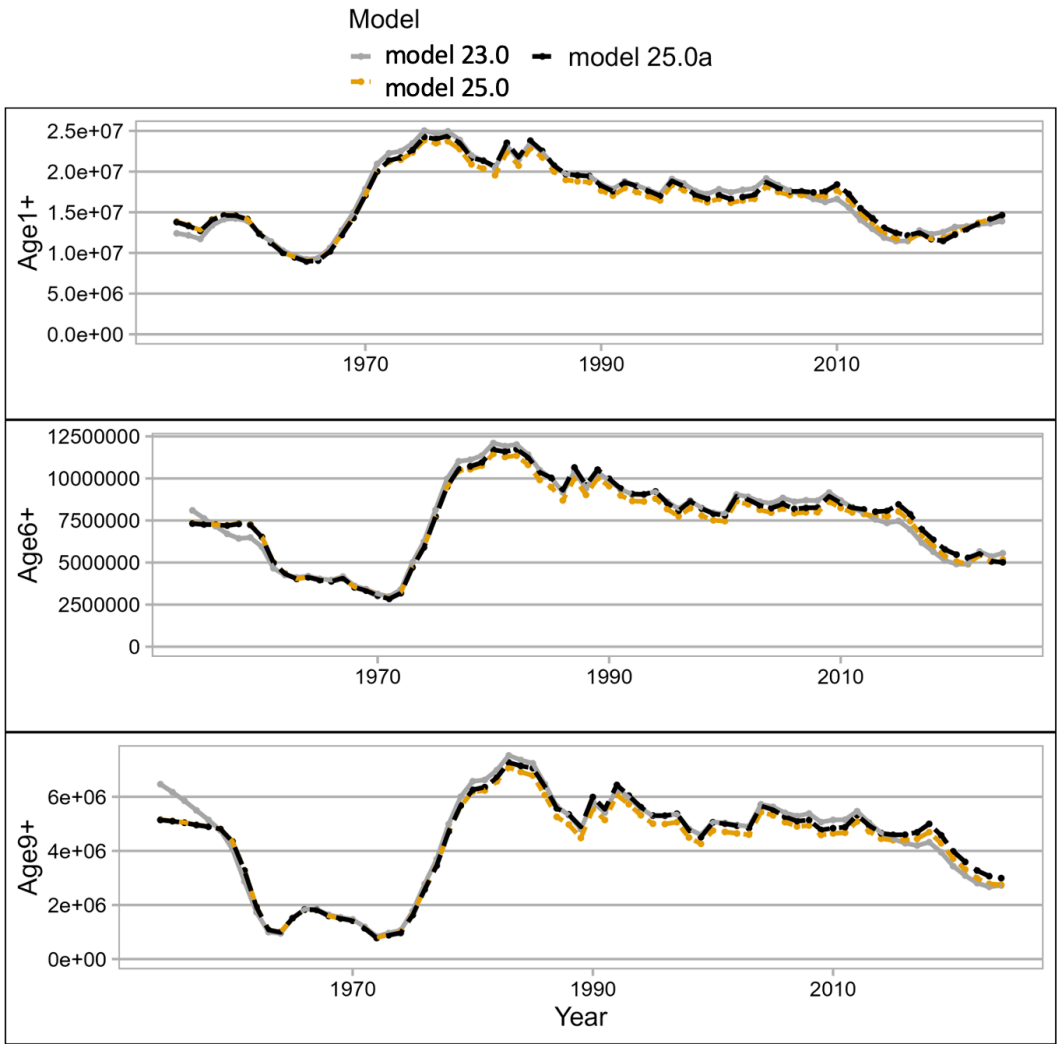


Estimation run showing fit to survey (left) and fishery (right) age compositions for Model 23.0, Model 25.0, and Model 25.0a.

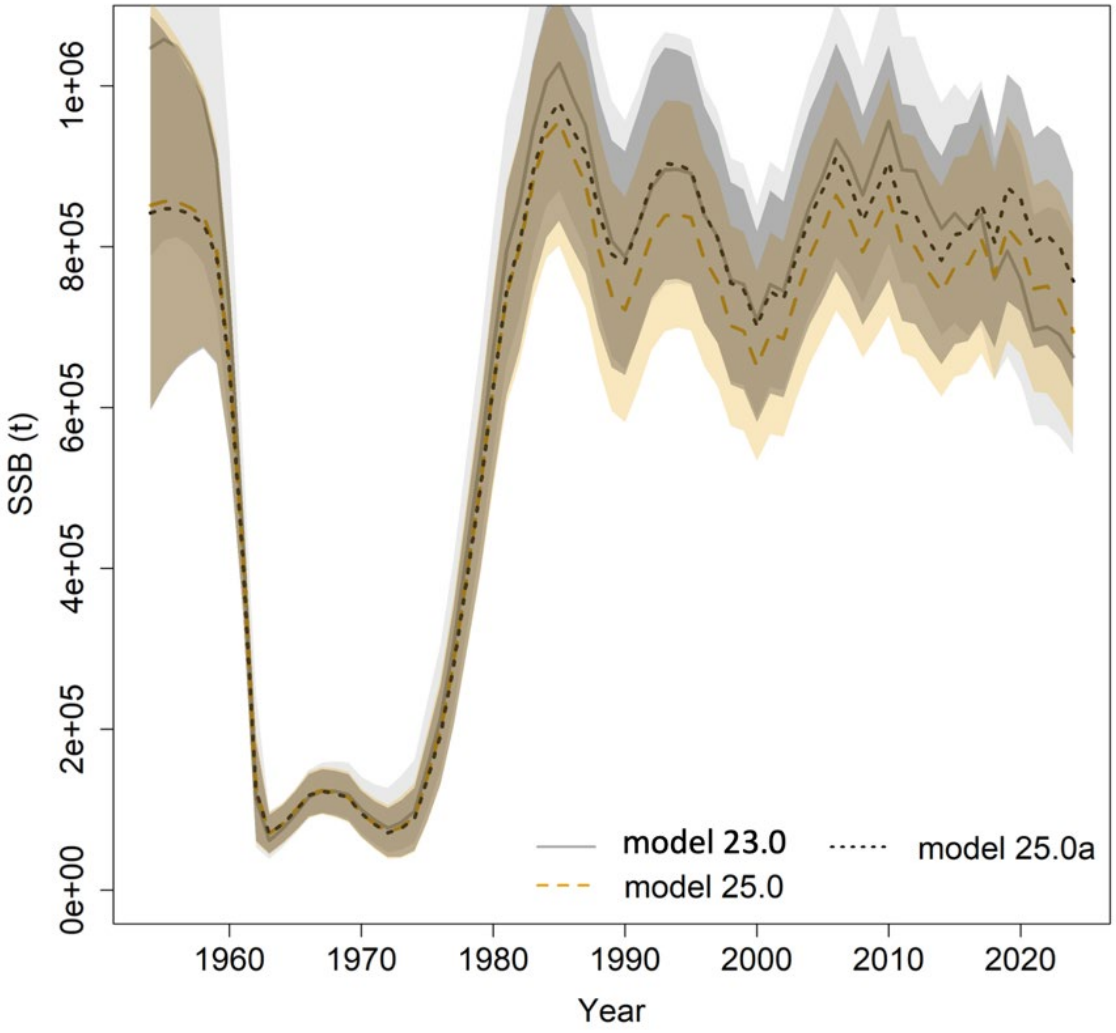




Estimation runs compositions for Model 23.0, Model 25.0, and Model 25.0a, showing numbers at all ages 1 and above (Age 1+), ages 6 and above (Age 6+), and ages 9 and above (Age 9+).



Estimation runs compositions for Model 23.0, Model 25.0, and Model 25.0a showing estimates of spawning biomass.



Diagnostics

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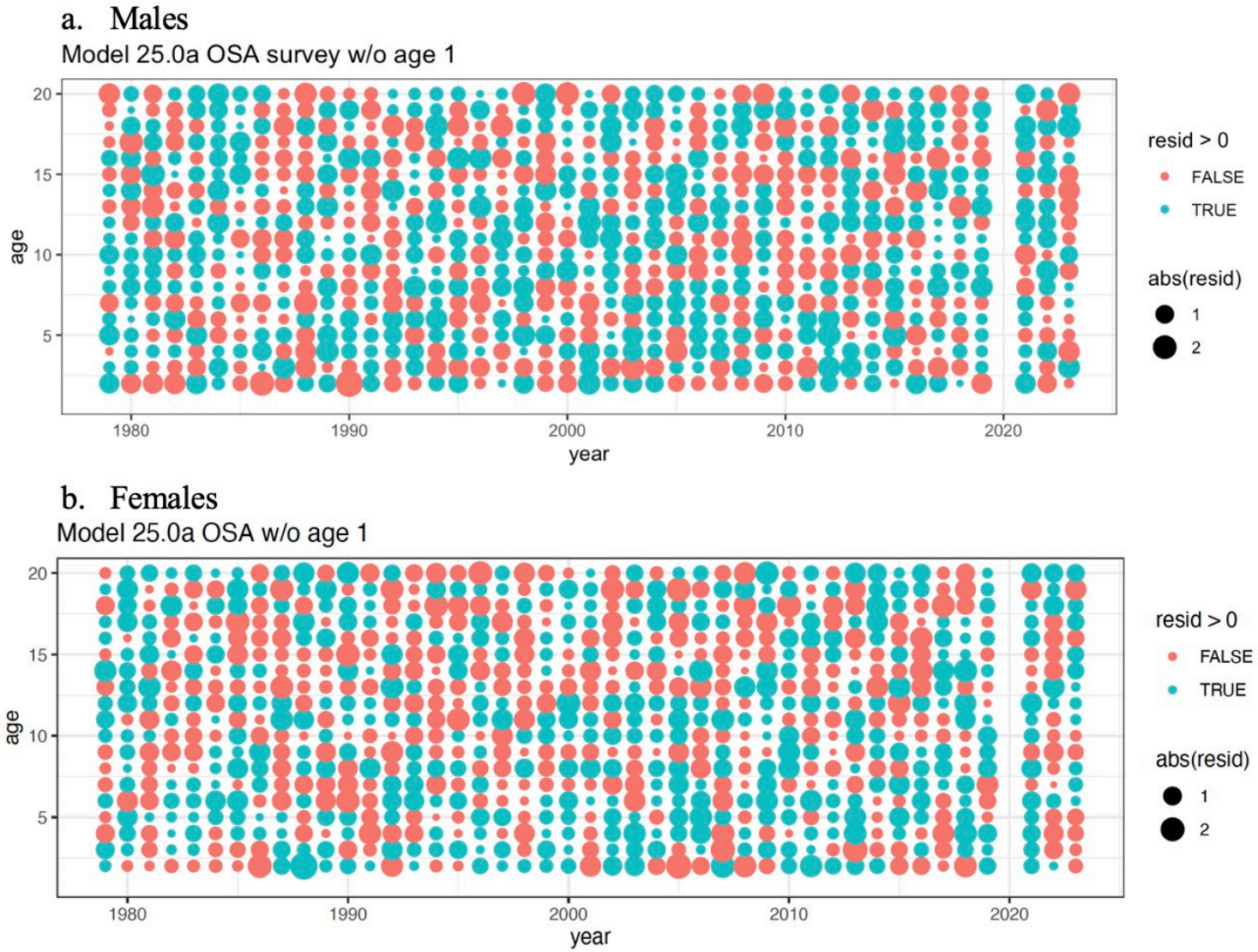
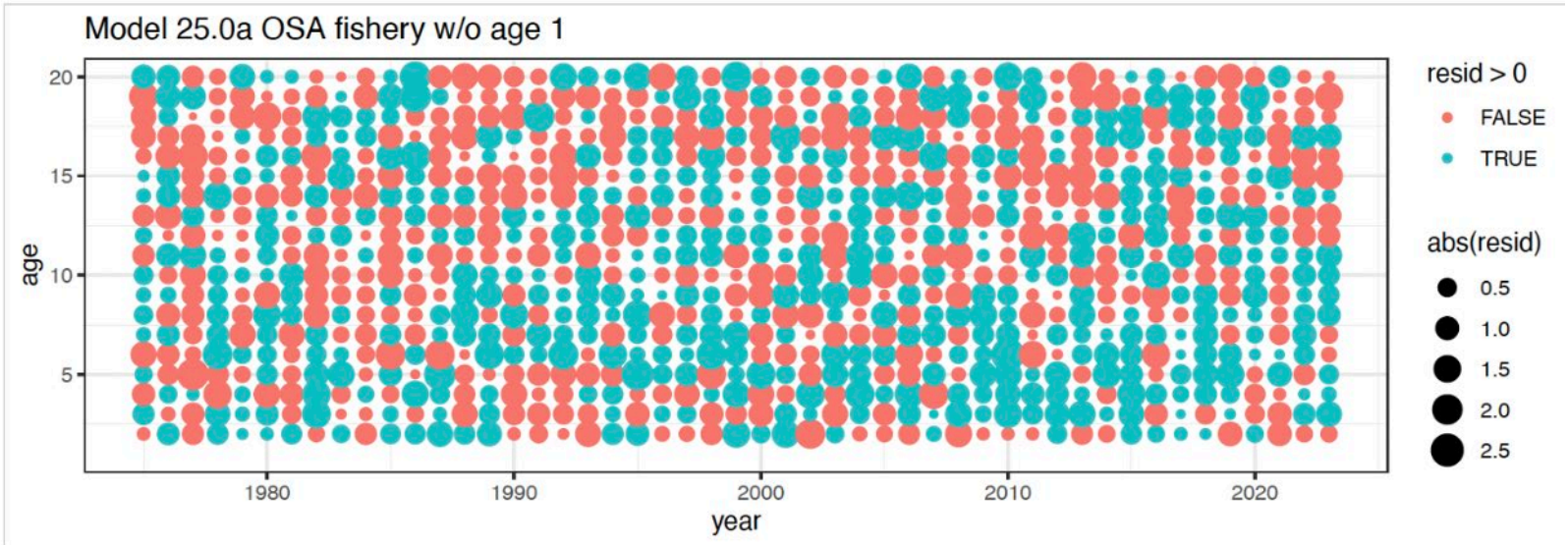
Model 25.0a survey age composition one step ahead males (upper panel), and females (lower panel).

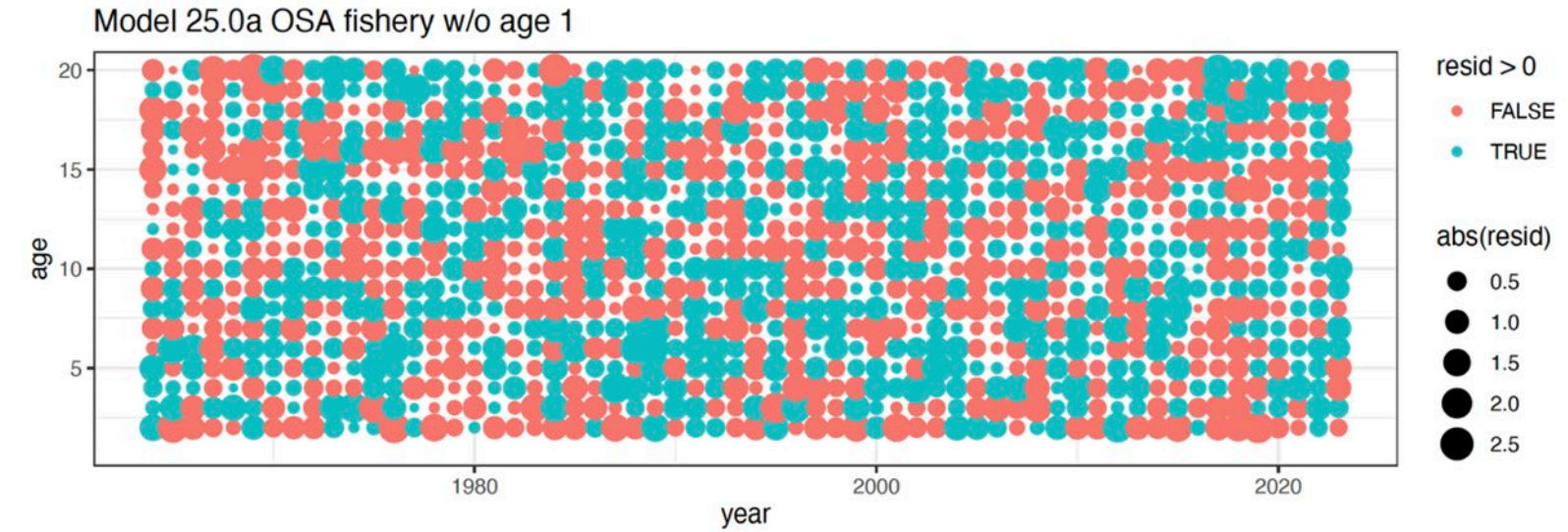


Model 25.0a fishery age composition one step ahead males (upper panel) and females (lower panel).

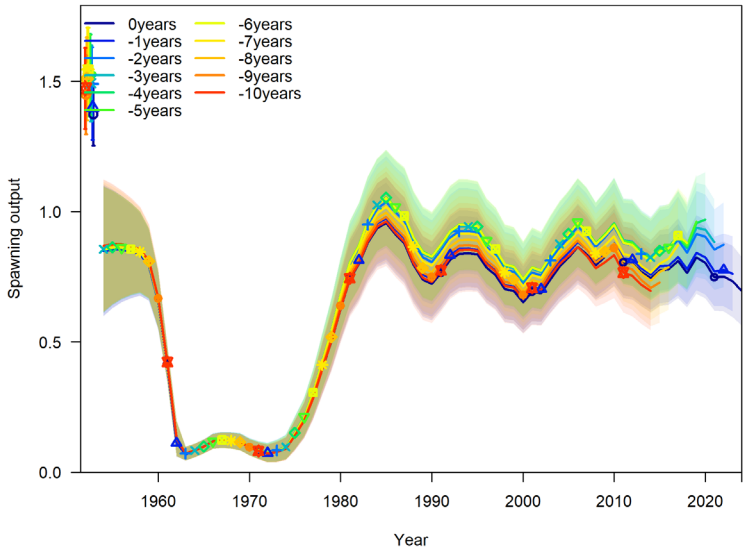
a. Males



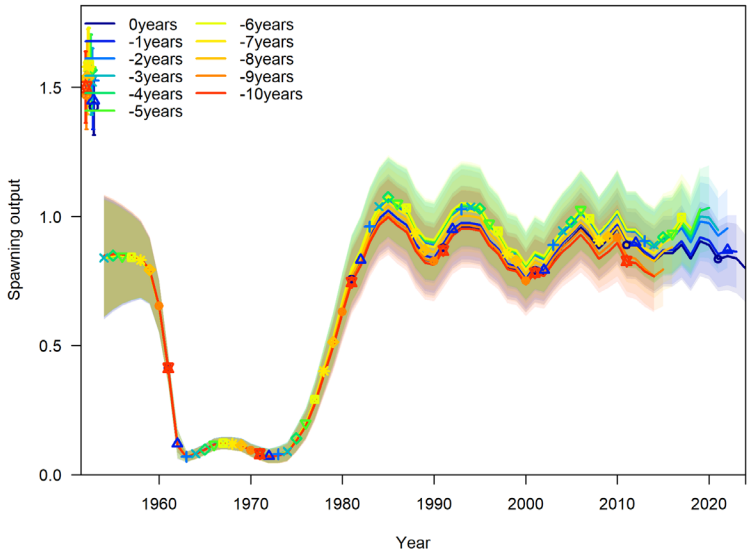
b. Females



Retrospective plot of spawning biomass for Model 25.0 (left) and Model 25.0a (right)



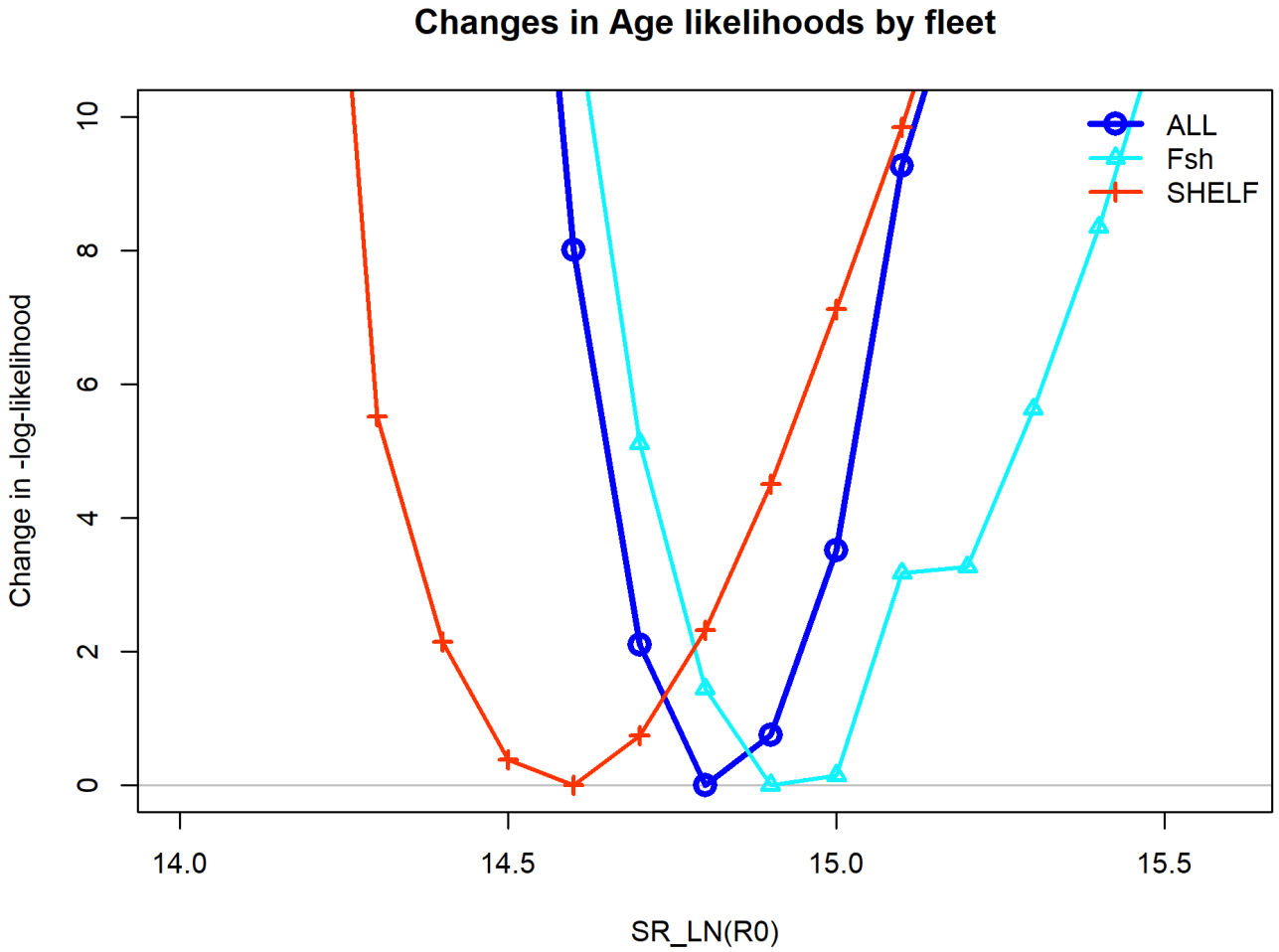
Mohn's rho = 0.09



Mohn's rho = 0.07

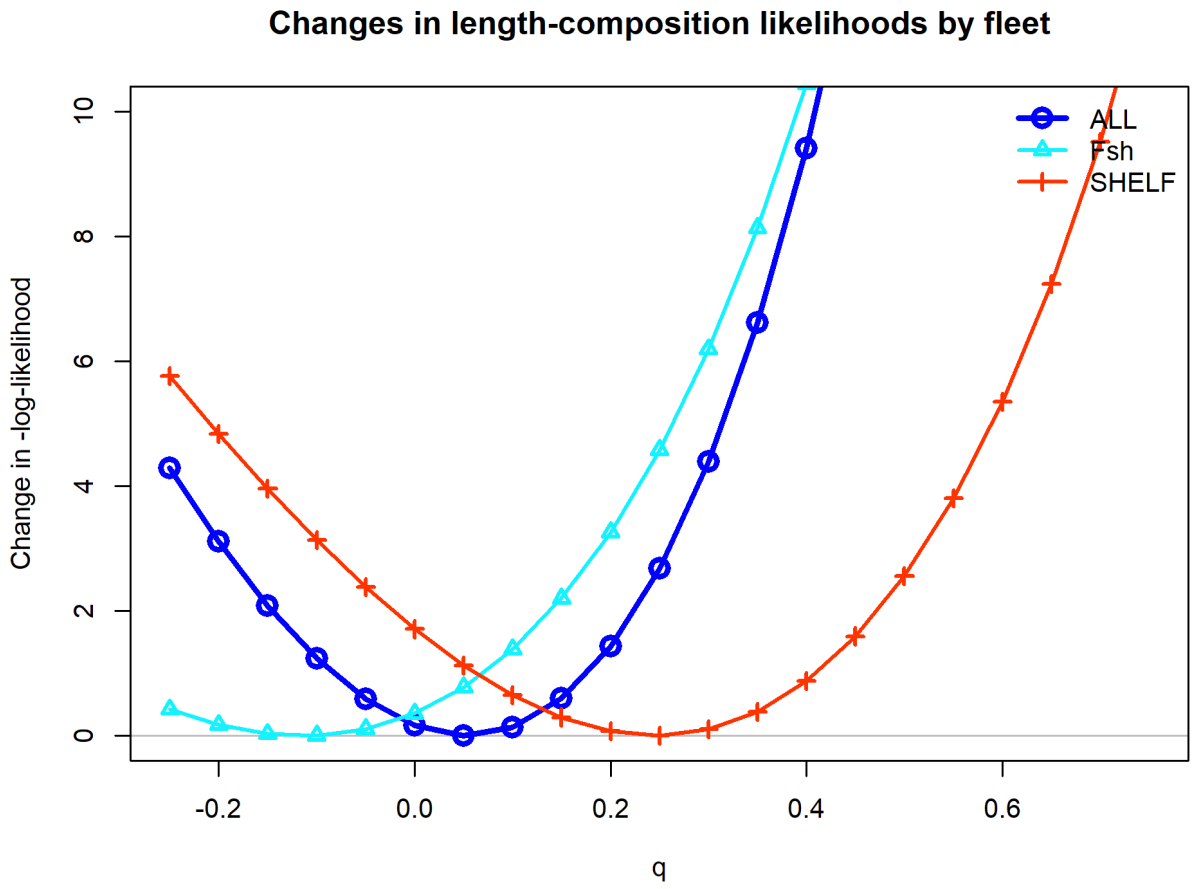
Mohn's rho for Model 23.0 in 2024 = 0.04

Model 25.0 likelihood profile over initial recruitment, R0.



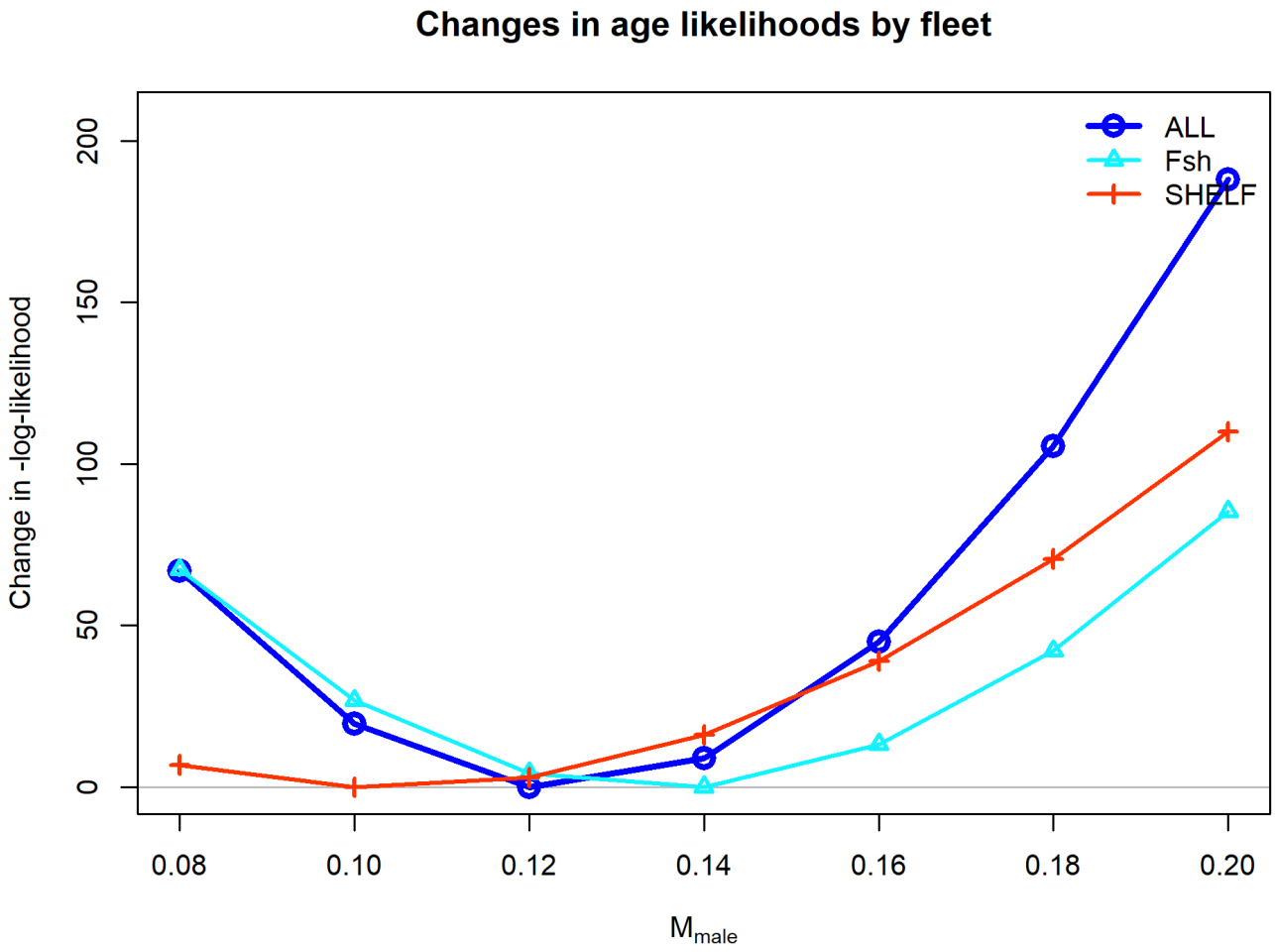
Survey indicates lower initial recruitment than the fishery.

Model 25.0 likelihood profile over catchability, q.



Survey indicates higher catchability than the fishery.

Model 25.0 likelihood profile over male M.



Are there a lot of changes?

- Shift from Tier 1 to Tier 3 supported by lack of data.
- Covariates on q should be changed to better use the data.
- Different platform (SS3) is a direct transfer (no change in methodology).

Authors prefer adopting Model 25.0a for ABC/OFL and status determination advice under the FMP.

- Makes use of SS3, for accessibility, flexibility and transition to FIMS platform.
- Removes collinearity of temperature covariates,
- Updates data weighting to the best scientific methodology.

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